Katrin Bergener
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Armin Stein *Editors*

The Art of Structuring

Bridging the Gap Between Information Systems Research and Practice

Springer

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Foreword

Opening this book, you may get the impression that you are looking at a Who-is-Who in Information Systems research—and, in a way, you'd certainly be right about that. What began with the simple idea to create an honorary publication for our dear colleague Jörg soon turned into an impressive account of contributions from all over the world.

How did this happen?

First, *time* certainly played an important role: Jörg was appointed Full Professor of Information Systems at the age of 31. Despite his still youthful appearance, he has thus been in office for almost 30 years now and has promoted numerous young academics, who today play important roles in both research and industry. Being the charming and energetic character that he is, Jörg has not only served the community as a great thinker but has also become a valued colleague and friend to many of us.

Second, another reason for Jörg's impressive network is certainly his great *scientific impact*. When talking about Jörg and his impact, of course, the "Retail H" needs to be mentioned. Some colleagues may recall this model to appear on Jörg's slides, regardless of what he has been invited to talk about, providing a great example of the many things we can learn from him. One of these things is his persistency in what he believes in, and one of the things he believes in (and lives by) is that Information Systems students must have three main abilities: namely, to (1) structure, (2) structure, and (3) structure.

There couldn't be a better title for this book.

But is it only the combination of time and impact that has led us here? There's another reason: It's Jörg. He certainly is one of his kind, a great character, so much fun to work with, solid as a rock (and cool as "icebricks"), always positive, and so encouraging. We all like to remember advice such as "Yes, others may work on this, too—but we will do it better" or "Don't worry, the workshop will be great—we don't need to know more than the others, just to think faster." This kind of inspiration also becomes apparent when organizing conferences with Jörg, serving on committees with him, or coauthoring papers—which, I think, is the actual reason why so many of his colleagues and friends have contributed chapters to this book.

Dear Jörg, with this book, over 80 authors would like to say thank you. We all are grateful for the many special moments we were able to experience with you. We would like to express our deepest appreciation for your remarkable achievements. Personally, I have been fortunate to learn from you for many years: As a young student at the University of Münster I sat in your lectures, and later you supported me during my dissertation and habilitation—and in the numerous other activities that would follow later. I've always been honored to work with you, and it is a great pleasure for me to write this foreword.

I would like to applaud the people who have made this book possible. Katrin (Bergener), Michael (Räckers), and Armin (Stein) not only took the initiative but have also done all the work—another example for the great spirit you are creating in your team. I wish all readers a lot of fun with this book. You can look forward to many interesting chapters, both personal chapters that pay tribute to Jörg and innovative chapters that present completely new perspectives and thoughts—a unique compilation of current contributions from the field of Information Systems.

Vaduz, Liechtenstein Jan vom Brocke

Jan vom Brocke is Professor of Information Systems, the Hilti Chair of Business Process Management and Director of the Institute of Information Systems at the University of Liechtenstein. He has published, among others, in MIS Quarterly (MISQ), Journal of Management Information Systems (JMIS), Journal of Information Technology (JIT), European Journal of Information Systems (EJIS), Information Systems Journal (ISJ), Communications of the ACM (CACM), and MIT Sloan Management Review (MIT SRM). He has held various editorial roles and academic leadership positions, and serves many organizations around the world as invited speaker and trusted advisor (see: www.janvombrocke.com).

Preface

"Strukturieren, strukturieren, strukturieren"—or, translated to English not sounding so "hip" anymore "To structure, to structure, to structure"[1]—are, according to Jörg Becker, the three core skills every "Wirtschaftsinformatik"[2] aficionado should be able to cover.

With this attitude, Jörg works at the Department of Information Systems at the School for Business and Economics at the University of Münster since 1990. We guess that all his academic offspring, 97 by the time of our editing, received the "Strukturieren" infusion and understand the importance of adding structure to the complexity of the world.

On January 27th, 2019, Jörg celebrated his 60th birthday. Together with 78 coauthors, having contributed to 50 articles, we want to praise his achievements with this Festschrift called "The Art of Structuring."

We asked the authors and their teams to think about the way they structure the field in which they work, what structure means to them and how—in their opinion—structure brings benefit to the world. When having been asked if the contributions should be "real" scientific papers, humorous reflections, personal experiences with Jörg or any other form of literature, we replied: "Do as you wish. This book is what we make of it. Just keep in mind that you write it as a present to Jörg".[3]

[1]For our non-German readers—the verb "Strukturieren" sounds like [ʃtʀʊktuˈʀiːʀən]. Whether you find this pleasant to the ear is up to you.

[2]The literal translation of "Wirtschaftsinformatik" to English would be "Business Informatics," a term that is widely used in the German-speaking Information Systems (IS) community. There are quite vivid discussions about the similarities and the differences among "Wirtschaftsinformatik," "Business Informatics" and "Information Systems," but for the sake of neutrality we happily *not* enter this discussion here.

[3]If the first part sounds familiar to you, the reason might be that you are familiar with the ERCIS network. This unpronounceable acronym stands for "European Research Center for Information Systems," a global network of IS research institutions, which he heads as Academic Director. Funny enough, "ERCIS is what we make of it" is his so not structured motive of the network, leaving the partners the freedom to contribute as good as they can, which in the end—so is his belief, and his belief seems to be justified—will result in something good.

The submissions we received are therefore very diverse in nature. We have "not so serious, very personal" submissions, and "very serious, less personal" contributions, and many in the space between. However, almost all of them have "structure" as a Leitmotiv. The list of invited coauthors spans his academic offspring that stayed in academia, his colleagues at the Department of Information Systems, his colleagues at the University of Münster School of Business and Economics, colleagues from the ERCIS[4] network, colleagues from joint projects, colleagues from journal editorial boards, conference committees, special interest groups, and from practice.

This explains the "structuring" part of the title. "The art" refers to two phenomena: First, finding the structure in things (or entities) is a difficult task. Explicating this inherent structure, explaining and describing it, is to a large extent "art." Second, it honors Jörg's love for fine arts. Music, for one, is a perfect example of structure in art. In general, the composition of music follows certain rules. Simply adhering to the rules does not create good music. It is an artistic (and skilled!) act to make music pleasant and making it reach the audience. Another example of the way how structure in the fine arts can inspire IS scholars and practitioners is one that Jörg loves to tell: It is an again artistic (and skilled!) act to explicate the relevant structure of an entity by abstraction. Pablo Picasso did this with his "Bull": Although he successively leaves details away, the last instance of the bull's depiction can still be interpreted as its origin. It is a skill to choose the right details to leave away, and the ones to keep.

In Jörg's deepest conviction, the subtitle "Bridging the Gap between IS Research and Practice" should be the underlying goal of any IS researcher. Everything should happen for a reason. "Wirtschaftsinformatik" exists to empower organizations to make use of Information Technology to their benefits. Organizations do not have to be Businesses, or, negatively seen, entities striving for financial excess, as "Wirtschaftsinformatik" critics often postulate; they might be Non-Governmental Organisations (NGOs), Public Administrations, Higher Education Institutions, or Associations, even Individuals. The non-exhaustive enumeration above reflects addressees of research projects Jörg and his chair were involved in, but also topics covered by the coauthors of this book. Although very pragmatic in nature, Jörg believes in grounded research that should then be transferred to practice.

Naturally, "Wirtschaftsinformatik" also and inherently bridges the gap between "Computer Science" (CS) and "Business Administration" (BA): Imagine a stock trader talking to an Assembler programmer about features to be included into the next generation market surveillance system. These two fields need a connecting body that speaks both languages—or at least can understand the problem and the solution space of both sides and bringing them together in the best way. One of the most prominent means to do this are conceptual models, be it BPMN models, icebricks models, PICTURE models, ER models, or UML models. All of them try to make both sides (CS and BA) understand each other at least to a certain extent. Creating good conceptual models is—again!—following some rules, but, on top, an

[4] See the explanation of the acronym ERCIS in the footnote above, if you skipped it.

artistic act. Now, unfortunately, “Bridging the Gap between IS Research and Practice, as well as between Business Administration and Computer Science, and between Many Other Things” is a subtitle way too long for such a book, which made us stick to the short version.

Getting to the content of the book. We were overwhelmed by the number of positive replies that we received when we approached potential authors. Although some expected us all to fail, as an inquiry one year before the publishing date was seen as—nicely put—too optimistic, the people involved in making this book happen proved them wrong. After the submission deadline (to be precise: after the fourth submission deadline, i.e., once we received all feature-complete submissions), we had the task to literally “structure” the articles for the table of contents. Luckily, all three of us call Jörg our doctoral supervisor, which means we feel infused with whatever it is that supports the act of structuring. If we did an artistic act, we do not know.

As a simple start, we are happy to have received a foreword by **Jan vom Brocke**, who spent his habilitation in Münster, and then moved to Liechtenstein, where he stays connected with Jörg as one of the most active members of the ERCIS network. As an introductory chapter, **Heike Trautmann**’s group at her Chair of Information Systems and Statistics at the Department of Information Systems in Münster, structured Jörg’s work and provides some interesting insights into his publications.

Structuring the remaining 50 submissions, we independently, but intuitively, came up with five topic clusters. Following the (lightweight version of a) process of a Delphi study, we decided on the following ones[5]:

Visions. The papers in this section have a rather discussing nature and partially go beyond application. Considering the title of the book, **Stefan Seidel** provides a very fitting and stimulating discussion about the connection between *structure* and *digital technologies*. He also takes a look at the noun *structure* and the related verb *to structure* in this context, nicely providing food for thought related to the title of this book. **Roland Holten and Christoph Rosenkranz** provide a comforting essay about the lack of capabilities of Artificial Intelligences to structure the unknown, a task that IS scholars and practitioners have to deal with every day. Like this, humans will—hopefully—remain the ones in charge. **Stanisław Wrycza** provides a thoughtful discussion on the structure of the Business Informatics field and the influences it is exposed to. **Shirley Gregor** looks at knowledge-action structures and their relation to the Information Systems discipline. She argues that knowledge can be understood as a machine form, that guides machines in its actions. As such, they deserve a closer look and consideration and open a field for further research.

[5]We are aware that we, for some cases, interpreted the clusters a bit more loosely, to avoid having clusters containing only one element. Furthermore, the order in which the articles are being described does not relate to the chapters but merely follows a content-approach. The articles in their respective chapters are sorted alphabetically, following the last name of the first coauthor.

Models. Models in any form and shape try to support the communication between stakeholders. Several contributions within this cluster deal with reference models, i.e., information models that are developed with the aim of being reused for similar application scenarios. **Christian Janiesch and Axel Winkelmann** compare the "Retail H," an invention by Jörg, with Microsofts Common Data Model (CDM) and, fortunately for Jörg, they come to the conclusion that the Retail H performs better. Additionally, **Karsten Kraume, Klaus Vormanns, and Jiaqing Zhong** propose an integrated reference model as a framework to structure transformation. Thinking about reference models in general, **Reinhard Schütte** claims that there is a low use of reference models in software development project and reflects on reasons, why hopeful claims of researchers have not been proven. Apart from reference models, another established research stream within this cluster is conceptual modeling. **Ulrich Frank** raises one of the most prominent questions that drives the conceptual modeling parts of our discipline: Will conceptual modeling languages, that create static models, or even reference models, still be means to deal with the inherently dynamic and flexible phenomenon of "Digital Transformation" in the future? His outlook provides a reassuring assumption that conceptual models will remain relevant as a means to structure, which is—for sure—good news for the jubilarian! Fittingly, **Elmar Sinz** gives an alternative view on modeling methods suitable for conceptual modeling while **Dimitris Karagiannis, Wilfrid Bork, and Dominik Utz** reflect on meta-models and conceptual modeling. In addition to the papers on reference modeling and conceptual modeling, we received papers that deal with different types of models in general. **Jos van Hillegersberg** contributes to this cluster on models by reflecting on research on maturity models and concluding that research on maturity models does not have a high level of maturity. **Robert Winter** outlines a data "black-boxing" research agenda to overcome the gap that conceptual data models inappropriately capture the essence of how business stakeholders analyze, design, and manage data-driven exploration. In line with the title of this edited volume, **Stephan Meisel** bridges the gap between research and practice with his contribution. He postulates an increasing need for decision support systems that are able to solve dynamic decision problems and applies his ideas to the contexts of service vehicle routing, energy storage management, and build to order manufacturing. **Ralf Knackstedt, Sebastian Bräuer, and Thorsten Schoormann** introduce three software prototypes for boosting model innovation and reflect on visualizing and analyzing business models with respect to sustainability while **Heinz Lothar Grob** describes his own idea of monetary evaluation of projects in the planning and control phase.

Processes. In this cluster, we collected submissions that at least to some extent deal with the "*self-contained, temporal and logical order (parallel and/or serial) of those activities, that are executed for the transformation of a business object with the goal of accomplishing a given task*."[6] Processes are, next to data, the most important business elements to study. Within this cluster, overviews over the history and development of the field are given by **Jan Mendling, Marlon Dumas,**

[6] Becker, Kahn 2003.

Marcello La Rosa and Hajo Heijers, as well as **Gottfried Vossen and Jens Lechtenbörger**, putting together procedure models, methods for process modeling as well as ideas for further development. Further submissions directly structure the aspect of robotic process automation as one very recent evolution in the field which will go beyond the "just" static structuring of the processes (**Peter Fettke and Peter Loos** as well as **August-Wilhelm Scheer**). The application of "Jörg's Process modeling language" icebricks is done by **Sascha Beilmann and Nico Clever**, whereas **Patrick Delfmann** is showing the importance of process modeling and the prediction of processes in the field of skiing routes. Prediction and even more the behavior of processes and why this in many cases does not fit to the static structure of a process model, discussed by **Wil van der Aalst**, closes this cluster.

Data. Data Management is one of the first lectures, where students at the Department of IS get in touch with Jörg. Learning the Entity-Relationship notation (ER notation) to conceptually describe how data is or should be connected in an application scenario makes the students also learn about using such languages for meta-modeling, thinking in entities and how they are related to each other, and how this relation can be, well, structured. The articles in this book reach beyond ER modeling. **Martin Dugas**, e.g., applies data models in the field of medicine. The challenge in the field of medicine is that medical data structures are not only complex, they also evolve due to medical progress and due to ambiguity in textual descriptions, therefore semantic annotations are also necessary. Similarly, **Wilfried Bernhardt** reflects on the structuring of meta-data in a completely different field, namely legal documents, as e.g., structuring attorney statements is not common practice in Germany so far. Bernhardt postulates that a digital processing of data could help judges in German courts managing documents more effectively. A second legal paper by **Thomas Hoeren and Philip Bitter** reflects on the interesting question on the ownership of data in the context of big data. Big data is also the topic of the contributions by Mathias Eggert and Oliver Müller. **Mathias Eggert** presents a literature review on business intelligence and data analytics and, building on that, proposes a framework to classify big data research results. **Oliver Müller** uses the advances in machine learning to extract useful knowledge from large amounts of unstructured data in order to bring structure to professional wine reviews and support the selection of suitable wines for a birthday party with the help of big data. Another hot topic that the contributions of Ulrich Müller-Funk and Stefan Stieglitz shed light upon are fake news or unwanted comments in social networks and online portals. **Ulrich Müller-Funk** reflects on how to determine "hate speech" or "abusive language" linguistically and how can algorithms do so. **Stefan Stieglitz** postulates that we need to collect and analyze communication and structure social media data in order to increase transparency and prevent misuse (e.g., shit storms or fake news). Data may, however, be used in completely different contexts as well. **Bernd Hellingrath and Sandra Lechtenberg** give an overview on the most interesting artificial intelligence (AI) approaches in Supply Chain Management (SCM) and come to the conclusion that many problems in SCM and logistics that may be tackled with AI successfully. **Cornelia Denz**, on the other hand, describes pioneering work in the field of holographic security marking for international fraud protection.

Organizations. Every discipline needs an object of investigation and design. Processes and data are embedded in organizations, see the discussion above. Finally, it is the purpose to make an organization better, when doing *the art of* structuring. In this sense, articles in this section deal with various aspects of organizations. **Reima Suomi** discusses the question how a network can be structured and why ERCIS is a perfect example of a network that Jörg structured—or not to let it evolve. Ultimately, it is not just structures that make a network, it is also "what you make of it," as we learned by Jörg! Taking the organizational genetics metaphor as a vehicle to understand the essential role of information systems in organizations is done by **Richard Baskerville**, **Isabel Ramos** is discussing how information technology supports organizational attention, e.g., by selecting relevant information and how that helps to structure organizations. As Information Systems in Münster is part of the Münster School of Business and Economics, is it part of the structuring view so see, how it is in these two fields as well. So, **Klaus Backhaus and Amir Awan** are discussing the apparent conflicts of Marketing and IT when looking together on an organization whereas **Andreas Pfingsten and Corinna Woyand** are taking the lens of banking regulations in their structuring perspective and **Theresia Theurl and Eric Meyer** are focussing on the boundaries of a firm, or organization, structuring their field along economic theories, which are important for that. Structuring public administrations is a field of research Jörg is dealing with for years. Addressing that, **Sara Hofmann** is collecting success factors of social media usage of public administrations whereas **Robert Krimmer** is discussing the *how* and *why* of e-Voting and **Björn Niehaves together with Kristina Röding and Frederike Oschinsky** is presenting a strategy for the digitization of municipalities. Being offsprings of Jörgs "school of thought" **Daniel Beverungen, Martin Matzner, and Jens Pöppelbuss** are continuing their aim of structuring the field of service science and smart service systems and—in the sense of bridging—bringing these thoughts to application whereas **Tobias Rieke** is reflecting on how and why project management in higher education institutions is a structuring challenge and **Michael Rosemann** is discussing how the challenges of structuring an organization are changing in the digital age. **Alessio Braccini and Stefano Za** are sorting organizational factors influencing the value of IT-projects negatively, and **Alexander Gromoff** is structuring aspects and factors for the digital transformation in general. **Alan Hevner and Richard Linger** are discussing different types of semantics necessary for the structured implementation of the Internet of things. The cluster of organizational aspects of structuring is closed by **Raimund Vogl, Dominik Rudolph and Anne Thoring** reflecting structuring purposes of research data management based on an appropriate research data infrastructure.

Technologies. This chapter touches the fundamental aspect of Information Systems—The implementation layer. **Sergei Gorlatch** points out that for decades, the usage of the Message Passing Interface seemed to be the method of choice when developing demanding programs. He argues, however, that for parallel programming, *send–receive* statements should be considered harmful, similar to *goto* statements in the late 1960s. He suggests to basically use well-structured collective operations as a remedy. **Herbert Kuchen** supports this view and recommends algorithmic skeletons for parallel programming—basically an approach that Sergei Gorlatch calls out for!

Summing up, we hope that this book fulfills two purposes.

First, we hope (and, not being too shy, we are quite sure) that our doctoral supervisor, colleague, friend Jörg is happy about this present from the community, celebrating his 60th birthday and honoring his undisputed contribution to the national and international community of our discipline. We as editors are grateful for the time and efforts that all the "conspirators," as we called all who were involved during the year of preparation, put into it. Thinking about the number of hours that were put into each of the parts of the book by highly skilled academics and practitioners makes one shiver.

Second, we believe that this book holds more than one gem that would make a valuable contribution to a journal of choice. We also believe that the various ways of how "structure" is being approached by the coauthors, the different perspectives, and the different cultural and academic backgrounds together form the bricks that constitute a border-spanning bridge.

We would like to thank all the coauthors of the contributions to this book, who believed that it can be done, and who delivered. Thank you very much for the smooth process and for keeping the silence during our "conspiracy"!

We would also like to thank Jan vom Brocke for his foreword, who accompanied Jörg and the ERCIS network for a very long time and closely works together with him.

Concluding, we are very grateful to Jörg who, as a doctoral supervisor and director, creates a spirit at his chair and the ERCIS headquarters that is characterized by freedom of work, flexibility, and opportunities—something that cannot be taken for granted. We believe that we speak for all of Jörg's "offspring" when saying that he provided and provides all of us with a fruitful environment, in which we were and are all able to grow and feel supported at all times. Thank you, and Happy Birthday!

Münster, Germany
January 2019

Katrin Bergener
Michael Räckers
Armin Stein

A Structured Approach to Systematically Structure J. B.'S Publication History on Structured Process Management

Heike Trautmann

Abstract In this paper, different analytical approaches are used in a structured fashion to get an overview about topics and scientific content of Joerg Becker's research based on his complete publication history. Moreover, we analyze his scientific network by investigating author- and coauthorships.

Keywords Publications • Word Clouds • Scientific Network

Overview and KPI's of Publication History

Jörg Becker's publications were cited over 15,000 times in total with peaks of roughly 1,500 citations in 2013 and 2017. About 850 publications were published in collaboration with more than 400 different coauthors. His excellent scientific expertise is reflected by an h-index of 56 and an i-10 index of 277 (August 2018).

Top 10 Publications (# Cites)

1. Becker, J., & Kahn, D. (2003). The Process in Focus. In J. Becker, M. Kugeler, & M. Rosemann (Eds.), *Process Management* (pp. 1–11). Berlin, Heidelberg: Springer.
2. Becker, J., & Schütte, R. (2004). *Handelsinformationssysteme: Domänenorientierte Einführung in die Wirtschaftsinformatik* (2. Aufl.). Frankfurt am Main: Redline Wirtschaft.
3. Becker, J., Rosemann, M., & von Uthmann, C. (2000). Guidelines of Business Process Modeling. In W. van der Aalst, J. Desel, & A. Oberweis (Eds.), *Business Process Management* (Vol. 1806, pp. 30–49). Berlin, Heidelberg: Springer.

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Scientific Network

An overview of Jörg Becker's scientific network with a huge number of coauthors is given below. The Top 10 coauthors in terms of the number of joint publications are as follows:

Top 10 Coauthors (# Joint Publications)

Ralf Knackstedt:	# 87
Daniel Beverungen:	# 44
Michael Räckers:	# 43
Björn Niehaves:	# 42
Martin Matzner:	# 38
Patrick Delfmann:	# 36
Axel Winkelmann:	# 35
Helmut Krcmar:	# 32
Dominic Breuker:	# 26
Michael Rosemann:	# 24

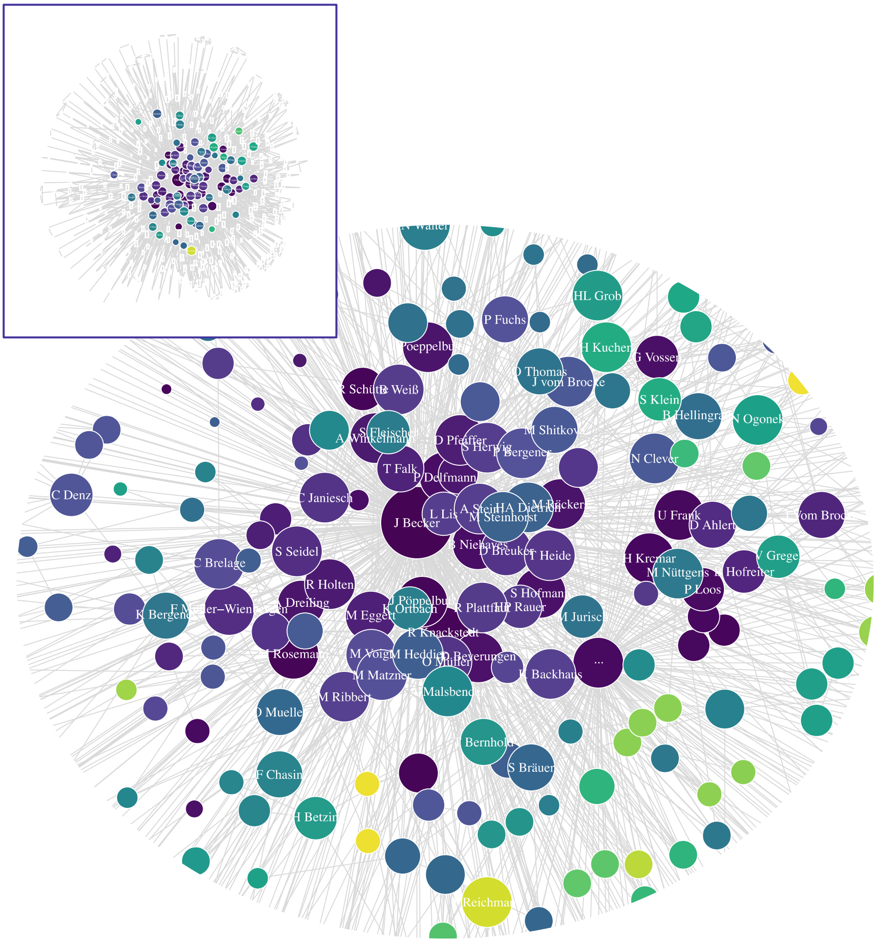
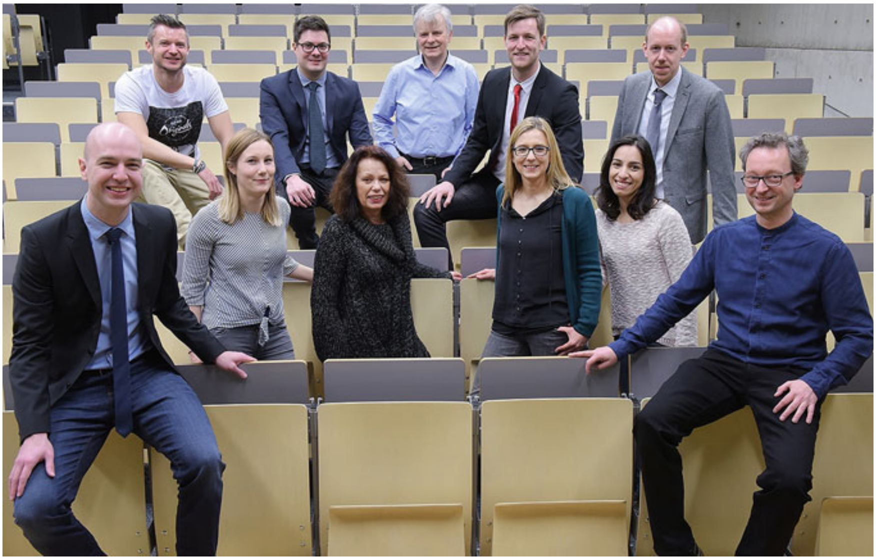


Fig. 1 Jörg Becker's Scientific Network. Coauthors are visualized by colored dots while the size of the dots reflects the number of joint publications

Structuring Publication Topics via Word Clouds

Publication topics of course changed during Jörg Becker's scientific career. However, based on a structured and systematic analysis of the titles of all his publications, we can observe a convergence behavior towards "business process management" combined with topics such as "modeling, analysis, design" reflecting his structured research approach.

Fig. 2 Word Clouds of publication titles from 1979 until 2018



Heike Trautmann is Head of the Information Systems and Statistics Group, University of Münster, Germany and a Director of ERCIS. Currently, she is also Vice-Dean for Internationalization at the Münster School of Business and Economics. The group contributes to the research areas of Data Science and Big Data, social media analytics, (multiobjective) optimization, evolutionary computation, algorithm selection, and computer games in international collaborations. Industrial collaborations support the transfer from theory to applications in industry.

Contents

About the Editors

Katrin Bergener is Assistant Professor at the Department of Information Systems at the University of Münster. She received her doctoral degree in Information Systems at the University of Münster in 2013 and holds a Master's degree in Linguistics from the University of Münster. She works at the headquarters of the European Research Center for Information Systems (ERCIS) in Münster and is Coordinator of the WWU Centre for Europe. In 2017, she was a fellow in the W30 program at UCLA. Katrin successfully applied for national and international research funding and worked in various projects. Her research interests comprise IS education, i.e., the development of new teaching formats, web-based career guidance for girls, as well as innovation management. Her work has appeared in peer-reviewed journals, i.e., BISE, as well as major international conferences including ECIS and HICSS.

Michael Räckers is an Associate Professor (Akademischer Oberrat) at the Department of Information Systems at the University of Münster. Michael is serving as CFO of the Department since 2010. He received his doctoral degree in Information Systems at the University of Münster in 2010 and holds a Master's degree (2006) and Bachelor's degree (2005) from the University of Münster. Since 2007, he is Head of the Competence Center E-Government at the European Research Center for Information Systems at the University of Münster. Michael was Project

Manager of several research projects funded by national and international funding organizations in the area of E-Government. His research interests include e-government, public service delivery, e-government adoption, and business process management.

Armin Stein is Managing Director of the European Research Center for Information Systems (ERCIS). In this role, he networks members of more than 30 national and international IS research institutions. He received his doctoral degree in Information Systems at the University of Münster in 2010 and holds a Master's degree (2006) and Bachelor's degree (2005) from the University of Münster. Armin's research interests comprise business process management, diversity in information systems, and conceptual modeling. Furthermore, together with Katrin, he likes to experiment with new teaching methods, and regularly establishes international courses and seminars for students on undergraduate, graduate, and postgraduate level.

Part I
Visions

"I can't understand why people are frightened of new ideas. I'm frightened of the old ones." (John Cage)

"Information Systems" is not a discipline that—at least currently, and most probably not soon—endangered to become outdated. Although challenging for society, the rapid technological advancements that we experience each day provide an environment that forms "our" body of analysis. Surely, looking back is important, however, we need to constantly think about new approaches to deal with the phenomenon.

Knowledge-Action Structures

Shirley Gregor

1 Introduction

An argument can be made that the whole of modern computing, including information systems, depends on the discovery that knowledge, as in applied logic, can take on a machine form that guides action by the machine. Hodges (2012, p. 199) describes how in 1939 Alan Turing combined knowledge including that of his Turing machine and mechanical engineering to begin the construction of what would become one of the world's first computers. Hodges says these ideas:

> spoke of making some connection between the abstract and the physical. It was not science, not 'applied mathematics', but a sort of special applied logic, something that had no name.

It appears that the implications of this special relationship between knowledge and its machine implementation may still not be fully appreciated. Denning and Martell (2015, pp. 15–17), in aiming to define fundamental principles characterizing the field of computing, say:

> The structures of computing are not just descriptive, they are generative. An **algorithm** is not just a description of a method for solving a problem, it causes the machine to solve the problem. The computing sciences are the only sciences with such a strong **emphasis on information causing action** [emphasis added].

These comments point to the importance of conceptual structures that relate knowledge and action. Thus, this chapter:

1. Focusses on *knowledge-action structures*, which are specifications of actions, or sequences of actions, and the entities to which they relate;
2. Discusses why it is important and relevant to study information technology (IT)-related *knowledge-action structures*;

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3. Examines potential approaches to *knowledge-action structuring*, with reference to a range of ontological perspectives, modelling tools and action logics that have been proposed in information systems and related fields.

The discussion here is conjectural and only touches on a limited number of the ideas that have been discussed and debated at length elsewhere. The brief treatment afforded here to some complex topics obscures a number of the nuances that can be observed when studying these topics in more detail. The aim is to draw together key ideas from a range of different fields concerning knowledge-action structures and highlight issues that arise when studying them in conjunction. These issues could be worthy of further attention.

2 Importance of Studying Knowledge-Action Structures

As shown in the introduction, some see the translation between actionable knowledge as developed by humans and its digital instantiation as the foundation of computing and thus related fields of IT, including information systems.

A significant amount of attention has been paid to approaches to the analysis and modelling of knowledge and information in ways that can inform the design of IT socio-technical systems, as witnessed by the many research articles, textbooks and university courses devoted to the topic. Some approaches concern the modelling of data and data structures (Connolly, Begg, & Holowczak, 2008), others concern the modelling of what we are here calling knowledge-action structures (e.g. as in business process modelling in Becker, Kugeler, & Rosemann, 2013) and others concern knowledge representation and reasoning in artificial intelligence (AI).

The motivation for this chapter arose because of a personal interest in the specification of design principles (Chandra, Seidel, & Gregor, 2015). It appears that although there has been concerted effort in information systems to find sound foundations for data modelling approaches in underlying philosophical views, particularly in work on ontology (e.g. see Weber, 1997, Burton-Jones, Recker, Indulska, Green, & Weber, 2017), there does not appear to have been anything comparable to the same degree for knowledge-action structures. Although object modelling approaches can be related to formalisms in set theory, there does not appear to be as much attention to finding a similar base for process modelling in imperative logics or similar.

An associated sub-question is whether some existing ontological approaches are actually inimical to the development of knowledge-action structures that are suitable, at least in part, for instantiation in IT-based systems. Exhibit 1 shows an example where a philosopher's approach to ontology, as represented in his view of logic as a form of language, is not appreciated by someone turning his mind to the construction of a computer that should not "fall down".

	In 1939 Alan Turing was appointed to give a lecture course at Cambridge University course on mathematical logic. He also attended a course by Ludwig Wittgenstein on Foundations of Mathematics, oriented towards the philosophy of mathematics. An exchange between the two was recorded (see Hodges, 2014, p. 195). Wittgenstein: citing a paradox in logic, argued that "it is just a useless language game and why should anyone be excited?" "Where will the harm come?" if there are contradictions. Turing: "The real harm will not come in unless there is an application, in which a bridge may fall down or something of that sort". "Although you do not know that the bridge will fall if there are no contradictions, yet is almost certain that if there are contradictions it will go wrong somewhere."	

Exhibit 1 Divergent views of a philosopher and a computer scientist respecting knowledge-action structuring. *Image Source* https://www.shutterstock.com/

3 Approaches to Knowledge-Action Structuring

The concern in this chapter is with special forms of language or other means of representation for knowledge-action structures such as design principles, ontologies, logic, modelling tools, and programming languages. An example of a design principle is: in order to achieve effective frustration-free interfaces offer informative feedback (Shneiderman, 2010). A process model represents a process: "a completely closed, timely and logical sequence of activities which are required to work on a process-oriented business object" (Becker et al., 2013, p. 4). These examples show that IT-related knowledge-action structures describe actions, or sequences of actions, and the entities to which they relate. The areas in which these knowledge-structures are developed include the whole range of IT-based systems in today's world: for example, enterprise systems, e-commerce, social media platforms, operating systems and intelligent agents. A characteristic of these structures is that they often take on a prescriptive role in that they show the steps that can be used to accomplish some goal or end.

Knowledge-action structures are dealt with in many different literatures. Here we will look first at their background in philosophy, at some tangential approaches, then at modelling approaches and artificial intelligence.

3.1 Background in Philosophy

The core areas of interest for knowledge-action structures, ontology and logic, have been studied in philosophy for many years (e.g. see Sowa, 2000). Ontology, as a branch of philosophy, deals with the nature of being, the categories of being, entities and types of entities and relationships between entities. Historically, basic distinctions in ontology have been made between positions such as realism, the view that there are things that exist independently of us and our perceptions of them, and idealism, a view that mind is the most basic reality and that the physical world is somehow a product of our minds. A very large number of variants on these positions exist.

Some philosophers have proposed underlying ontological positions that recognize more than just objective and subjective realities. Three-world ontologies have been proposed by Popper (1972) and Jürgen Habermas. Habermas (1984) distinguished the worlds of: (1) the objective world of physical things; (2) the subjective world of human inner experiences; and (3) the social world of roles, norms, and accepted beliefs. This perspective is mentioned in particular as it makes it possible to distinguish "knowledge" as an entity belonging to the third world of abstract things which have an objective existence arising from inter-subjective agreement amongst humans. The three world view of Habermas has also been used to inform design with intelligent agent communities (see Singh, 2000). Terms from the three world view of Habermas are used as short-hand labels for different realities in the remainder of this chapter: that is, objective, subjective and social realities.

The Stanford Encyclopaedia of Philosophy has an entry on the "Logic of Action" which provides an overview of how "action" has been dealt with in philosophy, linguistics, computer science and artificial intelligence (Segerberg, Meyer, & Kracht, 2016). This entry recognizes the importance of the logic of action for computer science and artificial intelligence and in that respect mentions a number of the formalisms that are dealt with in following sections, including temporal and dynamic logic.

3.2 Tangential Approaches

Before considering ontological approaches that are appear germane to the topic of this chapter, brief mention is made of approaches that have been proposed in the information systems field that appear to side-step issues that are the focus of this chapter.

One such approach is sociomaterialism, which, as proposed by Orlikowski and Scott (2008) is an ontological view that "the social and the material are inherently inseparable" (p. 456). That is, no distinction should be made between objective and subjective realities. It differs from the view that human beings and things exist as separate and self-contained entities that can interact and affect each other and is presented mainly in the context of information system use in organizations. It is difficult to see how this approach can inform considerations of how knowledge, generated in part at least by humans, can take up a machine form (that in the case of intelligent agents are capable of autonomous action). Cecez-Kecmanovic, Galliers, Henfridsson, Newell, and Vidgen (2014, p. 826) note that this body of literature has been criticized as having very little to offer the practitioner.

3.3 Modelling Approaches

Modelling approaches comprise foundational knowledge-action structures in computing. Hodges (2012) was referring to such an approach when he said that Alan Turing had found a special type of applied logic that could be given a machine form. A Turing machine uses predefined rules to determine a result from a set of given inputs and is equivalent at base to the expression of algorithms in programming languages as in:

> DO [Action 1], IF [Condition C1 AND Condition C2] THEN DO [Action 2], DO [Action 3], ….and so on

A language such as this can make use of propositional logic and truth tables to determine the value of compound conditions and can be converted to an electronic form. The representation of a process model in a flowchart could give a similar specification in a diagrammatic form. Design principles can take on a similar form, in that they are:

> Instructions to perform a finite set of actions, including manipulations of one or more artifacts, in a given order and with a given aim (Bunge, 1967, p. 132).

Aguilar-Savén (2004) provides a review of the main process modelling techniques, which includes flow charts, data flow diagrams, role activity diagrams, role interaction diagrams, Gantt Chart, Integrated Definition for Functioning Modelling (IDEF), Coloured Petri-net, object oriented methods, and workflow techniques. Van der Aalst and Van Hee (2002, p. 4) in discussing workflow management systems say that the ontology of a business process includes "a number of *tasks* that need to be carried out and a set of conditions that determine the order of the tasks".

Apart from process modelling, other approaches focus on the modelling of the entities of interest and their ontologies. Wand and Weber (1993) developed the Bunge-Wand-Weber (BWW) model which is based on a state tracking model and argues that an information system should be a faithful representation of part of the real world see also Weber (1997). BWW was later termed representation theory (see Burton-Jones et al., 2017) and assumes, for example, that if models are created with modelling grammars that adhere to the hypotheses in the BWW theory, then they are easier to interpret and use. The BWW model has received significant amounts of scholarly attention and led to fruitful avenues of research. Gehlert, Pfeiffer, and Becker (2007) review empirical articles that test propositions derived from the model and find good support for the representation model. However, they could not find studies of the state tracking model, which is the component that deals with events that trigger state changes.

Eriksson, Johannesson, and Bergholtz (2018) suggest that the BWW model is limited in that it describes only entities in the real world, as perceived by users (i.e. objective and subjective realities). These authors suggest instead that "conceptual modelling is concerned primarily with institutional reality" (p. 2) and institutional reality "is created and maintained by social interaction governed by rules; it is about human activities, as well as the relationships and facts that are created through these activities" (p. 2). Thus, they suggest that conceptual modelling approaches should include social as well as objective and subjective realities.

In sum, modelling approaches in many forms have proved useful for representing knowledge-action structures. It should be noted, however, that with these approaches the "knowledge" that is represented in entity or process modelling comes from human modellers or designers, who encode heuristics or rules in the models they produce. In many cases these rules will have been produced by processes of trial-and-error or experimentation, either for the purposes of constructing the IT system, or in the real-world system (or institution) that foreshadowed the IT system. The representation theory of Weber and colleagues appears to have one of the best developed formal modelling theories, although more for the component that represents entities, rather than the process-action state-tracking component.

3.4 Artificial Intelligence

In contrast to the modelling approaches discussed in the last section, research in artificial intelligence has considered how machines themselves can engage in processes of reasoning and problem solving. The processes in this case require more sophisticated logics, especially with regard to situations, time and events. Intelligent agents can plan and reason about their current situation and work out how to accomplish a desired goal. Space precludes discussion of these approaches in any depth. However, Russell and Norvig (2002) in their authoritative text discuss a number of approaches, including situation calculus and its ontology. There are also time and event calculus, which are alternatives to situation calculus when actions have duration and can overlap with each other.

Intelligent agents are of interest in information systems: for example, recommendation agents in e-commerce are a popular research topic.

Intelligent agents can work together in multi-agent communities, as instanced in agents that negotiate with each other in settling transactions in online exchanges. Interestingly, researchers have successfully used Habermas' work at a pragmatic level in designing inter-agent communication (see Russell & Norvig, 2002, Singh, 2000). Singh (2000) criticized early work on the communication between autonomous agents that relied on "mentalistic" concepts of desires, intentions, and beliefs by ascribing such concepts to other agents' internal subjective states and, thus, proposed extending speech act theory to use Habermas' three worlds concepts such that agents could access a "social" world of agreed public protocols and standards.

Recent rapid advances in deep machine learning mean that some systems may have little or no reliance on the logic and reasoning methods proposed by designers, but can develop their own approaches to problem solving. Humans may not know how these advanced algorithms do what they do (e.g. see Knight, 2017).

In terms of ontologies, there have been attempts in artificial intelligence (and elsewhere), to develop "upper" or general ontologies that provide a framework into which all entities of interest can be slotted. Niles and Pease (2001) reported on efforts to develop the Suggested Upper Merged Ontology (SUMO) as an upper level ontology by a working group of collaborators from the fields of engineering, philosophy, and information science. SUMO defined general-purpose terms and was to serve as a foundation for more specific domain ontologies. Russell and Norvig (2002) introduce their own general ontology, which organizes everything in the world into a hierarchy of categories. At the top level is "Everything" which is sub-divided into "Abstract/Objects" and "Generalized Events" and so on (p. 321).

Given that many ontologies exist for specific domains and yet there is a need for agents to be able to communicate with each other, Russell and Norvig (2002) pose the interesting question:

> For any special-purpose ontology, it is possible to make changes …to move toward greater generality. An obvious question then arises: do all these ontologies converge on a general-purpose ontology? After centuries of philosophical and computational investigation, the answer is "Possibly" (p. 322).

They further state:

> A general-purpose ontology should be applicable in more or less any special-purpose domain (with the addition of domain-specific axioms). This means that, as far as possible, no representational issue can be finessed or brushed under the carpet.
>
> In any sufficiently demanding domain, different areas of knowledge must be **unified**, because reasoning and problem-solving could involve several areas simultaneously (p. 322).

4 Discussion and Conclusions

This chapter has addressed the topic of knowledge-action structures, which are seen to be at the core of computing and information technology. It began with a claim by Denning and Martell (2015) that the computing disciplines are the only ones with such a strong emphasis on information and *knowledge becoming action*. The question is whether the implications of this state of affairs are fully realized.

Examples of knowledge-action structures are found in the modelling approaches that inform the design of IT-based systems, in both conceptual and process modelling, with more sophisticated techniques found in artificial intelligence.

At the heart of these approaches are the topics of ontology and action logics. With respect to action logics, one can see that although logic is used as a means of expression, the actual form of action sequences in general comes from the problem-solving work of designers. However, in new forms of deep learning, machines can develop knowledge themselves. With respect to ontology, there is an open issue. One can see that there are different ontological perspectives at a very high level. Some see only one reality (e.g. Orlikowski & Scott, 2008), some see two realities (objective and subjective) (e.g. Burton-Jones et al., 2017) and some see three realities (objective, subjective and social) (e.g. Eriksson et al., 2018, Singh, 2000).

How necessary is it for there to be more consensus on an over-arching ontological perspective that will cover a large proportion of the phenomena relating to IT-based systems, including intelligent agents? Russell and Norvig (2002) suggest that different areas of knowledge in a domain must be unified in order to avoid inconsistencies in reasoning amongst different areas. Or is it acceptable to keep divergent views, with each corresponding to different forms of Wittgenstein's language games?

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The Power of Structuring the Unknown–A Unique Human Capability

Roland Holten and Christoph Rosenkranz

1 Learning Cycles in Science and Design/Development

Science and systems design/development have one crucial activity in common: humans give structure to as yet unknown things. This does not necessarily mean that humans invent these things—but at least they invent how to talk about which aspects of these things. With science, the things themselves are part of the given nature humans try to make sense of. Learning cycles describe how and why science is able to create knowledge (for example, Fig. 1): given some data from nature, humans interpret this data using deductive logic; if their conclusions do not match the observation, inductive logic is used to create new interpretations of data. This way, given knowledge is confronted with data from nature and in case of mismatches knowledge is adapted. This is how science creates new or adapted knowledge about a given but so far unknown nature.

Basically the same happens when designing/developing a system to solve a new problem. In this situation it is not important if the problem is generally unsolved—then science might help—or just that the developer does not know about the solution—then the developer has to go the full distance. For example, Fig. 2 shows an approach to data warehouse development. The goal is to come up with a system supporting management decisions by providing presumably relevant information about business decisions to be made. The development approach is organized in development phases, which are repeated iteratively in a circular fashion. Every phase brings together design/development tasks belonging to a specific group such as, for example, "Requirements Presentation" or "ETL Design".

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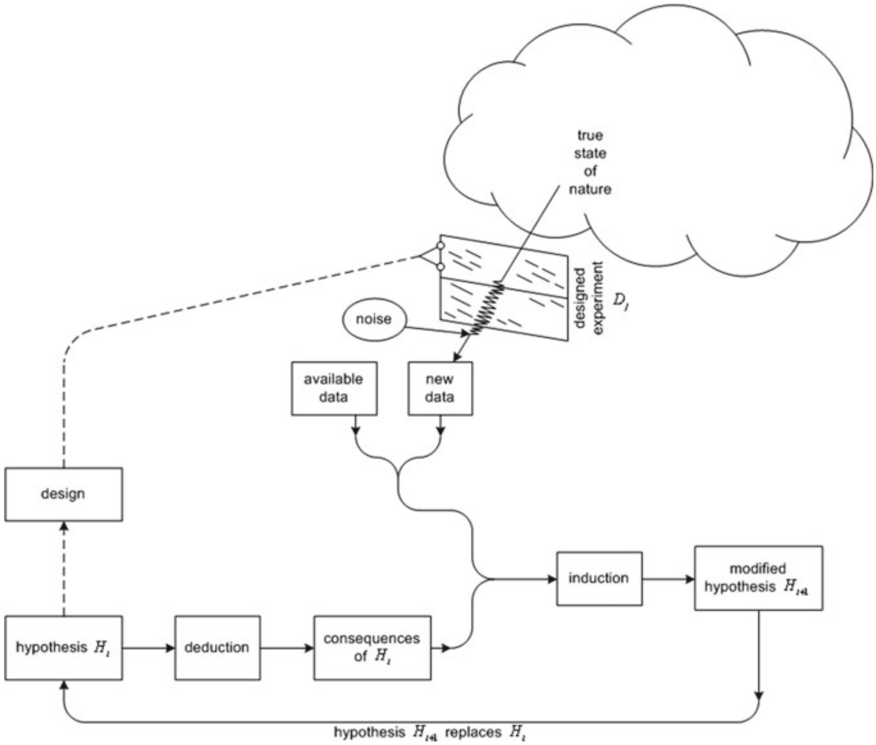

Fig. 1 The scientific method—a learning cycle (Box, Hunter, & Hunter, 1978, p. 4; Gauch, 2003, p. 407). Reproduced with kind permission of Wiley & Cambridge University Press

The goal is to structure data in a way that helps managers to make sense of a given business situation. Therefore, data from specific source systems may or may not fit into a predefined set of concepts describing a business situation. The designers/developers have to make sure that the source system data and the concepts used to build the data warehouse structure mean the same thing. If not, the data warehouse system's structure and its describing concepts have to be adapted, because the source systems' data is given and cannot be made to describe other things than it does. This typically happens when the data warehouse has to be adapted to support strategy changes or changes on process levels. In these cases data needs to be aggregated in new or changed ways.

Both models, the scientific learning cycle and the approach to data warehouse development, organize specific activities in sequences. Between and within these activities persons in charge with different professional backgrounds cooperate to achieve an intended goal. Their specific knowledge is localized, embedded, and invested in practice (Carlile, 2002, p. 445) and leads to certain boundaries impeding the intended cooperation. Therefore, considering the framework to manage knowledge boundaries proposed by Carlile (2004) will inform our following argument.

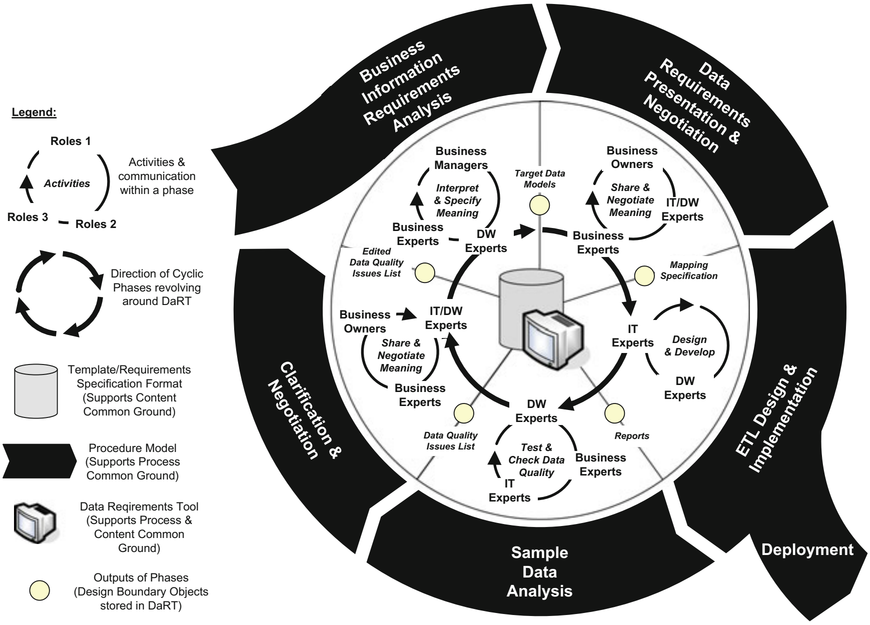

Fig. 2 Approach to data warehouse development (Rosenkranz, Holten, Räkers, & Behrmann, 2017). Reproduced with kind permission of T&F. Figure created by Roland Holten

Since stakeholders belong to different communities of practice, *knowledge boundaries* will occur. The higher the novelty—the degree of the unknown—the more actors in a design/development situation will drift apart, meaning that the respective knowledge boundary grows with novelty. In consequence, the degree of novelty increases the required effort to share and assess each other's knowledge at knowledge boundaries. Novelty, therefore, means a lack of common knowledge to adequately share and assess domain-specific knowledge at a boundary (Carlile, 2004, p. 557).

In consequence, communication about required knowledge will be complicated.

The question now is why in both situations, science and development, iterative cycles are used to handle knowledge boundaries. To understand the reason behind this, it makes sense to fall back to structuration theories of society.

2 Structuring and Structuration Theories

Basically, structuration theories claim that society should be understood in terms of action and structure; a duality rather than two separate entities (Poole & DeSanctis, 2003). On the one hand, social structures serve as templates for planning and accomplishing tasks; on the other hand, they are reproduced and altered through human interaction (DeSanctis & Poole, 1994). Therefore, structuration can be described as a

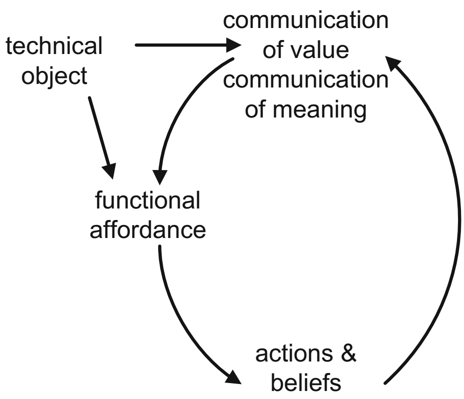

Fig. 3 Interplay of social structures and actions (Grgecic et al., 2015). Reproduced with kind permission of Wiley. Figure created by Roland Holten

circular process of (re-)producing social structures that shape human agents' actions and beliefs and are, in turn, shaped by human agents' actions (Al-Natour & Benbasat, 2009). For example, IT artefacts such as software or hardware have properties that may have causal potential for human action (Markus & Silver, 2008). Nevertheless, "it is the capabilities of the technology, just as much as the choices people make about how to use those capabilities, which explain the ultimate effects that technologies have on social structures. They are two sides of the same coin" (Leonardi, 2013). In this sense, IT artefacts as technical objects offer certain possibilities of action for an individual. This specific relation is called "functional affordance" and determines the potential use of a technical object for an individual (Markus & Silver, 2008). Nevertheless, before a person might evaluate the potential use of a given IT artefact, it is necessary, that (1) the person understands what the technological object is about, and (2) that the person agrees to the values the technological object conveys. The first aspect is called communication of meaning, the second aspect is called communication of value (Grgecic, Holten, & Rosenkranz, 2015). Values and meanings are subsets of social structures guiding actions (Fig. 3).

Since in social-technical systems (Bostrom & Heinen, 1977) the two sub-systems, the technical and the societal sub-system, are characterized by complex and dynamic interactions over time, structuration proposes a circular relation between actors' actions and beliefs on the one hand and communication of value and communication of meaning as structurational elements on the other hand. In other words: social structures, for example, shared meanings of a technical object, constrain actions, while actions impact social structures (Fig. 3). As Grgecic et al. (2015) demonstrate by using a timeline, this circular relationship leads to dual dynamics of structures constraining actions, and actions shaping structures (Fig. 4).

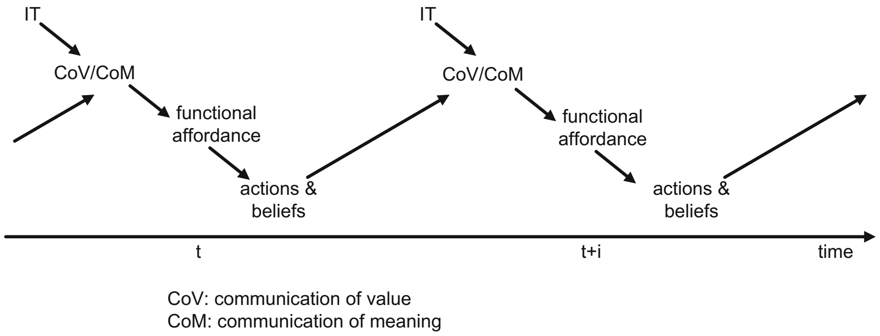

Fig. 4 Dynamics of social structures in socio technical systems (Grgecic et al., 2015). Reproduced with kind permission of Wiley. Figure created by Roland Holten

3 Linguistic Representations and Structuration

Interacting stakeholders in systems design/development first need to align their "interpretative schemes" (Giddens, 1984, p. 29) so that they are able to develop "intersubjectively-held mental models" (Gasson, 1999, p. 89) before they can begin to share knowledge, accumulate new knowledge, and build shared or common knowledge. In consequence, cooperative actions of coworkers will then impact social structures and meanings ascribed to technical objects as IT artefacts. The importance of linguistic alignment for successful communication in systems development processes has been shown by Corvera Charaf, Rosenkranz, and Holten (2013) and Rosenkranz, Corvera Charaf, and Holten (2013).

Agile approaches to systems development offer efficient ways to support the required cyclic adaptation of structures and actions because of their intended short feedback cycles. For example, development teams' response extensiveness and response efficiency in dealing with customer feedback both significantly influence system development success (Lee & Xia, 2010; Recker, Holten, Hummel, & Rosenkranz, 2017). With regard to the above discussion of the cyclic relationship between social structures and actions, a possible explanation for this finding is that knowledge boundaries between customers and developers could be overcome more efficiently if agile practices such as stand-up meetings are in use. These practices stimulate the alignment of interpretive schemes (Giddens, 1984) of developers and customers and thus help to avoid procrastination of the detection of misunderstandings.

To sum up: interacting stakeholders at knowledge boundaries need to overcome these boundaries by aligning their linguistic schemas, and a good way to do this is acting and speaking together, a way of interaction that is stimulated by agile development methods. Only if two actors share the understanding of a thing or concept can they share knowledge about the thing/concept, and start to accumulate new knowledge (Holten & Rosenkranz, 2011). This implies that there can never be shared knowledge without shared understanding; shared understanding is a logical prerequisite for shared knowledge. The alignment of linguistic schemas is cyclic in nature, because—if put on a timeline—linguistic schemas as subsets of social structures constrain actions, and actions shape social linguistic schemas. This mechanism enables developers and scientists to structure formerly unknown phenomena and meaningfully communicate about these phenomena. *Structuring the unknown* is the core operation enabling scientific learning and development cycles.

Alignment of linguistic representations at syntactic, semantic, and pragmatic levels, therefore, plays a causal role in the attainment of shared understanding. Failure to align at different levels of language, furthermore, may result in failure to communicate successfully.

An interesting question now is if recent developments in artificial intelligence and machine learning will result in systems having the means to structurally align knowledge in the same way as scientists and designers/developers do. Such kind of systems would—in the end—be able to develop themselves, adapt to any new situations and—ultimately—gain control over our social world—a nightmare for many! The scared reader might regard the following argument.

4 Human Brain Versus Artificial Intelligence

First of all, the technological basis for the human capacity to structure the unknown as described above is the human brain (Nikolić, 2015). The human brain has around 100 billion neurons, each comprising 1000 synapses. This leads to a total of around $10^{11} \times 1000 = 10^{14}$ (100 trillion) synapses (Nikolić, 2017). A single synapse can store 4.6 bits of information, which leads to a total of $2^{4.6} = 24.25$ states per synapse. In total the human brain thus can store 2.4×10^{15} different states. This number is roughly 500 TB of memory, and can be achieved by today's information technology (Nikolić, 2017). So, on first glance, a good case for the nightmare becoming true? Not at all!

Let us look into the capacity required to solve an easy problem that the human brain handles every day, namely the recognition of three-word sentences and five-word sentences (Nikolić, 2017): the English language has about 15,000 words (with around 5% adverbs = 750 words, 20% adjectives = 3000 words, 20% verbs = 3000 words, and 55% nouns = 8250 words); for three-word sentences we have $8250 \times 3000 \times 8250 \approx 2 \times 10^{11}$ combinations. The task is to recognize if a given sentence is meaningful, and then give the respective answer as "yes" or "no". So, clearly for three-word sentences, today's both AI-based machines and the human brain can do this because $2 \times 10^{11} < 2.4 \times 10^{15}$. Nevertheless, for five-word sentences the calculation (by adding adjectives for the nouns) leads to $2 \times 10^{11} \times 3000 \times 3000 \approx 2 \times 10^{18}$ combinations, which clearly exceeds the capacity of 2.4×10^{15} different states. This means, a simulation of an artificial neural network on a computer with 100 billion neurons, 1000 synapses per neuron and 4.6 bits per synapse would not be large enough to associate different responses for each possible five-word sentence but could only do it for three-word sentences (Nikolić, 2017, p. 537).

Nevertheless, we all know that for humans it is very easy to distinguish five-word sentences. As Nikolić (2015, 2017) shows, a theoretical explanation for the human brain's capability to solve the respective task lies in its architecture: the so called *ideatheca* (Nikolić, 2015, 2017) stores abstract knowledge and concepts and might have a capacity of 10^{12} states. This storage of concepts is used to adapt the properties of our neural network-in-use to recognize signals, for example, five-word sentences. Assuming that the neural network in charge to recognize signals has a capacity of "just" 10^{10} states, a combined system is created where ideatheca adapts the properties of the recognizing network within less than a second (Nikolić, 2015, 2017). Such a kind of a hierarchical structure, where ideatheca adapts the properties of the sensory network, would have a capacity of $10^{12} \times 10^{10} = 10^{22}$ states (Nikolić, 2015, 2017), clearly higher than the capacity of today's AI. Nevertheless, this hierarchical structure explains how and why the human brain can generate the required capacity to interpret input signals using semantic information.

Now, one could argue that technological advance will lead soon to systems with the required capacity—and then the nightmare would be back. Fortunately, this is impossible as long as AI technologically is based on the theoretical concepts of the Turing machine—as all computers today are (Holten, 2003, 2007; Holten & Rosenkranz, 2011): the fundamental operation underlying linguistic communication, called predication (Kamlah & Lorenzen, 1984), has to combine signs and meanings, and deals with sets which are not recursively enumerable. An operation of this type cannot be computable due to limitations of the Turing machine. Predication creates a term *t* by combining a sign *id* and a concept *c*:

$$\mathrm{t} = (\mathrm{id}, \mathrm{c})$$

Assume the concept *c* is encoded by taking every element p from an infinite but ordered set of parameters *P* and assign a suitable instance *i* from set I_p for that parameter. Parameters and instances are encoded as "0" and "1" in ascending order:

$$\begin{aligned} &\mathrm{p} \in \mathrm{P} = \left\{0^{\mathrm{k}}, \mathrm{k} \in \mathbb{N}\right\}, \\ &\mathrm{i} \in \mathrm{I_p} \subseteq \left\{1^{\mathrm{j}}, \mathrm{j} \in \mathbb{N}\right\} \end{aligned}$$

Using symbol "○" for concatenation, every concept is then encoded as a zero-one string of the following form:

$$\mathrm{c} = \bigcirc_{\substack{\mathrm{p} \in \mathrm{P} \\ \mathrm{i} \in \mathrm{I_p}}} \mathrm{pi}$$

The set of parameters has to be infinite because every potential characteristic of a concept has to be defined to separate it from any other concept. Yet this potentiality is infinite and therefore the code for every concept has to be infinite:

$$\left| \bigcirc_{\substack{p \in P \\ i \in I_p}} pi \right| = \infty$$

Transform these codes into the set of integers using two simple functions:

$$f_1 : I_p \rightarrow \{0, 1\} : f_1\left(1^j\right) = \begin{cases} 0, \text{ if } j = 1 \\ 1, \text{ if } j > 1 \end{cases},$$
$$f_2 : P \circ I_p \rightarrow I_p : f_2(pi) = (i)$$

Taking for simplicity *id* = 0, we see for every *c* and *t* = (*id, c*) that the concatenation of these functions yields a binary encoded real number between zero and one, and that (in principle) every real number in this set can be selected:

$$f_2 \circ f_1(t) \in [0, 1[\subset \mathbb{R}$$

Since we know that this subset of real numbers is not recursive enumerable, that is, this set cannot be enumerated by a Turing machine and therefore there cannot be an algorithm doing this (simply spoken: computers cannot do it!), we can conclude that predication as the operation we are interested in is not (Turing) computable.

5 Absolution and Salvation

We conclude that because of recent theories describing the functionality of the human brain and the above model of the fundamental operation the human capability of speech and language is based on, AI-based machines building on the Turing machine will never be able to structure the unknown. These kinds of AI will never exercise power over humans in the sense of the above mentioned nightmare. We conclude: the Power of Structuring the Unknown—persists a Unique Human Capability! Of course, the case may be different for quantum computers. But that is a thought for another day!

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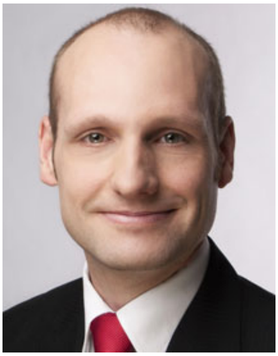

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Digital Technology and Structure

Stefan Seidel

1 Digital Technology: The Defining Ingredient of the Digital Age

Jörg Becker's statement "strukturieren, strukturieren, strukturieren" ("to structure, to structure, to structure") has been famous among Information Systems (IS) students in Münster for many years, and I have heard it often since my time as an undergrad. Jörg's ambition has always been to make sense of—and actively design—the complex world of organizations and digital technologies. In line with this ambition, the Oxford Dictionary (2018) defines *to structure* (the verb) as the process to "construct or arrange according to a plan; give a pattern or organization to" and *structure* (the noun) as "the arrangement of and relationship between the parts or elements of something complex."

But what do *to structure* (an activity or process) and *structure* (presumably the outcome of this activity or process) actually mean in the digital age? In this short essay, I provide some reflections on digital technology through the lenses of *to structure* and *structure*, which have been part of the lexicon of IS scholars for a long time and are useful to contemplate about the challenges of studying digital technologies. Perhaps Jörg would agree with my observations.

The digital age is characterized by pervasive digital technologies that are deeply embedded in products, services, and processes (Yoo, Boland, Lyytinen, & Majchrzak, 2012) and that impact on individuals, organizations, and society. Digital technologies are characterized by two key properties: their reprogrammability and the homogenization of data through binary representation (Yoo et al., 2012; Yoo, Henfridsson, & Lyytinen, 2010). They are increasingly pervasive as digital capabilities are incorporated into objects that used to be purely physical (Porter & Heppelmann, 2014; Yoo et al., 2012); example applications include smart factories, smart buildings, smart

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farms, smart watches, and many more. Understanding pervasive digital technologies involves understanding both their physical materiality (i.e. artifacts that can be seen and touched) *and* their digital materiality (i.e. software for manipulating digital representations) and how they interact with the environment (Yoo et al., 2012). Materiality refers to those properties of an artifact that are relatively stable and do not change from one moment to the next—which does however not mean that they do not change at all (Leonardi, 2012), as evidenced by the many updates we receive on our smartphones or laptop computers or the constant influx of new apps that enhance their functionality. This confluence of physical and digital materiality, their rapid development, and the emergence of combinatorial innovations based on digital technologies (Yoo et al., 2012) pose challenges to understanding how digital technologies are more and more deeply embedded in the social and material world around us. We can use the notion of *(to) structure* (both as noun and verb) to make some key observations:

- Digital technologies *have structure*, they are arrangements of material properties.
- Digital technologies *are related to,* and *deeply embedded in,* structures such as organizational structures.
- Digital technologies *can be structured*, referring to the activities involved in combining and recombining their material properties in the process of designing and implementing digital technologies.

The three perspectives are interrelated. Next, I explore these three perspectives; for each, I suggest a set of challenges for IS research. I conclude with a brief outlook.

2 Strukturieren #1: The Structure of Digital Technologies

Digital technologies are characterized by their materiality (Leonardi, 2012; Leonardi, Nardi, & Kallinikos, 2012) and we can define the structure of digital technologies as *the arrangement of their material properties.* The structure of digital technologies is malleable and changeable (because of their re-programmability and the homogenization of data). In light of the pace of digital innovation and the rapid emergence of smart connected products (Porter & Heppelmann, 2014) one might conclude that the structure of digital technologies is in constant flux. Still, it is also clear that we *can* say something about the structure of digital technology at any given point in time, and digital technologies have a certain stability (Faulkner & Runde, 2011; Leonardi, 2012). Otherwise there could not be any manuals or instruction material, and teaching information systems would be a nightmare.

In order to say something about the structure of digital technologies, we can decompose them into their constituent parts and identify their material properties at different levels of granularity—as any technology can be decomposed into its constituent parts (Arthur, 2009). This decomposition can be along various dimensions, including the physical and digital elements in cases where digital capabilities are built into physical products. Any analysis must define the scope, that is, what should be included and what should be excluded from the analysis—a challenging task because contemporary digital technology is characterized by evolving platforms (Tiwana, Konsynski, & Bush, 2010) and multi-layered architectures comprising of device layer, network layer, service layer, and contents layer (Yoo et al., 2010). When studying mobile technologies, for instance, what are their boundaries? Should we only consider the smartphone in the user's hand or perhaps the cloud to which a certain app is connected—or perhaps even the millions of smartphones that are connected to that cloud and enable interaction among users? Interventions through digital technology often have unintended—both positive and negative—consequences that might go beyond the defined boundary conditions, thereby providing important research opportunities for the IS field (Watson & Seidel, 2018).

Once the scope is defined, the researcher must make decisions about the appropriate level of abstraction for theorizing about the digital technology and its structural elements. If she only pays attention to idiographic detail without abstracting away from the idiosyncratic structure of the technology at hand, technological change will likely render her analysis meaningless very soon. Theorizing about digital technology should represent the technology's structure in a way that has durability across contexts and time and can thus transcend particular innovations (Watson & Seidel, 2018). An abstract blueprint of a multilayered architecture (Yoo et al., 2010) or a reference model for retail information systems (Becker & Schütte, 2004) are examples of conceptualizations that can be applied to describe a variety of situations involving digital technologies and can be expected to be useful across contexts and time.

Finally, when theorizing about the structure of pervasive digital technologies incorporating digital capabilities into physical products requires the researcher to analyze both physical and digital elements that co-constitute the structure of that technology. A key challenge is whether, and to what extent, physical and digital material properties can be analytically separated. A software that is embedded in a machine—perhaps a smart vacuum cleaner—might be completely useless without the hardware it controls—and the hardware might be useless without its software. Perhaps the hardware cannot even be understood without also considering its software component. Some may argue that we need theoretical lenses that are suited to theorize about the joined, inseparable structure of these cyber-physical systems.

To summarize, we can identify key challenges for the IS field:

(1) Defining the appropriate scope and level of abstraction when theorizing about the material properties of digital technology
(2) Simultaneously analyzing both physical and digital material properties that constitute and co-constitute the structure of pervasive digital technology.

3 Strukturieren #2: Digital Technologies in Structures

Digital technologies not only have structure, they are also *related to*, and *deeply embedded in*, structures, such as organizational structures. Giddens (1984), in the field of sociology, provides a generic definition of structure, where structural properties consist of the rules and resources that human agents use in their activity. These structures enable and constrain human action and, at the same time, they result from human action. In organizations, technology, and thus digital technology, is *one kind of structural property*—it "embodies and hence is an instantiation of some of the rules and resources constituting the structure of an organization" (Orlikowski, 1992). Digital technologies enable and constrain action and they interact with other structural properties. Just consider how your daily work practices are constrained and enabled by the digital technologies as well as structural elements such as the workplace policies you follow. Whether or not an employee has free access to the Internet (reflected in both the technology and in the rules the employee draws on) can make a huge difference in her daily work activities.

Providing an overview of research on the relationship between information technologies and organizations is out of the scope of this short essay. Instead, I would like to briefly discuss an important concept that helps us get at the relationships between users, digital technologies, and indeed organizational structures. The concept of affordance describes action potentials provided by technologies when they are interpreted by a specific user group (Leonardi, 2011; Markus & Silver, 2008). A smartphone, for instance, might afford communication, navigation, shopping, and many other activities—depending on the user group and their interpretation of that technology. Notably, this interpretation of what a technology can be used for in any situation involves drawing on organizational structures (Hultin & Mähring, 2014; Seidel & Berente, 2013)—what a technology affords not only depends on the material properties of the technology, but also, for instance, on the goals, values, and prescriptions an actor draws on (Berente & Yoo, 2012; Seidel & Berente, 2013). Affordances thus provide a conceptual framework for explaining how technologies and organizational structures are involved in providing action potentials that, if enacted, lead to observable practices (Strong et al., 2014; Volkoff & Strong, 2013). The concept of affordance has also been used to explain technological change in organizations (Leonardi, 2011); as the materiality of digital technology changes, so do the affordances.

The concept of affordance can also be a powerful analytical lens in the context of pervasive digital technologies, where digital capabilities are built into objects that used to be purely physical (Yoo et al., 2012). We can thus observe how the confluence of digital and physical materialities provides actionable spaces in light of certain organizational structures. This view can support the IS field in developing theory on the evolution and co-evolution of both physical and digital materialities.

To summarize, we can identify key challenges for the IS field:

(1) Developing theory on the development and (co)-evolution of digital and physical materialities
(2) Identifying the affordances that emerge from the confluence of physical and digital material properties if interpreted in relation to organizational structures.

4 Strukturieren #3: To Structure Digital Technologies

Digital technologies are designed to meet a purpose—at the individual, group, organizational, market, or societal level. This is also reflected in the IS field's interest of not only explaining the role of digital technologies, but also contributing something to the design of digital technologies (Gregor & Hevner, 2013; Österle et al., 2011). The designer *structures* digital technologies. Prescriptive knowledge in the IS field is commonly captured in the form of design principles (Chandra, Seidel, & Gregor, 2015; Gregor & Hevner, 2013), design theory (Gregor & Jones, 2007; Walls, Widmeyer, & El Sawy, 1992), or guidelines (Becker, Rosemann, & von Uthmann, 2000).

Because of their re-programmability and data homogenization (Yoo et al., 2010), digital technologies are malleable and can easily be (re-)combined to spawn new digital innovations (Yoo et al., 2012). Hence, one key question is what design principles remain stable and what design principles change as technology changes. As a scientific discipline, the IS field should proceed to an abstract body of knowledge that provides explanatory and prescriptive knowledge that can be applied across contexts and across time.

With the advent of smart, connected products that are characterized by both their physical and digital materiality, we are confronted with technologies where some elements (typically the digital) can more easily be changed than some other elements (typically the physical), and it can be expected that this will lead to varying rhythm, speed, and iteration in design and development processes, and perhaps even to entirely new design processes and a new understanding of design thinking. As an academic field, we are challenged to explore the design of this new breed of systems.

When designing digital technologies, this design is always in relation to some context that itself is characterized by various structural properties. Designing digital technologies thus requires the consideration of these structural properties along with user characteristics. Instead of assuming that digital technologies deterministically lead to certain outcomes, designers need to incorporate the social and organizational arrangements and *design digital technologies for practice.* It might, for instance, be useful to ask *what material properties of digital technology are likely to afford what action in what context of use*?

Finally, an increasing amount of design tasks that used to be conducted by humans are now conducted by autonomous tools that draw on methods known from the field of artificial intelligence—example application fields include the production of video games, semiconductor chips, or user interfaces (Berente, Lindberg, Lyytinen, & Nickerson, 2019). Digital technologies design digital technologies. It can be expected that this use of autonomous tools will fundamentally change the nature of design, for instance, by moving the control away from the designer towards the autonomous tool (Seidel et al., 2019).

From the perspective of designing (which involves the structuring of information systems by the designer), we can derive a number of challenges for the IS field:

(1) Identifying abstract design principles for digital technologies in an era of rapid technological change

(2) Designing systems consisting of both physical and digital materialities, where some components are relatively easy to change (typically the digital) while some are more stable and more difficult to change (typically the physical)
(3) Designing digital technologies under consideration of structural properties under which they are expected to afford action
(4) Exploring the use of autonomous tools in the design and evolution of digital technologies.

5 Concluding Remarks

Digital technologies are deeply penetrating into products, services, and processes and we see the emergence of a new breed of systems that are characterized by the confluence and co-evolution of physical and digital materialities and the rapid emergence of digital innovations. Clearly, these new types of systems pose challenges for both practitioners and scholars across disciplines and fields.

Inspired by Jörg Becker, in this short essay, I have used *structure* (the noun) and *to structure* (the verb) to contemplate about some of the challenges our field is confronted with, and I have presented a personal perspective on these challenges. By no means do I claim exhaustiveness. Also, others may come up with quite different challenges.

I believe the scholarly IS field has the potential to play a crucial role in shaping the digital age if it focuses attention on (a) developing foundational theory on digital technologies that transcends contexts and time (Grover & Lyytinen, 2015), (b) develops prescriptive knowledge that contributes to developing pervasive digital technologies (Seidel & Watson, 2014), and (c) addresses grand challenges as those related to societal and ecological challenges, as Jörg Becker might argue (Becker, vom Brocke, Heddier, & Seidel, 2015). In all these endeavors, it will be crucial to pay attention to structure in its different roles. Ergo: *strukturieren, strukturieren, strukturieren!*

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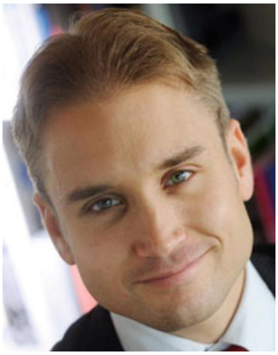

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The Challenge of Structuring Business Informatics as an Academic Discipline

Stanisław Wrycza

1 Introduction

Usually, an Introduction section gives an extensive review and critical analysis of the literature relevant to the subject matter of interest. In this paper, the Introduction is not presented as usual; instead, it is rather untypical. As such, there is no vast review of the thematic references. Such reviews have been performed commonly. I have spent dealing and working with Business Informatics at large, and they can be found by many of my publications. The most important task for this short publication is to present an original concept rather than the extensive review material.

The real sources of the model proposal and the paradigm presented here are as follows:

- the studies and critical analyses in the literature, in particular in the leading information systems/business informatics (IS/BI) journals,
- discussions at the leading IS/BI international conferences and consortia,
- participation in IS/BI research projects,
- assessments of requirements for IS/BI carried out and debated by experts in firms,
- extensive experience teaching different BI courses at the university level.

Through generalizing this knowledge and experience, I take up the main task of this publication—structuring Business Informatics as an academic field—by answering three basic questions:

- What should be structured?
- Why is this relevant to the world?
- How can this be structured?

The answers to these questions are included in the following chapters.

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2 Structuring Business Informatics as an Academic Field

The practical significance and usefulness of Business Informatics (BI) is widely accepted in business and management. The use of different tools and models—-such as CRM, ERP, SCM, WFM, e-business and, more recently, Cloud Computing, Big Data, Machine Learning, m-business and many others—is common practice by numerous firms and institutions worldwide. Paradoxically, this extraordinary experience has not resulted in an established structure of Business Informatics as an academic field. Such efforts have been taken up by many IS authorities, university teams and organizations like AIS (Association for Information Systems), and AIS journals offer a number of diversified proposals; however, the structure of BI as an academic area still is a challenge. As I have studied hundreds of publications regarding Management Information Systems (MIS) and *Wirtschaftsinformatik* foundations, I finally decided to present only the original concept of a BI academic structure in the form of a communication. The concept can be referred to, compared with, and discussed in the context of other proposals and concepts, including those by IS authorities.

This challenge has also been taken up by the Department of Business Informatics at the University of Gdansk in the form of research projects, organization of many international conferences and intensive teaching at the bachelor, master and doctoral levels. On the basis of this broad experience and profound studies of the thematic literature, the proposed structure of Business Informatics as an academic discipline was generated, as shown in Fig. 1. The model is under continuous development because of emerging concepts and whole areas of knowledge that are being absorbed by Business Informatics.

Each academic discipline has a stable canon of theoretical knowledge. Of course, in traditional fields of science, these canons have been established quite a long time ago in past decades or even centuries. Business Informatics is still an emerging academic discipline, as it is subject to ongoing research disputes that have been and still are observed and studied in the leading IS Journals, in particular in the "Senior Scholars' Basket" of IS Journals.

In the current article, critical analysis of the reference literature has not been performed because of the extremely extensive scope of material that would have to be reported in this short paper. However, the results and conclusions derived from the many studies and critical analyses of the versatile theories and approaches have been synthetized in Fig. 1, the proposed structure for the academic field of BI. While this proposed structure can be the subject of discussion for IS scholars, it should also be considered as dynamically changing, owing to the transformation of both digital technology and business. The pace of these changes is quickening. The first version of this paradigm was presented in the book *Business Informatics* (Wrycza, 2010). Graphically, the concept is shown as a circle surrounded by concentric rings; the rings structure the subfields of business informatics knowledge, starting with the fundamental, generic concepts in the inner rings and continuing on to more detailed and supporting concepts in the outer rings.

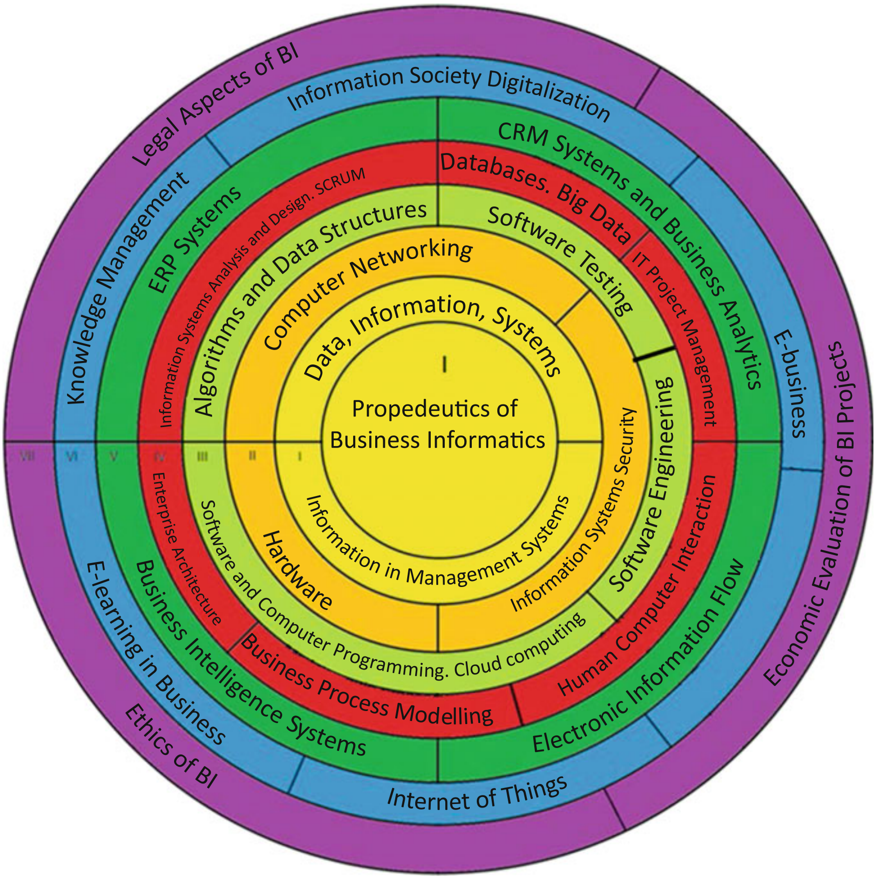

Fig. 1 The proposed structure of Business Informatics as an academic discipline

Each academic discipline should have its propedeutics, so the propedeutics of Business Informatics is in the centre of our discipline. Its prerequisites and content have been elaborated and explained for the academic community in Poland by Professor J. Becker (Becker & Lis, 2010) in the first chapter of Wrycza (2010). Starting from the centre, the succeeding subfields are structured as follows (compare also Fig. 1):

1. Theoretical Fundamentals of Business Informatics
    1.1. Propedeutics of Business Informatics
    1.2. Data, Information, Systems
    1.3. Management and Information Systems
2. Information Technologies
    2.1. Hardware

   2.2. Computer Networking
   2.3. Information Systems Security

3. Software

   3.1. Algorithms and Data Structures
   3.2. Software and Computer Programming. Cloud computing
   3.3. Software Testing
   3.4. Software Engineering

4. Information Systems Development

   4.1. Enterprise Architecture
   4.2. Business Process Modelling
   4.3. Human Computer Interaction
   4.4. Information Systems Analysis and Design. SCRUM
   4.5. Databases. Big Data
   4.6. IT Project Management

5. Information Systems in Management

   5.1. ERP Systems
   5.2. CRM Systems and Business Analytics
   5.3. Business Intelligence Systems
   5.4. WorkFlow Management

6. Digital Economy

   6.1. Knowledge Management
   6.2. Information Society Digitalization
   6.3. E-business
   6.4. Internet of Things
   6.5. E-learning in Business

7. Economics, Law and Ethics in BI

   7.1. Economic Evaluation of BI Projects
   7.2. Legal Aspects of BI
   7.3. Ethics in BI

The proposed structure of BI presented here is not fixed, but it is stabilized by the classical subdisciplines of BI, such as, first and foremost, the Propedeutics of BI and then Information Systems Development (part 4) and Managerial Information Systems, like CRM, ERP, WFM (part 5). In the second edition of the book (Wrycza & Maślankowski, 2018), new subareas were added to this stabilized kernel, i.e., Internet of Things. At the same time, almost every subfield was enriched and extended to include current challenges, methods, techniques, and tools such as Cloud Computing, Agile methods, SCRUM, Big Data and many other new concepts. In this way, the model of the business informatics structure presented in Fig. 1 reflects and the field's

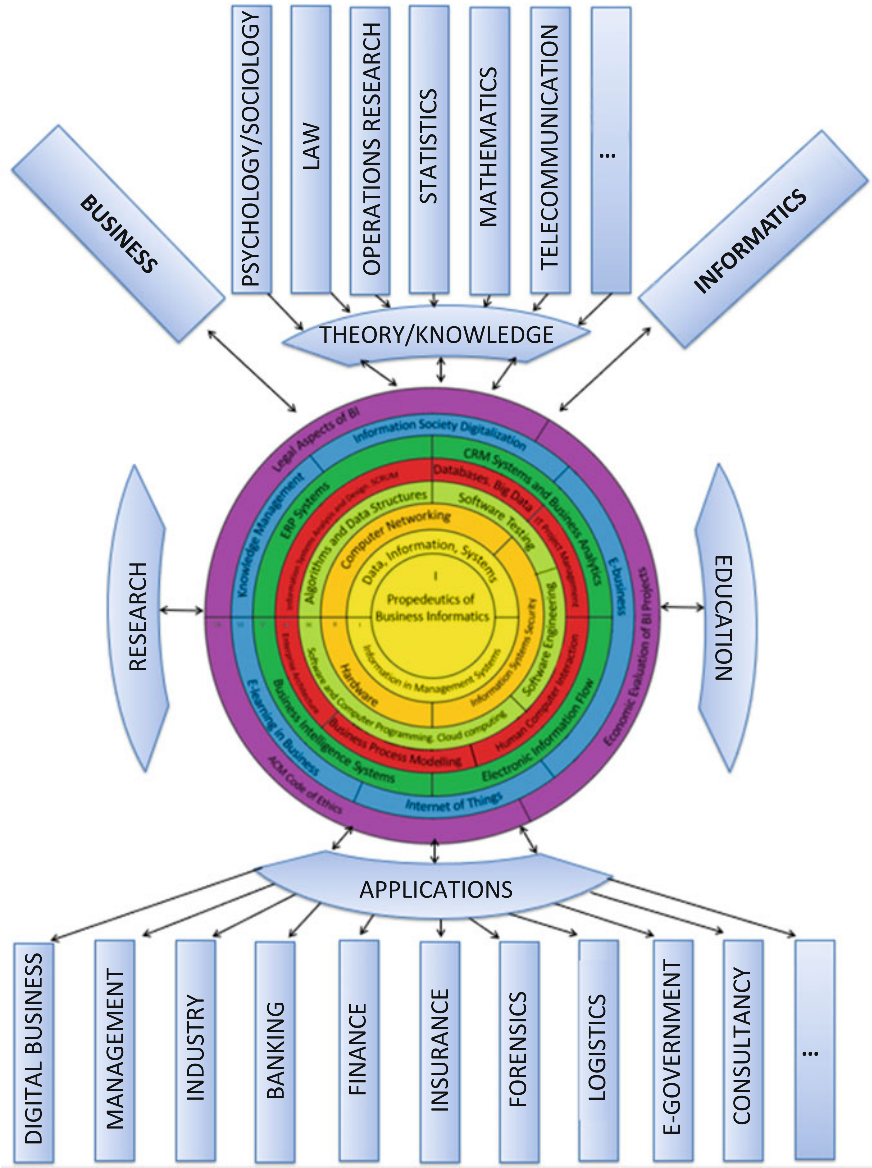

Fig. 2 The ecosphere of Business Informatics

dynamic nature and is clearly adaptable to current challenges, new knowledge and new technology.

3 The Ecosphere of Business Informatics

The proposed paradigm of BI structure can be considered in the wider ecosphere, which includes the influence of the following (compare Fig. 2):

- Theory/New Knowledge,
- Applications of BI,
- Research in BI,
- BI Education.

This ecosystem relies on mutual dependence among the main components. Just to describe them briefly –strong interrelations exist between business informatics and its applications. As shown in Fig. 2, BI is applied in many fields of business and administration; the most important fields have been selected and are shown here. Currently, the most rapidly growing field for BI application is in digital business. Regarding the basis of BI theory/new knowledge, Business Informatics takes inspiration from many related scientific disciplines, where the most important are economics (business) and informatics. In education, BI is taught at many universities worldwide, and many IT training and consulting firms offer thousands of courses.

Analysing Fig. 2 shows that many discrete variables, challenges, and emerging phenomena influence and thus change Business Informatics as a field, almost daily. However, for BI to be of interest and supported by academia and businesses, it will require certain stability or at least sustainable growth. Will Business Informatics be able to cope with this ever more difficult task? Will it remain a respected academic field by society? Or will it lose its identity in a growing wave of digital transformation? Good questions…

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Part II
Models

"It is not hard to compose, but is fabulously hard is to leave the superfluous notes under the table." (Johannes Brahms)

Concerning process models, it is still an ongoing discussion and challenge to find the right level of detail. Depending on the intended use case of a conceptual model, i.e., documentation, process-oriented reorganization, simulation, benchmarking, or software development, different details are important while others need "to be left under the table".

Linguistic Structures in the Light of the Digital Transformation: Addressing the Conflict Between Reference and Change

Ulrich Frank

1 Introduction

We are in the middle of a gigantic transformation that is unprecedented in the history of the humankind. While we do not know what the exact outcome of this transformation will be, it seems obvious that it will result in fundamental changes. It will not only change the way we work and live, but, also, how we learn, speak—and think. Change of this dimension leaves many puzzled, is perceived as a threat by not only a few, and regarded as a fabulous opportunity by some. As researchers in Business Information Systems we have the privilege to not only study the digital transformation and the manifold phenomena it creates, but also to be among those who are asked for advice with respect to shaping the transformation for the good of society. Therefore, the digital transformation does not only create fascinating research questions, but also a serious responsibility for researchers in our field. This situation demands for asking essential questions regarding the subject and objective of research in Business Information Systems. First, the prevalent model of research in Information Systems focusses on studying the actual use of information technology and its development. Following the impressively successful neo-positivist model of research in the natural sciences, it aims at describing and eventually explaining observable phenomena. For this purpose, hypotheses that were derived from theories are tested against empirical data. While this approach is convincing at first sight, because it corresponds to a wide-spread understanding of science, it is accompanied by serious doubts about its suitability. They comprise principal differences between social systems and nature, the peculiarities of human cognition and thought, and philosophical concerns about the applicability of the correspondence theory of truth. Against the background of the digital transformation, there is a further concern that might be even more convincing than epistemological or methodological objections: is it sufficient to study the

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present to develop attractive and feasible orientations for change? Can the structures that are identified with current patterns of developing and using information systems be applied to future systems and their use, too? Are they sufficient to develop images of a future world that could inspire the transformation? I am skeptical that this will be the case. Since there are no theories that would allow for predicting the future, it is a daring and careless, if not irresponsible assumption that the future will be an extrapolation of the past. A second, more specific question relates to the design of business information systems. The development of methods and tools for supporting analysis and design is at the core of research in Business Information Systems. Is it appropriate to use comprehensive analysis and design methods in times of disruptive change, where yesterday's requirements may be outdated today already? With respect to the development of business information systems, conceptual models have been for long the undisputed instrument of choice. In particular, reference models that serve as a foundation of a wide range of software systems are especially promising (Becker, Delfmann, & Knackstedt, 2007, Becker, Algermissen, Niehaves, & Delfmann, 2005, Fettke & Loos, 2007). They are not only an attractive research topic. Furthermore, they offer substantial benefits for organizations, too. The reuse of thoroughly developed conceptual models enables better software systems at lower costs. However, in recent years, this assumption has been challenged, especially by the proponents of so-called "agile" approaches. This brings us to a further essential question. Is it still appropriate to focus on conceptual models or are code-oriented approaches better suited to cope with the peculiarities of an ever-changing world?

To analyze these questions, I will at first look at a principal need of all systems, technical and social, to work properly and to satisfy economic constraints. Without reference, systems cannot survive. They would not allow for communication and integration, would not enable the evolution of economies of scale, and without reference, software systems would literally make no sense. Second, I will look at the need for designing information systems that are facilitators of change rather than inhibitors. At first sight, the need for reference, and the need for supporting change are in conflict. However, as I will try to show, there are ways to substantially relax this conflict. They do not only depend on the development of powerful abstractions, but also on education programs that emphasize the prospects of abstraction.

2 The Need for Reference

There is no communication without reference. The words or signs we use to express a thought need to refer to concepts that we share (or assume to share) with the recipients of our messages. Software systems depend on reference, too. This applies in two respects. First, the words used in program code refer to (virtual) memory locations, types, instructions, etc. Second, to make sense of software and, hence, to use it properly, it needs to include references to concepts its users are familiar with. This is typically achieved through words or signs used in the domain where a program is deployed. For communication, and for software to work properly, references must be reliable. References must not be corrupted, e.g. by redirecting them or by deleting the referenced concept or artefact. In other words, references should be stable.

2.1 *The Pivotal Role of Conceptual Models*

Software systems are linguistic artefacts. Their development requires some kind of implementation language, the constructs of which are mapped to the instruction set of a computer. In an ideal case, there is a formal implementation or specification language that allows taking advantage of formal methods to ensure that the software satisfies its requirements and is free of contradictions. However, apart from pure formal semantics, a formal representation does not include any meaning. In particular, it does not help with analyzing requirements and mapping them appropriately to a software architecture. For understanding a domain, to communicate about it, and for eventually re-organizing it, it is essential to use concepts that make sense to us and that are suited to guide us with appropriately structuring it. To serve this purpose, conceptual modelling makes use of modelling languages that allow referring simultaneously to concepts of implementation languages and to concepts of the language used in the targeted domain. Concepts of the domain language need to be reconstructed with the concepts offered by the modelling language. Figure 1 illustrates the role of conceptual models that are specified with a general-purpose modelling language (GMPL).

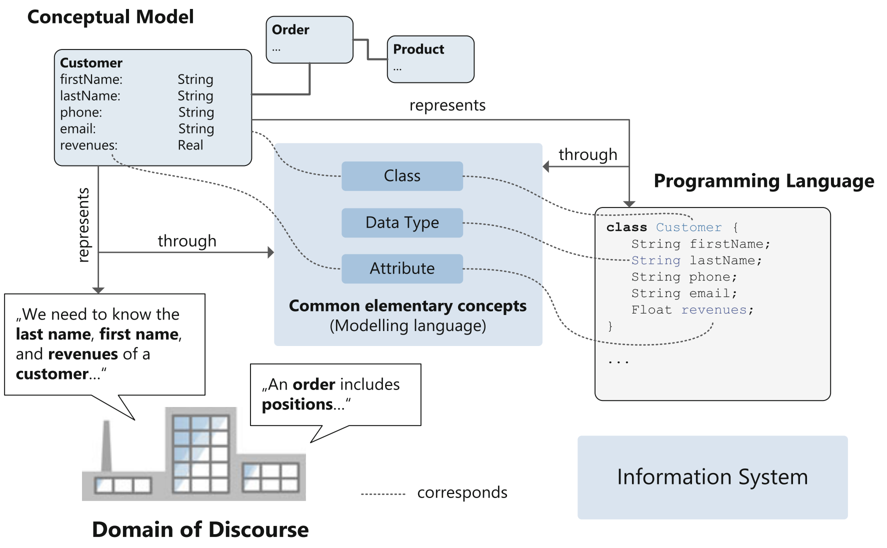

Fig. 1 Illustration of conceptual modelling

There have always been students and even professional programmers who claim that they would not need conceptual models. They are wrong. While it is conceivable to write code without drawing a diagram that represents a conceptual model, writing code without a model of the domain is not possible. Doing without conceptual models would mean doing without thinking: "But besides intuition there is no other kind of cognition than through concepts." (Kant, 1998, B93, A 68). It would also mean to ignore the pivotal relevance of codified knowledge: "Models are proffered truths. To proffer truth is the human means of acquiring knowledge. In this sense, cognitive acquisition, human learning is essentially mediated by representation." (Wartofsky, 1979).

A conceptual model serves as a reference in various ways. First, it provides a common representation for developers and prospective users they can refer to in order to reduce the chance of misunderstanding. Second, it can be used as a common reference by various development teams in order to foster cross-application reuse and integration. The benefits of conceptual modelling are accompanied by serious challenges. From an economic perspective, it is the question how much effort is justifiable for the development of conceptual models, and how this effort can be reduced. From an epistemological perspective, it is a challenge to assess the quality of a model, or, in other words, the quality of the knowledge represented by a model. From both perspectives, it is relevant to know how conceptual models need to be designed to enable flexible information systems that allow the convenient adaptation to changing requirements.

2.2 The Ambivalence of Semantics

Reuse is the most promising approach to reduce development costs. There are two principal approaches to promote reuse in conceptual models. Both approaches can be combined. Reference models cover a range of possible applications. At best, a reference model can be applied directly without adaptations. Domain-specific modelling languages (DSML) provide modellers with domain concepts (see Fig. 2). Hence, they narrow the gap between a domain and the representation of a corresponding software system. Thus, they foster modelling productivity and model quality. While GPML allow for designing any kind of model, even the most absurd ones, a DSML excludes models that violate the embedded domain-specific constraints.

Developing reference models with a DSML is especially promising, because it facilitates safe and convenient customization. However, designing a reference model or a DSML for reuse is confronted with a serious challenge. It is related to principal conflicts. On the one hand, there is a conflict between range of reuse and productivity of reuse. On the other hand, there is a conflict between stability of references and flexibility. The more specific a model artefact, or the concept of a modelling language, is, in other words, the more domain-specific the semantics it includes, the better it is suited to foster productivity of reuse. However, at the same time, specific concepts are limited to a certain context, that is, their range of reuse, and, hence, the

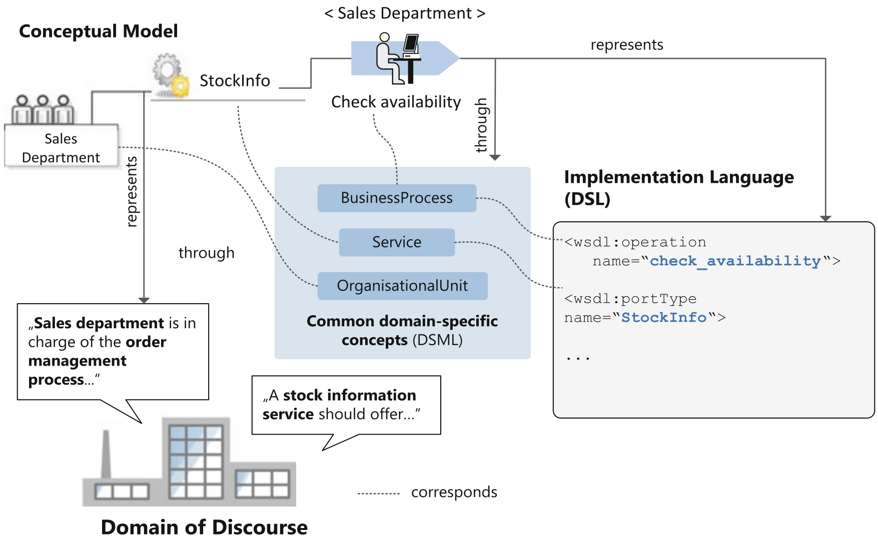

Fig. 2 Illustration of DSML

economies of scale they enable are restricted. To justify investments, reference models and modelling languages should be stable. At best, they should be standardized. However, at the same time, a standard may be an inhibitor of change, because the costs to abandon a standard may be prohibitively high. The more specific a model or a modelling language is, the more likely it is that it will not last for too long in an ever changing world.

The ambivalent nature of semantics also affects another pivotal aspect of information system design. Integration of system parts requires common concepts that all parts can refer to in order to communicate. The more specific these concepts are, the more effective communication will be, or the higher the level of integration they enable. Take, for example, two systems that exchange data, which represent products. If a product is represented by a string only, it can be mistaken for anything. The more semantics is incorporated in the representation, the better are the chances for the receiver to apply an appropriate interpretation. At the same time, the range of integration will decrease, since only components can be integrated that include references to a specific concept.

Against the background of this conflict, it seems reasonable to follow a widespread rationale of systems design, which is reflected by the slogan of “loose coupling” and by technologies such as service-oriented architectures. Components that are coupled via interfaces with little semantics only, e.g., XML documents, can be replaced by a wider range of other components that can cope with those interfaces, too. At the same time, such an approach is not satisfactory. On the one hand, it leads to redundancy across loosely coupled (badly integrated) components, which would compromise maintainability. On the other hand, it seems strange that the efficiency of communication between components is reduced. Who wanted to communicate in a language consisting of a few primitive concepts such as string, integer, etc. only?

3 Coping with Change

Conceptual models are sometimes seen as inhibitors of change. With respect to the effort and time it takes to create a comprehensive model, it is not beside the point to suppose they are already outdated at the time when they are released. Against this background, it does not come as a surprise that conceptual modelling has been discredited during the last years. At the same time, other approaches to cope with change have gained remarkable attention. They are based on the assumption that top-down approaches that demand for a comprehensive conceptualization before the implementation starts are not feasible or that having them done by humans is too expensive and too slow.

3.1 Agile Approaches to the Rescue?

About 20 years ago, a book on "extreme programming" (Beck, 2000) became a driver of a movement that had a remarkable impact on the practice of software development. Based on a manifesto of 12 principles, the proponents of so called agile approaches promised to uncover "better ways of developing software by doing it and helping others do it." (Agile Manifesto) They addressed various critical issues that the academic field of software engineering had widely ignored. Software development is not a mere engineering task. Instead, its success depends on communicating with customers, on collaboration, on budgets, management support and—on good software developers. While stressing the importance of these factors can be seen as an enrichment of traditional approaches to software development, a further aspect of the manifesto represents a radical criticism of software engineering. Software engineering is based on the assumption that the comprehensive design of a system before its implementation is a prerequisite of avoiding mistakes. Taken to the extreme, it means that programming is the task of proving an implementation against a given specification (Dijkstra, 1972). The proponents of agile approaches favour testing over proving, and, more important, the early realization of working software is given top priority. They do not deny that starting early with partial implementations bears the risk of missing requirements. However, they assume that requirements will change anyway. Therefore, they recommend turning a necessity into a virtue: "Welcome changing requirements, even late in development." (Agile Manifesto) To cope with changing requirements, they propose refactoring patterns (Fowler & Beck, 2010), which address certain change requests.

The agile movement is an enigmatic and ambivalent phenomenon. There is no doubt that it has been very successful. Many companies regard it as a necessity to implement agile processes—or at least to pay lip service to them. Who wants to blame developers that they prefer working in agile teams rather than in bureaucratic organisations? Focussing on customer needs, on communication, on organisational culture, or on testing, is certainly important. However, it seems bizarre that a software development approach, which is supposed to guide intelligent people, has facets of a religion, or, as Meyer ironically remarks: "With agile methods you are asked to kneel down and start praying." (Meyer, 2014, p. viii) Apart from that, it is the question whether agile approaches are the preferable way to cope with change. Analysing this question recommends to ask what it means to be agile. While the literature on agile approaches lacks a deep reflection of this question, it seems that it mainly emphasizes two aspects: agility as the ability to develop working solutions in time and to successfully cope with change. It is, however, not clear, what it takes to be agile. Preaching the slogan "embrace change" (Agile Manifesto) like a mantra is certainly not sufficient. No reasonable software developer will embrace changing requirements at a late stage in development (Meyer, 2014, p. 140). It is also daring to assume that "best architectures, requirements, and designs emerge from self-organizing teams." (Agile Manifesto) "Responding to change over following a plan" (Agile Manifesto) is a strange advice, too. On the one hand, it is worthless as long as it remains unclear how to respond adequately to change. On the other hand, it represents a radical criticism of one of our most valuable cultural assets, that is, the idea of rationality. However, it seems that the principles of the manifesto are not to be taken as too literal. The refusal of plans and documentation is often seen as an advice against models. But the manifesto does not explicitly offer such an advice. To the contrary, the memorandum includes a somewhat unmasking principle, too: "Continuous attention to technical excellence and good design enhances agility." Hence, the proponents of agile methods are not so insane as to recommend the abandonment of conceptual models. Furthermore, they are smart enough to identify a key success factor of agility: qualified and reflective developers. To attract those was probably one of the key drivers of the marketing campaign for agile approaches. Our brief analysis shows that apart from certain undisputed virtues, agile approaches do not represent a silver bullet to cope successfully with change. While they may supplement conceptual modelling, they are definitely not suited to replace it.

3.2 Prospects and Limitations of Induction

When it comes to flexibility, the largest information system of all times is probably the undisputed champion. Since its emergence in the early nineties of last century, it has not only grown in volume at a breath-taking pace, but also with respect to the spectrum of information and knowledge it represents. This kind of flexibility was enabled by an obvious violation of a fundamental principal of information system design. The qualification of data through types (or a schema) is of pivotal relevance for system integrity. Types serve to define semantics of data, that is, the range of possible values and a set of operations. The early versions of HTML, however, did not support data types apart from strings. Therefore, when I first came across HTML, it appeared to me like a fall-back into the stone-age of data processing, hence, like a big mistake. However, my judgement was inappropriate, because I did not realize that the simplicity of HTML and renouncing integrity were key enablers of flexibility and growth. Virtually every piece of information can be represented as string. Setting up a simple HTML document can be done quickly (and does not require an elaborate conceptual model), and changing it is not confronted with serious integrity constraints. Of course, this kind of flexibility does not come without a price. The lack of semantics makes it impossible to use HTML for serious data processing. It is also an obstacle to reliable information retrieval. Despite the impressive power of search engines, they do not enable the specification of elaborate queries that would allow to clearly identify the intended results. On the one hand, this is caused by the poor formal semantics of the representation. If it consists of strings only, a query that aims at finding all sales prices of a certain product below a specific value cannot be expressed, because that would require relational operators on numbers. On the other hand, data types alone would not solve the problem as long as there is a huge variety of conceptualizations (e.g., of products) and names referring to these concepts.

There are various approaches to address this limitation of HTML. Semantics of web pages can be enriched by annotating web pages with words of a standardized vocabulary that refer to entries of an ontology, such as, e.g., *schema.org*, that is supposed to represent a comprehensive net of relevant concepts. In addition, formal languages such as RDF or OWL were suggested to represent content within web pages. They do not only allow for the specification of advanced concepts, but enable deduction, too. Thus, more elaborate queries and machine analysis is possible. However, as long as only a fraction of web contents is enhanced by semantic web technologies, corresponding queries are likely to produce incomplete results. At the same time, updating existing web pages, the number of which is growing every second, ex post, is a Sisyphean task that is likely to create frustration. To cope with this challenge, statistical approaches to infer schemata inductively from data have been proposed in the semantic web community (e.g. Hellmann, Lehmann, & Auer, 2008; Völker & Niepert, 2011). While these approaches did not take off so far, the revival of artificial intelligence in general, of machine learning in particular, led to an optimistic, if not enthusiastic appraisal of inductive approaches, especially those enabled by various kinds of neural networks. According to its proponents, machine learning is suited to revolutionize the process of scientific inquiry, namely the creation of theories and hypotheses (Evans & Rzhetsky, 2010; King et al., 2009). Pentland even predicts the end of the social sciences (Pentland, 2015). With the increasing availability of data on social behaviour, machine learning could be used to discover invariant patterns that would enhance the body of scientific knowledge. According to Domingos, the demanding act of knowledge acquisition and conceptualization, which is at the core of conceptual modelling will be widely automated soon: “In industry, there’s no sign that knowledge engineering will ever be able to compete with machine learning outside of a few niche areas.” (Domingos, 2017, p. 25). As a consequence, the ability to change information systems quickly would be substantially advanced.

Many will probably feel uncomfortable with this vision of replacing scientists and system analysts by machine learning algorithms. But how realistic is it? There are indeed some impressive results of machine learning approaches such as the ex-post discovery of physical laws (King et al., 2009) or machine translation. However, there are serious arguments against the exuberant optimism shown by proponents like Domingos. Conceptual modelling does not just aim at finding some structure. Instead, the linguistic structure, that is, the concepts that are required depend on the purpose the targeted program should serve. This purpose is intentional and can hardly be accounted for by inductive procedures. Furthermore, for software to be usable, it needs to be represented through concepts its prospective users are familiar with. That requires accounting for the language they speak, instead of generating artificial concepts that reflect some kind of commonalities shared by large amounts of data. The strongest argument against the automation of conceptual modelling is directed at the core of inductive reasoning. Induction depends on existing data and concepts. The future, however, may be clearly different from an extrapolation of the past, especially in times of disruptive change. This does not only relate to data, but to the concepts that will emerge to enable, and to cope with future technologies and patterns of using them. In other words, the future is a (linguistic) world that is different from the world we live in. If we assume that change is contingent, we cannot predict the future. Instead, we could develop ideas of possible future worlds that could serve as an orientation for change. Domingos fades this challenge out by emphasizing a naïve realist worldview: "We're only interested in knowledge about our world, not about worlds that don't exist." (Domingos, 2017, p. 25).

4 Prospects of Abstraction

We cannot think without concepts, and we cannot develop software without conceptual models. At the same time, the design of conceptual models is confronted with a serious conflict. On the one hand, a conceptual model should serve as a stable and reliable reference. This aspect is in favor of "freezing" concepts (Hoppenbrouwers, 2003). On the other hand, models that cannot keep up with an ever changing world may impede progress. There is no recipe to eliminate this conflict. However, there are ways to clearly relax it.

4.1 Higher Level Models

Although conceptual models may compromise the adaptability of information systems, they are also mandatory for preparing us for change. Representations in general, conceptual models in particular serve us to develop not only an understanding of the world we live in, but also of possible future worlds: „Mit Modellen machen wir uns die Wirklichkeit des Vergangenen und die Möglichkeiten des Zukünftigen zur

Gegenwart."[1] (Mahr, 2015, p. 329). However, not every model is suited to support us with developing ideas of possible future worlds. At the same time, there is need for models that represent the present world in a sensible way to support the realization of software systems that fit today's requirements. This challenge is similar to the conflict we identified for the design of DSMLs, that is, the conflict between range of reuse and productivity of reuse. To promote range of reuse, a DSML should not be too specific. To promote productivity, it should be designed to specific purposes. How could models and modelling languages respectively look like to serve both purposes? There is, of course, no definite answer to this question. However, the structure of natural and technical languages as it has evolved in advanced societies may serve as an orientation. There are layers of concepts that built on each other. More specific languages reuse concepts defined in more general languages. At the top of this hierarchy are the concepts used in scientific disciplines followed by concepts that represent textbook knowledge. Those concepts are then refined step by step to suit more specific purposes. At the top level the range of reuse, that is, the range of possible applications, is large. At the bottom level, the range of reuse is small, but the productivity gain enabled through reuse, is high. Thus, such a hierarchical architecture of languages would not only enable to relax the conflict between range of reuse and productivity of reuse, but would also allow building information systems that satisfy current requirements and being open to change at the same time. The exemplary hierarchy of concepts in Fig. 3 illustrates this idea. The more abstract a language is, the wider is the range of possible instantiations it allows for, since it cannot only be instantiated directly into a more specific language, but also indirectly into further instances of its instances, etc. With respect to preparing for change that creates clearly more flexibility. If only small changes of a model (or a language) are required, they could be achieved on the very level of that model, e.g. by adding or modifying properties. If more comprehensive changes are needed, one could think of creating a different instance from the corresponding meta-model, that is, one would stay within the scope of the same language, but the particular concepts specified with this language would change. For more radical types of change, one could go further up the classification level and create new higher level models/languages.

Prevalent architectures of information systems are restricted to one or maybe two classification levels only. Hence, they do not allow for multiple levels of languages/models that are integrated in one model. A different paradigm is required to enable that. Multi-level modelling (Atkinson & Kühne, 2001, Frank, 2014) which extends object-oriented languages, is one approach that does not only enable modelling an arbitrary number of classification levels, but that is also supplemented with corresponding (meta-) programming languages (Clark, Sammut, & Willans, 2008). It is based on a recursive, self-reflective language architecture. Among other peculiarities, it introduces a new kind of abstraction that combines generalization and classification. The concept *Saddle SR1* in Fig. 3, for example, would inherit an attribute like *weight* from the corresponding meta-concept *Saddle*. At the same time, it would instantiate the attribute *color* into "black".

[1] "Through models we take the reality of the past and the possibilities of the future into the present."

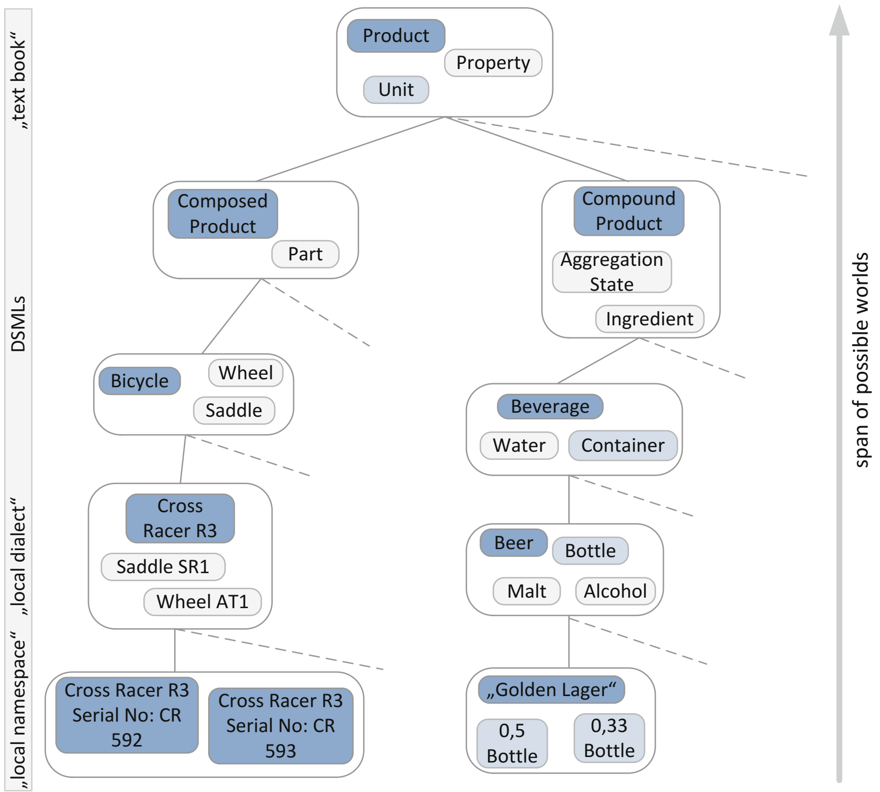

Fig. 3 Illustration of a multi-level model/language hierarchy

4.2 "Higher" Education

While increasing the flexibility of software systems is a major prerequisite of coping with change, it is not sufficient. "Technology creates possibilities and potential, but ultimately, the future we get will depend on the choices we make." (Brynjolfsson & McAfee, 2014, p. 256). It is widely undisputed that being able to make the right choices, hence, being able to benefit from the digital transformation instead of suffering from it depends chiefly on education. It is also acknowledged by many that there is need for new, more efficient ways of teaching and learning (Davidson, Goldberg, & Jones, 2010, Brynjolfsson & McAfee, 2014). It is, however, not clear what education should aim at to improve the ability to cope with change. In his conception of change, Bateson takes on the concept of motion in physics: "Change denotes process. But processes are themselves subject to "change"." (Bateson, 1972, p. 283) Hence, it makes sense to distinguish different orders of change. Based on these considerations, Bateson develops a theory of learning that suggests five different levels of learning, which are characterized by challenging previous knowledge and the processes used to acquire it, hence, by systematically raising the level of abstraction. This kind of learning through abstraction is indeed suited to increase flexibility. If, e.g., our knowledge is restricted to conceptualize our surroundings in a specific way, we will be in trouble, if we travel other countries with different cultures. If, however, we are conscious of the fact that the world we live in, that is, the technology, the social norms, the language we are used to, is one of many possible worlds, we will be less surprised, because we know that different conceptualizations are conceivable. Abstraction of this kind will also foster communication and integration, because it tells us that beyond the differences between specific cultural peculiarities, there are commonalities shared by all cultures. If our perception of the world is not restricted to actual experience, but to an open horizon of the possible, we will be able to make sense of a yet unknown future instead of feeling lost.

This, however, is a major challenge. While we need concepts to think a possible future, we need to be aware of the fact that the future will be constituted by a language different from the one we speak. Therefore, taking the creation of possible futures to the extreme is a frightening endeavor: “The future can only be anticipated in the form of an absolute danger. It is that which breaks absolutely with constituted normality and can only be proclaimed, presented, as a sort of monstrosity.” (Derrida, 1976, p. 5) There is certainly no recipe for a perfect curriculum to address this challenge, but I would hope that a university that does not only appreciate critical thinking, freedom, and originality, but provides an environment that allows taking them to an extreme, will be able to handle it.

5 Conclusions

As much as living and acting successfully in today’s world requires structure, there is need for structure to cope with the digital transformation, too. Ideas of possible future worlds need to be structured, as well as processes of change. While we do not know exactly how the future will look like, we can be pretty sure that it will be penetrated by software systems. Therefore, conceptual models are of pivotal relevance, since they are not only required to build software systems, but also to make sense of them and the environment they operate in. In the end, the development of conceptual models to prepare for the digital transformation implies to challenge and eventually reform the language we use—and the way we think: “We want to establish an order in our knowledge of the use of language: an order with a particular end in view; one out of many possible orders; not the order. To this end we shall constantly be giving prominence to distinctions which our ordinary forms of language easily make us overlook. This may make it look as if we saw it as our task to reform language.” (Wittgenstein, 1973, p. 132).

From a rational perspective, it does not seem satisfactory to create a possible future without some kind of evaluation—and hope. At least, it should not be worse than the presence, e.g., by destroying sense without offering alternative options for sense-making that are at least functionally equivalent (Luhmann, 1967, p. 101). At best, we would change the concepts we use “so as to make them serve our purposes better” (Rorty, 2000, p. 25), which recommends to reflect on our purposes, maybe by following an advice Wittgenstein gave to philosophers: “Laß Dir Zeit” (take your time).

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Structuring of an Evaluation Model for Projects

Heinz Lothar Grob

1 Conceptional

Projects play an important role in all scientific disciplines. In information systems—as in business organization theory—it is not only a matter of realizing projects in the strategic and operative sector of companies, but also of creating a theoretical basis for successfully designing projects. The economic perspective of the project—supplemented by technical, ecological and social aspects—is of particular importance.

All projects require a systematic structuring of the expected qualities, the cost-causing use of resources and the planned deadlines. The complexity of the structuring is shown by the fact that, in addition to the normally expected results, conceivable deviations must be analyzed, which quantify the risk of a project. Despite the complexity of the projects, which is regularly caused by a variety of tasks, multi-personality, scarcity of resources and deadline pressure, the fundamental question is quite simple: will the project be advantageous? It is considered advantageous if the planned quality features are realized in a financially and timely acceptable manner. This means that projects are declared as failed when budgets and deadlines are exceeded and/or when the planned quality could not be achieved (Fiedler, 2008). In the following, an instrument is presented which supports the monetary evaluation of projects in the planning and control phase.

The monetary component should not only include the costs of the project, as it is often presumed in project management. Instead, the financial consequences, incoming and outgoing payments of a project, should be considered due to its long-term nature. It can be critically objected that it is rarely possible to attribute payments to the planned project in practice. However, one way of dealing with this problem is to model incoming payments based on transfer prices not on a financial but on a cost basis. If this theoretically justified proposal is accepted in project management prac-

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tice, it is possible not only to determine payment surpluses and the profits generated from them over time, but also to enable the determination of significant business key figures, such as the return on total capital, the return on equity or the pay-off time of the projects.

The monetary decision consequences include both the original incoming and outgoing payments, which are recorded in the payment sequence of the project, and the derivative payments affecting net income, which include interest and income taxes. It should be considered that the TCO (Total Cost of Ownership) target value is often favored in literature on project management, which in the classic version contains neither interest nor taxes. However, due to the generally accepted principle of causation, which forms the logical basis for allocating the relevant payments to a decision alternative, the above-mentioned derivative payments must also be taken into account when assessing projects in addition to the operating payments (Grob & Lahme, 2004). If this requirement is met, the TCO can be determined with a VOFI.

The attempt to develop an evaluation model for projects demands what Jörg Becker himself (repeatedly) states in the title of this commemorative publication: "Structuring, structuring, structuring". It should now be interpreted that he calls for structuring three times. A first possibility of interpretation is that Jörg Becker regards structuring as very important wherefore he necessarily emphasizes it several times (more precisely: three times). However, an alternative interpretation is brought into focus which could be at least in this problem area described as following:

When implementing the project decision, exactly three levels have to be considered in structuring:

1. structuring and consolidation of the monetary consequences,
2. structuring of non-monetary targets,
3. and structuring of a model for the integration of all monetary and non-monetary consequences to formulate a final decision.

In this article the first structuring level is described in detail in Sect. 2. The other two levels are then briefly discussed in Sect. 3.

2 Structuring the Evaluation Model to Consolidate the Monetary Consequences

The basis for structuring the monetary consequences of a project is—as explained above—the VOFI. The name of this table-oriented method is an acronym for the term "complete financial plan" (Grob, 2006). It is well known that a VOFI is nothing more than a table containing all relevant monetary data necessary to determine a target value that quantifies the benefit of a project. The first task in decision preparation is therefore the structuring of the VOFI. A decision on the specification of the target value has to be made. The final value is considered the "natural target value" of the VOFI. This is determined automatically since there are no specific interventions in the algorithm for determining the target value. However, if the final value is not required for project management but, for example, the initial value or the annual profit, the process for determining the target value must be adjusted accordingly. For this purpose, a corresponding vector is assumed in the VOFI, which enables the transformation into the desired target values. In any case, the final value is important for generating VOFI key figures.

As an example of the structure of the VOFI the basic concept is presented (see Fig. 1). The duration of the project is defined by the period from $t = 0$ to $t = n$. $t = 0^*$ is defined to be one “logical second” before the start of the project. At this point in time, the company’s stock of own liquid funds is available, which must be relinquished in case that the project is realized. From $t = 0$ to $t = n$ the payments for the implementation of the project are planned in addition to the original payments (initial net investment, payment surpluses and liquidation surplus).

The following procedure could be used to forecast the payout sequence: First, the cells for the allocable resource consumption during the planning process must be structured. Subsequently, the quantities have to be evaluated with the corresponding cost rates. The same procedure could be followed for the original payments that will be made during the use phase of the project. If payments are made that do not dependent on consumption quantities, they must be considered as fixed components in the disbursement sequence (similar to cost accounting).

The expected outgoing payments must be compared with the incoming payments. When quantifying incoming payments, one has to perform a quantity framework with regard to the expected services. The components of this framework are then weighted with transfer prices, as suggested at the beginning. It is recommended that transfer prices are based on market prices.

The other rows of the VOFI include the use of own funds at the start of the project and the additional deposits planned over the course of the useful life. If distributions (or withdrawals) have to be taken into account, they must be included in the next row of the VOFI. The other positions include loans and additional investments (e.g. cash investments) and their financial consequences. The tax payments or tax refunds caused by these flow variables must be determined derivatively in auxiliary calculations and reported in the VOFI. The annual financial arrangements have to be determined in such a way that the financing balance is zero at all times. Below the row of the financing balances, the stock sized of financial assets and loans are mentioned.

All values above this row represent evaluation variables. This short description applies to the basic concept of a VOFI, which can be described as a reference model (vom Brocke, 2003, p. 34). It is the basis for the construction of a project-related VOFI.

When designing a project-related VOFI, the following structuring tasks must be completed. This concerns exclusively the structuring of the VOFI and not the financial consequences of the project. The prognosis of the data takes place in a later phase, in which feedback is also conceivable.

When generating a case-related VOFI, the planning period of the project must be fixed. Then it must be decided from when the use of the object is expected. The period up to the acquisition or production fixes the planning period of the object.

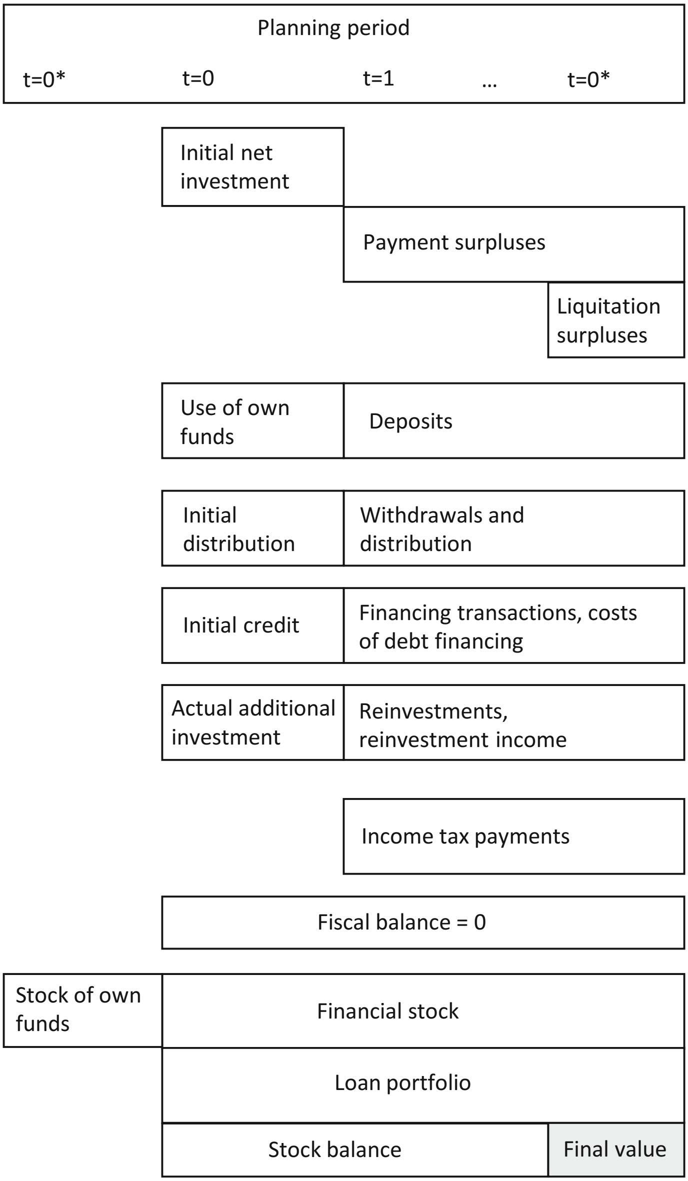

Fig. 1 Representation of a VOFI as a basis for a reference model

Incoming and outgoing payments are made at each point in time. Furthermore, the use of credit must be regularly adjusted to the financial requirements of the object.

With regard to self-financing, for which the financial resources available in t = 0* are used, but also the execution of deposits is conceivable, it must be clarified which cells of the table have to be activated. In general, the cell in which the use of the equity is shown, is identical to the start of the object. Whether additional deposits have to be made in the subsequent periods depends on the decision on the structure of the financing.

Whether the next position—distributions—has to be shown in the VOFI is determined by the target decision. If the objective (e.g. based on net present value concepts or shareholder value models) is the "maximization of the distribution in t = 0", a corresponding cell in t = 0 must be set up. If the objective is the "maximization of the average annual profit", then the cells in t = 1 to t = n must be set up in such a way that the vector of the variables (for example, by means of a target value search in Microsoft Excel) yields a maximum. In both cases, a certain final value (usually the final value of the opportunity is used as a reference value) is specified as a secondary condition.

With regard to debt financing, the VOFI provides cells for the borrowing, repayment and debit interest of all relevant loans. These could be, for example, loans with bullet repayment, annuity loans, installment loans, zero bond loans—but also overdraft facilities, since draw downs and repayments of these loans can be taken flexibly. It is also possible that the term of a loan exceeds the planning horizon t = n. In this case, an evaluation on the planning horizon is needed.

Similar considerations apply to the presentation of positions for possible reinvestments. It is customary to describe reinvestments by three parameters: investment, repayment and return of reinvestment. Due to this standard premise, the design task for reinvestments is relatively simple. Of course, individual planning of future investments can also be included in the VOFI.

The position "income tax payments" contains the result of a detailed supplementary calculation for determining period-related payments or refunds of income taxes. When structuring the auxiliary calculation module, the tax regulations (e.g. whether the project is carried out by a private company or a capital company) have to be considered. For an application example with the currently valid tax regulations and parameters of a corporation, refer to the following source (Grob, 2016, pp. 55–63).

3 Considerations for Further Structuring

In practice and in literature, the core task of forecasting the payment sequence of a project is often referred to costs and services. Strictly speaking, the deposits and withdrawals are relevant. To simplify modeling, it is therefore often assumed that costs and outgoing payments or services and incoming payments are identical in terms of amount and time. The reason why one has to calculate with incoming and outgoing payments is that payment sizes influence financial and credit balances and that these in turn represent the basis for determining the interest payments defined in accordance with the cause. Despite the current low interest rates, these interest payments have a significant impact on the monetary target value for long-term projects.

An analog simplification is usually used to determine taxes. It is assumed that parts of the incoming and outgoing payments are declared as income and expenses in the additional tax calculation, since these are normally used to calculate the assessment bases. However, if a distinction has to be made explicitly between payments, services and income and respectively between payments, costs and expenses, a system of vectors with differential quantities (e.g. between payments and costs) must be included in the VOFI and its additional tax calculations. This allows for a differentiated presentation of payment consequences, consequences of success and profit consequences.

A further structuring effort is required if the relevant elements of the payment sequence and the other vectors have to be determined in a process-oriented manner (vom Brocke & Grob, 2012, pp. 455–472). As in process cost calculation—supplemented by process performance calculation—the system of the corresponding consequences described above must be generated using event-driven methods. Indeed, these methods are normally used (Rosemann, Schwegmann, & Delfmann, 2012, p. 47 et seqq.) to routinely optimize actual and target processes—but why should they not be used as a simulation model to prepare unique decisions of projects?

So far, only the first level of the architecture of a project decision has been discussed. Finally, the two other levels will be mentioned briefly. While the monetary decision consequences are presented in a VOFI, the price-performance model (PPM) could be used for the compression of the non-monetary consequences (Grob & Bensberg, 2009, pp. 188–195). The application of this model can also methodically support the confrontation of monetary and non-monetary criteria. The price component of the PPM is nothing else than the monetary target value of the VOFI, such as the total cost of ownership taking into account taxes or—if payments have also been generated—the final value of the investment after taxes. Services have to be distinguished between performance requirements (the target services and the actual services of an alternative project). The decision that meets the price-performance level best is determined by an interactive process. In PPM, it is essential to relate the elements of this complex system in order to identify deviations. Here, too, the motto applies: structuring, structuring, structuring.

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The Goat Criteria—A Structured Assessment Approach for Reference Models

Christian Janiesch and Axel Winkelmann

1 Introduction

Reference modelling has been an ansatz in Information Systems research since the inception of the discipline (Becker, Niehaves, & Knackstedt, 2004; Fettke & Loos, 2007; Schwegmann, 1999; Thomas, 2006; vom Brocke, 2003). Reference models are generic models for a class of applications with certain properties: They can be the basis for specific models for a particular application and they can be references for comparisons, for example to benchmark one's structure or operations. Further, they can be used to educate and improve communication. They range from abstract frameworks and blueprints to ontologies.

Applying reference models goes beyond changing the exterior functional texture of companies, but they allow for structuring their business architecture as well as their process organizations. Hence, the leitmotif "*structure, organize, texture*" (in German: strukturieren, strukturieren, strukturieren).

The gestalt of reference models is diverse, the most common and extensive models focus on processes and data. In the last 50 years, the scientific community has provided a plethora of reference models (e.g., the "integriertes Gesamtmodell der betrieblichen Datenverarbeitung") (Grochla & Szypersk, 1971). Later works, for example those provided by Scheer or Kurbel (cf. e.g. Scheer, 1997), added valuable knowledge to the IS community.

In science and in particular in Münster, milestones of reference modelling research have been made culminating in eclectic reference models such as the Retail-H by Becker and Schütte (2004)—ranging back to works in 1993–1996—has provided

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significant value not only to the scientific but also to the IS community by capturing the zeitgeist of contemporary retail business processes and data.

In practice, especially SAP AG provided a stable reference model for its SAP R/3 that served the IT management forces in enterprises for two decades. In 2019, the community still talks about attributes such as lifnr (Lieferantennummer/ supplier number) or tables such as lfA1 (Lieferantenebene A1/ supplier level A1) in the respective systems. While the abbreviations are obvious for German enterprises, there is still confusion e.g. among foreign enterprises using SAP software. Recently, especially Microsoft (2017) introduced a new reference (data) model for enterprises, the Common Data Model (CDM). Microsoft has heavily invested into its Cloud strategy and its reference model is a major part of their ERP movements.

As mentioned above, a primary use case for a reference model is structuring enterprise data and the organizing corporate processes by providing a customizable blueprint or master model to initiate organizational change (vom Brocke, 2007). Yet, one question remains difficult to answer: Which reference model performs better in the long run. Here, companies should not focus on short-term gains but rather consider long-term achievements, which only start to pay off in the mid-term. This leads to the problem, that reference models need to be evaluated using strategic criteria rather than tactical or operational metrics (Fettke & Loos, 2003; Schütte, 2013).

In this festschrift, we introduce a new qualitative measurement scale to evaluate long-term perfection of reference models called the GOAT criteria. The term GOAT (also G.O.A.T.) has been popularized in another discipline by LL Cool J (2000).[1] Our GOAT criteria assess whether a reference model is *generic*, *objective*, *agnostic*, and *transferable*, which are important factors for enduring reference model success. They predicate whether a reference model indeed focuses on a class of applications rather than specialized circumstances, whether it abstains from unnecessary subjectivism, if it is agnostic of technology and implementation choices, and—last but not least—whether it is still practical to be applied in the real-world.

We use these above criteria to evaluate the following reference models:

(a) the Retail-H reference model of Becker and Schütte (2004), which is an established and proven conceptual specification of retail functions, processes, and data.
(b) the Microsoft Common Data Model of Microsoft (2017), which is a library for enterprise data elements as a representative of modern reference models.

Finally, we discuss our findings and summarize the results.

[1]The term GOAT is used in professional sports as well. It is attached to players such as Roger Federer, Wayne Gretzky, Tom Brady. We propose to attach the term GOAT to Jörg Becker for his achievement in reference modelling.

2 GOAT Criteria

2.1 Overview

Reference models can incorporate the constituent parts of any consistent idea, from system modules to business functions. Their common denominator is that they consist of a complete set of items for the reference domain. This frame of reference can then be employed design systems and data structures, initiate business process change management, or to communicate notions unambiguously among members of the same community.

Since reference models vary greatly in their scope and focus, it is impossible to develop detailed and still fair universal measurement catalogues across domains and applications. Hence, in the following we focus on providing high-level criteria, which can be used to assess the perfection of the reference model's ability to structure, organize, and texture enterprises.

Figure 1 provides an overview of the GOAT criteria, which are in detail: generic, objective, agnostic, and transferable. Each of the four dimensions can consist of assessment specific sub-dimensions, which we suggest to structure in a hierarchical fashion to improve clarity. We assume that models can be optimized for at most three dimensions while the fourth dimension introduces a trade-off.

2.2 Generic

A reference model has to be generic rather than specific. It has to provide information about circumstances of interest on an abstract level. A reference model has to describe the kinds or types of entities that may or may not exist in such a circumstance. A reference mode is not about specific entities and their attributes and relations that occur in a specific circumstance. It is not an ersatz for a company- or implementation-specific model.

For example: A reference model may specify that a sports game pitch needs goals and explain the concept of a goal by stating that the formative object of the sport (e.g. a ball) needs to travel in-between the posts to receive an advantage over the competitor (i.e. to score a goal). However, it does not specify exact dimensions or whether the goal needs to be equipped with a net as goals differ from sport to sport (e.g. compare goals in water polo to elephant polo).

That is, a reference model should describe types of entities and their relationships rather than include specific and detailed constraints. The more details a reference models exhibits, the more likely it is that it needs to be customized and that it cannot be applied consistently in its entirety. Further, for any reference model not only to structure data but also to organize a business, precedence relations between roles, tasks and functions need to be made explicate in a process description.

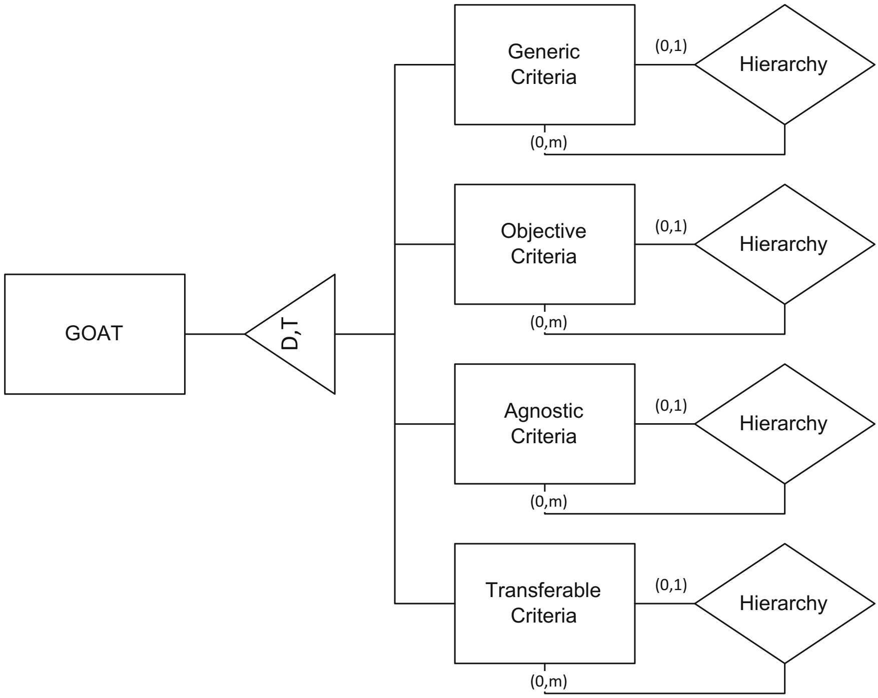

Fig. 1 Conceptual overview of the GOAT criteria

Concerning *composition*, the dimension *generic* of the GOAT criteria can be evaluated by assessing whether the reference model contains a general-purpose data model with entities and relationships as well as a high-level process description with tasks, roles and precedence relations.

Concerning *content*, the dimension *generic* of the GOAT criteria can be evaluated by assessing whether the reference model contains types of entities and tasks as well as their relations rather than specific instantiations thereof. If distinctions for cases have to be made within the model, generic meta categories should be employed to refrain from using situational denominations, which need to be replaced for use in other circumstances.

2.3 Objective

Objectivity informs essential processes in science and how evidence and truth is unearthed. Its central conception is to eliminate personal biases and to channel reproducible results. Objective reference models can be associated with a truth value and are in line with the objective truth as for example discussed in the Habermas Theory of Communicative Action (Habermas, 1984). For a discourse leading to a cre-dible result, i.e. the use of a reference model, the theory postulates, that apart other things the content of the message, i.e. the reference model, has to represent the circumstances it is thought to describe truthfully. An explicated research method associated to the reference model can provide this clarity.

The topic of objective truth is linked to the quality of information in the models for a realistic and error-free reproduction of the circumstances it is thought to describe. Quality can be based on the ability to satisfy declared or implied needs, based on its totality of characteristics (DIN, 2015). Wang and Strong (1996) provide a framework of dimensions for information quality with criteria to measure. They distinguish the dimensions of intrinsic, contextual, representational, and accessibility. Further criteria have been introduced by Schütte (2013) when extending the Guidelines of Modeling (Schütte & Rotthowe, 1998). For reference models it is particularly important to follow an established method, such as established general-purpose modeling languages as ERM (Chen, 1976) and BPMN (Object Management Group Inc., 2013).

Concerning *truth*, the dimension *objective* of the GOAT criteria can be evaluated by assessing whether the reference model contains an explicated research procedure to make the development process reproducible and whether it makes raw data available.

Concerning *quality*, the dimension *objective* of the GOAT criteria can be evaluated by assessing whether the reference model adheres to open quality standards such as established modelling languages, modelling guidelines, and/ or information quality criteria and integrates them in a homogenous and holistic fashion.

2.4 Agnostic

A reference model's longevity is limited if it necessitates certain technologies or platforms. A reference model's intent is to promote understanding and solutions a type of circumstances, not specific solutions specific situations. Hence, it should be agnostic of any technological or political constraint, which could—in the long run—entail a predicament. While reference models exist on various levels of abstraction, they should not include concrete implementations as otherwise the distinction towards technology specifications, which describe concrete technological solutions, is unsustainable.

Furthermore, the reference model should refrain from overly aligning with current and not well-understood trends. By seeking closeness to hyperbolic topics, a reference model may excel at appearing to be superior to previous revisions or older models. Yet, the shelf life of the reference model in question will most likely not benefit from this.

Concerning *technology*, the dimension *agnostic* of the GOAT criteria can be evaluated by assessing whether the reference model necessitates concrete technologies rather than generalizable IT-based functionality.

Concerning *hyperbole*, the dimension *agnostic* of the GOAT criteria can be evaluated by assessing whether the reference model contains an excessive number of current catchwords, which do not translate into distinguishable benefits.

2.5 Transferable

To be useful for reuse and implementation, a reference model need to be contextualized to specific situations or contexts when applied in practise. This dimension, thus, introduces a trade-off. While models need to be generic in their nature, objectively formulated, and agnostic in relation to their implementation to ensure enduring relevance, reference models need to be transferable into practise to be useful to the scientific community and—more importantly—to practice. There exists a body of research on reference model contextualization describing mechanisms that can assist this process (Delfmann, 2006).

Further, reference models should include a clear statement of the circumstances that it applies to and the problems it solves. For a reference model to be a relevant contribution to the community, it needs to solve a practical problem such as the design of a generic IT system for business functionality. Further, this problem needs to be non-trivial and the solution non-obvious, otherwise routine design should be preferred (Gregor & Hevner, 2013).

Concerning *adaptability*, the dimension *transferable* of the GOAT criteria can be evaluated by assessing how much adaptation in terms of customization and instantiation the reference model requires to be used in practise. Providing configuration mechanisms can alleviate the contextualization process.

Concerning *practicability*, the dimension *transferable* of the GOAT criteria can be evaluated by assessing whether the reference model solves a practical problem in a domain where solutions are non-obvious.

3 Reference Models for Enterprise Data

3.1 Retail-H

At the beginning of the 1990s, Jörg Becker and his research team conducted several research and consulting retail projects in the context of business information systems. With their aim to structure, organize, texture, they soon realized that a retailing company must perform three principal tasks, namely procurement, storage, and distribution of goods. This was an initial step of building the reference model Retail-H (German: “Handels-H”). All tasks concerned with the supplier are addressed within the “left leg”, all tasks associated with the customers within the “right leg” and

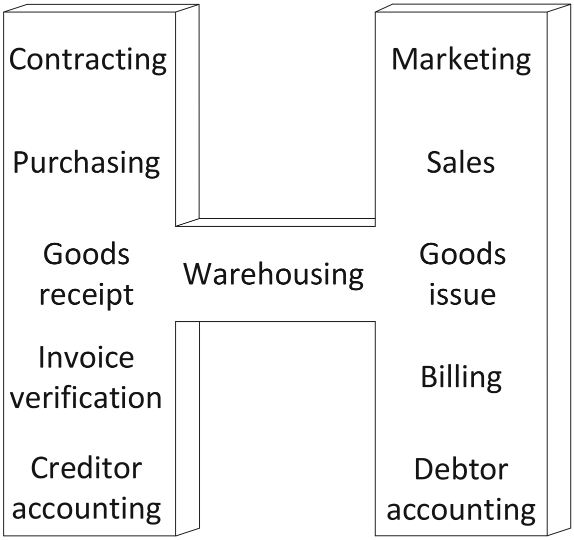

Fig. 2 Retailing H structure

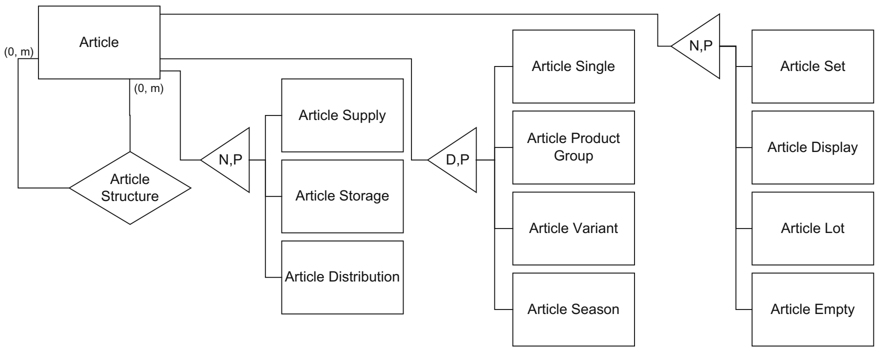

Fig. 3 Retail-H reference data model (cf. Becker & Schütte, 2004)

logistical functions with goods receipt, warehousing and goods issue are arranged horizontally. Hence, the structure of the retailing functions forms an H (cf. Fig. 2).

These tasks of procurement, distribution and logistics occur not only in retailing companies but also in industrial companies. However, retailing has some unique features that affect the form of the tasks and consequently the business information systems. Therefore, Becker and Schütte (2004) provided additional layers underneath the H structure in order to specify functions, processes and data needed for business information systems in retail. Next to functional decomposition diagrams and event-driven process chains (EPC) for reference process models, they provided various retail constructs. These ERM data models provide valuable insight into the necessary data specifications in retail (cf. Fig. 3).

3.2 Microsoft Common Data Model

Microsoft has changed its business model intensively during the last couple of years (Nadella, Shaw, & Nichols, 2017). It has become the world's #1 cloud provider and has spent much effort not only to provide its Office solutions within its Azure cloud but also its business software world. Lately, Microsoft has heavily invested into reconfiguring and reshaping its now cloud based ERP systems Microsoft Dynamics Business Edition and Enterprise Edition (both formerly known as NAV/Navision and AX/Axapta). A rigorous service orientation and modularization (in combination with Apps, Azure services, CRM services, LinkedIn, etc.) will provide more flexibility to customers in the future.

To enable service providers to understand and follow Microsoft's new approach, the company has defined a reference data model (cf. Fig. 4). The so-called Common Data Model (CDM) is an open-source definition of standard entities that represent commonly used concepts and activities across a variety of business and application domains within the Microsoft world. Their public CDM GitHub repository will be continuously enhanced with core entities spanning the entire business process landscape, additional vertical industry data models, and cross-spanning sources such as surveys, search engines, and product telemetry.[2] CDM offers well-defined, modular, and extensible business entities such as Account, Business Unit, Case, Contact, Lead, Opportunity, and Product, as well as interactions and relationships between vendors, workers, and customers, such as activities and service level agreements.

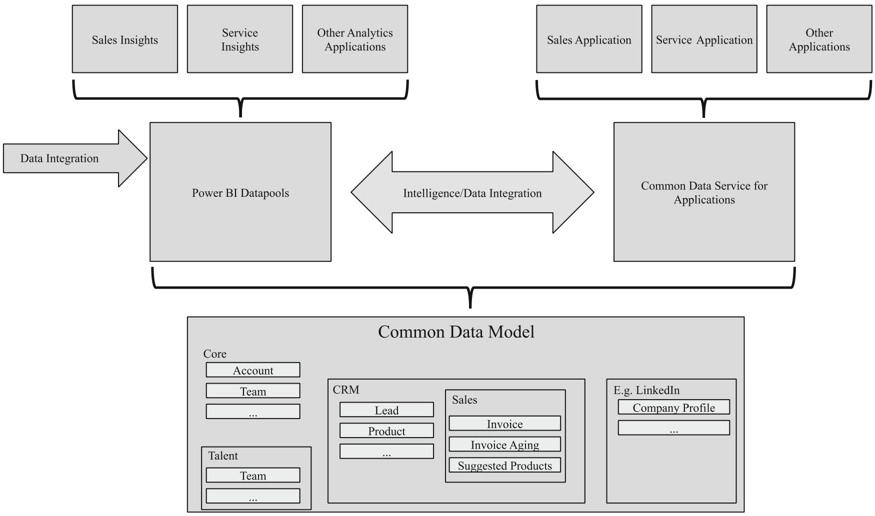

Fig. 4 Microsoft's common data reference model (cf. Microsoft Corporation, 2018)

[2]See https://github.com/Microsoft/CDM/.

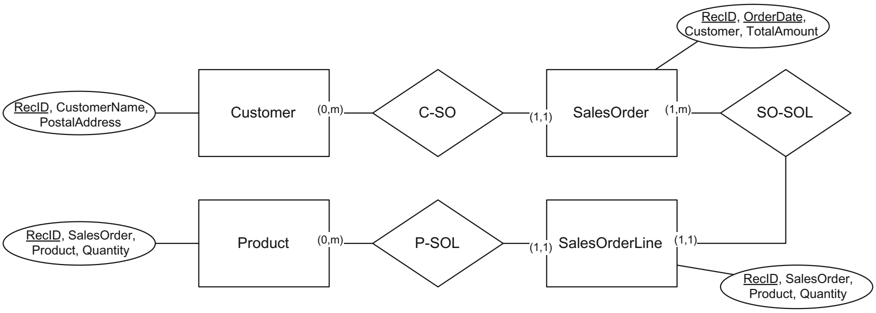

Fig. 5 CDM business entity "sales order" (cf. Microsoft Corporation, 2017)

CDM promises to overcome the challenges of data management by unifying data in a known form with structural and semantic consistency across applications and deployments. It will help integrate and disambiguate data collected from among others business processes, digital interactions, product telemetry, and people interactions. For each entity group, there is an ERM that describes the entities and their relationships with each other. The following ERM shows a—simplified—diagram for a sales order (Fig. 5).

4 Discussion and Conclusion

In the following, we provide a blueprint for a first assessment of the Retail-H and the Microsoft CDM as a representative of contemporary company-originated reference models. We have made a brief survey of the entirety of the two reference models and highlight our initial findings. We have arranged all criteria in Table 1.

Both models make extensive use of general-purpose modelling languages. From a scientific standpoint, the Retail-H provides a much more consistent and generic structure and content. Similarly, the Retail-H's development and description is based on a scientific process, while the CDM's content is not independently verifiable. Both provide high-quality conceptual models though. Further, the Retail-H is completely technology-agnostic while the CDM favours certain technologies. Both model refrain from overstatements. In terms of the being transferable, the CDM clearly has some advantages but its objective and agnostic limitations constrain its genericity toward the Microsoft-affiliated world. It is most likely kaput in other contexts.

As introduced early, it is impossible for a reference model to excel in all four dimensions. Hence, the GOAT criteria always have a qualitative component, which needs to value to different dimension's degree of fulfilment and their importance.

In this case—the case of longevity and versatility–, it is rather obvious that the first three dimensions should be valued at a higher ratio. Here, the Retail-H outperforms the CDM clearly and it lets one assume that the Retail-H will still be talked about

Table 1 Comparison of reference models using the GOAT criteria

GOAT	Retail-H	CDM
Generic	Structured along process, data, and function models; content is clearly generic and on type level and linked through complex relations	Data model only; content is mostly on type level but not fully normalized (e.g. SocialNetwork01, SocialNetwork02) and contemporary rather than generic (e.g. LinkedInIdentity, TwitterIdentity)
Objective	Stands on the shoulders of giants, many references; high-quality data models based on ERM, processes in EPC, further function and organization model of ARIS	No published research method, thus truth value unknown; high-quality data models based on ERM
Agnostic	Completely technology agnostic; no hyperboles	Links to Microsoft and third-party technologies (LinkedIn, Twitter), strong link to Microsoft Power Apps; no hyperboles
Transferable	High instantiation efforts necessary, but generic adaptation mechanisms are available for the included modelling languages; its practical use has been proven times over in the last 20 years	Low to medium instantiation efforts necessary, but only within the Microsoft Power Apps domain, concrete adaptability is thus unclear; but its practical use can be assumed

for the next 60 years to come while CDM's future is unclear and depending on the technological choices made implicitly and explicitly in the model.

Thus, we can conclude that the Retail-H represents a strong reference model with a high degree of perfection if not the GOAT of reference models. This analysis, however, is subject to future research.

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Metamodels as a Conceptual Structure: Some Semantical and Syntactical Operations

Dimitris Karagiannis, Dominik Bork and Wilfrid Utz

1 Metamodels and Conceptual Structures

In conceptual modelling, abstraction is applied to reduce complexity for a specific purpose. For example, abstraction can be used for "*developing model-driven methods and tools for the full-scale automated generation of implementation-ready IS*" as stressed in (Becker, Brocke, Heddier, & Seidel, 2015). The created models provide values of different quantity and quality: at least, conceptual models serve the purpose of documentation and understanding by human beings (Mylopoulus, 1992); to a wider extent, however, such models can also act as a formalized knowledge base that enables further processing. Karagiannis et al. (2017) elaborate on the possibilities of supporting knowledge management by conceptual modelling means. This broader notion is visualized in Fig. 1. Accordingly, a modelling method is composed of a *modelling language*, a *modelling procedure*, and *mechanisms & algorithms*. A modelling language is then further composed of *notation*, i.e., the graphical representation, *syntax*, i.e., the available language concepts, and *semantics*, i.e., the meaning of the concepts.

In order to leverage this broader notion of modelling methods, a co-creation metaphor, similar to value co-creation and service co-creation (Becker, Beverungen, Breuker, Hanns-Alexander, & Rauer, 2013a; Becker et al., 2013b), needs to be employed. Co-creation involves both, the development of a new metamodel by the method engineer as well as their application by the modeller. The method engineer develops a metamodel as a response to evolving needs and requirements from a spe-

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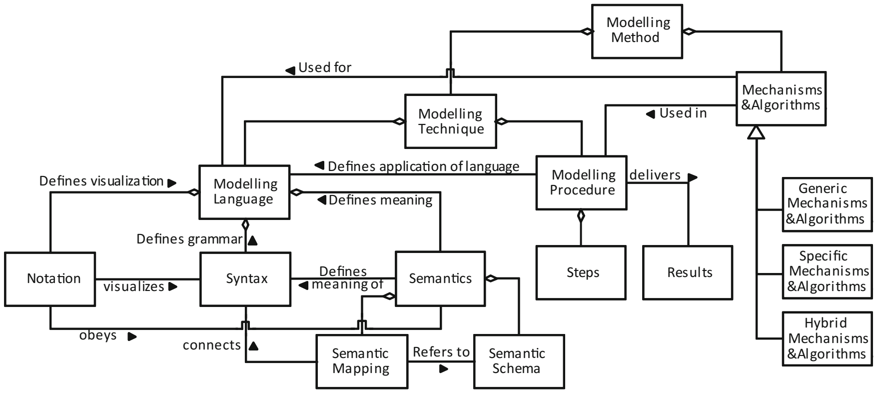

Fig. 1 Components of modelling methods (Karagiannis & Kühn, 2002)

cific domain. While designing this conceptual structure, design decisions determine utility, capabilities, and expressiveness of the conceptual modelling language—and, indirectly, the value of the created models (Bork, 2018). The modeller is then responsible for designing model artefacts, therefore having a direct influence on the model value.

When considering the purpose of a modelling language, domain-specific modelling languages (Karagiannis, Mayr, & Mylopoulus, 2016) can be distinguished from general-purpose ones like the Business Process Modeling and Notation (BPMN) and the Unified Modeling Language (UML). Whereas languages of the latter category evolve slowly and new languages emerge only scarcely, modelling languages designed to address domain-specific requirements emerge and evolve more frequently.

Due to this fluctuation, developing mechanisms and algorithms on a language-specific layer is inefficient. Moreover, scenarios build on heterogeneous modelling languages (Becker, Delfmann, Eggert, & Schwittay, 2012) require for alignment or even integration of metamodels. This paper amplifies the notion of metamodel from the formalized specification of a modelling language's syntax (Bork & Fill, 2014) towards the notion of "metamodel as a conceptual structure".

According to Jackendoff (1987), a conceptual structure relates to syntactic, phonological structure, and non-linguistic levels of representation. Our mapping of the conceptual structure theory to metamodeling is as follows: *decompositional*—because it decomposes relevant domain aspects in terms of metamodel concepts (e.g., modeltypes, classes, relations); *conceptualist*—because domain semantics are identified with metamodel concepts, and *localistic*—the geographical structuring in metamodels. Based on the characteristics and the utilization scenario, different types of conceptual structures can be differentiated: *syntactic conceptual structures* focus on the localistic aspect by specifying structural aspects like inheritance and composition on metamodel concepts; *semantic conceptual structures* focus on conceptualist aspects by precisely specifying the domain semantics, and *hybrid conceptual structures* provide a structure that integrates both, localistic and conceptualist aspects.

This broader notion treats metamodels as first-class citizens, enabling semantical and syntactical operations (see Sect. 2) that are language-agnostic but allow parameterization for specific languages. Specified on structural aspects of a metamodel, such operations can be used for any specific metamodel. Due to limited space, this paper sketches recent works and points interested readers to the relevant literature.

2 Operations on Metamodels

2.1 Modelling Language Mapping

When multiple modelling languages need to be aligned, e.g., in case of multi-view modelling (Bork, Buchmann, & Karagiannis, 2015), metamodels as a conceptual structure can serve as a basis for the specification of mappings and rules that determine the alignment. Zivkovic, Kuhn, and Karagiannis (2007) propose a conceptual structure that targets this research challenge by means of a metamodel mapping language as visualized in Fig. 2.

Zivkovic et al. (2007) identify the following set of mapping structures attached with cardinalities: (1) mapping structure: *class-to-class* (*C2C*), *attribute-to-attribute* (*A2A*), *relationship-to-relationship* (*R2R*), *attribute-to-class* (*A2C*), *attribute-to-relationship* (*A2R*), *relationship-to-class* (*R2C*), and (2) mapping cardinality: *one-to-one* (*1-1*), *one-to-many* (*1-N*), *many-to-many* (*M-N*). A recent work by Awadid,

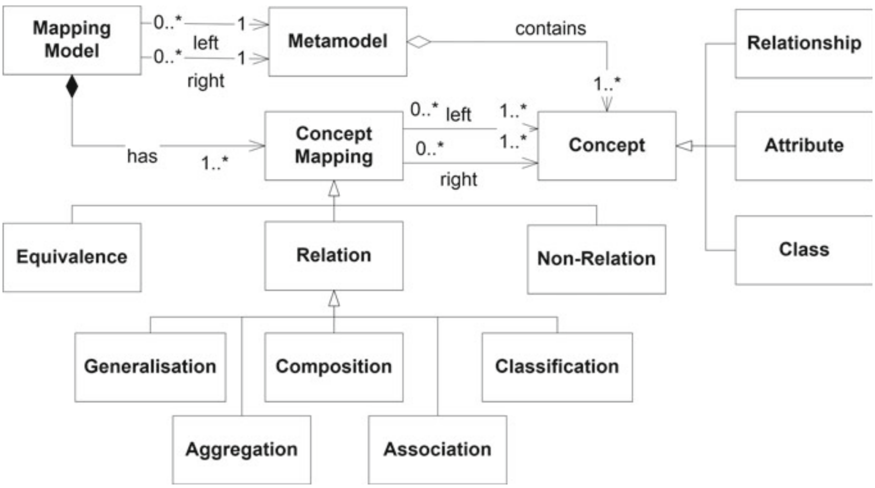

Fig. 2 A conceptual structure for mapping modelling languages (Zivkovic et al., 2007)

Bork, Karagiannis, and Nurcan (2018) further developed these mapping types toward patterns of metamodel relationships with an emphasis on multi-view consistency. These mappings and patterns contribute the design and analysis of new modelling methods comprising multiple metamodels.

2.2 Reference Alignment

A different way of integrating two or more metamodels is by incorporating an additional, language-agnostic metamodel that acts as the bridge between those other metamodels. Reference alignment is defined as aligning several metamodels to a common semantic backbone provided by a reference metamodel. Thus, reference alignment utilizes a mapping between multiple specific conceptual structures and a generic one which realizes modelling language independent functionality.

Reference alignment uses a generic conceptual structure as referencing structure. Common semantics can then be defined for the generic concepts—thus, this structure is domain- and/or purpose-specific. Moreover, model processing functionality can be realized on the generic structure and then utilized, by rule-based mappings, by all specific conceptual structures. Some possible options for referencing of concepts are: a concept that *captures merged meaning* (union of attribute sets); or a concept that *captures the overlapping meaning* (intersection of attribute sets).

A full-stack example, showing the possible strengths of the reference alignment approach is documented in (Prackwieser, Buchmann, Grossmann, & Karagiannis 2013) and visualized in Fig. 3. Here, a hybrid modelling and process simulation algorithm is realized on the generic conceptual structure, enabling its utilization for arbitrary referencing metamodels (i.e., specific conceptual structures). The example is based on a generic conceptual structure for process-related modelling languages. Thereafter, four modelling languages, i.e., Process Maps, Business Process Management Systems (BPMS), BPMN, and EPC reference to this generic conceptual structure. As a result, models of all four languages can be simulated in a hybrid manner, e.g. a subprocess of the BPMN is detailed in an EPC model. The hybrid simulation algorithm is capable of traversing multiple models of different modelling languages due to its generic implementation.

In order to equip an additional modelling language with the hybrid simulation capability, a method engineer only needs to map the new specific conceptual structure to the process simulation concepts of the generic conceptual structure. This generic conceptual structure comprises e.g., (cf. Prackwieser et al., 2013, p. 151 for a description): *Activity*, *Sub Process*, *Start*, *End*, *XOR*, *AND*, *Merge*, *Event*, and *Neutral*.

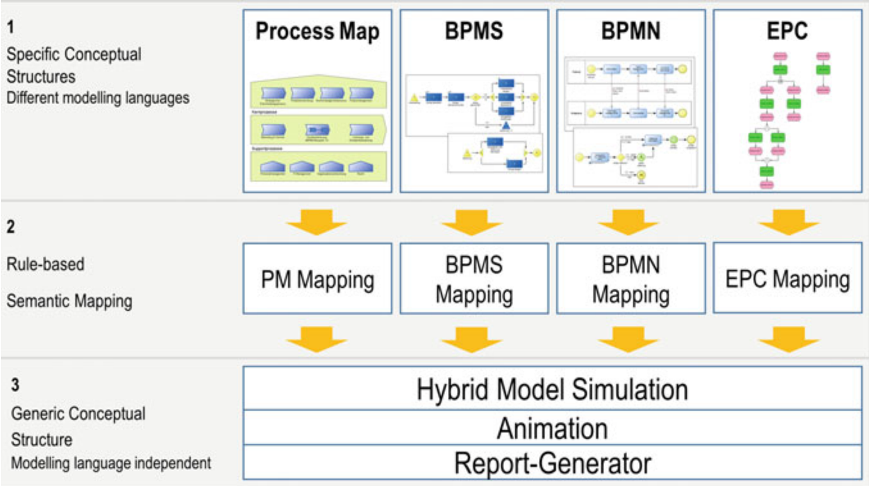

Fig. 3 Alignment between specific and generic conceptual structure

2.3 Semantic Lifting

A different approach, using a hybrid conceptual structure, targets the integration of ontological aspects in metamodels—*semantic lifting*. Semantic lifting refers to the process of associating syntactic conceptual structure items with suitable semantic conceptual structure items as metadata to create semantic knowledge resources. In the context of metamodelling, semantic lifting refers to the integration of formalized semantics as an extension of metamodels (c.f. Fill, 2011; Hrgovcic, Karagiannis, & Woitsch, 2013). The authors in (Woitsch, 2013) report on the conceptualization and ADOxx-based implementation of five different types of semantic lifting:

- *Non supported direct linkage* requires no changes in the metamodels, the user needs to manually enter the linkage in an existing suitable attribute;
- *Supported direct linkage*, can be realized by an AdoScript that accesses the other modelling tool and enables the selection of an object;
- *Indirect linkage* can be realized using a so-called transit model type where concepts of the corresponding other metamodel are included. Hence user-friendly mechanisms to reference model objects can be used.
- *Loose coupling* is a special form of indirect linkage, as the concepts that are referenced are not the target concepts but a reference ontology, which is referenced by the source and the target concept;
- *Direct and indirect linkage* is a combination of supported and non-supported linkage, by supporting a fixed core set of concepts but permit the flexibility to also allow agile evolving concepts.

Figure 4 exemplifies the indirect linkage semantic lifting type. Three different model types are necessary for this type of semantic lifting: (i) *original model* (in this case

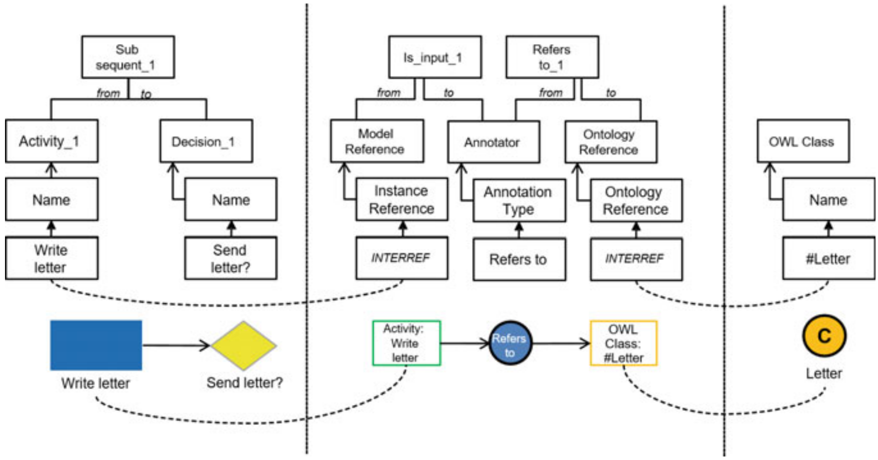

Fig. 4 Semantic lifting based on an indirect linkage conceptual structure (Fill, 2011)

a process model on the left side); (ii) *ontology model* (in this case based on OWL on the right side); and (iii) *annotation model* (visualized in the centre). The annotation model type acts as a conceptual structure referencing both, the elements of the process modelling language and the ontology model. It also permits to specify the annotation type—shown in Fig. 3 by the example of the *Refers-to* annotation type.

One strength of this approach is its flexibility and easy customizability for arbitrary modelling languages (left side of Fig. 4) and ontologies (right side of Fig. 4). The original modelling language only requires minor extensions by means of references to the annotation model type. In contrast to the related approach referred to in the literature as model weaving (Del Fabro & Valduriez, 2007), this semantic lifting approach employs visual means of specifying annotations.

2.4 Semantic Interoperability

In complex scenarios, e.g., enterprise modelling, all requirements cannot be covered in a single metamodel or a single ontology. The question arises of how to combine metamodels and ontologies in a coherent way that yields an integrated and comprehensive enterprise specification. Höfferer (2007) propose an integrated way of achieving interoperability by combining syntactic conceptual structure information with semantic conceptual structure information. Thus, this is an example utilizing a hybrid conceptual structure. Figure 5 visualizes the architecture for semantic interoperability. *Linguistic metamodelling*, i.e., the conventional meta-hierarchy as employed in conceptual modelling by meta^{2}model, metamodel, and model (c.f. Karagiannis & Kühn, 2002, pp. 3f.) is separated from *ontological metamodelling*, i.e., the semantic definition of the relevant aspects of the domain by means of ontologies.

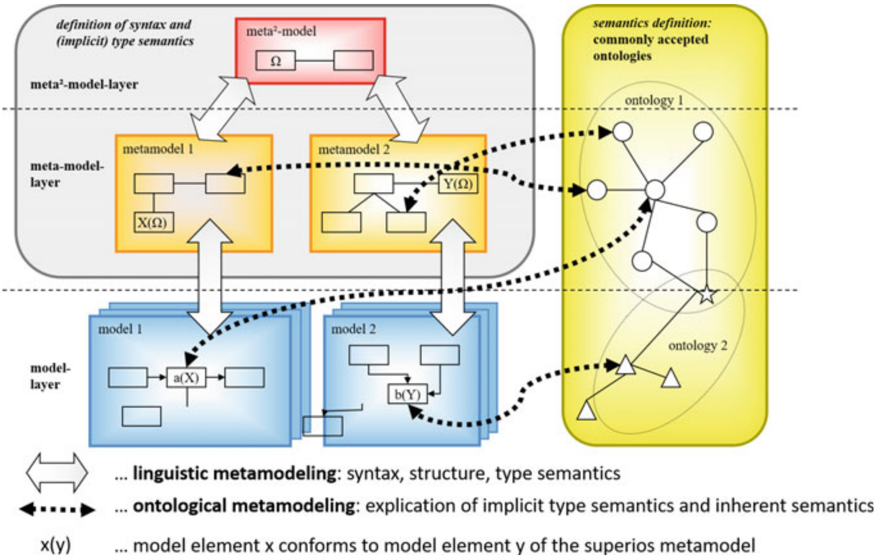

Fig. 5 A conceptual structure architecture for semantic interoperability (Höfferer, 2007)

"The basis for semantic interoperability is provided via linking model elements of arbitrary layers of the metamodel hierarchy with ontology concepts." (Höfferer, 2007; p. 1626) The approach further differentiates two layers where the integration of the ontologies and metamodels yield interoperability. On the upper two layers, linking meta^{2}model or metamodel concepts to ontological concepts enables the formal specification of *type semantics*—contributing to modelling language interoperability (e.g., the identification of semantic similarities between different meta^{2}models and metamodels). On the model layer, the semantics of the instantiated model elements can be specified by linking to concepts of the ontologies. This latter form is referred to as *inherent semantics*—contributing to model interoperability (e.g., the identification of semantic similarities in conceptual models).

2.5 Model Synchronization

A paramount requirement in complex modelling scenarios refers to the consistency among different models that jointly describe the system under study. It is common sense to refer to multi-view modelling approaches when aiming for a comprehensive specification of e.g., an enterprise, comprising structural, behavioural, and information perspectives. In Karagiannis, Buchmann, and Bork (2016) a consistency management approach is proposed that relies in semantic queries applied to a structured RDF serialization of metamodels and models. Consequently, this approach is one example building on a hybrid conceptual structure.

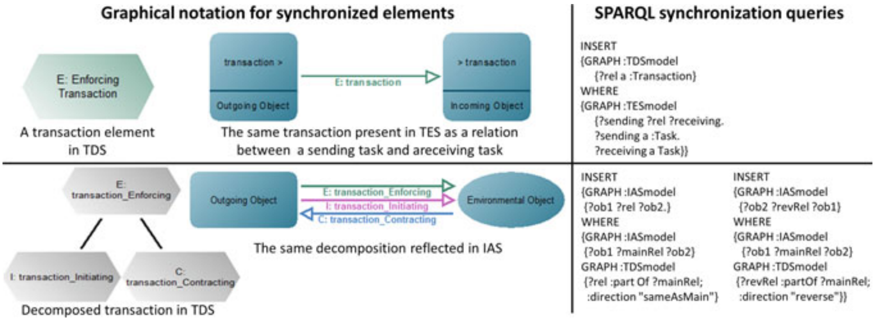

Fig. 6 Synchronization queries based on conceptual structures (Karagiannis et al., 2016)

Based on a generic RDF serialization proposed by Karagiannis and Buchmann (2016), the approach introduces two ways of managing consistency between multiple views: (i) s*emantic queries as view synchronization rules*, and (ii) *semantic queries for passive view consistency checks*. Figure 6 visualizes an example of consistency management for the Semantic Object Model (SOM) method (Ferstl & Sinz, 2013), realized in a modelling tool (Ferstl, Sinz, & Bork, 2016) by means of SPARQL queries that perform synchronizations on the RDF graph base. In the upper example, an enforcing transaction of the Transaction Decomposition Schema (TDS) of SOM needs to be synchronized with the corresponding relation in the Task-Event Schema, connected by a sending and a receiving task. The lower example covers the SOM decomposition rule no. 6 (see Ferstl & Sinz, 2013, p. 210). Accordingly, any business transaction can be decomposed into three sequential transactions (initiating, contracting, and enforcing). This information needs to be synchronized between the TDS and the Interaction Schema (IAS).

The semantic queries approach, as visualized in the right column of Fig. 6, utilizes SPARQL queries on RDF as an additional structure to bridge conceptual modelling with Semantic Web technologies. It thereby applies "knowledge engineering techniques in support of knowledge management concerns—that is, in support of managing the inherent complexity of knowledge externalized as multi-view enterprise models" (Karagiannis et al., 2016). Thus, modellers can concentrate on the correct representation of domain semantics by means of a conceptual model whereas the semantic queries, running in the background RDF structure of the metamodels and models manage consistency.

3 How to Structure Metamodels?

Recently, two research streams were initiated that target the question of *how to structure* relevant domain-specific aspects in metamodels. An attempt to assess the status-quo of domain-specific metamodels was published in Bork (2018). The paper

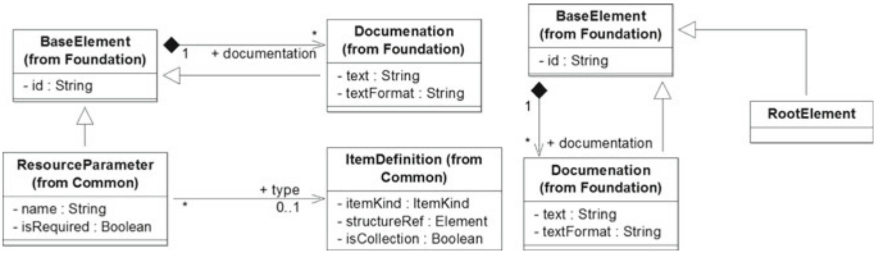

Fig. 7 Slicing metamodel specification technique in BPMN (Bork et al., 2018)

reports on the application of metrics to 40 domain-specific metamodels realized with the ADOxx metamodeling platform (ADOxx.org, 2018; Efendioglu, Woitsch, & Utz, 2016; Karagiannis & Fill, 2013). The paper compares the results with metrics on Ecore-based metamodels found in the literature. The lessons learned indicate points of interest in identifying metamodelling patterns and how such patterns can contribute to increasing the quality of metamodels.

A second recent research stream investigates how standardization consortia specify widely adopted industry modelling languages standards like BPMN, DMN, and UML. Bork, Karagiannis, and Pittl (2018) identify six different techniques that were applied in 11 investigated modelling language standards: *Slicing Metamodel*, *Referencing Metamodel*, *Generic Metamodel*, *Notation- aware Metamodel*, *Matrix Metamodel*, *Table Metamodel*. Thus, although some institutions like OMG are responsible for multiple investigated standards, no coherent way of specifying modelling language metamodels was found.

Figure 7 visualizes an example of the slicing metamodel specification technique as used by BPMN. The two metamodel slices redundantly specify the concepts Base *Element*, *Documentation*, and *the relationship* between those two. Such a specification technique enables structuring large metamodels by decomposing them into redundant slices. The redundant concepts foster comprehension and show, how the slices need to be assembled in order to derive the overarching metamodel. At the same time, these redundant concepts also increase the risk of inconsistent specifications as changes on concept and relationship level possibly need to be performed at multiple slices.

4 Concluding Remarks

This paper provides a brief overview on recent works in the field of metamodeling with an emphasis on amplifying the notion of metamodels toward "metamodels as a conceptual structure". This extended notion spans not only pure formal specification of a modelling language's syntax, but treats metamodels as a conceptual structure that enables further processing. A differentiation between *syntactical*, *semantical*, and *hybrid conceptual structures* has been considered, and example operations been illustrated, including modelling language mappings, hybrid simulation, and model synchronization.

Albeit the undisputable role of metamodels, it is surprising that, up until now, there exists no common standard for the metamodel specification itself (see Sect. 3). Not only the standardization institutions like OMG and the OpenGroup use different techniques to specify metamodels, also the research community uses a heterogeneous and uncontrolled set of techniques when introducing new metamodels. It is therefore one of our future research objectives to propose a specification technique that, when applied on a broader basis, enables easier comprehension and comparison of metamodels. We plan to deploy a first version of this specification technique in our Open Models Laboratory (OMiLAB) (Götzinger, Miron, & Staffel, 2016) community to gain feedback and agilely revise the technique accordingly.

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Tool Support for Designing Innovative Sustainable Business Models

Ralf Knackstedt, Sebastian Bräuer and Thorsten Schoormann

1 What Do We Structure and Why Do We Need to Structure It?

Constantly changing environments caused, for instance, by an increasing digitalization of services and products across various sectors, the decreasing availability of certain resources, and concerns about population growth and equity pose fundamental challenges for businesses and society (e.g., World Commission on Environment and Development 1987; Seidel, Recker, vom Brocke 2013). Facing these challenges, researchers and practitioners from diverse fields increasingly understand business model innovation as an all-purpose tool (e.g., Massa, Tucci, & Afuah, 2017). While economic aspects mostly still dominate, some pioneers emerge who address ecological sustainability and social sustainability as well (e.g., Lüdeke-Freund, Freudenreich, Schaltegger, Saviuc, & Stock, 2017). However, contributing to sustainability in a multidimensional manner requires crucial changes in consumption and production. Thus, novel business models need to be created and implemented, which should meet "*the needs of the present without compromising the ability of future generations*" (World Commission on Environment and Development, 1987).

To foster such sustainable innovations, creativity is becoming an essential competence in manifold contexts (e.g., Brown, 2008; John, 2016; Müller-Wienbergen, Müller, Seidel, & Becker, 2011). Thereby, Design Thinking is one of the prevailing forms of contributing to creativity as well as to innovation within and across organizations, and it is adopted by many companies (e.g., Brenner, Uebernickel, & Abrell,

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2016). For instance, Apple, IBM, Procter & Gamble, and SAP have already demonstrated the usefulness of Design Thinking for improving their businesses (Brenner et al., 2016; Dunne & Martin, 2006). In general, Design Thinking aims at supporting the development of innovative solutions (by using creative techniques) for complex problems or so-called 'wicked problems' that are hard or impossible to solve due to ill-defined, incomplete, conflicting, and changing requirements (Buchanan, 1992; Rittel & Webber, 1973). It is applied in numerous fields, for example, to digitalize banking (Fehér & Varga, 2017), innovate services (Engberts & Borgman, 2018), or to redesign entire business models (John, 2016). Different mindsets including procedure models and methods have been developed in research and practice to structure the design process (e.g., d.School, 2018; Design Council, 2018; Hasso-Plattner-Institut, 2018). Commonly, these mindsets promote an iterative process to achieve user-centered solutions in a multidisciplinary team and distinguish between divergent thinking (i.e., create a wide range of choices) and convergent thinking (i.e., curtailing choices).

Although creativity projects are so far typically carried out in an analog setting, an increasing amount of research deals with the use of information systems (IS) to facilitate such creativity processes (e.g., Seidel, Müller-Wienbergen, & Becker, 2010; Shneiderman, 2007; Voigt, Bergener, & Becker, 2013). For instance, Lattemann, Siemon, Dorawa, and Redlich (2017) explored the support of tools like digital whiteboards or file-sharing systems and John (2016) analyzed, how the creation of business model ideas can be supported by IT. While there are plenty of IT-based solutions that support single methods or activities within the Design Thinking process, we could not identify research that focuses on the IT-based documentation of Design Thinking projects as a whole. Nevertheless, documentation is a complex and fundamental task of Design Thinking, and good documentation allows for project standardization, captures and communicates design rationales, supports critical reflection of the design path (Menning, Beyhl, Giese, Weinberg, & Nicolai, 2014), and provides traceability to reproduce the way from a certain problem to a solution.

Against this background, we present some impressions from a software prototype that has been developed to foster a comprehensible, traceable, and collaborative documentation within a Design Thinking team to ultimately support rigorousness in conducting such creative processes. Moreover, driven by the illustrative case of developing a circular business model for used electric vehicle batteries, we integrate two further software prototypes, one for developing sustainable business models, and one for detailing the business model's value network and processes, into the Design Thinking process.

Corresponding parts of our research at the Institute of Business Administration and Information Systems at the University of Hildesheim are continuations and enhancements of seeds, treelets, and grown trees that have been planted at Jörg Becker's chair for Information Systems and Information Management over the last two decades. Although accepting the duality of behavioral science and design science in IS research (Österle et al., 2011), Jörg Becker always strongly promoted what has been described elsewhere as "virtues of German engineering (model a problem and solve it)" (Junglas et al., 2011, p. 2): An IS researcher's life-task is ideally not the mere observation and analysis of innovations, but the active shaping of innovation processes and the design of innovative IT artifacts with a strong link to practice, while attempting to solve a pressing real-world problem (Becker, 2008). In this article, we honor this mentality by presenting some of the main outcomes from three ongoing design science projects in an integrated manner.

2 How Do We Structure?

2.1 Electric Vehicle Battery Second Use as an Illustrative Use Case

Even though the quest for electrifying private transportation, driven by the need to significantly reduce greenhouse gas emissions in the transportation sector in Germany, faces several immediate challenges, such as an insufficient charging infrastructure and electric vehicles that do not live up to the expectations of prospective buyers in terms of range, charging speed, price, and model variety (Brzeski & Burk, 2017), a key influencing factor for the sustainability of electric vehicles on the long-run is their traction battery, henceforth called electric vehicle battery (EVB). As the hearth of an electric vehicle, the EVB not only powers the vehicle's engine and thus mainly determines the vehicle's range, acceleration, charging speed, and price, it also forms a class 9 dangerous good, restricting its handling by non-professionals due to potential hazards in terms of intoxication, ignition, explosion, and electric strikes (Deutsches Institut für Normung e.V., 2011; UNECE, 2016). However, and most importantly, the EVB's production is responsible for about 46% of the greenhouse gas emissions during vehicle manufacturing and for about 15% of overall greenhouse gas emissions from the cradle to the grave, under consideration of an expected automotive life of 6 to 10 years and using an average EU electricity mix as a calculation basis (Casals, García, Aguesse, & Iturrondobeitia, 2017). The EVB's automotive life is restricted due to the battery's aging by use (charging and discharging) and time, which leads to a decrease in the EVB's available capacity (limiting the range) and power (limiting charging speed and acceleration) (Spotnitz, 2003). To restore the vehicle's characteristics, a battery exchange is indispensable. Nonetheless, considering that the battery, at the end of its automotive life, is expected to still possess about 70–80% of its original capacity, a direct recycling would be a waste of potential (Bräuer, 2018). Instead, repurposing the battery and transferring it to a second life of another 6 to 10 years not only promises additional revenues, it also allows spreading the emissions caused by the EVB's production over a longer life cycle and thus rendering the battery more sustainable (Casals et al., 2017).

Developing a corresponding second life business model for used EVBs is a complex task. In most potential applications the used battery faces competition by new batteries, which have not aged over use and time and which do not build on outdated technology (Bräuer et al., 2016). Moreover, prospective buyers associate the used battery with a lowered performance, a higher risk of failure, and general insecurities concerning its performance and its fit to their expectations (Plenter et al., 2019). To address these challenges, a customer-centered and service-driven business model forms an answer.

For developing corresponding business models for second life battery energy storage systems (SLBESS) that are employed in private households, we build on our prototypes and a Design Thinking process model that integrates three spaces with a divergent and convergent phase in each space: The *problem space* comprises the phases *problem research* and *problem definition*. The *solution space* contains the phases *idea generation* and *idea elaboration*. Finally, the *implementation space* includes the phases *prototype implementation* and *prototype evaluation*.

2.2 Documenting the Design Thinking Process with the Design Thinking Documentation Tool (DT)²

In its core, Design Thinking is a mindset that is human-centered with a focus on empathy and human needs (Brown, 2008). People's needs and desires are the sources of inspiration; they generate insights that form an indispensable basis for creating new ideas (Brown, 2009). The Design Thinking process is iterative and thus designers explore a problem by generating and testing various solutions while constantly analyzing in-depth problem characteristics, insights, ideas, and solution concepts (Brown & Katz, 2011). The work in (usually interdisciplinary) teams aims to solve highly complex problems and to achieve innovation, collaboration is fundamentally (Brown & Katz, 2011). Other key factors of Design Thinking are the cognitive strategies, for instance, divergent and convergent thinking and making use of abductive thinking (Dunne & Martin, 2006). Design Thinkers commonly shift during the process between divergent and convergent phases. First, divergent thinking is used to create different ideas and choices, and afterward, convergent thinking is used to eliminate ideas and make choices (Brown & Katz, 2011). Design Thinking is a process with underlying design activities (d.School, 2018; Design Council, 2018; Hasso-Plattner-Institut, 2018). Unfortunately, we currently lack approaches for the IT-based documentation of Design Thinking projects. However, design documentation enables project standardization, captures and communicates design rationales, supports reflection of the design path, and provides traceability to reproduce the way from a certain problem to a solution. Thus, the overall goal of the Design Thinking Documentation Tool is to provide a comprehensible, traceable, and collaborative online documentation for Design Thinking projects (Hofer et al., 2019).

After opening a project room, our user is greeted with a project dashboard that includes an interactive knowledge map, a calendar view with upcoming appointments and deadlines, and links to access chat messages (Fig. 1). As a newcomer to Design Thinking, our user first explores the knowledge map that, in the beginning, visualizes an empty Design Thinking process model of the project manager's choice,

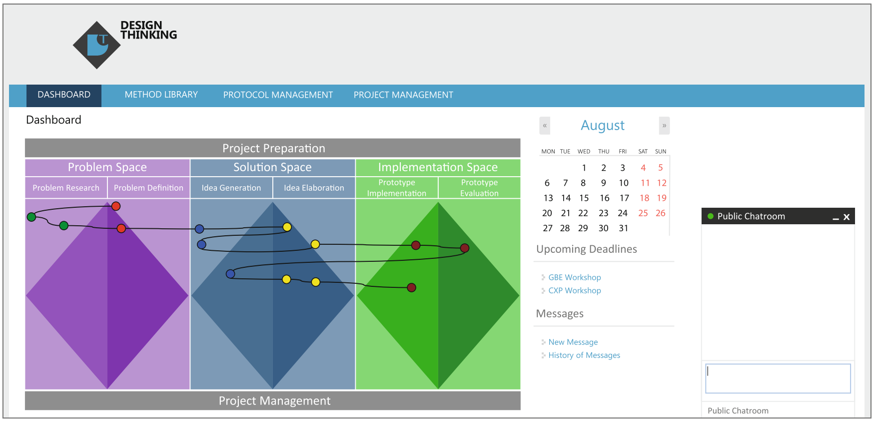

Fig. 1 Software prototype for supporting design thinking teams

by hovering over the different phases and by diving into a short description of the phases and phase-specific recommendation of suitable methods.

As time goes by, the project manager invites additional users to the platform and first workshops take place, to define the overall project's goal and context with the aid of the 6-W-Method and a PESTEL analysis. Moreover, results from a market study on regular battery energy storage systems for private households and from a study on the prospective customers' willingness to pay for second life battery energy storage systems have been presented in the team. As our user has been absent during these sessions, she can click on the bubbles representing the workshops on the interactive knowledge map and access the protocols, which have been generated based on a method-specific protocol template offered by the platform. Working through the protocols, our user learns that her colleagues recommend an alignment of the business model for SLBESS with price-conscious customers, a focus on core functionalities of the battery system without add-ons (e.g., remote access), and that her colleagues emphasize the need to build up close relationships to the automotive OEM, who acts as battery supplier and as battery usage data supplier, and to local electronic specialists, who install the system at the customers' site and who provide maintenance services (Bräuer, 2018; Bräuer et al., 2016). Moreover, our user learns that about 1/3 of prospective customers in a non-representative study would choose a leasing contract, a renting contract or a pay-per-use model over the battery system's purchase (Plenter et al., 2019). Being new to service-oriented business models, our user employs the platform's discussion functionalities linked to the protocols to ask for literature on this topic.

Next, our user consults the platform's method library to identify a suitable method. Based on the project's attributes, workshop history, anticipated participants (profiles, competencies), specified project milestones, and recommendations of other users, the platform suggests the development of personas during the next workshop. Our user invites other team members to the workshop and includes a link to the platform's method library with detailed information on the method and tips for workshop preparation in the invitation. With the aid of a member list that also indicates the status of other project members, our user contacts the project manager directly via chat when he appears online to exchange last instructions for the upcoming offline workshop. The workshop reveals that the team has quite conflicting views on the key characteristics of the to be developed personas. On the one hand, external studies show that buyers of regular battery energy storage systems are not per se purchasing the systems for means of earning money, but for increasing their independence from energy providers and for contributing to the energy transition (Balcombe, Rigby, & Azapagic, 2014; Figgener et al., 2018). Thus, the average customer is a house owner, wealthy, interested in technology, demanding in terms of reliability, and the customer's education level is above average. Parts of the group make a stand for adopting this customer segment for the SLBESS. On the other hand, the presented previous studies show that the markets for medium-priced and high-priced battery energy storage systems with numerous technical add-ons are quite competitive, long-term guarantees are issued, and the systems' longevity and reliability are key to marketing. These requirements cannot be easily met with SLBESS. Instead, the group finally decides for addressing price-conscious young families who currently do not purchase battery storage systems due to high investments but low monetary gains and who are still in a phase of professional orientation and thus rent their houses and want the flexibility to not lose an investment in case of moving. Hence, the families Hinz and Kunz are born.

After this workshop, our user finishes the online protocol, uploads pictures of key personas, and specifies follow-up tasks. The project manager then assigns these tasks to other project members and specifies deadlines. Moreover, the project manager sends a prompt to rate the workshop and the employed method's adequacy to all project members. As the project continues, the knowledge map is enriched with additional paths and activity nodes and several members added new methods to the platform and recommend them to specific scenarios. One of these methods builds on the utilization of the Green Business Modeling (GBM) Editor to develop a sustainable business model.

2.3 Developing Sustainable Business Models with the GBM Editor

Business models are of booming interest to both researchers and practitioners from various fields for achieving competitive advantages of firms (Massa et al., 2017). Research on business models includes, amongst others, streams on taxonomies for categorizing types of businesses, or business model notations for visualizing elements and their relationships (Zott, Amit, & Massa, 2011). In terms of software support, various Business Model Development Tools (BMDTs) have been developed (Szopinski, Schoormann, John, Knackstedt, & Kundisch, 2017), which have

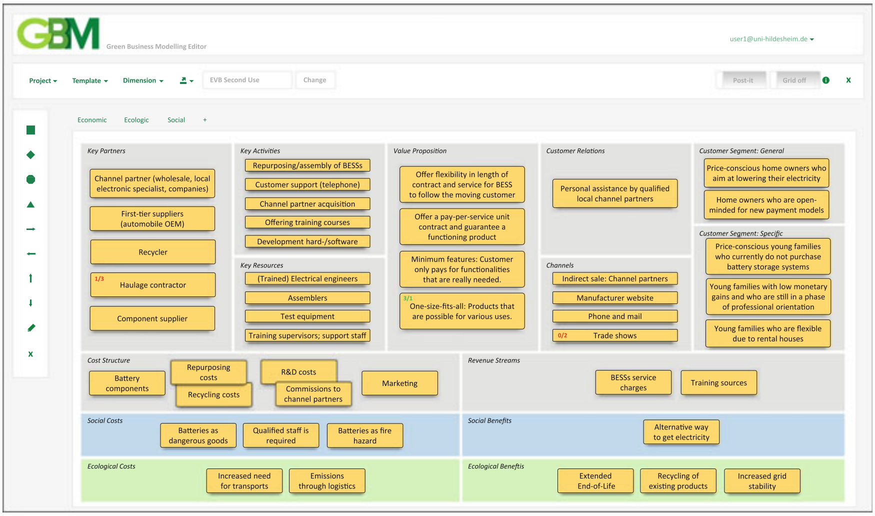

Fig. 2 Software prototype for sustainable business model development

the potential to contribute to certain tasks (e.g., sharing, modeling, assessing) more efficiently than the 'pen & paper' methods (Osterwalder, Pigneur, & Tucci, 2005). Hence, some tools have already gained popularity, for example, the *Canvanizer* app has more than 700.000 projects (Szopinski et al., 2017) and *Strategyzer* has over 22.000 active users (Strategyzer, 2018).

However, while most of these BMDTs focus on economic aspects, ecological and social sustainability are virtually neglected and not supported. Addressing this deficit, the goal of the GBM Editor is to support reflection of multidimensional sustainability during the development of new business models as well as during the analysis of existing ones (Schoormann, Behrens, & Knackstedt, 2018a, 2018b) (Fig. 2).

Based on results from the first phases of the Design Thinking process, initial business ideas have to be detailed and structured in the form of a business model. As a first step, because innovating a business model is a collaborative task that requires the involvement of actors from different disciplines, our project manager sets up an empty business model development project for 'Electric Vehicle Battery Second Use' and invites further collaborators to join the GBM Editor. Based on a set of different business modeling languages, our project manager decides to select the Business Model Canvas (Osterwalder & Pigneur, 2010) as it is by far the most widely used modeling language for business models. Next, the team starts to develop their business model by using Post-its for specific business model elements, for instance, recycler for the component key partners, or "price-conscious young families" for the component key customers, which have been detailed in the persona workshop (see Sect. 2.2). For discussion, the team uses features that allow writing and receiving messages as well as a discussion board. Moreover, they use a chain of reasoning to track different reasons of why a business model element is modeled in a certain way (e.g., legal regulations affecting lithium ion batteries).

After creating the first Post-its, our project manager reminds the team to further focus on aspects of sustainability, as the business model especially intends to support ecological effects. Therefore, additional information in the form of checklists are used, which allow considering key concepts for environmental (e.g., closed-loop production) and social (e.g., health promotion) sustainability. Guided by these lists, the project team focuses on repurposing activities of used batteries. Furthermore, to draw on existing schemas for the component cost structure, the team selects from predefined characteristics that present common elements for a certain component, for example, in the form of business model patterns.

To verify if some of the business model elements have positive or negative effects on sustainability, the project team applies the 'trade-off analysis' implemented in the GBM Editor. For instance, the team collects positive (e.g., easy to disassemble, lower use of resources, lower efforts) and negative (e.g., lower set of possible configuration options) impacts of the Post-it 'One-size-fits-all' that is specified as the value proposition. The number of collected reasons is displayed in each element.

Although the Business Model Canvas is a widely-accepted approach, a team member raises questions regarding how to represent the impacts of the entire business model. As a consequence, a team member suggests to extend the original Canvas (Schoormann, Behrens, Kolek, & Knackstedt, 2016) by adding new components for social benefits (e.g., business provides new ways of getting electricity) and for social costs (e.g., battery fire hazard) as well as for ecological benefits (e.g., extended life of batteries) and ecological costs (e.g., increased need for logistics in case of recycling and repurposing batteries).

After the workshop with the GBM Editor, the team realizes that the targeted company that should implement the second life business model, the so-called second life manufacturer, lacks key competencies to implement the business model on its own. To cope with this challenge, our user opens a new discussion in the Design Thinking prototype and suggests to further analyze the possibility to realize the pay-per-use business model with the aid of an organization-spanning service network. For planning the service network, the project manager suggests using the Cooperation Manager.

2.4 Planning Service Networks with the Cooperation Manager

The realization of service business models in service networks and the development from a "bilateral supplier-customer" and "service-value cocreation" towards "a multi-actor perspective" and an "ecosystem service-value cocreation" strongly influences service research (Ostrom, Parasuraman, Bowen, Patricio, & Voss, 2015). Further following Ostrom et al. (2015), understanding service networks and coordinating the distributed activities for value creation over the boundaries of a single organization forms one of the most important research priorities in this domain. Thereby, the information exchange between the partaking organizations forms a key mechanism to achieve coordination, which is in turn defined as "managing dependencies between activities" (Malone & Crowston, 1994, p. 90). In an inter- and intra-organizational setting, information exchange is the mechanism helping to ensure that an individual participant's tasks are executed coherently and that joint decisions are made efficiently (Durugbo, Tiwari, & Alcock, 2011).

For planning corresponding service networks and the underlying coordination mechanisms, the Cooperation Experience modeling method (Bräuer, Scholta, Strotmeier, & Knackstedt, 2017) and the Cooperation Manager software prototype (Strotmeier, Jähne, Riffel, & Winter, 2017) have been developed. Using a service network's integrated business model as a basis, users are guided through three hierarchically organized layers: starting with a representation of the network's framework including high-level activities, detailing the network's inter-organizational key activities and the necessary information exchanges and dependencies between the participants in cooperation scenarios, and lastly further defining single processes.

In the workshop, the team decides to first start modeling with pen and paper and later transfer the results to the Cooperation Manager, which allows them to achieve a consistent representation and to export the models to other business process management tools. Using the product-service systems framework (Deutsches Institut für Normung e.V., 2009) as a rough basis, the team first defines the network's high-level activities by analyzing the SLBESS's life cycle phases (Fig. 3, left). Based on the required key competencies and data, partners are suggested and assigned to the activities. Moreover, for each of these activities, the initiating (I) and terminating (T) partner is emphasized and the corresponding initiating and terminating information artifacts are described. As a final step, the managing activities (roof) and the supporting activities (base) are defined.

During the second part of the workshop, the team focuses on detailing the inter-organizational key activities by using cooperation scenarios (second layer). Each cooperation scenario integrates several cooperation modules that, in turn, consist of interdependent cooperation activities. For the cooperation module repurposing, the team identifies a total of five activities that strongly rely on information exchanges between the partaking partners (Fig. 3, right). Those activities that are exclusive to a single partner and that do not directly initiate an information exchange are not modeled on this layer but can be specified on the third layer. Consecutively, the team identifies cooperation activity-specific information flows and data respectively information encapsulating information artifacts and expresses possible dependencies between ingoing (left) and outgoing (right) information flows with the aid of simple XOR, OR, and AND operators. Main responsibilities are emphasized by number references.

A further detailing of the activities on the third layer is delayed to another workshop. Instead, the team decides, to rebuild the cooperation scenario models with the Cooperation Manager to benefit from the prototype's playback functionality that

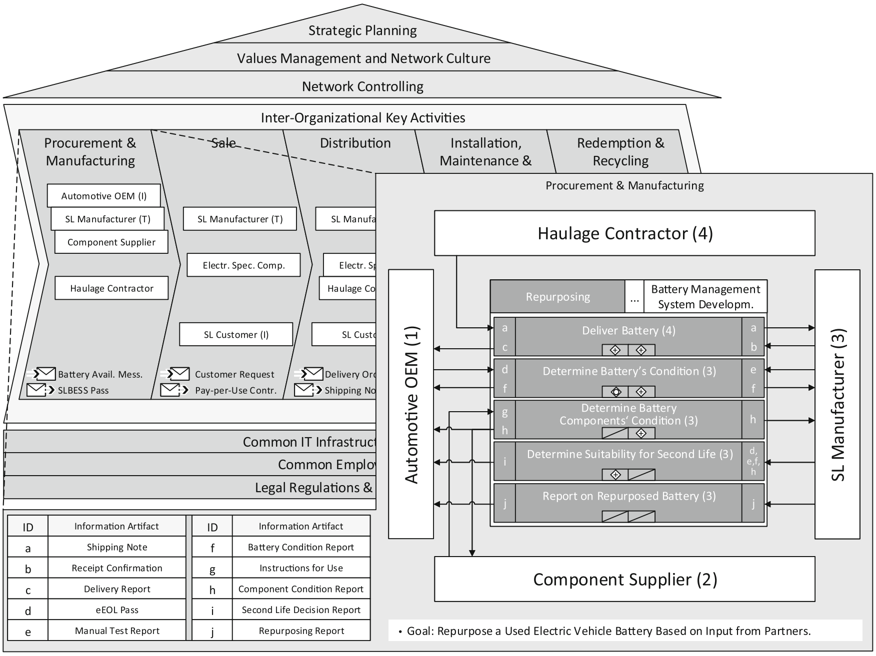

Fig. 3 Visualization of first and second layer built with the CXP modeling method

allows to filter and fade-in the information flows and information artifacts step by step for the sake of clarity and to facilitate self-reflection.

3 Where Do We Go Next?

In this article, we have proposed three different software prototypes from ongoing research projects that aim at boosting business model innovation and we have shortly demonstrated the prototypes' use and interplay against the background of developing a battery second life business model. In doing so, we addressed different stages of business model innovation projects, namely structuring and documenting the innovation process, generating new business ideas (both Design Thinking prototype), visualizing and analyzing business models with respect to sustainability (GBM Editor), and detailing business models through value networks respectively service networks as well as through underlying processes and information exchanges (Cooperation Manager).

The integration of the different software prototypes from originally separated research projects within a common development process promises to be a valuable starting point for exploring opportunities of a Design Thinking-focused ecosystem. Moreover, we plan to investigate how domain-specific knowledge can be more sophistically integrated into general purpose methods, for example, that are employed during the Design Thinking process, to address topics such as sustainability or life-design in a more elaborated manner. And of course, our future research endeavors will always be dominated by a prominent leitmotif: 'strukturieren, strukturieren, strukturieren'.

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How a Global Customer Service Leader is Using a Reference Model to Structure Its Transformation While Remaining Fast and Agile

Karsten Kraume, Klaus Voormanns and Jiaqing Zhong

1 Introduction

The way that companies manage customer service has changed greatly over the past two decades and will continue to evolve in the coming years (Everest, 2018). One of the reasons is that the emergence of new digital communication channels has made it easier for customers to communicate with brands 24/7, resulting in a rapid growth in interactions. At the same time, companies are increasingly using customer service as a way of standing out from the competition. According to Deloitte (2015), 62% of companies now view the contact center as a competitive differentiator. The result is that contact centers are becoming a central part of the brand experience, and high quality customer service is being offered across more and more product lines and channels.

However, most organizations still struggle with managing the resulting complexity. As a result, companies use expert knowledge by outsourcing their Customer Service. Global business process outsource (BPO) providers, such as Arvato CRM, design, deliver and differentiate customer service on behalf of brands (Arvato, 2017). The business is becoming more and more driven by the technology applied, differentiated by experience of managing the processes and ultimately powered by people (the ‘human touch’) who make the real difference (Arvato, 2017).

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To manage the complexity and maintain the dynamic of the business, customer service organizations need structure themselves in domains like process, people and technology. Reference models are a means to help this, so that efficiency and effectivity gains can be realized by reusing model components (Becker & Schütte, 2004).

The aim of this paper is to outline the particular challenges and opportunities in a BPO customer service context and to illustrate how a reference model structure can contribute to the digital transformation of global companies like Arvato CRM.

The remainder of this paper is organized as follows. Firstly, an overview of the market dynamic of customer services and what that means for customer service providers. Secondly, an introduction to the reference modelling, along with generic benefits. Thirdly, we illustrate how the reference model supports the business transformation while increasing speed and agility. And finally, we explore limitations and suggest some opportunities for further research and investigation in this field.

2 Context and Background

2.1 Market

As the business world becomes more competitive and commoditized, customer service is becoming a key way for brands to differentiate themselves. How a company treats its customers and, importantly, how it makes them feel, is now considered one of the most important factors influencing the buying decision. Indeed, it is estimated that over 80% of consumers would pay more for better customer experience (Capgemini, 2017).

In parallel, consumer behavior is also changing. The number and variety of channels to communicate with customer services like WhatsApp, Facebook, Chat, Mail or even Video interaction is growing and complex (Everest, 2018). In addition, consumer expectations to receive consistent feedback from brands, even when contacting them via different channels for the same intent, is increasing.

The number of service-based businesses is growing, for example due to the sharing economy and consumption-based models instead of ownership of physical assets. This leads to an exponential increase in the number of consumer service requests, which have to be answered by brands. In addition, experts expect the number of customer interactions to grow rapidly within the next 10 years, driven by better connectivity and more automation (Table 1).

Table 1 Global volumes of customer interactions. Source: Arvato, IBM, Bia/Kelsey, Gartner, Jupiter Research, nojitter.com

Year	2000	2010	2017	2022	2027
Global volumes of customer interactions	40 bn	100 bn	400 bn	1,000 bn	3,000 bn

Table 2 Channel development forecast 2013–2018 (in $bn). Gartner 2016

	Voice	Web chat	Email	SMS/M apps	Social CRM	Self service
2013	33.1	1.6	1.8	2.1	1.9	2.2
2018	32.2	4.1	1.1	5.9	6.3	5.6

As material possessions and products become more exchangeable, the customer service offered with products becomes more relevant. And customer service becomes a crucial factor (IDC, 2016) for consumers and allows brands to differentiate accordingly (Table 2).

The increasing number of interactions also goes along with changing channel preferences. As we can see in the diagram above, while Voice interactions remain a relevant part of the mix. Their relative importance decreases (Everest, 2018). In contrast, upcoming digital channels such as self-service and social media are gaining increasing importance for communication between brands and consumers.

Customer satisfaction is affected most by the quality of the response or the resolution of the issue and the perceived friendliness of the Customer Service Representative (Arvato-CRM, 2018a). This requires improving the capabilities of customer service BPO-players, from both a process and technology viewpoint. Given this complexity, companies need to review their operating model and staffing, or source accordingly, to truly ensure that humans and technology are working seamlessly together to provide the optimal solution for the customer who, after all, is also a human being (Arvato-CRM, 2018b).

The Internet of Things (IoT), is also changing the customer service business. Machines or devices initiate a growing amount of service requests. A rise in service requests due to the 'connected car' is already a reality—for example, break-down or emergency calls. Similarly, other sectors like insurance (pay as you drive services), healthcare (patient relationship management), high-tech (connected home) are progressing despite increasing regulation such as GDPR, and cybersecurity threats.

At the same time, the way companies operate is being transformed by huge advances in computer processing power and the development of ever more sophisticated self-learning algorithms. Technologies such as robotic process automation (RPA), artificial intelligence (AI) and big data analytics are allowing companies to automate entire workflows, creating new efficiencies and ways of interacting with customers.

Overall, consumers, regulators and companies across country borders and converging industries face challenges and opportunities arising from technology. More complexity increases the importance of a structured approach.

2.2 Arvato CRM

Arvato CRM's core business is customer interaction, provided as Business Process Outsourcing (BPO), to various brands. Arvato CRM has been named again a Leader in latest Everest Group PEAK Matrix™ (Everest, 2018). More than 45,000 employees around the globe support customer services in more than 20 languages. The changing market environment, as described above, applies to Arvato's CRM business as well. Customer service providers need to transform current business—and their organizations. Automation is becoming more and more relevant, also substituting human tasks. But this will not end up in 100% of processes being automated. Rather, we will see more hybrid models, blending automated services with human interactions.

Besides these general market challenges, there are specific requirements for Arvato CRM. The business has grown on a largely decentralized model. Strong and independent country organizations guarantee best-fit to local requirements, but also limit the ability to harmonize investments in IT or in standardized processes. This harmonization is needed for a successful digital transformation, which cannot be done at an individual country level.

In summary, Arvato CRM faces the following challenges:

- Transform the business from a pure human to a hybrid model—blending IT and people
  - Implement more technology
  - Change way of working
  - Re-position in the market
- Harmonize the organization—from a decentralized model to a centralized one:
  - IT Platforms
  - Processes
  - Portfolio.

A strategy process was initiated in 2015 to define this transformation and face the challenges mentioned above. The strategy process also had to:

- Ensure transparency on current processes, IT Systems, industries, clients, capabilities.
- Establish a way to share the structural information across the entire organization.
- Provide a common basis to discuss future changes.

To deliver on these objectives, Arvato CRM decided to apply BPM methodologies. Within collaboration with the ERCIS Arvato founded the Omni-Channel Lab, centered around integrating, modelling and analyzing data. The multiple research areas of the lab support the strategy execution.

3 Model Approach—An Academic View

Reference modeling is a method to build a model that represents business in a certain domain (Heuchert, 2017). A model is defined as an "*immaterial representation of an original for the purposes of a subject*" (Becker, Probandt, & Vering, 2012). It helps to structure complex environments and define a basis for common understanding. Three characteristics of models are identified: *Mapping, reduction and pragmatism* (Stachoviak, 1973). Mapping the reality in a model helps to structure the current environment and make it transparent across the entire organization. Reducing it to the relevant aspects helps to manage complexity and pragmatism helps with the selection of relevant elements for the specific intent of the model. The purpose of reference modeling can be the constitution of application systems or the organization (Rosemann, Schwegmann, & Delfmann, 2012)—which is also called Information Modeling. This is the focus here and covers aspects like IT systems, organizations, documentation, and process management. Creating information models is a complex task, which is why reference models are a useful means to reduce this effort (Becker, Delfmann, & Knackstedt, 2007).

There are different definitions for reference models in the literature. Common understanding is that reference models are set up for a defined domain, are not company specific and serve as source for specific models. Reference models help to reduce the effort in setting up a company specific model (Heuchert, 2017) (Fig. 1).

Becker and Schütte name benefits of reference models in combination with an explorative study (Schütte, 1998). They also distinguish between two different 'actors' being involved in reference models—Designers and Users—with specific benefits. While Designers aim for benefits in the model build phase. Users aim for benefits when consuming model information. One of the main aspects for Users is

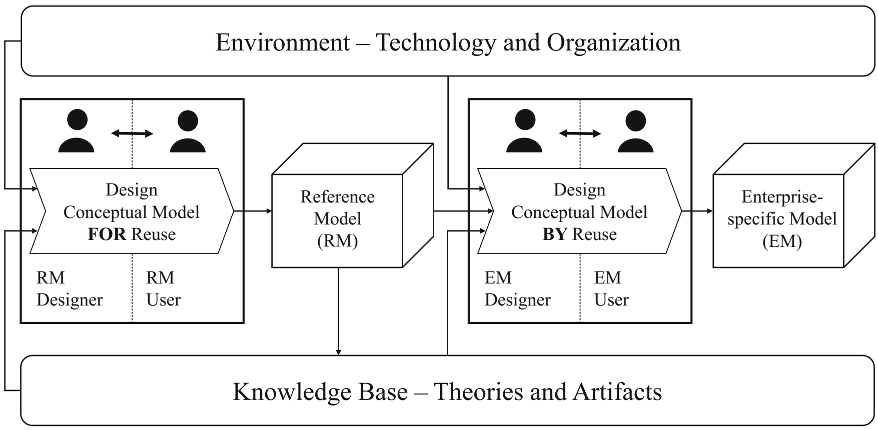

Fig. 1 Design process of reusable conceptual models Adapted from vom Brocke and Buddendick, (2006, p. 587)

the exchange of information inside the company, which benefits from a common base for discussion. It can be summarized as ‘best practice sharing’ (Heuchert, 2017).

One example for a reference model is the Retail-H, for the Retail domain developed by Becker and Schütte (2004).

Arvato CRM operates in a complex and heterogeneous environment. There are various stakeholders, many processes and different IT systems in place. To support the transformation, Arvato CRM decided, together with the ERCIS, to set up a domain-specific reference model for outsourcing providers in Customer Services.

4 A Reference Model to Structure the Transformation

4.1 An Integrated Reference Model as a Framework to Structure Transformation—The Elements of the Model

Arvato CRM selected a business process management (BPM) methodology to support reaching its harmonization goals. The intention was not to run a classic process optimization project to streamline the process flows, but rather to allow Arvato CRM to define and share standard information in the most relevant domains. Thus, the development and usage of a reference model was agreed as starting point. Reference information models (reference models) are information models that are developed with the aim of being reused for different but similar application scenarios (Becker et al., 2007).

Building blocks were defined within the enterprise structure, such as change in organizational set-up, process harmonization, IT system consolidation, innovation and data intelligence. Experts in the different functions across the globe work on the various work streams to support the transformation and to create competitive advantages for the organization (Fig. 2).

The following dimensions are reflected in the reference model:

- Process flow: Arvato CRM has applied the process flow following the Ice-bricks Methodology on four levels (Becker, n.d.). The process flow describes internal and external processes. Working processes for individual operations across channels and service types are documented and used as a standard for training and quality assurance purposes. This ensures that operations can be up and running with high efficiency and efficacy. There are also client management processes to further grow the business and manage the relationship with the clients. These include lead generation, client consulting, solution design, business transition, and implementation.
- Organization: “Culture beats strategy!” (Schein, 1985). Above all customer service is about people, because service is a human thing even if it is partially delivered by a robot. It is also people who apply technology and bring added value to the business based on their experience. To drive growth, innovation and optimization

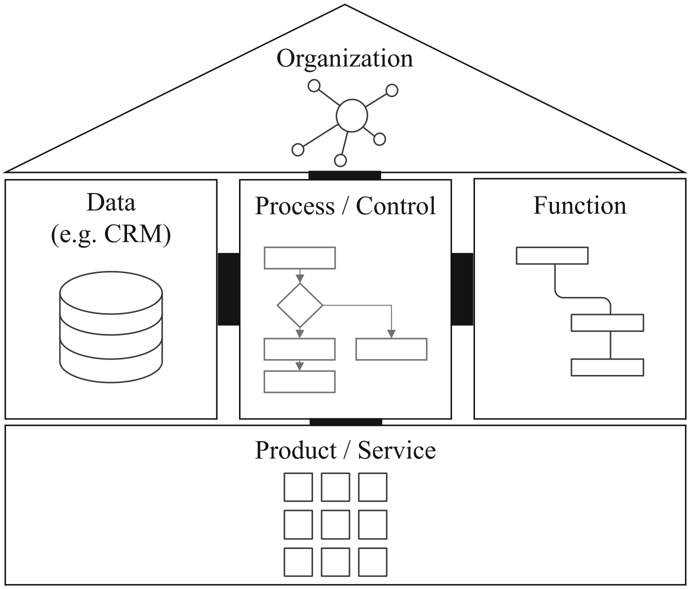

Fig. 2 Model building blocks. Adapted from ARIS Process framework. IDS Scheer

for the business, a well-designed organization is fundamental (Kaplan). For this, we work on a global level with more than 100 sales experts, around 1000 IT experts (including profiles like portfolio management and solution design), on top of a customer service organization with more than 40000 Customer Service Representatives. This organizational structure is also part of the reference model.

- IT Architecture: Given its decentralized origins, with more than 25 independent businesses and local technology organizations Arvato CRM faced a heterogeneous legacy IT-landscape. A structured, but pragmatic platform repository was built, serving as the inventory for all IT platforms. Based on insights regarding which technology has been applied and where, harmonization projects were launched to reduce complexity and generate synergy across the operations and regions. As result, the total number of different voice systems (for example) was reduced from more than 10 to one single core technology for the entire global organization. And instead of various different local workforce management systems Arvato CRM implemented a centralized standard technology for global accounts across countries. Managing the IT Architecture is crucial for Arvato CRM, hence the IT architecture is also part of the Arvato CRM model.
- Solutions: The services that Arvato CRM provides for its clients are structured into so-called 'Solutions'. The Solution Portfolio links client demands and Arvato CRM delivery, and is part of the reference model. A Solution can be either a product, to be adapted to meet the client's need, or Consulting Services. Consulting is also offered to identify client pain points and business challenges in order to

select best-fit solutions. This process is called the ‘Solution Design Processes’ and also follows the reference approach by applying innovative design methodologies.
- Customer journey mapping: Good customer experience is the core objective of customer service, which means that a perspective is needed within the model to map how consumers navigate through their specific experience. Customer Journey Mapping is a methodology that covers not just the process steps but also experience-specific parameters like the current channel used or the consumer’s mood when interacting with customer services. This helps to identify needs and challenges in the current process, and enables new solutions to be developed based on this insight. The customer journey mapping methodology is used alongside the solution design process.

4.2 Leveraging the Reference Model by Combining Different Model Elements

The reference model is used on a day-to-day basis. The highly structured views described above—all following a strong methodology—ensure consistency for experts in modelling. However, there is a need to share model information with wider audiences who are perhaps less familiar with modelling terminology. Less complex, reduced, and more attractive views are required to publish model information for this broader audience. This may end up in a model that combines different aspects with less information in a more attractive design.

The Arvato CRM Analytics Framework (the Arvato “A”) is one example of combining different model elements in one view—in this case giving an overview of Arvato CRM’s analytics services (Fig. 3).

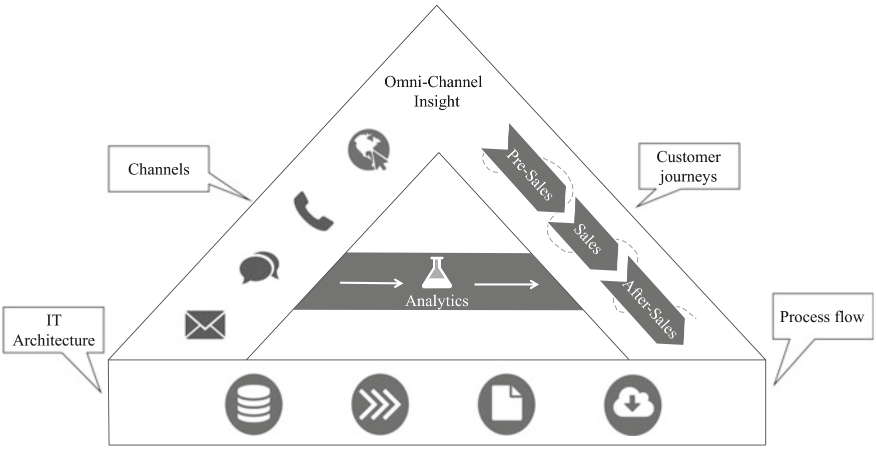

Fig. 3 The Arvato Analytics Framework

The Arvato "A" (Trautmann, Vossen, Homann, Carnein, & Kraume, 2017), combines parts of the process view with the customer journey and parts of the IT Architecture, and enhances this channel information. All these elements 'live' in different parts of the reference model and are combined for this specific view. The box in the middle is not covered in the current model, however, elements such as algorithms could be a good fit.

4.3 Keeping the Model Up-to-Date

Regular reviews and adaptations are essential to the business, and this also applies to the reference model—information needs to be monitored and updated on a regular basis. To ensure that the model is kept up to date. Arvato CRM has set up organizational and process structures. For example, by utilizing data analytics and visualization methodology, a transparent and structured overview of digital related skill-sets of employees has been created. This overview also helps to identify the white spots of the relevant skill-sets that the organization needs. This visualization also serves as reference for making management decisions on recruiting and re-structuring—and provides information to update the reference model.

5 Summary and Outlook

The case at hand shows why structure can be beneficial. Various perspectives need to be taken into consideration, such as stakeholder management, technology development and regulation etc., to ensure a synchronized and joint approach in an ever-faster changing environment.

It is important to understand that structure—like strategy—is not an end in itself. Strategy is means to a higher goal, often referred to as 'vision' or also described as path to a desired destination. Getting from a to b requires structure(s). While structural changes in the market can require structural adjustments in organizational set-ups or operating models, they do not alter each quarter, half-year, or year and consequently allow a learning curve and economies of know-how.

Properly applied basic structure is an enabler for speed and agility, especially in large, complex global organizations. Arvato CRM enhances the model systematically, in an agile mode, driven by priorities. But making the model available is a core challenge. This requires considerable alignment and engagement within the organization. Visualization and publication is also key, making the model understandable, smart and accessible within the organization and to different stakeholders who can accelerate acceptance and engagement. Furthermore, once the model is established, it still needs to be regularly reviewed and iterated to meet the demands in the fast changing market environment.

Above all, collaboration remains a human thing. Changes in the structure and process need to be properly aligned with changing mindset and culture. Communication is the key—and also one of the toughest issues which an organization is facing with during the entire process. But there are very few reference cases that specifically address the particular requirements described in this case. This means that there is an interesting opportunity for academic experts to further investigate and develop solutions with organizations to jointly tackle this challenge.

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All Dynamic Decision Problems Are Created with Equal Structure

Stephan Meisel

1 Introduction

A dynamic decision problem occurs every time an agent has to make a sequence of decisions with each decision having a potential impact on the agent's opportunities at later points in time. Against the background of this definition one realizes that dynamic decision problems occur in many situations in everyday life. We may think of simple cases such as going for a walk, where every step determines a person's location and thus restricts the set of locations reachable within the next n steps. Given the fact that making a step consumes time, and given the typical situation of a time limit for how long the walk may take, it is obvious that a person on a walk should continuously make deliberate decisions about where to step next.

Dynamic decision problems become even more difficult to solve in the presence of uncertainty. Think of going for a walk without a map or any other source of geographic information. Or think of the example of a farmer selling cut flowers on a farmer's market, and not knowing how many customers will show up during the market day. Given the initial amount of flowers for sale, the farmer faces a dynamic decision problem in terms of a sequence of decisions about updating the flower price during the day. Lowering the price may increase sales now, but may at the same time reduce the number of flowers available for sale at later points in time, where demand may be increasing significantly, and where sales may be possible at a higher price.

Both the person going for a walk and the farmer selling cut flowers face a problem where a decision that is made now has a potential impact on opportunities at later points in time. Obviously in both cases the decision maker could benefit greatly from receiving online information, such as updates on the current shortest path back home or updates of the demand forecast for the remainder of the day. In both cases, the

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updates can be an enabler of good decision making (avoiding the waste of future opportunities).

In recent years many companies from a large variety of different industries have been confronted with dynamic decision problems. The availability of modern information and communication technology has urged the need to understand business operations as dynamic decision problems and to build decision support systems that are able to solve these problems efficiently. In an increasing number of industries the ability to solve dynamic decision problems has become key to the competitive edge of companies.

At the same time, the ability to solve a dynamic decision problem efficiently, crucially depends on having a deep understanding of the problem structure. Hence the first and foremost task in building a decision support system for dynamic decision making is establishing structure by creating a mathematical model of the problem.

In many cases, the feature-richness and the complexity of real-world dynamic decision problems make modelling a significant challenge. At this point it turns out to be of great advantage for the modeller to be aware of the fact that—despite the vast variety of problems and application areas—all dynamic decision problems share one common structure, and that this structure needs to be imposed on the problem at hand, i.e., that all dynamic decision problems are created with equal structure. Clearly, the first and foremost task in building a decision support system for a dynamic decision problem may be reformulated as “strukturieren, strukturieren, strukturieren”.

In the remainder of this contribution, we proceed as follows: In Sect. 2 we discuss a few examples of dynamic decision problems that are of particular relevance in nowadays business environment. In Sect. 3 we discuss the common structure of dynamic decision problems, and in Sect. 4 we outline an example model of a dynamic decision problem. Section 5 summarizes approaches to problem solving, and Sect. 6 concludes this contribution.

2 Examples of Emerging Dynamic Decision Problems

Dynamic decision problems currently emerge in virtually all industries. In this section we briefly discuss three prominent examples of dynamic decision problems, touching on the three areas of service vehicle routing, energy storage management and build to order manufacturing. For more details on these and other examples we refer to Meisel (2011).

2.1 Service Vehicle Routing

An increasing number of business models rely on operating fleets of service vehicles. Beverage and grocery shopping home delivery services, parcel services, field services, and after-sales services are only a few of the many possible examples.

With all of these business models, companies typically rely on modern information and communication technology in order to continuously receive new information about customer orders, service requests, delivery delays, or about the traffic situation. Against the background of the continuous stream of newly arriving information, the company's fleet manager must repeatedly make decisions about which customer request to assign to which vehicle, and about how to sequence the customer requests assigned to one service vehicle.

Consider the Less-Than-Truckload (LTL) shipping business as an example. In LTL a service truck collects items from different customer locations and eventually heads to a hub where the items are transshipped for long distance transportation. As items in LTL shipping are mostly rather small and lightweight vehicle capacity limitations do typically not cause operational difficulties.

LTL companies aim at utilizing each service truck for serving as many customers as possible within the fixed period of time of a driver's shift. However, many customer requests are typically unknown at the point in time where the shift begins. Hence, late requesting customers may call in while the service truck already is en route, and the fleet manager must then decide for each late request if this request is accepted for same day service, or postponed for service at the next business day. In case of acceptance, both customer address and rerouting instructions must be communicated to the driver.

However, making acceptance decisions that realize the company's aim of maximizing the total number of requests served within the current driver shift typically is a hard challenge. On the one hand acceptance of a late request seems beneficial as it increases profits up to the current point in time. On the other hand an acceptance decision results in additional travel time, and thus possibly enforces rejection of more than one late request during the rest of the driver's shift.

The first step to building a decision support system that allows for deriving sound acceptance decisions is to model the LTL problem in terms of the typical structure of dynamic decision problems.

2.2 Energy Storage Management

Managing energy resources has become an important challenge for governments, utilities, companies and even for private households. Many countries have decided to advance the use of renewable energy sources, and some countries, such as Germany, even aim at making intermittent renewables the primary source of energy generation. In many cases, intelligent use of energy storage is supposed to make volatile energy production both manageable and profitable. Many new business models are being developed where companies continuously receive new information about energy prices and weather forecasts, and where energy managers must repeatedly make decisions about how much energy to store or retrieve from storage, and how much energy to buy and sell at the markets. The aim typically is to maximize the total profits from energy sales over time.

Consider the wind farm business as an example. Wind farm managers face the problem of uncertain future wind conditions, and in many cases they must periodically make advance commitments about the amount of wind energy to be offered at the spot market. In case of generating more energy than committed, the surplus may be transferred to the energy storage device, and in case of underproduction additional energy may be retrieved from storage. However, both store operations and retrieve operations cause costs in terms of energy losses, where the extent of loss depends on the type of energy storage in use. And obviously, it may occur that the manager does not have enough energy in the storage device to balance an incorrect generation estimate that had been used for making a commitment. In this case, the manager typically faces penalty costs in terms of having to buy energy from a high-price balancing market.

Making decisions about energy transfers between energy sources, storage devices and energy markets such that profits are maximized at the end of the day is a hard challenge. The decisions at each point in time immediately generate profits or losses, while at the same time determining how much energy is left in the storage device for use at later points in time where both price and weather conditions may have changed significantly. Again, the key to building a decision support system that allows for deriving sound energy transfer decisions is to model the storage management problem in terms of the typical structure of dynamic decision problems.

2.3 Build to Order Manufacturing

Mass customization is one of the major trends in manufacturing. Initiatives like the industrial internet and Industry 4.0 aim at manufacturing sites that are driven by a stream of incoming data about both actual and possible future customer orders. The ideal goal of future manufacturing is to have a customer's individual product ready-made not much later than the actual customer order arrives. In order to achieve this goal factory managers must constantly make decision about which flavour of a product to build next, and about which production resources to use for building the product.

In a manufacturing environment resources are often equivalent to machines, robots or tools. Creation of a specific product requires execution of a certain number of working steps, each of which is tied to a certain type of resource. Often the order of production steps is strictly predefined. The types of resources required as well as the amount of time a resource is required for production heavily depend on the specification of the resulting product.

In many cases a customer is granted a deadline for receiving his product. Hence, manufacturers must be reliable, i.e., they must aim at minimization of deadline violations. However, maintaining deadlines crucially depends on the scheduling decisions for production jobs. Such decisions must be made subject to a limited number of available resources as well as in many cases subject to the constraint of not suspending a job that is currently processed by a resource.

Scheduling decisions resulting in minimum deadline violations are hard to make particularly in the context of mass customization. The large variety of possible product specifications implies a high variation of resource occupation times between different production jobs. In addition, new customer orders appear while others are being either processed or scheduled for production. Releasing a production job as early as possible definitely is a good decision with respect to maintaining its deadline. Nevertheless an early release reduces flexibility by binding resources, and may thus cause massive deadline violations of future customer orders. As a consequence rescheduling decisions must be made if either new actual customer orders or new order forecasts become known. As with the previous examples in this section, the key to building a decision support system that allows for deriving sound scheduling decisions is to model the manufacturing problem in terms of the common structure of dynamic decision problems.

3 Common Structure of Dynamic Decision Problems

For a long time it had not been self-evident at all that all dynamic decision problems are created with equal structure. Only recently (Powell, Shapiro, & Simao, 2001) and (Powell, 2007, 2011) introduced a detailed modelling language for dynamic decision problems that identifies the common problem structure and that has become a guideline for researchers in the field of dynamic decision making. Figure 1 illustrates the structure of a dynamic decision problem as it evolves over time and shows the five core modelling elements that we briefly outline below without diving much into mathematical formalism:

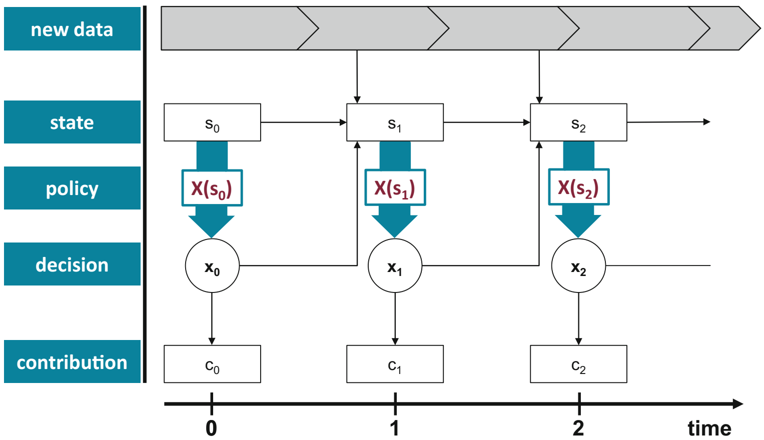

Fig. 1 Basic structure of a dynamic decision problem (Meisel, 2011)

- **Time**: The first modeling task consists in determining the time horizon of the problem. The modeler has to determine if the sequence of decisions happens, e.g., within one day, within a working shift of a certain duration, within one full year, or if the problem at hand has even has an infinite time horizon. As the time horizon is determined, the modeler should identify the shortest possible period of time that can elapse between two subsequent decisions. This period of time determines how much real time elapses in one time step in the model. In case of finite time horizon, the set of points in time $\{0, 1, \ldots\}$ where a decision is made can be derived from time horizon and the shortest possible period between two subsequent decisions.
- **State variable**: At each point in time, the decision maker (the system being considered by the decision maker) is in a certain state (denoted as S_t in Fig. 1, where t is the time index). The state variable represents the current information the decision maker has access to, and, more strictly speaking, the state variable must include all pieces of information that are required as basis for making a decision. Hence, the crucial task for deriving the state variable consists in identifying all data attributes that need to be considered for making a decision. Technically a company determines the current state right before making a decision by extracting the current values of the data attributes in the state variable from its IT-systems. Powell (2011) defines the state variable as the minimally dimensioned function of history that is necessary and sufficient to compute the decision function, the transition function and the contribution function, each of which we introduce below.
- **Exogenous processes**: Special care has to be taken with respect to the new data (see Fig. 1) that a company continuously receives from exogenous sources. As exogenous sources, we refer to all data and information sources that the company cannot fully control, and that therefore represent the origin of the uncertainty in the present dynamic decision problem. Exogenous data, such as new customer orders, price changes and weather updates, is of relevance only if the data may change the value of at least one of the elements of the state variable. For making decisions online, i.e., during the daily operations of a company, it is obviously not necessary to consult formal models (in terms of, e.g., stochastic processes) of the exogenous processes. However, deriving a solution of a dynamic decision problem typically requires simulating the problem (including exogenous processes) offline. In this case, all types of exogenous data must be analyzed using statistical methods, such that the exogenous processes can eventually be characterized in terms of probabilistic statements and stochastic models that can be used for simulating the dynamic decision problem offline.
- **Feasible decisions**: At each point in time, the set of feasible decisions needs to be derived based on the current state. Note that in daily operations "making a decision" often means making a (possibly large) number of decisions simultaneously. If, for example, a factory manager finds himself in a state with five new customer orders of which only two can be accepted due to capacity restrictions, then a total of five elementary decisions about acceptance are made at the same decision time. Figure 1 denotes a decision as x_t, where x_t represents a vector of elementary decisions at time t.

Depending on the dynamic decision problem at hand, the task of deriving a state-based representation of the set of feasible decisions at a point in time may of different degrees of difficulty. In some cases the set of feasible alternatives is appears as obvious, and can (given the current state) be fully enumerated within a small amount of time. In other cases, however, a large number of state-based constraints must be taken into account, and advanced modeling techniques known from the field of (mixed) integer programming need to be used.

- **Contribution function**: Each decision may cause an immediate contribution (denoted as C_t in Fig. 1) to the overall result of operations over time. The contribution typically occurs as immediate profits or costs, and represents a myopic measure of the quality of a decision. Depending on the dynamic decision problem at hand, profits and costs may also be given in terms of non-monetary measures, such as delays or travelled distances. The contribution function typically depends on both state S_t and decision x_t, i.e. $C_t = C(S_t, x_t)$. Note that the function does not take into account profits/costs that may be occurring in future points in time due to the current decision x_t. The overall result (overall profit or costs) of operations over time can be derived by adding the contributions of all points in time as soon as the given time horizon is reached. It may well occur that a decision that is good according to the myopic perspective of the contribution function will turn out to be bad with respect to the overall result at the end of the day.
- **Transition function**: Figure 1 illustrates that the next state S_{t+1} depends on the current state St, on the current decision x_t, as well as on the exogenous data that has arrived within time interval t+1. This relationship is modeled as state transition function (typically denoted as S^M, with $S_{t+1} = S^M(S_t, x_t, W_{t+1})$, where W_{t+1} represents the new data that arrived in interval t+1).
- **Decision function**: The decision function (often referred to as "policy", and denoted as $X(S_t)$ in Fig. 1) is a function that maps a given state to a feasible decision. Most of the research on dynamic decision making is about finding a policy that satisfies the decision maker's need to do as well as possible in terms of the expected sum of contributions over time. The research focus is on anticipatory policies (Meisel, 2011), i.e., on policies that map the current state to a decision by taking into account both expectations about new data arriving in the future and the decision maker's future decisions.

4 Illustrative Example

In order to illustrate the concepts introduced in the previous section, we consider a simplified example of a parcel service with one service truck. Assume that the parcel service has a customer base, and that the service truck is utilized for both delivering parcels to customers and picking up parcels from customers. Moreover, assume that the service truck leaves the depot in the morning and returns by the end of the driver's shift. All delivery customers are known at the beginning of the shift (when the truck is loaded), and must be served before the end of the shift. Pickup customers are initially unknown, but may call at any point in time during the shift, and must be either accepted for service today or postponed to the next day. The parcel service's goal is to minimize the number of postponed pickup customers while visiting all delivery customers. To keep the example simple, we assume that traffic conditions do not change over time. In the following, we provide an informal description of the core model elements for this problem. For a detailed mathematical version of the model we refer to Meisel and Wölck (2015).

- **Time**: In the considered example, the time horizon is determined by the driver's working shift, which could, e.g., be an eight hour shift. If pickup customers need to be informed right away about whether they are accepted for service within the current shift or not, one minute is recommended as the smallest possible time period between two subsequent decisions. As a consequence the dynamic decision problem has a total of 480 possible decision times.
- **State variable**: The information the decision maker has access to comprises three types of data attributes. First, the request state of each customer must be known in order to be able to make a decision, i.e., it must be known for each customer from the customer base, if the customer has already issued a request for service, if the customer has already been accepted or postponed, and if—in case of acceptance—he has already been served. Second, the decision maker must always know which customer location the vehicle is currently heading to, and third, he must know how long the vehicle still needs to reach its current destination. Under the assumptions made to simplify the problem for illustrative purposes, these three types of information are sufficient to compute the decision function, the transition function and the contribution function.
- **Exogenous processes**: The customers' request behaviors are the only type of exogenous process to be considered in the simplified example. In order to derive probabilistic statements about the customers' request behaviors, the parcel service could, e.g., analyze historic business data, and establish day- and time-dependent request probabilities.
- **Feasible decisions**: A number of constraints must be taken into account for identification of the state-dependent set of feasible decisions. First, the decision maker needs to know which of the currently requesting pickup customers are reachable within the remaining time of the driver's shift. Second, the decision maker must know which of the possible sequences of delivery customers and accepted customers the service truck can still process within the remaining time. In order to satisfy these requirements, the set of feasible decisions must be formulated as an integer program—in particular, as an integer program that closely resembles the integer programs know as orienteering problem in the literature. We refer to Meisel and Wölck (2015) for a full presentation of the integer program defining the set of feasible decisions.

- **Contribution function**: The contribution of a decision directly results from the parcel service's overall goal of minimization of the number of postponed pickup customers. At each decision time, the contribution function returns the number of pickup customers that have requested since the previous decision has been made and that have been postponed according to the current decision.

As soon as the above outline has been detailed in terms of a formal (mathematical) model, this model can be transferred into a simulation model allowing for experimentation with any given policy for the parcel service's dynamic decision problem. Then, the next challenge on the way to establishing a decision support system for the parcel service consists of using both the mathematical model and the simulation model to derive the best possible policy. The following Sect. 5 provides an outline of the classes of policies that may be considered.

5 Anticipatory Policies

For almost every dynamic decision problem occurring in the context of real-world business operations it is impossible to (purposely) derive an optimal policy. The mathematical models not only impose structure on dynamic decision problems, but they also unveil the enormous complexity that these problems bear (sometimes referred to as the curses of dimensionality in the literature (see, e.g., Meisel, 2011, p. 39). In order to still be able to derive a good policy, the mathematical model is transferred into a simulation model that allows for evaluation and algorithmic improvement of policies. In particular the research on dynamic decision problems aims at algorithms that derive anticipatory policies, i.e., policies that are able to take into account the future decision process when making a decision now. Four elementary classes of anticipatory policies exist (cf. Powell, 2011, p. 221):

- **Policy Function Approximations (PFAs)**: PFAs are relatively simple business rules or analytic functions, that derive decisions directly from one or more elements of the state variable. In the example problem of Sect. 4, a PFA could be the rule to accept a pickup customer if the remaining time allows for the service truck to serve this customer next before continuing with its currently planned customer sequence.
- **Contribution Function Approximations (CFAs)**: In contrast to PFAs, CFAs solve a proper optimization problem in order to make decisions. The optimization problem aims at maximization (or minimization) of the contribution function subject to at least one additional condition. In the application of Sect. 4, a CFA could, e.g., solve a type of orienteering problem at each point in time, with the problem formulation additionally requiring that a certain fraction of the remaining travel time is kept on hold for use at later points in time.
- **Value Function Approximations (VFAs)**: VFAs make decisions by taking into account the sum of contribution function and values of possible future states. The

required state values are typically determined approximately by combining the simulation model with statistical learning approaches.

- **Lookahead Policies (LAs)**: LAs rely on forecasts of exogenous information to formulate a multistage optimization problem that derives the decision at the current point in time by maximizing (or minimizing) the sum of contribution functions over a number of future time steps.

Powell (2011) concludes that every possible policy for a dynamic decision problem falls into one of the above policy classes, or represents a hybrid of a subset of the four classes. In practice, the type of the best performing policy for a given problem turns out to depend on the problem domain at hand. As an illustrative example, Powell and Meisel (2016) consider an energy storage management problem, and show for this problem that each of the four classes may be best depending on the nature of the present exogenous processes (market price of energy, customer loads, energy generation from renewable sources). The conclusion to be drawn from this study is that, all four problem classes should be considered when building a decision support system for a dynamic decision problem. In the absence of prior knowledge about which class works best with the problem to be solved, a decision support system should proceed by first analyzing the newly arriving data, and by then reacting to the detected types of exogenous processes in terms of choosing the policy that fits best.

6 Conclusions

The need for decision support systems that are able to solve dynamic decision problems has been increasing tremendously throughout the past years. It will be increasing even more in the years to come, as virtually all industries and companies are being transformed by the modern information technology that entails dynamic decision problems as a natural consequence. Having a decision support system that can efficiently solve the newly arising dynamic decision problems will be a major competitive edge.

It should be noted that developing such a decision support system requires a strictly interdisciplinary approach. System development is virtually impossible without sound integration of methods and technologies from the fields of statistical learning, mixed-integer programming, simulation, database systems and software engineering.

However, the important first step to developing a decision support system for dynamic decision making consists in establishing a correct model of the dynamic decision problem at hand. At this step, system developers may rely on the fact that all dynamic decision problems are created with equal structure, and lay the solid foundation of their decision support system by “strukturieren, strukturieren, strukturieren”.

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Reference Models for Standard Software—Scientific Myth Instead of Practical Reality?

Reinhard Schütte

1 Motivation

Information models are an important object of research in information systems (see, among others Loos & Scheer, 1995; Becker, Rosemann, & Schütte, 1995; Rosemann & Schütte, 1999; Frank, 1999, p. 695; Davies, Green, Rosemann, & Gallo, 2004, p. 165; Wand & Weber, 2002; Becker & Schütte, 2004, p. 74ff.; Fettke & Loos, 2004, p. 550; Persson & Stirna, 2002). In this article, because the discussion about the model definition in literature cannot be conducted here in the required brevity,[1] information models should be understood in short as a representation of something for something (Becker & Schütte, 2004, p. 65).

[1] In 1997, the author introduced the construction-oriented model concept into information systems, cf. Schütte (1998), which has been discussed in many publications over the last 20 years, cf. among others Wolf (2001), vom Brocke (2003), Wyssusek (2004), Thomas (2006). From the discussion, it has emerged that the boundary between "model" and "no model" is narrow, which in particular also speaks against any image postulate. The image-oriented definitions represent a demand on an artifact before something can be called a model. In this context, image-oriented definitions necessarily become entangled in the problems of verifiability or uncertainty, cf. also Zelewski (1995, pp. 24–25). For reasons of the general validity of the following explanations, no conceptual restriction with the associated reduced extensionality of the term model is undertaken. This also means that an information model is not as narrowly understood as Jörg Becker published in 2003 in the sense of a construction-oriented scientific theory position: "Against this background, an information model can be defined as a representation of a fact. Furthermore, an information model is always to be understood in the sense of current speech and will usually last as a brand and will not be transient. […] It is demanded that each modeling step and the insertion of each modeling component can be determined by reasons. As a representation of a fact, an information model consists of a set of elementary model statements that are linked to complex model statements. The truth of these statements can be verified by interpersonal verification" (Becker, Holten, Knackstedt, & Niehaves, 2003, p. 21).

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The purposes associated with information modelling have been the same since the Cologne Integration Model of Grochla (1974). These are to analyze and design information systems (Fettke, 2009). Information modelling is therefore not highly but outstandingly important for information systems (Fettke, 2009; Frank, 1999). This is also implicitly documented in the fact that the role of information models is emphasized in the standard literature on requirements engineering and software engineering, up to the efforts of Model Driven Architectures (cf. Pohl, 2010; Partsch, 2010; Wagner, Andres, & Lauer, 2007; Millet, 2013). The importance of information models in research and the significance for practice propagated by researchers was empirically investigated in the literature of Davies, Green, Rosemann and Gallo (2004), Davies, Green, Rosemann, Indulska and Gallo (2006), Sarshar, Loos and Weber (2006), Fettke (2009), among others.[2] The published empirical studies were usually carried out using questionnaires (in the more recent studies via the web and previously by sending the questionnaires via mail). In individual cases, also explorative approaches were used. The vast majority of the questions were asked as closed questions, and sometimes it was attempted to derive correlations using quantitative data. In the context of information modelling practice, this includes above all to the size of the company or the experience of the modelers and the intensity of use of information models. The works of Davies et al. (2006), Fettke (2009), Sarshar et al. (2006) document a considerably higher use of information models in larger companies than in smaller ones.[3] This statement is important for the further argumentation, because the author does not want to expose himself to the accusation of generality and will conduct the further discussion exclusively for the class of enterprises, for which the use of information models was judged to be significant.

2 Reference Models and Their Use for Application Systems

2.1 Reference Application System Models

Reference models (as a short form of reference information models) represent a subclass of information models. They not only represent a specific situation —regardless of whether existing or ideal—but claim to be suitable for a class

[2]There are older empirical studies, cf. the list by Fettke (2009, p. 555) as well as the work by Batra and Marakas (1995), Maier (1998) which, due to their age, are no longer considered here because they no longer seem appropriate for the evaluation of current modelling practice. The empirical study by Schütte (1998, p. 367ff.) will be used in the further course in order to be able to carry out a longitudinal section analysis.

[3]It should be noted that this is not a continuous process (cf. Fettke, 2009, p. 573ff.), but all studies come to the conclusion that the intensity of use in the class of the largest companies in the study is significantly higher than in the class of small companies. This applies in particular to the reference application system models to be addressed later, e.g. cf. the works by Sarshar et al. (2006).

of applications[4] (Delfmann, 2006; Fettke, 2006; Fettke & Loos, 2004; Knackstedt, 2006; Scheer, 1997; Schütte, 1998; Thomas, 2006; vom Brocke, 2003; vom Brocke & Fettke, 2016). This assumes reuse or reusability in different situations. This situation is present prima facie with standard application systems, since these are used in different enterprise contexts, which constitute a special type of reference models: the reference application system models. The main purpose of these is to document an existing standard system in order to enable a concrete technical system to be designed on this basis, as they are based on concrete application systems that have been designed not only for one case, but for several situations. Because of reuse in different situations, drawing on reference application system models is likely to be more economical than company-specific models. In any case, this presupposition is included in various versions in the literature.

With regard to reference models for standard application systems, the SAP reference model takes a special position, since it is regarded in the literature as the most developed and comprehensive reference model (on the history, see Fettke & Loos, 2004, p. 331; on the typology, see IWi 2018; on the evaluation as a particulary important application case of reference modelling, see Gottschalk, van der Aalst, & Jansen-Vullers, 2007; Leimeister, 2015).

The degree of usage concerning information modelling in business practice is not generally proven in empirical studies, even though the previously cited analyses show a usage.[5] In the various studies, however, there was always a one-dimensional question as to whether information modelling would be used and for what purpose it would be used. Whether an *intensive* use of information models takes place remains open in the investigations. It seems trivial that in a larger company in a department, one would find at least one employee describing data with an ER model or a process using a formal language. The dominance of languages for data modelling found by Davies et al. (2006, p. 368), Fettke (2009, p. 560) in the form of ERM or the more data-oriented UML at least indicates that such artifacts are mandatory for the development and adoption of software systems. However, the actual significance of information models is not documented by the fact that something is used. One question would be to answer *in what ways* and *how intensively* the use is in order to be able to evaluate a degree of utilization and thus also the actual benefit of information models. The methodical deficits in the empirical studies are therefore to be evaluated as considerable and consequently hardly allow an evaluation of the use in practice.

This problem seems to be even more pronounced for reference application system models: the adoption of a standard system should always involve the use of information models. However, the question arises as to whether information models are used by the software manufacturer or whether own information models are created and which of the models were actually reference application system models. In the study by Sarshar et al. (2006) this is does not become clear, so that the conclusions of the explorative study represent a starting point for the subsequent critical discussion.

[4]Therefore, the distinction between reference models in the field of objects and statements is artificial in Fettke and Loos (2004, p. 332).

[5]See the work outlined in the previous chapter on information model usage in general.

The study by Sarshar et al. (2006) assumes a positive correlation between the size of the company and the use of information modelling. Furthermore, the adoption of SAP is emphasized as a further influencing factor for more intensive use. The purposes of information model use are seen in "configuration of standard software" and "business process management". The preference for these application purposes was also the result of the study on reference model usage at Schütte (1998), so that in the sense of a longitudinal view the hypothesis is supported that those are the two dominant objectives for reference model usage.

In his professional past, the author of this article has been responsible for or accompanying several SAP or other standard application systems adoptions in large companies and cannot share the conclusions from the literature about the use of information models for the adoption of standard systems. In some sense, there is no conflict between the findings of the empirical studies and the evaluation by the author, because information models are used in operational practice. The author has not encountered a project in which at least one data model with an ERM or a class diagram with UML or a process model with event-driven process chains, with BPMN or any process description had not been used. The use of tools, as found for example in Sarshar et al. (2006) also indicates that although there is a use, it can hardly be described as intensive. With drawing tools such as Visio, other Microsoft Office products, etc. models can be created, but serious information modelling in the sense of long-term use is not possible. In contrast to the rather positive empirical studies, which—in the absence of an analysis of the intensity of information model use in real projects—only arrive at superficial confirmations, the experiences of the author are sobering. The importance of information models for the adoption of standard application software has declined significantly since the start of SAP's efforts, and sometimes the impression can be gained that information models no longer play a serious role in the adoption process.[6] This observation in more than a decade of adoption practice at various large companies should serve to point out the problems of reference modelling by explicating various propositions.

The demarcation point of the argumentation, which the author will use for his discussion of the use of reference application system models, must first be concretized. The empirical studies on information modelling in general have shown that the intensity of use increases with the size of the company and the modelling experience of the users. Modelling experience is also likely to be more pronounced in larger companies in percentage terms, as the proportion of employees with an academic degree is usually higher. Thus, it makes sense to choose the use of information models in large companies with experienced modelers as a starting point. This situation is particularly likely to affect large technology companies that want to describe their standard application systems during or after development. In addition to company size and

[6]The year 1993 was chosen as the reference time, as SAP documented the system processes using EPCs and data models during the introduction of R/3 and promoted the introduction of reference models in marketing terms. There were separate departments within SAP for these tasks, which was driven forward not least by Gerhard Keller as a former employee of August-Wilhelm Scheer for the process models and also by Michael Seubert for data modeling. Also confer a similar evaluation by Fettke and Loos (2004, p. 331), who see 1993 as the first high point of reference modeling practice.

modelling experience, there is also the situation that the models are reusable several times in different contexts, which should take particular account of the economic efficiency of model creation and use (cf. also the first empirical study on reference modelling at Schütte (1998, p. 367ff.), Sarshar et al. (2006)). In summary, based on the empirical studies, it can be concluded that the use of information models in general and reference models in particular would have to be especially pronounced for the adoption of SAP systems in large companies with many modelling experts.

2.2 Propositions on the Limited Usability of Reference Application System Models

2.2.1 Model Use Requires the Availability of Models from the Software Manufacturer

The reference model of the standard software manufacturer forms the basis for the use of the reference application system models. In recent decades, the application landscape of manufacturers has changed dramatically. Not least due to the course of digitalization, the view of one large application system is increasingly obsolete. Individual comprehensive applications are being replaced by architectures with many applications in which the scope of heterogeneous technology components has also increased.

In contrast to the first climax of reference modelling, which was advanced by SAP and August-Wilhelm Scheer with IDS—in cooperation with SAP—the prerequisites for the usage have changed since then, because the development of standard software has become more distributed and different products exist in the respective ecosystems, which are developed "independently" and in parallel. The standard software vendors are also very product-centered due to acquisitions (for example, SAP Business Objects, Hybris, Success Factors, Concur, etc.; on Oracle's company acquisitions cf. Oracle 2018) and cloud development and are to be understood as software ecosystems only. There are three main reasons for the poor availability of reference models, which will be briefly explained below: The complexity of the product variety of real application architectures, the platform problems and the changed development process of software.

The *enormous increase in complexity* of the solutions of the standard software providers has led to the fact that methodical guidelines for the development and methodical guidelines for the documentation of the software seem hardly to exist. In the course of this constant differentiation of the solutions offered, it is no longer possible to speak of a reference model anyway. A solution like ARIBA from SAP is in no way comparable to S/4 Finance, neither technologically nor in terms of documentation and implementation requirements. SAP currently provides the reference models via Solution Manager 7.2, whereby the individual reference models must be downloaded from the Internet, depending on the components to be implemented

. However, the availability of the models for individual applications is very unsatisfactory and only helpful in a few cases for the purpose of system implementation. In addition, Solution Manager provides tool support for creating own process models using BPMN in the phase of the business concept. Information models are used in many implementation projects. Last but not least, DSAG—the German-speaking SAP user group—recommends using the tools around SAP Solution Manager (DSAG, 2013) to create process models and implement Business Process Management. This also includes information on how the reference processes documented in the Solution Manager can be used. However, this is still not sufficient for the actual and subsequent adoption process of the software. The enormous change in the field of software solutions has contributed to the fact that software manufacturers—in this case SAP—have not been able to provide current reference models. The complexity of products and their combinatorics seem to make it impossible to keep reference models up-to-date. For reasons of market availability, the technical product is more important than the conceptual documentation. At the same time, this means that information modelling has not yet established itself in the creation of standard software. If an information model were created ex ante during the creation of standard software—in the sense of classical requirements engineering—the availability of the models would be guaranteed. The non-existence of information models after the development of a product proves that such a development practice is rarely found in software companies.

The non-existent reference models of standard software manufacturers are proof that reference models do not seem to have any added value for the manufacturers. If technology companies could be successful with even a minimum efficiency, then the question must also be asked why of all companies, those for which development is the very area of value creation, have not become pioneers of information model use (in contrast to the research expectations, see Becker, Delfmann, & Rieke, 2007). This circumstance should raise questions for the entire information modelling research as to whether the right problems are still being researched. Particularly due to the pronounced requirement pluralism in the implementation of requirements (since not only one situation but several are to be implemented) in standard software systems, it would seem obvious that information models are used due to the complexity of the task. The practice of software manufacturers not to resort to comprehensive information models before development can only be explained by the fact that it is either not economically advantageous or not yet economically necessary. The latter is the case if there is insufficient competition between the individual suppliers in the field of development which is important for the success of software companies. In this situation, the non-use of an important efficiency-enhancing instrument could be explained. However, in view of the fact that there has already been a significantly higher penetration of SAP in information modelling in the past, this does not appear to be a plausible reasoning.

The reasons for not applying information modelling at standard software vendors may have something to do with the division of labor in the development of software products. The development towards platforms such as Android, iOS, the HANA Cloud Platform, microservice architectures, etc. have led to software development becoming more distributed and above all "atomic". These are largely uncoordinated and there is an atomization of development, which may entail conceptual shortcomings (e.g. data integrity), but is accompanied economically by significantly faster availability of the solutions. The standard software manufacturers have recognized that they are less and less able to deliver additional functionality in a few releases, but instead have to rely on the power of the platform with the corresponding developers. The software market has developed into a platform market that can be described by Tirole's "two sided market" concept (Rochet & Tirole, 2003). The network effect now dominates the software world and this network effect was not that effective 25 years ago in software development, where software ecosystems were easier to control and were subject to other economic laws. It was possible to make guidelines and ensure coordination from a central location.

A third aspect, which can certainly be linked to the economic platform aspect, has something to do with the way of software development. Today, software is no longer developed on the basis of requirement documents alone as it has been in the past. Instead, the developers draw on frameworks within the programming environments to a considerable degree. This means that programming is no longer exclusively geared to the type of requirement, but must be integrated into the thought logic of the framework, as the developer interprets it. The components of the framework are thereby well known to the developers and are no longer "covered" by classical information models, so that the use of information models from a technical perspective is no longer mandatory. This technical view corresponds directly with the previously developed economic argumentation of the platform and the division of labour, because the technical change makes the outlined economic consequences possible. Taken together, the situation at the standard software manufacturers seems to speak against rather than in favor of an intensive reference model creation. It is also possible that the necessary framework conditions for information modelling are responsible for the existence of this situation. It would be the task of research to investigate this situation by means of explorative studies in order to develop solutions based on this in our construction-oriented information systems discipline.

2.2.2 Use of Reference Models During Adoption: The View of the Domain Companies

According to empirical studies, the domain companies that use information models in general and reference models in particular when adopting standard software strive to use models at least at the beginning of an implementation project. The main focus is on procedural considerations of BPM, as documented in the corresponding publications of DSAG (2013). The connection of the models with the configuration of software is rather implicit, because there is no model-driven customization of application software. As a rule, the reference models provided by standard application manufacturers have a very high level of abstraction in order to reflect the different application situations. The explicit presentation of variants that have also been the subject of considerations on language extensions in information systems (Schütte, 1998; Gottschalk et al., 2007; Rosemann & van der Aalst, 2007) has not yet gained acceptance. For domain companies, the focus is on the two main purposes "improvement of business processes" and "configuration and development of software" (Fettke, 2009, p. 558; Davies et al., 2004, p. 39, 2006, p. 371).

The purpose of improving business processes with reference models is not to be expected directly in reference application system models. In the literature, no distinction was made in the empirical studies between reference application system models and reference organization models. However, the study by Sarshar et al. (2006), which focuses exclusively on the adoption of standard software, yields surprising results. Standard software will only become operational through the process of de-standardization (Mormann, 2016). It is not the standard that is used, but the individualization of the software is imperative from the processes, the structures and the individual data elements in the system. The work in sociology and business administration documents in their research results that the economic legitimacy of the institutions is hardly likely to lie in their interchangeability. In view of the brevity of this contribution, this fundamental knowledge cannot be elaborated. However, the optimization of processes is less the task of a reference application system model than the subject of an individual project for the adoption of software. This purpose-pluralism of reference models, from which the distinction between organization-oriented and application-oriented reference models also arises, has been problematized much too little, although this integration perspective is an essential subject area of information systems (on the multi-perspectivity of reference models, see Rosemann & Schütte 1999). The high degree of abstraction of reference application system models, which is problematized below, leads to the loss of individuality, even though the process-related design of which should have the advantage for companies. This aspect will be even more far-reaching in times of digitalization, because the systems are penetrating evermore areas of application and disregarding the differences would lead to the interchangeability of companies.

With regard to the configuration and development of software using reference application system models, existing models from the standard software manufacturer are used for customization purposes and, if necessary, for customer-specific development. Two aspects need to be taken into account. First, there are so large deficits in the availability of reference models when adopting application architectures that continuous use via the subprojects of a comprehensive solution is often impossible (cf. Sect. 2.2.1). The adoption of ARIBA as a platform for tenders and networking with suppliers is impossible because of the lack of available reference models.[7] The master data creation that is to take place with an SAP S/4 HANA in conjunction with an SAP MDG is not represented in this scenario.[8] Secondly, it seems essential that the prefabricated product "standard software" becomes a final product for the companies only through a project. At the end of the adoption project,

[7] ARIBA is SAP's procurement and network platform, which SAP acquired in 2012. There processes of strategic purchasing, procurement, service procurement, etc. are supported.

[8] SAP MDG is SAP's master data government product, S/4 HANA stands for the core products of the new SAP generation, which is documented in the 4 for fourth generation. The S stands for Simple and replaces the old R for Realtime (which extends to R/3).

a first product version is used. From the point of view of the adopting company, the importance of the project is often more important than the selected prefabricated product. For information modelling, this means that considerable modelling work still has to be done and that the degree of abstraction of the manufacturer's models is usually too high. Thus, the configuration, the company-specific refinement of the manufacturer's models, and also the enrichment required for process design purposes must take place. Due to the need for versioning of the models, resulting from the software manufacturer's constantly developed releases, a continuous and very complex modelling has to be carried out by the domain company itself. Very often companies succeed in modelling to some extent during the adoption of standard software and then, after the adoption, this task becomes obsolete. However, even in the initial phase there are considerable restrictions to be made, because it would be necessary for documenting the requirements, which is prepared by consultants and system analysts or specialist department employees, to know the models of the software manufacturer. If these are known, it should be noted that the models are usually so abstract that the consultant and developer knowledge is much more profound, so that they would first have to refine the software model. Alternatively, the models remain at the high level of abstraction and are used as guidelines. The documentation of customization and the developments required for individualizing the system is made in text form. In the author's experience, the latter procedure is the dominant one. The information models are therefore of little use for the adoption of standard software, which may explain the low usage intensity. They are mainly used as an argumentation as to why the methodology used for the adoption was correct, not because the models have sustainable benefits. In many discussions, the models make a visualization contribution that supports the clarification of requirements up to a certain degree of abstraction. However, the use for the configuration or development of standard systems is not yet discernible to some extent.

3 Conclusion

The explanations have shown that there are good reasons for a low use of reference models, which already reside on the software manufacturers' side. The basis for the reference application system model research is above all one in which the software manufacturers create and consolidate the models, have a governance in the development, etc. The information systems discipline has hardly been able to provide any insight into the way standard software is developed using information models, which is a major deficit. There have been some research projects dealing with the extension of modelling languages—in cooperation with SAP (Rosemann & van der Aalst, 2007)—further research projects are not available. According to the author's assessment, the progress of knowledge over the last 20 years has been far too small; there is no adequate understanding of adoption projects with reference models.

In reality, the hopeful claims of researchers have not been proven, so their statements are more assertive than substantiating, which is scientifically disappointing. Information systems should be less concerned with myths and more with reality and consider how reference modelling research needs to be adapted to the practice-oriented nature of the discipline.

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On the Evolution of Methods for Conceptual Information Systems Modeling

Elmar J. Sinz

1 Conceptual Modeling

Models are among the most fundamental utilities of science. Becker and Vossen express their understanding of a model as follows: A model is an immaterial and abstract image of the real world for the purposes of a subject (Becker & Vossen, 1996, p. 19). It is abstract because it reduces the real world to the essential and omits unnecessary details. The purpose of a model is to capture the real world in terms that enable the subjects to understand, verify, communicate, build and apply the model. Finally, the subject of a model covers all its stakeholders.

Conceptual modeling is a special form of modeling. Thalheim underlines three dimensions: (1) Modeling language constructs that need to be well understood in syntax, semantics and pragmatics; (2) collection of application areas that allow understanding the problems to be solved; (3) engineering that allows reducing the problems to a manageable size (Thalheim, 2010, Sect. 1.1). Strahringer, who is focused on business problems, says that conceptual modeling is the creation of information models at the level of a business concept, which are strongly oriented towards the business problem and the common technical language and abstract from the IT-technical implementation (Strahringer, 2013).

This means that a conceptual model is specified in terms of the real world. The modeling method helps to capture the real world and to specify it as a model.

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2 Conceptual Modeling of Information Systems

One of the fundamental concepts of organizational theory is the term task. Every goal-oriented human action takes place in tasks. Tasks are generally performed by humans. With the development of business information systems engineering, a second actor stepped up to the human: the machine.

In the following we will only look at the tasks of information processing. These tasks, whether they are human or machine tasks, establish the information system.

Subsequently, a framework contributed by organizational theory is used (Fig. 1). It is based on the concept of the task, described from an inside and an outside perspective (Ferstl & Sinz, 2013, p. 95 ff).

The outside perspective of a task (grey) comprises a task object (O), goals (G) and pre- and post-events (E). The latter are prerequisites for the execution of a task or result from the execution. The goals specify the desired states of the task object after the task has been executed.

O, G and E determine the views on the outside perspective. The three views together allow a complete description of the outside perspective. If one or two views are missing, the description is correspondingly incomplete.

The inside perspective (white) refers to the solution procedure of the task. It consists of the actions (F) that are executed on the task object (D, I). The interaction component (I) assumes that the interaction channels between the sub-objects are part of the task object. The action control (P) triggers the respective actions; the actions report their results to the action control. The action control pursues the goals given in the outside perspective; it is released by pre-events and produces post-events.

D, I, F determine the static views, P is the dynamic view of the inside perspective of a task. The views of the inside perspective are terminologically closer to the IT-technical implementation. As in the outside perspective, the more views are given, the more complete is the specification of the inside perspective.

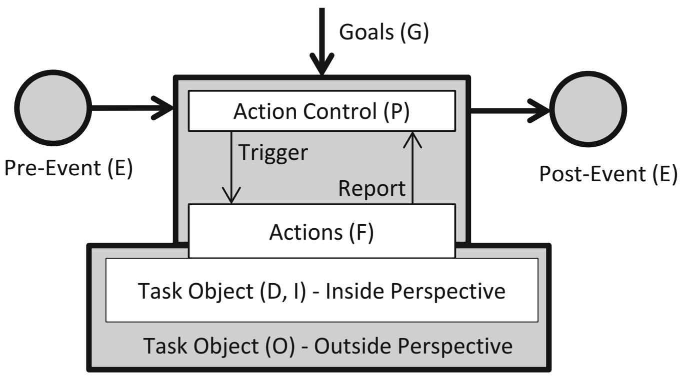

Fig. 1 Organizational view on a task (Ferstl & Sinz, 2013, 95ff)

To give an example, the order entry of a sales company is used. The task object consists of customers, articles and orders. The goal is to have a new order entered to the task object after the task is performed. The pre-event is marked by the arrival of an order that starts the solution procedure for the task. For this purpose, the action control triggers actions to check the customer, to check articles, to reserve items and finally write the entered order to the task object. The task is completed with the creation of a post-event for the entered order. This could be the pre-event for order picking, for example.

3 Evolution of Conceptual Information Systems Modeling

This short paper traces the evolution of important methods for conceptual information systems modeling.[1] Like many other trends, the evolution floats upstream, i.e. it goes step by step from inside to outside perspective. It starts with a look at programming (inside perspective) and ends with a complete conceptual modeling (outside perspective). Looking at the modeling methods, evolution begins with functional decomposition and ends with event-driven modeling.

As evolution progresses, more complex systems can be modeled. The complexity manifests itself the degree of automation and integration that can be managed via the models.

The following methods for information systems modeling have gained relevance and visibility in theory and practice (extended from Ferstl and Sinz 2013, p. 139 ff). All the methods can be applied to conceptual modeling, especially because their terms bridge the gap to the real world (Table 1).

3.1 Functional Decomposition

Functional decomposition is one the first methods used for conceptual modeling. It looks on the world as a function to be decomposed. The decomposition leads to sub-functions and so on until the sub-functions are small enough to be programmed. The method is limited to the inside perspective and the function view (F). Data (D) only occurs in the leaf nodes of the sub-function tree, but it is referenced and not modeled. The outside perspective does not occur.

Nowadays the functional decomposition plays no role within conceptual modeling. An example of a method is HIPO (Hierarchy of input-process-output) (e.g. Balzert, 1982).

[1]The evolution of modeling methods is presented from the subjective perspective of the author.

Table 1 Information systems modeling methods

Modeling method	Real world view	Example	Perspective	View
Functional decomposition	The world is a function to be decomposed	HIPO	Inside	F
Data flow modeling	The world is a set of data flows, transformed by activities	SADT, Structured Analysis	Inside	I, F, D
Data modeling	The base of the world is a set of related data structures	ERM, SERM, RM	Inside	D
Object modeling	The world consists of a set of interacting objects, each encapsulating data and function	OOA, OMT	Inside Outside	D, F, I O
Process modeling	The world is a set of processes	EPC, BPMN	Outside Inside	E P, F
Object and process modeling	The world consists of objects, which are coordinated to configure business processes	SOM	Outside Inside	G, O, E D, F, I, P
Service-oriented modeling	The world is a system of delivering and consuming services	e.g. Erl	Outside	G, O, E
Event-driven modeling	The world is a system of components, listening for events	e.g. Rommelspacher	Outside	G, O, E

Legend Inside perspective with static views on (F) function, (D) data, (I) interaction and a dynamic view on (P) processes. Outside view on (G) goals, (O) task object, (E) events (see Fig. 1)

3.2 Data Flow Modeling

Data flow modeling has accompanied the practical systems engineering for several decades. It looks at the world as a set of data flows, transformed by activities. Starting with the main activity, the activities are decomposed successively. At each layer, the data flows are modeled, so that a complete model is available along the hierarchy of decompositions. The method comprises three views, mainly the interaction (I) of activities, the activities themselves (F) and the data flows (D). Interestingly, the data within the data flows is referenced, but not modeled.

The method is used for the inside perspective because there is no notion for task object, goals or events. The main shortcoming of the method is its focus on activities as the item to be decomposed.

An example for a data flow modeling method is SADT (Structured Analysis and Design Technique) (Balzert, 1982). Another well-known example is SA (Structured Analysis) (DeMarco, 1979; Gane & Sarson, 1979) which is available in many of the older CASE tools.

3.3 Data Modeling

Data modeling considers the world as a set of related data structures. This is the platform on which all the functions can be implemented. Data models usually have a certain level of detail, hierarchical decomposition is not possible. The method focuses only on data (D). In contrast to the methods mentioned above, data structures are modeled with attributes, keys and relationships.

Data modeling is the first method used for enterprise-wide models. Its major disadvantage is the global view on data, which prevents a meaningful modularization of the overall system. Moreover, it is restricted to the inside perspective.

Examples of methods are the RM (Relational Model) (Codd, 1970), which comes closer to implementation, the ERM (Entity-Relationship Model) (Chen, 1976) or its modification for large schemas, the SERM (Structured Entity-Relationship Model) (Sinz, 1988).

3.4 Object Modeling

Object modeling marks a major step in programming, design and modeling of information systems. It looks at the world, which consists of a set of interacting objects, each encapsulating data and function. From programming languages like Smalltalk-80, and later C++ and Java, the principles for object modeling were adopted. OOA (Object-Oriented Analysis) (Coad & Yourdon, 1991) and OMT (Object-Modeling Technique) (Rumbaugh, Blaha, Premerlani, Eddy, & Lorensen, 1991) are among the first object modeling methods.

The success of object modeling is the concept of class, which encapsulates data (D) and function (F) without telling the environment how they are implemented. In addition, the interaction channels between classes (I) are defined.

Object modeling combines the three views D, F and I and thus enables an almost complete inside perspective. It is also used to model an outside perspective, despite missing goals and events.

3.5 Process Modeling

Process modeling looks at the world as a set of processes. It is the first time that a new view of modeling becomes visible: the process view (P). Process modeling is a natural continuation of object modeling. It sequences the small pieces of operations on objects.

Applied to the outside perspective of a task, process modeling is put into practice by event-driven process chains (EPC) (Nüttgens, 2013). The focus here is on events (E); the fact that functions are modeled and not task objects is ignored.

Used for the inside perspective, process modeling concentrates on the process view (P), describing the sequence of functions (F), which are not modeled in connection.

Another method for process modeling is business process model and notation (BPMN) (OMG, 2011). Here, switching between inside and outside perspective is supported by white-box and black-box pools. The interaction between the pools is described by message flows.

Process modeling attracted attention with business process modeling.

3.6 Object and Process Modeling

The world consists of objects, which are coordinated to configure business processes. Thus, this method combines object and process modeling.

This class of modeling methods is represented by the semantic object model (SOM) (Ferstl & Sinz, 1995). On the business process layer of the enterprise architecture, the outside perspective of tasks is modeled with task object (O), goals (G) and events (E). The tasks are connected by transactions that describe the coordination of the tasks. Two principles of coordination are available: choreography (negotiation; market) and orchestration (feedback-control loop; hierarchy).

The corresponding inside perspective is represented by the resource layer. The solution procedure of each task is modeled by conceptual objects representing the task objects (D) and the actions (F) on them. The interaction channels (I) are derived from the transactions. Process objects represent the action control (P).

3.7 Service-Oriented Modeling

In service-oriented modeling, the world is seen as a system of delivering and consuming services. It emphasizes the outside perspective on tasks and offers a lot of solutions for the inside perspective. On the one hand the notion of service is very close to the real world and on the other hand it harmonizes with implementation techniques, like the client-server principle. Therefore, service-oriented modeling is currently very popular.

Erl (2007) gives examples for service-oriented modeling methods.

3.8 Event-Driven Modeling

The world is seen as set of components, e.g. classes or services that listen to events (Rommelspacher, 2008). When a component feels responsible for an event, it starts to process it. No interaction channel must be predefined. Complex events are supported, i.e. compound events consisting of simpler events. As in service-oriented modeling, it emphasizes the outside perspective of tasks and enables a lot of solutions for the inside perspective.

Event-driven modeling convinces with its flexibility. If one component fails, another (if available) can take over the task. One problem with the inside perspective is the infrastructure that is necessary for event handling.

4 Lessons Learned

This paper takes an alternative view of modeling methods suitable for conceptual modeling. It considers the outside and inside perspective of tasks, the organizational building block of information systems. From this point of view, it is examined whether a modeling method can contribute to conceptual modeling.

If we look at the development of the methods, we see that evolution floats upstream from a single view on the inside perspective to multiple views and to the outside perspective. Modeling the outside perspective unfolds the full potential of conceptual modeling. Otherwise, starting with the outside perspective allows a secured transition to the inside perspective.

The evolution of methods for conceptual information systems modeling not only enables an increasing degree of automation and integration of information systems. At the same time it is also due to business-IT alignment, which tries to flexibly adapt IT to business requirements and to adopt upcoming IT platforms and technology to new business models.

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The Need for a Maturity Model for Maturity Modeling

Jos van Hillegersberg

1 Introduction

Since their inception in the field of quality management in the 1970 s, maturity models have gained popularity in various fields including information systems. As described by Becker et al. “A maturity model consists of a sequence of maturity levels for a class of objects. It represents an anticipated, desired, or typical evolution path of these objects shaped as discrete stages. Typically, these objects are organizations or processes” (Becker, Knackstedt, & Pöppelbuß, 2009).

The purpose of maturity models is “to give guidance through this evolutionary process by incorporating formality into the improvement activities (Mettler, Rohner, & Winter, 2010): A wide range of maturity models have been developed for the purpose of measuring and prescribing certain aspects of information systems “maturity” (Mettler et al., 2010). While maturity models come in various types and forms, the principal idea is that a maturity model, “describes in a few phrases, the typical behaviour exhibited by a firm at a number of levels of ‘maturity’, for each of several aspects of the area under study” (Fraser, Moultrie, & Gregory, 2002). This enables organizations to recognize good and desired practices and follow a transitional path towards achieving higher levels of maturity.

Maturity models have gained enormous popularity over the last decades in both research and practice. For virtually each emerging information systems trend, maturity models quickly follow to aid organizations in successful adoption of the novel technology. A literature review and mapping study published in 2012 identified 237 articles dealing with maturity model research covering more than 20 domains (Wendler, 2012). Recently, maturity models have been developed for business process management (Röglinger, Pöppelbuß, & Becker, 2012), cloud computing (Al-Ruithe & Benkhelifa, 2017), business intelligence (Hribar Rajterič,

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2010), IT Governance (Smits & van Hillergersberg, 2015) and block chain adoption (Wang, Chen, & Xu, 2016).

While the growing number of maturity models is to be applauded, there seems to be a lack of structure in the development of these models and an unclear sense of quality of the resulting maturity models. The purpose of this paper is to analyse the continuing popularity of maturity modelling in more depth and to explore if there is a need to apply a maturity model to maturity modelling itself.

2 Types and Structure of Maturity Models

Maturity models can have a fixed number of maturity levels or can define focus areas that define levels of capabilities in various functional areas. Fixed level maturity models often follow the maturity levels as defined in CMM (Paulk, Curtis, Chrissis, & Weber, 1993): (1) Initial, (2) Repeatable, (3) Defined, (4) Managed, (5) Optimizing. Each maturity level contains a number of Key Process Areas (KPA). In more detailed maturity models, each KPA consist of a description of elements, activities and sometimes metrics. In staged maturity models, all KPA need to be in place to achieve a certain maturity level. In continuous maturity models, KPAs can be scored at different levels allowing for a more gradual and varying improvement path. Focus area maturity models define a number of focus areas that have to be developed to achieve maturity in a functional domain. For each focus area a series of development steps in the form of progressively mature capabilities is provided (Van Steenbergen, Bos, Brinkkemper, Van De Weerd, & Bekkers, 2010). Contrary to fixed level maturity models, each focus area can have its own maturity level scale. Focus area maturity models can address a wide range of functional areas and combine existing maturity models to cover broad organizational improvement.

For example, the recently developed Maturity IT governance model (MIG) is a focus area maturity model that combines and extends existing maturity models to address maturity of both the hard and soft parts of governance. Table 1 illustrates the MIG. For each focus area in hard governance, the CMM maturity model is used, while for soft governance, each focus area makes use of a different maturity model such as the model of Collins for "leadership" (Collins, 2006).

Apart from Fixed versus Focus area maturity models, maturity models differ in several other ways. To organize and classify the ever growing number of maturity models, a classification scheme was developed by Mettler et al. (2010). They propose three categories of attributes to capture essential properties of a maturity model; (1) general model attributes, (2) maturity model design, (3) maturity model use (Table 2).

Table 1 The Maturity of IT Governance Model (MIG) is an example of a focus area maturity model that builds on and extends existing maturity models (Smits & van Hillergersberg, 2015)

Governance	Domain	Focus area
Soft	Behavior	Continuous improvement
		Leadership
	Collaboration	Participation
		Understanding and trust
Hard	Structure	Functions and roles
		Formal networks
	Process	IT decision-making
		Planning
		Monitoring
Context	Internal	Culture
		Informal organization
	External	Sector

3 Maturity of Maturity Models

Despite the multiple decades of research into maturity models several authors have observed varying quality. In his paper "The maturity of maturity model research: A systematic mapping study", Mendler surveys 237 studies on maturity models (Wendler, 2012). He observes that "theoretical reflective publications are scarce". Moreover, he finds that there is still a gap in evaluating and validating developed maturity models. Surveying 76 studies, Poeppelbuss et al. also find that "hardly any of the reviewed papers use existing theories as a foundation of research" (Poeppelbuss, Niehaves, Simons, & Becker, 2011). In a benchmark study of 16 maturity models, Kohlegger et al find that: "maturity models simply—and vaguely—build on their, often well-known, predecessors without critical discourse about how appropriate the assumptions are that form the basis of these models" (Kohlegger, Maier, & Thalmann, 2009). In a recent survey of various maturity models, Proença and Borbinha conclude that in many models, a precise definition of maturity is lacking (Proença & Borbinha, 2016).

Becker et al. call for a more methodical way of developing maturity models using a scientific design science like approach (Becker et al., 2009). They note that "procedures and methods that lead to these models have only been documented very sketchily". They further address the state of maturity modelling: "authors only rarely reveal their motivation and the development of the model, or their procedural method and the results of their evaluation".

Based on a broad literature review covering 117 maturity models, Mettler et al. observe that maturity models are often incompletely described and lack retrievability and reusability (Mettler et al., 2010). They also conclude that most maturity models lack validation and the majority of models found in the literature do not discuss the application of the model nor provide specific assessment methods or tools. Poeppel-

Table 2 Attributes of maturity models, this table summarizes the classification model proposed in Mettler et al. (2010), extended with an attribute capturing fixed versus focus are models

Attribute group	Attribute	Explanation
General	Name and acronym	
	Source	Primary and secondary sources
	Topic	Scope of Maturity addressed
	Origin	Academic or practicioner
	Target audience	Management-oriented versus a technology-focused audience, or no clear distinction
	Year of publication	
	Mode of access	Freely available or liable to pay a fee
Model design	Concept of maturity (Process, Object, People)	Does the model focus on specific processes, a product, people capabilities or a combination of these
	Levels (fixed or focus area)	Does the model contain a fixed number of levels or various focus areas with possibly different maturity levels
	Composition (grids, questionnaires or CMM like models)	Grids only use a simple contextual description. CMM uses a more formal architecture with stages and key process areas
	Degree of reliability (verified or validated)	Verification refers to how well the model represents the developer's conceptual description and specifications with sufficient accuracy. Validation represents the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model
	Mutability (form and functioning)	Mutability of the form includes possibilities to adapting e.g. the underlying meta-model or model schema, the descriptions of the maturity levels or question items). Mutability of the functioning is concerned with how maturity is assessed
Model use	Method of application	Self-assessment, third party assessment or certified practitioners
	Support of application	Textual description or software assessment tool
	Practicality of evidence	Implicit improvement activities or explicit recommendations

buss et al. surveying 35 papers that propose new maturity models, arrive at a similar conclusion, although they note that "conceptual research is increasingly complemented by empirical work, most notably in the form of case studies that serve as a proof-of-concept" (Pöppelbuß & Röglinger, 2011).

Tarhan et al. in a recent study of 61 Business Process Maturity Models, find a lack of empirical studies that validate the models. They also call for separating the assessment method used to evaluate the maturity level from the maturity model (Tarhan, Turetken, & Reijers, 2016). Their hypothesis that maturity models are mainly descriptive rather than prescriptive is also confirmed. The study concludes that this makes these maturity models less actionable. Proença and Borbinha also find that several maturity models lack an assessment method. Even if an assessment method is available, they find that many models do not specify improvement points explicitly, nor prioritize them (Proença & Borbinha, 2016). Finally, assessment methods tend to be highly complex, costly, lack training or certification, and continuity. They call for more automated and continuous assessment in future maturity models. …also report this omission in academic research: "academics often fall short in providing detailed guidelines and helpful (software-based or online) toolkits to support the practical adoption of models developed in academia" (Pöppelbuß & Röglinger, 2011).

Despite these wide range of critique on maturity models, the field is considered promising in both research and practice. Both practitioners and researchers find maturity models helpful. Becker et al. identify maturity model research in IS "as a study field of great relevance to practice that still bears a wide range of research potential to be exploited" (Becker, Niehaves, Pöppelbuß, & Simons, 2010)".

4 Discussion and Conclusion

From the studies summarized and surveyed in this paper, the key conclusion is that despite its growing popularity in research and practice, maturity modelling has not yet achieved a high level of maturity.

The way forward therefore seems to address the critiques raised and discussed above in future maturity modelling. Efforts in this area include a phased model for maturity model development (De Bruin, Freeze, Kaulkarni, & Rosemann, 2005), a structured list of requirements to guide maturity model development (Becker et al., 2009), and general design principles for maturity models as proposed in Pöppelbuß and Röglinger (2011). In addition to these efforts, a maturity model for maturity models may seem a logical and useful tool for improving maturity models. Obviously, the research and practitioners community that embraces maturity models will be keen on utilizing a maturity model to guide quality improvements in the field.

A promising direction for future research is the development of such a model. The model is likely to be a focus area maturity model. The focus areas covered should include the important elements of maturity models recognized in the papers surveyed, such as the definition of the maturity concept itself, the definition of the stages and descriptive/prescriptive elements, the design process of the model, the assessment method, the use and continuous improvement of the maturity model and the verification/validation process. The focus areas need to have capabilities, processes and a growth towards a higher stage of maturity model maturity. Clearly the Maturity model for Maturity Modeling (MM4MM) should be developed iteratively and in close collaboration with experts in maturity modelling. The author is keen on undertaking this endeavour and invites the interested reader to join this initiative.

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Blackboxing Data—Conceptualizing Data-Driven Exploration from a Business Perspective

Robert Winter

1 Introduction

In the late 20th century, structured analysis and later process modelling could rightfully claim to support a major portion of Information System (IS) analysis for business applications. Over the last two decades, however, digitalization and data-driven exploration call for increasingly multi-modal management approaches—and consequently require IS analysis support to be extended to cover this larger variety. We outline what we perceive as a multi-decade conceptualization journey from a business perspective: Having started with modelling functions, data stores and dataflows, having moved towards business process modelling, having expanded to modelling of value creation and value appropriation, now also business conceptualizations for purpose-driven, informed decision-making are needed. In this paper, we focus on the IS analysis support for data-driven exploration. Advanced analytics increasingly gain importance in many industries. Compared to most other business functions, analytics' explorative (rather than exploitative) character requires different conceptualizations to support IS analysis. While many conceptual data models have been proposed, we believe that their focus on (even semantic) 'data' structures inappropriately captures the essence of how business stakeholders analyze, design and manage data-driven exploration.

In Sect. 2, we outline how management approaches became more multi-modal over the last decades and how this development challenges IS analysis for business applications. Since IS analysis needs to abstract from constructional details and focus on the dominantly functional view that business stakeholders have, the necessity of data blackboxing is discussed in Sect. 3. In Sect. 4, we discuss the potential of various proposals from different fields to blackbox data exploration. In conclusion, we outline a data black-boxing research agenda that includes ontology and taxonomy design, the

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derivation of appropriate analysis and modelling methods/techniques, case analysis and pattern discovery in Sect. 5.

2 Management Becomes Increasingly Multi-modal

In the early 1990s, organizational design and performance management were fundamentally reshaped by shifting the focus from a **functional perspective** (e.g., inventory, production, accounting, or sales) towards a cross-functional **control of output flow** (e.g., order-to-cash). Process models and process-focused management since then allow to “manage the white space on the organization chart” (Rummler & Brache, 1995, p. 203). From a modelling perspective, this shift puts the **process concept** to the forefront, which integrates secondary concepts like function, output, resource, and performance indicator.

Pervasive digitalization of organizational life has become the “new” reality in IS research (Tilson, Lyytinen, & Sørensen, 2010). Consequently, organizational design and performance management have been challenged again by having to accommodate fast-changing, increasingly individualized, context-dependent digital interactions, which fundamentally differ from harmonized processes (Loebbecke & Picot, 2015). While certain aspects of digital interactions have a process character and thus may be analyzed, designed and managed from a business process perspective, other aspects like agility, individualization and context dependency require complementary perspectives. Consequently, Glushko and Tabas (2009) proposed to differentiate between a **front-stage** and a **back-stage** portion of organizations: Back-stage denotes the harmonized, comparatively stable components where business process management (BPM) proved to be highly successful. In contrast, front-stage denotes the components where individualization and fast adaptation to changing technologies, preferences and contexts need to be managed. From a modelling perspective, for managing the increasingly important front stage, the **value concept** has been put to the forefront (value proposition and appropriation), integrating secondary concepts like customer journey, objectives, context, and delivery process (Blaschke, Haki, Aier, & Winter, 2018).

For organizational design and performance management of both the organization’s back- and front-stages, the exploitation perspective (Benner & Tushman, 2003) is dominant. Conversely, the exploration perspective is traditionally dominant for innovation. For the increasingly important **data exploration** portion of the digitalized enterprise (Hashem et al., 2015), both perspectives increasingly overlap. In addition to the back- and front-stages, data-driven exploration emerges as a third, distinctive component of the organization. For conceptualizing the essence of data-driven exploration, neither analyzing, designing and managing harmonized output creation, nor individualized, context-dependent digital interactions seem to be appropriate. Data-driven exploration is all about purposeful testing hypotheses using rich data. Thus, the **informed decision concept** moves to the forefront. From a modelling perspective, data-driven exploration should not only link business activities and directly related data, but also integrate secondary concepts like data lineage and data quality (DalleMule & Davenport, 2017), purpose (Forgó, Hänold, & Schütze, 2017), and context. Existing conceptual data models, even if intended to capture (data) semantics, do only cover a fraction of these concepts.

In summary, it can be expected that digitalization and data-driven innovation increasingly require a multi-modal (Loebbecke & Picot, 2015) management approach. As a direct consequence, different types of conceptual models need to co-exist and to be linked. While for some portions of the multi-modal organization mature and comprehensive conceptual models are available, there is a lack of business-oriented modelling approaches for data-driven exploration.

3 Blackboxing Data

In contrast to white-box models, which represent the constructional design of a system, black-box models represent the interactions between the system and its environment (Dietz, 2006). Blackboxing means to abstract from constructional and operational details and to focus on the way the system "is used", i.e. how it transforms inputs from the environment into outputs back to the environment. Dietz (2006) illustrates the different modelling perspective by comparing a white-box and a black-box model of a car: Whereas the white-box decomposition typically represents "constructional" car components such as engine, steering wheel and disk brakes, the black-box decomposition typically represents "functional" car components for accelerating, steering and decelerating, etc. Blackboxing is a powerful concept to separate system requirements (how the system may be used) from system construction (how the system is designed).

For the analysis and design of IS in organizations (ISAD), researchers and practitioners have brought forward various blackboxing concepts. ISAD comprises two major areas (Iivari, Hirschheim, & Klein, 2000):

- **IS analysis** aims to gather, analyse, specify, and document IS requirements based on a common understanding, which stakeholders have about a real-world domain (de Kinderen & Ma, 2015). As such, IS analysis refers to "a number of activities in the early stages of IS development […] to identify and document the requirements for an information system to support organizational activities" (Iivari, Parsons, & Wand, 2006, p. 510). This discourse needs to be based on black-box models.
- **IS design** employs techniques to translate requirements into logical IS designs to eventually fulfil the requirements imposed by the real-world domain (Gregor & Hevner, 2013). As such, IS design refers to "the process of defining the system architecture, components, modules, interfaces, and data for a software system to satisfy the requirements specified during systems analysis" (Iivari et al., 2006, p. 510). This discourse needs to be based on white-box models.

During the development of IS applications for business, black-box models need to be "translated" into white-box models. If mature conceptual representations of business concepts exist (e.g. for functional organizations), this “whiteboxing” translation can be systematically designed and implemented. In cases where technical innovations, however, enable and drive organizational innovations, the translation process needs to be reverted: IT-related concepts need to be blackboxed in order to become understandable and usable by business stakeholders. We believe that the recent boom of Big Data and Advanced Analytics belongs to the latter group. New technical solutions for data-driven exploration need to be blackboxed in order to support an effective and efficient IS analysis discourse with and between business stakeholders.

4 Concurrent and Complementary “Blackboxing” Concepts

Over the last decades, a series of complementary blackboxing concepts have been developed for ISAD. Traditionally (e.g., in SADT (Ross & Schoman, 1977)), functions, data and data flows were used as core conceptualizations for functional organizational designs. These were subsequently “translated” into algorithms and data structures.

Beginning in the early 1990s, the business process emerged as core conceptualization for analyzing, designing and managing the parts of the enterprise that are harmonized for performance. The Architecture for Integrated IS (ARIS) meta model, for instance, has been proposed to support process-centred performance management. Functions, data, outcomes, performance, and organizational units/roles all are linked by the **business process** concept (Scheer, 1987). Being translated into the same white-box models (algorithms and data structures), a different blackboxing approach aims at supporting different business stakeholders with different functional business requirements.

For analyzing, designing and managing the parts of the enterprise that need to be customized, contextualized, and fast adapted to support customer journeys and (increasingly digital) service encounters, **value** has been established as a core concept. Early approaches to understanding and designing interactions at digital interfaces and IT-enabled interactions such as service blueprinting (Patrício, Fisk, Falcão e Cunha, & Constantine, 2011) are still process-oriented. Service is however primarily about value-in-use and value-in-context (Vargo, Maglio, & Akaka, 2008) so that process cannot be the core concept any more (Lusch & Nambisan, 2015; Vargo & Lusch, 2016). Consequently, emergent IS analysis approaches for the front-stage support value-centered performance management beyond mere process considerations, e.g. by linking value proposition/appropriation to customer journey, objectives, context and delivery process (Blaschke et al., 2018). Again, an additional, complementary blackboxing approach aims at supporting business stakeholders with specific functional requirements.

For analyzing, designing and managing the parts of the organization where data exploration is important, it is questionable whether process- or value-centric conceptualizations are appropriate. In data warehousing and business intelligence contexts, data exploration is traditionally analyzed and designed using a supply-chain ‘process’ perspective, which covers extraction, transformation, load, integration, enrichment, provision and analysis (Sen, Ramamurthy, & Sinha, 2011). But data-driven exploration is about the purpose-driven, flexible exploration of (re-)combination and reuse potentials of enriched data—harmonization and supply chain paradigms to not cover this essence (Chen, Chiang, & Storey, 2012). Data is explored for two purposes: decision making and innovation (Hashem et al., 2015). Consequently, **informed decision** appears to be a candidate for a suitable core concept. A conceptual model of informed decisions needs to link data sources (master, transaction, and derived data), enrichment processes (data lineage), business questions, exploration purpose(s), and context. A starting point could be a taxonomy of data exploration use case types.

Blackboxing business IS requires different conceptualizations for different uses, which have emerged over time. Having started with modelling functions, data stores and dataflows, having moved towards business process modelling, having expanded to modelling of value creation and value appropriation, now also business conceptualizations for purpose-driven, informed decision-making are needed. This blackboxing journey is illustrated by Fig. 1.

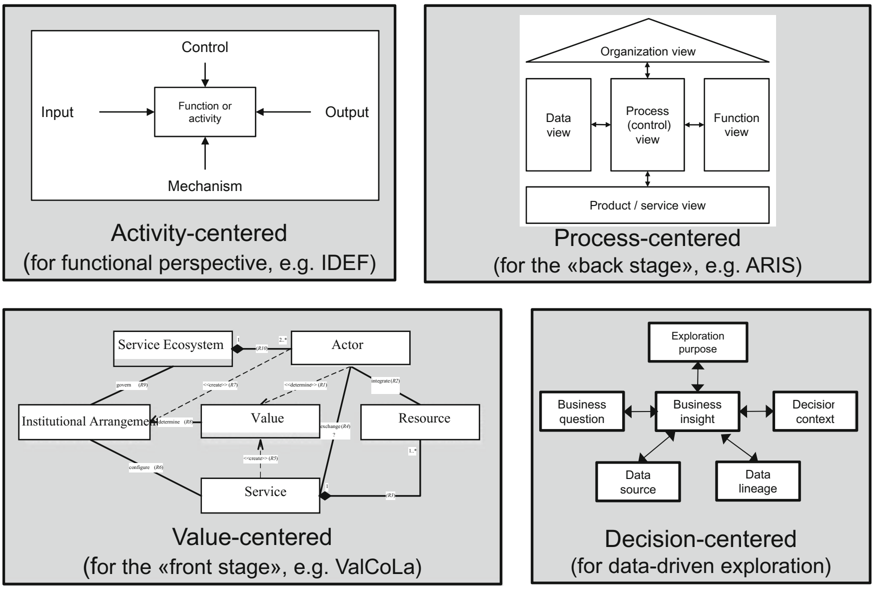

Fig. 1 Concurrent and complementary “black box” concepts

5 Promising Starting Points for Data Blackboxing

Numerous proposals aim at conceptualizing data and data use from a business perspective. Taking blackboxing seriously, however, dismisses all of them for further consideration because they are centred on data. **Semantic data models** are still representations of data (and their dependencies), i.e. constructional representations, and not representations of what business users do with data. They try to capture the "meaning" of data, but lack to capture why what data are combined in which way for what purposes. While **decision modelling** approaches, on the other hand, are obviously centered on decision-making, their model granularity and their focus on standard decisions (not data exploration) also dismisses them for further consideration. **Dimensional data modelling** puts facts into focus, allows to harmonize dimension-style references and is compatible with certain types of analytical processing. This approach however is also constructional and widely ignores how facts and dimensions relate to business questions, how data is gained and in what context it is used.

Information maps have been proposed by Strauch (2002) to generate aggregate business representations on how and for what data is used. Resulting from various analysis, homogenization, priorization and aggregation activities, they summarize information requirements by business users in a structured, aggregate form (see Fig. 2), which is generated from an information use repository. As information maps are being generated from the repository, a large variety of concepts regarding dimensions, periodicity, concept, synonyms, data sources, data uses, organizational units, etc. can be created, and content can be flexibly filtered. The contribution of information mapping for data blackboxing is that many of the proposed secondary conceptualizations (data source, organisational unit, data use, data meaning) are covered in the approach, and that the representations are highly flexible and thus suitable for business stakeholder discussions. The repository information, however, needs to be elicited and integrated in an expensive manual process, and the primary conceptualization is data, not decision—although business question-style diagrams can be easily generated from repository contents.

Information use canvases have been proposed by several authors (https://www.data-use-case-canvas.org/index_en.html, https://katrin-mathis.de/uploads/pics/Data-Canvas-Deutsch.jpg, see Fig. 3). As tools for supporting joint inquiry (Avdiji, Elikan, Missonier, & Pigneur, 2018), they serve as a communication and problem-solving tool rather than a specification tool. Coming very close to the purpose of blackboxing in that regard, the presented exemplars are lacking a comprehensive justificatory foundation like the one Osterwalder (2004) elaborated for his business model canvas.

Homogenisierter Informationsbedarf

		Kennzahlen						
		Anzahl aktive Verträge	Erwartete Prämien	Offene Schadenssumme	...	Schadenssumme	Anzahl Kunden	...
		I	I	I	I	S	S	S
Periodizität		monatlich	monatlich	wöchentlich		wöchentlich	wöchentlich	
Priorität		M	M	B		M	A	
Systeme		System A	System A	System B	...	System B	System A System C System D	
Organisation		Abteilung A	Abteilung A	Abteilung B	...	Abteilung B	Abteilung A Abteilung C Abteilung D	
Berechnungsvorschrift		f_1 (SysA.Tab1.AttrX, ...)	f_2 (SysA.Tab2.AttrY, ...)	f_3 (SysB.Tab1.AttrX, ...)	...	f_{37} (SysB.Tab1.AttrY, ...)	f_{38} (SysA.Tab1.AttrX, ...)	...
Dimensionen, Hierarchie								
Vertriebsstruktur	Agentur	X					X	
	Generalagentur					X	X	
Zeit	Tag			X		X		
	Woche			X			X	
	Monat	X		X			X	
	Jahr		X	D			X	
Kunde	Kunde			X				
Produkt	Produktgruppe						X	
	Produkt						X	
Vertrag	Vertragsart							
	Vertrag						X	
etc.	...							

Fig. 2 Information map (Strauch, 2002)

High-level data models (Hoberman, Burbank, & Bradley, 2009) have been proposed with the explicit goal of abstracting from "technical" aspects and providing a comprehensive, business oriented representation of data (see Fig. 4). While proposed exemplars appear being able to integrate the diverse secondary concepts, which are needed to blackbox data, they lack a formal clarification of underlying concepts and consequently cannot guarantee important properties like coherency or representation independence.

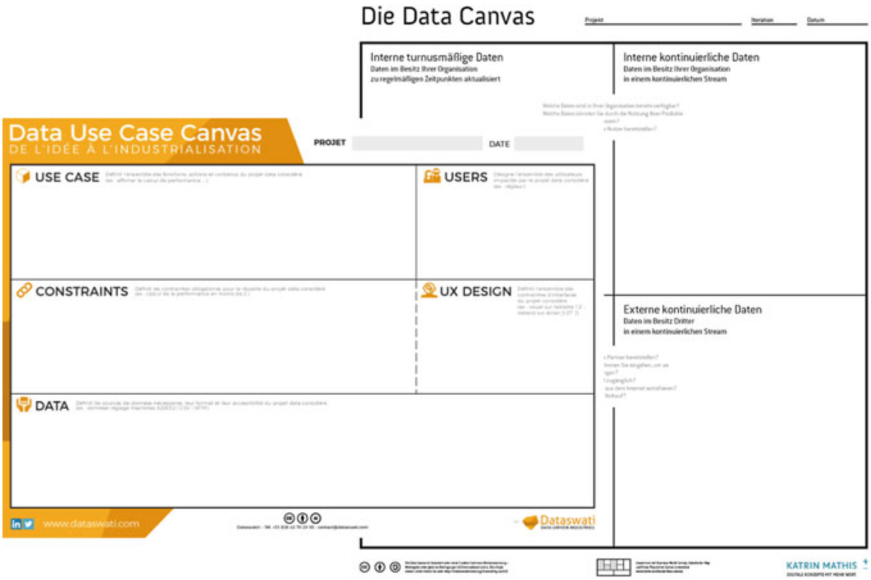

Fig. 3 Data canvas (https://www.data-use-case-canvas.org/index_en.html; https://katrin-mathis.de/uploads/pics/Data-Canvas-Deutsch.jpg)

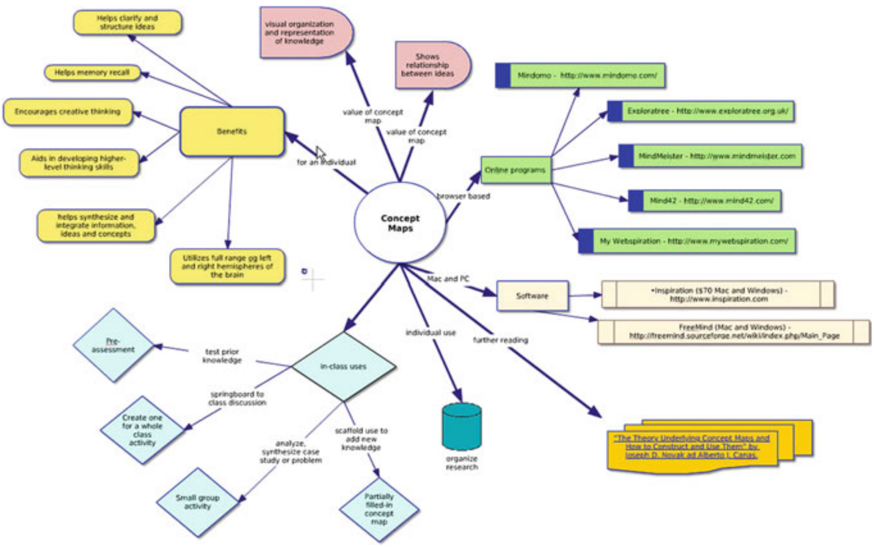

Fig. 4 High-level data model (Hoberman et al., 2009)

6 The Road Ahead

In the preceding sections, several important requirements for conceptualizing ("blackboxing") data-driven exploration were mentioned:

- A black-box model needs to abstract from constructional details while capturing all important "functional" business-related aspects;
- Its design should be based on a sound justificatory foundation;
- As an artefact it should be useful for supporting the discourse among business stakeholders, IS analysts and IS designers;
- It should be sufficiently flexible to support an explorative enterprise component;
- Its model instantiations should be efficient to populate and maintain (repository-based);
- It should be compatible with complementary conceptualizations for other enterprise components.

While none of the approaches introduced in the preceding section fulfils all these requirements, they can serve as starting points for extension and integration: The information mapping method and its associated analysis techniques show how comprehensive aggregate "informed decision" models can be systematically created and coherently generated from a repository. Information use canvases afford to visualize data use in order to support joint inquiry within and among the various involved stakeholder groups (from business, IS analysis and IS design). The further development of high-level data models may lead to effective and efficient ways to identify relevant second-order concepts and to structure analysis activities.

These starting points, however, need further complements to develop an approach that fulfils all stated requirements. First and foremost, a well-built and -evaluated ontology of "informed decision" needs to be developed that can serve as a foundation for all subsequent meta-modelling and method engineering activities. The value co-creation ontology development by Blaschke et al. (2018) could serve as a blueprint because it aims at black boxing digital platforms by conceptualizing value co-creation. Based on a well-crafted ontology, the phenomenon of data-driven exploration in enterprises can be systematically analysed by creating a taxonomy of observable practices. The taxonomy development approach by Nickerson et al. (2013) promises to be suitable for that purpose. Once the primary and secondary concepts (as well as their relationships) are clear and current practices are sufficiently understood, building blocks from the discussed blackboxing approaches can be adapted, extended and integrated on that basis. The emerging data exploration analysis "toolset" will then allow to create repositories of exploration practices, discover patterns and systematically link practices to performance, thereby paving the road for more advanced IS analysis and design artefacts such as reference models or maturity models.

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Part III
Processes

"Works of art make rules; rules do not make works of art." (Claude Debussy)

Business Processes—and especially Business Process Models—are the expression of how tasks and activities are performed in an organization, and by whom. With this expression of the flow of the tasks, processes and the corresponding models give guidance—or in other words rules—for performing the tasks, doing it in a structured way. The result of the art of creating, designing and defining a process gives us rules and leads us through the process flow—that is what the construction of processes is about!

Structuring Quality Management with the icebricks Business Process Management Approach

Sascha Beilmann and Nico Clever

1 Introduction

In today's world, enterprises are forced to deal with a number of issues like globalization, huge competition, and technological advances. In the end, organizational undertakings always come down to decision making. At this, enterprises do not just want to be able to make any decision, but to make the *best* decision possible. Therefore, a whole number of methods to support economical decisions exist. However, from our point of view personal and subjective opinions of decision takers and circumstantial factors of decision-making can never be fully eliminated. Thus, there is always at least some kind of irrationality in human decision-making left. This justifies the need to reduce the room for speculation. To this end, depicting the actual status quo in a structured and comprehensible way with pragmatic and sophisticated approaches, is advisable (Snowden & Boone, 2007). In doing so, the uncertainty of a decision can be reduced, potential irrationality is wiped out and a solid base for the *best* potential tangible and intangible value for a company can be reached. This, in turn, leads to the *best* utilization of scarce enterprise resources.

Quality Management (QM) is a means for enterprises to present the quality of their products and services to potential customers in a transparent, comprehensible way. This especially holds true for branches where a proper QM—along with its certificates—is customary and even obligatory. For example, in component supply markets, as in the automotive industry, it is obligatory to provide evidence of a proper QM. As mentioned above, a means for providing evidence of QM, certificates are used. They signal the customer that an enterprise adheres to well-known and accepted

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quality standards. In the context of QM, the 9000 series of the International Organization for Standardization (ISO) is the predominant certification. The ISO stated, that in 2016 1.1 million companies were certified according to the ISO 9000-standard (ISO, 2016). In the DIN EN ISO 9000-standard, the vocabulary and definitions are given; in the DIN EN ISO 90001-standard, the requirements for Quality Management Systems (QMS) are given. The most recent version of the standards[1] propagates a strictly process-oriented approach (Deutsches Institut für Normung e.V., 2015b) as opposed to the Quality Handbooks of the previous versions. As a process-oriented thinking in terms of Business Process Management (BPM) has been established in many enterprises for quite a long time now, this allows for establishing a standard-compliant QM with more ease. Although the possibility is there, only the fewest companies consequently align the two fields BPM and QM during the certification and afterwards. This leads to a discrepancy between the interest and wish for such a certification, on the one side, and the non-integration of these perfectly fitting approaches, on the other side.

Therefore, in this article, we show that using the proven BPM methodology icebricks for establishing QM as per the well-known ISO 9001 standard in a company proves to be an effective and efficient way of integrating the two fields BPM and QM. To this end, we show along a practical ISO 9001 certification case, that the icebricks BPM approach (Becker, Clever, Holler, Püster, & Shitkova, 2013) is able to cover all aspects demanded from a proper QMS as per the ISO 9001. The remainder of the paper is structured as follows: In Sect. 2, the methodical fit of BPM and QM is shortly covered. In Sect. 3, the icebricks methodology and the according tool are presented. In Sect. 4, the application case is introduced, and the application of the icebricks approach for an effective and efficient QM is presented. The article is closed by a summary and a discussion in Sect. 5.

2 Methodical Integration of BPM and QM

To be able to show that the icebricks BPM approach is suited for an effective and efficient QM, the two concepts have to be integrated. In the ISO 9000-standard, seven principles for a rigor QM are provided: customer orientation, leadership, involvement of people, a process-oriented approach, improvement, fact-based decision making, and relationship management (Deutsches Institut für Normung e.V., 2015a). In the ISO 9001, likewise, requirements for a certifiable QMS are given. These are also split into seven sections and covered in Chap. 4 through 10 of the ISO 9001 standard.[2] The seven chapters cover various aspects of a business undertaking and are structured

[1]The full denotation for the standards is DIN EN ISO 9000:2015 respectively DIN EN ISO 9001:2015. For simplicity reasons, from here on out, we will use the denotations ISO 9000 and ISO 9001 for the latest versions from the year 2015. Where intended, other versions are explicitly mentioned in the text.

[2]In Chapters 0 through 3, only introductory issues not covering actual QMS requirements are handled.

along a Plan-Do-Check-Act (PDCA) cycle. In this, Chaps. 4, 5 and 6 cover the *Plan*, whereas 7 and 8 belong to *Do*, while 9 and 10 address *Check* and *Act*, respectively. As stated in the Introduction, the major novelty of the ISO 9001:2015-version, with respect to the 2008-version, can be found in the strictly process-oriented approach and in a risk-based thinking. Although BPM is praised by the standard itself, it is rather seldom actively utilized for ISO 9001 certifications. A potential reason for that can be seen in the ongoing denial of the potentials of BPM in practice. Another reason may be the ignorance of potential benefits of the ISO 9001 certification itself.

Considering the methodical fit of well-known procedural BPM approaches and QM, the ignorance of utilizing BPM for QM seems even more ominous. Both prominent and well-known BPM procedure models provided by Becker, Kugeler and Rosemann (2012) and Weske (2012) and QM as per the ISO 9001 standard overlap to a great extent. For instance, the *Do*-phase is concerned with the support and operation within the ISO 9001. Considering the procedure models, the *Configuration* and *Enactment* phases, respectively *Process-oriented Organization Design*, *Process Implementation*, and *Continuous Process Management* steps perfectly represent the *Do*-phase of the ISO 9001. Thus, a proper BPM approach alongside a supporting tool can handle the requirements for QM(S) of the ISO 9001. Therefore, in the following, the icebricks BPM approach is described, its application in a practical QM case is shown, eventually resulting in the proof that (at least some) BPM approaches can help in the strive for an effective and efficient QM.

3 The icebricks Approach

3.1 Methodology

The problem of many BPM approaches, amongst others, is that process models created with them lack clarity, comparability and systematic design (Becker, Rosemann, & Schütte, 1995). This is due to the fact, that often there is a plethora of model elements, which the modelers can use during model creation. Moreover, there are no clear semantic rules to create the models. Although having a clear syntax most of the times, models created by different modelers are usually not or only hardly comparable. In huge BPM projects, which are standard even in medium-sized enterprises, this leads to unnecessary work since the models are not used any longer once they have been created. The icebricks methodology adheres to the Guidelines of Modeling (Becker et al., 1995) and the Seven Process Modeling Guidelines (Mendling, Reijers, & van der Aalst, 2010). It makes use of a clear four layer-structure and the principle of transferring the complexity of huge process models with many elements to attributes of each process step. To be clear, the information provided in many process models is not per se wrong and unnecessary. However, in big, confusing process models the important information is often not easily extractable. Within the

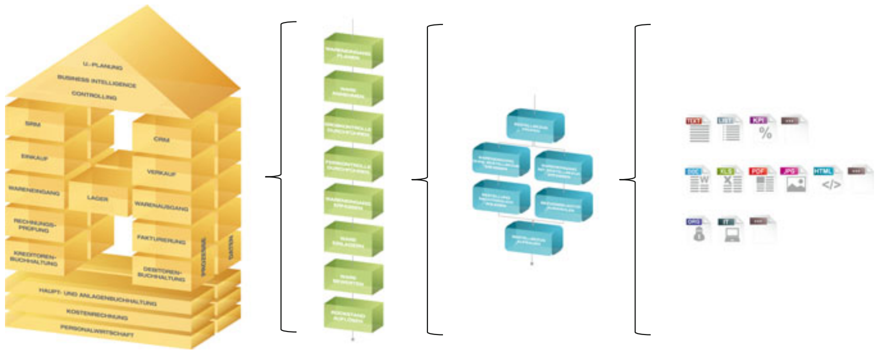

Fig. 1 Four layer-structure of the icebricks methodology

icebricks methodology, all information surplus to the actual steps or activities of a process is stored in additional *attributes* within the respective process modeling tool.

The *four layer-structure* of the icebricks methodology consists of a (process) framework, main processes, detail processes, and the most atomic process bricks (Becker et al., 2013). The *process framework* provides an overview depicting the process landscape of the business endeavor. The framework consists of *main processes*, which represent the main functions of the business undertaking. Here, often, a reference design for process frameworks in the form of a house is used (Meise, 2001), since it best represents the constituting value-adding processes (core), the support processes (fundament), and the management processes (roof). For example, the Retail-H is a prominent reference model for the retail sector making use of this house-form (Becker & Schütte, 2004). The main processes, in turn, consist of *detail processes*, which cover the steps necessary to carry out the functions of the main processes on a rather high level of abstraction. The detail processes themselves consist of *process bricks* which are the most atomic activities that have to be carried out to the processes' end. The clear four layer-structure of icebricks along with a practical example from the Retail-H (in German language) is shown in Fig. 1.

The processes on the main and detail process level follow a strict sequential flow, although *simple branching* is allowed. However, due to complexity reasons, it should only be used when really necessary. Often, branching decisions can better be depicted via the use of attributes. Branching may only be relevant, when, for example, an automatic process step can also be carried out manually, but more than one activity is necessary. Whenever there is a great deviation in process strings, *model variants*, which are available on every level of the icebricks structure, should be used.

As for the comparability and correctness of the process models, the process step labels—the actual activities—follow a predefined *phrase structure* consisting of business objects and the procedures, which can be carried out on them. The labels always adhere to a "<Procedure><Business object>" structure, e. g. "Print invoice" or "Commission goods".

Table 1 icebricks tool objectives

Group	ID	Objective
Collaboration	Obj.01	Conflict-free multi-user access
	Obj.02	Access rights management
	Obj.03	Version management
Standardization and facilitation of modeling	Obj.04	Simple notation
	Obj.05	Standardized level of abstraction
	Obj.06	Integration of enriched process information
	Obj.07	Semantic standardization
Integration and model re-use	Obj.08	Re-use of models
	Obj.09	Full process documentation export
	Obj.10	Attribute-based reporting

3.2 Tool Objectives

The software tool corresponding to the icebricks methodology was developed on the basis of a rigor research endeavor, following the principles of proper design-oriented design, development, application and evaluation of an IT artifact (Österle et al., 2010). First of all, several functional tool objectives were developed on the basis of literature and experience from everyday consultancy work. The functional objectives for the icebricks tool are classified in three groups and can be found in Table 1. Next to the functional requirements, the usability of a process modeling tool is of major importance, since nowadays process modeling tools are not only used by modeling experts but by domain experts without IT knowledge, as well (Di Francescomarino & Tonella, 2009; Lohrmann & Reichert, 2012). If the usability is taken care of while designing the tool, later tool support costs are reduced (Bevan & Bogomolni, 2000). Therefore, on top of the functional requirements, a non-functional objective for the tool is a sufficient level of usability (Obj. 11) for all of the tool's functionality.

In the dynamic business environment of today, the tool has to be accessible from any place and has to enable collaboration and conflict-free multi-user access to the modeling content for any BPM project member and stakeholders. Different access rights for different roles in BPM projects are necessary. It is crucial to keep track of the changes made to model content, especially in distributed modeling projects, because of hazardous modeling and loss of information (Clever, Holler, Püster, & Shitkova, 2013; Hadar & Soffer, 2006). These aspects form the *collaboration* group of tool objectives (Obj.01–Obj.03).

As stated above, to reduce information overload and complexity and to keep process models understandable, a simple yet expressive notation is needed with a standardized level of abstraction. Furthermore, attributes to store the enriched process information to prevent model overload, are important. The freedom provided by many of the existing process modeling languages, such as Business Process Model and Notation (BPMN) or Event-driven Process Chains (EPC) include a risk regarding inconsistencies in semantics and abstraction, hindering the models' understandability and comparability (see above). Therefore, a semantical and terminological standardization has to be provided in order for the models to be comparable and correct (Becker, Rosemann, & von Uthmann, 2000). These aspects form the *standardization and facilitation of modeling* group of tool objectives (Obj.04–Obj.07).

Re-use of model (elements) is of great importance to reduce redundant work, thus should be allowed by a process modeling tool. As often the full process information is to be delivered as a result in a BPM project, it should be extractable in a human-readable form. Moreover, analyses on the stored attributes should be possible to purposefully extract important information. These aspects form the integration and model re-use group of tool objectives (Obj.08–Obj.10).

3.3 Tool Design and Development

According to the tool objectives (see Sect. 3.2), the icebricks process modeling tool was designed, implemented, applied in real world-cases, and evaluated. In the following, these phases are described shortly.[3]

Complexity Management and Semantic Standardization Model complexity is the major factor for acceptance and understandability of process models and crucial to the usage of the models once they have been created. In this, process models have to as complex as necessary to depict all process information, but as simple as possible to be understandable. The icebricks methodology uses a simple four layer-structure with a simple set of process elements, a predefined phrase structure, and attribution of process steps to store all enriched process information (see Sect. 3.1). In the tool, attributes of various types can be used. These include text, numerical attributes, process links and external links, attachments, videos, hierarchical attributes for depicting process responsibilities or underlying IT infrastructure etc.

Integration and Model Re-use Within the icebricks tool, the re-use of models or model elements is fostered on every level of abstraction via a sophisticated interface. Using references to already existing model elements is also possible, thus, that when process information changes, this has to be done only in one place and is propagated throughout the system. This increases the speed and quality of modeling (no redundancies), reduces the modeling effort and enhances the consistency and comparability between the models.

[3]For detailed information, refer to Becker, Clever, Holler, Püster, et al. (2013) or Clever (2016).

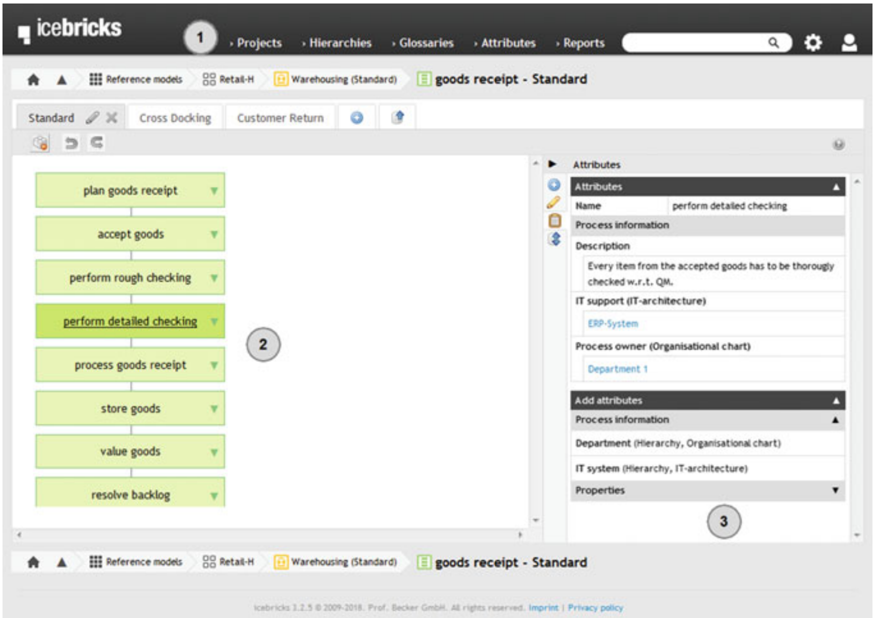

Fig. 2 The icebricks process modeling tool

Collaborative Modeling and Reporting Environment As BPM projects are usually carried out with many people involved, the artifact has to support collaborative modeling. Therefore, it was implemented as a web-based application based on the popular MVC framework Ruby on Rails[4] and enriched JavaScript in the frontend. It has a proper access and a rights and role management for depicting all separate permissions for different stakeholders of a BPM project. A basic reporting functionality including predefined standard reports is available, as well. The process models can be exported to Microsoft Word® and Excel® files, along with all relevant attribute information.

An excerpt of the resulting icebricks process modeling tool can be seen in Fig. 2. There, the user interface along with navigation (1), the modeling area with an exemplary process (2), and the attribute Sect. (3) can be seen.

[4]See https://rubyonrails.org/.

4 Application of the icebricks Approach for Effective and Efficient QM

4.1 Plan

In Chap. 4 of the ISO 9001 standard, the context of the enterprise is in focus. Here, a general understanding of the enterprise and its surroundings is pursued. To this end, all internal and external aspects relevant for the certification have to be defined. Internal aspects cover company-specific values, company culture, knowledge, and performance. External aspects include legal, technological, competitive, market-related, cultural, social, and economic surroundings. Information on all these aspects has to be gathered, verified, and monitored. Furthermore, all stakeholder needs and expectations have to be identified and the resulting requirements have to be documented. On the basis of the internal and external aspects, the stakeholders and their requirements, as well as the enterprises' products, the scope of the QMS is defined. Chapter 4 is concluded with the specification of all processes relevant for the QMS. Here, the strict process orientation of the 2015 version of the standard is beneficial w. r. t. BPM. A systematic documentation of the processes with a variable granularity (cf. icebricks layers) ensures integrity, intelligibility, and traceability of QMS-related aspects. This leads to a clear depiction and positioning of every process within the process landscape of an enterprise. In Sect. 4.4.1 of the ISO 9001 standard, a documentation of all processes of the QMS along with criteria and methods, resources and responsibilities, risks and opportunities is demanded (Deutsches Institut für Normung e.V., 2015b). This is achieved via the icebricks attribution of all processes on each layer, leading to transparent and manageable processes.

In Chap. 5, the ISO 9001 standard is concerned with leadership and their commitment, quality policy, and responsibilities. To achieve a tight integration of these QMS requirements within the BPM approach, responsibilities are stated for each and every process and process step. Both the person and all other stakeholders are informed and aware of this ownership. Therefore, so-called hierarchy elements (e.g., organizational structure, IT landscape etc.) can be linked to any process element, ensuring the transparency of responsibility and allowing for leadership promotion of this process-based requirement of the standard. Moreover, communicational issues and ambiguities are prohibited through the usage of a company-specific glossary with business objects and pre-defined, allowed procedures for a specific business object. Furthermore, these pre-defined business object-procedure combinations always follow a standardized phrase structure (e.g., "perform detailed checking"; see Fig. 2) to further wipe out ambiguities and enhance comparability.

After its definition, the quality policy is to be actively put to work. The web-based icebricks tool ensures that any relevant information is available at any time to any relevant stakeholder. Based on the process attributes, reports can be generated, and all process information can be exported to standard formats (cf. Sect. 3.3).

Fig. 3 Risk depiction in icebricks using attribute combinations

Chapter 6 of the ISO 9001 standard deals with risks and chances of the previously documented company's processes. A systematic approach to identify risks, to elaborate on and evaluate chances within the QMS is to be taken. With a consistent documentation of the risks and chances, their effects can be considerably reduced respectively enhanced. In icebricks, attributes are used to document and store the risks and chances separately for every process (step). Here, combinations of several attribute types (textual, numerical, hierarchical etc.) can be used. As can be seen in Fig. 3, for the risks of a process step, the description of the risk, its potential, and a proper handling can be documented.

4.2 Do

The aspects supporting the certification process are captured in Chap. 7 of the ISO 9001 standard. This includes resources, competencies, awareness, communication and documented information. Resources, internal or external, human or technological, belong to a specific process and can be depicted via the aforementioned attributes and hierarchical structures. The systematic knowledge management demanded by the ISO 9001 is fulfilled by the central, well-structured, and digital storage of icebricks. The detailed process information is in full alignment with the overall process landscape of the enterprise. As stated above, the web-based tool ensures anytime access for all stakeholders.

In Chap. 8, relevant tasks for the actual operation of the processes are captured. A clear communication directed internally as well as externally, is achieved by icebricks in using the aforementioned business glossary and the predefined phrase structure throughout the whole processes. This prevents ambiguities and inconsistencies in the wording. A common language also supports activities of checking externally provided products or the release of new products.

4.3 Check

Performance evaluation is covered in Chap. 9 of the ISO 9001 standard. Here, key figures and performance indicators are to be used for measuring and analyzing the instantiated processes. Again, this is achieved via the use of attributes within ice-bricks. A periodic evaluation of the quality and the QMS itself is done via internal audits. Therefore, a seamless documentation of all process information is essential. icebricks supports adjustments to the process information and facilitates internal as well as external examinations in being the central source of process information. Several standard reports are available for the preparation and conduct of these audits. Furthermore, a goal-driven comparison with previous reviews can be carried out on basis of all process information. The documentation of these is crucial for management reviews and can be stored as recommended by the ISO 9001.

4.4 Act

Chapter 10 of the ISO 9001 standard is concerned with improvements. The aforementioned results of the management reviews should be transformed into improvement potentials, which cover, amongst others, process changes for re-organization, resource optimization, and corrections to reduce undesired effects. Although every change should enhance customer satisfaction, discrepancies like customer complaints, the countermeasures taken, and their results are stored as demanded by the ISO 9001. This is done via a change report depicting all modifications of any process information.

5 Conclusion

In this article, it was shown, that BPM and QM form a strong alliance. By using the "right" BPM approach—in this case icebricks—a proper QM can be implemented in an enterprise leading to synergetic effects. BPM and QM are actively used by many organizations, yet their excellent interplay is often neglected or not seen. We strongly encourage seeing the benefits of a tight integration of the two and strive for further researching the advantage of combining these highly connected approaches. A reasonable start for this was given by the ISO itself in promoting a strict process orientation in the 2015 version of the ISO 9001 standard.

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Predictive Analytics of Winter Sports Processes Using Probabilistic Finite Automata

Patrick Delfmann

1 Introduction

Winter sports is the economically most important kind of sports in Central Europe (Roth, Krämer, & Görtz, 2012). Therefore, the winter sports industry in the European Alps, which comes with a yearly turnover of umpteen billion Euros (where the cableway operators alone register an annual turnover of more than five billion Euros (Domaines Skiables de France, 2017; Roth et al., 2012; Seilbahnen Schweiz, 2017; Wirtschaftskammer Österreich, 2017)), is highly interested in streamlining its business processes. While customers demand more and more comfort and ski resorts must comply with these demands to stay competitive, they have to keep cost as low as possible to be able to offer attractive pricing at the same time.

A great cost factor of ski resorts is driven by planning, installing, maintaining and finally, stripping down cableways, where the total cost are highly dependent on the cableway's capacity, i.e., how many persons can be maximally transported per hour. For instance, chairlifts can be adapted to different capacity needs by hooking in or detaching chairs or by increasing or decreasing speed, resulting in higher or lower electricity cost. Also the kind of chairlift (maximum capacity and detachability) highly influences the investment cost, where the higher the maximum capacity is, the higher the investment cost are, and detachable chairlifts are more expensive than fixed ones. Consequently, decision makers in ski resorts are highly interested in optimizing both maximum and flexible capacity of cableways, depending on expected maximum and temporal capacity demand.

While adapting the capacity of cableways by adapting the transportation speed is relatively easy and does not require any preparation as it can be done on-the-fly when a lift queue becomes crowded or vacant, adapting capacity by changing the number of total transport units of a cableway (i.e., chairs or gondolas) requires

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set-up time. Hence, to exploit all possibilities of transportation capacity adaptation, it is important to know about the expected required capacity before it takes effect. A possible solution to this problem is *prediction*.

In this article, we present an approach that enables ski resorts to predict the capacity demand of cableways depending on their current routes and historical movements of skiers. The prediction is realized through a probabilistic model that captures the structure of ski resorts with *Probabilistic Finite Automatons (PFA)* and regards skiers moving through the resorts as *flow objects*. The probabilistic model can be trained with *log data obtained from keyless entry systems* as they are common in ski resorts. As a result, we obtain a fitted PFA that we can use to make predictions of movements of skiers, depending on currently running process instances (i.e., people who are currently skiing). With such a tool, we can make predictions about the general cableway capacity that is needed in a ski resort, and, moreover, about the temporal capacity that is likely to be needed at different times on an individual ski day, based on the current positions of skiers and the way they have already taken on the current ski day. This way the flexible capacity of cableways can be individually adapted, both through the cableways' speed and their respective number of transportation units (given they are detachable). Besides the benefits that may be immediately realized by the operators of ski resorts through better planning of capacity demands, prediction might also be of interest for the ski resorts' customers, who can be informed about likely lift queues so that they can adapt their planned route. This report summarizes our previous work on predictive process analytics (Becker, Breuker, Delfmann, & Matzner, 2014; Breuker, Delfmann Matzner & Becker, 2015; Breuker, Matzner, Delfmann & Becker, 2016) and its application to the winter sports industry (Brunk, Riehle, & Delfmann, 2018).

2 Formalizing Ski Resorts and Skiers

In order to make predictions on the future behaviour of skiers in ski resorts, we first need to find an appropriate way of *structuring the domain*. Consider Fig. 1 as a starting point, which depicts the "Walmendigerhorn" part of the ski resort "Oberstdorf-Kleinwalsertal" in Germany and Austria.

A typical ski resort consists of cableways and pistes. Skiers can use cableways and pistes in an alternating way, however it is also possible to use multiple pistes or multiple cableways successively. To predict the future behaviour of skiers, we rely on their corresponding movement data. Movement data that are easily obtainable are those that are generated whenever a skier passes an entry gate of a cableway.

In most ski resorts, each cableway has such an entry gate, which opens only for those skiers who own a valid ski pass. Nowadays, these ski passes are designed in credit card format and contain an RFID (Radio Frequency Identification (Walton, 1983)) chip that communicates with the entry gate and transmits the ski pass data. With these data, we can trace back all cableway entries each skier has conducted and, in turn, her/his way through the resort. Therefore, for structuring and prediction

Fig. 1 Ski resort consisting of cableways and pistes. (taken from https://cdn.snowplaza.nl/content/WinterPanos/2500/11792.jpg)

purposes, we are mostly interested in which cableways a skier has used and not on what pistes the skier was skiing. Let us assume that skiers only use pistes, then we can easily derive the structure of the ski resort shown in Fig. 1.

On the left hand side of Fig. 2, we see a structured representation of the main part of the ski resort shown in Fig. 1, consisting of the cableways No. 56, 57 and 58, and the possibilities to ski from the upper terminus to the lower terminus of a cableway. Cableway No. 56 is an exception, because it operates both uphill and downhill rides. Summarizing, from the tops of all cableways, we can reach the bottom of all cableways and, in addition, from the tops of Cableways No. 56 and 57, we can also reach the top of Cableway No. 56 for a downhill ride. Lastly, after a downhill ride with Cableway No. 56, we can certainly again take an uphill ride with Cableway No. 56. Such a structured representation of a ski resort can further be formalized as a process model graph (right hand side of Fig. 2), where each vertex represents a cableway and each edge represents a transition between two cableways. To represent the uphill and downhill services of Cableway No. 56, it was split into two vertices, No. 56 for uphill, and No. 56’ for downhill. To represent entry and exit points of the ski resort, we add further vertices “Start” and “End”.

With such a process model, we can not only represent the ski resort in a structured way but also the skiers moving through it. Each ski day of a single skier can consequently be seen as a single instance of the process model producing a trace of cableway entries. For instance, the movements of a skier on a particular ski day can be represented as an event trace (e.g., <start, 56, 56, 57, 58, 58, 58, 57, 56’, 56, 56, 56, 58, end>), where each event consists of the number of the cableway, the entry time and the identification number of the skier. Such event traces can be recorded and used to build a model that predicts the movements of skiers based on current movements and historic movement data.

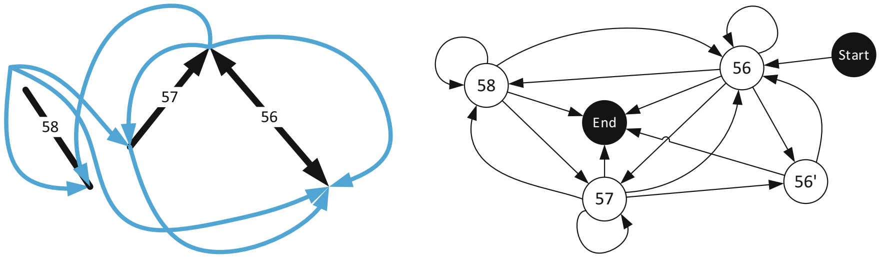

Fig. 2 Structured representation of the ski resort and corresponding process model

3 Predicting the Behaviour of Skiers

Let us assume that we observe the behaviour of skiers that currently move through the resort. Let us further assume that we would like to predict when and where cableways become crowded, based on the current behaviour of the skiers and our past experiences, that is, how skiers have moved through the resort in the past. Consider again the structured representation of the ski resort depicted as a process model (right hand side of Fig. 2). We could now take the data of past skier movements and project them onto the process model. A process model annotated with transition probabilities is the result. For instance, if we observed 100 skiers in the past who took cableway No. 58, and 10 of them moved to Cableway No. 56, 40 of them moved to Cableway No. 57, 25 of them took the same cableway again and the rest finished their ski day, then we would get the transition probabilities *P(58,56)* = *0.1*, *P(58,57)* = *0.4*, *P(58,58)* = *0.25*, and *P(58, End)* = *0.25*. If we now observed a skier who currently took Cableway No. 58, we could conclude that s/he will move to one of the next cableways with the calculated probabilities.

However, predicting the future behaviour of skiers solely based on their current position is not feasible. Experiences show that skiers mostly move through a ski resort in a typical way, rather than deciding where to go next each time they leave a cableway. For instance, observations made on ski excursions performed by the Sports Department of the University of Münster and during social events of the annual blocked seminar on Information Systems of the Chair of Information Systems and Information Management at the European Research Center for Information Systems and the Chair of Corporate Communication Systems at the University of Koblenz-Landau (a.k.a. the Ski Seminar) show that the typical movement behaviour of skiers results in characteristic routes through a ski resort. Consequently, the probability to which cableway a skier moves is not solely dependent on her/his current position but rather on the way s/he has already taken through the resort. Furthermore, assuming that the “true” structure of a ski resort can be read out of a ski map is problematic. For instance, in most ski resorts it is possible to move between cableways even if there is no piste between them. Consider again the “Oberstdorf-Kleinwalsertal” ski resort where it is possible to connect the officially separated resort sections of “Walmendingerhorn” and “Ifen” by taking an off-piste run (a.k.a. „The Hole“) from

Fig. 3 Considering off-piste routes. (taken from https://cdn.snowplaza.nl/content/WinterPanos/2500/12220.jpg, off-piste route added)

the upper terminus of Cableway No. 56 to the lower terminus of Ski Lift No. 68 (cf. dashed orange-black line in Fig. 3). As off-piste skiing becomes more and more popular and mainstream, considering such possibilities to move between cableways is inevitable to achieve a useful prediction accuracy.

Based on the above considerations, it makes more sense to base the prediction of future behaviour of skiers on a concept that already captures *the way a skier has already taken*. We call this concept a *state*. Each state captures one or more ways a skier could have taken to reach a certain position. From each state, a skier can move to a next state that again represents one or more already taken routes through the resort. Each state is connected to each other state via transitions. The transitions have different types that resemble the available cableways, so it is possible in principle to reach each state from each other one via any possible cableway. Each transition can be given a probability that expresses how likely it is *to move from a certain state X to a certain state Y* via *a certain cableway Z*. Indeed, there will be states from where it is impossible to reach another state via a specific cableway. Then the transition probability will be zero. To represent that each skier starts her/his ski day and ends it at some time, we add a *starting* state and an *ending* state, where we can reach any other state over any cableway from the starting state in principle, and the end state can be reached by any other state, however without any cableway. In our example, the transition probability from the starting state to another one will certainly only be higher than zero for the transition representing Cableway No. 56. All other transitions (i.e., Cableways No. 56', 57 and 58) are not reachable as they represent Cableways not accessible form the valley. Figure 4 shows an example of a corresponding representation. The example depicts a situation where we have four states plus the starting and ending states.

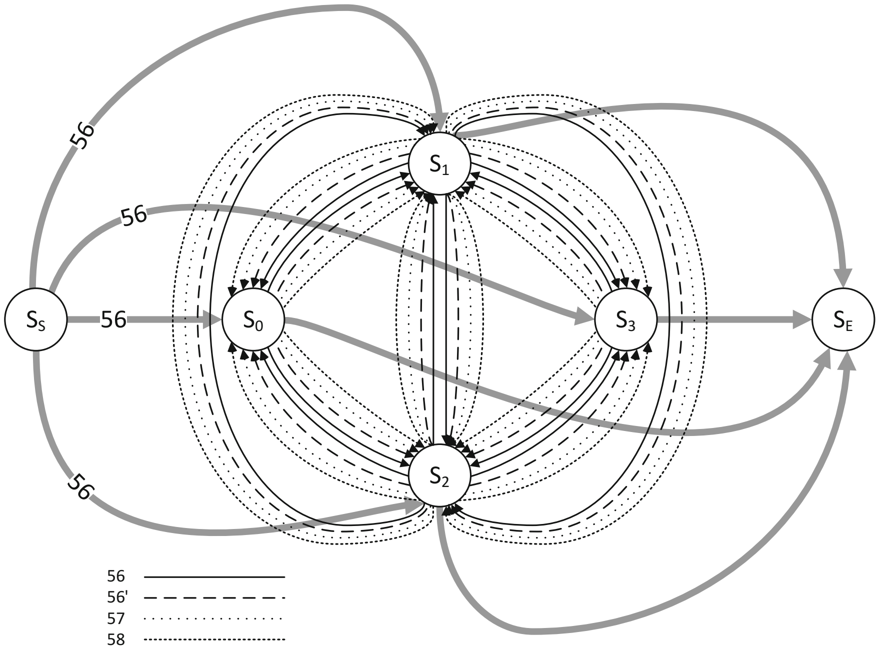

Fig. 4 State-based representation of skiers' behaviour in ski resorts

The example in the figure brings us to the next question: how many states do we need? The answer is: we don't know before we haven't analysed the historical movement data of the skiers. This is due to our definition of states: the states represent the ways the skiers have already taken. In our example, we know which ways are possible in the resort in principle, however we do not know the particular ways the skiers have already taken unless we analyse the historical data (i.e., the instances of the skiers' movement process). Thus we have to estimate the number of states using some kind of estimation procedure.

To select an appropriate estimation procedure, consider the structure of the state-based model shown in Fig. 4. It resembles a (slightly modified) *Probabilistic Finite Automaton* (PFA, see (Vidal, Thollard, & de la Higuera, 2005) for details), a well-known kind of model frequently used to solve grammatical inference problems. Correspondingly, there exists an algorithm that can calculate the transition probabilities of a PFA using an estimator similar to the maximum likelihood concept (Pinch, 2016). This algorithm is called the *Expectation Maximization* algorithm (EM, (Dempster, Laird, & Rubin, 1977)). The reason why we cannot simply use a pure maximum likelihood estimator is that the PFA contains hidden variables, in our case: the states. The states in our model are artefacts that cannot be observed, that is, they are neither part of the historical movement data of the skiers, nor are they part of the ski resort's structure. However, this is a problem the EM algorithm can cope with. The algorithm takes an "empty" PFA (i.e., a PFA that already contains the states and the transitions, but not the transition probabilities) as input, together with the ski resort's process log (the historical movement data of the skiers). Then, it passes the skiers' routes through the PFA multiple times and this way estimates the transition probabilities iteratively (please see (Breuker et al., 2016) for details).

The result is a PFA that is fitted to the log data and provides a suitable basis for the prediction of future movement behaviour of skiers. However, as already stated, the states are hidden variables and we do not know how many states there are. This is true for PFAs in general, and in our particular situation, this means that we do not know which routes that skiers have already taken lead to the same situation, i.e., in which the probabilities of taking the next cableways are the same (e.g., maybe the routes 56, 56, 56 and 56, 57, 58, 58 result in the same state). Actually, to find a PFA that fits the observed movement data best requires to try out initial (i.e., "empty") PFAs with different numbers of states and have them all fitted by the EM algorithm. After that, each fitted PFA can be tested against the log data using common evaluation criteria (e.g., cross entropy or the Akaike Information Criterion (AIC), see (Breuker et al., 2016)), and we can choose the PFA that fits the log data best for our further analyses.

Summarizing, to predict future movements of skiers in a ski resort, we have to walk through the following steps: (1) retrieve log data from the ski resort containing n types of events (= numbers of cableways), (2) create a number of empty PFAs with different amounts of states allowing each n different kinds of transitions between each pair of states in both directions, (3) fit the PFAs using the EM algorithm and (4) select the PFA representing the log best based on statistical evaluation criteria.

4 Predicting Skiers' Movements in Two Major Ski Resorts in the European Alps

Creating a predictive process analytics approach for skiers is fun, however it is even more fun to test it in the field (besides the scientific necessity to evaluate it). Correspondingly, we applied the approach using two large datasets provided by two major ski resorts situated in the European Alps (Brunk et al., 2018). The datasets were log files from one ski season (2015/2016), each for one ski resort. The logs contained all cableway usage data recorded within the ski season. This way, we could reproduce the complete routes of each skier that moved through the resorts in said season.

Both logs were processed in the described way. To test the prediction accuracy, we split the logs into parts: one part (further divided into learning and evaluation data) to train the PFAs with EM, and another one to simulate movements of skiers currently using the resort. The latter was necessary as it was not possible to observe the skiers while they were skiing (the experiments were conducted in summer).

As one purpose of the prediction is to estimate when on a specific ski day we have to expect congestion or near-idle situations at cableways (cf. Sect. 1), we have to predict the number of skiers that will likely arrive at a specific cableway within a

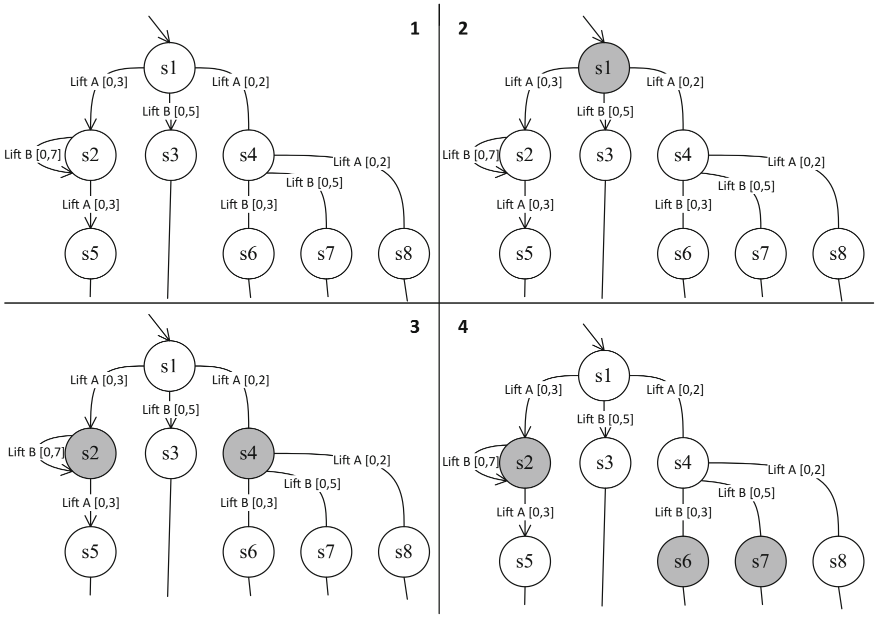

Fig. 5 Using the PFA to estimate where a skier will move to across multiple states. (taken from (Brunk et al. 2018))

given timeframe. The times when skiers arrived at a cableway are known from the log, so we can also estimate how long it takes to ride between using two cableways. Now assume we start the prediction at a specific daytime. Based on the current positions of the skiers and their route up to now, we can predict which cableway they will take next, after next and so on and with which probabilities. Including the transition times into the considerations makes it possible to estimate, for instance, how many skiers will most likely arrive at a given cableway within a given timeframe. Of course, we have to predict where every skier that currently moves through the resort will move until the timeframe of interest.

Figure 5 illustrates how we can follow a skier across her/his future way through the resort who is currently in a specific state. Assume that a skier has reached State 1 due to the recorded past movement data. The next possible cableways are Lift A and Lift B, where the skier can reach either State 2 or State 4 using Lift A or State 3 using Lift B. All transitions have probabilities, so we can calculate the probability that the skier takes one specific way. For instance, the probability that this particular skier takes the way < Lift A, Lift B > next is 0.3*0.7 + 0.2*0.3 + 0.2*0.5 = 0.37. So, for instance, if there are three skiers currently in state one, then we can assume that one of them will effectively take this route, and we also know how long the way will take in average. This way, we can calculate the number of skiers that will most probably arrive at any lift at any time.

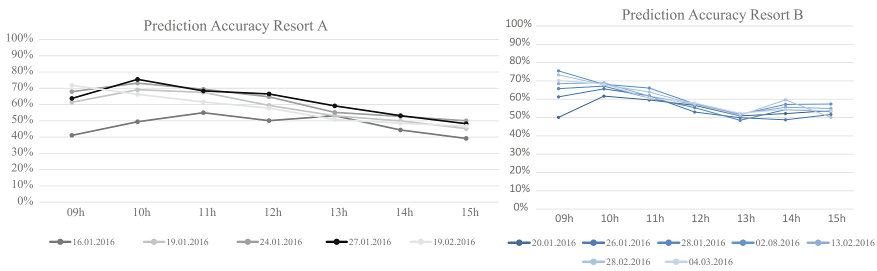

Fig. 6 Prediction accuracy. (taken from (Brunk et al. 2018))

Our experimental results are promising. Figure 6 shows the prediction accuracy when we asked the PFA "how many skiers will arrive at the cableways at 10 h?" for both resorts that were under investigation. The considered arrival timeframe was 09:45 h to 10:15, and the prediction time was 09:15, i.e., half an hour before the beginning of the timeframe. This is about the time we need to initiate interventions at a cableway to change its capacity. The accuracy values are averaged and depict the prediction accuracy for each cableway. In particular, the prediction accuracy for one cableway is calculated as follows:

$$Acc(C_i) = 1 - \frac{|npp_i - npl_i|}{npl_i}$$

where C_i is cableway i, npp_i is the number of persons that have been predicted to arrive at cableway i within a given timeframe and npl_i is the number of persons that have really arrived at cableway i in that timeframe according to the test log data. In the figures, we show the overall prediction accuracy, that is, averaged over all cableways. Depending on the particular ski day, we see prediction accuracies from about 40% to about 75% which means that we must consider deviations from 25% to 60% when we predict the number of persons that will likely arrive at a cableway. At a first glance, such accuracy seems only fair. However, to initiate capacity changes, we only need to consider person numbers that are very high or low. Hence the prediction accuracy is not yet sufficient to apply the approach productively, however can be considered sufficient to initiate field experiments as a next step.

5 Conclusion and Outlook

Leisure and sports are important for the well-being of people and society. Thus, industries supporting both are becoming more and more important and generate vast amounts of turnover. Besides the fact that such industries are interesting objects of investigation, supporting those with novel business process analytics approaches might even be indirectly beneficial for society in turn. With our predictive process analytics approach we have provided a corresponding contribution.

As experiments have shown, the prediction accuracy is not yet outstanding, however we have identified a number of reasons for this problem that can be addressed: If we specifically regard the domain of ski resorts, we see that the movement behaviour of skiers is not uniform, but it changes in different contexts. For instance, in the log data we found ski days where the behaviour of skiers was significantly deviating. A closer look revealed that some cableways were hardly visited on these days, especially those far away from the main entry points of the ski resort and those situated on greater altitude. We concluded that on such days the skiers had to cope with unpleasant weather conditions such as storm or heavy snowfall. Further deviations could be detected at different daytimes. Skiers that only ski in the morning prefer routes that are different from those that only ski in the afternoon. Furthermore, snow conditions influence the possible routes because, for example, in spring, some lower cableways have to close.

We concluded that not only the pure process information, i.e. the skiers' routes, is important to obtain a good prediction model, but also their context. Thus, the next step will be to extend the probabilistic model so it can also capture context variables and modify the learning algorithm correspondingly. Much context information can easily be obtained, such as weather and snow conditions and closed cableways. Further context information can be obtained from the resorts' operators, such as type of skier (e.g., adult, child, senior, ski instructor) or type of ski pass (e.g., daily ticket, weekly ticket, season ticket).

In the future, we also plan to conduct experiments not only with the operators of ski resorts, but also with the customers. Predictive apps might also help the skiers to better plan their routes so they do not have to wait at lift queues. Our annual ski seminar that we love so much and that hopefully will last until we both retire (better even longer!) will be a perfect experimental environment.

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“Strukturieren, Strukturieren, Strukturieren” in the Era of Robotic Process Automation

Peter Fettke and Peter Loos

> *“The computer and the new decision-making techniques associated with it are bringing changes to white-collar, executive, and professional work as momentous as those the introduction of machinery has brought to manual jobs”.*
>
> Simon (1960, p. xi)
>
> *“Es ist Aufgabe des Wirtschaftsinformatikers, in schnelllebiger Zeit sein Erkenntnisobjekt so zu* strukturieren*, dass die konzeptionellen Überlegungen längerzyklischer sind als technologische Entwicklungen, dennoch aber die Möglichkeit eröffnen, jene zu integrieren.”*
>
> Becker (2001, p. 14, original without page numbers)

1 The Dawn of the Second Machine Age

During the first machine age, the automation of labour and physical power was in focus, e.g. automation by power loom, steam machine, industry robots etc. This development began in the 18th century and is still ongoing. In the mid of the 20th century, the second machine age has started: During the second machine age, the automation of intellectual work is in focus. Of course, in many domains, machine performance is not nearly as good as human performance and there are manifold examples in which machines are neither equal nor even approximately comparative to humans. Today, however, machines can already outperform humans in various examples, e.g. they perform superhumanly in many board games (Bostrom, 2016). Aside from marketing-driven milestones, Table 1 lists examples for typical tasks that

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Table 1 Typical application areas of machine learning [based on Ng (2016)]

Input	Output	Application
Picture	Are there human faces?	Photo tagging
Loan application	Will they repay the loan?	Loan approvals
Ad plus user information	Will user click on ad?	Targeted online ads
Audio file	Transcript of audio file	Speech recognition
English sentence	German sentence	Language translation
Sensors from machines, engine etc.	Will it fail?	Preventive maintenance
Car camera and other sensors	Position of other cars	Self-driving cars

can nowadays be automated by machine learning. These examples show the wide spectrum of intellectual work which can be automated by machines.

The evaluation and comparison of human and machine performance is interesting, but often challenging. In many scenarios, such a comparison is not that simple, e.g. in many board games like chess or Go, it is easy to identify the superior performance if one player beats his opponent. However, evaluating the performance of a machine translator is not that easy, e.g. if an English text is translated into German, it is not only relevant how fast the translator works, but the translation's quality is also of major importance. In addition, in machine translation and other domains, the evaluation of a machine performance is more difficult, since machines and humans can collaborate. For example, the machine can assist the human worker by pointing to grammatical issues of the hand-crafted translation or recommending a raw translation. These features make the evaluation of the machine performance more complicated.

This brings us to the area of Robotic Process Automation (RPA). Similar to the substitution of physical work in manufacturing processes with physical robots (blue-collar automation), RPA tries to substitute intellectual work in office and administration processes with software robots (white-collar automation). RPA is strongly related to business process management; however, tools for RPA originated from dedicated stand-alone software. Today, RPA functionalities are also integrated into elaborated process management suites.

Although one might argue that RPA is "old wine in new bottles" (Friedman, 1991), the recently discussed RPA approach has some characteristics that should be emphasized:

(1) RPA approaches do not aim to develop a completely new software system (greenfield approach). In contrast, they assume that some IT systems are already developed and running. These legacy systems should not be replaced by new software, instead it should be extended by RPA (brownfield approach).
(2) Compared to other ideas, RPA is used for the idea of developing software programs "that operate on the user interface of other computer systems in the way a human would do" (Kirchmer, 2017; van der Aalst, Bichler, & Heinzl, 2018). Hence, RPA software typically uses a traditional user interface for humans, e.g. graphical interface or command line interface.

(3) RPA uses techniques from the field of artificial intelligence (AI), particularly from machine learning, e.g. learning from and imitating user behaviour. Such an approach can be understood as the automation of automation: robots are not explicitly programmed by an algorithm, instead the development of the algorithm is automated by machine learning.

In the following, we will discuss RPA in the context of Jörg's leitmotif "Strukturieren, Strukturieren, Strukturieren". Against that background, we address two questions:

(1) Structuring *of* RPA: How can the concept of RPA be structured? By introducing a structure of RPA, we like to add to the understanding of RPA in general.
(2) Structuring *by* RPA: Although not explicitly stated, structuring in the context of Business Informatics is assumed to be done by humans. However, we illustrate that structuring can also be done by machines. This idea is not science fiction anymore, which is demonstrated by several well-known examples.

The remainder of this article will discuss question 1 in Sect. 2. Section 3 will address question 2; Sect. 4 concludes the article.

2 Structuring of Robotic Process Automation

A business application supports people's work in a company, e.g. order management, production planning, or financial bookkeeping. Although, nowadays, many business activities are automated, there are no doubts that business applications do not automate all business activities done in a company. In other words: there is plenty of work done by humans, particularly at the interfaces between humans and machines and between different software applications. The main idea of RPA is substituting the work done by humans with robots.

The high-level structure of a robot can be viewed as an intelligent machine which has three typical components: Robots can grasp their environment by *sensors,* which generate data about the environment of the robot, and manipulate their environment by *actuators,* which allow the robot to change or move in the environment. The *intelligence centre* of a robot processes the input data of the sensors and controls the actuators.

Figure 1 depicts the structure of a robot with more details:

- Input components: The input interface consists of sensors in a narrow sense and a general alpha-numerical interface. Typical sensors in a narrow sense provide optical, acoustical, and tactile information about the environment. These input data are pre-processed, before syntactical and plausibility checks are executed. Additionally, often some kind of data transformation, aggregation, or fusion is done.
- Intelligence centre: The intelligence centre determines the intelligence level of a robot. Sophisticated robots must be at least composed of the following components: (a) concepts and methods for knowledge representation, (b) concepts and methods

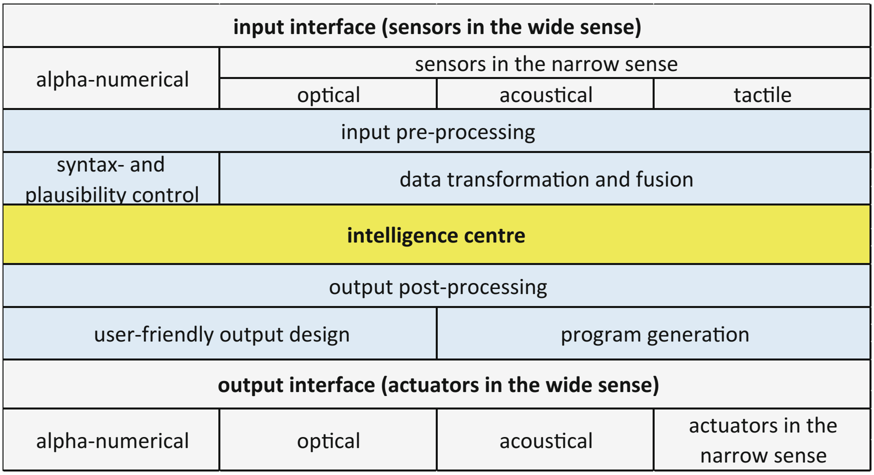


Fig. 1 Schematic structure of a robot [based on von Zelewski (1986, p. 165)]

for problem solving, and (c) concepts and methods for learning and reasoning based on new data about the environment. There exist many different techniques for realizing these components.

- Output components: The output of the intelligence centre is typically post-processed. Sometimes, it is necessary to generate new programs, which are used for programming other robots. Also, it might be necessary that the output is transformed to a user-friendly design. The output interface in the wide sense consists of alpha-numerical, optical, or acoustical devices and actuators in the narrow sense, e.g. hydromantic, electric, or pneumatic components for moving the robot or interacting with its environment.

As said before, RPA assumes that all components mentioned above are realized by software. Hence, robots in the sense of RPA are not regarded to be physical robots. Typical examples are:

- Data integration tasks: Data about important domain objects, e.g. employers, is often stored in different databases. The task of the robot is to maintain consistency between the employer data, e.g. if the address of an employer is changed in one database, the robot changes the data in other databases automatically. From a greenfield perspective, it is clear that applications should use an integrated database. But from the perspective of the brownfield approach to RPA, a real application landscape often consists of several databases, which must be updated simultaneously.
- Process integration tasks: The next task of a running case should be started automatically after some work is done, e.g. after the customer order is entered, the processing of this order done by another software system can be automatically called.

- Data transformation task: A customer order is received via a web form and must be transferred to an ERP system. For fulfilling this task, the data must be checked for plausibility, transformed to a new data format, and be transferred to the order management component of the ERP system.

It is obvious that the given examples are relatively simple compared to the rich conceptual background of intelligent machines introduced before. Also, the functions of RPA software available at the software market is often limited to such simple RPA scenarios, e.g.:

- The RPA solutions have only some simple interfaces for reading data, e.g. some form of screen scraping functionalities.
- The RPA software only allows some simple form of data processing, e.g. the data is just transferred from one application to another.
- The data output is very simple, e.g. data is just inserted into a database or a mouse move and click is emulated.

Nevertheless, RPA is still interesting from a practical point of view:

- There are many real-world processes that consist of such simple, but massively occurring tasks. In other words, there is a demand for such solutions.
- The use of RPA may be simpler and more cost-efficient compared to other solutions because the already implemented software system will be left untouched. It is unclear whether this solution will have drawbacks in the long-run, e.g., cost for maintenance and coordination of RPA and legacy systems.
- Although, at first glance, these tasks might be easy to automate, there are often several technical hurdles that must be solved, e.g. consistency checks or exception/error handling, which are often easy for humans but difficult for machines. Additionally, problems may be caused by layout changes of the user interface that are just marginal for humans but significant for machines.

We like to point out that the idea of RPA is not conceptually limited to these rather simple RPA tasks. In fact, such a limitation looks more like a technical restriction of known RPA software. In contrast to that, there are many more sophisticated applications possible, e.g.:

- Understanding and processing of business documents: The example "data transformation" given before can be made more complex. For example, the order may not be received by a web form but via a paper document. For processing this document, it must be first scanned and classified as a customer order. After that, the necessary data must be extracted, e.g. the name of the customer must be identified, the ordered article, the quantity etc. This data must be checked for plausibility and be transferred to the order management component of the ERP system.
- Personal assistance: For example, making a reservation at a hairdresser or a restaurant is often done by a phone call. Such dialogues can be automated by robots with natural-language interfaces.

Table 2 Simple versus cognitive Robotic Process Automation [based on Scheer (2017)]

	Simple RPA	Cognitive RPA
Type of tasks automated	Routine tasks	Non-routine tasks
Capability of robot	Follow instructions	Come to conclusions
Application focus	Broader	Narrower
Market offerings	Maturing	Emerging
Implementation and ongoing costs	Lower	Higher
Implementation timeframe	Weeks	Months

- Automating decision-making: Simple decisions, e.g. approval of a standard travel request or simple purchase order, can be automated by using historical data about prior decision-behaviour.
- Making predictions about the future: Based on known behaviour in past situations, predictions about the future can be made.

Broadening the scope of RPA is already proposed by others, who distinguish between simple RPA and cognitive RPA, as compared in Table 2. Of course, it can be argued, that cognitive RPA requires completely different technologies than those that are provided by known RPA software. However, as said before, from a conceptual point of view, the idea of using software robots smoothly fits into the idea of substituting intellectual work done by humans with robots.

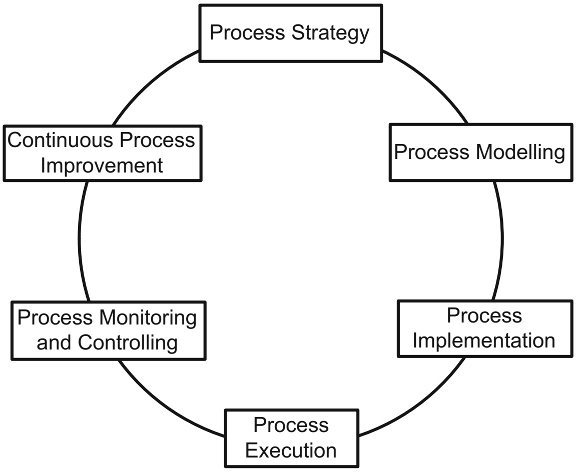
It is obvious that there is a continuous spectrum of simple and complex tasks. By introducing the general idea of a robot, the degree of this simplicity can be defined more precisely by using the different dimensions of a robot mentioned before: simple RPA operates on simple user interfaces, has no sophisticated output interface, and their intelligence centre is just capable of simple data manipulations. On the other hand, cognitive RPA incorporates more powerful components which might even include physical humanoid robots. Against this background, simple and cognitive RPA are the two poles of a wide continuum of possible RPA software solutions. By introducing the idea of cognitive RPA, we now turn to the question how RPA can be used for structuring processes.

3 Structuring by Robotic Process Automation

Typically, structuring implicates that humans are the actors who do the structuring work. However, in the second machine age, the structuring is not only done by humans but also by machines.

One of the most obvious examples of structuring processes done by machines is the idea nowadays known under the term “process mining” (van der Aalst, 2012). Process mining originates from the idea of using data mining on data that is generated while executing business applications (Scheer, 2000). This data can be analysed and

Fig. 2 Structure of the process management lifecycle based on Houy et al. (2010)



used to reason about the status of business applications. Process discovery, the most prominent form of process mining, uses data to automatically construct as-is process models.

This idea can be understood as one particular form of RPA: Without RPA, as-is processes are typically developed by asking process and domain experts questions, conducting workshops with relevant people, or by observing the environment. It is evident that defining a process model implies a lot of structuring work, e.g. relevant business activities and events must be identified and named, the order of these activities must be defined, and the business logic must be specified. With process mining, a lot of this work can be conducted by machines: typically, such an automation task assumes a structured workflow log and induces the relevant structure of activities. Of course, this is not the typical application of RPA. However, it is evident that the intellectual work of structuring a process is not done by humans but by machines and, in this sense, this is a typical example of RPA or the dawn of the second machine age in the domain of structuring processes.

It can be debated whether the process models obtained by process mining are equal to hand-crafted models regarding their quality. Such comparison strongly depends on the evaluation criteria. This discussion is similar to the quality of machine-translated texts already mentioned in the introduction. On the one hand, it is clear that process mining can only be applied when appropriate log data is available. On the other hand, if such data is available, the manual analysis of this data is tedious and not very effective since machines typically have much more reasoning power.

In the following, we point to more applications of RPA for structuring process. Our illustration is based on a well-established structure of the process management life-cycle depicted in Fig. 2.

- Process Strategy: Strategic actions and decisions are one paradigmatic example of innovative, non-routine activities. Nevertheless, there are already some examples how machines can support these activities. One example is the business model advisor, which gives advice with respect to relevant technologies, sales channels etc. (Di Valentin, Emrich, Werth, & Loos, 2013). Another example is the development of business process blueprints from a configurable business model (Fettke & Loos, 2004, 2007).

- Process Modelling: Process mining was already discussed in detail before. Furthermore, there are numerous more examples. Several works develop approaches for automatically constructing process models from text documents (Riefer, Ternis, & Thaler, 2016). Drawing process models on flipcharts by hand is typically done during process elicitation. There are solutions to automatically transfer these sketches to process modelling tools (Zapp, Fettke, & Loos, 2017). Furthermore, there is a long research history on modelling recommender systems (Koschmider, Hornung, & Oberweis, 2011). Additionally, the inductive development of reference models or the comparison of enterprise and reference models are interesting approaches (Rehse, Fettke, & Loos, 2015).
- Process Implementation: In academia, there is a long history of computational models of human software engineering activities, e.g. the international journal "Automated Software Engineering" was launched in 1994. Particularly in the context of process automation, the idea of generating code from process models is well researched, e.g. in the context of model-driven architecture (Fettke & Loos, 2003; Krumeich, Zapp, Mayer, Werth, & Loos, 2016).
- Process Execution: During process execution, the execution of necessary process steps is guided by so-called process guidance systems (Morana, Schacht, & Maedche, 2016). Another application area is automated business process planning that is inspired by the artificial intelligence domain of automated planning. Process planning has strong interdependencies with modelling, but is particularly useful in the context of process execution, e.g. the definition of process states, process goals, and available sets of business activities can dynamically control the execution of a process (Heinrich, Klier, & Zimmermann, 2015).
- Process Monitoring and Controlling: Typically process monitoring and controlling use process data of the past to gain information on the process status. However, this historical data on process executions can be used to predict how running process instances will evolve. By doing this, the process outcome, next process steps, or process indicators such as time, cost, quality can be estimated (Evermann, Rehse, & Fettke, 2017). Another application area is process compliance checking which allows the automatic comparison of as-is and to-be processes (van der Aalst, 2012).
- Continuous Process Improvement: Process enhancement is a well-known further application area of process mining, which automatically gives advice on how companies can improve their process organization (van der Aalst, 2012). A more general approach is the idea of so-called intelligent maturity models, which is based on the classical idea of paper-based maturity models and allows to give advice for gaining a better process maturity (Krivograd, Fettke, & Loos, 2014).

These examples show that there are already numerous ideas how robots can be used for structuring processes.

4 Conclusions

More than 50 years after Simon's prediction quoted at the beginning of this article, it is still not fully understood how computers will influence intellectual work. In fact, after an AI winter in the mid-1980s, we are nowadays facing a boom of artificial intelligence; some already say that "AI is the new organic!".

Nevertheless, the tremendous technological progress of machine performance in the last years opens interesting possibilities for RPA. Compared with typical RPA use cases, there are many more examples for more sophisticated applications. It is time to embrace the changes and to broaden the understanding of RPA. Structuring processes is not the domain of human experts anymore because intelligent machines can support this task significantly. This development has several implications: RPA supports the automation in general and provides new possibilities for human assistance. In the long run, it fosters the transformation of well-established business models and provides the basis for new business models. In other words, it might always be open how computers will change business applications and how to find stable and adequate structures that can be used as reference models for designing business applications.

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Structuring Business Process Management

Jan Mendling, Marlon Dumas, Marcello La Rosa and Hajo A. Reijers

1 What Is Business Process Management?

Processes are everywhere (Dumas, La Rosa, Mendling, & Reijers, 2018). Every organization, no matter if it is a governmental agency, a non-profit organization, or an enterprise, has to manage a number of processes. A typical example of business process is the order-to-cash process. This process is executed by a vendor. It starts when a customer submits an order to purchase a product or service, includes activities for checking the order, delivering the product or service, and for handing the invoice, and ends when the customer has made the corresponding payment. Another common example is the quote-to-order process, which precedes the order-to-cash process. It starts when a vendor receives a request for quote for the purchase of a product or service, includes activities for preparing the quote, and ends when the customer places a purchase order based on this quote.

These examples illustrate that a business process includes a number of events and activities. Events happen instantaneously during the execution of a process, such as the arrival of an order from a customer. Activities have durations, require resources to be performed, and we can look at them on different levels of granularity. When

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an activity is rather simple and can be seen as one single unit of work, we also call it a task. The term task refers to a fine-grained unit of work performed by a single process participant, while the term activity is used to refer to both fine-grained or coarse-grained units of work. Processes also involve actors. These actors are human agents, whole organizations, or software systems that act on behalf of humans or organizations. Processes manipulate different objects. These objects can be physical objects like equipment, materials, products, or paper documents, or informational objects like electronic invoices or other types of electronic records. Finally, the execution of a process is expected to lead to a desired outcome. Ideally, an outcome should deliver value to the actors involved in the process. In some cases, this value is not achieved or is only partially achieved. This represents a negative outcome, as opposed to a positive outcome that delivers value to the actors involved. Those actors that consume the outcomes of a process are referred to as customers. Based on these explanations, we can define a business process as follows.

> *A business process is as a collection of inter-related events, activities, and decision points that involve a number of actors and objects, which collectively lead to an outcome that is of value to at least one customer* (Dumas et al., 2018).

Since processes are at the heart of every organization, there is a need to manage them systematically. This is the objective of Business Process Management (BPM). Accordingly, we define BPM as follows.

> *BPM is a body of methods, techniques, and tools to identify, discover, analyse, redesign, execute, and monitor business processes in order to optimize their performance* (Dumas et al., 2018).

2 Why Is Business Process Management Relevant?

Business Process Management is essential for any organization that operates based on division of labour, which creates handoffs, context switches, responsibility and knowledge gaps, and other sources of inefficiencies and defects (or *wastes* as identified in the Toyota production system). This mode of operation has strongly evolved during the First Industrial Revolution. A witness of these developments was Adam Smith (1723–1790), Scottish economist and philosopher, who is best known for his book "An inquiry into the nature and causes of the wealth of nations". Among others, this book discusses the division of labour that is used by a manufacturing company for producing pins. He emphasizes that the design of the process (what he calls division of labour combination) contributes the most to good performance. He explains the process of pin-making to illustrate his point (Smith, 1776).

> One man draws out the wire, another straights it, a third cuts it, a fourth points it, a fifth grinds it at the top for receiving the head; to make the head requires two or three distinct operations; to put it on, is a peculiar business, to whiten the pins is another; it is even a trade by itself to put them into the paper; and the important business of making a pin is, in this manner, divided into about eighteen distinct operations, which, in some manufactories, are all performed

> by distinct hands, though in others the same man will sometimes perform two or three of them. I have seen a small manufactory of this kind where ten men only were employed, and where some of them consequently performed two or three distinct operations. [. . .] Those ten persons, therefore, could make among them upwards of forty-eight thousand pins in a day. Each person, therefore, making a tenth part of forty-eight thousand pins, might be considered as making four thousand eight hundred pins in a day. But if they had all wrought separately and independently, and without any of them having been educated to this peculiar business, they certainly could not each of them have made twenty, perhaps not one pin in a day; that is, certainly, not the two hundred and fortieth, perhaps not the four thousand eight hundredth part of what they are at present capable of performing, in consequence of a proper division and combination of their different operations.

In the second half of the nineteenth century towards the First World War, many of such small manufacturers had grown to become major factories. A name that is inseparably linked with these developments is that of Frederick W. Taylor (1856–1915), who proposed a set of principles known as scientific management. A key element in Taylor's approach is an extreme form of labour division and work analysis (Taylor, 1914). A side effect of the ideas of Taylor and his contemporaries was the emergence of an altogether new class of professionals—the class of managers who oversee the productivity of the workers. Moreover, the units and their managers were structured hierarchically. For example, groups started being placed under departments, departments under business units, etc. These units were organized as functional units, which are still familiar to us today when we think about organizations: purchasing, sales, warehousing, finance, marketing, human resource management, etc. The functional organization that emerged from the mindset of the Second Industrial Revolution dominated the corporate landscape for the greatest part of the nineteenth and twentieth centuries.

In the 1980s, new IT capabilities gave rise to a new way of organizing work around processes. These ideas crystalized in what Champy and Hammer (1993) call Business Process Reengineering (BPR), i.e. "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service, and speed." Its view on how to look at organizational performance was formulated by Davenport and Short (1990). Their article urged managers to look at entire, end-to-end processes when trying to improve the operations of their business, instead of looking at one particular task or business function. They present support of various cases where this particular approach proved to be successful and where information technology played an important role for the redesign of existing business processes.

Today, the potential of IT to improve business processes is well established. New information technology can improve business processes in different ways. Mooney et al. (1996) distinguish automational effects, informational effects, and transformational effects. Automational effects materialize when a new technology is used to automate tasks that have been previously done manually in a business process. Informational effects materialize from better tracking, monitoring, and analytical insights. Transformational effects relate to the changes in the mechanisms of coordination, including disintermediation, outsourcing or offshoring. The distinction of these different types of effects helps to assess the improvement potential of emerging technologies such as machine learning, robotic process automation or blockchains (Mendling et al., 2018; Mendling, Decker, Hull, Reijers, & Weber, 2018). In this way, BPM is a key methodology to reap benefits from the emergence of new technologies.

3 How to Structure Business Process Management?

The textbook edited by Becker et al. (2003) plays an important role in structuring the field of BPM. Together with the works by Scheer (1994; Scheer & Nüttgens, 2000), it was the first work that systematically integrated BPM and business process modelling. Today, business process models play a key role in facilitating BPM-related management activities. These business process models are often modelled using BPMN, a standard process modelling language with a precise semantics (Dijkman, Dumas, & Ouyang, 2008). A prominent approach to structure the BPM discipline is via *BPM lifecycle models*. Here, we refer to the BPM lifecycle with six phases described by Dumas et al. (2018) and illustrated in Fig. 1.

Process identification is the phase, in which a business problem is posed. Processes relevant to the problem are identified, delimited, and inter-related. The outcome of process identification is a new or updated process architecture, which provides an overall picture of the processes in an organization and their relationships. This

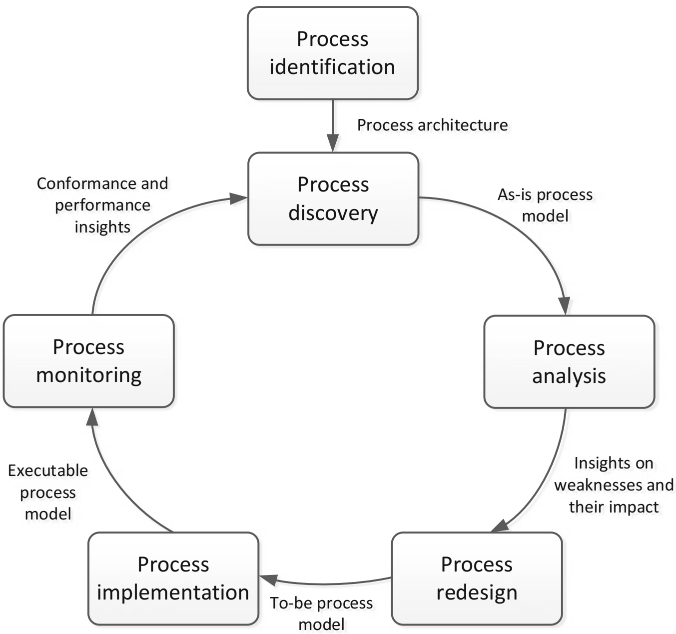

Fig. 1 BPM lifecycle (Dumas et al., 2018)

architecture is then used to select which process to manage through the remaining phases of the lifecycle. Typically, process identification is done in parallel with performance measure identification.

Process discovery (also called as-is process modelling) is concerned with the documentation of the current state of each of the relevant processes, typically in the form of one or several as-is process models.

During process analysis, issues associated with the as-is process are identified, documented, and whenever possible quantified using performance measures. The output of this phase is a structured collection of issues. These issues are prioritized based on their impact and the estimated effort to resolve them.

Process redesign (also called process improvement) has the goal to identify changes to the process that would help to address the issues identified in the previous phase and allow the organization to meet its performance objectives. To this end, change measures are analysed and compared using performance measures. Often, process redesign and process analysis go hand-in-hand: As new change options are proposed, they are analysed using process analysis techniques. Eventually, the most promising change options are retained and combined into a redesigned process. The output is a to-be process model.

During process implementation, the changes required to move from the as-is process to the to-be process are prepared and performed. Process implementation covers two aspects: organizational change management and automation. Organizational change management refers to the set of activities required to change the way of working of all participants involved in the process. Process automation refers to the development and deployment of IT systems that support the to-be process.

Process monitoring is an ongoing task. Once the redesigned process is running, relevant data are collected and analysed to determine how well the process performs. Bottlenecks, recurrent errors, or deviations with respect to the intended behaviour are identified and corrective actions are taken. New issues may arise, in the same or in other processes, which requires the cycle to be repeated.

4 How to Structure the Context of Business Process Management?

BPM is not only about methods and IT tools, such as those that support the BPM lifecycle described above. In order to systematically develop BPM within an organisation, we have to consider six critical success factors: (i) strategic alignment, (ii) governance, (iii) methods, (iv) IT, (v) people, and (vi) culture. These factors have been specified in the maturity model of Rosemann and de Bruin (2005). Figure 2 illustrates these six factors and the aspects (called calability areas) to which they refer. The following description builds on the discussion in (Dumas et al., 2018).

Strategic alignment measures the role and impact of business strategy on BPM, as well as the role and impact of BPM on business strategy. It is concerned with

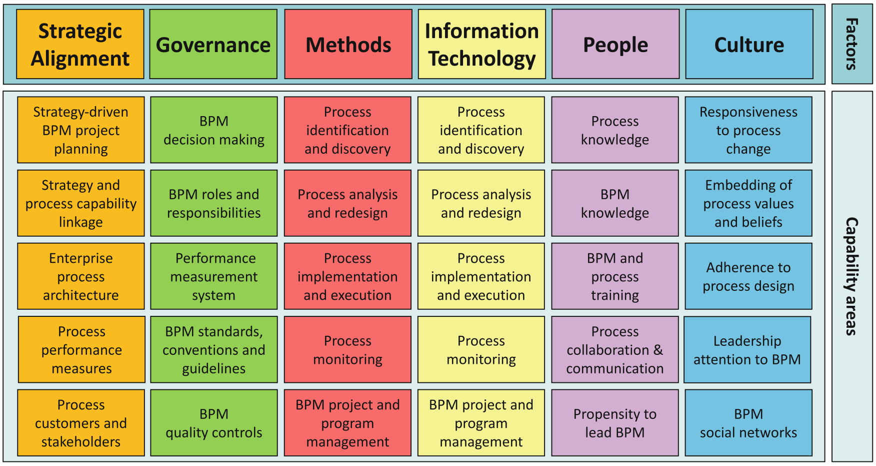

Fig. 2 The BPM maturity model (Dumas et al., 2018) Adapted from Rosemann and de Bruin (2005)

the following topics. Strategy-driven BPM project planning has to decide which methods and tools are used in each phase of the BPM lifecycle. Strategy and process capability linkage needs to clarify how the business strategy influences the business processes and vice versa. Enterprise process architecture supports various analysis tasks. Process performance measures have to be defined that measure to which extent process outcomes are achieved. Finally, also the views of process customers and stakeholders have to be constantly monitored.

BPM governance is concerned with the definition of appropriate and transparent accountability in terms of roles and responsibilities for different levels of BPM. Furthermore, it is tasked with the design of decision-making and reward processes to guide process-related actions. It is also related to BPM roles and responsibilities. These have to be clearly defined. Governance needs a process performance measurement system to build upon. Also, BPM standards, conventions, and guidelines have to be established and corresponding quality controls.

The BPM methods and IT capabilities are largely covered by the BPM lifecycle. As can be seen from Fig. 2, they are often structured using the BPM lifecycle. Additionally, project and program management capabilities are added.

The people factor is about the different individuals and groups that are directly involved in carrying out the various BPM projects but, just as importantly, also about those that are affected by such projects. What needs to be understood is what knowledge people have access to and how the interaction between them takes place to realize an improvement of business process performance.

Finally, the measures in culture quantify the extent to which corporate culture is supportive of BPM. Corporate culture, in essence, refers to the values and beliefs of the persons working in the organization and, more specifically, how far these stimulate a process-thinking mindset and a positive attitude towards process redesign. Culture covers, among others, the responsiveness to process change in the organization, the embedding of process values and beliefs, the adherence to process design, leadership attention to BPM, and BPM social networks.

A prominent case of adopting a holistic approach to BPM is that of the software vendor SAP (Reisert, Zelt, & Wacker, 2018). Other cases of industrial uptake are included in a recent book by Mendling and vom Brocke (2018).

5 Business Process Management in the Future

We expect that BPM will continue to be a crucial tool for any organization that is trying to improve its operations. New technologies will emerge providing new opportunities to obtain automational effects, informational effects, and transformational effects. In their study on how digitisation will change jobs and work profiles, Frey and Osborne (2017) conclude their analysis as follows: "The extent of computerisation in the twenty-first century will thus partly depend on innovative approaches to task restructuring." Restructuring tasks, and more broadly operations, is exactly what BPM is concerned with. Beyond that, BPM is developing a stronger strategical perspective, which has the potential to support digital strategies of customer engagement and digitized solutions (Sebastian et al., 2017). On the other hand, BPM is evolving towards "finer-grained structure" via Robotic Process Automation, which seeks to improve efficiency and quality from the automation of high-volume repetitive routines (Lacity & Willcocks, 2015). All this will require further efforts towards "structuring, structuring, structuring" in the spirit of Jörg Becker.

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The Development Lines of Process Automation

August-Wilhelm Scheer

1 Business Process Management (BPM)—from Process Model to Application System

A BPM project (see Fig. 1) begins with the selection of the business processes that are to be reorganised from the company's digitalisation strategy. In a (short) as-is analysis they are illustrated graphically in an as-is process model and their weak points analysed. Subsequently, the new processes are defined and likewise documented graphically. To carry out this modelling, methods such as EPC are used where the primary project emphasis is business management, and methods such as BPMN, BPEL or UML are used in projects that are more geared towards the technical implementation.

The modelling methods are semiformal and are supported by empirical principles (Becker, Rosemann, & Schütte, 1995) and by formal, methodological rules (Van der Aalst, 2016). The models are created using BPM tools, e.g. in accordance with the ARIS concept developed by the author of this article, and administered in a process model bank.

In the next step, the required software is identified on the basis of the to-be process model. This can be done by customising the standard software of an ERP system or by developing or creating a customised solution using a workflow-oriented business process management system (BPMS). Standard software has become increasingly aligned with business processes over the last few years and has opened up to the idea of model-based customising. Workflow-oriented systems are already being developed in alignment with processes from the start. In both these cases an executable solution for the redesigned business processes is then available and the narrow BPM approach "from problem identification to ready-to-use application system" is completed.

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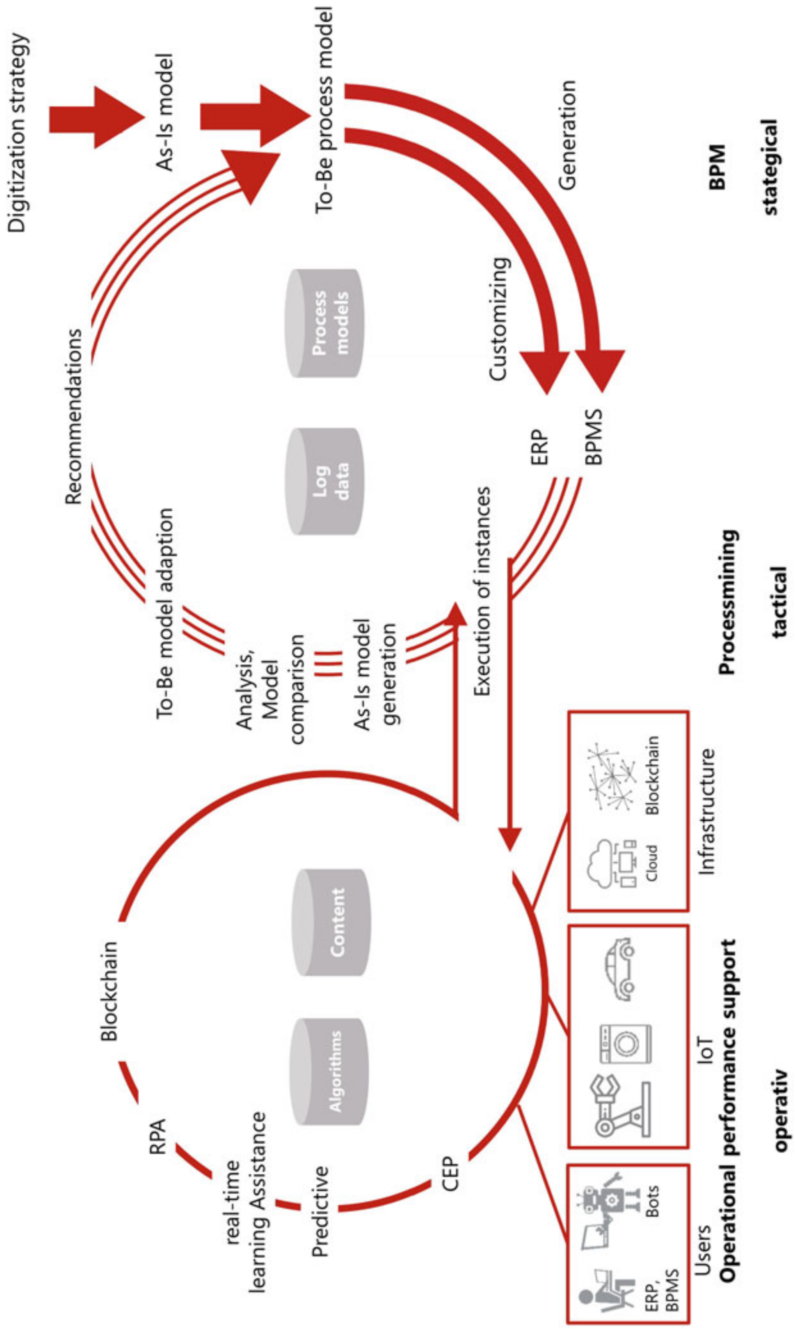

Fig. 1 Cycles of business process automation

But only the subsequent implementation of the processes can reveal whether the expected benefits of any given BPM project is realised.

2 Process Mining

In theory and practice, the focus of interest is increasingly moving from producing a general description of a typical or optimal process structure for the traditional BPM approach to the execution of the individual business processes, known as process instances. This is indicated graphically in Fig. 1 by the change from the thick lines to three thinner lines.

In theory, the instances should follow the business process model or the software configured using it. However, that is only the case when no unforeseen deviations arise. In such cases, all processes are predefined and run automatically. But, of course, that is only the case in theory. In reality, changes occur in the envisaged allocations of organisational units, such as persons and machines, to specific functions. Mistakes arise, rectifications become necessary, and technical disruptions crop up. People then step in and make ad-hoc changes to processes, deviating from the to-be model.

Such deviations are the reason behind the interest in the implementation of real process instances, and they open up the field of process mining. Even though the first developments date back to the early 1990s, it is only in the last few years that this has become a core focus of theory and practice.

The individual process operations leave data traces from the execution systems in the form of event information in what's known as log files, which are then available for process mining analysis.

This analysis attempts to identify and process unexpected patterns and correlations from the data traces from the process operations.

In the first step the traces from the business processes are captured in a log file as they are carried out, and the performance observed (process monitoring). The key events captured in the log file are the beginning and end of a function execution (in IT processes this corresponds, for example, to the start and end of a transaction in an ERP system), but organisational data such as the employees involved can also be gathered. This data can be assigned to the existing to-be model. Interesting lines of analysis can then include the identification of the paths used most frequently within the process model and the identification of functions that need to be analysed in greater detail, e.g. as marked by the frequency of processing and by a broad spread of processing times.

If the to-be model is outdated, we lack a strong basis for the process analysis. For that reason, algorithms have been developed to automatically generate an as-is model from the data in the log file in a second step of the process mining (Van der Aalst, 2016). The automatic generation of an as-is model on the basis of the log file is particularly useful where there is no to-be model. This saves time-consuming manual modelling work.

If a to-be model and a generated as-is model are available, both models can be compared to each other in the third step. The discrepancies are analysed in order to adapt the to-be model to the reality (step four).

In the fifth step, all the analysis results are evaluated and used to provide recommendations for action for the organisational improvement of process management. Process mining can provide information on whether compliance rules are broken in the course of process execution, on the places where capacity bottlenecks develop, on whether there are deviations from the expected capacity allocations, and on patterns in process times and quality, and so on. Typical measures introduced to improve processes include training employees to avoid processing errors, stricter adherence to organisational rules and the adjustment of software to new requirements.

In order to automatically draw conclusions for the improvement of processes it is necessary to use complex AI methods, and machine learning in particular.

The strategic BPM approach must be started over if substantial changes occur in the process environment that give rise to a fundamental review of the process structure, or should new application software be introduced.

Process mining is currently the subject of intensive scientific research. The aim of this work is to automate process mining almost completely by developing complex algorithms. However, forgoing the input of human expertise sometimes leads to excessive complexity in the algorithms for tasks an experienced process manager can carry out easily, intuitively and more effectively. In such cases, a combination of automation and human expertise makes more sense.

Under the direction of the author of this article, in the early 1990s the company then known as IDS Scheer AG developed the ARIS PPM (Process Performance Manager) system as one of the first process mining software products. It has been used successfully around the world since.

By now there is an ever-expanding range of commercial software systems available for process mining. Producers of application software also offer process mining functions in order to support their software platforms or application software, e.g. Scheer GmbH (Scheer 2018) with its Scheer PAS software suite.

3 Operational Performance Support

Process mining analyses elapsed process instances at certain time intervals. The process instances themselves can no longer be changed—the insights gained can only be applied to make organisational improvements to future processes. That is why the operational performance support concept pursues the goal of influencing running process instances during the process time.

To illustrate this, the implementation cycle on the left side has been added to the model of the process cycle shown in Fig. 1.

Because the individual process sequence is being observed, it is denoted with a single line. The circle then leads into process mining. The process sequence is gathered with the processes of the observation period and periodically evaluated (post-mortem).

The functions of the implementation cycle include the planning and management of the instance, the event-driven response to certain status changes of the process, prospective analyses and action recommendations to avoid unplanned effects, as well as online learning aids for users in problem situations.

In the field of operations research, numerous optimisation processes have been developed for industrial production control that can also be applied to general business processes, and that in a real-time environment. Based on certain optimisation criteria—such as the minimisation of cycle times or the maximisation of capacity utilisation—the individual work steps of a process instance are then organised in a specific order and assigned to the processing positions, for which the process models form the data foundation, just as the work plans do in manufacturing. To optimise the process, control room concepts or manufacturing execution systems (MES) can be adopted from the production plant.

Thanks to concepts such as IoT, it is possible to support monitoring and control functions on a granular level in manufacturing and logistics processes, smart city, smart car and smart home by using sensors and actuators. Sensors supply events about conditions and changes in condition from the objects (devices) that carry out the process. These can then be evaluated in real-time by a complex event processing (CEP) system, and used as a basis for immediate decisions (real-time decision support). The processes are viewed on a deeper and more technical level of detail.

In more business-oriented process management, the focus is on the control flow of the business process, i.e. the sequence of the functions to be carried out with logical connectors. With CEP the focus is on the technical objects and the definition of interesting events, their summarisation into more complex patterns, and triggering real-time actions. Some examples of data for a CEP logistics application include capturing the goods in transit with RFID, measurement data from sensors for the start of the vehicle, temperature measurements in the cargo hold, and the location of the vehicle by GPS.

Faults can occur while the process instance is being processed. In such cases it can be interesting to learn how, from the current situation onwards, the rest of the procedure is organised in terms of the schedule. The view is therefore directed forwards from the instance's processing status in order to adjust to new situations or to avoid unfavourable developments. Relevant algorithms are being developed for this purpose in the field of predictive analytics, and in machine learning in particular.

Machine learning algorithms 'learn' system behaviour through observation in order to analyse it for predictions. The best-known process in this field is artificial neuronal networks. By way of an example, AI analysis of sensor data is used in car manufacturing plants after the pressing and punching process to identify tiny faults in the bodywork that would lead to substantial subsequent costs if they were only discovered later. When, for example, hairline cracks are not identified until the final assembly, rectifying the problem becomes very expensive.

More and more attention is given to real-time learning aids during instance processing. If a processor comes across a situation they do not understand, they can be directly fed information that can help them.

Until now, IT support has been provided through helpdesks to which the user can turn for advice, or they simply ask colleagues. However, this takes up the time of additional employees. Approaches are therefore being developed to automate these kinds of helpdesk functions. New developments in digital learning support are being used to this end.

A system that supplies the user with the required, context-related information must know the application and the process step currently being carried out, and it must have knowledge (content) of support measures.

The experience-based knowledge of outstanding employees (champions) is used to achieve this. The stored content is kept constantly up-to-date with new experiences so that learning effects occur.

Such systems support the processing chain both in the computer-supported office and in the production plant. In the office they are used in particular to provide user support for standard application software, for example in a major insurance company as part of the introduction of SAP software.

In the production plant, the employee is (e.g. when new machinery is introduced) shown explanatory texts about the machine on their smartphone or on augmented reality (AR) glasses.

Virtual reality (VR) applications are also playing an increasingly important role. Using a 360-degree 3D camera, the user is provided with detailed real-time images that help to identify even very minor material defects.

4 Robotic Process Automation (RPA)

Robots have long taken over whole production lines in the manufacturing industry: they work independently around the clock, they never get tired, they operate faultlessly at a consistent level of quality, they can document their work comprehensively and they are flexible enough to be trained to carry out new tasks. Thanks to the robotic process automation (RPA) concept, these advantages can also be realised in the office area. A number of application systems in this field still require a human administrator—to handle special cases, to make decisions, to bring together data from different media or to resolve problems.

It is for applications such as these that the RPA principle was developed. The human administrator is, as in the production plant, replaced by a robot, although in this case it is a software robot. The application system itself remains unchanged. The software robot acts like the human administrator did before it, using—for example—a virtual keyboard or a virtual mouse. It docks onto the user interfaces of the systems, and carries out the work steps just as the human employee did before.

Simple RPA applications such as the ones used in address administration have now reached a professional level of development.

The methods of artificial intelligence are increasingly being tested with RPA. The robot can then also understand natural languages, it identifies and interprets structured and unstructured data (such as emails), and possesses cognitive learning abilities.

With this intelligent RPA (IRPA) it is also possible to automate more complex business processes such as customer dialogues (chat-bots) for agreeing service appointments and identifying customer requests.

5 The Impact of IT Infrastructure on Process Automation

Disruptive changes in infrastructure can have an effect on process organisation. Over the last few years this has already been the case in the development of cloud computing, and the impact could be even bigger in future with the use of blockchain architecture.

From the process management standpoint, there is a tendency with cloud computing towards greater organisational standardisation of processes because changes to and expansions of the applications involve significantly higher costs for the user, and they are also unpopular with the cloud providers.

Blockchain architecture is arousing great interest because it is not only a technical innovation, but also an organisational innovation in that new forms of collaboration between partners are supported. It is also an economic innovation because it leads to new business models and companies. The spectacular price development of the cryptocurrency Bitcoin, which is built on blockchain architecture, has also attracted enormous media coverage.

At the core of a blockchain application is the concept of a distributed database in which all transactions are stored in immutable form.

The concept of the blockchain database in which all transactions are recorded in sequential blocks is reminiscent of the land register in the cadastral field, and of the general ledger in financial accounting. That is why the blockchain architecture is also called distributed ledger technology (DLT).

It is also possible to use smart contracts to automate complete processes and significantly expand the original blockchain concept.

Practicable process applications include the development process of new products because all the development steps are then immutably documented and errors can be back-traced. Manufacturing and logistics processes can also be documented end-to-end for manufacturer liability and defect claims.

In public administration, the cadastre system and the population registry system are possible fields of application.

In the world of finance, people are even going as far as to suggest that banks may become obsolete.

In the field of insurance, the administration of contracts and the management of an electronic health record are suitable candidates.

In the energy sector, renewable energy concepts could mean that users also become producers. This process, including payments, can all be handled using blockchain.

With this in mind, blockchain architecture is rightly regarded as one of the main drivers of disruptive process innovations. However, it is important to advise caution against excessive political consequences. This applies in particular to the hoped-for democratisation and decentralisation of digital processes. The internet was originally seen as a technology that would bring democratisation and decentralisation. What we have seen instead is the emergence of a small number of monopolistic global giants.

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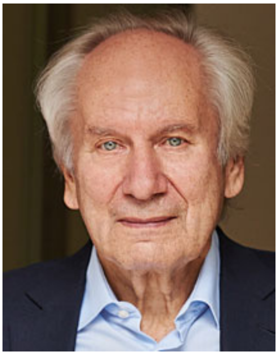

Prof. Dr. Dr. h.c. mult. August-Wilhelm Scheer is one of the most influential scientists and businessmen in German computer science and software industry. ARIS, the business process and IT management method developed by him, is in operation in practically all DAX listed companies and also internationally. His scientific books are bestsellers and have been translated into multiple languages. He is the founder of successful IT companies, including IDS Scheer AG, Scheer GmbH and imc AG. In 2014 he founded the AWS-Institute for Digital Products and Processes gGmbH—a non-profit research organization. He was independent advisor to political decision makers at federal and state level.

Structuring Behavior or Not, That is the Question

Wil van der Aalst

1 Introduction

It is a great pleasure to contribute to this "Festschrift" devoted to Jörg Becker's 60th birthday. Jörg has been one of Germany's leading "Wirtschaftsinformatiker" for decades and played a key role in the development of the field. He worked on many topics related to information systems (e-business, e-government, information modeling, IT maturity, reference modeling, etc.) and is probably best known for his work on Business Process Management (BPM) (Becker, Beverungen, & Knackstedt, 2010; Becker, Knackstedt, & Pöppelbuß, 2009; Becker, Rosemann, & von Uthmann, 2000; Röglinger, Pöppelbuß, & Becker, 2012).

Jörg Becker supervised numerous PhD students of which many became very successful in both academia and industry. He created an "IS school" where the credo is: "structure, structure, structure". His guiding principle has been that information system engineering is all about finding a suitable structure. Process modeling and information modeling play a key role in this.

This contribution focuses on the interplay between structure and data (van der Aalst, 2016). When dealing with real processes, one often finds that process executions follow a Pareto distribution. Some behaviors are highly frequent an easy to capture. However, the "tail of the Pareto distribution" is the real challenge in information system engineering. Although 80% of the process instances may be explained by 20% of the process variants, often most of the resources are put into handling the remaining 20% of process instances that deviate from the so-called "happy paths".

In the remainder, a simple example is used to show that reality often diverges from simplistic PowerPoint models. The makes it far from trivial to structure real-life processes. Process miners typically distinguish between Lasagna and Spaghetti processes. Process models may be viewed as maps that need to be tailored towards specific questions. As such, structuring can be viewed as finding the right map.

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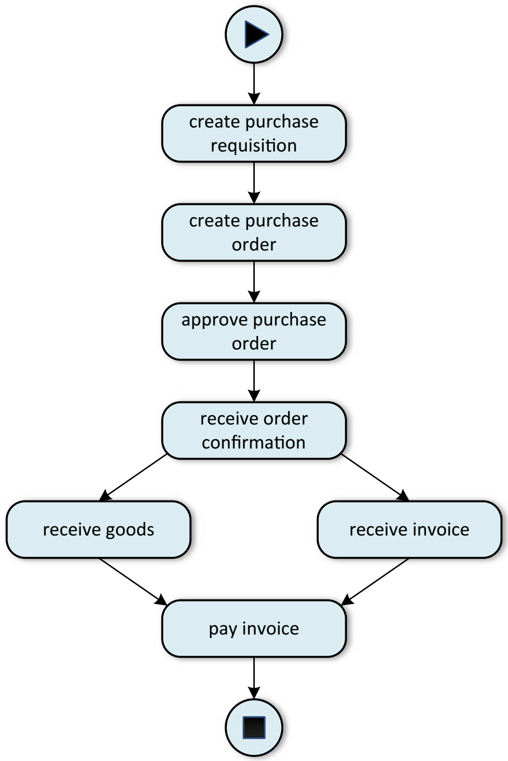

Fig. 1 Purchase-to-Pay (P2P) process only considering the "happy path"

2 An Example: Purchase-to-Pay (P2P)

To illustrate the surprising complexity of real-life processes consider the Purchase-to-Pay (P2P) process found in almost any organization. P2P refers to the operational process that covers activities of requesting (requisitioning), purchasing, receiving, paying for and accounting for goods and services. This process is supported by Enterprise Application Software (EAS) from vendors such as SAP, Oracle, Microsoft, and Salesforce. At first glance, this process seems simple, and indeed most cases follow the so-called "happy path" depicted in Fig. 1. The activities "create purchase requisition", "create purchase order", "approve purchase order", and "receive order confirmation" are executed in sequence. Then the activities "receive goods" and "receive invoice" can be performed in any order followed by activity "pay invoice" as the final activity.

The process depicted does not reflect the many variants of the process. Taking a sample of 2654 cases (i.e., purchase orders) and showing all the paths reveals the true complexity of the process. Figure 2 shows the so-called directly follows relation. Here we can see which activities follow one another. The 2654 purchase

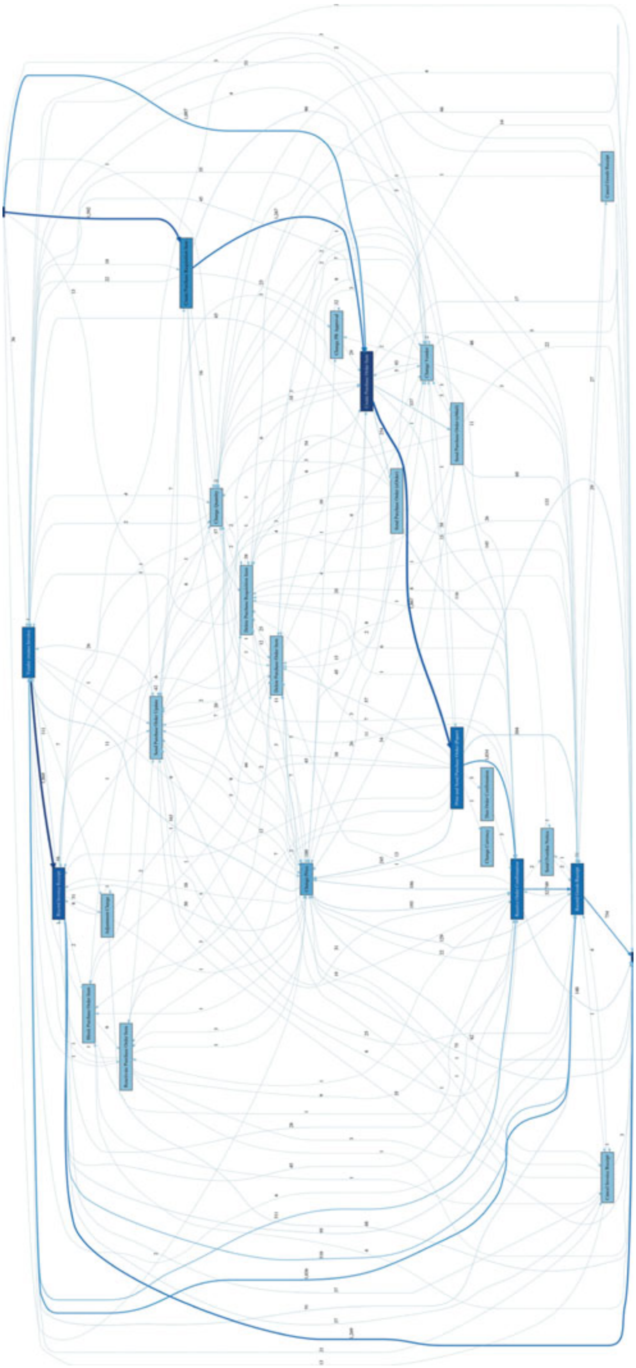

Fig. 2 The real P2P process: 2654 purchase orders follow 685 unique paths

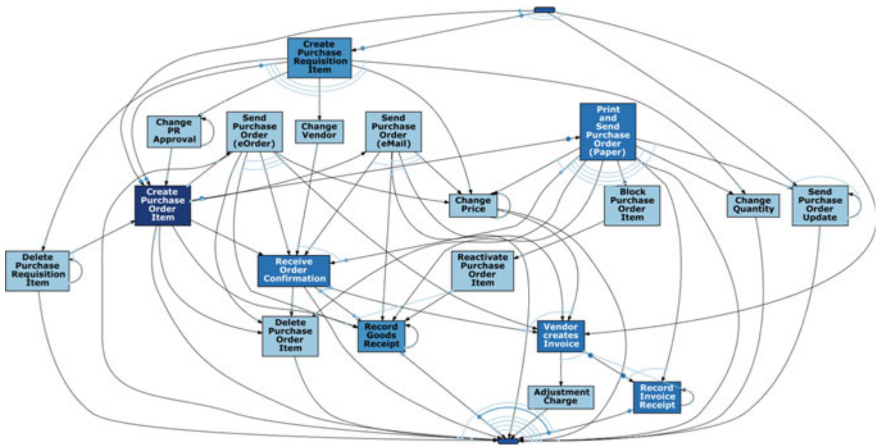

Fig. 3 A so-called Causal Net (C-Net) describing the process model

orders follow 685 unique paths. Clearly, the cases follow a Pareto distribution. The most frequent path is taken by 201 cases. The second most frequent path is taken by 170 cases. 68% of the variants are unique and account for only 17% of the cases. 63% of the cases can be explained by 8% of the variants, and 82% of the cases can be explained by 31% of the variants. Hence, the distribution approximates the well-known 80–20 distribution. Note that this example is not exceptional. This holds for most P2P processes and also applies to similar processes that are not fully controlled by software.

Process mining techniques can cope with such complexities (van der Aalst, 2016). By removing some of the infrequent paths, we can find the process model depicted in Fig. 3. Such a model can also be translated to a Petri net, BPMN model, UML activity model, or EPC. The model can be further simplified setting thresholds on frequencies.

The different process variants may have very different behaviors, not only in terms of control-flow, but also in terms of Key Performance Indicators (KPIs). For example, a price change may add a delay of 4.5 days on average. Infrequent paths may point to fraud. For example, orders that were paid but never delivered.

3 Between Lasagna and Spaghetti

The simple P2P process shows that reality may be surprisingly different from reference models and PowerPoint diagrams. The terms Lasagna and Spaghetti refer to the different types of processes. A simple metric is the number of process variants (unique traces) divided by the number of cases. This yields a number between zero and one. The closer to one, the more Spaghetti-like the process is. The closer to zero, the more Lasagna-like the process is. For the P2P process discussed, the metric is

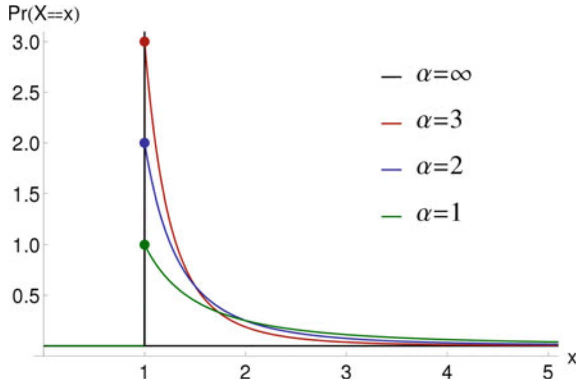

Fig. 4 Pareto Type I probability density functions for various α values

685/2654 = 0.2581. This is one of many ways to characterize event logs and the underlying processes.

Figure 4 shows the Pareto Type I probability density function for various values of α. The x-axis corresponds to the different traces (unique behaviors) sorted by frequency. The y-axis represents the relative frequency of each trace. The higher the value of α, the more uneven the distribution. Note that the distribution has a "head" (left-hand part of the distribution composed of the most frequent cases) and a "tail" (right-hand part of the distribution composed of the less frequent cases). The tail is often long. Analysis may focus on the head (e.g., when improving performance) or the tail (e.g., when dealing with compliance problems). This shows that the boundary between Lasagna and Spaghetti is not so clear-cut. Even within the same process, one can find both types of behaviors.

4 Structuring = Finding a Suitable Map

So how does this relate to Jörg's credo "structure, structure, structure"? It is not so easy to find structure when dealing with real-life processes. However, it remains important to look at the problem from the right angle. One can view process models as geographic "maps" describing reality. A subway map looks very different from a bicycle map although they aim to describe the same city. What is the best map? This depends on the purpose. The same holds for process models. What is a good model? This depends on the questions it intends to answer. The large availability of event data allows us to seamlessly generate and use process models in ways we could not imagine in the 1990s. However, the challenge to find structure remains.

Process discovery techniques that start from the actual behavior shed new light on the suitability of process model notations. There is a gap between techniques that return formal process models (precisely describing the possible behaviors) and techniques that return imprecise process models ("pictures" not allowing for any form of formal reasoning). However, parts of a process may be clearly structured, whereas other parts are not. Hybrid process models have formal and informal elements, thereby exploiting deliberate vagueness (van der Aalst, De Masellis, Di Francescomarino, & Ghidini, 2017). One should not try to structure behaviors that have no structure; otherwise, one there is the risk of overfitting the data. Applications of process mining clearly demonstrate the advantages of being precise when possible and remaining "vague" when there is not enough "evidence" in the data or standard modeling constructs do not "fit" (van der Aalst et al., 2017). We envision that the next generation of commercial process mining tools will support such hybrid models.

To conclude, I would like to congratulate Jörg again with his 60th birthday! A milestone in a remarkable career.

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Structuring What You Are Doing: 20 Years of Business Process Modelling

Gottfried Vossen and Jens Lechtenbörger

1 Introduction

Throughout the past decades, the fields of business process modelling (BPM) and management have seen a wide variety of contributions, which have shaped how we perceive, structure, and manage businesses today. The fields received particular attention in 1993, when two books related to the "reengineering" of businesses and their processes appeared and gained considerable popularity (Champy & Hammer, 1993; Davenport, 1993) due to their relevance for organizational operation and development at large. In response, the questions of *what* organizations are really doing and how the findings could be *structured*, received considerable attention in academia and industry. Indeed, the axiomatic principle of Hammer (2015) that "all work is process work" demonstrates the *relevance* of business process management in our world.

From the perspectives of computer science and information systems, *modelling* is a key practice for structured abstraction, communication, and the design of information systems based on a common understanding of relevant aspects in a particular domain for a particular purpose by the use of a suitable modelling language. *Process models*, in particular ones with mathematically precise, yet intuitively understandable semantics, such as Petri nets introduced by Petri (1962), have been around for a long time. Nevertheless, the systematic modelling of business processes took several decades to mature. Among the activities along that way was a joint meeting of the German special interest groups EMISA and MobIS in 1994 in Münster, Germany,

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which led to the publication of the edited book (Vossen & Becker, 1996) on business process modelling and workflow management. The editors asserted the central importance of both fields for the developments of information systems, characterized both fields as young and vibrant but far from consolidated, and pointed to the emerging breadth of models, methods, and systems. In the meantime, the discipline of business process management has emerged and subsumed both fields and more, see (Rosemann & vom Brocke, 2015). Indeed, about 20 years later van der Aalst et al. (2016) suggested in a survey on business process management that a "«process thinking» mindset is common in most organizations" but identified a "considerable gap" between the state-of-the art in business process management and practitioners' methods and needs.

In view of this ongoing debate, the present chapter contains a subjective perspective on selected developments concerning the modelling of business processes, primarily with contributions by authors with ties to the Department of Information Systems or based on the simple test-of-time that they were presented in Vossen and Becker (1996) and are still relevant today.

Towards this end, the remainder of this work is structured as follows. Section 2 provides a brief background of data modelling and processing, whose core ideas of abstraction and layering inform the discussion of BPM in Sect. 3. Section 4 presents the Horus Method to structure modelling in the context of an integrated analysis, and the paper concludes in Sect. 5.

2 Data Modelling and Processing

Before we delve into a discussion of modelling business processes, we briefly remind the reader about key insights concerning data and information modelling and processing. Since the inception of the Entity-Relationship (ER) model by Chen (1976), the design of information systems in general and database design in particular involves the following phases: The design process starts with a *requirements* analysis and specification, which often results in informal textual descriptions of information needs, relevant domain concepts, and their relationships. Afterwards, design proceeds in several phases on different *levels of abstraction*, where more and more technical details are added on each subsequent level while also employing different languages to move from informal descriptions to formal specifications that can be implemented in target systems. In a nutshell, based on the requirements specification, the design process continues with *conceptual* design (for example using ER or UML diagrams), includes transformations of those diagrams into *logical* schemata of the formal model of a chosen target database system (dominantly, the Relational Model introduced by Codd (1970), and ends with the implementation of *physical*, optimized schemata in the target system. Fahrner and Vossen (1995) described the aforementioned design process and its phases in detail, in particular with a focus on automatic transformation steps for several data models, for purposes of forward as well as reverse engineering.

Importantly, conceptual diagrams are supposed to be precise enough to capture the relevant essence of the application domain for subsequent (semi-) automatic transformations on the one hand, but also understandable enough to support communication among various stakeholders on the other. Further, conceptual diagrams focus on core domain concepts, without restrictions imposed by specific technologies to be selected in later design phases.

In parallel to the sketched modelling of information via multiple levels of abstractions, also *processing* of data occurs at multiple levels of abstraction: SQL, the standard query language for relational data, is a *declarative* language in the sense that users specify *how* the result should look like (what attributes from what tables to include under what selection conditions). The details of what to execute in what order is irrelevant to users. Instead, as described by Vossen (2008), the database management system's query optimizer transforms the declarative input query into a *procedural/imperative* query evaluation plan based on the Relational Algebra for efficient query execution. Along the way, the optimizer determines into what steps (or operations from the algebra) to decompose the query, in what order to execute those steps, and which algorithms to use for each step based on what access paths. While the details of query processing are not relevant to our present discussion, we revisit the idea of modelling at different levels of abstraction with different types of modelling languages in the next section.

3 Business Process Modelling

According to Becker et al. (2011), a business process is a "completely closed, timely and logical sequence of activities which are required to work on a process-oriented business object." Business process modelling is a design process which aims to produce a model, i.e., a design artefact in a suitable modelling language, for a given business process.

In view of data modelling as sketched in the previous section, van der Aalst (2013) noted in a survey on business process management that "there has been consensus on the fundamental concepts for the information-centric view of information systems for decades." In contrast, concerning business processes he stated that the "process-centric view on information systems [...] can be characterized by the term «divergence»." Indeed, Recker et al. (2009) presented a comparative analysis of twelve process modelling techniques and found shortcomings "such as lack of process decomposition and integration of business rule specification." With respect to the lack of integration of business rule specification we note that such a lack seems to be inherent in the *procedural/imperative* paradigm of process modelling, while *declarative* approaches start directly from business goals, rules, and constraints. According to Goedertier et al. (2013), declarative BPM focuses "on what should be done in order to achieve business goals, without prescribing how an end state should be reached." Towards that goal, business rules and other constraints are *declared* as logical expressions in a suitable formal logic. The expressions specify preconditions for and dependencies between activities. Changes in the state of business processes are only allowed if they do not violate the given constraints. Thus, modellers do not need to specify a precise sequence or order of activities, which can be inferred from the declared expressions.

In contrast, the bulk of BPM approaches falls into the procedural paradigm, where modellers explicitly specify the so-called control-flow of activities, resulting in graphs where nodes represent activities and directed arcs define what activities to execute and in which order.

3.1 Selected Procedural Approaches for BPM

In terms of common approaches, the survey by Recker et al. (2009) as well as Vossen and Becker (1996) address event-driven process chains (EPCs) (Keller, Nüttgens, & Scheer, 1992) and Petri nets (Petri, 1962). Scheer and Jost (1996) describe EPC as key technique in ARIS, the architecture for integrated information systems. ARIS rests upon the following ideas: It aims to support business process management in general and the modelling and implementation of application or information systems in particular in multiple views (organization, data, control or process, function), in multiple layers (conceptual, logical, implementation), and with appropriate languages for the different views and their layers.

According to Scheer and Jost (1996), business processes are modelled as graphs called EPCs in the process view and involve three main types of nodes: *functions* and their logical and chronological dependencies, *events*, and (logical) *connectors*. Functions can be detailed at different levels of abstraction, where a function of one level may itself be refined by an entire business process at the next level. Functions may trigger or be triggered by events, which cause changes of process state and data. To model choices and parallel executions, different types of logical connectors are available ("and," "or," "xor"). Further types of nodes connect the process view with other views such as data and organization. Nowadays, more nodes are available, e.g., to indicate messages, necessary hard- and software, or environmental data (Scheer, Thomas, & Adam, 2005). A sample EPC for a process to decide about a loan request from Mendling (2008) involving a decision based on a risk assessment is shown in Fig. 1. In that figure, events are visualized as hexagons, functions as rectangles, and the xor connector as "X" inside a circle.

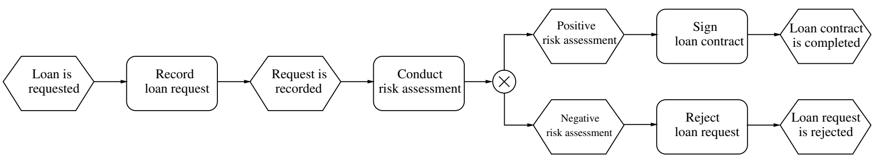

Fig. 1 Sample loan request process as EPC [*Source* Mendling (2008)]

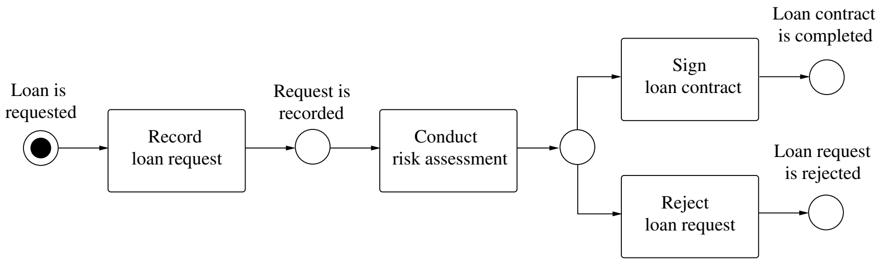

Fig. 2 Sample loan request process as Petri Net [*Source* Mendling (2008)]

While EPCs were initially defined without an underlying formal semantics, other BPM notations came with such semantics right away, enabling simulation and formal analysis beyond intuitive reasoning. Indeed, in chapters of Vossen and Becker (1996), Elgass, Krcmar and Oberweis (1996) and Jaeschke (1996) argued for formal BPM based on Petri nets. Elgass et al. (1996) advocated the methodical planning and design of business processes in an evolutionary fashion, which resembles the different layers of abstraction known from database design (as sketched in Sect. 2): Starting from informal process descriptions, semi-formal process models are derived, which are then successively transformed into formal, executable models (predicate/transition Petri nets).

Petri nets allow to model concurrent activities using two types of nodes, namely places (which represent information objects) and transitions (which represent activities). Petri nets can be analysed statically as well as dynamically for correctness and efficiency. Similarly to different levels of detail and abstraction of functions in EPCs, transitions in Petri nets can be refined hierarchically into other Petri nets which refine activities. A Petri net for the sample loan request process is shown in Fig. 2, where places are visualized as circles, transitions as rectangles. Places can hold one or more so-called tokens (here indicated by the black circle in the first place "Loan is requested"), which activate subsequent transitions. When a transition executes, it moves tokens from its preceding place(s) to its subsequent place(s). For example, the decision based on the risk assessment is modelled implicitly in Fig. 2 as the transferred token can only activate either transition "Sign loan contract" or transition "Reject loan request." Alternative models could avoid this "nondeterminism" with separate places or different "colours" for tokens (van der Aalst, 1998). Also, the net shown in Fig. 2 is a so-called terminating net in the sense that the process can only be executed exactly once (and deadlocks in the end); by starting the process with a transition (say "Receive loan request") repeated executions would be enabled.

Based on Petri nets and the same project background as Elgass et al. (1996), Jaeschke (1996) described INCOME, a method and tools for analysis, simulation, and implementation of business processes. Since then, INCOME has been widely applied in practice and evolved into the Horus method, to be presented in the next section.

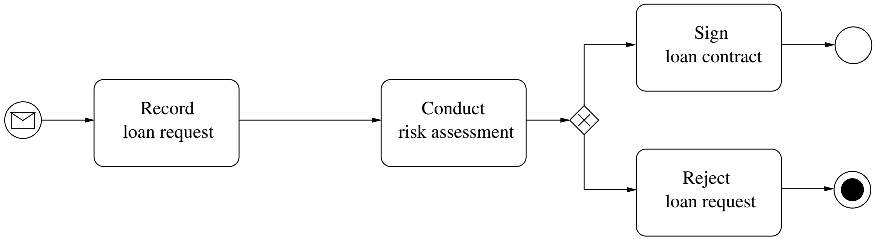

Fig. 3 Sample loan request process in BPMN notation [*Source* Mendling (2008)]

Business Process Model and Notation (BPMN) is a graphical BPM language, which nowadays is maintained and specified by the Object Management Group, currently as version BPMN 2.0 (OMG, 2011). According to OMG (2011), BPMN's purpose is to enable communication in business process management projects by creating "a standardized bridge for the gap between the business process design and process implementation." Towards that end, BPMN 2.0 includes process diagrams, collaboration diagrams, and choreography diagrams. In BPMN, so-called pools represent different participants (business entities), collaborations depict interactions between activities of different pools, and choreographies describe message exchanges between different participants. The sample loan request process is shown as BPMN process (without additional elements of BPMN 2.0) in Fig. 3, where activities are visualized by rectangles, events by circles, and a gateway by a smaller rotated square with internal marker (to represent the different paths depending on the outcome of the risk assessment).

While all approaches so far *allow* to model processes at different levels of abstraction and detail, the tool icebricks presented by Becker et al. (2013) *enforces* modelling at four layers of abstraction to provide stricter guidance for modellers. Besides, the method includes an attribution mechanism to add detailed information via attributes to any modelling element on any layer. Furthermore, to prevent inconsistencies and heterogeneity from uncontrolled use of terminology by individual modellers (with different educational, organizational, and regional backgrounds), icebrick modelling pursues an approach towards semantic standardization based on a glossary. That glossary is to be defined for relevant business objects ahead of modelling activities, which then refer to documented terminology. Icebricks, which started as research prototype, has seen considerable success in practice.

3.2 Declarative Ideas for BPM

Declarative languages provide powerful abstraction mechanisms for different purposes with the common basis that logical expressions describe *what* needs to be performed without the burden of specifying the (procedural) *order* of execution. Indeed, the declarative query language SQL mentioned in Sect. 2 falls under the general paradigm of declarative programming languages. Not surprisingly, declarative specifications have also found their way into BPM.

Indeed, Lechtenbörger and Thoben (1999) presented an approach for BPM based on the process algebra CCS (Milner, 1989), where logical formulas express declarative specifications of desirable process properties. Process algebras in general enable the formal study of concurrent, communicating systems in algebraic frameworks. Essentially, a fixed set of operator symbols allows to create more and more complex processes based on constructors such as sequence, alternative, or parallel composition. The semantics of such operators is typically defined via axioms, assigning a precise semantics to modelled processes. While processes modelled via process algebras still have a procedural nature due to their inherently procedural constructors, their formal semantics allows the verification of declaratively specified properties. Examples given by Lechtenbörger and Thoben (1999) include general safety and liveness properties as well as specific properties concerning the confidentiality of communication and fair exchanges (e.g., of money and goods).

In the meantime, progress has been achieved towards declarative modelling of business processes. Following Goedertier et al. (2013), the focus is on achieving business goals while the explicit modelling of (procedural) control flow is not necessary. Instead, dependencies between activities are derived from business rules and constraints. In particular, as explained by Goedertier et al. (2013).

- business rules are specified once and automatically affect every process, avoiding redundancies,
- different modalities can be modelled (*ought*, *should*, *can*, *is*; in addition to the default *must* of procedural approaches),
- flexibility at runtime increases as no control flow is precomputed or specified ahead of time, and
- as each constraint needs to be specified explicitly, a minimum set of constraints is likely, which again increases flexibility (in contrast to procedural models which are more prone to over-specification).

De Smedt et al. (2016) observed that "a real trade-off exists between the readable, rather inflexible procedural models, and the highly-expressive but cognitively demanding declarative models containing a lot of implicit behaviour." In view of this trade-off, they presented an approach towards a hybrid of declarative and procedural process modelling based on a combination of Petri nets and Declare (Pesic, Schonenberg, & van der Aalst, 2007).

4 The Horus Method

Petri nets are popular in business process modelling due to the simplicity of their graphical presentation and their expressive power. However, as mentioned in the context of icebricks, a modelling language alone is not enough, since users require guidance and assistance in the preparation of models, i.e., during an *application* of the

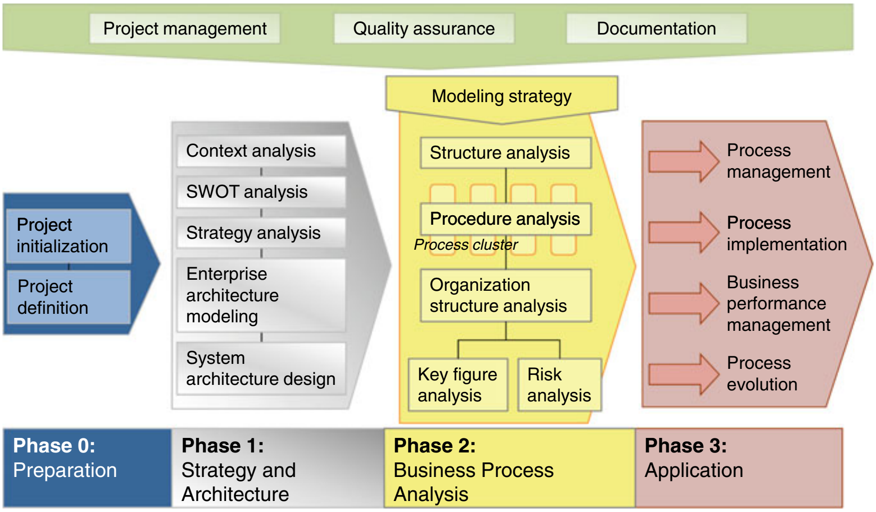

Fig. 4 Structure and steps of the Horus method (Schönthaler et al., 2012)

language. This is where the Horus® Method[1] comes in, which breaks modelling into various phases and emphasizes an integrated analysis of all aspects that are relevant to the processes under consideration. More precisely, Horus subdivides business process engineering into four phases. Phase 0 is the *preparation* of the engineering project. Phase 1 is the *strategy and architecture* phase to study the strategic aspects and definition of enterprise and system architecture. Phase 2 is the detailed *business process analysis*. Phase 3 is the subsequent *usage* of the model. Beyond these phases, modelling is accompanied by *project management*, measures for *quality assurance*, and up-to-date *documentation*. The Horus Method is shown in Fig. 4 and described in detail by Schönthaler et al. (2012).

Project definition in Phase 0 takes place together with the initialization of the project; this determines which parts of an organization will be examined and what budget and time frames are available for this purpose. Project goals to be accomplished are additionally outlined and examined regarding their strategic and economic value, including a subsequent budget comparison. Phases 1 and 2 form the core of Horus modelling. They deal with the analysis and modelling of strategic aspects associated with the business and system architecture, as well as a detailed examination of the business processes. A special feature of the Petri nets used here is their simulation capability. In practice, simulation proves itself as an instrument for the dynamic analysis and testing of models "under load." Simulation results can be visualized in a simple, understandable and meaningful form by way of graphic animations. When, to which extent and with which intensity the simulation will be used has to be clarified on an individual basis with regard to cost and benefit aspects.

[1]The Horus® Method is a product of Horus software GmbH, Ettlingen, Germany.

The most important principle of the Horus Method is *abstraction*, a thought process with respect to specific objects of reality, where general and specific properties are separated from one another to then depict the generally valid properties in a more general or simpler theoretical model. *Structuring* is another fundamental principle that is recurrent in the Horus Method. Structuring creates the possibility to model even large-scale systems in a detailed, yet comprehensive and understandable manner. This is achieved by describing facts and circumstances of different types with the most appropriate languages in different sub-models (e.g., process models, object models, roles models, etc.), which can then be connected to one another through well-defined links.

The Horus Business Modeler is the BPM tool accompanying the Horus Method. Pflanzl (2018) argued how gamification, i.e., the use of game elements in non-game contexts (Deterding, Dixon, Khaled, & Nacke, 2011), can improve business process modelling in general, and he designed, implemented, and evaluated a gamified version of the Horus Business Modeler. In a nutshell, gamification can improve model quality and the effectiveness of education and training, lowering entry barriers and addressing some challenges of *Social* BPM, a democratized, bottom-up approach to process management.

5 Summary and Conclusions

Modelling in computer science and information systems in general and with respect to business processes in particular involves the use of appropriate modelling languages at different layers of abstraction. While a wide variety of procedural languages exists that enjoy widespread use in practice (a sample of which was sketched here), research into declarative modelling is far less mature but might provide more flexibility for process executions. In any case, modelling languages need to be embedded into overarching management processes, for which selected approaches were put into perspective (ARIS, icebricks, and Horus Method).

Analytical techniques in times of big data offer alternative avenues (in addition to declarative modelling) towards more flexibility (Breuker, Matzner, Delfmann, & Becker, 2016). Process executions can be captured in event logs, which on the one hand allow mining for process patterns and which on the other might also prove useful for *predictions* about upcoming events, e.g., in the sense of early warning systems and anomaly detection. In this context, Breuker et al. (2016) applied grammatical inference techniques for predictive modelling of business processes. Their approach generates probabilistic models based on past process executions to predict future behaviour of ongoing process executions. While the approach only used past event data for predications and mining, we expect more research to appear that also takes other data sources into account (e.g., business news, weather forecasts, and supply chain states), offering ample opportunities for future research.

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Part IV
Data

"Art is the elimination of the unnecessary." (Pablo Picasso)

Picasso was a master of abstraction. In many of his pieces of art, he simplifies his observations, offering a different approach to romanticism, when depicting what we see. Nowadays, institutions tend to collect as many data as possible, and one of the most important objectives for finding meaning—or information—in data is revealing the necessary and distinguishing it from the unnecessary.

Structuring Judicial Communication

Wilfried Bernhardt

1 What Should be Structured?

Jörg Becker always emphasizes the requirement of structuring processes. In order to achieve good target processes, one should subdivide processes into sub-steps before digitization, check the individual sub-steps in terms of their need, simplify them and optimize them by structuring so as not to produce automated nonsense (Mörs, 2018).

Legal proceedings depend on efficiency-enhancing measures. Even though the number of civil judicial proceedings is currently decreasing, within the next seven years it will prove problematic to deal with the number of judicial proceedings in a reasonable time, especially in the new German federal states. The problems are due to the so-called echo effect of German unity with a shortage of judges, which at the beginning of the 90s provoked politics. In approximately the middle of the coming decade, many judges who were appointed to their positions by the new federal states at the time of German unity will go into retirement, and this challenge cannot be overcome solely by hiring new judges. Yet, the requirement of effective legal protection, guaranteed by Article 19 Paragraph 4 of the German Basic Law and for civil-legal disputes based on the rule of law, demands that legal protection must also be granted within a reasonable period of time. Thus, intensive measures are required to relieve the strain on the future judiciary without cutting back on effective legal protection. Digitization alone does not provide sufficient assurance for that, because the digitization of paper-based pleadings is not enough (Bernhardt, 2015; Köbler, 2016).

In the civil litigation process, the difficulties regarding efficiency begin with the fact that statements of claims must be seen by the office of the courts and then manually assigned to the competent judges. Then, judges have to struggle laboriously

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through unstructured documents of the litigants in order to find the core of the legal dispute. In doing so, judges lose important and valuable time needed for their main task of decision-making.

Therefore, once the requirement of process management in the business sector and in the public administration has been recognized, the judicial procedure—in particular the beginning of the procedure that starts with the written pleadings—requires new structuring.

The digital structuring of legal documents and data has been discussed for several years in the legal literature. These discussions have centred around structuring to facilitate the further processing of data from judicial registers and procedural briefs using information technology. While other European countries such as France and the United Kingdom already legally prescribe and practice the structuring of attorney statements (Zwickel, 2018), no consensus has yet been reached in Germany as to whether and how intensively the legislator should set a structure in terms of content. This has been demanded on several occasions in the literature (Gaier, 2013, 2015; Vorwerk, 2017; Zwickel, 2016).

Formal structural requirements for the statements of claim addressed to the court are only rudimentary: Section 253 (2) of the German Code of Civil Procedure provides that the statement of claim must include the designation of the parties and of the court, exact information on the subject matter and the grounds for filing the claim, and a precisely specified petition. Furthermore, the statement of claim should provide information as to whether, prior to the complaint being brought, attempts were made at mediation or any other proceedings to find an alternative resolution of the conflict, and it shall also state whether any reasons exist preventing such proceedings from being pursued. Wherever the subject matter of the litigation does not consist of a specific amount of money, information on the value of the subject matter of the litigation is to be provided, insofar as this is relevant for determining whether or not the court has jurisdiction. Further, the statement of claim shall state if there is any reason the matter should not be ruled on by a judge sitting alone. Section 130 of the German Code of Civil Procedure prescribes certain formal information for the preparatory written pleadings, such as the designation of the parties and their legal representatives by name, status or business, place of residence and position as a party; the designation of the court and of the subject matter of the litigation; information on the factual circumstances serving as grounds for the petitions; the declarations of the facts alleged by the opponent; and finally, the designation of the evidence that the party intends to submit as proof of any facts alleged or as a rebuttal to the allegations, as well as a declaration regarding the evidence designated by the opponent.

There are no further requirements for structuring the content of the arguments. The "principle of party disposition" is a procedural maxim prevailing in civil proceedings. It is up to the parties to bring forward all the relevant facts, on the basis of which the court then makes a decision. So, the litigants themselves are required to submit the relevant content-related aspects of the dispute to the court, and the court may base its decision only on those facts and evidence brought in by the litigants themselves. The lack of structuring, however, means that judges often have to laboriously filter out and structure the relevant party arguments in civil proceedings from the documents of the parties in order to be able to make a legal assessment.

In 2014, the process law department of the *Deutsche Juristentag* (German Lawyers' Committee) recommended by a narrow majority that "binding rules" should be used to "ensure that the litigants structure their pleadings on the actual and legal submissions" (Deutscher Juristentag e.V., 2014). The Federal Minister of Justice and Consumer Protection Heiko Maas, however, saw no reason to act.

2 Why is This Relevant to the World?

Judges' demands to require structuring of legal claims in addition to substantive reasoning are not based solely on the desire to implement digitization. Similar types of litigation would also benefit if the statement of claims and the statement of defense were clearly structured, thus facilitating the judge's task to contrast the factual representations and legal arguments of the plaintiff and the defendant, to work out disputed and undisputed statements of fact as well as to draw out facts that are relevant to the arguments and to subsume the facts under the legal norms. However, the digitization of court procedures and judicial decision-making create a very important additional argument for a document structure.

It is well known that many lawyers and judges find it hard to completely transform their traditional paper-based work into digital work. In particular, lawyers and judges who shy away from the conversion effort and show little willingness to be trained on the new technology argue that electronic court documents offer no advantage over analogue files if they only represent an electronic copy of the previous paper files. Such objections can only be met if the use of digital instruments actually promises added value in terms of making judges' work easier and increasing the efficiency of judicial work. In addition to allowing for simpler research and better accessibility, it is, above all, the (more structured) handling of the documents that will convince judges of the advantages of digital work. Until such practices are obligatory, digitally open-minded judges can use IT tools that allow one to highlight certain assertions and factual representations when reading the briefs, digitally structure them and connect the information in a targeted and multidimensional way so that the relevant information can be retrieved quickly and be opened by a simple click on a screen at any time (Fallsoft GmbH, n.d.; Normfall GmbH, n.d.). The structuring tool, which is partially integrated into electronic court-record system software, helps to structure and reduce the complexity of the dispute, but it leaves the task of structuring to the judge. Providing structured texts for the judge could help here. Digitally structured texts facilitate automatic reading and digital processing of the data.

Another advantage digitally structuring legally relevant data became clear in the work on the so-called Network of Judicial Registers (NJR). The aim of this electronic data exchange of German and French criminal records initiated on the occasion of the 40th anniversary of the Franco-German friendship treaty (Élysée Treaty) was to facilitate the (inefficient) and much too slow (paper) exchange and also to improve the quality of information exchanged. National courts often pass sentences on the basis of past convictions an offender has in their national register; they currently do not consider convictions in other EU countries.

The NJR should enable courts, prosecutors and other competent authorities and agencies to detect cross-border crime and prevent offenders from simply stripping off their criminal past and escaping conviction by moving to another EU country. With the results of the NJR, it is now possible to quickly detect whether a person already has been convicted in another member state and, in the event of a new conviction, their prior criminal offenses can be adequately taken into account. As early as 2003, work was initially being carried out between Germany and France, and later with other EU member states, to structure the electronic information regarding convictions in such a way that it could be more easily read out through the register of another member state and processed for its own purposes. For this aim, reference lists were developed which translated certain information into the language of the other member state, not only for the framework data of the conviction, but also for the content of the convicted offenses. For example, criminal laws of the member states involved in the NJR project were analysed and assigned into certain categories of penal standards applicable throughout Europe. In this way, information was able to be transmitted to law enforcement agencies and courts in proceedings of another member state in its official language. From the NJR, then emerged the European Criminal Records Information System (ECRIS). It was established in April 2012 in order to improve the exchange of information on criminal records throughout all the EU countries. In the system, each criminal act is assigned a uniform ECRIS code that enables a correct interpretation of the criminal record information by other EU member states in each country.

Similarly, structured data can also be translated into other languages in certain simplified civil litigation procedures, such as the EU order for payment procedure. In the case of a cross-border, undisputed claim, an applicant in an EU member state may apply for a European order for payment in his own language using an electronic form. These electronic forms can be accessed in all EU languages. If the form has been completed correctly, the court issues the European order for payment. The defendant then orders payment in his native language without relying on translators or electronic translation programs. If the defendant does not object, the European order for payment becomes automatically enforceable (Europäische Kommission, 2017b). Here, too, it can be seen that the structuring of data—both formal data about the applicant, the defendant and the competent court as well as content data on the asserted claims—can be of value cross-border for legal prosecution, not only because it facilitates the overcoming of language barriers but also because differences between different legal systems can be identified easily so that these differences can be taken into account for legal decisions.

3 How Can Data be Structured?

The structuring of party writings can be done in various ways.

3.1 Structuring of Metadata

On the one hand, metadata for process-initiating and process-preparatory documents can be structured. Metadata, in the sense of information about other information resources, refers here to the framework data of the legal documents. For this type of data structuring, the judiciary in Germany has a long tradition. For example, the Federal-State Commission for Data Processing and Rationalization in the Judiciary (BLK) developed organizational and technical guidelines for electronic legal relations with the courts and public prosecutors (OT-Leit-ERV) shortly after the creation of legal regulations for so-called electronic legal transactions. These transactions included XML records for the exchange of structured data between litigants (citizens, businesses, lawyers) and the courts (XJustice), which were released for live operation on May 13, 2005. XJustiz includes a basic module with commonly needed data (e.g. court name, file number) and particular modules with subject-specific data (e.g. criminal proceedings, dunning procedures, registers) as well as value lists (e.g. name of states). A completely redesigned XJustiz 2.0 release was published on December 31, 2016 (BGBl.I, 2017, p. 3803).[1] For many years, the XJustiz dataset was recommended to lawyers who use electronic legal transactions in order to incorporate the structured data into the judicial procedures and thus contribute to accelerated processing of the data. Now, Section 2 (3) of the *Elektronischer-Rechtsverkehr-Verordnung* of 24 November 2017 (BGBl.I, 2017, p. 3803) regulates that “The electronic document is to be accompanied by a structured machine-readable data set in the XML file format, which can be found on the website or at least the following: 1. the name of the court; if known, the file number of the procedure; the designation of the parties or parties to the proceedings; the indication of the subject of the proceedings; if known, the file number of a case concerning the same subject-matter and the name of the institution leading the file.”

[1]Specialized modules for family court proceedings, information about the pension claims, insolvency matters, register matters, criminal matters, order for payment procedures, land register matters, the central register of the federal chamber of public notaries, communication of the public notaries, for small claims, for electronic filing between courts and the German pension insurance, for payments on the basis of the Single Euro Payments Area, for the e-customs software, bailiff software, foreclosure, e-files and file structures, electronic delivery certificate.

3.2 Structuring of Content Data

Beyond these approaches at the metadata level, there are also forms, which include content structures for certain types of proceedings in the judiciary. This applies to, for example, the aforementioned payment order proceedings at national and European levels. Since there has been no judicial examination of the merits of content structuring in the German payment order proceedings, the structuring of content is only slightly higher than the structuring of metadata. On the other hand, the European order for payment procedure (EOP)—based on an EU regulation (Council of the European Union & European Parliament, 2016)—provides for a shortened judicial examination of the merits of the case. Also, in this respect the electronic forms allow for a substantive examination by the competent courts. An application in the European Small Claims procedure, formalized by an EU regulation (Council of the European Union & European Parliament, 2015), also provides electronic forms available in all official languages. Receipts, invoices, etc. are attached. The court, in turn fills out a "reply form" and sends it along with a copy of the claim form to the defendant, who must complete a portion of the reply form on his part (Europäische Kommission, 2017a). In the further course of the proceedings—without or with oral proceedings (possibly also as a videoconference)—a judgment enforceable in all other EU member states can be issued. A Small Claims verdict can be recognized and enforced in another member state without the need for a declaration of enforceability and the possibility of challenging it.

It is conceivable that in addition to these simplified procedures, other legal proceedings can be carried out more efficiently by means of structural specifications. In doing so, developments such as Legal Tech should serve as a model that have partially revolutionized the work of lawyers in recent years.

3.3 Legal Tech

For lawyers, Legal Technology ("Legal Tech") is already partially structuring the legal work today. Legal Tech refers to software programs and online services that support legal work electronically or even enable automatic implementation. Thus, there are electronic dynamic forms with which information can be queried and solution proposals can be worked out for specific constellations. The *Anwaltsblatt-Honorartool* of the German Bar Association provides lawyers with question/answer forms for checking if a remuneration agreement is exceptionally inadmissible and what form requirements are to be observed. In addition, lawyers can use interactive tools for process risk analysis. E-discovery tools can be used to review contracts relevant to due diligence. Efforts are aimed at automating individual legal services, in part or in full, through information structured in forms. Internet platforms are available that offer online mediation based on structures. With the help of online platform operators such as flightright.de, claims for passenger compensation can be asserted, *Hartz 4-Bescheide* (decision on the granting of social assistance) can be reviewed by Hartz4widerspruch.de, and claims can be asserted as consequence of the so-called diesel exhaust scandal (myright.de). Further support tools can be found on the website https://tobschall.de/legaltech/. For example, legal online platforms are offered that can be tailored to specific individual needs, for example for employment contracts, dismissals, employment certificates, company foundations, and contract reviews in the course of company acquisitions. Platforms such as https://rechtsmart.de/ offer users the option of completing structured question/answer forms even without legal support or of writing letters to assert or defend claims, and then the platform automatically sends them to companies as computer faxes to ship.

3.4 Benefits and Challenges for Judges

Because these developments are based on programs, structured data, and electronic forms that lawyers use as instruments for out-of-court dispute resolution or, for example, in order to prepare applications, judges should also be interested in being able to use these instruments, without, however, relinquishing their responsibility for the proceedings and the possibility of making independent decisions in the proceedings. Especially with regard to the preservation of constitutional principles, to which the judiciary is especially committed, the use of new technologies requires a legal foundation.

Thus, Section 130c of the German Code of Civil Procedure, which entered into force in 2014, authorizes the Federal Ministry of Justice to issue statutory instruments: “The statutory instrument may determine that the information provided in the forms is to be transmitted, either in its entirety or in part, in structured, machine-readable format. The forms are to be made available for use on a communications platform on the internet determined in the statutory instrument”. The goal is to promote the IT-based processing of the case with the courts. Finally, the form user can identify him- or herself and authorize the form by using their electronic ID card or electronic residence permit. Such forms can also be used to define structures for the statements of claim. This concerns both the specification of metadata and, theoretically, the specification of content data. Unfortunately, the power to issue statutory instruments has not been used yet. Apparently, the Federal Ministry of Justice and for Consumer Protection, which is responsible for this, is still reluctant to venture so far into digitization through structuring.

In addition to the mentioned requirements for forms, *Köbler* proposes to develop forms and structures that are used conjointly by plaintiffs and defendants and are therefore related to each other (Köbler, 2016).

On the one hand, the structural requirements must be adequately concrete and binding in order to enable the court to benefit from true accelerating and effective added value. On the other hand, the structural requirements should not be too restrictive. Certain facts and legal assessments that would be important in a comprehensive legal assessment should not be excluded from the process because the forms are too rigid. Also, for example, the structure chosen by the plaintiff should not compel the defendant to submit in his presentation to a specific consideration of the plaintiff.

Finally, in view of the constitutional principle of the independence of judges (Article 97 (1) of the German Basic Law), care must be taken to ensure that the judge is not prevented by rigid legal forms from being able to make his or her own legal considerations.

It will therefore be crucial in which process and with what effect forms are used. In legally simple, standardized procedures (payment order proceedings, small claims), the use of forms is more appropriate than in atypical, complex procedures.

3.5 Effects of Artificial Intelligence

Finally, the opportunities and effects of artificial intelligence should be considered: Forms can make it easier to use instruments of artificial intelligence and to link to the publication of decisions for similar disputes. Programs could thus take over part of the judicial review required by the judge (Zwickel, 2018). On the other hand, in theory, artificial intelligence tools may make the creation of particular structures and electronic forms superfluous. Self-learning programs are already being used today, and they can, for example, analyse an unstructured statement of claim and submit the document to the competent judge in accordance with the allocation of court business (Section 21e German Courts Constitution Act). Why should such programs not be able, in the future, to evolve legal case solutions from unstructured data?

Recently, however, more and more criticism has been voiced that artificial intelligence, based on non-transparent algorithms, can lead to dangerous one-sided decisions (Beuth, 2016). If developers of artificial intelligence judicial systems decide not to disclose their algorithms on the basis of trade secrets (Zwickel, 2018), then it would be unacceptable for judges to use these algorithms to decide on judicial cases. In criminal proceedings, the consequences of such non-transparent artificial intelligence is even more serious, as shown by a case decided in the United States (Smith, 2016; Tashea, 2017). Structures using public electronic forms allow a more transparent view of the data in court proceedings and will therefore not lose their significance in the near future.

3.6 Conclusion

The above analysis shows that discussions about structuring the data to be processed in a judicial procedure must continue intensively. It is worthwhile to apply the recommendations for structuring prior to digitization to the field of e-government, recommendations that were largely initiated by Jörg Becker, but it is also important to apply them to the field of e-Justice.

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Structuring and Securing Data with Holography—A Holistic Interdisciplinary Approach

Cornelia Denz

1 Motivation: Holography, Structure and Information Systems—How Do They Come Together?

A hologram is a physical structure that allows creating a three-dimensional (3D) image of a previously registered object by the optical process of diffraction. Typically, the term "hologram" refers to both, the encoded material structure as well as the resulting image. The holographic image in turn can be observed by looking into an illuminated holographic print or by directing a laser through a hologram and projecting the image onto a screen. While the first case is considered as an *embossed hologram*, the second one is known as an *optical hologram*.

There are three features that make holograms completely different from classical imaging. At a first instance, holograms create a 3D image of a real object that strikingly resembles the object itself. Its physical principle is based on interference and will be described in Chap. 2. Often however, other methods of projecting and reflecting object images in such a way that a 3D impression is created are also (wrongly or misleadingly) referred to as holograms. Mostly, these structures are virtual images created by stereoscopic techniques, by multiple interferences in space, or by lens- or mirror based imaging. In these cases, the resulting optical field, its spatial quality and its colour representation tempt to call them "holograms". Actual examples of the perfection of these virtual image reconstructions are on the one hand polarization-based stereo imaging in 3D cinema (Chandler, 2015) or interference of three projection directions leading to virtual images projected into free space with a pyramidal spatial area (CPP Studios GmbH, 2018). And finally, Pepper's ghost technique (Perry, 2014), which uses a partially reflective surface to mix an image with the scene beyond and was originally demonstrated by John Henry Pepper in

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the 1860s, has recently been revived and is employed for overlaying visual elements onto a real physical structure to obtain a "holographic" impression.

Second, a hologram can also be considered as a storage device of the information of an object in its structure. The principle of holography is relying on the physics effect of interference, which is created by the overlap of light coming from the object with a so-called reference wave. The transfer of the resulting light structure into a physical change in a hologram, i.e. by exposure of a film or modifying the depth of a material, can be considered as a process of storing optical information into a material.

Third, the structure of a hologram is different from the structure of an image. Whereas in a photography—being on a classical silver halogenide paper or a digital representation of bits—each area or pixel refers to an area in the object being imaged, a hologram does not reflect the object in such a direct way. Since its generation is based on light interference, the spatial variation within a hologram mimics the interference structure and thus encodes the information of an object in a distributed way throughout its transverse face (Lauterborn & Kurz, 1993). Consequently, a hologram does not represent the image of an object as we know it from photography, but encodes image information in such a way that is can only be decoded if the reference wave is known. In terms of information encryption, holograms encode data in an inherently and highly secure way (Denz, Müller, Visinka, Berger, & Tschudi, 2000).

Since the 1990s and the beginning of the new century, holograms have thus been considered as a unique approach to store information data safely, in a naturally encrypted way, and with a tremendously high capacity. Instead of using holography to store object information, scientists started to store patterns of black and white areas representing digital data, thereby creating a paradigm change to store digital instead of analogue data (Heanue, Bashaw, & Hesselink, 1994).

Digital holographic data storage has a number of advantages over classical data storage on magnetic tapes or compact disks. Whereas in these techniques data are stored in a serial way, holography allows storing data in parallel on a so-called data page. Such a page may contain today from 2 Gbyte (High definition resolution—HD) to 8 Gbyte (ultrahigh definition resolution UHD) data if each pixel is associated with a storage unit. Since many pages can be stored at the same location by superimposing different holograms using distinct reference beams, and since these data are distributed over the whole space of the storage device, holographic data storage is considered as the most promising next generation securely encrypted data storage device (Su & Sun, 2012). Applications are typically seen in ultrahigh data storage systems as data warehousing, multimedia data or videos or data archives for weather, health or military data. Especially the ultrafast data recovery with a rate of many Gbits per second makes holographic data storage well suited for on-demand data streaming (Ashley et al., 2000).

The potential of holograms also to be stored on the surface of materials has opened a second area of applications that has become as important as high capacity data storage in the first years of this century: holograms embossed on goods and paper can be used to encode information about these things, and thus are an ideal means of protecting goods from forgery, fraud and counterfeit (tesa scribos GmbH, 2018). Especially the potential to superimpose a hologram containing data with a watermark hologram reconstructing a 3D image, thus cloaking the information, has boosted applications in consumer goods as well as in data protection of paper-based administration documents.

By these approaches of holographic data handling it becomes obvious that cutting-edge data management in information systems also include techniques of holographic data storage. One of the pioneers in establishing holographic approaches in information systems is Jörg Becker, who paved the way to use embossed holograms for paper-based customs and tax declarations in order to combine original digital system data with a unique holographic label.

2 Structures with Light: Holography in a Nutshell

2.1 From Two-Dimensional Images to Three-Dimensional Structures

The idea to understand how three-dimensional perception works in order to exploit it dates back to 280 AD when Euclid recognized that depth perception can be obtained when each eye simultaneously receives one of two dissimilar images of the same object. Much later, Leonardo da Vinci studied the perception of depth, and, unlike most of contemporary artists, used shading, texture and viewpoint projection in order to create a three-dimensional impression in his drawings. Around 1600, Giovanni Battista della Porta produced the first artificial 3D drawing based on Euclid's idea with two different stereoscopic parts. However, his drawings were lost, such that when in 1611 Kepler's Dioptrice was published, a detailed description of the projection theory of human stereo vision was witnessed.

With the invention of photography, the idea of stereoscopic imaging boosted. In 1838, Sir Charles Wheatstone invented the stereoscope to give depth to images. His device presented two offset images separately to the left and right eye of the viewer (Fig. 1, left). These two-dimensional images were then combined in the brain of a viewer to give a perception of three-dimensional depths. Since Wheatstone's original invention was rather complex, Sir David Brewster invented in 1849 a lens-based stereoscope which reduced the size of the stereoscope and allowed to create hand-held devices which were one of the highlighted inventions in the world exhibition in the crystal palace 1851 in London (Fig. 1, right).

The discovery of colour-coded, anaglyphic stereoscopic images appeared in the 1850's as the result of experiments by the French scientist Joseph D'Almeida. Colour separation was achieved using red/green or red/blue filters. With the invention of plastic colour filters, anaglyphic films became a huge success in the 1920's. It was not until 1932, when Edwin H. Land patented a stereoscopic approach based on polarization, the direction of the oscillation of the electric field of the light. This marked the breakthrough in three-dimensional cinema, and is still the principle of

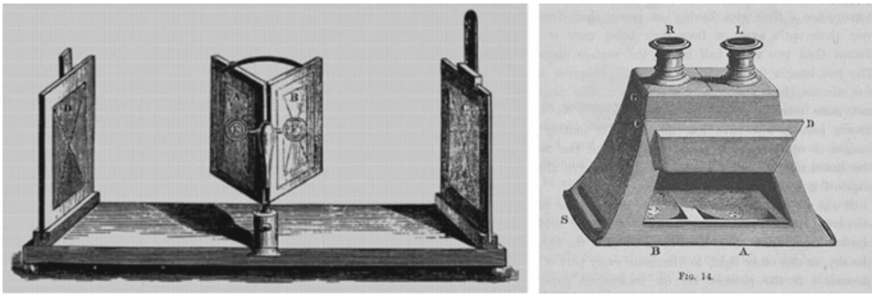

Fig. 1 The first apparatus for three-dimensional image observation dates from 1838, the Wheatstone mirror stereoscope (left) (Wheatstone, 1838), and its development into a hand-held device by David Brewster in 1849 (right) (Brewster, 1856) which is similar to the iconic View Master that has been put on market in the early 1960s

nowadays 3D cinema, especially since cheap and reliable polarization glasses can be employed. With the development of photography and film and its paradigm change to digital imaging, 3D imaging became a considerable commercial movie market and also enlarged its possibilities. Today the movement has blossomed from movies to gaming and even learning.

This in turn paved the way to modern devices that do no longer rely on discriminating two view of a scene to the two eyes, but display light scenes within a certain areas in three dimensions by superimposing image projections. This idea goes back to Pepper's ghost technique. This visual illusion is based on superimposing an image with its twin that is reflected by a 45-degree oriented mirror. The superposition can be shifted in such a way that under certain viewing directions a 3D image is seen. If images from three of four directions are superimposed, the 3D illusion in a certain area of space is almost perfect. Having had its impressive inauguration in a large projection unit in fashion when Kate Moss appeared as an advanced video projection in Alexander McQueens "Widows of Culloden' show in fall 2006 in Paris, the concept of ghost projection by a pyramidal structure is now famous as the "hologram" technique to create 3D videos out of smart phone or tablet readers. The simple approach can even be realized by a self-made device.

However though being impressive projections, its nature is not holographic, but advanced stereoscopic viewing.

2.2 Holography for Three-Dimensional Image Representations

Holography dates from 1947, when Dennis Gabor, a native Hungarian British scientists was trying to improve the resolution of electron microscopes (Lauterborn & Kurz, 1993). Gabor coined the term hologram from the Greek words holos, meaning

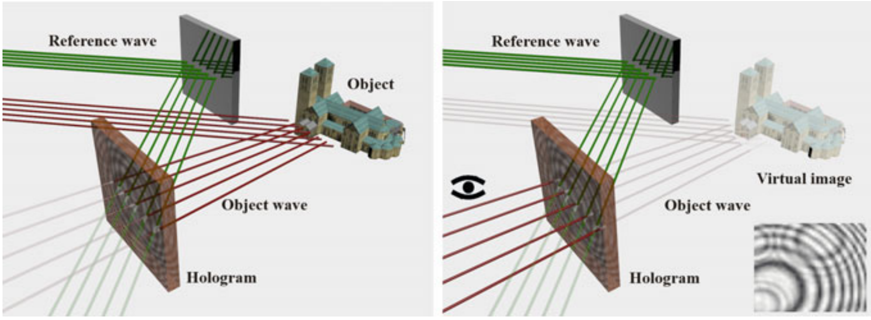

Fig. 2 Principle of holographic recording (left) and reconstruction (right), leading to a hologram that contains the stored information in a distributed, encrypted way (inlet. right)

"whole," and gramma, meaning "message". His approach of superimposing a bad electron image with scattering light in order to create a photo plate that recovers the original image in a better way was later on known as inline holography. Further development in the field however where precluded during the next decade because light sources available at the time were not truly monochromatic or one-color, from a single point, and of a single wavelength in order to make further use of the concept.

This situation was overcome with the invention of the laser in 1960, whose features, being a high-intensity light source with a fixed wavelength that is well collimated, were ideal for fabricating holograms. Shortly after, in 1962, Emmett Leith and Juris Upatnieks developed Gabor's technique into an off-axis holography that allowed to separate the object and its 3D image such that the observation of the holographic image become possible by the eye or a camera. Leith and Upatnieks' iconic transmission hologram of simple 3D objects (a toy train and bird, Fig. 3 left) witnessed imaging with clarity and realistic depth but required laser light to view the holographic image.

This pioneering approach is the principle of holography today and is illustrated in Fig. 2. It relies on separating a laser into a wave directed to an object, and a reference wave. Both beams are superimposed on a photosensitive material, either a photographic plate, polymer or even a solid state material. The superimposed beams create an interference structure as shown in the inlet in Fig. 2 that highlights the nature of a holographic storage: information is not registered in a point-by-point way as it is the situation for photography, but in a distributed way. Only in the second step of holography, the reconstruction, the 3D image is recovered. For this purpose, the reference wave is directed onto the hologram plate, and reconstructs the image of the object as a virtual 3D image at the same place where the object was positioned during hologram recording.

Also in 1962, Yuri N. Denisyuk combined holography with 1908 Nobel Laureate Gabriel Lippmann's work in natural colour photography such that hologram reconstruction became possible with white-light reflection.

Fig. 3 Iconic holograms: Bird and train by Leith and Upathnieks, 1964 (left) (Leith & Upathnieks, 1964) and the "rainbow" version of Benton around 1968 (right) (Benton, 1975)

The subsequent advance that was achieved by Stephen A. Benton in 1968 who invented white-light transmission holography based on polymeric films (Benton, 1969) (see Fig. 3, right) while working with Polaroid company paved the way for holography becoming a new tool in art photography and a popular public attraction (Johnston, 2004). Benton's invention is particularly significant because it made mass production of holograms accessible using an embossing technique. These holograms are "printed" by stamping the interference pattern onto plastic. The resulting hologram can be duplicated millions of times in a cheap way. From an information systems aspect this step is the most important towards application of holograms in publishing, advertising, and banking industries.

2.3 Holographic Data Storage

From an information science perspective, the signal wave in holography can be considered as an information-carrying signal, whereas the reference is designated to be a simple wave that reproduces the signal (Ashley et al., 2000; Coufal, Psaltis, & Sincerbox, 2000). The two waves travel different paths, and are overlapped on the light sensitive holographic medium, where the interference pattern between the two waves is recorded. A key property of this interferometric recording on the hologram is that the signal wave is reconstructed upon illumination with the reference beam. In terms of physics, some of the light is diffracted by the hologram from the straight path of the reference wave to "reconstruct" a weak copy of the signal wave. If the signal wave was created by reflecting light off a 3D object, then the reconstructed hologram makes the 3D object appear behind the holographic medium. If the signal is an information data page, the reconstruction will make the stored data being recovered "at once", in a parallel read-out process, by the reference wave. When the hologram is recorded in a thin photosensitive material, the readout wave can differ from the reference wave used for recording in terms of direction, and the 3D scene will still appear.

When the same hologram is recorded in a thick material, the portion of incident light diffracted into the direction of the object wave depends on the similarity between the readout and the original reference wave. A small difference in one of the parameters of a wave, either the wavelength, the angle or the phase of the readout wave is sufficient to make the holographic reconstruction effectively disappear. The sensitivity of the reconstruction process to these small variations in the wave increases, approximately linearly, with material thickness. Therefore, by using thick recording materials, the hologram is a sensitive unit, and one can exploit the parameter dependence to record multiple holograms—a technique known as hologram multiplexing. A second hologram recording with a different signal can be achieved with a reference wave that differs from the reference wave of the first hologram by angle, wavelengths or phase. Thus, pairs of characteristic, unique signal and reference waves can be stored in the volume of the hologram material. The two signals can be independently accessed by changing the readout laser wave with respect to this parameter. As an example, for an 1 cm hologram thickness, the angular sensitivity is one over a few thousand. Therefore, it becomes possible to store thousands of holograms within the allowable range of reference wave angles by multiplexing. The maximum number of holograms stored at a single location to date is 10.000 (Psaltis & Burr, 1998). Wavelength tuning has also been successfully used, and phase encoding of volume holograms has the advantage of having no moving parts and allowing information processing of reconstructed data (Denz, Dellwig, Lembcke, & Tschudi, 1996; Denz, Pauliat, Roosen, & Tschudi, 1991)

To develop volume holography into a competitive storage technology (Curtis, Dhar, Hill, Wilson, & Ayres, 2010; Heanue et al., 1994), the digital data to be stored must be imprinted onto the object wave for recording in the volume of the storage medium (see Fig. 4). Later, they are retrieved from the reconstructed object wave during readout. The input device for the system should be able to store a two-dimensional page of digital data. A respective device is called a spatial light modulator, or SLM. The SLM is a planar array of thousands of pixels. Each individual pixel represents an independent optical switch that can be set to either block or pass light. The output device is a similar array of detector pixels, such as a CCD camera or a CMOS pixel array. The object wave often passes through a set of lenses that image the SLM pixel array onto the output pixel array, ensuring effective data handling and maximized storage capacity. Thus, a storage page can store 2–8 Mbyte of data, depending on the resolution of the SLM which nowadays can reach ultra high density (UHD) data capacity. The hologram can be formed anywhere in the imaging path between the input pixel array and the output pixel array. To maximize the storage density, the hologram is usually recorded where the object beam attains a tight focus, realizing storage volumes below 1 mm^3. Since about 1.000 pages can be formed in one location, several ten Terabyte of data can be stored in a storage volume of the size of a sugar cube (Denz, 1999a, 1999b).

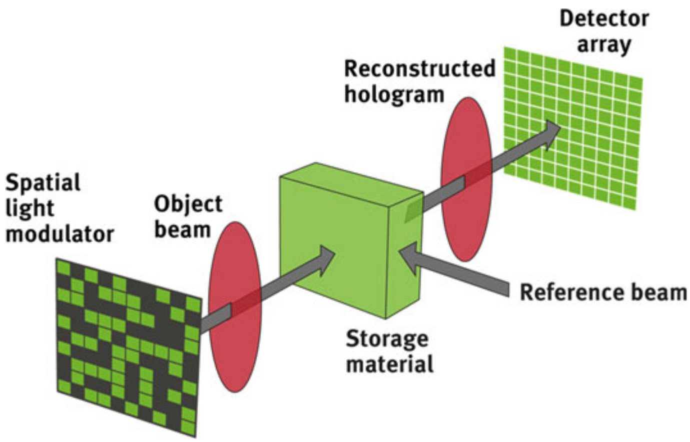

Fig. 4 Principle of holographic data storage: a page of digital data, impressed on the object wave by a spatial light modulator, is stored in a volume storage material. Subsequent reconstruction by the appropriate reference wave results in the reconstructed data

3 Data Encryption and Security by Holography

With the ever increasing importance of information security, optical data and image security has become increasingly important in many current application areas. Images can be secured in different ways. On the one hand, an image as a data page in volume holographic data storage can be secured in a first instance by holography itself based on its distributed storage principle. The nature of volume holography also allows to encode every data page to be stored with different phase codes such that a combination of angular and phase encoded data storage represents a highly secure code.

On a second stage, image security may include optical image encryption, image hiding and image watermarking which especially utilizes the parallel features of optical data storage. Among the most successful image encoding techniques is random phase encoding that distributes arbitrary phase keys over an image or a data page.

Especially for embossed holograms (see Fig. 5), overlaying the digital hologram with an image hologram containing a company label or other images as watermarks has been identified as an excellent tool for high security hybrid encryption. It especially useful if the object to be labeled is a paper document since an embossed hybrid hologram thus represents a characteristic label as well as a fixed security label.

Finally, in a third stage, all digital data that are included in a holographic data page can be encoded and secured with classical private symmetric or public asymmetric keys. Typically, in optical data storage, classical reliable key generators as triple Data Encryption Standard (DES), Advanced Encryption Standard (AES), or Rivest-Shamir-Adleman (RSA) key encryption are used. The nature of formatting digital data on a two-dimensional page makes optical data encoding especially well-suited to use innovative encryption techniques as Blowfish or Twofish.

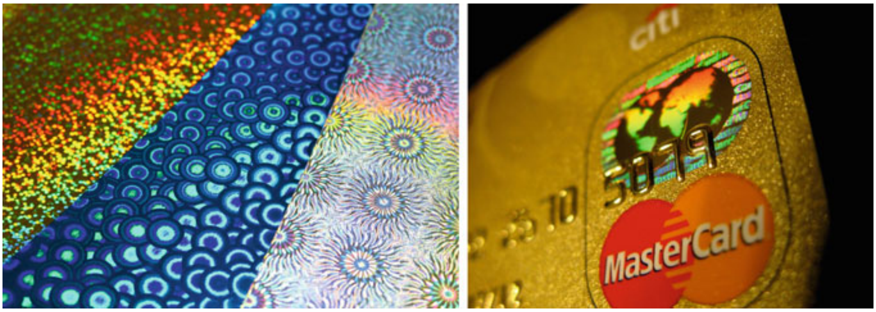

Fig. 5 Examples of embossed holograms as artwork or security labels. Public domain

Since attacks are constantly evolving, up-to-date security approaches combine different schemes to safekeep from hacker attacks. Also, so-called honey encryption which add up fake data for every incorrect guess of the key code, can be implemented in optical systems as well as multiple level encoding techniques that are inherent to optics and quantum optics.

4 Structuring Security Labels for Luxury Goods and Federal Declaration Documents

Counterfeit, piracy and plagiarism are actions threatening national security. While counterfeiting is representing an industrial property infringement that includes illegal manufacturing of objects and goods that affects primarily the luxury goods market, in particular perfumes and cars, the medical market and design, piracy and plagiarism are breaching copyright and related rights and are headed against print documents as well as electronic data. Especially the latter ones touch on the one hand governmental rights and rules in terms of legitimization of documents as passports, tax or customs documents, and on the other hand moral and material interests of authors or creators of any scientific, intellectual property, literary or artistic work (Europol, 2017).

Thus, the development of security labels has become a huge market in the past ten years. The search for highly reliable, non-reproducible safety labels that contain information about the item protected as well as characteristic labels. Forgery-proof labels are urgently searched for, and holographic labels have been forthcoming as an ultimate solution. Their cryptographic and holographic features allow to implement a multi-level 3D code that contains as well security or originality data as well as 3D labelling, thus uniquely identifying a product or document that refers to its original nature. It can be considered as a novel, data-based fingerprint that distinguishes products from their imitations and original documents from their copies. The data code introduced into the label allows tracking and identifying production charges and locations, delivery pathways, and receiver identities.

Within a pioneering project uniting information systems experts, encryption experts and physicists, a machine-readable holographic multilevel label based on embossing holograms on paper and product surfaces was developed for use in pharmacy, car documents, personal documents and documents with high security requirements. A special feature of such a hologram is its high information density even on a single layer allowing for data redundancy, its highly safe encryption that can be asymmetric, as well as the overlaying visual holographic imaging. In addition, the distributed storage of holographic data allows reading data even when an attempt to destroy them is undertaken. Its realization as a multi-level embossed hologram still makes its production cheap and enables fabrication for the mass market.

5 Conclusions and Actual Developments

The concepts developed in the 1990s and early 2000 years by the author together with a consortium including information systems expert Jörg Becker are today even more actual than ever. Globalized markets, word-wide value-added chains and distribution of goods via the internet contribute to a continuous increase of forgery and counterfeit. Also, counterfeit merchandise comes closer and closer to their respective originals. In the past years, European customs have confiscated more than 40 Million of goods and identified more than 90.000 forgers. Among the goods that have been mostly copied are cigarettes, alcohol, perfumes, toys, food, and luxury packaging (Europol, 2017).

Thus, holographic security labelling found especially applications when using cheap polymeric materials combined with the safety of holographic data storage. Techniques based on spatial light modulators and embossing devices allow to realize multi-level approaches in thin materials. Among the application areas, holographic labels for perfumes, high-end alcohol and pharmaceutical products are forthcoming. Product labels as Tesa VeoMark (Tesa scribos GmbH, 2018) are witnessing the spreading of the approach.

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Cornelia Denz has obtained her Ph.D. in physics at Darmstadt University of Technology on optical neural networks which she partly realized at the Institut d'Optique in Orsay, France. It was honored with the Lise Meitner award of the state of Hessen in 1993. This thesis laid the foundation to phase-encoded holographic data storage. After her habilitation on pattern formation in nonlinear optics in 1999 she became a professor at University of Muenster. Since 2003 she is director of the Institute of Applied Physics. From 2010 to 2016, she was a Vice-Rector for International Affairs and Young Researchers of the University of Muenster. Cornelia Denz is an author of more than 250 publications in peer-reviewed journals, three books and numerous book chapters. She is a fellow of the Optical Society of America and of the European Optical Society. She is a member of the Academy of Science and Arts of the state of North Rhine-Westphalia.

Data Structures in Medicine—On the Road to Data Standards

Martin Dugas

1 Introduction

An information system is characterized by three types of models: a governance model, a process model and a data model. An appropriate level of structure is of key importance for all these models. Jörg Becker performed important scientific work in the field of process modelling and published key textbooks related to the process aspects of information systems such as Becker, Kugeler and Rosemann (2012).

Data models of information systems are specific for certain domains. My work is focussed on data models in the field of medicine. The health economy plays a major role from a business perspective: As of 2016, in Germany 5.5 million people, i.e. every 8th employee, is working in healthcare with an increasing trend.[1] Medicine is highly complex: The Systematized Nomenclature of Medicine (SNOMED) contains approximately 800.000 medical terms (non-synonymous ~300.000); for comparison: the language of Johann Wolfgang Goethe consists of ~75.000 terms. The International Classification of Diseases in Medicine (ICD) contains more than 13.000 diagnoses, and for each diagnosis other data elements are relevant. In addition, data structures in medicine are language-dependent, because medicine is practiced in the local language, i.a. from a global perspective in more than 100 languages.

Structured medical data is key for medical information systems: It is needed for administrative tasks like billing, routine patient care, medical quality management, medical research as well as clinical decision support. Medical data structures are not only complex, they change over time due to medical progress.

In the following sections, the approach of the Portal of Medical Data Models (Dugas et al., 2016) regarding data structures is presented.

[1] https://www.bundesgesundheitsministerium.de/themen/gesundheitswesen/gesundheitswirtschaft/gesundheitswirtschaft-als-jobmotor.html.

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2 Methods

Data is typically structured in entities and related attributes (also known as items or data elements), for example "size" of an object. However, such textual descriptions of attributes are ambiguous. Figure 1 presents three completely different types of size. This ambiguity is a major challenge for implementation of information systems. For example, in data warehousing different data sources need to be integrated. When data attributes are ambiguous, laborious and error-prone manual mapping of attributes is required. This problem is aggravated by the dynamics of data structures: data models change over time. To mitigate this problem, *semantic annotations* should be added to data attributes (Dugas, 2014).

In the domain of medicine there are well-established terminologies which can be used for semantic annotation. The largest system for medical terminology codes is the Unified Medical Language System (UMLS[2]), which is maintained by the US National Library of Medicine. It contains more than four Million codes, which are derived from>100 source terminologies. For instance, UMLS code C0011900 denotes a diagnosis attribute in a language-independent manner. But even four Million codes are not enough to describe all medical data attributes in detail. For example,

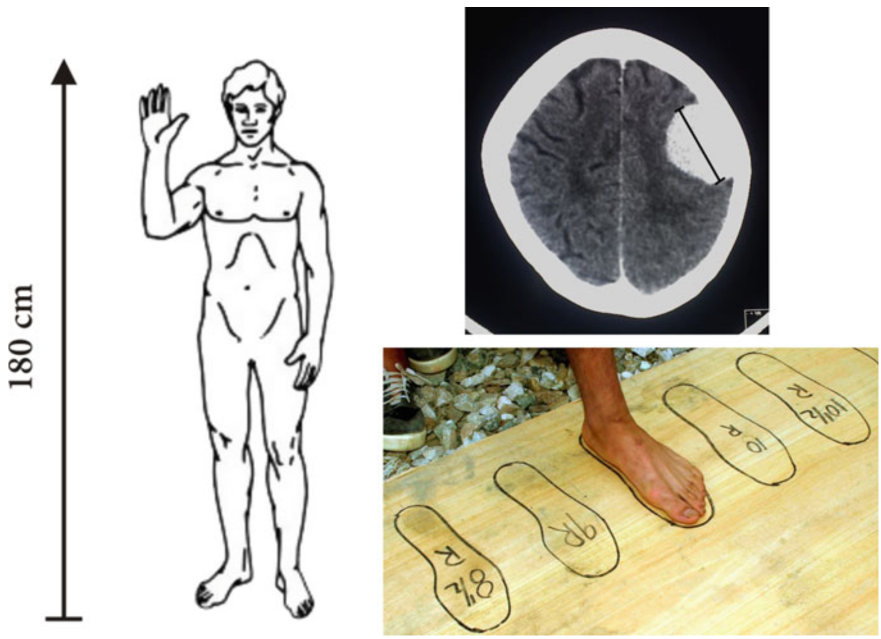

Fig. 1 The term "size" is ambiguous: It can refer to body height, tumor size or shoe size. Therefore additional semantic annotation is required to resolve this ambiguity

[2]http://www.nlm.nih.gov/research/umls/.

a data item "patient has side effect X from drug Y yes/no", cannot be coded with one UMLS code, simply because there are too many combinations of side effects and drugs. In such situations, a combination of UMLS codes can be used for precise semantic annotation; this procedure is called post-coordination of semantic codes, in contrast to pre-coordination of codes, when one code is sufficient.

Another important aspect of data structures is *transparency* of data models. There are very many (in fact, astronomically) ways to build similar, but incompatible data models. For example, the severity of a symptom can be graded on a scale 1–5 or 1–4. There can be a long discussion, what type of data structure is most appropriate in a given setting—however, when there a two data sources with different data structures, data merging is only possible with high information loss through transformation or even impossible. To overcome this problem, a discussion and consensus between all stakeholders is needed, what type of data structures should be used for a given setting. To enable this standardization process, transparency of data models is a prerequisite. Finding the right balance between highly structured and simple data models with only few attributes is a challenge, because there are different needs of the various stakeholders of information systems. Typically, data producers prefer few and loosely defined data attributes—to minimize the data collection work-, while data consumers are in favor of highly structured and high quality data attributes. Again, transparency of data models is needed to foster the dialog between data producers and data consumers in the design phase of an information system. In the domain of medicine the need for transparent data models was elaborated in the Memorandum Open Metadata (Dugas et al., 2015). To foster the development and application of transparent medical data models with semantic annotations, the Portal of Medical Data Models (Dugas, 2018; Dugas et al., 2016) was developed, which is described in the following sections.

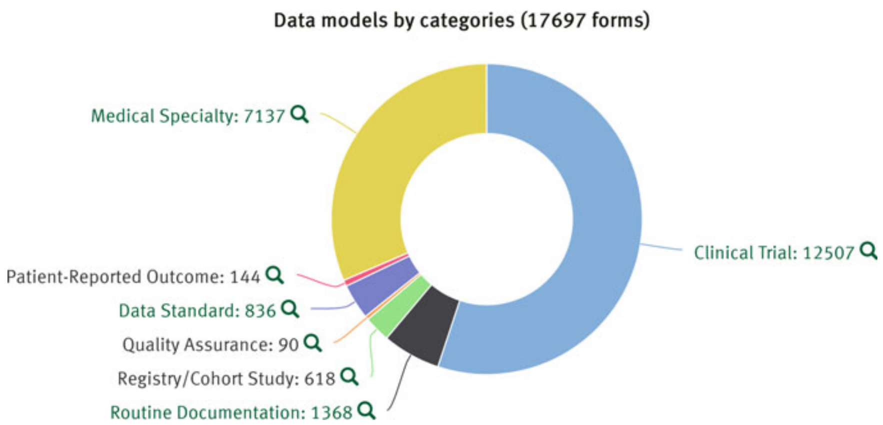

Fig. 2 Overview of the portal of medical data models (MDM-Portal—Dugas, 2018). Most data models (n = 12.507) belong to medical research (clinical trials). 7137 models belong to dedicated medical specialties, such as oncology, cardiology etc.

3 Results

The MDM-Portal is a system for creating, analyzing, sharing and reusing medical data structures. As of 2018, it constitutes Europe's largest collection of medical data models with >17.000 documentation forms and >400.000 data attributes. It is available on the Internet at https://medical-data-models.org. Figure 2 provides an overview of available contents. It is a registered information infrastructure, dedicated to support integration of routine patient care and medical research. A flexible search engine (Fig. 3) supports the users to identify the best matching data model for a given setting. Various filter options (such as categories based on Medical Subject Headings) are available; user ratings are also taken into account to extract search results. Of note, published data standards in medicine can be selected. A review process was established to indicate draft, active and deprecated data standards. Figure 4 presents a simple example of a data model with five attributes. This is a standardized questionnaire, which was developed by the World Health Organization (WHO) in 30 different languages. Figure 5 presents more details on this model, in particular semantic codes. It also demonstrates the multilingual features of MDM portal. The portal only contains metadata, no individual patient data. All data models can be exported in several technical formats (Fig. 6) to support implementation in local information systems on various technical platforms. A metadata registry (MDR) component is available which enables to find most frequent data element definitions and thereby supports the design phase of new information systems (see Fig. 7).

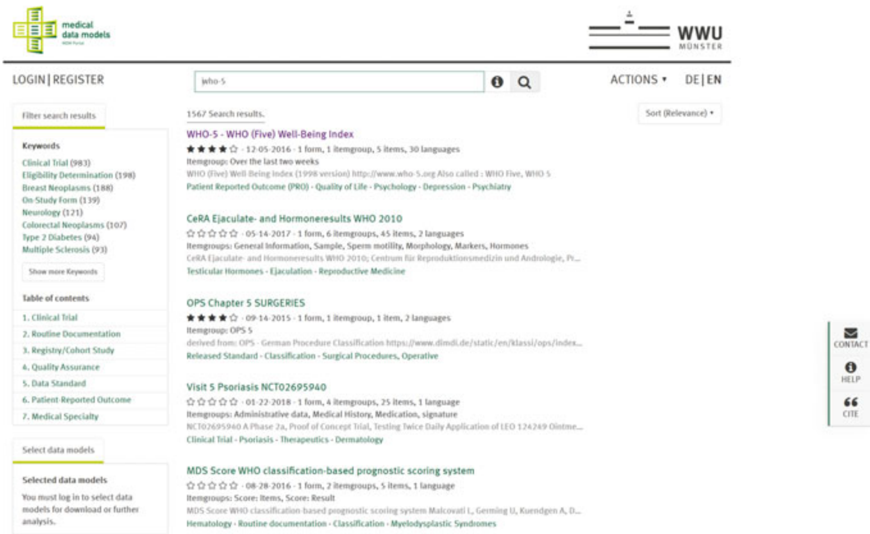

Fig. 3 Example for the search functionality of the MDM-Portal. (Dugas, 2018) Data models can be found via search string, keyword or table of contents. A user rating (0–5 stars) helps to find highly-rated data structures

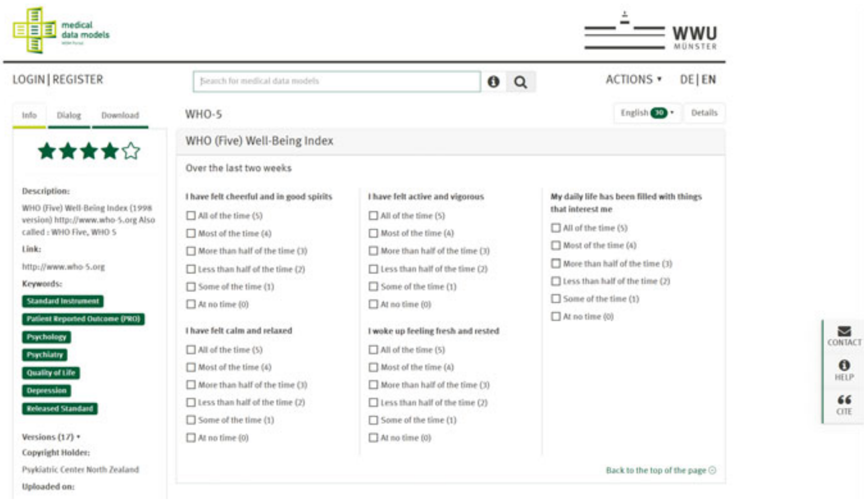

Fig. 4 The WHO-5 questionnaire for quality of life (QoL) is presented. It is available in 30 languages. These five data items can be used to calculate a QoL score for patients

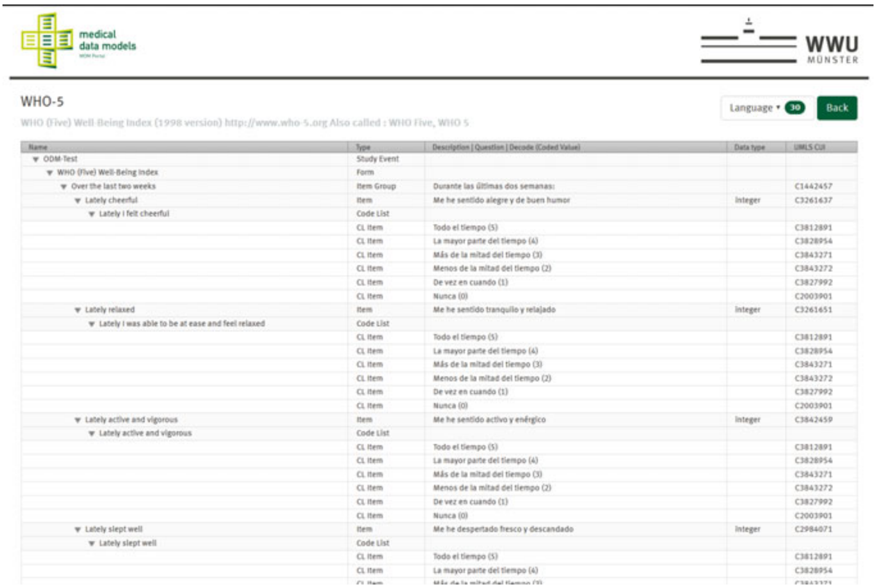

Fig. 5 Detailed view of the WHO-5 questionnaire. The right column contains semantic codes (UMLS) for each attribute and all code list items

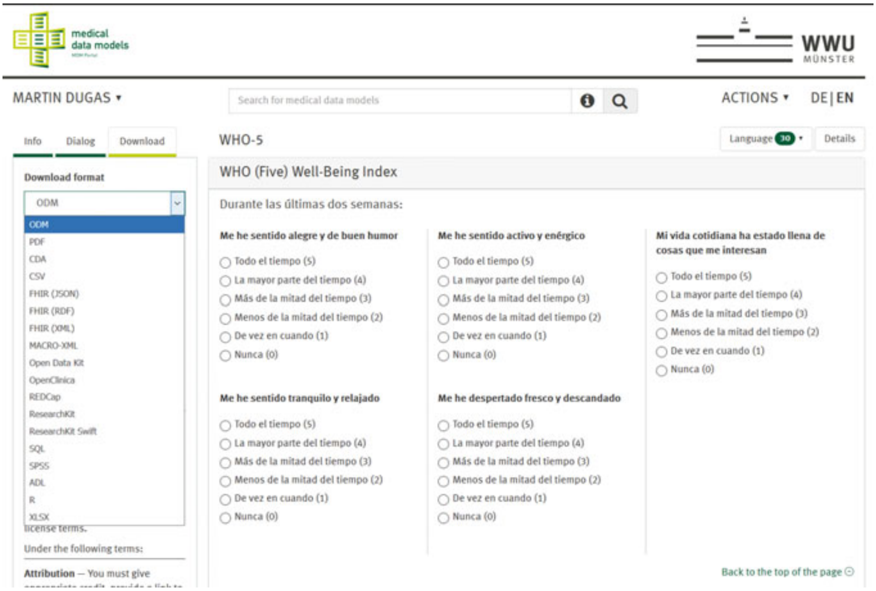

Fig. 6 Download formats for medical data models: 18 formats are available to foster implementation in different system environments

MetaData Registry (MDR): Data Elements of MDM English

Item Name weight (e.g. weight, height, pulse, ASA, temperature, systolic blood pressure, age, potassium)

Showing 1 to 10 of 1,625 entries

Frequency	Data element	Data type	Range check	Unit	Values	Semantic Code	Models
175	Weight	FLOAT		kg		C0005910	
33	Weight	FLOAT		Kg		C25209, C0005910, C16960, C25208	
61	Weight (kg)	FLOAT		Kg		C25209, C0005910, C16960, C25208	
20	Body weight	FLOAT	>=0	kg		C0005910	
40	Body weight	FLOAT		kg		C0005910	
15	Weight	FLOAT		kg		C0005910	
13	Weight	TEXT		kg		C0005910	
10	Weight (in Kg):	FLOAT		Kg		C0005910	
12	Weight	FLOAT		kg		C0005910	
12	Weight	TEXT				C0005910	
Frequency	Data element	Data type	Range check	Unit	Values	Semantic Code	Models

Show 10 entries First Previous 1 2 3 4 5 ... 163 Next Last

Fig. 7 MDR-component: What is the most frequent definition for a certain data element? In this example, weight is presented. This tool is applied to foster data standardization

4 Discussion

This work is about structuring of medical data. It started in 2009 as a bachelor project in collaboration between the Institute of Medical Informatics and the Department of Information Systems at the University of Münster. Nowadays it is a national DFG-funded information infrastructure and it continues to grow. Well-structured data is the basis of digitization. The selection of the best data model is a non-trivial task, there needs to be a balance between the needs of data producers and data consumers. Currently, the wheel is re-invented again and again: many similar, but incompatible data models are being generated. This problem is very relevant in medicine due to the high complexity of its data structures—but it can be assumed that similar problems exist in other domains as well. Well-structured data is key for high data quality; and high data quality is required for reliable and powerful information systems. Currently there is a large hype about machine learning and artificial intelligence. For high quality medical data sets new machine learning techniques have already shown their potential—however, even for a sophisticated artificial intelligence system the old wisdom "garbage in—garbage out" holds true.

The MDM portal follows a wikipedia-like, dynamic and democratic standardization approach: Basically, everyone can publish data models. There is no central authority to decide which data model is right or wrong. Users can discuss online, how a data model should be designed. Semantic annotation and the various search functions enable to find the most frequent data structures with best user rating for a given topic, independent of the language. This approach is well accepted in the global user community (Fig. 8).

Fig. 8 Geographical distribution of MDM users. As of 2018, more than 1000 users worldwide are registered in the system

ERCIS with the great leadership of Jörg Becker can play an important role to bring the idea of well-structured, open data standards on the European Level and to make it sustainable, which is key for the success of digitization in medicine and beyond.

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Big Data Research—How to Structure the Changes of the Past Decade?

Mathias Eggert

1 Introduction

The analysis of data fascinates many IS researchers all over the world. Consequently, the community publishes a lot in the area of data analyses, also known as Business Intelligence (BI) or Management Information Systems. In the past decades, analyses of data focussed mainly on the collection, extraction and representation of structured data within organisations (Chaudhuri, Dayal, & Narasayya, 2011; Turban, 2008). Until the early 2000s, the use of new technologies like the Internet of Things (IoT), RFID and smart phones with its opportunities to generate data grew steadily. In 2011 the Economist announced that the number of smart phones and tables surpassed the number of PCs (The Economist, 2011). This development opens many new research opportunities for IS researchers that are addressed in the article.

Against this background, Chen, Chiang, & Storey (2012) determine three evolution phases of Business Intelligence and Analytics (BI & A) and data analytics. Evolution phase 1 (BI & A 1.0) comprises the analyses of structured data and the creation of standard reports within a company. BI & A 2.0 comprises the analyses of data that comes from the web and that is unstructured, such as videos and music files. BI & A 3.0 addresses the evolution of iot and the spreading of smart phones and its effects on the data volume (Chen et al., 2012). Based on the three evolution phases introduced by Chen et al. (2012), the article at hand presents a research framework for structuring current IS research work in the area of BI & A 3.0 and for identifying research gaps.

The article is structured as follows. The second chapter briefly introduces BI & A 3.0 and gives an overview about the evolution of Big Data. In the third chapter, current literature reviews in the area of BI & A are analysed regarding its structure and content

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in order to argue for the relevance of a new research framework. Chapter 4 comprises the research framework and its exemplary application. Chapter 5 summarizes the results and provides an outlook for ongoing research work.

2 Research Background

2.1 Business Intelligence and Analytics

Turban (2008) defines Business Intelligence as an umbrella term that comprises architectures, tools, databases and methodologies. The term has many different meanings. For example, Chen et al. (2012) highlight the different data types that might be analysed by BI approaches. Wixom and Watson (2010) state that BI supports decision making processes by combining organization internal and external information. Thus, BI is more than just the extraction and representation of data. Moreover, the basic goal of BI is to analyse data in order to generate new knowledge and to support decision processes.

Dicision support is one of the main uses of BI systems. Many IS researchers focus on the design of decision support systems and to investigate the effectiveness of BI systems (i.e. Arnott & Pervan, 2008; Nunamaker, Dennis, Valacich, & Vogel, 1991; Wixom & Watson, 2001). All of them have in common that they search for new ways to support decisions. Figure 1 comprise the five basis steps that are necessary to extract information from data and to use them for decision processes.

For Chen et al. (2012), BI & A are closely related to each other. Their differences are so small, so that the authors recommend to use both terms at once. The difference between business intelligence and business analytics lies in the analytical power that is inherent in describing and understanding data in Business Intelligence. Business analytics goes beyond descriptive statistics. The applied statistical optimization and prediction methods are more complex. Improving decisions is the common goal of both (Laudon, Laudon, & Schoder, 2016). Davenport (2013) argues similarly. For him, reporting (mainly reporting on the past) is the core task of Business Intelligence. The prediction of future developments or the detailed discussion of reports is, however, task of Analytics.

Fig. 1 Information value chain (Adapted from Abbasi, Sarker, & Chiang, 2016)

2.2 Evolution Phases

Business Intelligence and Analytics 1.0

The first stage of evolution of BI & A took place between 1990 until to the early 2000s. The main goal to centralize the data flow within the organization. For this purpose, non-connected individual systems, which handle, for example, everyday business transactions, are integrated. Individual systems process and extract the mostly structured data and store them in data warehouses or data marts. The applied statistical methods are mainly based on descriptive statistics rather than on predictive statistics (Chen et al., 2012).

Business Intelligence and Analytics 2.0

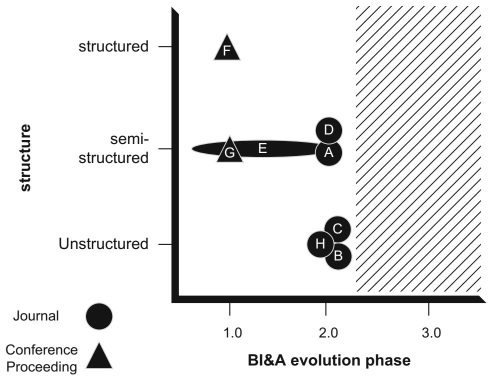
With the spread of the Internet in the 2000s, a new evolutionary stage evolves. The Internet and related technologies are opening up new, different types of data. These data, called big data, are characterized by three main characteristics: Volume, Velocity, Variety (Chen et al., 2012; Davenport, 2013; McAfee & Brynjolfsson, 2012). *Volume* refers to the enormous amounts of data that are generated by countless data sources and that organizations have to deal with. *Velocity* describes the speed of generating and processing data. *Variety* comprises the variety of data types and sources. From the perspective of an organization, this means the enrichment of internal systems with external sources. Growing demands lead to the proliferation of new systems that provide the software and digital infrastructure from external service providers over the Internet. An important technology for linking internal and external data, processing various types of data, and large volumes is Apache Hadoop. It represents the requirements of BI & A 2.0 and its systemic implementation (Zikopoulos, 2012).

Business Intelligence and Analytics 3.0

Since the 2010s and the massive spread of Internet-enabled devices such as smartphones and tablets, the evolution phase is called BI & A 3.0 (Chen et al., 2012). Many everyday objects are connected to the Internet and can generate many data via sensors. These devices are part of the so-called Internet of Things. These data are largely generated by sensors, which usually have a permanent data flow. Networked sensors and actors are the basic elements of so called cyber-physical systems (Lee, 2008). The sensor-based content and data of mobile devices open up new analytics opportunities for organizations (Chen et al., 2012).

3 Literature Reviews on Business Intelligence and Analytics

Many literature reviews investigate the current state of the art in researching BI and Analytics. In this chapter, literature searches about BI & A from the last few years are analyzed with regard to the search structure and the BI & A evolutionary phases. For this purpose, I reviewed BI literature articles from 2010 to 2017. Therefore, I analyzed



A	(Akter & Wamba, 2016)
B	(Abbasi et al., 2016)
C	(Phillips-Wren, Iyer, Kulkarni, & Ariyachandra, 2015)
D	(Günther, Rezazade Mehrizi, Huysman, & Feldberg, 2017)
E	(Trieu, 2017)
F	(Kowalczyk, Buxmann, & Besier, 2013)
G	(Shollo & Kautz, 2010)
H	(Yacioob et al., 2016)

Fig. 2 Current BI & A literature reviews

the A+, A, B, and TOP 30 C journals of the journal ranking VHB-JOURQUAL 3 (Hennig-Thurau & Sattler, 2015).

The criterion *structure* has three characteristics: unstructured, semi-structured and structured. A structured review is a quantitative literature search that examines comprehensible attributes and follows a logical methodology (Vom Brocke et al., 2009; Webster & Watson, 2002). An unstructured review does not have traceable standardized characteristics. In a semi-structured review, such approaches are present to some extent. However, a consistent methodology is not applied adequately.

The criterion *evolution stage* comprises the three phases of evolution described by (Chen et al., 2012): BI & A 1.0, 2.0 and 3.0. The analyzed literature reviews might address one or more evolutionary phases of BI & A. Figure 2 represents the results.

The literature reviews B, C and H are unstructured and deal with BI & A 2.0. The reviews A, D and E also deal with BI & A 2.0. They are, however, semi-structured. Review E covers the contents of BI & A 1.0 and 2.0. Literature review G, which covers only BI & A 1.0, is semi-structured. Only one research paper (F) contains a structured literature review regarding BI & A. However, Kowalczyk et al. (2013) solely work on BI & A 1.0. Furthermore, the results provide insights into the distribution of journal and conference contributions. It is noticeable that conference proceedings tend to use a more structured research design than the journal contributions. However, only two conference contributions are included.

The results provide evidence that currently there exists no structured literature review that covers BI & A 3.0 aspects, in particular data privacy aspects. Indeed, BI & A 3.0 has not been sufficiently investigated yet. The research work at hand addresses this gap by providing a framework for a structured literature review. Chapter 4 introduces all framework categories and its attributes.

4 Framework for Big Data Research

4.1 Framework Development

With the help of a so-called concept matrix (Webster & Watson, 2002), researchers can meaningfully structure relevant literature. The concept matrix improves transparency and makes the process easier to understand for the reader. In addition, a structure helps to guide through the entire work.

On the one hand, the concept matrix at hand based on the describing attributes of BI & A 3.0. On the other hand, further extensions are taken into account in order to represent current developments in the research area BI & A. The concept matrix consists of seven categories: BI & A 3.0 attributes, technique, technology, research area, research method and evaluation, application area and data privacy. Figure 3 depicts the complete concept matrix with all categories and attribute values.

BI & A 3.0 attributes

The aim of this category is to check the attributes of BI & A 3.0 for their most frequent use. In Addition, this category is part of quality assurance regarding the clear assignment of an article to the BI & A evolution phase 3.0. Only articles that address one or more category values clearly count as BI & A 3.0 relevant. The category contains seven fields: sensor-based content, mobile device data, location-based analysis, person-centered analysis, context-relevant analysis, mobile visualization, human-computer interaction. All of them were derived from Chen et al. (2012).

Technique The aim of the category technique is to evaluate which techniques are used in BI & A 3.0 research outcome. For structuring the category techniques, I apply the taxonomy of big data analytics techniques presented by Goes (2014). He presents seven techniques: statistics, econometrics, artificial intelligence, computer-aided methods, linguistics, optimization and simulation. *Statistics* summarizes different quantitative methods. This includes descriptive and inductive statistics. It also

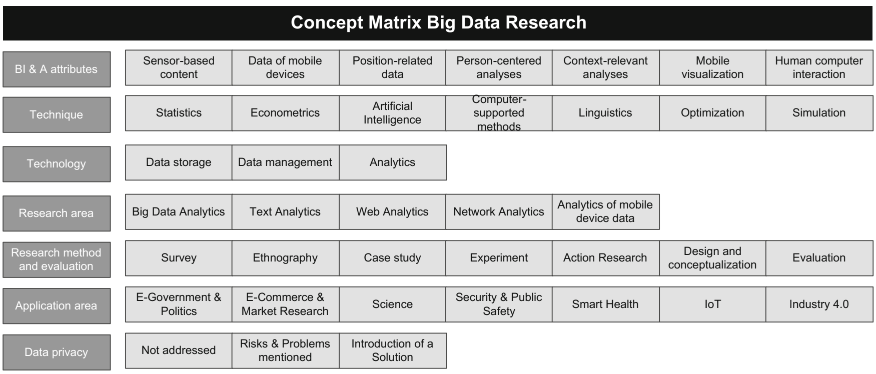


Fig. 3 Concept matrix for big data research

includes stochastics, which in turn is composed of inductive statistics and probability theory. *Econometrics* is part of empirical economic research. Economic, statistical and empirical methods are used to investigate the behavior of market players in the economy. Crucial is the quantitative nature of the models and forecasts (Dreger, Kosfeld, & Eckey, 2014). *Artificial Intelligence* is the computer-aided processing and evaluation of data whose performance can be improved without direct intervention by programmers (Laudon et al., 2016, p. 669). *Computer-aided methods* are methods that are not done by human intervention alone, but by the convenience of computers. *Linguistics* deals with human language in different forms. These include, in addition to many other manifestations, both the spoken and the written language (Carstensen et al., 2010). *Optimization* is the process of finding optimal solutions for problems. With regard to BI & A, there are many interfaces to sub-disciplines of economics such as operations research or management science (Papageorgiou, Leibold, & Buss, 2015, p. 1–2). *Simulation* contains models of the structure of the system to be examined. The simulation user choose parameters, model boundaries and other assumptions in a way that the real environmental conditions are mapped as accurately as possible for the purpose at hand (Laudon et al., 2016, p. 63).

Technology

The category technology combines the work of Chen et al. (2012) and Goes (2014). Both researchers do no present explicit taxonomies for BI & A technologies. However, the works contain implicit categories, which I use for creating the technology category. *Data storage* refers to the physical storage of data on data storage media as well as the necessary software. *Data management* is the design and use of databases to make the data accessible for processing (Laudon et al., 2016, p. 307f). This includes, for example, data models, data management and data modeling (Chen et al., 2012). The term *analytics* includes various technologies for the evaluation, processing and preparation of data for decision support. In the context of BI & A 3.0, these include four major technologies: visualization, explanatory, exploratory and predictive analytics (Goes, 2014).

Research area

Chen et al. (2012) defined promising research opportunities for BI & A, which I adapt for the research framework at hand. It covers the categories (Big) Data Analytics, Text Analytics, Web Analytics, Network Analytics and Mobile Device Analytics. The purpose of this category is to provide a structured overview about addressed research fields and to identify research areas of less or no interest. The main research opportunities in *(Big) Data analysis* are the continuation of data mining technologies and statistical methods. *Text analysis* refers to the processing and evaluation of texts in different data formats. The possibility to create structured texts from unstructured text elements is a large field of research. Particularly mobile devices such as smartphones generate many texts whose contents can be analyzed. It is not just about the correct merging of a text. *Web Analytics* is "the measurement, collection, analysis and reporting of Internet data for the purposes of understanding and optimizing Web usage" (Web Analytics Association, 2008). The decentralization of sensor data and the data of mobile devices is a potential field of research to enable evaluations in near real-time (Chen et al., 2012). The basic paradigm of *Network Analytics* is to mine hidden patterns through mining data form an information network, which is defined as "an abstraction of the real world, focusing on objects and the interaction among these objects" (Shi & Yu, 2017).

Research method and evaluation
The category research methods and evaluation classifies research outcome among their applied research methods as well as the evaluation of the approach. The research methods in IS research represent a bundle of methods, tools and procedures for conducting scientific research. I derive six relevant research methods form Oates (2006): survey, ethnography, case studies, experiment, action research, and design and conception. The practical *evaluation* of the proposed research approach is strongly associated with the chosen research methodology. An evaluated approach applies the environment of an organization or a company in order to prove its functionality.

Application area This category comprises the application area, to which the analyzed research work contributes. I extended the five application areas of Chen et al. (2012) (E-government and politics, E-commerce and market research, Science, Security and Public Safety, Smart Health) by adding two more areas (Industry 4.0 and Internet of Things). *E-government and politics* is the application of digital technologies in public administration and politics. The mobile and sensor-based data in the field of *e-commerce and market research* provide new opportunities to analyze the behavior of market participants and the performance of products or services. In *science,* sensor data are important, because research often uses measuring instruments for experiments etc. *Security and public safety* is concerned with the functioning of state institutions, human security and data security. *Smart Health* is concerned with the digitization of the healthcare system. Hospitals can store patient data digitally and nurses might retrieve information via mobile devices. *Internet of Things* deals with objects that are equipped with different (sensor) interfaces as well as an internet connection. Companies can analyze and use new data sources to learn more about the behavior of customers or processes in the enterprise (Akhbar, Chang, Yao, & Méndez Muñoz, 2016). *Industry 4.0* is a concept that describes the digital transformation of the manufacturing industry. Especially data with a high level of detail, such as sensor data, is a key factor in the implementation of Industry 4.0 (Lasi, Fettke, Kemper, Feld, & Hoffmann, 2014; Santos et al., 2017).

Data privacy
The purpose of this category is to review the extent to which big data research addresses data protection and related issues. Data protection ensures that the personal data of an individual is not misused and that the right to informal self-determination is

respected. The concept matrix contains three forms of data protection: the research paper does not address data protection (*not addressed)*, *risks and problems* mentioned, and the *introduction of a solution* for dealing with data protection.

4.2 Framework Application

The main purpose of the research framework represented in Sect. 4.1 is to classify big data research results. In order to demonstrate the applicability of the shown framework, I analyze three relevant scientific research papers on big data (Frey et al., 2017; Han, Park, & Oh, 2016; Krumeich, Werth, & Loos, 2016). I classify the papers by applying the provided research framework.

Frey et al. (2017) conducted a field study to predict consumers interest by analyzing installed apps on mobile phones. The authors present a machine-learning model that predicts user profiles in real-time and up to 48,81% more precise than a random guess.

Han et al. (2016) present a multiple discrete-continuous choice framework for mobile app analyses. Based on large-scale data form a Korean market research agency, the authors develop a model that represent the relationship between choice, consumption and utility maximization for mobile-app consumers. The model helps to predict the usage of mobile apps.

Krumeich et al. (2016) introduce a concept for business process predictions in the process manufacturing industry based on machine sensor data. Furthermore, they present a generic architecture for a sensor-based enterprise system to detect complex event patterns. Figure 4 contains the framework application for the three exemplary research papers.

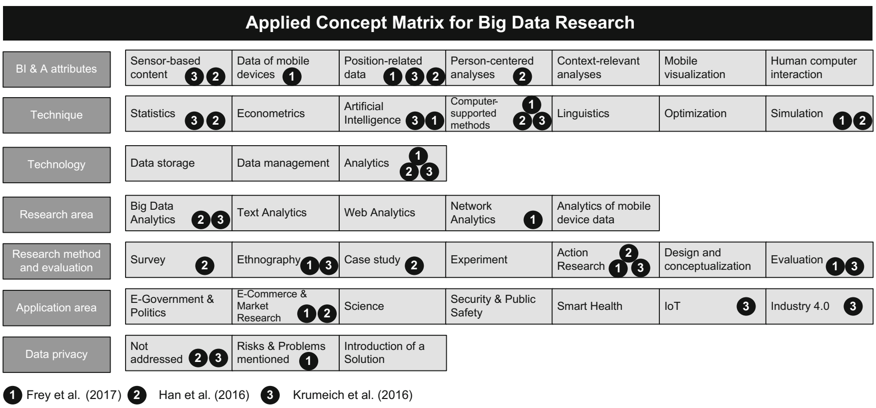


Fig. 4 Applied research framework for big data analysis

5 Summary and Outlook

Structuring IS research results in the area of big data become more and more relevant since new technologies, such as networked mobile devices and sensors took place and as new data protection regulations have been enacted. In this paper, I present the results of a search for literature reviews on big data research. So far, only Kowalczyk et al. (2013) conducted a BI literature search by using a clear structure in order to compare the different research results and to identify research gaps. However, big data analysis research moved forward and new technologies have been invented that open new room for research—in particular for IS research. Therefore, I present a structured research framework for big data research.

The framework consists of seven categories (BI & A Attributes, Technique, Technology, Research area, Research method and evaluation, Application area, and Data privacy) and enables IS researchers to structure his or her big data research output. Furthermore, IS researchers might apply the developed framework for an extended literature review in order to identify research gaps. Companies might use the framework to identify industry-relevant research results in the area of big data.

So far, I applied the framework for classifying three example papers. Thus, I could show the applicability within a small scope. Further research should be done to apply the framework on a larger scope, possibly identified with a strict and rigorous search method (Webster & Watson, 2002). The paper at hand contains the first step towards a structured overview about the status quo of big data research.

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Applications of Artificial Intelligence in Supply Chain Management and Logistics: Focusing Onto Recognition for Supply Chain Execution

Bernd Hellingrath and Sandra Lechtenberg

1 Introduction

The development of new technology has always been a driver of change. Nowadays, higher computing power, more data storage and process capabilities etc. allow for new technology- and data-enabled business models, such as online retailers or mobile app service providers (Emenike, Eyk, & Hoffman, 2016).

Emerging technologies such as the Internet of Things (IoT) or big data analytics are also changing the way supply chain management (SCM) is done and have the potential to create a digital supply chain, which can be understood as a "flexibly interconnected, complex, distributed system based on a continuous and autonomous exchange of data and information between human actors and physical, technical objects" (BVL, 2017b). Apart from the already mentioned technologies, especially methods of so-called Artificial Intelligence (AI) are expected to contribute to the digitalization in SCM. In general, the application of AI techniques to not only analyze data or automate decision-making but also to optimize the whole supply chain is considered to be highly relevant and an enabler for a supply chain's digital transformation (BVL, 2017a). Nonetheless, the question on what exactly AI is and which methods do belong to the set of AI techniques remains and has not been answered by scientific literature yet. Instead, the term AI is viewed and defined from different angles focusing e.g. on "agents that receive percepts from the environment and perform actions" (Russell & Norvig, 2010) or on "computational systems that perform tasks commonly viewed as requiring intelligence" (Poole & Mackworth, 2017). It can be subsumed, that there is no common definition of what AI is. Moreover, the understanding of "intelligent" has been changing over the years, which is described

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by the AI effect. It describes the circumstance that the notion of AI changes due to advancements in the field as well as the emergence of new technologies. If something a computer can do becomes common enough that a majority of the people are used to it, it is no longer considered as AI (McCorduck, 2004). So while approaches such as genetic algorithms or expert systems are no longer considered to belong to the set of AI techniques anymore, recent progress in the fields of information processing or sensing technology as well as the shift to a data-driven paradigm have led to major advances in the field of AI such as deep learning, reinforcement learning, robotics, computer vision or natural language processing (Stone et al., 2016).

Therefore, it is necessary to answer the questions which approaches from the field of AI are applied within the SCM domain as well as which SCM problems or tasks are addressed with AI approaches.

A first answer to these two questions has already been given based on the results of a structured literature review being presented at the 9th International Scientific Symposium on Logistics (ISSL).[1] A summary of the methodology and how it has been applied are described in Sect. 2. The results are summarized in Sects. 3 and 4.

While working on these questions, an interesting point has been noticed: Despite problems of object or image recognition are rarely discussed in the investigated scientific literature, they are considered as a suitable AI application possibility especially for supply chain execution. This observation led to the idea to extend the previously mentioned results by specifically searching for literature dealing with this approach/task combination. Hence, this paper aims at answering the following question:

What are currently researched application areas for recognition approaches in supply chain execution?

This paper aims at providing an overview of which areas within supply chain execution research is most interested in, i.e. which application cases are already existent. This knowledge might then be used as a basis for further research in order to e.g. identify more promising application cases.

Section 5 describes the way the search to deepen the initial results of the already existing paper has been done and which application areas and cases could be identified. The paper is closed with a conclusion summarizing the presented work and its most important implications as well as shortly discussing limitations and future research possibilities.

2 Methodology

A structured literature review (SLR) has been utilized to identify (i) which AI approaches are applied within the SCM domain and (ii) which SCM problems or tasks are addressed with these. SLRs aim at creating rigorous research and at making the reasoning process, which has led to results presented later on, more understand-

[1] https://www.bvl.de/issl.

able and comprehensible. The SLR presented in this paper has been based on the framework by Thomé et al. (2016) who propose a step-by-step guideline on how to ensure a rigorous literature search.

Before conducting the actual SLR, a first initial literature search has been carried out in order to identify which AI approaches are used in the SCM domain, using the very general search term "artificial intelligence" AND ("supply chain management" OR logistics) within the databases of Sciencedirect, Web of Science and Scopus. After the elimination of duplicates two people evaluated the abstract of the 1366 remaining sources independently and if at least one of those regarded a paper as relevant based on this evaluation, it has been included in the following process.

After analyzing the remaining 231 publications, five major approach-groups have been identified: (1) metaheuristics, (2) machine learning, (3) multi-agent systems, (4) recognition and (5) natural language processing. The analysis showed a strong bias towards the first group, the application of metaheuristics such as evolutionary algorithms, ant or bee colony optimization or particle swarm optimization. More than 50% of the relevant sources used an approach from this group to address a SCM problem, especially from the area of transport planning. However, the question whether metaheuristics do belong to the set of AI approaches is still discussed in research and there is no definite answer. Moreover, the high number of sources, which mainly stem from the earlier of the considered years, as well as some existing reviews (e.g. Griffis, Bell, & Closs, 2012) show that the application of metaheuristics to the SCM domain is not a new and already well researched field. Therefore the decision to exclude the group of metaheuristic approaches from the further review has been made.

The remaining four approach groups have been transformed into new approach-specific search terms in order to conduct the SLR:

("machine learning" OR "self-learning" OR "neural network" OR "support vector machine") AND "supply chain"

"natural language processing" AND "supply chain"

("image recognition" OR "object recognition") AND "supply chain"

((intelligen* OR smart OR knowledge OR reasoning) AND agent) AND "supply chain".

The search and review has been conducted in accordance again with the framework presented by Thomé et al. (2016). Out of 630 hits after removing duplicates, a final set of 153 relevant sources remained after abstract and full-text review. These have been analyzed with regard to the questions which approach they apply and which problem they address with it. A synthesis of the results is presented in the next sections.

In order to address the application of recognition approaches specifically for supply chain execution in more detail, a second literature search has been conducted. However, this has not been following a framework for a structured literature review but a more "try-and-error"-focused approach has been used.

3 Applied AI Approaches

In scientific literature numerous different AI approaches are used. The number is even increased, since many researchers adapt known algorithms to their needs and publish this variation with a new name. To provide a better overview the classification scheme based on Poole and Mackworth (2017) and Russell and Norvig (2010) has been used. Table 1 provides an explanation and examples for each class as well as an indication of how many of the sources identified as relevant in the literature search do belong to this problem class. The percentages are not only based on the sources identified in the SLR but also include the ones from the literature search focusing on recognition problems in supply chain execution (for more detail on this search cf. Sect. 5). Hence, the percentages differ from the ones presented in the ISSL paper and a higher proportion of the sources can now be attributed to the recognition problem class.

In general, independent from the problem class, variants of neural networks are with 58% the by far most applied AI approach. Such networks consist of one input layer, one output layer and at least one hidden layer between them. The majority of identified sources utilizes so called *deep learning* for their neural networks, i.e. the networks possess many hidden layers which allows them to process greater amounts of and more complex data in shorter time. This composition of many layers allows neural networks to learn very complex functions (LeCun, Bengio, & Hinton, 2015; Poole & Mackworth, 2017). Moreover, many authors show that neural networks outperform other approaches with regard to e.g. solution quality or convergence speed towards a good solution (e.g. Aengchuan & Phruksaphanrat, 2018; Ma, Wang, & Wang, 2018). Neural networks are mostly used to solve prediction, classification/clustering, optimization, recognition or NLP problems. The second-most used approach, multi-agent systems (MAS), is applied for knowledge representation and reasoning problems. In a MAS, different agents follow their individual goals and strategies. Based on these they perform actions and propose different solution alternatives, which are often presented to a human decision maker who is responsible for the final decision.

Considering the different problem classes, it becomes obvious that the majority of sources uses AI approaches to predict something, e.g. customer demand (Watanabe et al., 2016) or supplier performance (Mirkouei & Haapala, 2014). Therefore, a strong suitability of AI approaches to solve prediction tasks can be concluded. The same holds true for classification/clustering as well as knowledge representation and reasoning problems. The amount of sources considering these problem classes is lower than the ones for prediction problems but still a considerable number of sources deals with these categories. An example from the classification class is presented by Ye, Xiao, and Zhu (2015) who classify companies according to which supply chain disruptions they can expect. Knowledge representation and reasoning problems dealt with by scientific literature are e.g. the analysis of the effects that information sharing has on supply chain performance (Ponte, Pino, & La Fuente, 2014).

Table 1 Problem class of relevant sources (classes based on Poole and Mackworth 2017 and Russell and Norvig 2010)

Problem class	Examples	Percentage of sources (%)
Prediction Based on training with examples, approaches predict an output for given input values	Demand prediction Supplier performance prediction Production completion time prediction	48
Classification/Clustering Approaches that identify classes in datasets either based on known labels (classification) or without additional information (clustering)	Classification of disturbances in a supply chain Identification of customer groups	17
Knowledge representation and reasoning Approaches used to not only find a solution but rather to present different alternatives and the reasoning that has led to them	Analysis of the effects of information sharing on supply chain performance	14
Recognition Approaches which are able to detect something on images or recognize objects in a 3D space	Food quality recognition based on images Automatic container unloading	11
Optimization Identifying an optimal (or at least very good) solution to a given problem	Vehicle routing problem Inventory level optimization	6
Natural language processing Approaches for understanding and processing human language (text or voice)	Extraction of sentiment from social media comments Analysis of reports to predict failures	3

Rather rarely approached problem classes are optimization, recognition and natural language processing (NLP). However, especially the two latter ones should not be considered as unsuitable since recent sources show high potential for applications in the SCM domain e.g. for food quality recognition (Cavallo, Cefola, Pace, Logrieco, & Attolico, 2018), or the analysis of documents to automatically derive information such as failure predictions (Aqlan & Saha, 2015). Also the area of warehouse automation is considered as highly relevant for AI applications. For example, Thamer et al. (2018) examine application possibilities of deep learning in this field and present a way to increase the intelligence of a forklift within a dynamic warehouse environment to make it able to recognize people.

Overall, it can be subsumed that variants of neural networks are clearly the most utilized AI approach in the SCM domain. These are used to not only solve regression and classification but also optimization, recognition and NLP problems. The second-most used technology, MAS, is mostly applied to reasoning problems to better understand a system or estimate the effects of certain strategies or actions. While SVMs are also more or less frequently applied, other methods such as decision trees, fuzzy reinforcement learning or named entity recognition are only considered by a minority of the sources.

4 Addressed SCM Task

It is also possible to classify the different sources according to which SCM problem or task they are applying AI approaches to. Fleischmann et al. (2005) provide a good overview of SCM planning tasks in their Supply Chain Planning Matrix and depict them along two dimensions: the planning horizon (long-term, mid-term, short-term) and the type of supply chain process (procurement, production, distribution, sales) (cf. Fig. 1).

However, the matrix solely focuses on planning tasks and hence had to be extended to also depict tasks from supply chain execution as well as ones providing support along the supply chain, e.g. performance evaluation. The tasks mentioned in Fig. 1 as examples for each class are quite general and their configuration depends on the specific situation at hand. However, they give a good overview of the various kinds of tasks which are part of SCM.

Table 2 gives an overview of the percentage of relevant sources dealing with the tasks of the extended supply chain planning matrix. Again, the sources from the

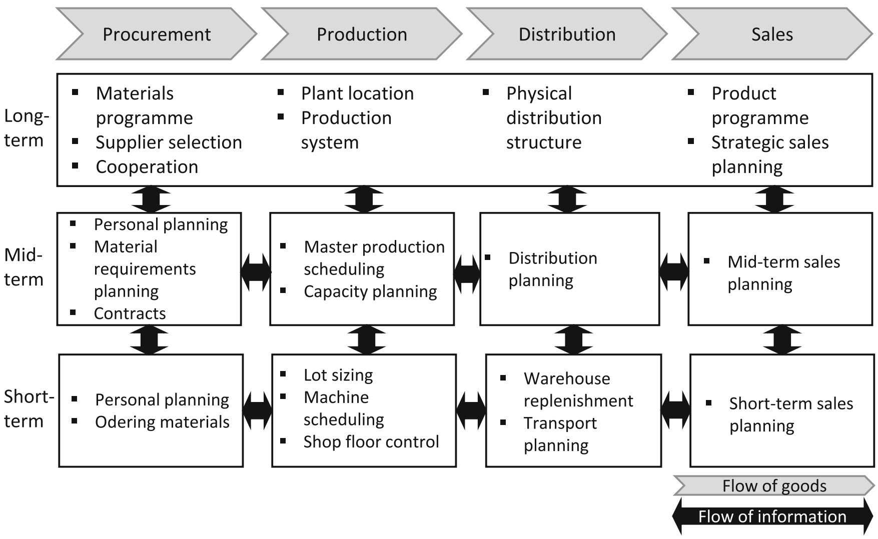

Fig. 1 Supply chain planning matrix (Fleischmann et al., 2005)

Table 2 Addressed SCM task

	Procurement	Production	Distribution	Sales	Support
Long-term	23%				12%
Mid- and short-term	3%	7%	12%	19%	
Execution	24%				

literature search focused on recognition problems in supply chain execution have been considered when calculating the percentages. Therefore, the number of papers dealing with execution has increased when compared to the first investigation.

The top three application areas within SCM are—at least according to scientific literature—long-term planning, mid-and short-term sales planning as well as execution. Sources of the category long-term planning typically deal with supply chain or network configurations. Usually variations of neural networks are applied to e.g. predict the capability of a supply chain to fulfill all customer orders (Silva, Ferreira, Silva, Magalhães, & Neto, 2017) or multi-agent systems are used to e.g. examine the influence of different communication and collaboration strategies on SC performance (Medini & Rabénasolo, 2014). Another area is focusing on supplier selection and evaluation, for example in agricultural supply chains (Guo & Lu, 2013) or to estimate a supplier's resilience capability (Hosseini & Khaled, 2016).

Mid- and short-term planning is dealt with by 41% and among the different functions, mid- and short-term sales planning is the most prominent one. All sources from this task category aim at forecasting demand for hard to forecast products such as blood transfusions (Khaldi, El Afia, Chiheb, & Faizi, 2017) or at improving demand forecasts by incorporating external information such as weather data (Watanabe et al., 2016) or social media information (Cui, Gallino, Moreno, & Zhang, 2017).

The third task category having received lots of attention from research is supply chain execution. Here, two different tasks show a high occurrence among the identified sources: First, supply chain monitoring e.g. for cold chain transports (Emenike et al. 2016) and second, automated warehousing and production encompassing tasks such as the development of an automated ordering management system (Mortazavi, Arshadi Khamseh, & Azimi, 2015).

5 Recognition Approaches for Supply Chain Execution

As mentioned before, the number of sources applying AI approaches to recognition problems has been surprisingly low in the SLR presented in Sect. 3. Especially after looking at the tasks AI approaches are applied to both in research and industry the impression of a high suitability for applications in supply chain execution has been strengthened. Many sources apply neural networks and support vector machines to address recognition problems from the area of supply chain execution and report realizable benefits such as high accuracy in recognition (Schlüter, Niebuhr, Lehr,

& Krüger, 2018) or the possibility to deal with external factors such as lightning or weather conditions when recognizing objects from camera images (Huang, Li, Chen, Zhang, & Lang, 2017).

In order to identify more sources dealing with this apparently promising area, the literature review presented before has been complemented by a further search process. Instead of following another structured approach, publications specifically dealing with the topic of interest have been searched with a few different methods. First, further databases, namely IEEE Xplore and Google Scholar have been queried with the search term ("image recognition" OR "object recognition") AND "supply chain" which has already been used in the SLR presented before. Having talked to experts from the field of robotics it became imminent that the conducted search focuses on SCM-domain-oriented databases and e.g. neglects ones indexing more technology-focused journals and conferences. Therefore an extension of the set of databases has led to a few more relevant results. Additionally, the set of utilized keywords for the search term has been adapted several times. For example, the term "logistics", which was dropped as a search term in the first literature review due to it causing many false positive results, has been re-introduced since the overall number of results for this very specific search has been low enough for a manual identification of false positives. Furthermore, once a promising application area such as warehouse automation has been identified this keyword has been utilized to detect more sources from this area and give an indication on whether the perceived relevance can be supported. It has to be noted that the search process has not been extensive and has not been capable to detect all relevant sources. Instead, once an area has been identified as suitable for the application of AI approaches, i.e. a few sources doing so have been found, no further publications have been looked for. Since the purpose of this focus-section is to give an overview on possible and promising application fields and not to identify all possible applications, it has been regarded as sufficient to provide a set of examples for each of the fields. However, due to the non-structured search process this section cannot and does not want to claim to be comprehensible. Since the search was conducted more or less on a "try-and-error" basis and further results were retrieved based on initial ones, it of course is possible that important application areas have been missed. Nonetheless, this way it is possible to get a first impression on where many applications are already existing. And since the search process has mainly been based on sources initially identified in the SLR presented before it is considered as unlikely that major areas have been missed.

In the following the identified areas, where applications of AI approaches to address recognition problems in supply chain execution are already existent, are presented and examples for such applications are given. The information as well as the example cases are taken both from research and industry.

5.1 Warehouse Automation

Warehouse automation is one of the highly researched fields for the application of AI recognition approaches. Not only research but especially industry is interested in using advances in AI as well as robotics to automate typical warehouse operations such as bin picking. Amazon even has organized a "bin picking challenge" to encourage teams from different universities etc. to let their solutions for picking robots compete against each other (for a summary of the first Amazon Picking Challenge and lessons learned from it, compare Correll et al. 2018).

The design of picking robots seems to be a highly interesting topic and numerous researchers deal with different aspects of these robots. One of the most important ones is enabling the robot to recognize the objects it is supposed to pick. Usually this is realized by applying a machine learning algorithm trained with and learning from example images. Typical setups of a bin picking robot are stationary and include a robot arm with a gripper that detects objects based on a 3D sensor and plans its motions accordingly (Nieuwenhuisen et al. 2013). To extend this scenario and make the robot more flexible with regard to its operation space Holz et al. (2014) and Nieuwenhuisen et al. (2013) propose a complete system with a mobile robot capable of active object recognition and also grasp planning. Previous to the operation, the robot learns object models that represent objects in graphs depicting compounds of primitive shapes and contours such as cylinders. Having been trained, the robot is able to recognize objects by detecting parts of the graph to be looked for in the captured scene, e.g. detecting a single screw in a transport box filled with several screws or even other objects. The presented approach shows a robust behavior "even in the presence of noise, occlusions, erroneous measurements and missing information" (Holz et al., 2014).

Laskey et al. (2016) also propose a picking robot which is capable of picking objects even when access to it is blocked by other object, i.e. grasping in clutter. They iteratively train the robot based on humans demonstrating the picking actions and giving direct feedback to the robot on its current policy. Moreover, a hierarchy of supervisors is used in order to decrease the amount of human demonstrations needed for the robot to learn to pick objects amid clutter. On the first stage, the robot learns from a simple motion planner that ignores the obstacles, i.e. other objects, when grasping the desired object. Then crowd-sourced human workers are used as supervisors on the second stage and finally, an expert from the field of robotics is supervising the robot. With this approach it is possible to achieve a reliability of 90% (Laskey et al., 2016). Another example for the utilization of AI approaches to address recognition problems in a warehouse setting, resp. in the context of picking, is provided by Mo and Lorchirachoonkul (2016) who present a way how to automatically detect which item has been picked and what has been done with it by capturing the worker's physical interaction and gestures within the picking environment with an array of 3D cameras.

However, not only bin packing is addressed with AI approaches. Similar robots resp. approaches to enable them to recognize objects can also be applied to the problem of automatic container unloading (Uriarte, Thamer, Freitag, & Thoben, 2016). For example, Stoyanov et al. (2016) propose a robot to automatically unload coffee sacks. Uriarte et al. (2016) additionally propose the so-called “celluveyor”, a modular conveying system which can be utilized to automate the flow of material in a warehouse.

The provided examples show, that especially when combined with advances in robotics and other technologies, AI approaches to solve recognition problems are capable of automating many warehouse processes. This indicates a high potential for the application of AI. However, DHL for example states that only 5% of today’s warehouses are automated (DHL, 2016). This number shows that the available potential still has to be realized.

5.2 Operation Support

This category subsumes applications supporting people in their every-day operations for example in manufacturing or transport. For example, Sharma et al. (2018) utilize a neural network to automatically parse geographical addresses. This supports the delivery process of mails and parcels which is of high relevance especially due to the increasing amount ordered due to e-commerce etc. The special challenge with regard to addresses is that they exist in various formats and an approach to recognize important parts such as the street name therefore has to be able to deal with this high variety. A neural network is proposed that is capable of extracting individual fields from an address in raw text format and provide a standardized representation (Sharma et al., 2018).

Support can also be provided in manufacturing. Longo et al. (2016) develop a system that is equipped with a neural network to process human voice and is able to recognize what the user is currently doing, e.g. which parts are currently handled. Based on this information the system is able to answer questions and give information relevant and suited for the situation and problem at hand. Other applications to support manufacturing operations are e.g. the automatic detection of counterfeited electronic parts to avoid their assembly and possible resulting issues (Frazier, Gilmore, Collins, & Chouika, 2016) or the automatic detection of parts to remanufacture, i.e. to recognize parts which can and which cannot be used further (Schlüter et al., 2018).

Another example for how to support actions happening on an everyday basis is provided by Tuszynski et al. (2013). They apply a deep learning neural network to analyze so-called container manifest, documents stating which goods are in a container, and the corresponding container. Radiography images are taken of the container and based on that containers with loads inconsistent from their manifest can be detected.

As said before, these are the areas which have been identified as promising application fields of AI recognition approaches in supply chain execution. While the list of classes or examples is certainly not comprehensive, it still is able to give an impression on what has already been developed in this field and provide ideas on where possibly to look at for further applications.

Overall, it also needs to be noted that major advances concerning approaches such as deep learning, robotics and computer vision—as already mentioned in the introduction—have just been made and are a requirement for successful applications. Therefore, much more can be expected for these problem classes in the future.

6 Conclusion

In summary, the paper aimed at giving a short overview on the most interesting AI approaches and the SCM tasks most often addressed in research. Furthermore, a focus on the application of recognition approaches for tasks from supply chain execution has been set.

Looking at results from scientific literature, the main implication that can be derived is that there is a high variety of AI approaches and there are many problems in SCM and logistics to be tackled with AI successfully. Regarding the applied approaches it is obvious, that—while research shows a high variety of them—machine learning in general and neural networks specifically are the by far most applied method. Interestingly, the number of sources dealing with recognition problems is still rather small, but by specifically looking for more examples from this area, it became obvious that there is a great suitability for applying AI to solve issues regarding recognition, especially in supply chain execution.

However, research still mainly deals with developing or improving algorithms and not with actually applying them in a real-world setting. There is only a limited set of pilots or specific real application scenarios. Most publications test their approach on a dataset based on e.g. simulations or bench-mark data. Moreover, organizational, process- and human-related issues are rarely discussed. This connects to a more general issue. The identified sources mainly do not report on the process on how to identify good and promising application cases nor on how to choose a suitable approach and implement it. Publications show a focus on applying an AI approach to a given problem but in order to receive a successful solution, it is first necessary to estimate how suitable an application case is. Only this way, the chance of success can at least be increased and the possibility to fail with applying AI can be lowered. Since this aspect has so far not been considered by any of the identified sources, it is a good opportunity for future research.

While the paper aimed at basing the results on a structured and understandable way, it cannot claim to be comprehensive. Especially, the chapter focusing on recognition and supply chain execution only can provide an introduction to possible applications. Nonetheless, the goal to give a first idea on suitable application cases and raise awareness on how SCM has so far benefited from is considered to be achieved successfully. Therefore the presented applications classes (warehouse automation and operations support) can be regarded as a starting point for more research on utilizing recognition approaches for supply chain execution. In the future it could be possible to identify more application cases within these classes or examine more supply chain execution problems regarding their suitability for applying AI. Since the technologies enabling the utilization of new and more enhanced AI approaches are developed further, the set of application cases can be expected to also increase and broaden in the future.

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(Re)Structuring Data Law: Approaches to Data Property

Thomas Hoeren and Philip Bitter

1 Preface

In times of big data, it must be allowed to ask whether the civil legal system can provide an answer to an emerging industry 4.0 (Bräutigam & Klindt, 2015, p. 1137; Zech, 2015b, p. 1151). If data is traded on a large scale, it should be clarified which rights a person has to data beyond the existing contractual agreements. The issue is preceded by the question of a legal classification of data. According to that, scholars have already thought about structuring data rights in terms of "data ownership". Current legislation may have a few solutions to this end. The protection of goods under traditional property law in the BGB (German Civil Law Code), though, is based on corporeal objects. Intellectual property rights to certain data or rather to the content of data also already exist. However, such options do not grant a property-like right to data as such. Data is nevertheless a suitable object of purchase according to Sect. 453 (1) second alternative BGB (Beckmann, 2013, Sect. 453 para. 37). So "data ownership" was originally about how *de lege lata* a property-like right of disposal ("Verfügungsrecht") could be created (Wagner, 2017, Sect. 823 para. 296). It must be asked how the relationship between data as such, the content, and the data carrier can be further approached by means of law (Hoeren & Völkel, 2014, p. 12; Zech, 2015a, p. 138). Considerations about "data ownership" still range from a comprehensive rejection to the establishment of certain rights *de lege lata* or even exclusive rights *de lege ferenda*. And the data term is not even used consistently. Some approaches concern data at the level of signs, i.e. data as such (Arbeitsgruppe "Digitaler Neustart", 2017; Zech, 2015a, p. 138). The term can therefore be defined as "reinterpretable representation of information" in accordance with the ISO standard

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(ISO/IEC, 2015). In other considerations, data and information are used synonymously (Determann, 2018, p. 6). This is also the case in the GDPR (General Data Protection Regulation, Article 4 No. 1). However, the distinction is not trivial. Data as such can also be indirectly protected by the aforementioned protection of the content or the data carrier.

2 Review and Recent Developments

Based on the economic value of data, data trading seems to cry out for legal certainty on a European level. The European Commission therefore brought into play the introduction of a "data producer's right" (European Commission, 2017a, p. 13, 2017b, pp. 33 et seq.) Moreover, the main focus was on promoting competition in a European digital single market. To this end, the Commission launched the "free flow of data initiative" (European Commission, 2015, p. 15), which was specified in a proposal for a regulation on a framework for the free flow of non-personal data (European Commission, 2017b). In this context, though, the focus has shifted from the introduction of an exclusive right to data to a regulation of portability and access rights to data (European Comission, 2017d, p. 74; Drexl, 2017a, p. 257; Kerber, 2016, p. 989). The largely economic thoughts at European level were *inter alia* preceded by considerations of some scholars, who have started to investigate how to establish a property-like right *de lege lata*, for example to mobility data from the automotive industry. The initial aim was to establish rights to data in a connected car. Furthermore, it was also based on the rather German idea that a contractual deal under the law of obligations ("Verpflichtungsgeschäft") should also be followed by further, separate allocation in rem ("dingliche Zuordnung"). The approach was merely intended to point out dogmatic options of a classification of data as such detached from content and carrier medium. It was well known that the ownership of the data carrier medium and intellectual property rights to the content for example could have priority as well as data protection law and thus only a small scope of application existed (Hoeren, 2013, p. 490). Nonetheless, this led to very different approaches. The term "data property" was later associated with the requirement of legislative intervention. Subsequently, the creation of a neighbouring right to data was discussed (Ensthaler, 2016, pp. 3476 et seq.; European Commission, 2017a, p. 13, 2017c, pp. 33 et seq.). The legitimate initial question of the assignment of data to a person by establishing a property-like right *de lege lata* thus became a question of general data ownership *de lege ferenda*. Then, at least after the Report of the Working Group "Digitaler Neustart" of the German Conference of Ministers of Justice in May 2017, one seemed to agree that such considerations on general data ownership lead nowhere in the complex question of an assignment of data rights to a person. Particularly from an economic point of view and in the context of the existing rights to content and carrier, such a general ownership of data was assessed as not desirable (Arbeitsgruppe "Digitaler Neustart", 2017, p. 88; Kerber, 2016, p. 989). It could even promote misguided monopolization of data instead of preventing it.

Nonetheless, due to the mention of the topic in the coalition agreement of the German Federal Government in 2018, the discussion has gained momentum once again.

3 Approaches to Data Property

3.1 Contractual Allocation

Contractual agreements on the use of data only apply between the parties and not to everyone (Zech, 2015a, p. 140). In addition, contractual solutions alone may entail the risk of nullity of contracts, high transaction costs, potential market failure and conflicting laws (Grützmacher, 2016, p. 486). Even if "data ownership" is contractually assigned in practice, there is no corresponding right in rem as property is only assigned by name (Boehm, 2016, pp. 379 et seq.; Jülicher, 2015a, p. 2066).

3.2 Approaches de Lege Lata

There are already various concepts to assign rights to certain data to a person under current legislation. Most of them are related to the content and therefore not to data as "representation by signs". However, the crucial point of the initial question of "data ownership" was just to approach the relationship between data, its content, and data carriers in civil law. The cases concerned were those in which the current protection regimes for the protection of content or carrier medium did not seem to provide a solution for civil law protection and classification of data as a definable entity. Dealing with the independent meaning of data as such seemed to be unavoidable. If data is a suitable object under the law of obligations, it may also have to be assigned as a right in rem. There may be even a practical need for such a right, particularly in the case of nullity of contracts that allocate certain rights to data. The question of the property-like right to dispose of data also determines whether data can be segregated in the event of the cloud provider's insolvency (Jülicher, 2015a, p. 2065, 2015b, p. 450) or how a lien on data can be justified (Court of Appeal, 2013). Hence, as regards the issue of a right in rem to data as such under civil law, the first thing to consider is the application of property law. Though the traditional law of property applies to tangible goods, it does not apply to intangibles (Althammer, 2016, Introduction to Sects. 903 et seq., para. 3 et seq.; Brückner, 2017, Sect. 903, para. 3). Referring to Sect. 903 s. 1 BGB, the owner of a "thing" has the positive rights to "deal with the thing at his discretion" and the negative rights to "exclude others from every influence", limited in statutes and the rights of third parties (Althammer, 2016, Sect. 903, para. 9 et seq.; Brückner, 2017, Sect. 903, para. 22 et seq.). Sect. 90 BGB states that only corporeal objects are "things". In contrast to data carriers, thus data as such is not regarded as "things" as defined by law (Stresemann, 2015, Sect. 90, para. 25). Secondary protection of data may exist through the property right to the data carrier. This may be the case above all if the owner of the storage medium is also the "owner" of the data. This does not necessarily mean that ownership of the data must correspond to ownership of the storage medium. Storing data in a cloud should serve as an example. Data in a cloud should not necessarily belong to the cloud provider, as the cloud provider should not be able to handle the data at will. As a result, property law is not directly applicable.

However, if the rules on the sale of goods (Sects. 433 et seq. BGB) apply to data as "other items" in accordance with Sect. 453 (1) second alternative, a corresponding assignment of a property-like right to dispose should still be considered. Thoughts from German criminal law, especially to Sect. 303a StGB (German Criminal Act), can be helpful here. Section 303a StGB makes the unlawful deletion, suppression, disabling or alteration of data a punishable offence. It therefore requires a person entitled to dispose (Heger, 2018, Sect. 303a, para. 4; Stree & Hecker, 2014, Sect. 303a, para. 3). For this reason, an analogy to Sect. 903 BGB was drawn in part (Hilgendorf, 1996, p. 890; Stree & Hecker, 2014, Sect. 303a, ref. 3). In the sense of the unity of the legal system, thus an analogy was also considered in civil law. However, such a property-like right would be subject to many restrictions. It would also be largely subsidiary to the rights to the data carrier and to the data content. At least, the person entitled under criminal law should also be recognised as the person entitled to dispose under civil law. Then the so-called *"Skripturakt"* (Welp, 1988, p. 447), as developed under Sect. 303a StGB, appeared to be the most suitable criterion even for the allocation of data to a person. Data ownership is therefore assigned to the technical manufacturer of the data or to the person who initiated the *"Skripturakt"* (Hoeren, 2013, p. 487). "*Skripturakt*" and case law, in particular on Sect. 950 BGB, may thus help to assign a property-like right to data (Hoeren & Völkel, 2014, pp. 34 et seq.). Anyway, a general reference to the limited number of use cases does not prevent such a property-like assignment of data to a person *de lege lata* nor does it meet the significance of data as such. The above mentioned cloud computing and segregation of data in insolvency serve as practical examples for the required discussion.

Besides that, some other rules exist for the handling of certain data. In addition to the ownership of tangible goods, absolute rights can also exist in terms of personal rights or intellectual property rights. However, the protection does not refer to data as such, but to the content of the data. Content can be protected by copyright or industrial property rights according to the creation process or investment. Data protection law protects personal data, but also relates to information.

Copyright law, for example, grants an exclusive right of exploitation and restriction (Heerma, 2014, Sect. 15, para. 2; Schulze, 2018, Sect. 15 para. 5), but presupposes a work by personal intellectual creation according to Sect. 2 (2) UrhG (German Copyright Act). Therefore a threshold of originality is required (Wiebe, 2015, Sect. 2, para. 2). Data may therefore be the representation by signs of a work protected as a form. Yet, data in this technical sense and in particular automatically generated data may not reach the required level of originality. Neither will machine-generated data be classified as personal creation (Schulze, 2018, Sect. 2, para. 8). The protection of computer programs under Sects. 69a et seq. UrhG requires a personal intellectual creation as well, Sect. 69a (3) s. 1 UrhG. Database works according to Sect. 4 (2) s. 1 can be protected as collections, Sect. 4 (1) UrhG. According to Sects. 4 (1) and 2 (2) UrhG, though, database protection also only covers the selection or arrangement of elements as a collection that can be regarded as a personal intellectual creation (CJEU, 2012, para. 37; Dreier, 2018, Sect. 4, para. 19). Sections 87a et seq. UrhG assign a *sui generis* right to the maker of a database. In accordance with Sect. 87b (1) s. 1 UrhG, the maker thus obtains an exclusive right to the duplication, distribution and public reproduction. As a neighbouring right, though, it is not a personal creation of a database that is required, but a substantial investment made in the obtaining, verification or presentation of the content, Sect. 87a (1) s. 1 UrhG (Dreier, 2015, Sect. 87a, para. 1). In assessing the substantial investment, a distinction shall therefore be made between the relevant resources of creation and operation of the database, and the generation of data as independent materials (Dreier, 2015, Sect. 87a, para. 12 et seq.; CJEU, 2004a, para. 31, 2004b, para. 24, 2004c, para. 40, 2004d, para. 34). The latter is not taken into account. Although rights to certain data may exist in this context, data as such is not protected either (Dorner, 2014, p. 622; Zieger & Smirra, 2013, p. 419). There is no property-like right to dispose of data as such through copyright or *sui generis* right for databases.

The directive on the protection of trade secrets is a further legal framework that reveals the problems in establishing the scope of an absolute right to data. Article 12 (1) and (2) provide the holder of misappropriated trade secrets with certain rights. Article 14 states that the trade secret holder can claim damages against the infringer. According to Article 2 (1), a trade secret is information, which is a secret that is not generally known among or readily accessible to persons within the circles that normally deal with the specific information (a), which has commercial value because it is secret (b), and which has been subject to reasonable steps to keep it secret (c). The directive may thus also concern certain data or rather the contained information that is to be classified as a trade secret. Article 4 deems the acquisition (2), use and disclosure (3) of trade secrets without the secret holder's consent unlawful. According to Article 4 (2) lit. a, for instance, the acquisition of a trade secret without the consent of the trade secret holder shall be considered unlawful when it is carried out by, for example, appropriation or copying of electronic files that are lawfully under control of the trade secret holder, that contain the trade secret or from which the trade secret can be deduced. However, it is based on factual secrecy and subject to many limitations, including Article 3 on the lawful acquisition, use and disclosure or the exceptions in Article 5. It thus leads to rights to certain data but it does not grant a property-like right to data as such.

Data protection law also protects the content that can be presented by data. Article 4 No. 1 GDPR states that "personal data" means any information relating to an identified or identifiable natural person. Moreover, current data protection law does not appear to be able to provide comprehensive ownership of data (Dorner, 2014, p. 624; Specht, 2017, p. 1041 et seq.). It rather has a defensive function against processing of personal data by others. In defining the right to informational self-determination, the BVerfG (German Federal Constitutional Court) stated that "information, even if it is personal, is an image of social reality that cannot be attributed exclusively to the person concerned". In view of the increasing economic importance of personal data, though, there are different approaches to establishing personal rights and data protection law as property-like rights (Buchner, 2006, pp. 201 et seq.; Ladeur, 2000, p. 1980; Schwartz, 2004).

3.3 Approaches **de Lege Ferenda**

Finally, the creation of a neighbouring right for data *de lege ferenda* was discussed (Ensthaler, 2016, pp. 3476 et seq.; European Commission, 2017a, p. 13, 2017c, pp. 33 et seq.). However, an exclusive general data ownership right is not considered to be economically reasonable (Dorner, 2014, p. 617; Drexl, 2017a, p. 257; Hugenholtz, 2018; Kerber, 2016, p. 989; Spindler, 2016, p. 805). This is already shown by the aforementioned developments at European level. Moreover, to prevent a "super IP right" (Drexl, 2017b, p. 343; European Commission, 2017c, p. 34; Wiebe & Schur, 2017, p. 470), there should be no protection of the content beyond the limits of the existing intellectual property rights. Comparable to the solution via contractual regulations only, the creation of a general data ownership right even poses a risk of misguided monopolisation.

4 Conclusion

Legislative action on general data ownership, for example in terms of a new neighbouring right, is incapable of solving the initial "data property" issue. On the one hand, it is not considered economically reasonable. On the other hand, it could not help to clarify the original question of a property-like right to dispose of data ("Verfügungsrecht") *de lege lata*. Instead, the approach by means of the "Skripturakt" may have allowed an approximation to the relationship between data, content and data carrier in civil law. In addition, there are already many protection regimes for certain data, for example due to the data carrier or the content. Current legislation can therefore be seen as a largely sufficient basis. A comprehensive restructuring of data law *de lege ferenda* does not seem to be indicated in this context. However, further research questions seem to arise in relation to data possession and access regulation to data.

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Structuring Unstructured Data—Or: How Machine Learning Can Make You a Wine Sommelier

Oliver Müller

1 Motivation

We have witnessed an unprecedented growth in data volume, variety, and velocity during the last decade, a phenomenon often referred to as "big data." Estimates suggest that about 80% of this data is unstructured in nature (Dhar, 2013; IDC, 2014). Unlike structured data that is mostly numeric in content and can easily be organized in rows and columns of relational database tables, unstructured data is typically textual in content and does not adhere to pre-defined data models. Examples of unstructured textual data include documents, e-mails, instant messages, or user-generated posts and comments on social media.

Processing unstructured text data represents a challenge for data analysts, as it often comes in messy formats and is ambiguous in meaning. Furthermore, the generation of insights from unstructured text is restricted by the limited ability of computers to understand human language (Jurafsky & Martin, 2000). However, recent advances in natural language processing and machine learning algorithms enable us to extract implicit, previously unknown, and potentially useful knowledge from large amounts of unstructured textual data in a scalable and repeatable way (Fan, Wallace, Rich, & Zhang, 2006; Frawley, Piatetsky-Shapiro, & Matheus, 1992). Especially when fed with sufficiently large datasets, machine learning has shown to be a useful tool for analysing text data (Halevy, Norvig, & Pereira, 2009).

An exemplary use case for the application of machine learning to analyse large amounts of unstructured textual data are online customer reviews. Online customer reviews, defined as "peer-generated product evaluations posted on company or third-party websites" (Mudambi & Schuff, 2010, p. 186), are reports of product or service experiences and it has been shown that they strongly influence customers' decision-making processes (BrightLocal, 2014). Online customer reviews are ubiq-

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uitous today. At the time of writing, the travel advice website TripAdvisor.com alone hosted more than 600 million reviews about almost any touristic spot in the world (Statista, 2017). The enormous volume and the unstructured and ambiguous nature of these reviews—they typically comprise only of a free-text field and a numerical "star" rating—make it difficult for customers and analysts to derive valid and reliable insights from them.

In this chapter, we showcase how a combination of unsupervised machine learning methods and visualization techniques can help to bring structure and meaning to large collections of textual online reviews. We use reviews about wine as an example, but the general methodology can easily be adapted to other types of texts.

2 Machine Learning for Text Analysis

Since the early 1950's, researchers have been trying to automate the analysis of human language. Early systems for natural language processing relied on hand-crafted syntactic and semantic rules for extracting meaning from texts, an approach that required enormous manual effort and was not robust to variations in natural language. It was not before the so-called "statistical revolution" in the 1990s, which was driven by the increasing availability of digitized texts from the Internet and increases in speed and memory of computers, that systems based on machine learning algorithms made computer-based text analysis useful for real-world applications (Jurafsky & Martin, 2000).

Topic modeling is a popular example of a computational text analysis technique that is based on statistical machine learning (Blei, 2012; Blei, Ng, & Jordan, 2003). The idea behind topic modeling algorithms like Latent Dirichlet Allocation (LDA) is that texts exhibit multiple topics in different proportions. For example, 50% of the text of a hotel review might describe the size and cleanliness of the hotel room, 25% of the text might be about the available facilities (e.g., pool, gym), and the remaining 25% might cover the quality of the food in the restaurant. Each of these topics, in turn, is characterized by the use of a specific vocabulary. For example, the description of the room most likely contains words like "bed", "bathroom", and "clean", while the part about the restaurant probably contains words like "menu", "breakfast", or "wine". The LDA algorithm is able to automatically discover such topics and the words that are used to describe them from a large collection of texts and to annotate individual documents with probabilistic topic labels. In statistical terms, each document is represented by a distribution over a fixed number of topics (the topic probabilities for a given document sum up to 100%) and each topic is defined by a distribution over a controlled vocabulary of words (again, the word probabilities for a given topic sum up to 100%). Hence, the resulting topic model can be used as a high-level quantitative summary of the content of each document. Grouping and aggregating the topic probabilities for thousands of documents by document metadata (e.g., author, time of creation) allows, for example, to gain an overview about which topics are important, to identify who writes about which topics, or to track the evolution of topics over time.

3 Vignette: A Topic Model of Wine Reviews

In the following we will demonstrate the use of LDA for exploring a large corpus of online reviews. Imagine you are planning the celebrations for your 60th birthday. One of the tasks is to choose a suitable wine for the party. Unfortunately, you are a beer-drinker type of person and overwhelmed by the large number of varieties of grapes, countries of origin, and vineyards. You could go to the wine shop and seek for personal advice, read a book about wine and its varieties, or browse through online wine reviews, but all these activities take time, which you do not have. But luckily you are an experienced data analyst and it is easy to find datasets of wine reviews on the Internet—the website WineMag.com lists more than 19,000 reviews for Cabernet Sauvignon alone! So, you could try out your natural language processing and machine learning skills on this data.[1]

The data science platform Kaggle.com hosts a dataset with approximately 130,000 professional wine reviews scrapped in November 2017 from WineMag.com.[2] Each review contains the name of the wine (e.g., St. Julian 2013 Reserve Late Harvest Riesling), its variety (e.g., Riesling) and vintage (e.g., 2013), a couple of sentences from a professional sommelier describing the wine's taste, smell, look, etc. (e.g. "Pineapple rind, lemon pith and orange blossom start off the aromas. The palate is a bit more opulent, with notes of honey-drizzled guava and mango giving way to a slightly astringent, semi-dry finish."), the sommelier's numerical quality rating on a scale from 1 to 100 (e.g., 87), and information about the country (e.g., United States), province (e.g., Michigan), region (e.g., Lake Michigan Shore), and vineyard (e.g., St. Julian) where the wine was made. In order to avoid that outliers distort our analysis, we limit our analysis to the most popular varieties, vintages, and countries of origin (i.e., categories with more than 1,000 reviews).

After filtering the dataset to the most popular countries, varieties, and vintages and removing reviews with missing data (e.g., missing vintage), we are left with 83,033 reviews about 76,464 unique wines of 27 varieties from 12 countries. We then proceed with pre-processing the textual parts of the reviews by filtering out uninformative stop words (e.g., the, and, wine, review) and transforming all remaining words to their base dictionary forms (e.g., cherries ⇒ cherry, tastes ⇒ taste). After pre-processing the raw texts, we apply the LDA topic modelling algorithm to the main review text written by the sommelier in order to extract the 20 most prevalent topics[3] describing

[1] All data analysis steps in the following analysis were performed in Python (mainly using the spaCy, NLTK, genism, and scikit-learn packages) and all visualizations were created with Tableau.

[2] The dataset can be downloaded at https://www.kaggle.com/zynicide/wine-reviews.

[3] For a discussion of the optimal number of topics see, e.g., Debortoli, Müller, Junglas, & vom Brocke (2016) or Schmiedel, Müller, & vom Brocke (2018).

the taste of the wine and other sensory experiences. The result of this step are two matrices, the per-topic word distribution matrix, which shows how relevant a word is for describing a specific topic, and the per-document topic distribution matrix, which shows to which extent each topic appears in each document (review).

The typical first step in interpreting a topic model is to inspect the per-topic word distributions. Figure 1 shows bubble charts visualizing the word distributions of three exemplary topics of our wine topic model (the size and saturation of the bubbles represent the importance of a word for the given topic). The topic on the top left contains many words with high probability that refer to names of citrus fruits (e.g., citrus, lemon, lime, grapefruit) as well as adjectives that signify a fresh and clean taste. Similarly, the topic on the bottom contains many names of stone fruits (except cherries), such as peach, pear, and apricot, and adjectives referring to a tropical or flowery taste. In contrast, the topic on the bottom right contains words like coffee, espresso, or chocolate as well as oak and tannin, all representing strong and heavy roast aromas.

Figure 2 summarizes the prevalence of all 20 topics over the whole corpus of wine reviews. We can see that the topic labelled "tannin" is the most frequent topic (more than 12% of the review texts are about this topic), followed by the topics "cherries & herbs" and "cherries & blackberries". We can also note that not all topics describe the taste of the wine; we also find topics about wine barrels, bottles, vineyards, or the colour and alcohol level of a wine.

Because the LDA algorithm annotated each wine review with a vector of topic probabilities, indicating how much of each topic appears in each review text, we can group reviews by their metadata and aggregate the respective topic vectors. Figure 3 visualizes the prevalence of all 20 topics grouped and aggregated by type of wine, that is, red and white wine. The top-3 most frequent topics in reviews of red wines are "tannin", "cherries & spices", and "cherries & blackberries", while the top-3 topics in white wine reviews are "peach, apricot, pear, & honey", "acidity & texture", and "citrus fruits". The difference in topic distributions confirm our prior amateur knowledge about red and white wines, namely, that red wines tend to taste strong and heavy and white wines fresh and light.

We can further drill down into specific geographies and varieties of wine. Figure 4 (left) shows a similar topic distribution, but only for wines from Germany. In addition, the colours of the bars represent the two main types of wines (i.e., red and white). The visualization reveals a number of insights. First, most German wines are white wines. Second, German white wines predominantly taste like stone fruits, such as, peaches, pears, and apricots. Third, red wines from Germany are characterized by a light or medium body and are relatively low in tannin; although red wines in general tend to have a heavy body and strong tannin taste. Figure 4 (right) shows the prevalence of the topic "light/medium body" for different countries using a heatmap (lighter colour means lighter body). We can see that wines from Germany, South Africa, and New Zealand have a relatively light body, while wines from France, Spain, Italy, Argentina, Chile have a heavier body.

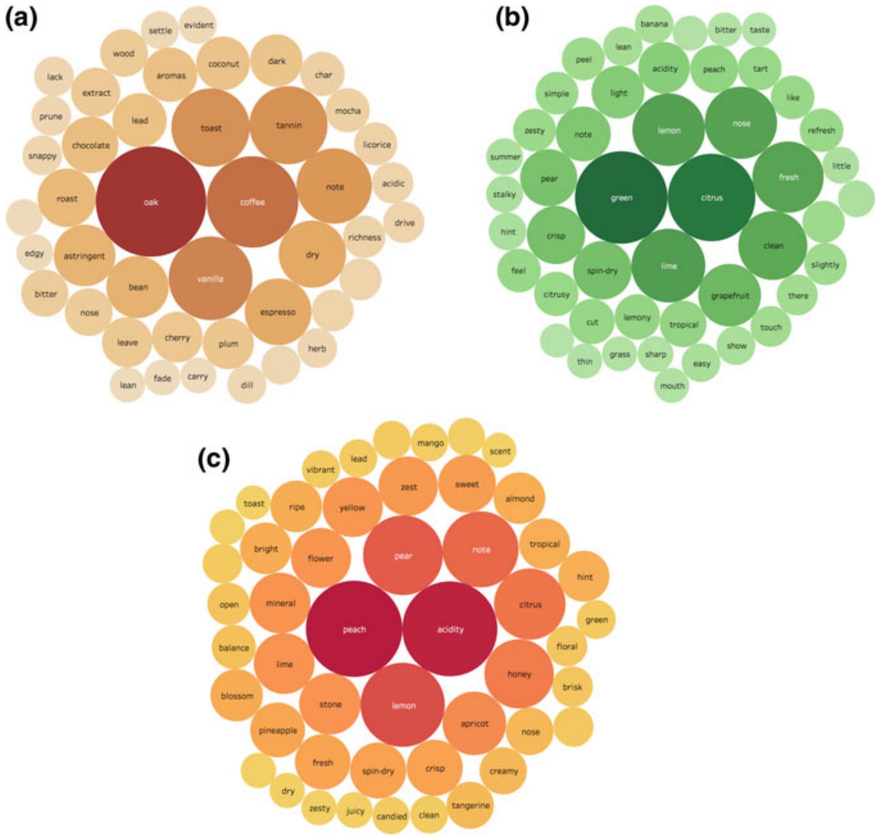

Fig. 1 Word distributions for three selected topics. The topic on the top left (green) has been labelled "citrus fruits", the topic on the top right (brown) has been labelled "oak, coffee, & vanilla", and the topic on the bottom (orange) has been labelled "peach, apricot, pear, & honey"

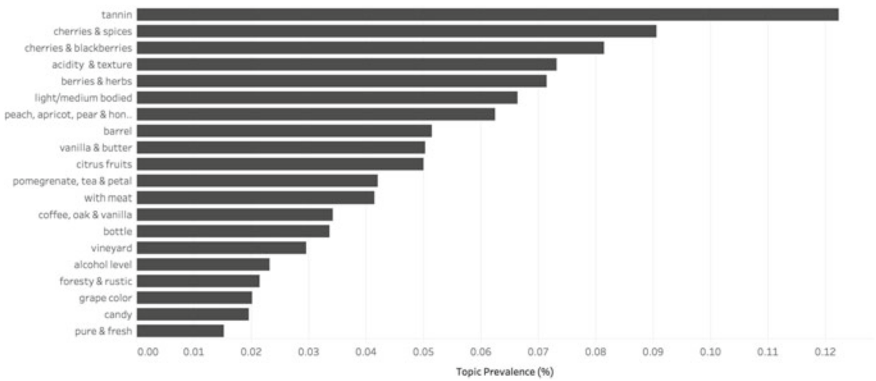

Fig. 2 Prevalence of each of the 20 topics over the whole corpus of reviews. Topics are not uniformly distributed over reviews, but vary from 1.5 to 12% in prevalence (mean topic prevalence is 5%)

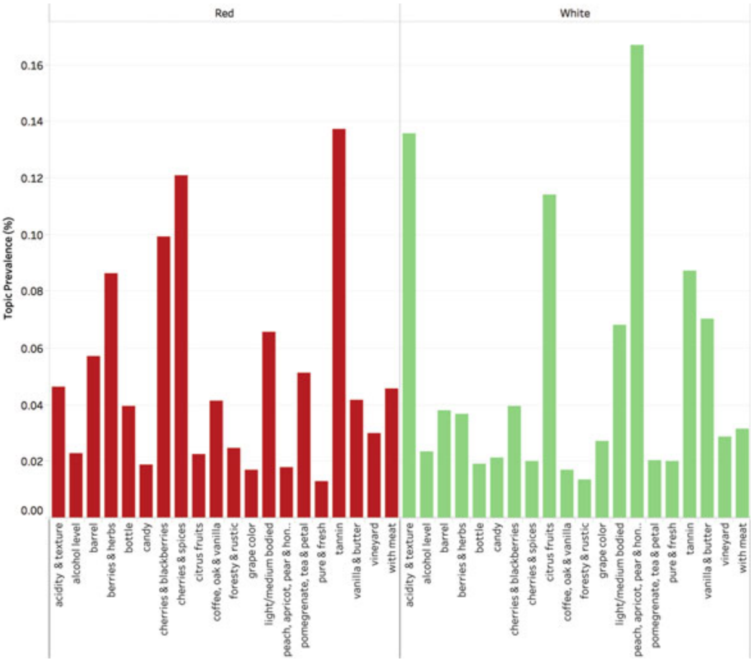

Fig. 3 Topic prevalence split up by red and white wines. The plot shows that red and white wines have distinct topic profiles

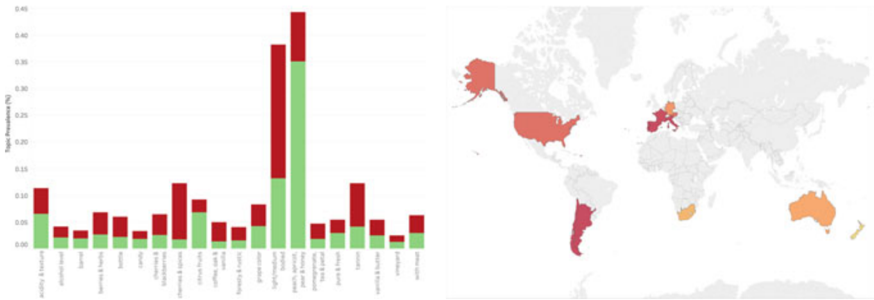

Fig. 4 Left: Distribution of topics for wines from Germany. Right: Prevalence of the topic "light/medium body" in the major wine producing countries

Next, we want to explore how the taste of wines, as represented by the extracted topics, has changed over the years, or vintages. Unfortunately, the original dataset did not contain a field with the year of production. However, as the names of the wines almost always included their vintage year, we were able to extract the year using a regular expression. Figure 5 shows a time series chart tracking exemplary topics over the years. While the importance of the topic "tannin" (brown) is more or less constant over time, reviewers wrote much less about a taste of "cherries &

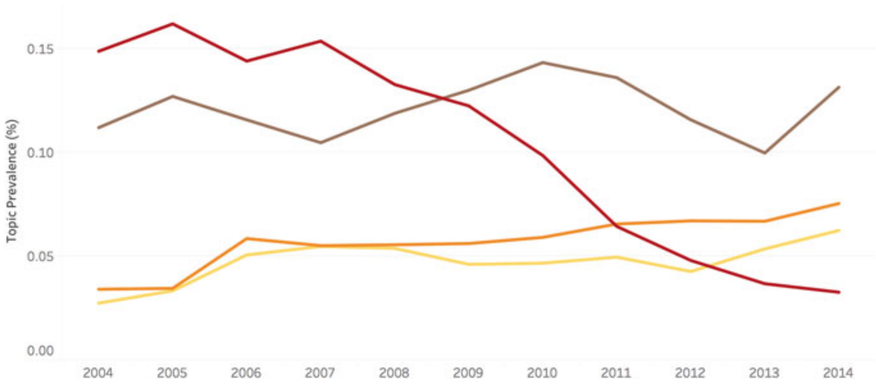

Fig. 5 Change of topic prevalence over time for four selected topics (red: "cherries & blackberries", brown: "tannin", orange: "peach, apricot, pear, & honey", yellow: "citrus fruits")

blackberries" (red) in 2014 than in 2004. In contrast, the topics "peach, apricot, pear, & honey" (orange) and "citrus fruits" (yellow) became more prominent over time. Without a deeper investigation, we can only speculate about the reasons for these trends. They could be caused by changes in consumers' tastes, by economic reasons, by geological or meteorological factors, or by biases in the dataset. However, it seems to be the case that modern wines have a lighter and fresher taste than wines that were produced 10 years ago.

Finally, we can analyse the specifics of different varieties of wine. Figure 6 shows the most popular wine varieties in our dataset. The x-and-y position of each variety has been determined by performing a principal components analysis (PCA) and reducing the topics to their first two principal components, each of which is a linear combination of the 20 original topics (see Friedman, Hastie, & Tibshirani, (2013) for more details on PCA). The different shapes used to symbolize the varieties correspond to their cluster assignment, as determined by a hierarchical cluster analysis with five clusters (again, see Hastie, Tibshirani, & Friedman (2013) for more details on clustering). Finally, the colour of the shapes signifies whether the variety is a red or white wine, and their size relates to the average points which wines of this variety have received by the sommeliers. Consequently, varieties that are placed close to each other and are represented by the same shape and colour supposedly share many

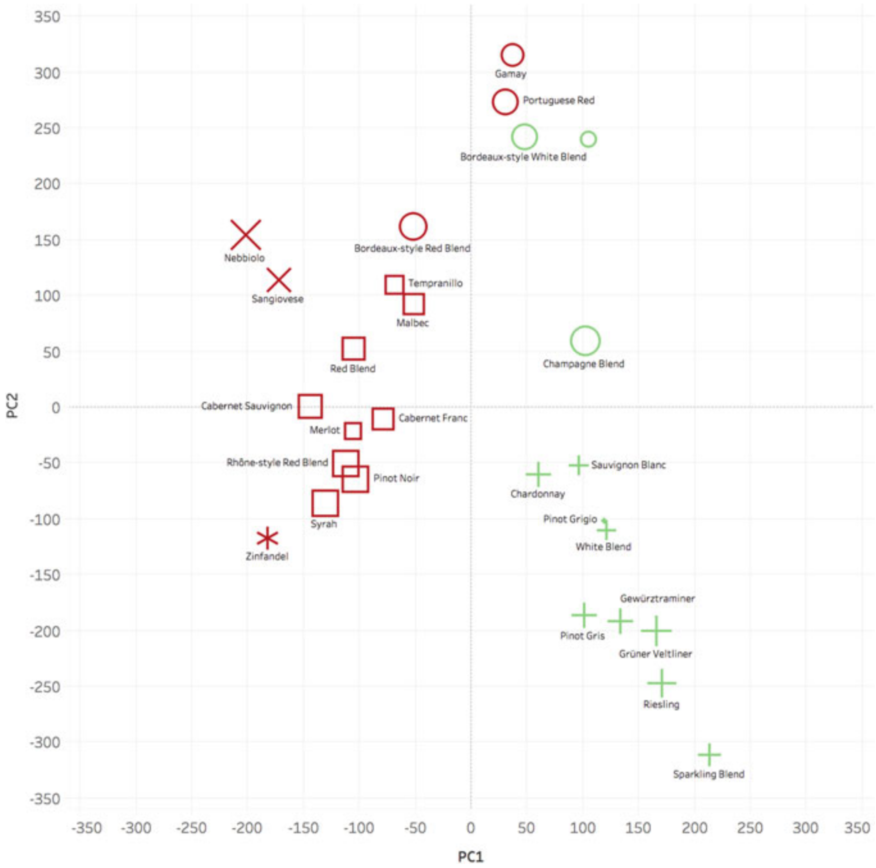

Fig. 6 Overview of most popular wine varieties. The plot has been created by combining the results of a principal components analysis and hierarchal cluster analysis on the per-document topic probabilities

similarities. For example, the two white wine varieties Riesling and Grüner Veltliner or the two red wine varieties Nebbiolo and Sangiovese seem to be very similar in taste, smell, and look—yet there are big differences between those wines (Fig. 7). While a typical Riesling tastes like stone and citrus fruits, has a lot of acidity, and a light/medium body, Sangiovese usually tastes like cherries, spices, coffee, and chocolate and can be paired nicely with meat. As wines of both varieties on average also get high quality ratings, they seem to be appropriate choices for a 60th birthday celebration.

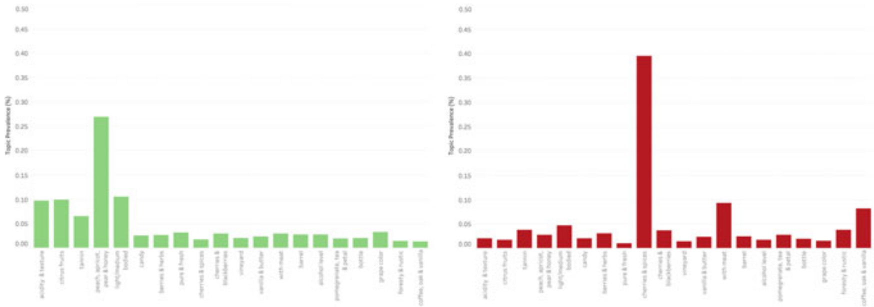

Fig. 7 Topic distribution of Riesling (left) and Sangiovese (right)

4 Conclusion

Textual data is unstructured in format and ambiguous in meaning. Hence, it is difficult to analyse textual data with computational methods. However, recent advances in machine learning algorithms make it possible to semi-automatically extract knowledge from large amounts of unstructured textual data. Although these machine learning algorithms only scratch the surface of the semantics of natural language, they can produce useful results in many domains. In this book chapter we have showcased the application of unsupervised machine learning algorithms—i.e., topic modelling, principal components analysis, and hierarchical clustering—and visualization techniques to extract knowledge about wine from a corpus of more than 100,000 professional wine reviews available on the Internet. We learned, for example, how different types and varieties of wine are described by experts, how geography and time influence the character of a wine, and which wines taste, smell, and look similar; all without drinking a single sip of wine—what a shame.

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Mining for the Evil—Or But Poking in Shades of Grey?

Ulrich Müller-Funk

1 The Evil

Automatic detection of unacceptable statements in social networks and in on-line portals is an urgent topic. Legislators enacted special laws to erase objectionable contributions. The German "Netzwerkdurchsetzungsgesetz" is an example. Due to the volume of such text data, IT-support will be absolutely necessary in the long run. The design of adequate (pre-) filters is tied up with various difficulties. Hence, the topic is put up for discussion in varied scientific communities. In first place, of course, the evil has to be made precise. The freedom of opinion and speech is a constitutional right in every western society, confined only by the law. Accordingly, it takes understandable concepts, criteria and rules on which the moderation of such medias can be based. The task seemingly amounts to the development of what might be termed "infringement mining", supplemented if necessary by a spam-filter suppressing vulgar phrases (in a colloquial sense).

The legal aspect, however, is given only secondary importance in the debate. Primarily, targets are pursued that also include legally acceptable opinions but considered to be undesirable "otherwise". The most prominent examples are "hate mining" resp. "abusive language mining". (In the literature, a few more kinds of bad languages are treated. We refrain from quoting them and their taxonomy.) That, of course, provokes the questions: "What is meant by hatred? What is the definition of abusive language?". As both concepts express the departure of an accepted standard, those questions can be rephrased: "What is to replace the penal code as for a non-controversial norm?". Any answer like "public sentiments, ethics and values" certainly would not help. It is common practise, therefore, to leave the standard in the dark but try to paraphrase deviations from any "normality" directly. See the recent survey by Köffer et al. (2018). Moreover, both concepts do not aim at contents

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of the comment under consideration but instead drive at behavioural characteristics of its hidden writer. That way, one ends up with interpretations of “hatred” etc. in terms that again are much in need of an explanation. For instance, constructs like “malicious intent”, “demagogic contents”, “ethnocentricity” etc. are used to characterize “hatred”- all very vague and subjective. To seek refuge in meta-concepts, is the wrong way from an analytical perspective-totally and utterly. Linguistic constructs are fuzzy and not directly observable in a message.

Consequently, one must enter upon a way in the opposite direction. Juridical concepts like “defamation”, in contrast, are more likely candidates to be formatively circumscribed by notions more precise and more manifest—a device familiar from structural equation modelling.

There is a further aspect. Most questionable tweets etc. are related to political issues. The assessments and the vocabulary quickly change in part. For instance, opinions considered to be inhuman and xenophobic at the climax of the “refugees welcome” period 2015 became mainstream but two years later. “Post-truth” (“post-faktisch” in German) was Germany‘s word of the year 2016 and is completely out of use now. Conversely, the mentioning of “Heimat” (roughly translated into “homeland”) would have pointed to a right- wing person only three years ago. Today, the idea is discussed in political parties and the responsibility of a federal minister. Glossaries of terms describing e.g. “hatred”, accordingly, might be rather short-lived.

Summing up, it may be said that “abusive language”, “hate-speech” and the like are inappropriate starting points for media moderation. They all lack a levelling rule and lead to an opaque vocabulary—rendering them inapproachable by means of statistical learning. To deal with relevant juristic conceptions and to bring infringement mining to life will be difficult enough. To put it bluntly: For mining it takes rocks, may be on a low scale of hardness– but swamps just won’t do.

To end this section, we shortly address “fake news”, another kind of evil discussed in the literature. “Fake”, again, refers to the behaviour of the writer in the background. The intention, to deceive the readership deliberately via disinformation, may be especially hard to read out from a short message, e.g. a tweet comprising at most 280 symbols. How to distinguish that case from a message where some author is just overemphasizing some aspects to foster his point of view? What is a “news”? It can be a fact, an opinion or a rhetorical question. Even numerical information is often difficult to check and open to speculations. In addition, there is a rich literature informing cheaters how to lie with statistics and pictures, starting with Huff (1954). Statistical laymen and algorithms used by them will typically miss the trick. Omissions, too, represent an effective method for deception, often hard to recognize even by humans. Why to expect that from an algorithm? Moreover, a non-trivial standard for “non-fake” cannot be formulated. Content based fake mining, accordingly, does not seem to become a very promising mission.

2 Shades of Grey

At the end of all mining efforts, tweets and comments in the text basis for learning will have to be categorized. That task can be facilitated in two ways. First, it would be a bad idea to formalize that problem in a black (negative) and white (positive) fashion, because the algorithm would be forced to decide in favour of one of these classes in doubtful cases, too. That would create additional label-noise and, hence, be detrimental to the learning effect. Accordingly, it is wise to include "grey" (undecidable) as an additional category and to use trinary classifiers. Secondly, the goal "detect infringement" is too complex to be handled in just one stroke as it comprises a diversity of sub-goals, e.g. "libel" and "sedition". It is near at hand, to partition the illegalities regularly observed in a media into homogeneous subgroups and to work them out serially. For instance, "libel" might include "insult", "slander" and "defamation".

The training of a multi-layer classifier—based on a learning sample—follows a simple path: The seemingly easiest sub-goal is handled first. For "black" messages the process stops. The "white "and the "grey" ones of the initial classification step become the input of the second ranked sub-goal and so on. To substantiate the idea, however, the formal requirements of a classification problem must be ensured.

In what follows, we shall have to work at the following points:

- Identify the aspects, i.e. the collection of all key words in the text basis relevant for the target under consideration. That activity corresponds to feature selection in classical data analysis.
- Determine the orientation of each aspect, i.e. assign to it one of the values −1, 0, 1—expressing black, grey and white. That coding, of course, appraises the effect of an aspect on the sentiment of each message showing it. That activity results in a vector of qualitative predictors—depending on the sub-goal. Accordingly, no classifier is admissible that requires quantitative input variables.
- Add a class label to each message, i.e. look at all aspects in that message and their orientation. Decide upon the class-label on that basis. For that purpose, a formal rule might be laid down as a guideline to standardize the labelling process and to reduce noise. By the third step, supervised learning becomes possible.

Which key words are relevant, typically, will be decided with the help of a glossary which on the one hand side reflects the sentiments of the moderators, and on the other side will be influenced by previous experience. The labelling process, too, depends on the "culture" of a specific social network or portal. A seemingly trite remark: As for infringement mining—but not only for that topic, it seems advisable to rely on people that are sufficiently knowledgeable about the subject.

The approach above is in the spirit of sentiment analysis (SA) as outlined in the monograph by Liu (2011) and some of the terminology is adopted, too. The definition of a "(regular) opinion" presented there is simplified in-so-far as the anonymous opinion holder as well as the time stamp are ignored. A glance at the pertaining literature reveals that many authors orientate themselves by techniques from information retrieval (IR), i.e. make use of bag of terms models. SA, sometimes called opinion mining, is advocated by a minority only. This comes as a surprise in-so-far, as IR was designed for a purpose that has not much in common with the aims of SA. Distinctions are listed below:

- Data situation: In IR there is a query, typically short, and are large number of documents of sizes that might vary from short to very, very long. In SA, on the other hand, there is no query but some piece of news or a tweet or … that provokes reactions. The number of such comments or retweets depends on the media as well and might range from close to zero up to a very large number in case of a shit-storm. As a rule, however, all messages are short. (All amounts, of course, are measured on a cursory scale.) Consequently, word frequencies might vary significantly in the IR context only.
- Aims and ends: IR deals with a matching problem connected with the query. Solutions depend on similarity measurements, relevance feedbacks and rankings. All operating figures depend on term frequencies and react on their volatility. Sentiments that might be expressed in documents are irrelevant. SA, in contrast, strives for the detection of sentiments and is a classification problem. Solutions depend on text features resp. aspects, orientations, post-labelling and the choice of the classifier—as explained above. Term frequencies are irrelevant because (i) it takes only one noticeable indicator for the violation of a law—and not five and (ii) even if the number of violations would be of interest, the data shows too little variation in term frequencies -as mentioned above—to provide an answer.
- Numerical representation and toolkit: In IR every document is represented by a vector of quantitative variables, the weights. (This is not true for the Boolean model that, by now, hardly plays any role.) Accordingly, the whole of vector space methods is available and quite a part of it has been used. Latent semantic indexing, for instance, is based on the singular value decomposition (which settles the generalized eigenvalue problem). It is the wrong place to dispute such devices. In SA, in contrast, every message is coded in a purely qualitative way, i.e. by a vector each entry of which is trinary. Sophisticated mathematics are neither in want nor available.
- Conclusion: IR and SA have hardly anything in common, not conceptually and not methodologically. Accordingly, we are thrown upon what has been developed for SA so far.

3 Mining or Poking

The classifier, from a methodological point of view, is the core of any sentiment analysis. The whole tool-kit developed for classifying structured, numerical data seemingly already got a try. Typically, however, the classifier of the analyst's choice is not justified, but just used in a "why not"-fashion. It is certainly true, that there cannot be a globally best classifier, only a local optimal one. Unfortunately, this local hero depends on the unknown distribution governing the randomness. This sad fact, however, is not a justification for the attitude just mentioned. Some authors try to tide over that situation with the help of computer simulations, typically based on "benchmark data". These data sets, unfortunately, do not represent the situation under consideration. They are nice for illustration, but not of any interest beyond that.

Classification procedures differ in the underlying rational, in their properties as well as in their requirements. It was already mentioned, that only classifiers allowing for qualitative predictors are feasible in the context of sentiment analysis. That excludes Fisher's discriminant analysis, for instance. There are other restrictions as well. (1) As the labelling process is cumbersome, the learning sample is usually of only moderately large size. That, of course, excludes procedures depending on a large number of parameters. (2) Classifiers differ in stability. Unfortunately, "stable" is used in various ways even within statistical learning. What is meant here, is a continuity property: Small variation in the database have only little effect on the classifier. Due to the labelling step in a sentiment analysis, we have to be prepared to work with noisy labels what makes stability a desirable quality. (3) Many classification techniques are but black boxes, i.e. might be good predictors without providing any explanation as for the result. This property is especially undesirable in the present mining context. Social networks and portals are requested to render the moderation process as transparent as possible to avoid the impression of a political bias or even censorship. Interpretability, hence, is a criterion as well. (4) Boosting is a method designed to pay special attention to objects that are hard to classify. They work iteratively and give more weight to "difficult" objects than to "willing" ones. (5) Recurrent neural networks (CNN) are designed to cope with structured tasks. A multi-layer classifier fits into that scheme.

There are still other reasons to advocate or to reject a type of classifiers. The naïve Bayes method, that figures prominently among machine learners, is not well accepted in most quarters of the statistical community. In first place, this is due to a rather questionable independence assumption. In what follows,

We shall now have a look at some prominent family of classifiers.

Support vector machines (SVM) are based on a very elegant mathematical theory but suffer from various drawbacks and are not to be recommended here. On the one hand side, they enjoy the blessing of dimensionality—resulting in a good separability, on the other side they suffer from the curse of dimensionality—resulting in the sample size necessary for computing the separating hyperplane. Moreover, the are primarily designed for binary classification. Extensions proposed to deal with more than two classes are not really convincing. The idea underlying SVM is easy to explain but it is a black box procedure anyhow. Not much seems to be known as for their stability.

Nearest neighbourhood classifiers only make sense if the distances to the neighbours are suitably weighted. As the predictors in a sentiment analysis are qualitative and all entries trinary, a special choice of the distance function is required. To the best of our knowledge, a suitable variant is not available in standard software.

Trees are popular because they immediately provide a clear rule set. Their lack of stability, due to the overlearning effect, motivated bagging and random forests, both of which could be applied for sentiment analysis. May be even more promising is one out of the stochastic boosting methods, that combines the ideas underlying random forests resp. the by now almost classical ADA-boost. A drawback: The approach is not easy to communicate and—in the end—a black box again.

Last not least, we come to recurrent neural networks, already mentioned above, which are worth a try as well. Objections: We are not aware of stability statements in the sense sketched above. Moreover, they are black boxes as well. Some analysts might be tempted to overcome that by hinting at "neurocomputation". That would be a hoax, as that interpretation is linked to their graphical representation. By their very nature, they are but generalized linear models.

In the end, every classifier must be judged by its ability to decide correctly, measured by means of both the error rates. With tree classes, we have to look at err(1) and err(-1). Here, err(1) is the number of negatives erroneously classified to be positives—divided by the number of objects classified either positive or negative. err(-1) is defined accordingly. In most applications, both errors are considered to be of equal importance. Typically, the sum of both is considered to be the rate of inaccuracy. That attitude is not always appropriate as errors might different consequences. That way of thinking is popular in the statistical testing theory, initiated by J. Neyman and E.S. Pearson. As not both errors can be controlled simultaneously, they suggested to control the error more crucial and try to minimize the other one. In the moderation business, the first error is committed if an unacceptable comment is erroneously tolerated, the second one corresponds to the erasure of a serious reaction, i.e. a sort of censorship. If the first error gets penalized, say on legal grounds, but the second error is for free, then it is easy to predict the consequences. Conclusion: Sensitivity as for the treatment of error rates should be more common.

4 …but

…there is still a lot to do, both theoretically and empirically.

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Social Media Data—A Glorious Mess

Stefan Stieglitz

1 Introduction

Social media contains data, produced by societal actors such as organisations and their spokespersons, journalists, politicians, celebrities, private persons, and a broad range of other entities. Moreover, 'social bots' and other types of automated players spread content in social media distorting the results of opinion making of the public as well as results of academic studies as bots often try to imitate human behaviour. Thus, innovative methods to adjust the data by filtering personal messages from news feeds and other non-human activity need to be developed. Cleaned structured data allows an identification of the main actors and a tracing of fragmentations in societal discourse. Based on such insights, predictions about societal trends and developments can be made. Furthermore, hate-speech and the spreading of rumours, misinformation, and propaganda could be identified. Such forms of uncivil and disruptive speech are omnipresent in current public discussions relating to the international migration crisis, the spreading of 'fake news', and other flashpoints.

As a result of the high popularity of social media and the massive amounts of data generated every day, social media analytics has gained substantial importance for academics and practitioners (Stieglitz, Dang-Xuan, Bruns, & Neuberger, 2014). SMA is defined as "an emerging interdisciplinary research field that aims on combining, extending, and adapting methods for analysis of social media data. On the one hand, it can support Information Systems and other research disciplines to answer their research questions and on the other hand it helps to provide architectural designs as well as solution frameworks for new social media-based applications and information systems". Important contributions to SMA have been made by many disciplines, including information systems, media, communication, and cultural studies, and computer and network science. SMA uses structured, semi-structured, and

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unstructured online data (e.g. text, images, time-series data, metadata, network relationships) (Carlsson, Zafeiropoulou, & Sarker, 2015; Holsapple, Hsiao, & Pakath, 2014). It enables organisations to structure and interpret a large volume of public online data for assessing people's behaviours and attitudes (Kurniawati, Shanks, & Bekmamedova, 2013).

SMA is highly relevant in various contexts, such as political communication and elections, crisis situations, the production of and engagement with news and journalism, business contexts (for example, stakeholder analysis and market intelligence or internal communication among employees), and entertainment. It is even relevant for Business Process Management (vom Brocke et al., 2011). SMA aims to improve relevant tasks such as the tracking, preparation, and analysis as well as the aggregation, visualisation, and interpretation of social media data. SMA enables researchers and practitioners to address important questions including, for example, how information diffuses through social media or how predictions about future behaviour can be made based on social media data.

However, as any new field, structuring social media data faces several challenges that make it difficult for researchers and practitioners to engage with the data and derive insights from them. In a comprehensive literature review, Stieglitz et al. (2018) identified several such obstacles. The first one is that there is an "unhelpful gulf" between researchers from the social and the computational sciences. Researchers with training in different disciplines rarely work together, which hinders progress especially in an inherently interdisciplinary field such as SMA. SMA is also faced with a number of other challenges of a more technical nature. These include the discovery of relevant topics in what has been called massive social media data, and the choice of a data storage architecture that can deal with "big" social media data of high volume, velocity and variety. While solutions for these problems may be readily available in some disciplines such as computer science and information systems, researchers from other domains do not usually have access to them.

2 Social Media Data

2.1 Platforms

Social media are not a homogenous type of data and platforms. In fact, new platforms with their specific norms and functionalities come up regularly. E.g. StudiVZ was one of the most popular social media platforms in Germany in 2010 (when I started to work as an assistant professor at the University of Münster). Within a few months it literally disappeared. Facebook is also challenged now by other platforms and it is less used by younger students nowadays. It seems that social media usage is a generation-related experience, which is in contrast to other media such as TV, which used to be an essential media for several generations.

Besides different users and usage patterns, data access varies between all these platforms. Some platforms are quite open to share data with researchers (e.g. Twitter) while others are more restricted and limit their APIs. For researchers, but also for managers it is hard to decide what platforms are worth to be investigated and to put engagement on.

2.2 Roles and Actors

In order to generate significant further advancements in social media analytics and to develop more comprehensive theoretical approaches and instruments, it is necessary to sharpen the underlying conceptualisations of essential social media analytics elements, such as roles and actors and topics and dynamics. Following Forestier et al. (2012), 'roles' describe the nodes in a social network based on their connections and relationships with other nodes. In the context of social media, certain roles may be identified: for example, 'information sharer', 'intermediary', or 'information receiver'. By contrast, the term 'actor' describes accounts and their characteristics independent of their position in the network (e.g. police, journalist, media, enterprise, politician). But current understandings of roles and actors in social media remain rather limited and idiosyncratic; although some promising first steps beyond this stage have recently been made there is a pressing need for further research that investigates more systematically and comprehensively how certain nodes achieve their positions in the network, how they engage with others around them, and what impact they actually have on opinion-making and information diffusion.

2.3 Topics and Dynamics

Two other important elements that are subject of structuring of social media analytics are 'topics', understood generally as the subjects and themes addressed in the discursive contributions of social media users, and 'dynamics', describing the diachronic patterns and longitudinal evolution of communication processes and social network structures. Considerable more knowledge is necessary to improve our understanding of these essential elements and their impact across different application domains. Research on the 'topics' of social media activity largely remains dispersed across a multitude of individual case studies that examine communicative phenomena in various application domains, with few more comprehensive and comparative studies that seek to address the relative presence of different themes and topics within social media platforms in general. However, such studies are crucial for the further comparison and contextualisation of existing case studies as part of a more comprehensive picture of the uses and impact of social media in society. Research on large-scale 'dynamics' in social media is similarly rare, since most research initiatives address relatively short-term phenomena and consider the underlying networks of interconnection between accounts as static structures, thus neglecting changes and transformations over time and failing to take into account the interactions and spill-overs that occur between different social media platforms, and between such platforms and traditional media channels. Here, too, there is a significant gap in the literature that further research must address in order to develop a more accurate picture of the interplay of different forces (platform providers, platform operators, algorithms, individual and institutional users, regulators, etc.) in the social shaping of the technologies and use practices of social media platforms.

3 Impact on Organizations and Society

3.1 Organizations and Enterprises

Companies use social media in many ways. The most important goals are to identify new customers and sell products to them, to increase customer loyalty, to recruit new staff or to simply promote brands and products.

Enterprises are also affected by social crisis (aka shit storms) that might damage their reputation. By structuring and analysing data in real-time, companies might discover threats in an early stage enabling them to react earlier. One key application for SMA is the support of communication and collaboration in crisis situations. Social media can be utilised from almost everywhere, at any time; the real-time dissemination of news is therefore also especially important in crisis contexts as it allows users to stay informed or to disseminate news quickly in unexpected, uncertain, and fast-changing situations. As a result, SMA can be applied to track crisis communication processes and support the management of crisis situations. A considerable range of existing research provides case studies drawing on social media data from a variety of crises, offering deeper knowledge of processes, roles, and topics as they evolve in social media communication during such situations.

Examples for such applications include research into the Red River flood and the Oklahoma Fires in 2009, the 2010 Haiti earthquake, the 2011 Tunisian revolution, the 2011 Norway terrorist attacks, the 2011 Egypt revolution and uprisings, the Hurricane Sandy in 2012, the Boston Marathon bombing in 2013, the typhoon Haiyan in the Philippines 2013, the Sydney siege in 2014, and the Paris and Brussels terror attacks in 2015/16. Some frameworks for the identification of roles and actors in the context of crisis communication already exist. For example, Fritz and Mathewson (1957) found that five convergent behaviour archetypes are typically in evidence during disaster events (returnees, anxious, helpers, curious, exploiters). However, research on how these roles could be identified in social media or what impact they may have on the overall crisis situation has not yet been undertaken.

3.2 Society

Social media now indisputably represent a critical component of the overall mediasphere. The Reuters Institute for the Study of Journalism at the University of Oxford has documented the growing importance of social media as a source of news for an increasingly large segment of the overall population, for instance: across the European Union, some 46% of citizens relied on social media as one source for news by 2016 (nearly double the percentage recorded in 2013), and news distributed via social media is especially effective at reaching audiences who are not typically dedicated followers of conventional broadcast and print news publications—including younger demographics and female users. Additionally, social news recommendations through one's networks of friends on platforms such as Facebook and Twitter have also been shown to be especially persuasive: such 'social filtering' of the news tends to lead to deeper engagement with news content and improves the chance for the 'serendipitous' discovery of news stories that a user would not otherwise have encountered, as the US-based Pew Research Center has found. Over the past decade, journalists and news outlets have reacted to such trends by gradually incorporating social media into their day-to-day practices, as tools for the sourcing, dissemination, curation, and discussion of news stories, and as a means of building personal brands independent of the news outlets for which they work. Additionally, news organisations are monitoring the social media impact of their published stories increasingly closely, and such monitoring is also beginning to affect their future editorial and gatekeeping decisions.

At the same time, the notable circulation of demonstrably false, yet nonetheless widely disseminated 'fake news' and political propaganda around certain topics—-for instance in relation to the UK Brexit campaign or the US presidential election in 2016, and to a range of other public debates in Europe and elsewhere—have also raised fears of the susceptibility of social media users to such mis- and disinformation especially if it is being spread virally through their social networks. There are concerns that social media users may find themselves in, or actively seek out, 'echo chambers' or 'filter bubbles' that are characterised by a pronounced homophily amongst participating users, permitting only information that reinforces the community's established views and prejudices and—through 'spiral of silence' processes—actively ostracising silencing dissenting voices. At the same time, research by the Pew Center, conducted in the lead-up to the 2016 US presidential election, found that social media users do frequently encounter dissenting voices, and are from time to time even persuaded to change their mind about political issues by their social media contacts; the full dynamics of the dissemination of news and political information through social media, of their discussion by social media users, and of their effect on the formation of individual and public opinion, have yet to be fully understood.

Such processes are further complicated by the increasingly well-documented role that social bots and other automated accounts involved in "computational propaganda" campaigns, as well as centrally coordinated networks of manually operated propaganda accounts, are beginning to play in online political discussions. These actors, among others, may engage in the artificial amplification of selected viewpoints through the coordinated repetition of these messages by several apparently unrelated accounts (so-called 'sockpuppeting' or 'astroturfing'); in the deliberate disruption of meaningful public communication through off-topic spamming; or in the aggressive ostracising of political opponents through personal attacks and threats (trolling). State actors, especially including propaganda and intelligence agencies in Russia, have been strongly suspected of deep involvement in such activities, and if true their activities pose a considerable threat to the stability of democratic societies in Europe and elsewhere (Oh, Agrawal, & Rao, 2013). The threat is amplified by the fact that especially the most active social media users—younger people—are also least equipped to distinguish 'real' from 'fake' news.

The need to better understand and analyse information dissemination and sharing in public debates via social media is especially pronounced given the considerable challenges currently facing various nations. The rise of certain roles and actors, especially including populist and anti-democratic forces, in a growing number of democratic countries is well documented and is threatening social cohesion and democratic processes; it is no exaggeration to speak of these developments as a significant societal crisis. Social media did not cause this crisis, but serve both as amplifiers of its impact, and as tools in overcoming it, and there is therefore a considerable need to further understand exactly what role social media play—across a number of local, national, and international contexts—in public communication and the public sphere. Current debates identify a number of possible approaches to addressing this crisis, inter alia including legislative (e.g. German and French initiatives to force social media platforms to remove 'fake news' postings), self-regulatory (e.g. Facebook's and Twitter's vows to police trolling and abuse more strictly), educative (e.g. school programmes to develop better social media literacies in young users), industry (e.g. news organisations' plans to extend their fact-checking units), and social initiatives (e.g. civil society organisations' programmes to promote discourse and deliberation across partisan boundaries). In this context, information extraction and social media analytics play a major role in identifying structures of social media communication and optimizing information dissemination. This could help to uncover rumours and 'fake news' and improve our knowledge of cohesion and fragmentation dynamics in society.

4 Social Media Analytics

4.1 Process Model

Overall, then, although social media analytics has already established itself as a field of research with very substantial impact on society and economy, it still faces the problems of a young, emerging field, including a lack of standards, a lack of comprehensive theoretical models, and a lack of methods and instruments.

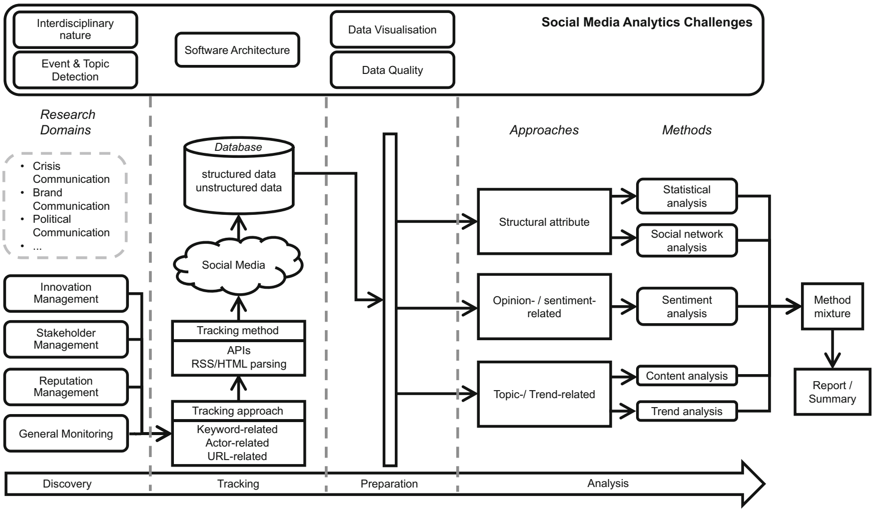

Fig. 1 Process model for social media analytics (Stieglitz et al., 2018)

As good researchers in Information Systems of course we need models that structure the process of social media analytics including different stages and methods (see Fig. 1).

Following this framework might help researchers and practitioners to conduct social media analytics and to structure their data in a beneficial and meaningful way. However, we are still facing many challenges, e.g. regarding theories and methods.

4.2 Theoretical Challenges in Social Media Research

Scientific analysis of the networks of social media users are often centred around the concept of roles. Some users are thought to be especially important for amplifying information, others to bridge different communities. Although researchers agree on these fundamental principles, there is no scientific consensus on which roles exist, and how they can be operationalised. Most previous studies are case studies. It is often unclear whether the results will hold on a different social media site, or in a different culture. This problem is exacerbated by the variety of different and often short-lived platforms. Researchers addresses this gap in current theoretical frameworks by conducting in-depth, large-scale social network analysis across a number of leading social media platforms and practices to identify and define typical actor types and to develop comprehensive theoretical concepts.

Even though researchers from different disciplines started to apply their theories on social media communication, there is still a lack of comprehensive theories and models. On the one hand, there still exist promising theories in different academic areas that have hardly been adapted to social media yet. Examples from communication science are the concepts of spiral of silence and echo chambers. Moreover, predictive models about the evolution of topics over time, e.g. on information cascades, have made large strides forward but have not been systematically added to the portfolio of social media analytics methods. Besides adapting theories from other disciplines, researchers also seek to develop new theoretical approaches based on the massive amount of data we will be able to analyse and based on the unique expertise of the involved academics. Researcher need to apply these theoretical models to a variety of real-world problems, thereby validating them in different situations and implementing them for use by academics and practitioners.

4.3 Methodological Challenges in Social Media Research

Text mining aims at interpreting text messages and summarizing or grouping them. It can be used to find patterns and important keywords in discussion, identify redundant information in and across messages, and to generate features for text classification. Classification and machine learning methods for text message classification, can be based on features generated by text-mining, but also on other attributes, such as time, location, or author, will be adapted for performing classification tasks. Advanced methodological approaches, such as convolutional ('deep') networks for automated feature generation, three-way classification and multi-class classifiers will be used to support the learning process. Moreover, compression-based classification and information theoretical methods could be a valuable tool for identifying messages that are likely generated by bots and/or trolls.

Methods from complex network analysis have crucial role in the SMA methodological toolkit. Researchers need to aim for matching the right method to the SMA task and perform research to make it more suitable to real-world data. E.g. centrality measures can assist in the tasks and the right types of centrality measures of actors need to be identified, e.g. betweenness centrality in order to identify information hubs, and Eigenvector centrality to identify the most influential actors in the network. Community detection in multiplex networks will be a key methodology for identifying clustering or fragmentation of networks into different roles and to study the phenomenon of fragmentation and its impact on the information dynamics of topics, e.g. the spread of rumours, and also of relevant information.

Examining social networks as graphs put the entire battery of graph and network theory at the disposal of researchers with an interest in social media analytics. Here, network theory comprises methods on topology analysis (centrality measures, community detection, motif recognition) as well as methods of simulation of emergent phenomena (e.g., fragmentation, resilience) and information spread across multilayered networks. So far, only a fraction of these methods has entered the canon of SMA methods. Harnessing this untapped potential contributes to the data-driven revolution that is taking place in the social sciences. At the same time, for many of the questions asked by researchers in the social sciences, there are no satisfactory solutions yet.

Social media data has fuelled the development of new natural language processing (NLP) methods to analyse the written word. From deep convolutional neural networks to word embeddings, state-of-the-art NLP methods augment and outperform the lexicon- and rule-based classifiers that many researchers still rely on to detect dynamics, topics, and classify the sentiment of texts. However, deploying these up-to-date tools requires specialized knowledge of NLP and machine learning methods. Also, determining the relevant features, compiling training corpora and evaluating a model in context requires knowledge of the domain, e.g. crises and society. Furthermore, developing a machine learning system for the real world means understanding and weighing the often-conflicting requirements its users have and striking a balance.

Summarized it can be said that there is a whole universe of methods that can be used to structure social media data. On the other hand, the amount and heterogeneity of data is growing continuously.

5 Resumé

As it was shown, there is a strong need for research on social media data. And it was often mentioned by Jörg Becker it is a key requirement to structure, to structure, and to structure data and processes to get a better understanding about the world. However, structuring of course is not enough! As Jörg always said, we should never forget that Information Systems also means to responsibly develop new solutions and prototypes in order to increase the welfare of everybody, which he always did. During my time in Münster, Jörg sometimes called me "Facebook-Professor" (even if I hardly did any research on Facebook). Even though this sounds a bit funny, the fact, that he and his colleagues at the Department of Information Systems in Münster created a position for a professorship with an emphasis on social media, shows, that they correctly estimated the high impact and the radical developments in this area.

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Part V
Organizations

"One cannot start with the end." (Frédéric Chopin)

For us, processes and data do not exist without context—they were implemented and generated with a certain task or idea in mind. We love to structure them, depict them in models, discuss them, and—in the best case—improve them or get meaning from them. Although we love doing that, we must not forget the context in which they appear—organizations. Without understanding them first, there can be no meaning in the processes or the data.

The Paradigm Shift in Customer Analysis: Marketing or IT-Driven?

Klaus Backhaus and Amir Awan

1 Prologue: Attacking the Corresponding Research Fields

While analysing customer behaviour we have to differentiate two basic approaches.

(1) *Theory driven and*
(2) *Data driven concepts*

This fuels the conflict between customer behaviour (theory driven) and IT (data driven). This "conflict" has been personalized in our faculty by the two heads of the marketing and IT department. Jörg Becker (head of the IT department) and Klaus Backhaus (head of the Business-to-Business marketing department), wherever they meet, start kidding about how to discriminate the respective partner by defining what characterizes the respective research fields. To give an example, how the corresponding partner interprets the respective research areas, please see the following exchange of comments:

> *J. B.: "Klaus, marketing is represented by people who have no knowledge about anything but they make you feel as if you were the dummy." Or: "Never trust a marketing guy, there is nothing behind his overwhelming appearance."*
>
> *K. B.: "When you are talking about Marketing, Jörg, there is absolutely no reason to be so judgy. Especially, since IT is even worse, because it's nothing else but just drawing boxes and arrows. You do not solve any problems, you are part of them." Or: "IT is a theoryless science, which means it's not a science at all."*

You couldn't have a dialogue like this, with every colleague but Jörg and I don't take those remarks as an insult but as a joke. And that is good so far, as the relationship between Marketing and IT has changed completely and is about to be written completely new in the age of digitalization, anyway.

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2 On the Way to Homo Digitalis

Customer behaviour has been regularly analysed on the background of various theories. However, when systemizing the diverse approaches it becomes apparent that the distribution of customer knowledge between the different market partners is consistently presumed to be in favour of the customer side. Subsequently, suppliers have to invest in market research to be able to generate enough information to adequately satisfy the customer needs.

This holds true for all kinds of theoretical underpinning, be it the theoretical world of the Homo Oeconomicus as well as for the behavioural approaches (Kirchgässner, 2008; Kremser, 2013). The former is a hypothetical construct, which is defined by behavioural assumptions comprising complete rationality with a straightforward objective of utility maximization, while keeping the premises of a transparent market and no time constrains. Hereby, the respective purchase behaviour is understood as the combination of preferences and restrictions. Although the preferences are considered to be given, restrictions are seen to be modifiable. Subsequently, the Homo Oeconomicus is able to differentiate between attractive and less attractive alternatives based on his utility function (Backhaus & Spinnen, 2018; Goebel, 2002; Haaker, 2013; Kirchgässner, 2008).

As the construct of the Homo Oeconomicus can not be found in reality, a perspective from New Institutional Economic (NIE) promised a modified interpretation of the strict Homo Oeconomicus. This theoretical construct shares behavioural expectations of the strict Homo Oeconomicus, while neglecting previously institutionalized restrictions such as full market transparency and no time constraints. The novelty of the NIE is the approach of understanding customers as individuals, who are in an interactive relationship with other market participants rather than individuals who are understood to only act under the predefined preferences and restrictions. Thus, the NIE constitutes a shift from a decision-based logic to a strategic-based behavioural approach, especially in respect of the negotiation of contracts (Aufderheide & Backhaus, 1995).

In contrast to the strict and modified Homo Oeconomicus, the so-called Homo Psychologicus—a behaviour-oriented construct—captures the consumer having influenceable preferences.

On this base, there is a number of marketing concepts, which were developed with the objective to alter the customer preferences in favour of the company's offerings. Hereby, two behaviourism models are of special interest, namely the S-R (Stimulus Response) model and the (Stimulus Organism Response) S-O-R model. Whereas the S-R model merely describes which Stimulus leads to which Response, the S-O-R model answers the question why a certain Stimulus leads to a certain Response.

3 Theories or Algorithms? The Impact of Digitalization on Marketing Theory

The consequence of digitalization can not be seen as a simple (linear) add-on of the existing approach. It is a disruptive innovation that calls out for new ideas and/or new Business Models. Suddenly, the supplier is enabled to track his customers individually and learn about his individual needs and the process he follows during the customer journey. Hereby, the supplier has to manage this process on the basis of a big data set (Erevelles, Fukawa, & Swayne, 2016). The cycle of technological developments related to the emerging tools to handle the different problems of big data sets is relatively short.

Thus, marketing has to prepare for playing in new, digitalized arenas. This is hard for both parties. The marketing manager will have to learn more about technical processes and the IT people have to learn that there is no room for objective features: Marketing is concerned with perception of measures and perception is selective and depending on the subjective view of the aspired target.

To underline this aspect we take Artificial Intelligence (AI) as an example for a novel instrument in marketing. AI describes a set of technologies that can operate in a way that human engagement is not necessary. The English Oxford Dictionary defines AI as "the theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages." AI is not a product of the future; it is already in the market.

As a subset of AI, Machine Learning (ML) makes use of data to teach itself how to complete a process with the help of AI capabilities (Dzyabura & Yoganarasimhan, 2018). As an advanced tool that uses data to derive effective solutions when facing complex digital marketing problems, ML can improve businesses by helping them eliciting insights from the available consumer data and hence, help to streamline marketing processes.

Consequently, ongoing technological advancements—e.g. with the Internet of Things—enable the companies to track customer journeys in a direct and automated manner by collecting data at various touchpoints. This data set can be enhanced by data acquired from data specialists. On this basis companies develop dynamic buying profiles of their customers, which can ultimately detect latent preferences of which even the customer himself is not aware. The information asymmetry shifts to the favour of the supplier's side. This approach, characterized by theoryless number crunching to detect behaviour patterns without knowing how these patterns can be rationalized, is a fall back from S-O-R models to simple S-R models, the latter not needing a theoretical explanation.

To sum up: Up to here we tried to prove that the new technologies demand solutions and approaches, which are data based. This data base can be structured through software programs, which are completely explorative and theory averse. Instead, in the centre of interest are search algorithms, which are developed in a market-oriented fashion or specifically tailor made for an individual customer. This moves IT-people

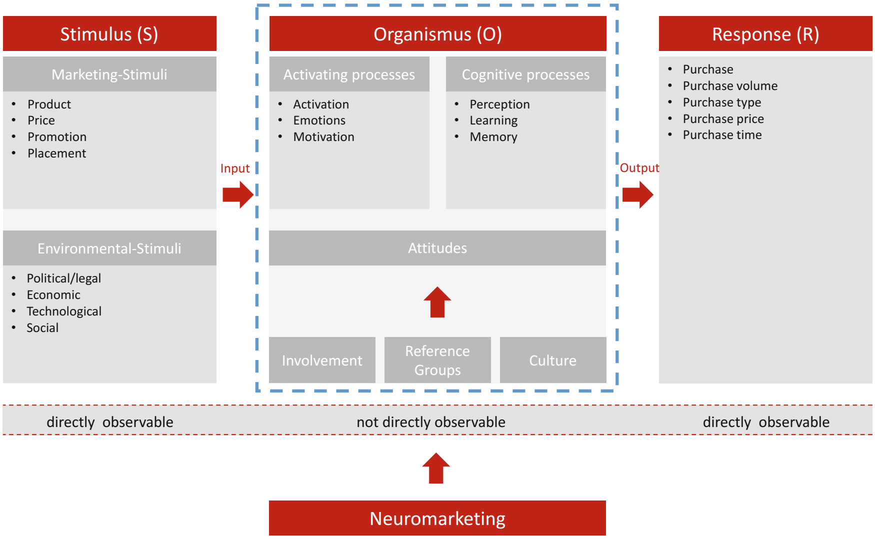

Fig. 1 Differentiating the stimulus-response and stimulus-organism-response models (Pispers & Dabrowski, 2011)

to a highly prominent position. We will discuss, if e.g. marketing questions lose their impact in the new world of the Homo Digitalis. Perhaps, Marketing and IT will cooperate to accelerate new solutions. Answering these questions will depend on what is in the centre of interest.

The Homo Digitalis is a construct that needs to be analysed, because it is built on other grounds as the established Homines (Backhaus & Paulsen, 2017). The Homo Digitalis is characterized by being an explorative data mining construct mirroring the respective behavioural profile and thus, allowing companies to analyse dynamic buying profiles of their customers on an individual level. Whereas the S-R model merely observes which Stimulus (S) leads to which Reaction (R), the S-O-R model takes the not directly observable processes of the Organism into account, which ultimately leads to the observable Response (R) (Meffert et al., 2015). Thereby, it is important to note that the latter model is the one, which sheds light on the question *why* exactly a certain Stimulus (S) leads to a certain Response (R). Hence, the S-O-R Model allows marketing actions to manipulate the behavioural construct in a more targeted approach. Figure 1 shows that the not directly observable construct, namely Organism (O), is reflected by hypothetical constructs comprising activating processes, cognitive processes, and the attitude, which thereby includes influences stemming from the external environment. We look at the Demand Side.

Earlier versions of the Homo Digitalis skip the O-Box of the S-O-R model and contemplate the relationship S-R, only as a regression relationship between the input variable S and its impact on R. Thus, we consider a statistical relationship to stand for the Homo Digitalis, neglecting any trial to explain the reasons why the relationship exists. The magic expression is "algorithms instead of theory".

The Big Data set allows to detect hidden structures embedded in the ongoing information flow. Finally, it is a structuring process that gives the user the power to edit the profiling information on which basis the supplier derives latent structures and ultimately develops highly targeted offers accordingly. The search for simple or even complex structures in a data set is completely algorithm based, that is IT-driven. This is not a great problem for practical purposes because the demand for theoretical explanations does not provide direct value for practitioners. They are interested in structured profiles that allow them to predict and/or influence customer behavior in respect of purchase decisions.

4 How Does Digitalization Influence Marketing Programs?—Examples from the Marketing Frontier

We have tried to demonstrate that the Homo Digitalis is the foundation of a new paradigm. Although for practical purposes it is of major interest to be able to describe each Homo Digitalis by his own profile, it is of great interest to find out if there are clusters of Homines Digitales that can be described by similar profiles. This would enable us to develop marketing strategies targeting the same type of Homo Digitalis and hence, amplify the degree of perceived personalization of the respective marketing activities. This high level of individual and contextual targeting is only possible in co-development with IT (Song, Nason, & Benedetto, 2008). As a result, there is a change in the way how we interact with the customer and how we analyze the customer behavior. Against this background, the personalization of the marketing activities do not only influence the promotion, but also the price (e.g. dynamic pricing based on context and individual price elasticity) and product (e.g. customized products with 3D printing) (Ban & Keskin, 2017). Contemplating the high degree of personalization on the dimensions product, price, and promotion, IT applications can amplify the influence of marketing on the development of products and services and therefore change the focus and influence of marketing activities.

As exemplified above, the digital connectivity and the change in customer behavior calls out for new marketing solutions, which can be jointly developed with the IT department:

(1) **Optimizing Marketing Budgets**

The combination of AI and highly targeted marketing activities allow the marketers to monitor and direct their marketing campaigns with more control, while eliciting new insights on the customer's preferences and behavior (Gebhardt & Handschuh, 2016). As a result, the marketing efforts result in higher conversion rates and therefore increase the return on investment (ROI) of the respective marketing campaigns. Thus, IT based AI helps marketing to account for success. Further AI applications may support the efficiency of marketing activities. For instance, AI can optimize the marketing budget. Therefore, the AI application develops the most efficient marketing mix based on predefined budget, campaign goals, and runtime (Fahrbach & Schumacher, 2018).

(2) **Hyper-Targeted and Personalized Marketing**

As discussed above, the new elements of customer behavior constitute a new human-centric era of marketing, which is characterized by the interaction process between humans, social and online platforms, and IoT objects. Hence, it becomes feasible to track the customer journey in real-time to an unprecedented manner. Customer data will show where the customer will be in each step and what appeals to him. Subsequently, the marketing activities can be designed accordingly, while personalizing every interaction point along the sales funnel (Neubauer, 2018). As a result, customers will be subject to hyper-targeted personalized marketing actions, ranging from personalized product offerings, e-mails and landing pages to personalized, dynamic pricing in combination with referral systems and personalized promotion.

(3) **Novel Forms of Interactive Media**

Alongside with the possibility to interact with the customers in a more targeted way along the customer journey, new formats to engage and amplify the interaction are evolving. Video proves itself as a powerful and influential tool to boost digital content and can result in a tremendous positive impact for the business success. For instance, the case of the company Dollar Shave Club is a textbook example of how viral videos can boost success in times of social media (Schwertfeger, 2017). This company offers different sets of equipment for shaving (e.g. Starter and Advanced Package), while providing their customers continuously on a monthly fee basis. However, their heavily reported success is owed to their entertaining video introducing their business concept, which went viral on social media. As a result, their website crashed due to traffic and their inventory was sold out in the first six hours. Starting out in 2012 the revenue of Dollar Shave Club amounted to $4 million and grew in 2014 to $65 million. In times of understanding attention as a currency, video content can prove itself valuable by boosting search engine rankings and increasing engagement and website traffic rates. In turn, social media platforms have introduced new features, which companies can leverage on, such as with the Live Video feature.

Going further, the concept of voice recognition is gaining on importance as a conversational and naturally interactive user interface. Google reports that already 20% of its mobile queries are voice searches. It is expected for this percentage to increase, as customers will get more comfortable asking Apple's Siri, Amazon's Alexa, or their smart fridge what to buy.

(4) **The Virtual Service Consultant: Chat Bots, Talking Assistants and Affective Computing**

One frequently mentioned use case for AI applications in a marketing context are intelligent chat bots (Sotolongo & Copulsky, 2018). They allow customers to formulate questions in writing, while offering assistance in a direct manner at any time. Fully developed chat bots can therefore offer an atomized and cost efficient first-level support. However, chat bots are not limited to customer service. They can also be configurated to assist in online marketing. Hereby, intelligent chat bots can consult the customer for a personalized online shopping experience and thus increase the conversion rates.

Furthermore, the technological advancements allow the customer to interact with the virtual customer service consultants via voice recognition (Sotolongo & Copulsky, 2018). Hereby, Google plays a dominant role, as they have demonstrated with their release of their talking assistant. This assistant can arrange meetings between multiple parties and the customers can't tell that easily that they are not talking with a human.

However, one important component is still missing when contemplating novel human-machine interfaces. The underlying algorithms are predominantly collecting "hard customer data"—merely observing how the digital customer behaves but not being able to understand what the underlying reason for the observed and perhaps predicted behavior is (Hahn & Maier, 2018). With the developments in Affective Computing, AI applications are increasingly collecting "soft customer data", which comprise "soft factors" such as emotions (Hahn & Maier, 2018; Ma, Xu, Bai, Sun, & Zhu, 2012). Objective is to feed the AI application with "soft customer data" (e.g. emotions), which in turn help to understand the question "why" a customer behaves a certain way. As a result, computers will be able to act under consideration of our emotional response. Only on this basis, it will be possible to develop an empathic human-machine interface.

(5) **Artificial Intelligence (AI) and Machine Learning (ML)**

Machine Learning, a subset of AI, can be used to advance the process of new customer acquisition and lead generation (Neubauer, 2018; Dzyabura & Yoganarasimhan, 2018). Therefore, the ML applications have to be fed with predefined buying profiles, which are derived in a group effort between marketing, sales, and strategy. In a second step, the ML application has to be connected with external data sources, for instance providing financial and marketing data of the potential customer. Finally, the ML application will provide increasingly accurate hit lists of leads, with the results changing over time as the algorithm may for instance monitor customer interaction with the brand.

The use of AI when contemplating and managing churn behavior of customers is another promising use case of AI in marketing. Having in mind that personalized marketing campaigns can be realized with AI, AI and predictive analytics can further help to decide which would be the appropriate context to trigger the respective personalized marketing campaign. One direct benefit of launching a marketing campaign is that the number of customer churning decreases. In other words, this means that if a marketing campaign is launched shortly before the customer is likely to churn, it may help to win the customer back in time. Against the background that it is far more expensive to acquire new customers than to keep the current customer base, this kind of AI applications can provide great value for marketing. In this vein, predictive algorithms try to detect when a customer is likely to churn, while being able to automatically trigger a personalized marketing campaign and thus, strengthening the customer relationship at the identified week spots. Hereby, the customer will be confronted with a personalized price, based on the assumptions of his individual price elasticity.

(6) **Predictive Algorithms and Predictive Delivery**

Furthermore, online giants such as Amazon make use of predictive algorithms in combination with predictive delivery. In case of a predictive algorithm detecting a customer, who is likely to buy a certain product (e.g. his purchase history indicates preferences of a certain author), Amazon would send the respective product to the nearest warehouse of the customer without having the customer actively triggering the buying process. In a next step, Amazon could send a novel of the preferred author to the customer, giving him the option to buy the product on a discount or to send it back. Hereby, Amazon could make use of predictive delivery, which informs the customer when exactly the delivery would reach his home, while considering past data indicating a timing most convenient for the customer to receive the package.

5 What Will Happen in the Future?—Nobody Knows

5.1 The New Task: Reconciling Marketing and IT

The driver for the outlined changes in marketing and customer analysis is the continuous development of technology. Hence, it is important to throw a look at the future developments of the underlying technologies and the respective challenges, which the companies face when implementing novel technological marketing tools. We have seen that the Homo Digitalis is in the center of the developments; IT may even be in the driver seat. Contemplating the developments of marketing in contrast to IT, we find ourselves in a situation where we marketers already have troubles in developing and implementing novel marketing tools as fast as necessary. To cope with the IT technology, marketing has not only to develop new marketing tools but also has to speed up.

It is important to understand that it is not enough to feed an AI database with as much data as possible and hope for the “magical algorithm” to increase the effectivity and efficiency of marketing. No, it is a painful structuring and data collection process, which is required to provide the necessary base. Companies often collect their data sources in silo-structures. As a result, one department may collect and save the relevant data separately from other departments, who might need the same data. This is why companies are recommended to establish a centralized and specialized unit for Big Data and Analytics. This will increase the quality of the data, which in turn will increase the success of AI applications. However, once the database is structured and ready for use, it is of utmost importance to clearly define the use case and its objections (e.g. decrease churn rates by automating contextual and personalized marketing campaigns at (predicted) critical phases of the customer relationship). In this vein, the company can evaluate beforehand, which data might be of importance for the desired AI application.

Moving away from the challenges of the technological and strategic implementation of AI in marketing, it is worthwhile throwing a glance at the technological landscape and its developments. As explained above, the technological developments have triggered a paradigmatic shift in customer analysis due to the shift of information asymmetry in favour of companies. The digital footprint of the customers allow the companies to collect their individual data and to derive latent preferences and dynamic buying profiles. This is only possible under the premise that companies have the sovereignty over the data, leaving consequently little to no control for the customer regarding the use of the personal data.

Against the background of platform-based companies following new rules of competition, exemplified by the Winner-Takes-All principle, customers have reason to question the monopolistic companies such as Facebook or Amazon in respect of the use of their private data. For instance, the "Cambridge Analytica" scandal triggered a new wave of customers stepping up against the use of their personal data for electoral manipulation. It was revealed that Facebook—counting more than 2 billion users—was involved in leaking personal data of their customers. Hereby, Cambridge Analytica analysed the data and derived psychographic customer profiles of users and their friends, which were then used for targeted political ads in the UK's Brexit referendum campaign, as well as by Trump's team during the 2016 US election.

5.2 Safety: A Necessary Precondition

With the newly introduced European General Data Protection Regulation (EU-DSGVO) a meaningful step was undertaken to protect the customers' private data and to claim more transparency and control for the customer. For instance, customers are allowed to request a company to disclose all personal data, which was collected and saved by the company. Hereby, the EU-DSGVO cautions the companies to provide the information in a meaningful and understandable way. Hereby, the customer can decide whether the company must (partially) delete their personal data.

However, the desire of customers to have more control over their data expresses itself furthermore in the technological developments. Let us throw a glance at an interesting development. The Blockchain (BC) technology is a distributed and immutable ledger technology, which doesn't need an intermediary by definition due to the way the data is stored and managed. Hence, important features of platform companies could be disrupted by the respective Blockchain technology. The revolutionary feature of the BC technology is that value (e.g. assets or Intellectual Property) can be transmitted via Internet, ultimately moving the internet of information to the internet of value, without needing a trusted intermediary due to the technologies consensus mechanisms. Despite having its first application in the financial industry, the BC technology has a very broad field of possible applications.

Coming back to the before mentioned dilemma of intermediary companies benefitting from an information asymmetry, while customers not having transparency and control over their data, the BC technology might be the key for customer sovereignty in the digital era. For instance, the BC technology can be used for identity and access management of the customer's personal data. Instead of handing over personal data to centralized organizations, while being forced to trust them, BC offers the technological solution for the self-governance of the personal digital identity. Ultimately, customers are empowered to manage the authorizations of who gets which data for which purpose. Hereby, it is not only the immutable BC but also the so called "Smart Contracts", which can result in an increase of customer sovereignty concerning personal data. Smart Contracts are contracts, which are translated in programming language and integrated in the Blockchain. This way, customers can predefine under which circumstances they want to share their personal data and automate the authorization process via Smart Contracts. In this vein, Wiesel (2017, p. 142) expresses his hypotheses that companies will utilize data security and transparency issues as a competitive advantage, offering customers (perceived) data sovereignty and hence, building a basis for a valuable, long-term customer relationship.

5.3 1 + 1 = 3? On the Synergy Effects of Aligned Behaviour

The Homo Digitalis is a theoretical construct, which tries to reflect a customer and track his behavior based on the digital footprint he leaves behind. Hereby, the construct is heavily dependent on two factors, namely the technological developments and the decision of the customer of how transparent he wants to participate in the digital world. Both, the technological developments and the willingness of customers to share data, are dynamic and hence, very difficult to forecast, which in turn makes it difficult to formulate accurate projections concerning the development of the Homo Digitalis.

However, when looking at the interdisciplinary developments, the following is of great importance: To be successful in future we have to learn more about each other. That makes it necessary to improve the understanding between the two disciplines, especially since marketing and IT already have problems with the respective language.

Nevertheless, based on the previously mentioned trends regarding Blockchain and other sophisticated AI applications, such as Affective, Emotional Computing, we will share our thoughts on how the Homo Digitalis could develop.

The Homo Digitalis 2.0 takes advantages of the technological developments, especially of those AI applications, which are enriched by Emotional Intelligence. Hereby, the concept of Affective Computing, which has been introduced when talking about the Virtual Customer Consultant, plays a role. Instead of merely considering "hard customer data", as Homo Digitalis 1.0 does it, Homo Digitalis 2.0 comprises "soft customer data" (e.g. emotional response) in order to answer the question why there was a response and why exactly there will be a response in future. Thus, the algorithms describing Homo Digitalis 2.0 have found a way to incorporate theories in order to shed light on the important question “why”.

The later version of the Homo Digitalis are personal opinions on the development. It has to be seen in the light of further technological developments (e.g. Blockchain Technology), which facilitate the necessary technology for the customers to have more control over their personal data. As discussed previously, a Blockchain solution may give the power to the customers concerning who gets which data for which purpose. By having control over who gets which kind of data, the customers can ultimately manipulate the Stimulus of the respective SOR model. This can come in handy for people who prefer getting real personalized marketing campaigns based on personal preferences, which they willingly share via Blockchain. In addition, the traditional way of Response may be altered. Smart Contracts (SC) can automate the response to certain stimuli based on the customer’s preference. As a result, we can deduce that with this kind of technological developments, customers will be increasingly empowered. In this picture, the customer can partially control for the Stimulus via Blockchain data access, while being able to automate the Response via Smart Contracts.

6 Epilogue: The New Relationship Between Marketing and IT

These examples demonstrate that (information) technology opens up a chance for structuring and managing the digital interaction process between customers and suppliers. To develop fully new marketing tools in the century of digitalization (e.g. the Virtual Customer Consultant and AI in marketing campaigns) the marketing management has to understand how technological development can serve as a basis for new digitalized marketing endeavours. That can effectively and efficiently only be done when the IT department and Marketing Department learning from each other and cooperating instead of working against each other.

Ten years from now we will live in a complete new world where you, Jörg, and I are not only both Professors emirite, but we will also have to rethink, how to tease each other. Perhaps the dialogue will be as follows:

> K. B.: “IT has proven itself to be the driver of technologies of the novel marketing tools… but marketing has developed applications that improve the interactive process between customers and suppliers.”
>
> J. B.: “That’s the way it is: We got to learn that we are sitting in the same boat and it doesn’t matter if there is a hole in the boat where IT or marketing is located. If the boat sinks, both of us will drown.”
>
> Both: “Jesus, what a great perspective!”

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Information Systems as the Genetic Material of Organizations: The Contributions of Jörg Becker

Richard Baskerville

1 Organizational Genetics

In biology, the genetic code is a set of rules defining how information encoded in *genetic material* is translated into proteins by living cells. It is the code by which our cells operate. In human organizations, the genetic material provides a metaphor that helps us understand the fundamental set of rules by which the most elementary units of the organization create productions. This *organizational genetics* view generally concentrates on selection of organizational forms (ala natural selection), e.g., the importance of heterogeneity in the population of organizational forms (Hannan & Freeman, 1977). In relation to organizational genetics, there is a notable equivalence of information and structure:

> Biological analyses are greatly simplified by the fact that most useful information concerning adaptation to the environment (which information we call structure) is transmitted genetically. Genetic processes are so nearly invariant that extreme continuity in structure is the rule. (Hannan & Freeman, 1977, p. 936)

The notion of equivalence between information and structure, when coupled with the effects on information systems from extensive digitalization, suggest the works of Jörg Becker may be deeply fundamental to both organizations and information systems. The design of digital artefacts, and the potential impact of these artefacts at an organizational genetics level, call for revisiting the relationship between an organization's genetics, its reproduction, and the structures embodied by the information systems.

In human organizations, the most *elementary units* of organizations are people and autonomous machines. Each of these units is capable of autonomously making

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productions. People are innately autonomous, with the freedom to act according to their own will. They may choose to follow rules, or not. People can also guide machines, such as driving a vehicle or manipulating a keyboard, but in these cases the autonomy belongs to the person, not the machine. People will usually follow the rules in their productions. Machines can also operate autonomously, such as self-driving vehicles and factory robots. Autonomous machines generally follow the rules encoded in their algorithms without deviation.

In human organizations the *genetic code* takes different forms that match the elementary units. In terms of practical productions, people usually operate according to technological rules (Bunge, 1967). A technological rule will include a goal, a condition, and an action. Such rules take the form of, 'in order to achieve goal *g* in situation *c*, take action *a*' (van Aken, 2004). Autonomous machines act according to algorithms that have been coded in computer programming languages. These languages are typically procedural and most commonly operate in a von Neumann architecture. Artificial intelligence approaches may code the rules in non-von Neumann architectures, such as neural networks and declarative languages. In such cases the machines are "trained" in the fundamental rules rather than procedurally programmed.

The *genetic material* of organizations is embodied by the organization's structures: reporting arrangements, policies and strategic plans, budgets, procedures, etc. The genetic code (the rules) define how the genetic material (the structures) are translated by elementary units (people and autonomous machines) into productions.

A great deal of the genetic material of organizations is embodied in its information systems. This embodiment arises because a sizable proportion of the genetic code is operating within digital systems. Many of the organization's structures have been institutionalized by enshrining them in algorithms of its information systems. Compensation policies are coded into payroll systems. Customer invoicing policies are coded into billing systems. Corporate strategic plans are coded into supply chain logistics systems. Even when people are enacting technological rules, they may not only need digital systems to help them determine their situation ("Am I in situation *c*?"), but also to help them take action ("I am sending an email to take action *a*."). It seems the either the organization's structures are completely embodied in its information systems, or people are enacting processes that necessarily require them to interact with the information systems.

2 The Genetic Metaphor and Organizational Reproduction

We can see that this embodiment of the genetic material of organizations in information systems (i.e., the organization's structures) provides the information that enables the organization to generate productions according to its genetic code. But we are also accustomed to such genetics concepts being applied to heredity rather than existence. We must suppose that organizations inherit this genetic material from its ancestors. This viewpoint is the focus for most work in organizational genetics (Hannan & Freeman, 1986).

Human organizations evolve differently than do biological organisms. Of course, organizations die: they may fail economically, they may obsolesce, they may be outlawed, etc. But organizations reproduce in life cycles. These cycles are thought to depend on the ability of an organization to transform itself when its entropy levels rise to a degree that the organization no longer fits its environment.

This rising level of entropy arises from dissipative structures that drive organizational transformation or failure (Leifer, 1989). Stable organizations must increasingly lose touch with their environments because these environments continuously change. An unchanging organization in a changing environment will necessarily become ever more inefficient. If for no other reason, it will be due to the increasing mismatch between the organization's inputs and the environment's outputs and between the organization's outputs in the environment's inputs. As a consequence the organization must increasingly do additional work in order to translate more and more of its inputs and outputs to match its environment. When one part of the organization does adapt, such as one part that feeds an output to the environment, then other parts of the organization may have to do additional in order to interact with this changed organizational element. All of this additional work represents an increasing degree of disorder (i.e., entropy) within the organization.

The rising entropy accompanies aging efficiencies due to the evolution of cooperating efficient systems. When part of the organization becomes efficient (e.g., because of an adaptive structure) but holds its old structures steady, overall misalignment with the changing needs of the rest of the organization grows. This growing misalignment is called a dissipative organizational structure because entropy steadily dissipates throughout the organization. Transformation occurs when the situation is recognized, and more extensive change unfolds. Previously unchanged steady structures are revised and realigned, allowing overall efficiency to rise. It is a form of an organizational reproductive life cycle in which entropy rises in the old organization and falls in the reproduced organization as both internal and external processes restructure in response to historical environmental changes. The recognition of a need to restructure provides the negative entropy to revise and evolve. Information systems embody much of the structural aspect of this response.

Other versions of this life cycle view of organizational change have followed subsequent to Leifer's systems science view. The punctuated equilibrium model also noted periods of seeming equilibrium in which change is incremental, punctuated by points of more metamorphic change (Lyytinen & Newman, 2008). Greiner (1972) described this model as evolutionary versus revolutionary change. These models regard the process of coping with environmental changes as leading to a point where the organization's ability to manage complexity must either rise or fall in keeping with the amount of entropy present. Leifer (1989) calls this the bifurcation point. See Fig. 1. At this bifurcation point, the organization will either transform in order to cope with the rising entropy, or further contribute to the disorder by inefficiently dedicating more and more managerial resources to operational treatment of the complexity. In terms of genetic material, the bifurcation point is the moment where the organization either begins its reproduction or begins to die.

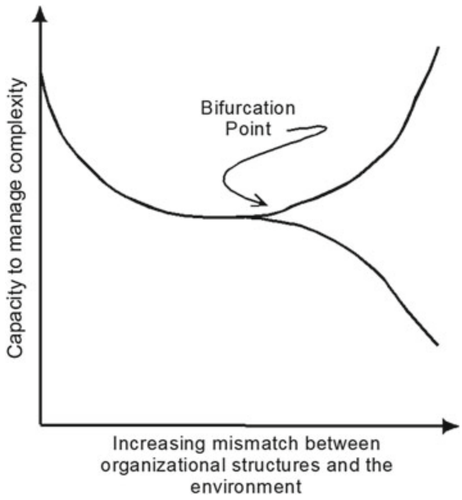

Fig. 1 Bifurcation point in complexity management (adapted from Leifer, 1989)

Leifer's (1989) overall model of dissipative structures is shown in Fig. 2. At the lower left hand point of the cycle organization is instability and equilibrium with its environment however, as the environment begins to change there is an increase in the mismatch between organizational and environmental inputs and outputs. This ineffective coping diminishes the equilibrium and sets up a trigger event at which point the organization must reproduce itself in a transformational sense or die. At this bifurcation point the organization will either reframe, transform, and renew; or deny the situation and persist in a death March. Transformation occurs at the height of organizational entropy and leads to a reproductive process that produces a transformed organization with a more fitting stability and equilibrium. Denial and persistence permits entropy to continue rising until the organization fails without reproducing.

Leifer's model has been used to explain how an organization's rebirth requires the development of revolutionary information systems artefacts (Baskerville & Vaishnavi, 2016). Such artefacts represent novel structures that embody the revised genetic material of the newly reproduced organization. As we might also expect in biological organisms, through the genetic material, the reproduced human organization inherits many of the traits of its ancestor. These traits involve the transfer of genetic material (the structures) to the reproduced organization.

The reframing and transformative aspects of Leifer's model require the selection of which structures to retain, which to abandon, and which new structures to create. Stated differently, some process must determine what parts of the genetic material to transfer and what parts to replace. It is Leifer's experimentation and resynthesis stages that make this determination.

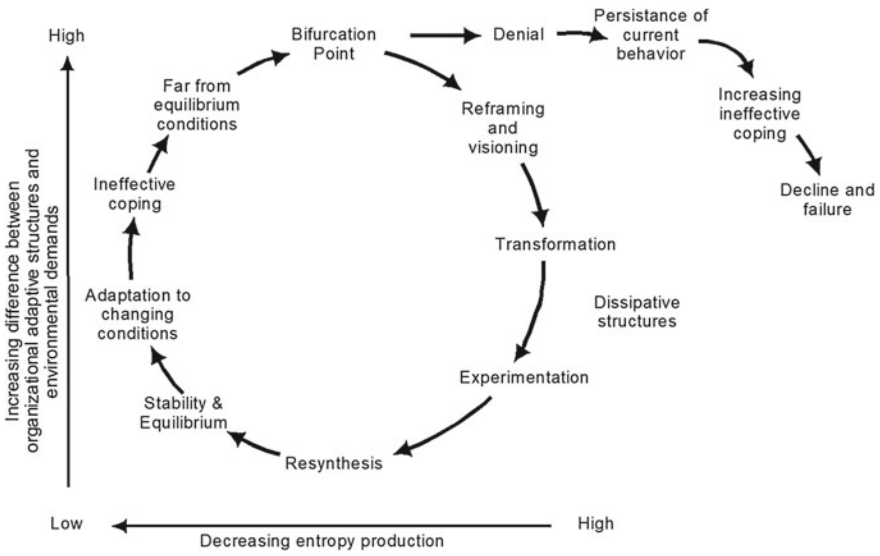

Fig. 2 Overall model of dissipative structures (adapted from Leifer, 1989)

3 Adding or Replacing Structure

The organizational literature has noticed this mechanism in practice. Organizations avoid complete restructuring. It is very expensive and often unnecessarily disruptive. Extensive restructuring is seen as an obsolete strategy because new strategic mechanisms, such as the balanced scorecard can achieve transformation without restructuring (Kaplan & Norton, 2006). Stated genetically, the reproduced organization can retain more of its ancestor's genetic material by synthesizing new material.

There is also a natural tendency to add structure rather than replacing structure in organizations. When faced with an unstructured problem, one of the common approaches is to add structure (Devine & Kozlowski, 1995). The same applies to organizational management. When problems develop in an ill-structured aspect of an organization, managers will often add structure: new policies, new procedures, new information systems, etc. (Greiner, 1972).

Adding structure not only grows organizational structure, but it also tends to reproduce ancestral structure. An organization's existing structure provides has historical effects on subsequent structures. In other words, the existing structures are the main point of reference for new structures. This tendency plays out in information systems because, as we noted above, much of modern organizational structure (its genetic material) is embodied by its information system. For example, Valiente (2006) studied the transformation of the Stockholm Taxi Service's dispatch information system. In designing this new system, the common point of reference for all stakeholders was the existing, soon-to-be previous system. Valiente noted that this case illustrated the degree to which truly revolutionary new systems were hampered by the grounding of any such system in historical (previous) systems. As noted in the work in organizational restructuring, revolutions are not just economically expensive, they are cognitively and socially expensive.

This tendency is also noted in the work in autopoiesis of biological and social systems (Luhmann, 1986; Varela, Maturana, & Uribe, 1974). Organizations, like other kinds of biological and social systems, are necessarily self-referential in their reproduction.

We can see the characteristic that an organization's information systems embodies a large part of its genetic material. For contemporary organizations, the organizational life cycles can be denoted by the evolution, not the revolution, of its information systems. Adding structure, not replacing structure, to information systems may now be most emblematic of organizational renovation. It is equivalent to adding, rather than destroying, genetic material to the organization.

4 Toward Information Systems as Organizational Genetics

Jörg Becker's work illustrates the essence of this characteristic, especially in his focus on process modelling. For example, in "Guidelines of Business Process Modelling", Becker, Rosemann, and von Uthmann (2000) examine processes that will often seem, on the surface, ill-structured. By designing and constructing a process modeller, this work adds structure by moving up a level of abstraction. The modeller rises above the seeming ill-defined structures of various processes to provide higher level structures in generic processes. Making these structures dynamic will match them better to the organizational situation. The discovery of the modeller can be used to add genetic material to organizations by adding structure to the organization's information-systems-based processes.

Another example is the "Adaptive Reference Modelling" from Becker, Delfmann, and Knackstedt (2007). They move to the next higher level of abstraction by adding adaptive structures to reference modelling techniques and languages. This additional structure added to reference modelling techniques and languages better supports their adaptation to unique kinds of organizations. Overall it better compensates for modelling the seemingly ill-structured setting for many unique organizations by adding a higher layer of structure to configure new generic models or organizational structures and processes. This discovery provides a practical means to add more suitable structure to the organization's information-systems-based processes. In Leifer's terms, the additional structure will better dissipate the organizational entropy and extend the lifespan of the reproduced organization. In genetic terms, there is new genetic material that will help the organization fit its environment better.

A feature of this work is its timeliness. Adding unsuitable genetic material to an organization is unlikely to extend the lifespan of the reproduced organization. Adding genetic material that provides an adaptation to an emerging environment seems crucial. For example, Becker, Beverungen, and Knackstedt (2010) break out new ways to model organizational processes where the products are an integration of both manufactured goods and services. Such processes are the basis of increased competition in integrated marketplaces of diverse bundled products developed across organizations and units. Again, by adding structure at a higher level of abstraction, this work provides new ways to manage the lower level structures. Where these lower level structures may have seemed ill-defined because of the dynamic shift into a new market of "value bundles", Becker's work adds new structure without necessarily restructuring the existing processes. It enables organizations to keep what is working while identifying and revising what isn't: "the purpose of modelling languages is to formally specify the structure of conceptual models and reference models … conceptual models have to account for the modelling needs of the physical goods and service components of the value bundle." (p. 54)

Of course, not all of Becker's work has involved adding higher level structures in order to define ill-defined lower level structures. His range of projects also include the discovery and prescription of structure directly for ill-defined problem settings. For example, Becker, Knackstedt, and Pöppelbuß (2009) discovered a common process (and criteria) for developing maturity models. Prior to this work, the constellation of maturity models were only seen as an ill-defined collection of diversely produced and uniquely structured guidelines and criteria for process improvements. In Becker, zur Muehlen, and Gille (2002), similarly dissected workflow systems to detect the higher level structures of workflow systems that range across "human-centred organizational processes to autonomous software processes, both confined to, or extending beyond, the boundaries of an enterprise". (p. 49)

5 Conclusion

Many organizations that are considered long-lived have, in fact, died and reproduced many times. Their organizational structures, or more specifically, their information systems embody the genetic material that inform the organizational productions. They inform what the organization produces as well as how the organization conducts such productions. Synthesizing and growing this genetic material is essential to reproducing an organization in new forms that have better potential to survive. Studies of how organizations can add appropriate structures, as well as replacing inappropriate ones, are essential for our understanding of how organizations are to survive as digitalization expands the presence of information systems in organizations.

To this extent, Jörg Becker has moved us toward more sophisticated and more essential notions of the nature of information systems. His focus on structure has opened a possible path to examine organizations and their information systems from a genetics perspective. While notions of organizational genetics have been with us since the 1970's, this viewpoint has mainly focused on the genetic selection of organizational forms that are well-adapted for their environment (Hannan & Freeman, 1977; Hannan & Freeman, 1986). The viewpoint in this paper is more concerned with the mechanics of the processes by which an organization's genetics are created: the structures (information) embodied in its information systems, how these operate, and how these develop genetically. It is a promising return to the notion of organizational genetics, which illuminated by Becker's work, brings a better understanding the spreading phenomena of information systems. Perhaps these will prove to be the footsteps that opened new ground for pioneering organizational geneticists using design science research methods. They may very well bring information management into its new millennial.

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Structure, Structure, Structure? Designing and Managing Smart Service Systems as Socio-Technical Structures

Daniel Beverungen, Martin Matzner and Jens Poeppelbuss

1 From Hybrid Value Creation to Smart Service Systems

Few trends in the industry are as profoundly shifting the way in which value is created as the ever-increasing trend for servitization (Vandermerwe & Rada, 1988; Baines, Lightfoot, Benedettini, & Kay, 2009). Servitization becomes manifest in many industries. In mechanical engineering, we have witnessed many product-focused companies shifting their business models and value-creation logics towards offering services along with their products or shifting towards integrated and customized solutions (Tuli, Kohli, & Bharadwaj, 2007). This strategy has long been advocated to compete on markets with decreasing margins, by offering value propositions to clients that would relieve them of a problem or would enable them to grasp an opportunity. In the software industry, a similar trend has brought software vendors to offer their applications, operating systems, and hardware resources as-a-service, which enables them to tailor their offerings to the changing needs of their clients.

At the WWU Muenster, the authors of this article investigated this trend in various consortium research projects (Österle & Otto, 2010) and designed new IT artifacts that enable companies to design, model, configure, offer, and deliver services and product-service systems, predominantly in the machine tool industry. At the time, the focus of German research on this topic was framed by the terms *hybrid offerings* and *hybrid value creation* (Ulaga & Reinartz, 2011; Velamuri, Neyer, & Möslein,

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2011); terms that express that physical goods and services are combined to solutions that are offered to (mostly business) customers. A standard we developed with the German Institute for Standardization (DIN) defined hybrid value creation (German: *hybride Wertschöpfung*) as value creation with hybrid offerings (German: *hybride Leistungsbündel*), consisting of physical goods and services, which are put together to solve a particular problem for a customer (Deutsches Institut für Normung e.V., 2009).

The notion of hybrid value creation came with some limitations. First, the term seemed overly complex and research-focused, creating a need for providing explanations when talking to practitioners. Second, from a research perspective, it incompletely addressed or even ignored key properties inherent to the concept of 'hybridity' (Becker, Beverungen, & Knackstedt, 2008). Third, the term focused on putting together physical goods and services as disjoint offerings, while other (more marketing-focused) researchers at the time argued that both goods and services offer *service*, based on making knowledge and skills of providers accessible for customers (Vargo & Lusch, 2008, 2016). Fourth, the distinction of goods and services was conceptually inaccurate, since it was based on *matter* (goods as material offerings versus services as immaterial offerings, which was state-of-the-art at that time, see e.g., Zeithaml, Parasuraman, & Berry, 1985), while the main difference between both types of offerings was later argued to be *ownership*, culminating in the rental-access paradigm (Lovelock & Gummesson, 2004).

Apart from these shortcomings, however, the German service research community came up with innovative solutions that would enable companies to transform their business models, business processes, and software applications towards entering the service economy. On the way, some main concepts that now constitute the Service Science discipline became more manifest, defining *service* as "the application of specialized competencies (operant resources—knowledge and skills), through deeds, processes, and performances for the benefit of another entity or the entity itself" (Vargo & Lusch, 2008, p. 26), and *service systems* as "configurations of people, technologies, and other resources that interact with other service systems to create mutual value" (Maglio, Vargo, Caswell, & Spohrer, 2009, p. 395).

Even if the service community so managed to establish some main concepts that can be used to discuss and research service phenomena, these concepts sometimes lack sufficient detail and applicability to particular developments in the industry. One major trend in German manufacturing that was not explicitly taken up by these concepts was that in product-focused industries, service (still) relies on physical core products that are owned by the customers themselves. From the point of view of Service Marketing, this was nothing particularly noteworthy, since the service-dominant logic of marketing emphasized that goods also offer service. Hence, from the point of view of customers, they would be just another vehicle to make value propositions to customers and co-create value with them. From our point of view, however, this was a perspective that seemed not quite compatible with the corporate cultures and perspectives in many goods-focused organizations.

This unresolved conflict motivated us to revisit value co-creation of goods-focused firms with their (business) clients. It soon became apparent that value is co-created using physical goods that are in the field, acting both as physical goods performing mechanical tasks and as distribution mechanisms for services that complement the physical core product. It occurred to us that these goods are boundary objects, i.e., artifacts that reside at the interfaces between different fields or communities and enable cross-boundary information and knowledge transfer (Becker et al., 2013a; Carlile, 2002; Star, 1989, 2010; Star & Griesemer, 1989). Based on this observation, we adapted the notion of service systems to *smart service systems*, which are a specific type of service systems in which physical objects serve as boundary objects and integrate service providers and service customers (Beverungen, Matzner, & Janiesch, 2017; Beverungen, Müller, Matzner, Mendling, & vom Brocke, 2017). As is often the case, this idea evolved from our design of boundary objects in terms of IT artifacts that integrate business processes of service providers, manufacturing companies, and customers (in the spirit of *hybride Wertschöpfung*) a couple of years earlier (Becker et al., 2013a).

2 Exemplary IT Artifacts for Smart Service Systems Engineering

Smart service systems are socio-technical structures that can to a good deal be designed and influenced using smart service systems engineering processes. Some years earlier, the German research community contributed many methods and tools that companies can adopt to establish service innovations (Beverungen, Lüttenberg, & Wolf, 2018). However, most of these methods seemed quite cumbersome to use as they displayed dozens of activities and stage-gate processes. It is fair to say that most methods have scared away practitioners with complex, even if accurate, process models.

Based on several initiatives that we started at our research groups at the Universities of Bochum, Erlangen-Nuremberg, and Paderborn, we conclude that the discipline requires more lightweight methods that support the iterative process of smart service systems engineering and that resemble agile and user-oriented principles as can be found in process models of design thinking and software development. It also seems right to shift the focus of smart service systems engineering away from the physical core product (and from engineering-style development methods) towards process models that are advocated by the software industry; after all, the extent of software in smart service systems keeps rising, such that an increasing part of value is created based on software components.

At the University of Paderborn, we designed a process model for smart service systems engineering according to this basic idea (Beverungen et al., 2018). The iterative process model of this approach comprises three main activities, including Service System Analysis, Service System Design, and Service System Transformation (Fig. 1). All three main activities are connected by a Decision Point, at which an organization can decide to start, commence, or leave the design cycle. A particular

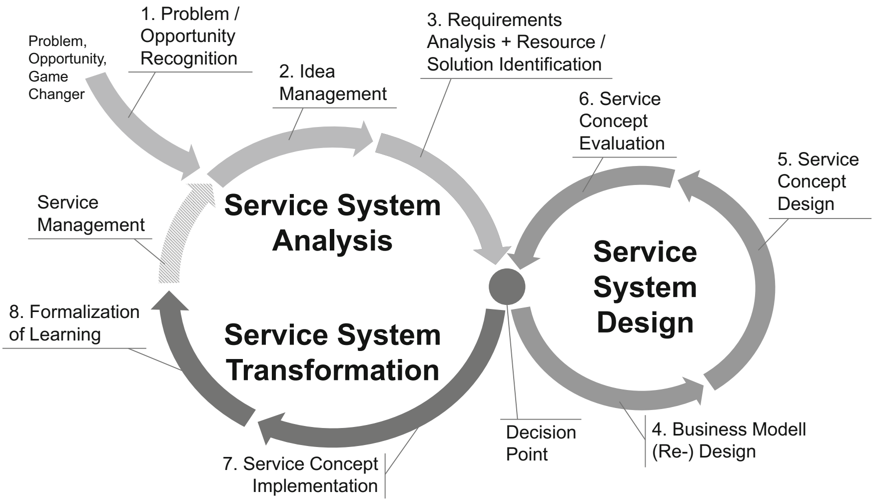

Fig. 1 Recombinant service systems engineering (Beverungen et al., 2018)

idea that is implemented into the approach was to include recombinant innovation, which enables companies to integrate decisive resources and skills with the resources and skills of others, to build up smart service systems more quickly, with faster return-on-investment, and reduced project risk.

Each activity contained in our process model can be performed with more detailed methods and tools. For instance, Problem/Opportunity Recognition and Idea Management are usually conducted in interactive workshops, in which value propositions and smart service systems are socially constructed by a group of people (Becker et al., 2013b). For analyzing and designing smart service systems in workshop settings, IT artifacts that help to visualize the as-is state as well as to conceptualize drafts for to-be service systems have proven helpful in many of our workshops.

At the Ruhr-Universität Bochum, the Smart Service Canvas has been developed as such an artifact to support the visualization of smart service systems especially during the design and analysis phases, but also as a target image supporting the transformation phase (Pöppelbuß & Durst, 2017). A canvas representation is a concise, easy to understand, and visually appealing overview of the key components required for a specific subject area (here: the engineering of smart service systems). Hence, it also has similarities with the concept of an *Ordnungsrahmen* (engl.: conceptual framework; Becker, et al., 2008; Becker & Meise, 2012) that gives an aggregated overview of a domain or a system. Structuring domains with the help of *Ordnungsrahmen* has always been a key research activity of Jörg Becker, with the Retail-H (Becker & Schütte, 2004) being particularly popular.

The Smart Service Canvas builds on the Value Proposition Canvas by Osterwalder, Pigneur, Bernarda, & Smith (2014) for two reasons. First, the Value Proposition Canvas provides a customer-centered view on the development of a smart service

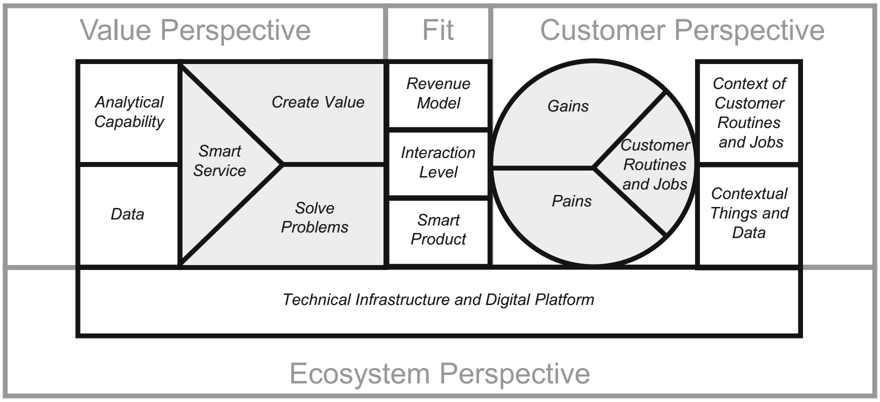

Fig. 2 Perspectives and fields of the Smart Service Canvas

value proposition as it focuses on two of the nine fields of the popular Business Model Canvas (value propositions and customer segments; Osterwalder & Pigneur, 2010). We regard customer-orientation as fundamental for the success of smart service systems since service systems need to generate customer value, and not just make up new ideas of how to process data that have become available through smart products. Second, an established approach like the Value Proposition Canvas, which is already known to and applied by a lot of people, will increase the likelihood that the extensions provided by the Smart Service Canvas will be adopted in practice.

The Smart Service Canvas allows for modeling and assessing a smart service system in its as-is state and to design to-be concepts along four perspectives (Fig. 2). The value map and the customer profile conveyed by the Value Proposition Canvas (Osterwalder et al., 2014) serve as anchor points for the Smart Service Canvas. The Smart Service Canvas adds an ecosystem perspective and fits the perspectives mentioned before together. The fit refers to the boundary object that connects provider and customer. In some first workshops, the Smart Service Canvas has been applied successfully.

The general direction of filling out the Smart Service Canvas is similar to using the Value Proposition Canvas (Osterwalder et al., 2014). To focus on customer demands independent of possible restrictions on the provider side, the *customer perspective* on the right is addressed first. Then, the *value perspective* on the left comes next, followed by the *ecosystem perspective* that defines the digital architecture and platform, which connects the customer with the smart service provider. Finally, the *fit* between the customer perspective and the value perspective is developed.

The customer perspective describes a specific customer segment (Osterwalder et al., 2014). It comprises the three fields of the customer profile as proposed by the Value Proposition Canvas: customer routines and jobs, customer pains, and customer gains. For smart service systems, this perspective is supplemented by the *context of customer routines and jobs* and *contextual things and data*. These two additional fields emphasize that the special value proposition of a smart service is generally based on the synthesis of data from different sources and a comprehensive understanding of the customer's context (Beverungen, et al., 2017; Osterwalder et al., 2014; Tuli et al., 2007).

The *value perspective* adapts the value map from the left half of the Value Proposition Canvas (Osterwalder et al., 2014): smart service (originally products and services), pain relievers, and gain creators. This perspective is also supplemented by two specific fields for the application to smart service, namely *analytical capabilities* and *data*. These additional fields emphasize that the availability of relevant data and the skills required for their meaningful processing form a central basis for offering smart service (Allmendinger & Lombreglia, 2005; Beverungen, et al., 2017).

The *ecosystem perspective* consists of a generic field describing the technical infrastructure and digital platform, i.e., the digital architecture of the smart service system (Beverungen, et al., 2017). The technical infrastructure refers, among others, to basic infrastructure like power supply, wired and wireless network connection, and mobile network coverage that warrant smart products' connectivity and access to their data. Digital platforms allow the distribution and marketing of the smart service in digital ecosystems (e.g., through industrial platforms like AXOOM or Siemens MindSphere). The market mechanisms, governance, and the openness of digital platforms are also relevant here.

Fit between the previous views is established when customers are enthusiastic about the smart service offered and when the offering fits well into their routines, jobs, and contexts. A prerequisite is that the smart service concept addresses important customer jobs, thereby reducing problems and creating advantages that are of particular relevance to customers (Osterwalder et al., 2014). Furthermore, it is important that the technical equipment, data flows, and economic incentives of the smart service system are compatible with the ecosystem that it is embedded into. The Smart Service Canvas provides three fields in this regard, which help to concretize the fit at different levels and capture corresponding design decisions. The *smart product* corresponds to the boundary object that links the smart service system. Typically, this is a physical object with embedded systems and networking capability, which is typically located at the customer site. It can be a machine at the customer's plant, but might also be a stationary or mobile device that offers a user interface to access a smart service. The *interaction level* is closely related to the degree of automation of providing a smart service. In this regard, Herterich, Buehnen, Uebernickel, & Brenner (2016) distinguish between person-centered, semi-automated, and automated service processes, whereby highly standardized and automated processes, in particular, ensure the scalability of the smart service concept. The *revenue model* specifies the modes by which revenue flows are generated, to allow service providers to appropriate or capture value. Such modes include, for instance, subscription fees, advertising fees, license fees, transaction fees, or sales commissions (Amit & Zott, 2001; Bouwman, Faber, Haaker, Kijl, & De Reuver, 2008).

3 Guided Emergence of Smart Service Systems

Smart service systems engineering is a process for establishing smart service systems as socio-technical structures. As a design process, it culminates in the design of various conceptual artifacts, including information models of resources, processes, and value propositions, from rather informal representations like the Smart Service Canvas (Pöppelbuß & Durst, 2017) to models using more formal notations like BPMN 2.0, UML, or e3value. In a transformation phase, these artifacts are implemented into organizations to make them ready for co-creating smart service with their clients and business partners. This transformation includes implementing software applications, hiring new staff and/or training staff to acquire new competencies and establishing new business processes.

However laudable, it has been noted that social structure cannot be implemented solely in a top-down engineering approach. Instead, the literature on organizational routines (Beverungen, 2014; Pentland & Feldman, 2008) and structuration theory (Giddens, 1984) tells us that social structure will emerge only based on the day-to-day work performed by people in organizations. Therefore, Pentland & Feldman, (2008) note that IT artifacts cannot per se establish or change routines in organizations; it is rather that employees perform activities as effortful accomplishments that might be enabled and constrained (but cannot be determined fully) by IT artifacts. Hence, any attempt to design smart service systems is bounded by how artifacts are used in the performance of peoples' day-to-day work.

With this conceptual inability of fully designing smart service systems comes the responsibility to manage the actions of people in service systems in a way that is consistent with the intentions of its designers. Adaptive structuration theory (DeSanctis & Poole, 1994) highlights here that *consistency* means to use IT artifacts in a way that is consistent with how designers *intended* these artifacts to be used. Therefore, service system managers must have an eye on the inner workings and evolution of a smart service system, making its further progress a continuous management task. During his time as a *Prorektor for Strategic Planning and Information Systems* at the WWU Münster, Jörg Becker implemented a similar management practice, which he termed *guided emergence*. This practice substitutes a design metaphor, in which designers fully control the design and appropriation of artifacts, with a growing metaphor, in which designers create artifacts and also govern the further progress of a system, by accompanying people while they use artifacts and constitute social systems.

4 How Consortium Research Influences Service Science

Publicly funded (consortium) research projects (Österle & Otto, 2010) were the organizational setting in which we conducted service research at Jörg Becker's chair. These projects bring together small-and-medium-sized firms, large companies, and research institutions, integrating their complementary resources and core competencies for a common goal. In our projects, we established new service systems and designed IT artifacts that apply to other contexts, too.

The *European Research Center for Information Systems (ERCIS)*, founded by Jörg Becker, provided us with an excellent platform to conduct our research endeavors. We can now point to a long list of high-volume service research projects that we successfully conducted under his supervision, including *CrowdStrom*, *EOL-IS*, *FlexNet*, *KollaPro, Networked Service Society*, *ServDEA*, and *ServPay*, spanning twelve consecutive years of service research. In 2006, we established the *Service Science Competence Center,* which soon became one of the focal research areas of the *ERCIS*.

All these projects were part of comprehensive research programs that the German Federal Ministry for Education and Research (BMBF) implemented at the early stages of our academic careers. Far beyond influencing our career paths, these initiatives promoted the emergence of a global and interdisciplinary service research community, while they also emphasized practical relevance. With the results derived from the projects, many companies manage to compete in a global service economy.

This impact is due to leveraging effects that extend beyond any single research project (Matzner, Plenter, Chasin, Betzing, & von Hoffen, 2018). Research programs are set up to address general societal goals, political goals, and research needs. Specifically, a major focus of German service research is to leverage industrial service in the German manufacturing sector, to safeguard high-quality jobs, and to develop key technologies further. Instantiating these goals, the BMBF created more specific calls to which we proposed project ideas with our business partners. In the projects themselves, we designed tools and software applications to establish new service systems and, in a broader sense, contributed to political and societal goals and global research needs. Reflecting on these funding initiatives is worthwhile to cherish their significant impact on the early service research discipline as well as on business success.

The governmentally funded consortium projects initiated by the BMBF substantially shaped the course of the early *Service Science discipline* in at least three regards: First, concerning the subject matter of service research, the discipline was focused on knowledge-intensive and financial services at that time, reflecting priorities of the U.S. economy. The BMBF funding programs enabled German service researchers to focus on industrial services and to put this topic on international agendas. Terminology like *hybrid value creation* and *hybrid products* made their ways into the global research communities. Second, the programs promoted interdisciplinary research. The successful development of industrial services requires research at the intersection of various disciplines, including industrial engineering, mechanical engineering, marketing, and information systems. BMBF motivated researchers to join forces across disciplines, which led to sustained cooperations between researchers from different areas. Third, design research became more present in service research, complementing the U.S. based tradition of empirical service (marketing and management) research. Intersectoral cooperation in BMBF projects and its focus on tangible outcomes that are of immediate utility for companies instantiated the best principles of design-oriented research.

The BMBF programs also left a strong footprint on the *development of service business models in companies*. German industrial companies derived and also exploited business potential resulting from service innovation, long before topics such as *Industrie 4.0* and *platform economy* were on everyone's lips. For instance, our research project *FlexNet* (2006–2010) introduced an IS reference architecture for connecting companies' business processes and application systems in networks. On that note, *FlexNet* was pioneering on a topic that is only now discussed broadly, including the question of how to use smart products like modern cars or smart factories to establish smart service systems.

This dual influence of consortium research projects on service research and practice are in line with some of Jörg Becker's core beliefs, which also shaped the research of his work group at WWU. One of his fundamental doctrines is that deep knowledge of an application domain is a mandatory prerequisite of conducting any meaningful IS research, which is why he encouraged us to dig deeply into the service sector ourselves. Another doctrine is to foster intersectoral and international cooperation. The ERCIS network provided us with a unique institutional platform for this cooperation, building ties with companies and researchers from other fields and countries. Third, Jörg Becker encouraged us to focus on fundamental principles rather than to chase fashionable and temporary topics. Fourth, as a researcher and an entrepreneur, he reiterates that it is a design researcher's responsibility to transfer useful results into business application. The BMBF service projects with their built-in dissemination pathways from research to commercial exploitation offered just the right conditions for this transition to happen.

In this spirit, we wish for many young researchers that hurl themselves into the service domain to find new and unexpected challenges at first hand; we wish for a scientific community that cherishes their ideas and does not bury them under exuberant methodical and formal discussions; and we wish for a *can-do attitude* and the entrepreneurial mindset to transfer new IT artifacts into business application.

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A Multiple Case Study Investigating Factors Negatively Influencing IT Value

Alessio Maria Braccini and Stefano Za

1 Introduction

The literature highlights that IT resources produce organizational benefits (Devaraj & Kohli, 2003; Kohli & Grover, 2008; Zammuto, Griffith, Majchrzak, Dougherty, & Faraj, 2007). These benefits are achieved when IT resources are combined with adequate organizational practices and capabilities (Zammuto et al., 2007). The benefits of IT resources manifest in different ways, and are subject to context conditions that may make them latent or evanescent (Kohli & Grover, 2008; Nevo & Wade, 2010).

While large part of the literature focuses on how to measure IT value (Za & Braccini, 2017), few studies tackle the role of organizational contextual factors that mediate the realization of the prospected benefits (Nevo & Wade, 2010). IT resources interact with other organizational resources (Aral & Weill, 2007; Melville, Kraemer, & Gurbaxani, 2004). The consequences of such interaction, and the role of organizational factors on the IT value generation process is still limited (Nevo & Wade, 2010; Ragowsky, Stern, & Adams, 2000).

This paper studies the consequence of the structuration of IT departments in organizations on the organizational benefits of IT, and specifically discusses the role of organizational factors that hamper the possibility to achieve value out of IT resources, to answer the following research question: *how do organizational factors negatively influence the IT value generation process?* The paper is based on the analysis of four cases of as many different organizations that failed in achieved the expected benefits from their IT resources. The analysis contributes to identify five organizational factors antecedents of poor organizational integration, and a process

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that, through the creation of IT slacks, increases the complexity of IT infrastructure and of its management.

2 IT Value and Organizational Structuration

In nowadays organizations IT resources contribute to the value generation process only when IT resources interact with organizational structures, strategy, values, competition, and agents' conjectures (Pitelis, 2009). At the theoretical level, the relationship between IT resources and organizational value is explained by the IT value generation process of Melville, Kraemer, and Gurbaxani (2004) framework (see Fig. 1). In the IT value generation process IT resources—both technology and human—interact with complementary organizational resources, and impact business processes. The impact on business processes is the consequence of the exploitation of IT resources innovation and transformation capabilities (Scheepers & Scheepers, 2008; Zammuto et al., 2007). The organizational benefits of the impact of IT resources on business processes is captured by improved business process performance. The improved performance at the business process level eventually leads to improved organizational performance.

IT resources and organizational resources act in a synergy (Wade & Hulland, 2004). The complementary organizational resources are in the form of managerial praxes, routines, policies, organizational systems, knowledge assets, relationship assets, culture, and structure (Scheepers & Scheepers, 2008).

Through the years, the complexity of IT infrastructures has increased both in terms of number, diversity, and interdependence among IT resources. In modern infrastructures IT resources and business processes are highly interrelated. Multiple resources can impact multiple business processes with ripple effects (Scheepers & Scheepers, 2008; vom Brocke, Braccini, Sonnenberg, & Spagnoletti, 2014).

To manage this complexity, organizations structure IT departments seeking labour and competence division to achieve specialisation. IT departments manage the main IT management processes through which IT delivers services to the rest of the orga-

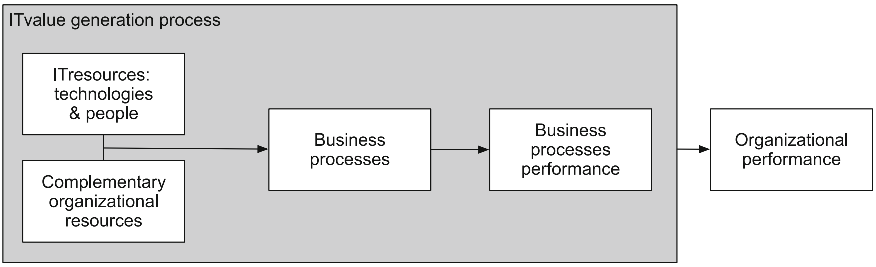

Fig. 1 The IT value generation process

nizational structure and contributes to the overall value generation process (Peppard, 2007). IT departments are in turn structured in sub-units specialised on a set of technologies, customers, or applications. These different units shall work as a single entity, given the fact that they show different forms of interdependences. Given that both specialisation and integration are source of organizational performance (Barki & Pinsonneault, 2005; Mukhopadhyay & Kekre, 2002), the structuration of IT departments shall balance specialisation and integration.

3 Research Design

The paper is based on a case study with four case units (Yin, 2011). All the case units are firms which make use of IT resources to support their daily operations, in which the IT resources are managed by specific internal organizational units, which run similar processes in terms of information intensity in business processes, and which are structured following the IT service management approach.

In all the four case units the value expected from specific IT investments was eventually not achieved due to organizational related causes. In all the four units the business organizations run internal assessments to identify problems causing the lack of value generation, and to design solutions. This allowed the authors to study both the original organizational structure and the changes produced to it.

Given these considerations the cases are relevant for the research question, and have adequate similarities (lack of value generated, relevance of IT resources in business processes, common structures in the IT departments) and diversities (size, functional units involved, and domain) to support the validity and the analytical generalizability of the results of the analysis.

The researcher had access to primary and secondary sources of data. Interviewees with key organizational actors involved in the four units were the main data sources complemented by technical, financial, and managerial reports, and observations (see Table 1). The data collection was aimed at reconstructing the chain of events and consequences of the IT investments in all the case units.

The analysis aimed at identifying causes (organizational factors) of events that leaded to the outcome (the lack of value achieved out of IT investments). The data collection and analysis were performed in an iterative way. Intermediate results of the analysis were confronted with business organization stakeholders which were called to assess the validity of the results of the research.

4 Case Contexts

For the needs of reporting the results of the analysis all case units are anonymized and identified by a number. Each case context, diagnose, and solution is described in the four following sub-sections.

Table 1 Data sources for the four case units

	Case unit 1	Case units 2	Case unit 3	Case unit 4
Primary data	Interviews with key staff members: general manager, CIO, IT team leaders, three IT team members	Interviews with key staff members: general manager, CIO, 2 IT managers	Interview with key staff members: CIO, CFO, IT controlling manager, IT portfolio manager, 2 IT infrastructure managers, IT staff members	Interview with key staff members: CIO, IT staff members, director of the department, head of student office
Secondary data	Observations of software artefacts	Financial data	Financial data	Observations of software artefacts
		IT assets catalogue	IT assets and service catalogue	
		Organizational assessment report	Organizational assessment report	

4.1 Unit Case One

The unit case one is a high education institution (HEI) which uses IT services to (i) dematerialize and control key administrative processes, and (ii) to disseminate information both to internal and external stakeholders. The IT management works in cooperation with two outsourcers. IT management responsibilities are shared by two functional units: (i) the IT department composed by a CIO and seven staff members, and (ii) the business intelligence (BI) unit composed by a team leader and two team members. The IT department oversees planning, operations, and management of organizational information systems (ISs) and web-based platforms. The BI unit oversees the management of a learning content management system, used by students and lecturers, and the operation and evolution of business intelligence reporting services on the data produced by ISs. The two units were under different reporting lines, under the eventual control of the CEO.

The unit case planned an IT service integration project to rationalize the internal information management with the objective of (i) adopting web 2.0 and mobile technologies compliant solutions, (ii) reducing the number of platforms and outsourcing contracts, and (iii) substituting all manual data exchange processes among the different platforms with automatic ones. The unit case expected benefits of time savings on administrative and coordination processes, timeliness and accuracy of information dissemination trough internet and intranet portals, and costs savings through the reduction of outsourcers and the consequent decommissioning of the specific system.

To achieve such objectives the CEO nominated a task force composed by members of the IT department and of the BI unit. The task force had to study the problem and propose a technical and operational plan to implement the designed solution if approved by the top management. The task force started working at problem analysis, but eventually worked separately exploring and implementing two different and incompatible prototypal solutions. The daily activities of the two units (IT department and BI team) were slowed down by the efforts on the prototypal solutions.

After one year without results the CEO stopped the task force and restructured the project by nominating a project manager in charge of managing and integrating the activities of the two groups, and directly reporting to the top management. The integration project was completed with two and half years of delay. The contract with the outsourcer one was renewed for one year beyond the planned decommissioning date. The courses portal was eventually decommissioned two years after the expected date. A total amount of 8 man/months of work were wasted on the prototypal abandoned solutions.

4.2 Unit Case Two

The unit of analysis 2 is a public transportation company which uses IT services to (i) run organizational ISs to automatize and control administrative processes, (ii) plan the transport services, and (iii) deliver the information to internal and external stakeholders. IT management responsibilities are shared by two functional units: (i) the IT department in charge of managing the IT infrastructure, the ISs, and the networking and telecommunication services; and (ii) the intelligent transport systems department in charge of managing transport planning and information dissemination services running on the IT infrastructure provided by the IT department. The units were under different reporting lines, under the indirect control of the CEO.

The unit experienced difficulties in IT investments planning and operations due to the internal bureaucratic processes necessary to approve IT assets purchase. Each purchase had to be approved by the financial department, external to the two IT units. Such approval process required significant delays due to internal administrative activities. Moreover, when the assets to be purchased overpassed the financial threshold of about 20K €, the organization was forced by law to run public tenders, which included extra administrative efforts and costs.

To overpass these limitations the unit decided to switch to a private cloud strategy for the IT infrastructure and services with prospected benefits of: reduced IT infrastructure costs and administrative burden for IT assets management (including planning, operating, and maintaining). The private cloud IT infrastructure was dimensioned to satisfy the prospected transactional needs for eight years. With this infrastructure IT resources provisioning to internal customers was the result of a decision internal to the IT department. Such responsibility was moved to a different person two and half years later as the previous one in charge left the organization. The new person found that the capacity of the private cloud was close to saturation though internal IT demand did not change significantly. She started to review all IT assets usage under the concern of increasing costs for IT management raised by the top management (which summed up to about 2.5 Euro million per year back then).

The initiative highlighted that IT assets management was not under control in the organization. First, there was a potential duplication of IT assets across the two IT units involving about 7% of all the IT assets in use (in total 145 server). Secondly several IT assets were assigned to internal units upon request, without a clear need, and were never released when no longer needed. About 23% of IT assets where either inactive, unnecessarily shadowing other IT services, or without a clear business function. They were anyhow consuming other infrastructural services (network bandwidth, storage, and backup) increasing costs for storage, backup, and restore services by 8% each year. A total amount of 4.5 man/months were considered wasted by the internal review effort of the IT asset manager.

4.3 Unit Case Three

The unit case three is a multinational industrial private company which uses IT services to manage all the IT infrastructure and the ISs to support both operational and administrative processes, and to manage the multinational business. IT management is under the responsibility of an IT department with about 200 employees with 50% of them concentrated in the organizational headquarter, and the rest spread across five geographical locations across the globe. The largest part of the IT infrastructure (about 550 hardware assets and 200 software assets) is also located in the organizational headquarter. The IT department is managed by the CIO reporting to the CFO. Internally, the management of IT assets was shared by four units, all under the direct control of the CIO: unit 1—networking, unit 2—storage and backup services, unit 3—Unix servers, unit 4—windows servers.

The IT department was increasingly pushed by the financial department to plan IT asset management in advance to rationalize IT expenditures. The IT units had difficulties in fulfilling these requests because they had a full view of the IT assets they managed but not of low costs assets which were bought and managed as consumable, but which eventually consumed IT infrastructure costs (network bandwidth, system storage and backup services). Secondly, they had not full control of the lifecycle status of their IT assets, since technical and financial information were misaligned. Finally, they had difficulties in coordinating for physical shared resources usage (data centre rooms and storage).

The IT department cross-charged costs to other internal organizational units for their IT services consumption. In these conditions, they were not able to calculate the actual services cost or to make precise estimations of productivity improvements of the IT department (measured by the reduction of costs across two different budget periods, confronting planned and actual costs) which were instead quite frequently breached.

To improve the internal IT assets managerial capability the unit decided to appoint a project manager for: defining IT assets and services catalogues, proposing a solution to align IT infrastructure information across the three units, and redesigning the IT infrastructure management processes of demand, planning and decommission. At the end of the project the company assessed that their suppliers forced them to pay 45% more for outsourced services compared to how much they would cost internally. A total cost of 3 man/months were required for the alignment of the IT infrastructure management.

4.4 Unit Case Four

The unit case four is a HEI which uses IT services (i) to digitize administrative processes, (ii) to disseminate information to internal and external stakeholders and (iii) to support teaching activities. The IT department is composed by the CIO and five members distributed across the IT development, IT architecture, networking architecture, information systems, and web development units. The unit had an internal IT project for adopting a specific learning management system (LMS). Back then, each teacher used different—and own managed—external digital platforms to share teaching material with students. This prevented the HEI to have an overview of the learning contents produced by teachers, to safeguard the privacy on such data, and to have an overview of students' activities online.

The IT department started installing the LMS, customising, and integrating it with infrastructural authentication services, and administrative information systems to make students enrolment and students management by teachers easier. The integration had to be deployed before the beginning of the teaching semester and to involve different sub units. The networking and IT architecture units had to install and configure the LMS, and to integrate it with the corporate user authentication infrastructure. The information systems unit had to provide the integration with courses and students data from the administrative systems. The IT development unit had to integrate the students' enrolment procedure on the LMS with the students and courses data available from the administrative systems.

During this project the IT department planned also to migrate the infrastructural authentication services, and that would impact both students and teachers access to HEI systems, including the LMS. The IT department ensured the ability to complete both projects before the start of the courses but as a matter of fact students were able to access to the LMS courses two months after the beginning of the teaching semester. The services still contained glitches as few courses did not show-up in the LMS, and some teachers and students could not access the contents after a successful login. This situation produced disservices and dissatisfaction to teachers, students, and administrative offices.

Following these difficulties, the HEI decided to involve an expert facilitator to help translating the institutional needs and the IT constraints. The deployment of the LMS produced an increasing effort on the IT helpdesk for managing users' claims. For this reason, other resources were temporary allocated to these tasks. In total, an extra effort of 2 man/months was required for the management of users claim, and further 6 man/months were required for the work of the facilitator.

5 Case Analysis

Table 2 summarizes the evidences of the case units. Interviewees reported lack of shared knowledge necessary to sustain the IT management processes. The analysis showed that the lack of shared knowledge followed the lack of information circulation among units which, focusing on their areas of specialisation, had not time and little incentive to coordinate, neither they were required by specific organizational structures to establish formal communications. In two of the case units the lack of information circulation was further complicated by the presence of functional units under different reporting lines. Finally, in all the four case units, none of the human resources had a clear ownership of the missing integration tasks and activities. Coordination among the sub-units was left to voluntary efforts (case 3). The lack of coordination was felt as a waste of resources (case 1 and 2) or caused failures of projects (case 1 and 4).

Such contextual conditions produced consequences that affect IT resources management in all the four units, and wasted the organizational benefits potentially expected by the internal innovation processes. The lack of integration among the units in charge of IT management stimulated a set of local praxes that leaded to the presence of IT resources without a clear ownership and stemming out of IT resources shadowing and internalization praxes. With IT resources shadowing, units duplicated IT services without a clear business need, and created IT slacks in the IT infrastructure not required by any business process, and hence not contributing to the IT value generation process.

Though potentially reusable for business purposes in case of specific needs, the IT slacks contribute only to increase IT infrastructure complexity both in terms of number of resources to be managed (like for the assets in the list of case 2, the prototypal platforms and the platform to be dismissed for case 1), and of increased IT resources usage as resulting from coupling among them in the IT infrastructure.

6 Discussion and Conclusion

In this paper we studied contextual organizational factors and how they negatively affect the IT business value generation process. The analysis contributed to identify five factors (technical specialisation, lack of formal communication, lack of formal ownership, different reporting lines, and lack of horizontal coordination mechanisms), producing lack of organizational integration. They impact the management of IT resources, and negatively affect the IT business value generation process.

Table 2 Summary of the four cases

	Unit 1	Unit 2	Unit 3	Unit 4
Action	Platforms integration	Switch to virtual infrastructure	Specialization of asset management	Platform integration
	Infrastructure simplification			
Expected benefits	Reduced administrative efforts	Reduced administrative efforts	Effective IT asset management	Improved information control
	Improved information dissemination timeliness	Increased effectiveness and flexibility of IT asset management		
	Costs reduction			
	IT infrastructure simplification			
Achieved results	Duplication of resources	Duplication of resources	Excess of costs payed to suppliers	Extra costs
	Internal competition	Extra costs	Lack of control of IT assets planning	Extra time
	Extra costs	Lack of control of IT assets		Disservice
	Extra time			
Organizational units characteristics	Horiz. differentiation	Horiz. differentiation	Horiz. differentiation	Horiz. differentiation
	Two units under two managers (CIO & CFO)	Two units under two managers (CIO & CEO)	Four units under the same manager (CIO)	Five units under the same manager (CIO)
Diagnosis	Lack of horizontal communica-tion	Lack of horizontal communica-tion	Lack of integration	Lack of horizontal communica-tion
	Lack of integration	Lack of integration	Lack of coordination	Different perception on failure
	Privatization of shared IT resources	Poor demand management	Misalignment and misman-agement of asset data	
		Privatization of shared IT resources		

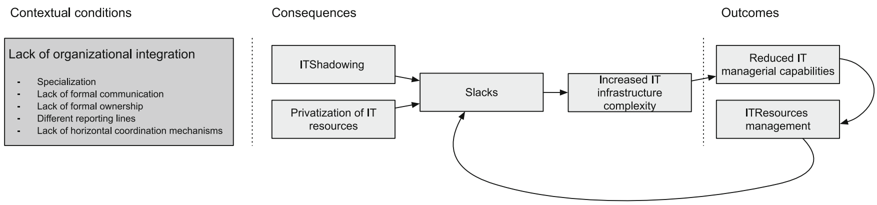

Fig. 2 Production of IT slacks and IT managerial capabilities

Specialisation creates the conditions for a strict focus of organizational units on technologies or resources. Specialisation is justified by organizational design choices, and functional to effective management of IT resources. However, specialisation is detrimental for the IT resources management capabilities when coupled with lack of formal communication, ownership, and lack of horizontal coordination mechanisms. These factors disincentivize information exchange in IT departments. Finally, different reporting lines and the activation of hierarchy to coordinate different functional units managing IT resources, also negatively affects the IT resources management processes.

Under the presence of these factors, the consequences are praxes of IT shadowing and privatization of IT resources. IT assets are introduced in the infrastructure following a local demand management (i.e. for the need of a specific sub-unit), not associated to business processes, or unnecessarily shadowing existing IT resources. These potentially unexploited resources, not being connected to internal customers or business processes, do not contribute to business processes performance. These resources remain in the IT infrastructure as technical IT slacks, increasing infrastructural complexity.

Though ambivalent, the literature sees in slacks a positive potential, as organizations have the chance to exploit them in case of crisis or unexpected needs (Barki & Pinsonneault, 2005; Byrd, Lewis, & Bryan, 2006; Kettinger, Grover, Guha, & Segars, 1994). However, IT slack produce a negative consequence on the management of IT resources, given their very nature. IT slacks consume other IT and complementary organizational resources (e.g. backup services, disaster recovery services, physical space in the data centre, energy for power and cooling), and contribute to increase the complexity of the IT infrastructure in a vicious cycle. More IT slacks increase the infrastructure complexity. An increased infrastructure complexity reduces the IT managerial capabilities by increasing the chance of losing control over IT resources management, which in turn increases IT slacks.

Figure 2 visually represents the theorized mechanism. The results were discussed with practitioners in the organization, and with IT and non-IT executives and experts.

Out of the four units of analysis, unit 1 and 2 belong to the public sector, while unit 3 and 4 to the private sector. While observations are consistent through the units, they anyhow differ in terms of value creation logic (i.e. public versus private value). Hence a first research implication would be of investigating specifically to what extent IT slack resources are detrimental for the IT value generation process given the underpinning public and private value logic. A second implication concerns instead the interdependences among IT resources. Technical IT resources are not to be seen as individual assets, but as set of systems of resources (Scheepers & Scheepers, 2008; vom Brocke et al., 2014). While many of these resources are independent among each other, others are coupled in sets by technical reasons. Further studies should deepen the consequences of the interdependences among technical and human IT resources, the different activities performed, and the interdependences among the different IT resources in use. A managerial implication is the need to establish formal horizontal coordination and communication mechanisms, and to establish clear responsibilities on the coordination tasks, and a clear ownership on the alignment process or artefact. An adequate level of attention should be raised towards the creation of slack resources which IT management shall always keep under control, also with forms of authorization to the creation of the slacks themselves.

The research presented here is limited on the identification of factors negatively affecting the IT business value generation process. Our results do not mean that the five factors are the only ones activating the vicious circle. Further factors, not investigated here, may still create the conditions to produce the same negative effects. Finally, the paper does not inform on the factors positively influence the IT value generation process (Depaoli & Za, 2017).

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Management in View of Digital Transformation

Alexander I. Gromoff

We don't need no education,
We don't need no thought control,
No dark sarcasm in the classroom,
Teachers, leave them kids alone.
'Another Brick in the Wall',
(Floyd, Guthrie, & Waters, 1979)

1 Motivation and Walk-around Discussion

Today, it is clear that 'digitization' or 'digital transformation' are not just catchy marketing slogans, they are an essential element in every aspect of daily life. There is no way of guessing which particular economic sector will be next to fully digitize and thus be transformed, but those who are pioneering in this direction will be and already are benefiting. Digitization concerns not only technological aspects and productivity, it also has a sociological impact, creating new cultural interrelations in the cyber-physical spaces of digitized reality.

A host of terms have been introduced to refer to digitization (e.g. digital transformation, Industry 4.0, digitization and digital economy). These appear to be associated with something specific, but there is no consensus on exactly what they mean since people on different social levels (from the ruling classes to the marginalised) interpret the ideas differently. Even in the 1970s, most people thought that everything would be robotized and digitized within 5–10 years, and that artificial intelligence would provide us with nutritious breakfasts and take care of our children. Numerous publications in the scientific literature and in the mass media have discussed various applications of the digital transformation in everyday life for civilians, combatants, governments and industry stakeholders. Much has happened on that front, but efforts have stalled because of over-romanticized ideas, cultural unreadiness and a general combination of the following factors:

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- Ever-growing clip consciousness combined with a steady decrease in IQ over the last two decades;
- A society that is, on the whole, poorly educated about information;
- A society that tolerates and even accepts information from unproven sources;
- Information storing resources of low productivity and unclear policy by Cloud providers;
- Incompatible standards of information exchange and storage, despite the presence of the WfMC;[1]
- Lack of secure, reliable and proven communication channels;
- Lack of legal support in the field of information exchange and use;
- Computational power.

The first seven factors can be aggregated into three classic groups: People, Technology and Processes (PTP). The last factor has played a very specific role. In the 1970s, it seemed that the growth of computational power and the miniaturization of computer chips would solve the problem of securing enough electrical power. Further, enough innovative technologies were adopted by the mainstream that the social ignorance threshold was thought to have been overcome, and a bright future seemed to be on the horizon. However, at that time, no one paid serious attention to the social and cultural problems of digitization or to the impact of digital information sources on behavioural reflexion. These problems relate to unstructured access in the web space and, further, the acceptance of the information content without any concern or doubt about its validity. The other problems relate to the amount of energy needed by computer facilities and corresponding calculations mainly regarding heat emissions. It appears that information will soon be measured in kW, as well as in national treasuries and currency procurement.

Digitization has already brought about notable results regarding tangible production and manufacturing, and it is sure to reach even higher heights. However, industrial digitization has not played a serious role in business strategies or in socially oriented aspects; but when considering industrial balance sheets, it is surprising that more than 30% of all energy expenses can be traced back to digitization. Some industrial business owners have even considered hiring low-cost workers to replace electrically powered devices in a bid to cut costs.

At the same time a trend is only now developing towards DT in the service sector, and the first steps are being taken, from simple operational maintenance functions to providing conclusions and resolving complicated scenario tasks. In any case, the current role of IT as a globalized vendor and enabler is as a fulcrum for worldwide DT: its role is more significant than even that of the steam engine in the industrial revolution of the nineteenth century, or of nuclear energy in the twentieth. Meanwhile, there have been no changes in the roles played by management. Digitization now provides an opportunity to shift the management paradigm from its rigidity in a socio-technical system to the flexibility and agility of a socio-cultural system. The

[1] WfMC—The Workflow Management Coalition was founded in 1993 and became a global organization of adopters, developers, consultants, and university and research groups engaged in workflow implementation and BPM.

benefits of such a shift are intelligent functions for customers affecting essential areas of human living such as in the concept of the smart city (see TechCity, 2016).

Production processes in digital environments are turning to hybrids of robotically empowered physical assembly lines enhanced by AI management. AI itself is a reflection of the level of the human will to excellence, if someone is able in future to implement it without bugs. A number of researchers have expressed the same conclusions in a variety of works (Lay, 2014; Ren et al., 2008; Raja, Johnson, & Goffin, 2015; Rigby & Bilodeau, 2015; Tsou & Hsu, 2015; Stary & Neubauer, 2017; among others).

In view of the existing DT, there is much talk of the skills required for the upcoming demands of transforming services, industries, manufacturing, arts and intellectual implementations. A vision of educational structuring aligned with the integrated model appears in conjunction with new skill requirements in traditional education. This structure is based on classic knowledge imbedded in education processes such as computer science under the scope of economic opportunity and social mobility. Consequently, a number of new interdisciplinary educational programs and syllabuses must be changed and modified to meet the latest needs and requirements (i.e. up-to-date technical skills need to be complemented with business know-how, or medical skills with computer science, etc.).

Even with a clear view of what has to be learned to satisfy the growing requirements arising from the DT process, a brand-new set of problems arises.

- How to structure new skills that align with the requirements of the approaching transformation?
- How to structure the social mass of the desired new skills implementation?
- Who will teach people all the knowledge that is wanted and needed?
- Where will the teachers be trained?
- Who will prepare all the necessary manuals for teachers and then for students?

This is not simply rhetorical exclamation. A very simple and preliminary calculation gives exciting results; just try to estimate the resources that are really required for the realization of such a trend or tendency. That does not mean that it is impossible to make progress in this direction, but it is important to realize that the path will be long and difficult. And here is an attempt to show that, by default, nothing positive will happen without the risk of encountering Neo-Luddism and technophobia.

But these will, in the integral sense, result in overall changes in relations between humans and power, between mere mortals and governments; *Homo sapiens* is becoming *Homo cognitus*. From the ability to think through learning and rethinking, man is coming to an understanding of equality. The spirit of inequity is dormant while one's vocabulary remains below 2500 lexemes[2] in one's native language. That was achieved a posteriori on the long road of the history of civilization, and was used under all forms of rule to limit people's education. Special syllabuses and curriculums were developed for mere mortals and nobles; even more grades were used in

[2]Lexeme is a minimal unit of language that has a semantic interpretation and embodies a distinct cultural concept.

segregation. Has anything changed since those times? Much has been declared but very little achieved.

Certain researchers have proven that quantitative differences alone in the amount of information that must be adopted in education in different social sectors varies by a factor of 10. The most demonstrative factors in this differentiation are the number of lexemes used in learning resources, and the second is the volume of reworked materials in bytes. As an example, over the course of their educational career the average European (75%) gets around 3 Mb of learning materials on a basis of 3,000 lexemes, but in higher education (15–18%) they get around 50 Mb for their studies with around 25,000 lexemes.

A similar situation can be observed in all other countries in the developed world. The active electorate from the educated part of society only makes up 15–20% of the total. Consequently, the social majority elects politicians to power with low responsibility for their decision, since they are unable to recognize all the quirks and characteristics of politicians and the false information that surrounds them. Their active vocabulary varies around the level of 3 K lexemes, while the average electoral politician uses about 7–9 K in their election campaigns and manifestos (Khandaker, Barnett, White, & Jones, 2011).

From the mid-1980s to the mid-1990s, mass media in the English-speaking world artificially reduced the level of the content of lexemes from 5 K to around 2.5 K, and since that time the average IQ level has decreased significantly from around 110 to around 90 (Buj, 1981; Lynn & Vanhanen, 2012; Hunt, 2011).[3] Cognitive skills and the ability to justify inequity are well correlated among other features (Khandaker et al., 2011). The conclusion from the above consideration is self-evident: serious conflicts of interests, or even a red-neck revolution?

That was only one social aspect and impact arising from the long-term digital transformation of our world, a process that actually started the moment humans needed to count. The next aspect is the issue of AI, and this lies very close to the problems of servitization and semantic unevenness. AI has still not become a futuristic reality even today, but not to pay attention to this phenomenon is to assume the position of an ostrich, with one's head in the sand. The threat is not one of malevolent or inhuman intentions on the part of AI, but in faulty concepts embedded in the basic rules of AI's constraints. The general risk from AI is in the inconspicuous substitution of human intelligence for AI, especially in assuming that any particular resulting actions were brought about on a human's initiative rather than having, in reality, been generated by AI.

In 1966, the University of Illinois Press published John von Neiman's *Theory of Self-reproducing Automata*. The work essentially started a revolution in the development of artificial intelligence. The self-reproducing automata are now called intelligent agents, but the core theory embodies the same principles that were first developed in the 1960s. There are many approaches to the architecture of AI that can

[3]This is not a discussion of the validity of the data or methods of analysis presented by the referenced authors, but observations of student results in three European universities over the last decade correlate well with their conclusions.

compete with von Neiman's theory, but the most fruitful ideas still belong to him (Von Neumann, 1966).

The topic of AI as a threat to human existence is extremely multidimensional and polyhedral—whole volumes could be dedicated to it. High-profile figures such as (Hawking, 2014) and (Musk, 2016) have brought attention to the issue and even appealed to the international community to introduce legal regulation in the field of AI development and use. The general problem of the application of AI in day-to-day life today is not in its use and methods of utilization—it is more serious than that. An army of poorly educated novices who have just read Dan Brown's[4] latest adventure in sacred settings starts hype coding something that could be called AI and they launch it on a market that is always open to new, well-marketed products.

AI is not based on ordinary sequences of logical predicates, or prototypes of neural networks as most people think. Practically all of what is achieved now in AI development is an impressive imitation of intellectual activity with big gaps in parts of the human psyche and ethics. Amateur attempts at AI development can be as dangerous as untrained neurosurgeons. The results are unpredictable since what is potentially missed in the code sequences is much more difficult to test for vulnerabilities than is the case with operating systems—this is now not a rare occurrence even in market-leading products.

Since AI is such an attractive tool that can be employed in different ways to generate profits with the minimum of operational risk and therefore expenses, to expect businesses to maintain high moral standards where that could limit profits is futile. It is also necessary to add politicians to this band of 'misunderstanders'. This group rubs their hands with glee over the possibility of manipulating social opinion, something that becomes very simple and achievable with the help of AI applications, as demonstrated by recent political events around the globe.

When it comes to amateurish attempts to develop cheap realizations of AI, there is one problem that has never been touched on before, mainly due to the restrictions imposed by political correctness. That problem is the fact that multiculturalism and intercultural differences are ignored. As outlined above, the greatest challenge in AI development is the study and simulation of the human psyche and ethics as natural barriers in the regulation of AI behaviour. AI's behaviour depends on a set of rules developed by humans. These rules are not formal logical expressions, they also reflect certain frames of human morality and ethics. The result is directly bound with the creator of AI, as his body of ethics, morality and psyche is imbedded in the AI ruling reasoning. The existing multicultural concept tends to mean that we avoid thinking about how different the results of intellectual activity could be in the field of applying logic and reasoning: human logic is taken to be universal, following Aristotle. But:

- Can we conclude the same within the framework of the human psyche and ethics?
- Have we studied these concepts sufficiently to allow us to judge how the psyche and ethics depend on cultural roots?
- And how can we structure ethics and the psyche in order to implement them in AI realization?

[4]Dan Brown is a modern popular novelist. See danbrown.com.

2 Considering the Position

Let us now consider the key aspects of digital transformation as a comprehensive term that covers all the core synonyms such as ‘digitization’, ‘Industry 4.0’ or ‘digital economy’, and everything that is referred to today as ‘smart’. Here the PTP abbreviation is used as mentioned above. Under the scope of DT, people (the first P) are usually regarded as a weak link or a source of operational risk in digitization and servitization managing processes. Relatively weak links must be substituted by AI. There are no practical discussions regarding attempts to reconsider and restructure DT concepts from a position of empowering human (P) abilities up to the strongest link in the resulting management structure.

In addition, computers are considered from the viewpoint of their productivity or number of calculations per second. DT will open up that issue, and the two questions of power supply and the release of heat emission from expanding computational facilities are at the top of the discussion agenda. A very simple example illustrates this perspective: sending just one message from one device to another requires enough power to heat a teacup.

Today, all the digital resources of our world consume around a third of the total energy produced. According to research by the Gartner Group, DT will require at least double the IT power in 3–5 years’ time. We currently do not have such extensive reserves of power since alternative electricity sources are still not effective enough. That is another ‘brick in the wall’.

It has thus become apparent that power consumption is a key factor in DT. Consider the retrieved results on the requests ‘digital economy’ and ‘digital transformation’ to understand the influence of the first P factor. In summary, it can be concluded that digital business transformation (DBT) or digital business optimization (DBO) are the next ‘bricks’ in this wall. That leads us to the question of HR restructuring, adaptation and education.

Below is a simple diagram (Fig. 1) that illustrates very schematically the breakdown of digital economy elements, keeping in mind the impact and dependence of culture and society, as mentioned above.

This diagram might be taken to suggest that the implementation of the digital economy initiative at this present moment is easy. That, however, is only an illusion arising from the apparent similarity of the blocks in the lowest row. The ‘workflow’, ‘big data’, ‘ERP’ and ‘RPA’ components mentioned above have been discussed and used for around 30 years, and a list of abbreviations such as ‘CRM’ and ‘BPR’ could extend even longer.

In all the proposed transformations among many proofs of benefits and rosy futures there is one delicate and often-ignored factor of the impact on social background. In cases where social aspects are discussed, in nine cases in ten authors write about knowledge management or avoid mentioning the topic. It is clear that to touch on the theme of psychological influence on the social mass from rapid environmental transformation is dangerous: to do so is to risk losing out on budget increases if people in high places begin to doubt in the perspective of the future generations.

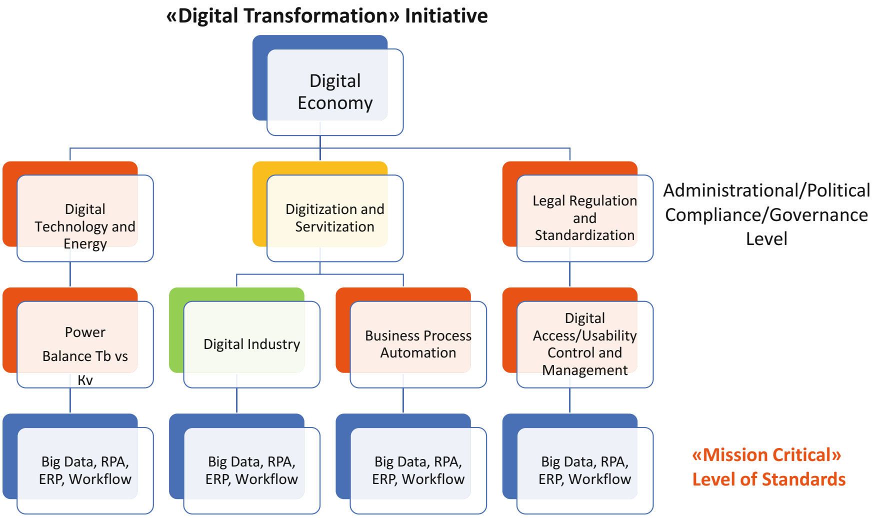

Fig. 1 The essential components of the digital economy

The general problem with all these digitized information technologies is that there are few practically approved statistics. Figures indicating the implementations of particular technologies exist in the success stories of each vendor, but where are the reports on the effectiveness of the chosen enactments over the long term? Is any statistical research being carried out on the duration of the specific application utilizations and the accumulating effect of their use in real working environments?

3 Research and Results

Consider the results of the valuable research presented by the group of master's students at the BPM Chair of the National Research University Higher School of Economics. The research results are presented in the table below and could certainly disappoint enthusiasts of the digital economy and DT initiatives. In short, it can be concluded that as long as applications of workflow methodology are not accepted in business practice and culture, any attempt to move towards digitization is made in vain. The research was based on the hypothesis that the Gartner Hype Cycle methodology is not universally sustainable and can be used as a very rough estimation or even just for marketing purposes. As a reminder, here are the five main phases of Gartner's methodology:

A. **Innovation Trigger**: A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.

B. **Peak of Inflated Expectations**: Early publicity produces a number of success stories—often accompanied by scores of failures. Some companies take action, many do not.
C. **Trough of Disillusionment**: Interest wanes as experiments and implementations fail to deliver. Producers of the technology drop out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.
D. **Slope of Enlightenment**: More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.
E. **Plateau of Productivity**: Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off.

Since 1995 the methodology has proven its validity after it was presented by the Gartner Group for extensive use. But in the research, an attempt was made to check 'how often phase C ends with a fail' in the case of the implementation of the manifested technology, since the process of implementing anything new is seemingly not different from the innovation development process.

The core idea of business process modelling is automation, or as it manifests today: digital transformation. In the research, branded technology was chosen for study in the field of BPM (business process management). This field of examination was chosen since this is where we find the clearest evidence of the influence on DT implementation in the rigid life of an enterprise. The general task of business process automation realization was considered in four large mission-critical enterprises located in northern and eastern Europe. Due to non-disclosure agreements, the names and specific attributes will not be disclosed in the work, but the companies were chosen due to their annual reports, which provided information regarding improvements in effectiveness, awards for best practice in workflow implementation and similarities in the technologies used.

It is clear that any BPM system automation project will involve three general phases:

(a) the study and documentation of business processes (or comparing previous results of process documentation with the current state);
(b) correcting process bottlenecks or logical faults, and building process logic for the next automation;
(c) the implementation of the chosen workflow variant.

The (a) phase was realized on the ARIS platform in all cases. The (b) phase mainly depends on the professionalism of the analytical skills applied in it. And the (c) phase has many variations in terms of realization, but LOTUS was used in these cases. Consequently, an attempt was made in the study to trace the effectiveness of ARIS involvement in all stages of the enterprises' aspiration in process management automation. That was controlled and audited by the next parameters in dependence of time:

a. Number of business process models allocated in the repository or process registry and its correlation with actual state-of-the-art enterprise architecture;
b. Update records for each model and its lag from the current date;
c. Correctness of the model within the obvious logic of the described process;
d. Correctness of the semantics for model description;
e. Difference between process model and realized workflow or number of iterations needed for conversion of model in digitized process;
f. Percentage of RPA steps from actual modelled process steps;
g. Percentage of end-to-end processes in workflow realization;
h. Number of interfaces between business processes and their actual interdependence on business logic;
i. Number of IT systems in bookkeeping records vs in action and use.

Indeed, the notion of collecting accurate information reflecting all nine parameters was unrealistic, but the researchers believed that the majority of business stakeholders will be interested in an unusual vision for their businesses. It would be possible to prove to company directors that this information can fundamentally improve their understanding of the effectiveness of all business, and lead the way for serious enhancement in process management and in the coordination of strategic achievement.

This is evidently not a SWOT variant, but this set of nine characteristics reveals a more or less clear picture of business process maturity. And if the angle of discussion is turned but slightly, it would be possible to answer the questions of alignment between IT and business in the enterprise and the situation with HR. The issue of alignment between business and IT is as old as the history of IT; it was already widely discussed in the 1970s and 1980s. Many outstanding studies have been published on this topic, including (Peak, Guynes, & Kroon, 2005; Weill & Broadbent, 1998; Henderson & Venkatraman, 1993; Carr, 2008; Luftman, 2000).

These two aspects (maturity and alignment) are now gaining in importance since DT requires a clear understanding of the readiness of economic entities for the waves of digitization. Again, the question of how deep workflow is integrated in business processes can be answered from the angles of maturity and alignment. Each measurement from above nine factors is a particular indicator of enterprise diagnosis. All values presented in the table are non-dimensional in the range 0–1 so as to be comparable with each other for differences in scale sources. A, B, C, D are mentioned before four mission-critical enterprises in business areas such as airports, railroads, bridge maintenance and healthcare.

Without a long examination of the research's results, here are the conclusions:

1. General controllability of the discovered businesses is low and maintained mainly by the professional skills of experienced personnel.
2. Effectiveness of process modelling is quite low, which seriously hinders the implementation of low-level process automation, e.g. workflow.
3. Knowledge level of modelling personnel is not sufficient to support digital transformation as a macro process, and there is no will to improve this knowledge.

4. Business and IT architectures are not correlated and synchronized, and there is a lack of serious investment in digitization.
5. The D and E phases are not achieved in the Gartner Hype Cycle. Interest wanes as process modelling and further IT implementations fail to deliver, or require many iterations for final productive result. Continued implementations are a factor of personnel responsibilities and reputational risks.
6. There is no hype trend or tendency towards DT on the level of executive personnel due to a lack of motivation and the existence of fear (Table 1).

4 Conclusion

Indeed, without any scholarly illusions, the above considerations and combined observations on the current and preceding situations in the implementation of IT methods and tools in real life and in projects are summarized below.

1. In spite of the fact that DT appears to mainly affect technology and the infrastructure of the communication environment, its main impact is actually the cultural transformation of enterprise social levels.
2. Any enterprise is a socio-technical system in which information performs the role of an interface between man–man and machine, but their activity is based on knowledge, which is particular semantic information that is required for the

Table 1 Nine factors explored in the research illuminate the 'dark side of the moon' in companies with bright reports

Factors	A	B	C	D
a. BP models in repository and its correlation with actual state-of-the-art (model relevance)	0.2	0.3	0.5	0.2
b. Update records for each model and its lag from the current date (model actuality)	0.4	0.3	0.1	0.2
c. Correctness of model in obvious logic of the described process (logical sustainability)	0.5	0.4	0.4	0.3
d. Correctness of the semantics for model description (tool's applicability)	0.4	0.3	0.4	0.2
e. Difference between process model and realized workflow (modelling effectiveness)	0.1	0.1	0.2	0.04
f. Percentage of RPA steps from actual modelled process steps (digitizability)	0.0	0.0	0.03	0.0
g. Percentage of end-to-end processes in workflow realization (IT involvement)	0.2	0.1	0.3	0.1
h. Number of interfaces between business processes (system complexity)	0.5	0.6	0.5	0.7
i. Number of IT systems in bookkeeping records vs in action and use (IT architecture sustainability)	0.2	0.3	0.5	0.2

system to support its own existence and to achieve goals in a condition of unincreased entropy. In reality, the analysed semantic information is uneven and unsynchronized. Nowhere is entropy controlled.

3. Therefore, to make DT worthwhile, it has to structure the enterprise's semantic information to build activity ontology and unified information field/space. Meanwhile, it has to structure the personnel's knowledge in communicating the logic of executing processes that will impact on the effectiveness of IT implementation and digitization.
4. As long as low levels of DT ensures the adaptation of personnel to the new communication culture, a higher level of servitization has to be structured in order to maintain new, developing communication facilities to reflect the activity of staff.

Finally, if digital transformation is to succeed and prosper, it should be able to *structure* activity information into a unified semantic field, the so-called 'semantic kernel', then to *structure* personnel skills in line with the processing logic requirements in view of the elaborated semantic, then to *structure* digital services in line with personnel skills requirements in the accounting of interrelating communication. It is then necessary to *structure* external environments to achieve a breath of agility, and finally to try to take off with all that has not yet been structured.

The work is dedicated to Prof. Dr Jörg Becker of Münster University since one of his main statements as to what Information Systems is all about is 'strukturieren, strukturieren, strukturieren'.

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Augmenting Internet of Things (IoT) Architectures with Semantic Capabilities

Alan Hevner and Richard Linger

1 IoT System Realities

Internet of Things (IoT) systems exhibit unprecedented levels of scale and complexity (Atzori, Iera, & Morabito, 2010). These systems are characterized by very-large-scale heterogeneous networks with often unknown and unknowable boundaries and components. Nodes, connections, configurations, and capabilities come and go in unpredictable ways, and failures and compromises are ever-present. Dynamic interconnectivity of systems-of-systems limits visibility and intellectual control of functionalities and qualities, such as security, reliability, and performance. User transaction flows traverse systems and components with varying requirements for services and qualities. Additional complications arise from the variety of architectures, platforms, languages, protocols, organizations, and users that will be involved. Yet IoT systems must provide unprecedented levels of reliability and dependability for effective operations, such as needed for Smart Cities IoT systems (Gil-Castineira et al., 2011; Vlacheas et al., 2013). A critical question is how a well-defined semantics and rigorous engineering discipline can be defined for designing, developing, evolving, and operating such massive, complex, and unpredictable IoT systems.

The burden of un-mastered complexity leads to loss of intellectual control when it exceeds human capabilities for reasoning and analysis. Intellectual control means understanding IoT system behaviors at all levels in all circumstances of use. It does not mean the absence of uncertainty—that will always be with us—but rather the capabilities, through engineering and management processes, to deal with it.

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The essential role of governance of IoT systems addresses resource facilitation along with organizational authorities, responsibilities, and accountabilities (Weber, 2013). IoT governance requires a clear and detailed reference architecture as a basis for analyzing, designing, regulating and communicating IoT activities. Current IoT reference architecture proposals, such as the EU's Architectural Reference Model (ARM, 2013) and Cisco's Internet of Things Reference Model (Cisco, 2014), provide extensive detail on structural requirements for IoT systems, but say little with respect to requirements for behavioral semantics of IoT system applications. This is a gap that we attempt to understand and to begin to address in this research stream. Our motivation is simple: without rigorous behavioral semantics as a foundation for IoT applications such as Smart Cities, attempts to develop and deploy these systems will collapse under their own logical weight.

2 IoT Reference Architectures

An IoT reference architecture provides a common understanding and vocabulary for interoperability and communication across various platforms in an IoT system. Given a standard reference architecture, businesses and developers can create compliant IoT solutions for specific application ecosystems. The complexities and compromises in developing an acceptable IoT reference architecture are enormous, and we are just beginning to see initial proposals from standards organizations (e.g. ARM, 2013) and industry (e.g. Cisco, 2014). We observe that these initial reference architectures have a primary focus on IoT structures, including:

- Components—Sensors, Computers, Data Repositories, Servers, Platforms, etc.
- Connectors—Networks, Pipes, Telecommunications, etc.
- Configurations—Patterns for components and connectors in well-defined arrangements.
- Protocols—Detailed support for data flows and control flows within and between configurations.

While such architectural details are essential for providing and enforcing the syntactical structures of IoT systems, there is little attention to the behavioral semantics needed to support engineering of IoT applications. A recent survey of Smart City software architectures finds a great disparity in the range of requirements considered important for inclusion in the various architecture descriptions (Da Silva, Tomas, Alvaro, Dias, & Garcia, 2013). They conclude that no current Smart City architecture fulfills all essential requirements for application development. Further, they identify an overriding focus on technical issues with a significant gap on human-centered (i.e. social and behavioral) issues of the Smart City applications.

We posit that IoT application development requires stable and dependable anchors for specification, design, and verification in a unified engineering discipline. In addressing this need, we build on our previous research stream on Flow-Service-Quality (FSQ) technologies, which we adapt here to IoT system applications (Hevner, Linger, Pleszkoch, Prowell, & Walton, 2009; Hevner, Linger, Sobel, & Walton, 2002; Linger, Pleszkoch, Walton, & Hevner, 2002). We propose and study three overarching semantic concepts that contribute to foundations for IoT development—Flow Semantics, Quality Semantics, and Evolution Semantics. In the next three sections, we briefly define these concepts and provide examples of underlying engineering foundations.

3 Flow Semantics

IoT transactions are composed of flows of control and data through IoT architectural structures (i.e. components, connectors, and configurations). Methods for creation, instantiation, execution, monitoring, completion, and deletion of IoT transactions are required for any application domain. User task flows and their refinements into invocations of other flows and system services can provide a unified engineering foundation for analysis, specification, design, and verification of required functionality and quality attributes on the flows. Engineering development of task flows can be augmented by computational automation for behavioral analysis of flows and their components.

3.1 Flow Definition

A flow is a traversal of IoT network components to perform a specific task for a user (person or machine) or another flow. A flow combines functional capabilities of components such sensors, actuators, computations, protocols, communications, and services, any of which can be operating asynchronously, in order to complete its specified task. Flows can range from large and complex to small and simple. Flows can invoke other flows, and can be grouped into flowsets that implement particular mission objectives.

We identify two overarching requirements for flows and their constituent components:

- Flows must be deterministic to permit design and verification under intellectual control despite the underlying complexity and asynchronism of service uses.
- Flows must provide suitable responses despite the Uncertainty Factors (i.e. robustness) to permit dependable operational use.

In informal terms, flows and their components must be self-contained in a semantic sense to permit localized development and verification under intellectual control, yet still embody all uses of external flows and services required to complete their specified tasks, but whose responses cannot be predicted.

Because of moment-to-moment unpredictability in reliability, availability and other properties (termed the Uncertainty Factors), an IoT system can serve up absolutely anything as a response to a flow when it invokes external flows and services. To achieve a self-contained and localized view of a flow for development while accommodating necessary use of external capabilities, it is necessary that a flow "doesn't care" what the system serves up, but will always employ what is served up to carry out its task. If what is served up is complete and correct, the flow satisfies its nominal specification. If what is served up is incorrect or incomplete, the flow does not fail, but rather communicates its status for other flows to take action, and satisfies its specification in this way. That is, both ordinary and extraordinary behaviors, and everything in between, are defined in its specification. This is a critical property for flows and their components—it localizes reasoning for development yet permits use of external functionality for task completion. This property is a cornerstone of Flow Semantics. It prescribes a special semantic model for development and verification that accommodates Uncertainty Factors and can be standardized across all flows in an IoT system (Linger & Hevner, 2018).

3.2 IoT Flow Engineering

User task flows are defined by specifications based on mission objectives. These task flow specifications are refined into function-equivalent compositions of sub-specifications for IoT system services and data. These sub-specifications are in turn refined into lower-level task flows of compositions of function-equivalent sub-specifications of services and data in a stepwise process. At each step, designs can be expressed as compositions of single-entry, single-exit control structures, including sequence, alternation, and iteration, and their variants. Local sub-specifications are defined and documented with each refinement for use in verification. Services can invoke other flows and system services through stimulus/response interactions in a hierarchical structure as defined by Response-Based Flow Semantics (Linger & Hevner, 2018). This process can produce flow designs that explicitly deal with the Uncertainty Factors.

Flow designs can be implemented within IoT architectures. The union of flows for a given application can suggest a sufficient, but possibly inefficient, IoT architecture. Based on this basic description of flow engineering, the following concepts can be addressed in IoT applications:

Flow Abstraction. Existing flows can be abstracted for analysis and evolution through a process of stepwise abstraction that reverses the flow development process. This technique allows a designer to fully understand the full range of transactions that are embedded in an IoT environment.

Managing Uncertainty. Uncertainty Factor engineering deals with risk management and mission survivability, as well as management and governance of IoT operations. Definition of standards for Uncertainty Factor detection and responses can simplify and organize this aspect of flow design. This technique surfaces and highlights the key uncertainty issues in IoT environments.

Flow Verification. Because flows are deterministic, traditional function-theoretic verification can be employed, as defined in mathematical equations that enumerate equivalences between functional specifications and their procedural refinements (Linger, Mills, & Witt, 1979). The functional forms represent the behavior signatures of the decision control structures. They can be obtained through function composition and case analysis as described in (Pleszkoch, Linger, Prowell, Sayre, & Burns, 2012). These correctness relations can be verified in team reviews, and can also form the basis for automated analysis.

Future research on Flow Semantics will include case studies dealing with real-world problems in IoT system development. Research in Flow Semantics automation will help drive adoption of this technology. Of particular importance in this regard is extension of the science and technology of automated software behavior computation (e.g. Linger, 2018; Linger, Pleszkoch, Burns, Hevner, & Walton, 2007) for development and verification of flowsets across IoT architectures and languages. Behavior computation operates on the deep functional semantics of software and will address many objectives in IoT system development, verification, and operation.

4 Quality Semantics

Quality attributes can be associated with flows and the system services they invoke and can be specified as dynamic mathematical properties to be computed, rather than as static, priori predictions of limited value in real-time operations. Quality Semantics can be dynamically managed in operational use to provide required levels of system qualities, such as availability, security, and performance (Walton, Longstaff, & Linger, 2009).

4.1 Quality Definition

We define system qualities as functions to be computed rather than simply as capabilities to be achieved. Such a function is a *computational quality attribute* (CQA). Each CQA is a mathematical function mapping current usage information, status of required flows and services, and IoT environmental information to an attribute value that represents the current relevant measure of quality. This approach supports the description of any set of quality attributes and any models for describing each attribute, provided each model yields a representative numerical value for the quality attribute.

Three semantic quality objectives can be identified.

1. A flow transaction will require minimum levels of quality to be successfully performed. How do we define the quality requirements of a designed user transaction on an IoT architecture?

2. As a transaction is instantiated on a particular IoT system at a given point in time, how can we predict the quality levels that are available? This will depend on the current state of the IoT system in terms of capacity, load, reliability, and many other system state variables. If the required levels of quality cannot be currently provided, a decision must be made whether to perform the transaction or wait until a sufficient level of quality can be provided by the system.
3. What management mechanisms are needed in an IoT system to monitor the progress of an executing transaction to ensure that the quality levels are achieved? If certain qualities are falling short, dynamic flow management may be required to alter the flow path or abort the transaction and reinitiate it at a later time. In essence, quality attribute status must be known and dynamically managed in IoT systems for all user flows.

4.2 IoT Quality Engineering

The engineering of quality requirements in complex IoT systems is a challenging research and development field. To illustrate the ideas of quality semantics, we will present a short case study of engineering computational security attributes (CSA) into an IoT environment (Hevner & Linger, 2012).

Our engineering premise is that security properties have functional characteristics amenable to computational approaches. Thus, it is appropriate to focus on the question "What can be computed with respect to security attributes?" The ultimate goal is to develop and describe mathematical foundations and their engineering automation to permit:

- rigorous specification, evaluation, and improvement of the security attributes of IoT software and systems during development,
- specification and evaluation of the security attributes of acquired IoT architecture components,
- verification of the as-built security attributes of IoT systems, and
- real-time evaluation of security attributes during IoT system operation.

Complete definitions of the required behaviors of security attributes of interest can be created based solely on data and transformations of data. These definitions can then be used to analyze the security properties of programs. Computational security attribute (CSA) analysis consists of three steps (Walton et al., 2009).

1. **Define required security behavior**. Specify security attributes in terms of required behavior during execution expressed in terms of data and transformations on data.
2. **Calculate program behavior**. Create a behavior catalog that specifies the complete "as built" functional behavior of the code.
3. **Compare program behavior to required security behavior**. Compare the computed behavior catalog with required security attribute behavior to verify whether it is correct or not.

Requirements for security attribute behavior must explicitly define expected behavior of code in all circumstances of interest. Thus, the requirements for security attribute behavior must include a minimal definition of required behavior for all inputs of interest to the security attributes, including desired inputs (for example, an authenticated user id) and undesired inputs (for example, an unknown user id). Usage environment conditions related to security attributes are specified in the same manner as inputs to the system. For example, availability of the network might be specified by a Boolean value that indicates whether or not the network is currently available. Security successes and failures are also specified in terms of data. For example, system control data can be used to indicate whether the current user has been authenticated using a trusted authentication mechanism.

Verification that a security property in an IoT flow transaction is satisfied requires verification of both the data at rest (i.e., the control data values) and the data in motion (i.e., the mechanisms used to perform the data transformations). Some common tasks to verify data at rest include checking to make sure that a specific task (for example, an audit task) will always be carried out to validate the contents of a specific control data structure. Advantages of this approach to security attribute verification include the use of constraints and boundary conditions that can make any assumptions explicit. People and process issues can be handled by the CSA approach by using assumptions and constraints as part of the reference architecture quality behavior semantics. Behaviors can embody requirements for a given security architecture. The attribute verification process will expose security vulnerabilities, making it easier to address evolution of code, environment, use, and so forth.

The CSA verification process can provide important engineering opportunities for improved acquisition and third-party verification. A "user" of an IoT system might be a person, a device, or a software component. The user may be the intended user or may be an unexpected and/or hostile user. An issue that must be considered with commercial off-the-shelf (COTS) products and reuse is that the definition of "user" embodied in the security behavior requirements may not be the same definition that was employed in the COTS or reused component. The same issue occurs when unknown components are employed as "black boxes" in systems of systems environments. If, in the composition of services or systems, it doesn't matter what a specific "black box" does with respect to security attribute requirements, then that component can be used. However, if the behavior of a component does matter, it cannot be used until its security attributes have been verified. In this case, a behavior description can be calculated for the component using its executable, even if documentation and source code are not available. Only externally observable behaviors are of interest to security attribute analysis. Thus, while the behavior semantics will have to be produced for the entire system in order to extract the externally observable behaviors, there is no need to expose the algorithm or source code, and there's no need to understand the entire state space.

Computational security attribute (CSA) analysis is a step toward a computational security engineering discipline. It can potentially transform systems security engineering by rigorously defining security attributes of IoT systems and replacing or augmenting labor-intensive, subjective, human security evaluation. Advantages of the CSA approach include the following:

- A rigorous engineering method is used to specify security attributes in terms of the actual semantic behaviors and to verify that the behaviors are correct with respect to security attributes.
- The specified security behaviors can provide requirements for security architectures.
- Traceability capabilities can be defined and verified outside of the automated processes.
- Vulnerabilities can be well understood, making it easier to address evolution of code, environment, use, and users.
- The use of constraints provides a mechanism for explicitly defining all assumptions.

CSA technology addresses the specification of security attributes of IoT systems before they are built, specification and evaluation of security attributes of acquired system components, verification of the as-built security attributes of systems, and real-time evaluation of security attributes during system operation.

5 Evolution Semantics

Flow Semantics and Quality Semantics prescribe requirements for IoT architecture semantics focused on management and governance of user functionalities, data, and qualities in a bounded application domain. In complex IoT environments, however, it is not possible to completely predict all possible system behaviors. New and unpredictable behaviors will emerge over time and must be recognized and managed. Also, an IoT architecture must evolve and adapt over time based on changes in goals, ecosystems, and technologies. Evolution Semantics will prescribe processes for managing and directing this evolution while maintaining current operational capabilities.

5.1 Evolution Definition

IoT environments face constant change as new technologies, stakeholders, requirements (functional and quality), and organizational structures come into play over time. We contend that the ability of an IoT architecture to evolve effectively becomes just as interesting, if not more interesting, than the usefulness of a particular IoT architecture at any point in time. The validity of this premise is likely to depend on the problem space in which it is situated. For very static environments, for example, a particular IoT architecture may exist for a very long time with high capability. In a highly dynamic environment, however, the architecture's potential to evolve needs to

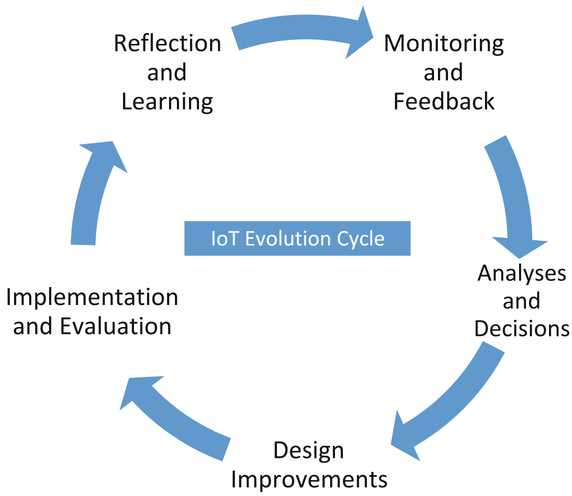

Fig. 1 Continuous IoT evolution cycle. (Adapted from Mullarkey and Hevner (2018))

be given much greater weight. The benefits of encouraging diversity and openness of IoT system designs as insurance against major changes in the problem space would be of paramount importance. Our belief is that such dynamism describes most IoT environments and forces such as globalization, energy conservation, social media, and advances in telecommunications will likely serve to increase such environmental turbulence.

Recently, Agarwal and Tiwana (2015), explore the characteristics of evolvable systems, understood as software-based information systems. They define the evolvability of a system as its capacity to efficiently serve new purposes and emerging possibilities. They argue that systems evolvability is an important and underexplored topic since most research generally focuses on the first use of a software system and the phases that precede it, not on evolution that takes place afterwards during operations. Thus, we contend that an effective IoT reference architecture must provide clear semantics to support the evolution of the system to manage environmental changes.

5.2 *IoT Evolution Engineering*

The engineering activities of evolution should be clearly embedded in the operational performance of the IoT system. Figure 1 illustrates the continuous operation of an iterative engineering cycle of system evolution.

The engineering stages in the cycle are:

- Monitoring and Feedback—All data and control flows in the IoT system are monitored for ordinary and extraordinary patterns. In addition, feedback from the system stakeholders on the use and effectiveness of the system is recorded and studied. Together these data provide an operational system profile with clearly identifiable gaps and opportunities for improvements.

- Analyses and Decisions—The governance team will actively analyse the operational profile of the IoT system and decide on its desired evolution. Evolutionary activities may include the addition, deletion, and modification of transactional flows, quality attributes, IoT architectures, organizational structures, and stakeholders. The costs and benefits of the proposed system evolutions will be considered in the decisions whether or not to modify the IoT system.
- Design Improvements—The improved capabilities of the IoT system will be designed for efficient integration into the existing environment.
- Implementation and Evaluation—The development team will implement the designs and evaluate their intended improvements.
- Reflection and Learning—The IoT governance team will reflect on the activities of this evolution cycle and institutionalize what was learned. The start of one or more new evolutionary cycles will be planned and initiated.

The execution of multiple and, perhaps, parallel, evolutionary cycles will maintain the relevance of the IoT system over time as the environment changes and the IoT system solutions evolve to meet these changes. We note that the evolutionary processes of problem re-formulation, technology advancements, design improvements, refactoring, and continual re-engineering interventions may be a long-term organizational project and will continue to generate knowledge useful to the various system stakeholders.

6 Conclusion

Future research directions in IoT reference architectures must support the semantics of flows, qualities, and evolution. Current reference architectures for IoT focus primarily on structural properties. While structural aspects are important for IoT development, the semantics of IoT operations, which are software-defined at virtually every level, are essential to developing and governing these systems. We believe rigorous semantic definitions and complete and verifiable processes must play an important role in a unified engineering discipline for IoT systems, with substantial impacts on their specification, development, verification, operation, and survivability. The focus on semantics of IoT architectures opens opportunities for new forms of computational analysis of flows and their quality attributes. These computational capabilities will be essential to maintain intellectual control over the scope and scale of complex IoT systems.

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Structuring Governments' Success Factors in Social Media

Sara Hofmann

1 Introduction

Social media offer various potentials for taking the interaction between citizens and government institutions to a new level. They can, for example, enhance democratic participation in the sense that citizens are enabled to engage in a participatory dialogue with governments and contribute to the development and implementation of innovative ideas (Bertot, Jaeger, & Hansen, 2012). Since citizens are no longer passive consumers of information, they can contribute to value creation and problem solving by expressing their opinion or by integrating their ideas into the design of new government services (Bekkers, Edwards, Moody, & Beunders, 2011). Famous examples of integrating citizens are participatory budgeting or open innovation contests, thus bringing to life the idea of open government. This new openness from the government side is supposed to increase citizens' trust in the public sector (Chun, Shulman, Sandoval, & Hovy, 2010; Hong, 2013), thus promising to reduce barriers for the interaction between governments and citizens.

However, it is still unclear how governments can leverage these theoretical potentials of social media. Put differently, there is the need to identify the success factors for the interaction between government and citizens in social media. In order to give guidance on how governments can improve their social media activities, the goal of this paper is to provide structured guidelines for governments' use of social media. These guidelines were derived from theoretical findings from the literature and empirical studies. From a theoretical perspective, I analyse the potentials that social media can offer for a successful interaction between governments and citizens as well as the existing shortcomings. From an empirical perspective, a mixed-method approach was used, consisting of analysing governments' social media profiles with

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the help of content analysis and qualitative interviews with both governments and citizens. This paper consists of passages from my Ph.D. thesis that Jörg has supervised (c.f. Hofmann, 2014a).

2 Social Media in Governments

Social media have become popular in the early years of the 21st century when social networking sites such as MySpace (in 2003), Facebook (in 2005) or video platforms like YouTube (in 2005) were founded (Boyd & Ellison, 2007). Social media are "a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content" (Kaplan & Haenlein, 2010, p. 61). According to their functionality, social media are categorised into weblogs—also called blogs—social networking sites (like Facebook), collaborative projects (e.g. Wikipedia), content communities (e.g. YouTube), virtual social worlds (e.g. Second Life) as well as virtual game worlds (e.g. World of Warcraft).

Social media offer many opportunities for government communication. They can alter the roles of sender and receiver in the communication act between governments and citizens from a one-directional or bi-directional to a many-to-many way of communicating (Agostino, 2013). Governments cannot only enter into a direct relationship with citizens but they can furthermore contribute to citizens connecting with each other by providing a communication platform (Chun et al., 2010). This can enhance the sense of belonging among members of a community. Furthermore, by analysing the published comments in social media, governments can learn about their citizens' needs and wishes and, thus, become more citizen-centric and responsive (Bonsón, Torres, Royo, & Flores, 2012). In case of critical events like natural disasters, governments can filter the social media content and gather real-time information by monitoring social media data (Kavanaugh et al., 2012). Social media can contribute to the goals of open government, i.e. they can support transparency, participation, and collaboration (Chun et al., 2010). By providing a platform for disclosing information to a large audience, social media can help to create a level of openness and make government activities more transparent. In doing so, governments can adhere to their task of giving accountability about their actions to the public (Bertot, Jaeger, & Grimes, 2010). Finally, with the help of social media, governments can reach citizen segments they could not adequately address before such as young people (Bonsón et al., 2012).

However, managing a successful social media site poses diverse challenges. Since especially governments enter new territory with social media communication, public managers lack expertise in this domain. Moreover, governments need to integrate their social media activities into their corporate communication strategy (Meredith, 2012). This includes internal guidelines for employees that determine how to act in social media. Furthermore, governments need to measure the success in order to evaluate and improve their social media strategy. However, in many cases adequate ratios for determining the impact as well as a clear set of goals are missing (Mergel, 2013). Further problems that governments are currently facing can be ascribed to the unclear legal situation. Present legal regulations do not adequately cover all issues that governments touch on with their online activities because most laws date back to the pre-social media time. Especially topics like privacy, security of government data as well as whether and how to ensure the accuracy of data published on social media sites are legal gray areas. Finally, an often neglected issue refers to the question what citizens actually expect from a government in social media (Mossberger, Wu, & Crawford, 2013). In order to provide a successful communication channel, governments need to identify the demands and wishes of their target group.

When reviewing the literature, the discrepancy between the theoretical potentials and guidelines on the one hand and the actual implementation of government profiles in social media on the other hand is striking. Although social media use in governments is widely spread—for example, 92% of American governments have created a Facebook profile, and 78% use Twitter (Maultasch Oliveira & Welch, 2013)—governments do not adapt to the new communication patterns. They rather continue using their one-way communication behaviour by disseminating information instead of starting an interactive dialogue with citizens (Waters & Williams, 2011). Whereas the aim of creating transparency is met by many governments, neither a corporate dialogue nor the promotion of e-participation through social media is often implemented (Bonsón et al., 2012). In cases a bi-directional communication takes place, social media sites do not seem suitable for in-depth discussions about complex political issues but they are rather used for advertising events like municipal celebrations (Chun & Warner, 2010; Magnusson, Bellström, & Thoren, 2012).

3 Method

In order to understand governments' communication in social media and citizens' perception as well as to derive success factors, a multi-method approach was used, consisting of content analysis and qualitative interviews.

Together with my coauthors, I analysed the Facebook profiles of the 25 largest German cities automatically via the Facebook API. In addition to this, we chose three out of the ten largest cities for an in-depth study of their Facebook communication and evaluated in how far they exploited the potentials of social media (Hofmann, Beverungen, Räckers, & Becker, 2013a, 2013b). Based on this analysis of how governments communicate on social networking sites, we examined which presentation features of governments' posts and which topics were most and which were least successful. In order to determine the success of post topics, we selected the 10% most and the 10% least commented posts on the Facebook profiles of the three cities. We classified the topics of these posts according to a taxonomy that we had developed. In addition to the post topics, we assessed the polarity of the related comments by citizens with the help of sentiment analysis (Argamon et al., 2007). Sentiment analysis works by comparing the words of the text to be considered with a predefined list of expressions that either assigns a positive or a negative value to each expression. In our study we used AlchemyAPI (http://www.alchemyapi.com), which is a sentiment analysis tool that is free for academic purposes and that assigns a value between −1 (negative) and +1 (positive) to a text. For evaluating which presentation features of posts (e.g. posts including pictures or videos) were successful, we again analysed both the number of comments and 'likes' as well as the sentiments of citizens' related comments.

For a deeper understanding of governments' social media activities, we conducted semi-structured, exploratory interviews (Hofmann, 2014b). We developed an interview guideline that was based on the literature concerning the potentials and the challenges of social media for governments. Among others, the guideline encompassed questions about governments' social media strategy, their way of using the social networking site Facebook, their motives, and their experiences. We contacted the 200 largest municipalities in Germany for conducting the interviews. If possible, we directly addressed the PR officers since usually they are responsible for maintaining the government profiles in social media. The resulting interviews were conducted via telephone or Skype. In doing so, we recorded the interviews and later transcribed them.

In order to understand citizens' perceptions of government profiles on Facebook as well as their motivation (not) to 'like' these profiles, we conducted semi-structured, exploratory interviews (Hofmann, 2016). Based on the related work, we developed an interview guideline both for 'likers' as well as for 'non-likers' of government profiles on Facebook. Among others, this guidelines contained questions about the way citizens became aware of government profiles on Facebook and about their reasons for 'liking' or not 'liking' the profiles. In addition, we asked the 'likers' to evaluate, for example, the content and the way governments presented their information. We contacted 97 randomly chosen cities with a government profile on Facebook and asked them to post a call for participation in our study. In total, 28 governments posted this request on their Facebook profile. Based on this call, the potential participants contacted us via e-mail or Facebook, and we agreed on an interview date. In addition to interviewing these 'likers', we used convenience sampling in our environment to select participants for the group of 'non-likers'. According to the interviewees' preferences, we conducted the interviews via telephone, Skype or if possible in a face-to-face setting. We recorded and later transcribed the interviews.

Afterwards, we used content analysis for analysing the interviews. Based on the related work, we developed a coding scheme to categorise the interviews, which we refined while coding the interviews.

4 A Structure for Governments' Success Factors in Social Media

While in theory, social media seem adequate for increasing the interaction with citizens (cf. e.g. Bekkers et al., 2011), in practice, however, governments do not fully exploit these potentials. Furthermore, citizens do not perceive the expected benefit when interacting with governments via social media. Combining the theoretical and empirical findings has resulted in 13 success factors for governments' social media activities. The recommendations are structured along two categories: *Strategically embedding of social media*, dealing with how social media can be integrated in an internal strategy, and *Effective interaction with citizens in social media,* including operational success factor for interacting with citizens.

4.1 Strategic Embedding of Social Media

A social media strategy is "a well-defined and tightly focused social media action plan, which has clear business objectives, specific policies, desired audience, desired resources and predefined metrics for measuring the social media impacts" (Ng & Wang, 2013, p. 2). Although governments would benefit from setting up a strategy (Agostino, 2013), the majority does not plan their social media activities strategically. Therefore, the following success factors provide a structure for governments on how to strategically embed their social media activities.

1. *Integrating social media into the communication strategy*

It is crucial when developing a social media strategy to integrate it in the existing corporate communication strategy (Meredith, 2012). In doing so, the relation between social media and offline respectively web 1.0 media needs to be considered, and governments need to identify the communication channel that is most adequate for a certain topic and a certain target audience. While some *"cannot do without paper and print media"*, other governments are sure that *"traditional media will be replaced by social media"* (Hofmann, 2014b). Since governments cannot reach all their citizens via social media, they need to keep in mind that social media can never be the single source of communication with citizens.

2. *Defining targets and adequate metrics to measure the success*

In order to assess the success of social media activities, governments need to identify adequate metrics. However, only few governments rely on predefined metrics but rather rely on individual perceptions: *"I think you feel it a little bit. We do not have great tools and do not spend money for this"* (Hofmann, 2014b). A major inhibitor to identifying adequate metrics is the missing definition of targets that should be fulfilled by social media (Larson & Watson, 2011), which again relates to the non-existence of strategies. If the target was to spread information, governments, for example, might analyse the number of 'likes' or followers (Mergel, Müller, Parycek, & Schulz, 2013).

3. *Defining internal competencies and developing guidelines for employees*

It is imperative to define who is responsible for maintaining a government's official social media accounts. Unlike traditional communication channels, which are typically organised by the PR department, social media can be used by all employees. In order to define *who* is allowed to publish *what*, governments should develop guidelines for employees' behaviour and define the competencies for maintaining the social media accounts. Social media activities can either be centrally managed by the PR department or decentrally by the operating departments (Mergel et al., 2013). Furthermore, governments need to define guidelines for dealing with citizens' reactions since *"[p]eople almost expect an immediate answer. How can you guarantee that? In fact also on weekends."* (Hofmann, 2014b)

4. *Clarifying the legal situation*

One inhibitor to using social media is governments' privacy regulations, e.g. *"[there] is the order by the data protection officers that local governments should no longer use this Facebook one click-like button"* (Hofmann, 2014b). In most cases, the current legal situation stems from a pre-social media era and thus does not adequately cover the possibilities provided by these platforms (Picazo-Vela, Gutiérrez-Martínez, & Luna-Reyes, 2012). Especially regulations concerning privacy, data security, storing and archiving communication data, and the binding character of information published on social media need to be covered by new laws (Bertot et al., 2012). However, governments are only responsible for adjusting the legal situations only to a certain extent. While it is necessary for them to seek legal clarity, updating regulations often lies outside of their competences.

5. *Developing a new self-understanding*

Social media can change the relationships between governments and citizens by altering the roles of the sender and the receiver in communication (Agostino, 2013). Governments themselves have acknowledged a changing communication behaviour by *"communicat[ing] on Facebook more informally than [they] would do on [the] homepage"* (Hofmann, 2014b). This is expected to lead to a decrease in the power distance between citizens and governments, thus challenging governments' self-understanding. Therefore, governments need to identify how to understand themselves in the new communication environment.

6. *Identifying the target group*

Closely linked to the strategy and targets of their social media activities, governments need to identify the target group they would like to address. Governments have expressed the intention to reach especially younger citizens whom they cannot get hold of via traditional communication channels. However, it seems that the younger target group is less interested in information provided by governments (Coursaris, Van Osch, & Balogh, 2013). This implies that governments need to adjust their appearance on social media. However, in recent years, social media have also experienced a user increase in older citizens (Mergel et al., 2013). Thus, governments need to define clearly which target audience they would like to attract and identify whether this target group can actually be reached via social media.

7. *Integrating citizens' demands and wishes*

As will be shown in Sect. 4.2, governments' expectations and citizens' perception of social media communication often differ. Although considering citizens' wishes is a success factor for social media activities (Mossberger et al., 2013), governments seldom collect feedback from citizens. Therefore, governments are advised to pay attention to their target audience's expectations, e.g. by enquiring them directly or by analysing their communication behaviour on government's social media pages in terms of comments and posts (Bonsón et al., 2012).

4.2 Effective Interaction with Citizens in Social Media

In addition to strategically embedding social media into the organization, governments are advised to make sure they interact effectively with citizens. The following success factors provide a structure for how governments should shape their interaction on social media.

8. *Offering adequate e-government interaction stages*

From a theoretical point of view, the e-government interaction stages *information provision*, *two-way communication*, and *e-participation* are especially suited for taking place on social media (Bertot et al., 2012). However, our empirical results show that while citizens appreciate to receive information, they are less interested in communication or participation offers. Unlike the claims of some researchers that "[u]sers of [social media] are no longer the passive consumer of content; they have become co-producers and co-creators" (Bekkers et al., 2011, p. 1007), our results suggest that at least in Germany, citizens are far from using social media as a platform for e-participation. Therefore, governments need to increase their efforts in attracting citizens for active participation, for example by publishing interesting content or appealing multi-media features (see recommendations below). Mergel et al. (2013) further suggest that e-participation activities should not take place on regular government profiles but they should rather create a new social media page in order not to overcrowd their profile.

9. *Publishing interesting content*

Governments need to decide which topics to post on social media. Government PR officers regret that mainly 'soft' topics are preferred by citizens: *"Not a soul is interested in hard topics… Be it stories about financial cuts, education topics–no one is interested. […] but things that go down well are photo collections, videos and these* *'blah' topics."* (Hofmann, 2014b) Citizens benefit from governments providing up-to-date information on current government activities such as changing office hours or road works. In addition, they consult government social media pages when looking for news in crises, e.g. when unexploded bombs from the Second World War have been found or when the city is threatened by a flood. In contrast to traditional channels, social media allow publishing information almost in real-time (Bertot, Jaeger, Munson, & Glaisyer, 2010). In order to both attract and entertain citizens as well as to inform them about topics that are important to governments, an adequate mix of information between 'soft' and serious content should be published.

10. *Presenting the content adequately*

In addition to the decision what to post, governments also need to think about how to present their posts. Citizens' preferred way of presenting information is to post a short teaser text, a picture to draw attention to the post and a link to an external page: *"I definitely prefer photos with a very short text. For example a photo of a bomb and next to it: 'Bomb found. Please check if you are in the radius of evacuation.', and then a further link that tells you how to proceed."* (Hofmann, 2016). Choosing the adequate form of presentation strongly depends on the content that governments would like to impart. Especially 'hard' topics like local politics or government information that seem less attractive can be made more interesting by adding pictures. Furthermore, governments should be prepared for citizens' expecting them to communicate less formally.

11. *Disclosing how data are used and privacy is ensured*

Privacy concerns inhibit many citizens from using government social media sites: *"Because I don't trust [Facebook] an inch and think that they can do a lot with the data. As long as the state is our friend, it's okay but this can change."* (Hofmann, 2016). Citizens need to trust the government (i.e. the party offering the service), the Internet (the underlying technology) but also the social media provider, which is a further party providing the technological platform. Governments can partly compensate this weakness by pointing out how the providers of the social media site (claim to) deal with private data. In addition, in order to increase citizens' trust in governments' behaviour, governments should provide information about the way they deal with citizens' information they can gather on social media.

12. *Marketing the profile in social media*

The main inhibitor for not 'liking' a government profile on social networking sites is missing awareness: *"I […] never came up with the idea that [governments are] on Facebook."* (Hofmann, 2016). According to our findings as well as to the KGst (2006), one of the biggest problem of e-government adoption in general is citizens' ignorance of the services that governments offer electronically. Therefore, governments need to advertise their profile in social media.

13. *Moderating comments and posts*

Governments should always moderate the posts and discussions on their social media pages according to their internal guidelines. On the one hand, they should be able to react to citizens' requests promptly (Lee & Lee Elser, 2010) since *"[p]eople almost expect an immediate answer"* (Hofmann, 2014b). This is especially important if governments decide to use social media for discussing with citizens. On the other hand, governments have to ensure that content on their sites published by external users is correct, not offending and not undesired by their citizens. For example, they should ensure that external advertisement is deleted since citizens in general do not appreciate it.

5 Conclusion

In order to give guidance on how governments can improve their social media activities, I presented the success factors, which I have structured into 13 guidelines. These guidelines are the result of several theoretical and empirical studies. From a theoretical perspective, I analysed the potentials that social media can offer for a successful interaction between governments and citizens as well as the existing shortcomings. From an empirical perspective, governments' social media activities were analysed. Furthermore, interviews both with governments and citizens concerning their interaction on social media served as a basis for deriving the structure of the success factors.

On the one hand, governments need to embed the use of social media strategically into their organisation. This means they have to integrate social media sites in their overall communication strategy (1), they need to define targets and derive adequate metrics to measure the success of using social media (2), and they should define internal competencies as well as guidelines for their employees (3). In order to cope with the intransparent legal situation, governments have to clarify which laws apply (4). Furthermore, induced by the unfamiliar role they take in social media, governments should develop a new self-understanding (5). They also need to identify the target group they would like to address by using social media (6) and collect and integrate the wishes and demands of their citizens (7).

On the other hand, several operational activities have turned out to be best practices for governments' use of social media. Governments have to identify adequate e-government interaction stages that can be offered in social media (8). According to our results, this is especially *information provision*. However, also *two-way communication* and *participation* can be possible. In addition, governments need to choose which topics to publish (9) as well as which form of presenting this content is most adequate (10). Based on the results, I suggest a mix of 'soft' and hard topics with a focus on 'soft' content as well as a purposeful use of pictures and links to external web sites. In order to decrease citizens' distrust, governments should disclose how citizens' data are used and how privacy is ensured on their profile (11). Furthermore, governments should market their profile in social media since the largest obstacle to 'liking' their profile is citizens' unawareness (12). Finally, they are advised to adequately moderate the profile in order to answer citizens' requests quickly and to avoid undesired external content (13).

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A Structure for New Voting Technologies: What They Are, How They Are Used and Why

Robert Krimmer

1 Introduction

Since the early beginning of elections technology was used to support their conduct. Even the early Greeks and Romans used simple voting machines to speed up the counting. In the twentieth century, well known inventors like Thomas Edison or Werner von Siemens came up with the idea to record member of parliaments' votes electronically, but failed to convince the politicians.

Nowadays, modern information and communication technology (ICT) give election organizers a whole new range of possibilities: New voting technologies (NVT)—encompassing the use of ICT in any phase of the electoral process, not only voting—include electronic voter lists, comprehensive electronic election administration systems, optical scanners as well as classical electronic voting machines or internet voting procedures, or even simple spreadsheet tools for the tabulation of votes on personal computers. While without the latter the conduct of elections seems unthinkable, the use of devices to cast votes electronically is not uniform within states in the Northern hemisphere.

Electronic voting machines and optical scanners are in use in Belgium, France, the Russian Federation, and the United States. In Germany, Kazakhstan, the Netherlands the use of this equipment was stopped either due to political decision after a public hack, the lack of public support, respectively a constitutional court ruling. Ireland had already bought the machines when it decided to not use them due to a very intense public debate. Bulgaria and Finland ran pilot projects with varying degrees of success.

With the emergence of the Internet, several states have started to gain experience with Internet voting procedures, which can be compared with postal voting and constitute voting in an uncontrolled environment without of an electoral committee.

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The forerunner in this respect is Estonia, which introduced this remote electronic voting channel as alternative measure to all forms of elections in 2005. Similarly, Switzerland offered it to citizens residing abroad, who were registered in one of four cantons (Basle, Geneva, Grisons, and St. Gallen), in their federal elections in 2011. Austria, Norway, and the United Kingdom ran legally binding pilots.

2 Forms of New Voting Technologies

The question, which means are actually used to count, transmit or cast votes, is crucial for the determination of the process and the entire election.

(1) **Stand-alone voting machines**. Elections can be supported by electronic means through stand-alone voting machines that store the casted votes locally and count and transmit the results at the end of the election. However, these machines can be designed in very different ways. They can consist of a computer limited by software to that particular use. The machines can also utilize push-button machinery or touchscreens. There are also voice-activated machines for visually-impaired voters, but naming all possible designs is not the objective of this study. Another option with stand-alone voting machines are stand-alone machines that have no connection to other machines, which would require the election results to be summed up by election officials.

(2) **Internet elections** are possible in many ways and have several subgroups and different names, such as remote E-Voting or mobile voting. The important aspect of this voting method is that the vote must be able to be casted from any laptop, tablet or mobile phone, and the eligibility to vote must also be verified via an online channel. Internet voting is the electronic equivalent of postal voting. Next to these four clear election forms, there are two additional election processes that cannot be accounted to one group alone.

(3) **Ballot scanning** is one of such mixed forms, as the system still uses paper ballots that are scanned and accounted for electronically. The scanning process is usually conducted in one of two forms. First, a central counting center is erected, where the ballots are transported and counted. Second, a scanner is installed above every ballot box; when a voter introduces the vote, the scanner scans the ballot directly and transmits the result to a central counting position. Scanning is usually a suitable technology to accustom voters and election officials to an electronic back-end system, since important parts of the election process are now conducted electronically, but voters do not have to get used to changes within their election habits.

The last possibility is a mixed form between remote and presence voting.

(4) **Locally operated Internet voting systems** voting uses electronic election machinery, but the machinery is, in this case, not placed in ballot stations but in libraries, schools or other public buildings. The environment is not controlled in this situation.

Table 1 Overview of different possible uses of voting technologies

Medium	Place of voting		
	Used in a controlled environment	Used in an uncontrolled environment	Used in mixed environments
Voting with paper ballots	Voting with paper ballots in polling stations	Postal voting	Mobile ballot box voting
Voting with electronic means	(1) Electronic voting systems; (4) Locally operated Internet voting	(2) Internet voting	Hybrid electronic voting solutions: Systems using Internet voting technology
Paper ballots and electronic counting	(3) Ballot scanner		Centrally-counted postal votes using ballot scanners

The Table 1 from (OSCE/ODIHR, 2013) summarizes these forms in the following overview. This exemplifies the different possibilities within an election design.

3 Motivational Factors

The motives for considering new forms of technology for casting and counting votes are manifold.

In the past, the first motivating factor behind these discussions was to enable secret voting. Later, those in charge of determining the process of elections—election administrators—tried to devise ways to conduct elections in the best way available to them. Therefore, their aim has been to limit the number of unintentionally spoilt ballots due to human error (Churov, 2010), to organize elections more effectively (and combatting fraud, see Saltman, 2006), and to count the votes quicker and more accurately (Arnold, 1999). They were supported by inventors who proposed technological advancements during phases of electoral reform and were interested in selling their patents and machines.

Notably, advanced technology can enable handicapped and vision-impaired voters to cast votes independently of a third party's help (HAVA, 2002). Similarly, average voters might benefit from IT support that would help them to cast their votes. In addition, voters living outside a country's territory must e-vote over the Internet if they wish to overcome distance (Auslandsschweizer-Organisation [ASO], 2012). Last but not least, politicians can benefit from a first mover advantage and the appearance of embracing modern technologies (Drechsler & Madise, 2004). They are also concerned about how the electorate will change and who might benefit from these changes (Mahrer & Krimmer, 2005). Other arguments include reducing the polling

Table 2 Motivating factors of stakeholders for the introduction of ICT to elections (Own compilation)

Motivation \ Driver	Administrator	Voter	Politician	Inventor (Vendor)
Appearance of embracing modern technologies			☒	
Cast votes independent of third persons' help		☒		
Changes in electorate result in different chances of being elected			☒	
Combat fraud	☒			
Count the votes more accurately and quicker	☒			
Establish trust in the election administration	☒			
First mover advantage			☒	
Maintain (raise) the voter turn-out	☒			
Organize elections more effectively	☒			
Participate in elections despite living outside a country's territory		☒		
Propose / advice on technological advancements				☒
Reduce the polling costs in the long run	☒			
Reduce unintentionally spoilt ballots due to human error	☒			
Sell voting technology				☒

costs in the long run, maintaining or raising the voter turn-out, and establishing trust in the election administration (ACE Project, 2005; Council of Europe, 2004; Volkamer & Krimmer, 2006; Zukerman, 1925).

Therefore, all forms of e-voting technologies (see previous chapter) affect the three main stakeholder groups involved in elections: (i) voters, (ii) election administrators and (iii) politicians. Moreover, they introduce a fourth category, (iv) the vendor. The figure below displays a compilation of motivating factors, which it attributes to their respective stakeholder groups.

However, the use of ICT in elections results in challenges in addition to the positive effects for anyone involved in elections. Voters also have to spend more time understanding the broader process, and they might fear that voting technology makes it easier for administrators to rig an election. Therefore, administrators have to cope with an increased need for staff training. Finally, yet importantly, politicians may fear losing vote shares when the electorate changes due to new ways of voting, and they may hinder the decision-making process for this reason (Mahrer & Krimmer, 2005).

For another group of election stakeholders, which comprises the media and election observers, the use of e-voting is also posing more difficulties, because this group plays a relatively passive role in the election process. They believe the voters share their struggle to understanding e-voting technologies. Due to the inherent nature of these technologies, it is not possible for one to "see" the actual process of recording a vote with a human eye; one can touch and feel paper but cannot do so with electronic bits and bytes (Lenarčič, 2010), which is why assessing e-voting technologies is quite challenging.

The use of ICT in elections has manifold motivations, most of them can be explained by the interests of each participating stakeholder. Although the introduction and promotion of a voting technology may not seem overwhelmingly difficult, implementing the transformation requires a lot of planning and knowledge about how the system can be best implemented in a given setting (Table 2).

4 Conclusion

In this article we showed how the technologies available to use in elections can be structured. Last, we provide an analysis of the motivational factors for their use.

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Structural Features of Digital Strategies for Municipalities

Björn Niehaves, Kristina Röding and Frederike Marie Oschinsky

1 Introduction

The age of digitization demands municipalities to quickly adapt to technological developments. In doing so, demographic change and rural depopulation requests from them to orient these progresses to the needs of their citizens. The risk of not getting skilled workers or of an endangered social life in villages and communities due to a too small or too old population is high. To address this challenge, there are many federal state projects helping municipalities to integrate digitization. For example, some federal states try to help their municipalities with state subsidies. The result is that many municipalities use those state subsidies to run projects regarding digitization in different sectors. However, those projects only last for the duration of the funding as afterwards, the lack of monetary support cause the projects to be abandoned. This is a phenomenon often seen nowadays, but what else can help municipalities ensure these projects continue to their fruition?

This is where digital strategies become important. Digital strategies are discussed brightly in the existing literature. Aligning to the Information Systems (IS) literature, digital strategies related to a business can be described as an "organizational strategy formulated and executed by leveraging digital resources to create differential value" (Bharadwaj, El Sawy, Pavlou, & Venkatraman, 2013, p. 472). Such a digital strategy could help municipalities to initiate a local digital development.

In line with previous literature that has contributed to a deeper understanding of strategies in the IS (Arvidsson, Holmström, & Lyytinen, 2014; Bharadwaj et al.,

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2013; Chen, Mocker, Preston, & Teubner, 2010; Cummings & Wilson, 2003) and regarding smart cities (Almirall et al., 2016; Anthopoulos & Reddick, 2016; Meijer & Bolívar, 2016), we want to aim to continue this tradition in light of current technological developments. Specifically, we seek to shift the focus from previous conceptualizations to a new form of conceptualization that considers structural elements of digital strategies, especially for municipalities.

Recognizing the need to get a better understanding of the formation of digital strategies, the goal of our study is to contribute to the exiting literature and to give information about how a digital strategy can be structured in the public sector, especially for municipalities, by proposing a framework for the formation of digital strategies for municipalities. In order to address our objective, this paper is guided by the following research question (RQ):

RQ: How can a digital strategy be structured in the public sector, especially for municipalities?

The paper is structured as follows. In section two, we derive our research question giving an overview of the current literature regarding digital strategies. Section three describes the research design of this study. In section four, the conceptual framework for the structural features of digital strategies for municipalities is introduced, then tested in all 427 municipalities in North Rhine-Westphalia, Germany, the results of which are detailed in Section Five. In Section Six implications for theory and practice are discussed as well as the limitations of the study giving recommendations for future research.

2 Background

The importance of developing and implementing policy papers has been discussed actively in existing literature (Bardach & Patashnik, 2016; Sabatier & Mazmanian, 1980). Policy papers have the aim of structuring the world around us by giving behavioural advice and regulation. (Bardach & Patashnik, 2016).

In our study, we are looking at policy papers for municipalities and specifically, strategies for coping with digitisation. As prior research on strategies in the IS field has been influenced by the field of strategic management (Chan & Huff, 1992), we first give an overview of strategies in the strategic management literature.

The construct of strategy as a policy paper has been discussed from various angles in the strategic management literature (Cummings & Wilson, 2003). The existing literature shows, that there is not one common definition of strategy (Bourgeois, 1980; Gluck, Kaufman, & Walleck, 1982; Hatten, 1979; Lenz, 1980; Chaffee, 1985; Mintzberg, 1978, 1987). A single strategy model, which has met general approval, does not exist either (Markides, 1999). Instead, different models explaining strategies (e.g., Porter's five-forces (Porter, 1980), core competency theory (Prahalad & Hamel, 1990) and the resource based view of the firm (Barney, 1991; Rivard, Raymond, & Verreault, 2006)) can be found in the present literature. Mintzberg (1987) attempted to bring more clarification into the construct of strategy. With his five P's for strategy

(strategy defined as plan, ploy, pattern, position and perspective), Mintzberg brought different definitions of strategy together giving researchers an overview of strategy definitions (Mintzberg, 1987).

Chen et al. (2010) conducted a comprehensive literature review on strategy from the IS perspective. They define IS strategy as "the organizational perspective on the investment in, deployment, use, and management of information systems" (Chen et al., 2010). In their literature review, Chen et al. (2010) found that a variation of expressions have been engaged to represent similar constructs such as IT strategy, IS strategy, IS/IT strategy or information strategy (Chen et al., 2010). When we are looking at digital strategies, we see that they are understood to be even more far-reaching, when looking at a range of action fields, for instance, not on the investment and management of information systems but rather on the whole business (Bharadwaj et al., 2013).

Against the background of the existing literature, we want to define digital strategies for municipalities. We define a digital strategy for municipalities *as an organizational strategy for municipalities formulated and executed by leveraging digital resources to create differential value* (Bharadwaj et al., 2013) *to support or shape a municipality's development goals, (and) its plan for gaining and maintaining locational advantage in the digital age* (Chan & Huff, 1992). Recognising the need to get a better understanding of digital strategies for municipalities, we define our objective as analysing structural features of digital strategies for municipalities.

3 Method

In order to explore relevant elements of digital strategies, we applied a multi-method approach of qualitative and quantitative research (Bryman, 2006). We conducted multiple case studies (Yin, 2013) consisting of qualitative and quantitative content analysis of implemented digital strategy documents. Based on the results, we did a qualitative process analysis combined with expert interviews and reflected on our results with experts in a subsequent workshop. Based on our conclusion from existing literature, the case studies and the expert workshop, we developed a survey afterwards (Fig. 1).

Case studies are a useful method for investing complex phenomena that have not been fully explored yet (Benbasat & Taylor, 1978; Yin, 2013). Furthermore, case

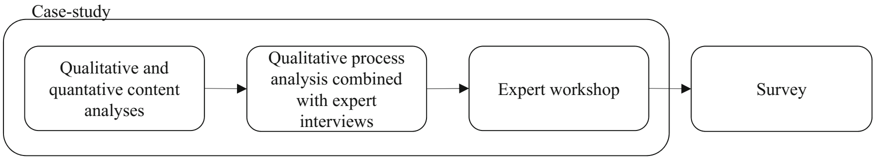

Fig. 1 Research design

studies allow an in-depth analysis of phenomena that are related to the context where those phenomena occur (Bonoma, 1985). Since both mentioned aspects are relevant to our study, case study research is a well-suited method for the first part of our endeavour. In general, it is supposed that the strength of case studies lies in their internal validity whilst their weakness is often to be the external validity. Therefore, we took two forms of measures to increase the external validity of our case study: First, our research was conducted in a team. At least three researchers conducted all phases, which are described in the following. With this, we aimed for reducing idiosyncratic perceptions (Eisenhardt, 1989). Furthermore, with the use of multiple investigators, we were able to implement triangulation (investigator triangulation, (Benbasat & Taylor, 1978)). Second, we included multiple cases to reduce case-specific findings (Benbasat, Goldstein, & Mead, 1987; Yin, 2013).

In the first part of our case study analysis, we conducted qualitative and quantitative content analysis following the eightfold path by Bardach and Patashnik (2016). In a first step, we defined the problem we are looking at. In our case, we looked at how digital strategies are structured in the public sector. In a second step, we selected some evidence from municipalities, constructed alternatives (step 3) and selected criteria for the analysis of digital strategies (step 4). As the assembling of evidence recurs through the entire process of the analysis (Bardach & Patashnik, 2016), we analysed in sum 21 digital strategies of national and international best practice municipalities (Birmingham, Brussels, Cape Town, Copenhagen, Den Haag, Dubai, Duesseldorf, Edmonton, Eindhoven, Gothenburg, Hamburg, Leipzig London, Manchester, New York City, Oldenburg, Sonderborg, Stavanger, Sydney, Tallinn and Vienna). We projected our outcomes (step 5), confronted the trade-offs (step 6), stopped, focused and narrowed our outcomes (step 7) to successfully show structural features for digital strategies of municipalities in the end (step 8) (Bardach & Patashnik, 2016).

In the second part of our case study, we conducted a qualitative process analysis combined with seven in-depth interviews with experts of the municipalities we analysed in the first part (Den Haag, Eindhoven, Leipzig, Oldenburg, Sonderborg, Tallinn and Vienna). We analysed the process of developing a digital strategy and conducted our interviews using an interview guide approach, as this is more comprehensive and systematic for data collection than purely conversational interviews. Furthermore, we developed our interview guideline to be mostly open ended in order to allow the experts to bring up additional concerns that we did not cover in our guidelines (Darke, Shanks, & Broadbent, 1998). The duration of interviews ranged from approximately 60 min to 100 min. We transcribed the interviews and assembled even more evidence for the structural features of digital strategies for municipalities.

In the third part of our analysis, we reflected our outcomes in an expert workshop. Our outcomes, projected from the content analysis (first part) and the process analysis combined with expert interviews (second part), were reflected together with experts from different municipalities in Germany. We revised our structural features of digital strategies based on the expert's feedback in a last step.

4 Conceptual Framework

In order to empirically assess structural features of digital strategies for municipalities by means of a survey, we develop a conceptual framework. Our survey is based on the findings from different stages of the case studies that were mentioned above. Thus, the survey consists out of questions concerning the structural features of digital strategies. These features are findings taken out of the case studies, which we linked back into the existing literature. As an example, we found strategic alignment to be an important dimension emerging from the qualitative analysis of the strategic documents, which was confirmed through the expert interview and later on in the expert workshop. In the existing literature, we also found the construct of strategic alignment and adapted it in relation to our findings from the case studies so that the wording fitted well to the NRW-municipalities. This procedure was repeated for every structural feature. Our final conceptual framework for our survey can be seen in Fig. 2.

Strategic Alignment. The construct strategic alignment was adapted from the construct of strategic alignment used by Preston and Karahanna (2009) and (Tallon, Kraemer, & Gurbaxani, 2000). With the results from our case studies, we adapted the items for municipalities in NRW, asking: "Your digital strategy is (1) …aligned with super ordinated digital strategies (e.g., country, federal government). (2) …aligned with different organizations' digital strategies (e.g., economic, scientific and political parties). (3) …coordinated with further own strategies, concepts or similar (e.g., IT-/E-Government-/urban development strategies)."

Strategy Formulation. The construct of strategy formulation is based on Altiok (2011), Wheelen and Hunger (2012) and David (2014), who described strategy formulation for companies in the strategic management literature. With the results from our case studies, we adapted the items for municipalities in NRW, asking: "If you do have a digital strategy or your digital strategy is under development: Which aspects matter? (If you do not have any digital strategy, please indicate to what extent the following aspects are significant in your opinion.) (1) The digital strategy contains a vision/mission statement. (2) The digital strategy contains goals. (3) The digital strategy contains fields of actions. (4) The digital strategy contains a catalogue of measures. (5) The digital strategy contains a monitoring concept. (6) The digital strategy contains digital risks (e.g., data protection)."

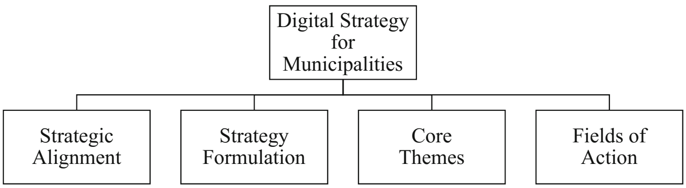

Fig. 2 Conceptual framework for the structural features of digital strategies for municipalities

Core Themes. The question for core themes of digital strategies for municipalities was self-developed from our case studies focusing on the three main topics a digital strategy for municipalities can look at. In our case studies, we found that the core themes are space, service and society. Against this background, the following items were developed and used for the survey: "Your digital strategy considers the core areas: (1) Digital services (e.g., digital civil office). (2) Space (e.g., sensor technology for urban development). (3) Society (e.g., co-working spaces)."

Fields of Action. Based on Giffinger and Gudrun (2010) and in line with the results from our case studies, we developed the following items to ask for the different fields of action focused on in the digital strategies: "Your municipal digital strategy considers additional fields of action: (1) Governance, (2) Economy, (3) Environment, (4) Tourism, (5) Education, (6) Health, (7) Mobility, (8) Others."

Every item was asked using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Afterwards, we cumulated the answers 1 and 2 from the Likert scale to one new scale called "fully disagree" and 4 and 5 to "fully agree". Number 3 of the Likert scale stayed as "neither". Using relative frequencies, we were able to show how often and strong individuals of the municipalities agreed or disagreed with the proposed structural features of digital strategies for municipalities.

When rolling out our survey, we first run a pre-test in 300 municipalities in Germany. We chose the municipalities regarding their number of inhabitants in relation to the overall population of the state the municipality is located in. The number of municipalities taken for a state was calculated in relation to the number of municipalities in general. As the survey was going to be run in the federal state of NRW in Germany, the pre-test was conducted in every state in Germany leaving NRW out of the scope.

After we adapted our survey regarding the results from the pre-test, we conducted the survey in the state of NRW. We asked all 396 NRW-municipalities and 31 districts to participate in our study. With a response rate of 34%, we were pleased that 133 municipalities and 12 districts took part in our study. As we wanted control of the employees answering our survey, we put a question asking for the name and position of the employee. We found that in each answered survey, employees or mayors, who are concentrating on the topic of digitalization in their municipalities, answered our survey.

5 Findings

Strategic Alignment. We found that 80% of the municipalities in NRW that took part in the survey are orienting their strategies on super ordinated digital strategies from, e.g., the country or federal government. 45% are aligning their strategies on different parties' digital strategies (e.g., economic, scientific and political parties) and 88% with further own strategies, concepts or similar strategies (e.g., IT-/E-Government-/urban development strategies). In general, we noticed that there is a need of aligning digital strategies to other strategies on different levels in order to structure and to position municipalities' own digital strategy. Looking at the NRW municipalities, we see that the importance of alignment is noticed by them and practiced already in most of their strategic developments.

Strategy Formulation. Our results show, that 92% of the NRW-municipalities that participated see the vision as an important element of the formulation of a digital strategy. 95% define goals in their digital strategy that they want to achieve in a considered timeframe. 93% answered, that mentioning fields of action, a roadmap und digital risks is important in their digital strategy, but only 84% of the municipalities are talking about the importance of monitoring elements for their digital strategy. As many municipalities in NRW are still at the beginning of digitization, it is understandable that only 84% are considering monitoring as an important element. You only monitor when you already developed or implemented a strategy and projects.

With more than 90% of the municipalities formulating a vision, defining goals and mentioning fields of action and a roadmap, we recognise a difference in the timeframe municipalities have to define with those elements. Formulating a vision is a long-time definition for future developments, whereas formulating a roadmap means defining a middle term time horizon. Formulating an action plan as well, as the municipality of Vienna did in our best practices, shows a short-term orientation defining specific next steps. We recognized that it can be helpful for municipalities to differentiate between formulating a vision, a roadmap and an action plan in order to be able to structure their digital strategies more transparent regarding their defined goals.

Core Themes. NRW-municipalities are mostly concentrating on digital services in their digital strategies (100%). Only 63% of the municipalities are focusing on the core theme space. The core theme society is integrated in the digital strategy by even less municipalities (only 55%). For the municipalities in NRW it would be recommended to not only concentrate on one of the core themes but also to see digitization as chance to connect all three core themes with each other. Doing so can help municipalities to generate synergetic effects. Showing that municipalities consider every core theme to be part of their digital strategy still gives them the possibility to concentrate on one of the core themes in more detail in order to specialize and position themselves as municipality in the digital age.

Fields of Action. 100% of the municipalities are concentrating on the field of Governance. Education is considered to be integrated into the digital strategy by 89% of the municipalities. 82% are concentrating on Mobility. Economy (78%) and Tourism (73%) are even less integrated and only 63% of the NRW-municipalities consider Environment to be part of their strategy. Even less (53%) concentrate on Health. Noticing that 100% of the municipalities consider Governance to be an important field of action, we recommend municipalities to see digitization as more than digitization of the government and administration, but rather to see it as a chance to integrate different fields of action and connect them in the long run.

6 Discussion and Conclusion

Implications for Theory. As the existing literature has no common perspective or view regarding digital strategies or even digital strategies for municipalities, our study can help to give guidance on how to structure digital strategies for municipalities. Referring to our conceptual framework (Fig. 2) structural features based on existing literature and the case studies could be developed.

We enrich the construct of strategic alignment developed by Preston and Karahanna (2009) and Tallon et al. (2000) showing another perspective of alignment specifically adapted for municipalities. Whereas organizations have the possibility to align their strategies congruent with their corporate business strategy or their corporate strategic plan, municipalities have the possibility to align their strategy with super ordinated digital strategies, different parties' digital strategies and with further own strategies and concepts.

We also contribute to the construct of strategy formulation by Altiok (2011), Wheelen and Hunger (2012) and David (2014), showing that formulating a digital strategy for organizations and municipalities follows specific elements. Looking at our results from NRW municipalities, we found that formulating a vision, goals and defining fields of action and developing a roadmap are the most important elements for digital strategies.

Giffinger and Gudrun (2010) suggested the existence of six different fields of action municipalities are working on while becoming a smart city. We found in our case studies that the different fields were addressed in varied ways, regarding the name and content of the field of action. Based on our case studies we extended Giffinger and Gudrun's (2010) list of fields of action and tested it within our NRW-municipalities. We could enhance the research by Giffinger and Gudrun (2010) adding a new field of action to their list.

Implications for Practice. Based on our findings we can derive practical implications for municipalities while developing a digital strategy. First, based on the results of 145 municipalities in NRW, municipalities should align their digital strategy with super ordinated digital strategies, different organizations' digital strategies and with further own strategies and concepts if possible. Second, municipalities should be clear in their formulation of their digital strategy. It might be a more transparent way to have three different parts of digital strategy addressing different time horizons. For example, a municipality should formulate a vision and goals for future guidance, develop a roadmap for middle term projects and achievements and define an action plan for specific next steps, which have to be taken on the way. Third, there are chances for municipalities to see digitalization as more than the digitalization of the government but as an instrument, they can design to connect their core themes and fields of action they want to specify on with each other in order to gain synergies.

Limitations and Outlook. Despite the theoretical and practical relevance of our study, it is fraught with difficulties and shortcomings that leave room for future research. Besides the regular limitations of case studies (e.g., weak internal validations), our study is of an explorative nature. Its intention is therefore to extend current perspectives on structural features of digital strategies, especially for municipalities. Our research can therefore be used to further develop structural features for digital strategies (MacKenzie, Podsakoff, & Podsakoff, 2011), but is somewhat weak in its theoretical contribution. Second, the unit of analysis is the municipality. As we asked for digital strategies for municipalities, only one of the employees of the municipal administration answered our survey representing the whole municipality. We asked for the name and position to control the employees answering our survey to make sure that they are familiar with digitization and strategic developments. We had to trust those employees who answered our survey. In order to overcome these limitations, future research might ask more than one employee in a municipality and make sure the employees are familiar with digitization and strategy development as well as ensuring that they answer the survey by themselves. Since the municipalities' way to a Smart City or Smart Region is still in its infancy in many places, future studies will have the potential to pursue this transformation empirically and to reconstruct the liveliness of the strategies directly on site. In addition, there are links to neighboring disciplines (e.g., architecture, social science, geography, etc.) and topics (e.g., open data, digital competence management, participation, etc.). Moreover, our study provides initial insights how to structure digital strategies at other levels of government (e.g., federal level). Finally, as the relevance of digitization in society and politics are still developing, we expect many future research questions to come.

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Banking Regulation and Banking Supervision: Current Structure and Challenges

Andreas Pfingsten and Corinna Woyand

1 Introduction

Since the global financial crisis, the issue of regulating and supervising banks adequately has gained increasing attention. In their role as financial intermediaries, banks provide important transformation functions, whereby taking comparably high risks (Hartmann-Wendels, Pfingsten, & Weber, 2014, p. 11). In particular, banks are exposed to a certain bank run risk (Diamond & Dybvig, 1983). At the beginning of the financial crisis, the British bank Northern Rock made their own first-hand experience as concerned customers rushed to withdraw their deposits, because they lost trust in the bank's liquidity. As a consequence of this bank run, Northern Rock was indeed unable to repay its liabilities and finally taken into state ownership to avoid its bankruptcy (Shin, 2009).

Unlike most other industries, a bankruptcy of a single bank can have severe consequences for the whole economy, especially in case of a spillover on further banks or even on other financial systems. Actually, this so-called contagion effect occurred after the investment bank Lehman Brothers collapsed in September 2008. As a result, several banks around the globe needed governmental support (Hartmann-Wendels et al., 2014, p. 310). Due to the high economic importance of the banking system and the demonstrated consequences in case of bankruptcy, banks are generally regulated much stricter than other corporations. The regulation and supervision of banks through a governmental oversight body aims to ensure the stability of the financial system in general (Hartmann-Wendels et al., 2014, p. 309).

The Basel I accord, introduced in 1988 by the Basel Committee of Banking Supervision (BCBS), lays the foundation for international banking regulation (Basel

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Committee on Banking Supervision (BCBS), 1988). Since then, the structure and scope of banking regulation and supervision has been constantly developed. The subsequent Basel II and Basel III capital adequacy frameworks substantially raised the complexity for banks as well as for supervisors since the compliance with a large number of rules and requirements needs to be assessed appropriately (Basel Committee on Banking Supervision, 2004, 2017). The Basel framework provides comprehensive guidelines to be applied by each BCBS member country, while it is no legislative act. Instead, these guidelines need to be translated into national policies and actions (Deutsche Bundesbank, 2013, p. 57).

In order to achieve an integrated financial framework at a European level, the two-layer structure of banking regulation and supervision in the EU differing from non-EU Basel member states, must be observed. Thus, the Basel frameworks are implemented into EU-law first before being translated into national law. Moreover, responsibilities for the prudential supervision of credit institutions are conferred on the European Central Bank (ECB). Hence, the pure national task of banking oversight has become an overall European task (European Central Bank (ECB), 2014). This comparably complex structure of European supervisory practices results in new conflicts of interest. Therefore, several EU-specific problems and challenges are currently apparent.

In this context, this paper aims to structure international banking regulation and supervisory practices with a particular focus on the European banking market. We point to current challenges resulting from the specific structure of European banking regulation and supervision and discuss consequences and policy implications. In detail, we consider the lack of separation between monetary policy and supervisory functions of the ECB, discuss the affected competitive conditions, and illustrate limitations for the intended European level playing field.

In doing so, we firstly give a short overview of the general objectives and the current structure of international banking regulation in Sect. 2. In a similar manner, we present the objectives and current structure of banking supervision in Sect. 3, focusing on the specific characteristics of European supervisory practices. In Sect. 4, we finally present and discuss current challenges for European supervisors and regulators and derive specific policy implications. Section 5 concludes.

2 The Objectives and Structure of Banking Regulation

As presented in the introduction, banks play a major role for the economy as a whole. They act as financial intermediaries and thereby provide important transformation functions, namely lot size transformation, risk transformation and term transformation (Hartmann-Wendels et al., 2014, p. 11). Regulators argue that the resulting risks, such as default risk, interest rate risk or liquidity risk, need to be monitored to guarantee the financial stability of the banking system (Basel Committee on Banking Supervision (BCBS), 2004). However, because of its complexity, the banking industry is characterized by comparably high informational asymmetries and resulting agency problems. Due to their limited liability, bank owners and bank managers are incentivized to take higher risks at the costs of their debtors, especially in a poor earnings situation (so-called gambling for resurrection) (Dewatripont & Tirole, 1994, p. 123). Particularly private depositors are neither willing nor able to monitor banks by themselves to prevent such a behavior. Therefore, banking regulation provides official rules and guidelines to be fulfilled in order to safeguard the overall financial soundness by ensuring the adequacy of each bank's capital and risk structure to protect private investors and to restore their confidence (Hartmann-Wendels et al., 2014, p. 309).

In this paper, we look at international banking regulation with a particular focus on European features. Thereby, regulation can be structured into three main levels. Firstly, international policy makers of the BCBS of the Bank of International Settlements (BIS) establish certain rules and guidelines, commonly referred to as the Basel Capital Adequacy Framework. Secondly, at a European level, authorities transfer such guidelines into EU-law, which, thirdly, may have to be implemented at a national level as applicable law. In the following, we present each level in more detail.

At the international level, the BCBS sets the main standards and develops specific regulatory requirements and capital adequacy guidelines. The BCBS consists in total of 28 member countries, including the European Union, which is institutionally represented by the ECB. Because banking regulation is an evolving process, the Basel Committee verifies steadily the usefulness of established rules, adjusts existing guidelines, and provides new rules if gaps are detected (Basel Committee on Banking Supervision (BCBS), 1988, 2004, 2017). Since the introduction of Basel I in 1988, the Basel capital adequacy framework underwent two major revisions and was extended by several additional standards. The finalization of Basel III (sometimes referred to as Basel IV) was recently published in December 2017 and aims to correct shortcomings of previous frameworks, which became apparent during the financial crisis (Basel Committee on Banking Supervision (BCBS), 2017).

With the introduction of Basel II, the Basel framework was structured into three main pillars. The first pillar—*minimum capital requirements*—deals with the regulatory capital for credit risk, market risk, and operational risk. The second pillar—*supervisory review process*—aims to ensure an Internal Capital Adequacy Assessment Process (ICAAP). In contrast, the purpose of the third pillar—*market discipline*—is to enable the monitoring by external market participants and specifies disclosure requirements in order to increase the transparency and comparability across bank reports (Basel Committee on Banking Supervision (BCBS), 2004).

However, standards and requirements established by international policy makers need to be implemented as national law. Due to the ongoing integration of the European banking market, the Basel guidelines are not directly transferred into German law, but adjusted beforehand at the European level. The European Parliament and the European Council aim to establish consistent standards across all European countries. Therefore, the third Basel Accord was implemented into European law via two legal acts. The first element is the Capital Requirements Directive (CRD IV) and the second element is the Capital Requirements Regulation (CRR).

At the national level, the German Parliament, the Federal Council and the Ministry of Finance have to transform EU-directives into German law, while EU regulations apply directly. The German Banking Act (Kreditwesengesetz, KWG) contains most rules regarding capital requirements and definitions. The German Solvency Regulation (Solvabilitätsverordnung, SolvV) further specifies the rules of §§ 10 KWG on banks' minimum capital requirements (pillar I of the Basel framework) and also contains the disclosure requirements of the third pillar. Finally, the minimum supervisory requirements for risk management (Mindestanforderungen an das Risikomanagement, MaRisk) spell out the requirements on banks' internal risk controlling (pillar II of the Basel framework) (Hartmann-Wendels et al., 2014, p. 336).

These rules are legally binding. Banks incur effort and costs to fulfil such a large number of regulatory requirements. In particular, strict banking regulation might constrain banks in their business activities. Hence, the incentive to comply voluntarily with such rules and minimum requirements is rather low. Therefore, it is necessary that a governmental oversight body monitors and verifies the compliance with regulatory standards. The next section presents and discusses the objectives and structure of banking supervision, again with a focus on the European banking market.

3 The Objectives and Structure of Banking Supervision in Europe and Particularly in Germany

To make sure that banks satisfy the rules and guidelines established by regulators, national supervisory authorities are required to oversee each bank in the respective country. The main task of the supervisor is to monitor banks' capital adequacy and to verify the correct and sufficient application of national law (Deutsche Bundesbank, 2017a, p. 129). Due to the specific structure of the integrated European banking market, European banking supervisory practices deviate from the standard case of a pure national oversight body. In the following, we present the current structure of European banking supervision.

The EU member states agreed upon a European Banking Union being subject to the so-called Single Rulebook. In order to create a set of harmonised prudential rules, the European Banking Authority (EBA) develops specific technical standards and guidelines (Regulation (EU) No 1093/2010). The intended Banking Union can be structured into three core elements. The first core element—*Single Supervisory Mechanism (SSM)*—plays a key role for this paper and is therefore explained in more detail hereafter. Just for completeness, the second core element—*Single Resolution Mechanism (SRM)*—and the third core element—*European Deposit Insurance Scheme (EDIS)*—are also briefly mentioned (European Central Bank (ECB), 2014, p. 21). The SRM complements the SSM and aims to establish adequate mechanisms to manage banking failures. As part of the EDIS, the European Commission sets up a deposit insurance scheme in the Euro area to protect bank deposits up to 100,000 € (European Union, 2018, Art. 6(1)).

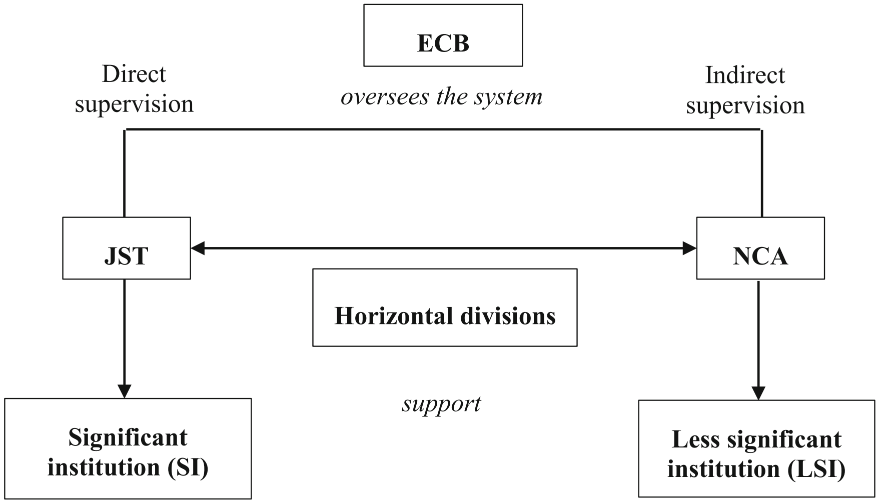

Fig. 1. The distribution of tasks within the SSM (Source: ECB, 2014, p. 11)

Figure 1 visualizes the distribution of tasks within the SSM and illustrates the key role of the ECB for the prudential supervision of banks in the Euro area. The ECB is responsible for the oversight of all significant institutions, while only indirectly supervising less significant institutions in the Euro area. Instead, the national competent authorities (NCAs), in some cases the national central banks themselves and in others in collaboration with the national central banks, still directly supervise these less significant banks. In Germany, "*BaFin and the Deutsche Bundesbank share banking supervision […]. Their cooperation is governed by Sect. 7 of the German Banking Act […], which stipulates that, among other things, the Deutsche Bundesbank shall, as part of the ongoing supervision process, analyse the reports and returns that institutions have to submit on a regular basis and assess whether their capital and risk management procedures are adequate.*" (Bundesanstalt für Finanzdienstleistungsaufsicht (BaFin), 2016).

Banks are classified into significant and less significant institutions according to different criteria. In particular, a bank is categorized as a significant institution if the total value of its assets exceeds 30 billion Euro or if the bank is one of the three largest credit institutions in a country (European Central Bank (ECB), 2014, p. 10).

Prudential supervision of SIs is a major competence of the ECB. So-called Joint Supervisory Teams (JSTs), comprising ECB members and national supervisors, conduct the direct oversight of such institutions and are supported by horizontal and specialised expertise divisions regarding the micro-prudential supervision (European Central Bank (ECB), 2014, p. 11). The collaboration has the objective to reach consistent supervisory practices across the EU member states. Moreover, this structure intends to ensure a more reliable supervision for all systemically relevant institutions in a country to assure that violations of rules and significant risks are recognised and evaluated at an early stage. This is thought to lead to more financial soundness in general (European Central Bank (ECB), 2014, p. 5). As a consequence of this complex supervisory structure, European banking supervision is currently exposed to several problems and challenges. We will discuss three key issues in more detail in the next section.

4 Current Challenges for European and National Supervisors

In the following, we discuss three major issues resulting from the current structure of European banking supervision. First of all, the ECB's key role for both banking supervision and monetary policy induces certain conflicts of interest. Secondly, we point to differences in supervisory practices between European authorities and national authorities, each representing its specific interests. Thirdly, we illustrate problems with respect to the intended European level playing field across all member states resulting from differences in supervisory stringency across the EU member states.

4.1 Combination of Supervisory and Monetary Policy Functions

In general, central banks play a key role for the financial system as they are mandated to ensure price stability. However, the additional assignment of major supervisory tasks to the ECB implies a strong concentration of power. There has been an ongoing discussion on the usefulness of combining both functions under the ECB. Some countries even withdrew their central banks mandate for supervising banks (e.g., UK, Japan or Canada) (European Central Bank (ECB), 2001, p. 4). In Germany, we observe a mixed form since staff of the German central bank are involved in supervisory tasks. In general, there are two opposing views on the combination of monetary policy and supervisory functions.

On the one hand, opponents of the conferral of prudential supervisory tasks on a central bank argue that this aggregation results in severe conflicts of interest. In particular, the ECB might be incentivized to perform its monetary policy function as to ensure the stability of banking markets and therefore may adjust the interest rates not purely according the main objective, price stability. This was observed in the USA during the Savings and Loans crisis (Ioannidou, 2005, pp. 63). Hence, monetary policy might be "misused" to avoid bank failures and especially spillover effects on further banks. Some critics even argue that the ECB largely exceeded its mandates (Matthes & Demary, 2013). Furthermore, because Euro area banks heavily rely on ECB liquidity, the combination of these two functions may increase the link between sovereigns and banks (House of Lords, & European Union Commitee, 2012, p. 16).

On the other hand, proponents of a combination of these two functions argue that the ECB seems to be the most appropriate institution to undertake the role as a European supervisor for the Banking Union (European Central Bank (ECB), 2001, p. 3). Especially, not refraining from separating those tasks allows to link both functions related to the overall objective of financial stability. In this double role, the central bank could gather useful information from banking supervision to enhance its monetary policy function (Ioannidou, 2005, p. 61). Moreover, the ECB is therefore able to decide reasonably whether to act as a lender of last resort for specific banks or not (e.g., it would not be reasonable if a bank is nearly insolvent anyway) (Ioannidou, 2005, pp. 61). As stated above, the ECB could nevertheless be incentivized to rescue certain banks to ensure the overall financial soundness. However, the ECB clearly states that price stability is the major aim (European Union, 2016, Art. 127(1)).

Overall, we can conclude that the combination of monetary policy and prudential supervision functions at the ECB leads to certain conflicts of interest. However, changing the European supervisory structure by withdrawing the ECB's supervisory task might not be a reasonable solution either. It would instead be necessary to ensure a clear separation of staff members of both divisions and to define tasks in case of a crisis. Hence, it is important to guarantee that the ECB acts independently in its role as price stabilizer (Great Britain et al., 2012, p. 18).

4.2 Differences Between European and National Supervisory Practices

As presented in the previous section, JSTs are required to supervise all significant institutions of each EU member state, while national supervisors still oversee all other institutions. However, it has to be taken into account that each country's banking system has its own specific national characteristics and is affected by different economic conditions. With the increasing number of regulatory requirements and rules, an overall harmonized regulatory standard across all banks is therefore frequently criticized (Hackethal & Inderst, 2015). For example, the German banking system is characterized by a three pillar structure comprising savings banks, cooperative banks, and commercial banks. Savings banks and cooperative banks mainly act regionally. Such smaller, local banks are less complex and less risky, whereas the business models of commercial banks, in particular the largest bank holding companies, are internationally oriented and often categorized as systemically important (Hartmann-Wendels et al., 2014, pp. 28).

Such a diversified and decentralized system requires a differentiated regulation among banks (Deutsche Bundesbank, 2017b, p. 45). Nevertheless, all EU banks are subject to the same Single Rulebook leading to a high administrative burden for locally oriented and less risky banks that are too small to implement own regulatory departments. Therefore, small banks are faced with comparably high bureaucratic expenditures to comply with all regulatory standards and disclosure requirements

(Hackethal & Inderst, 2015). In this context, the proportionality principle determined in the CRD states that the internal governance "*shall be comprehensive and proportionate to the nature, scale and complexity of the risks inherent in the business model and the institution's activities.*" (European Union, 2013, Art. 74 (2)). Hence, the proportionality principle refers to the second pillar of the Basel framework (ICAAP, see Sect. 2). However, Andreas Dombret, former member of the Executive Board of the German central bank, recently suggested to elaborate a so-called Small Banking Box containing a separate set of rules for smaller, locally oriented, and less risky institutions (Dombret, 2017).

Apparently, national supervisory authorities are typically aware of the specific characteristics of their country's banking system and therefore consider the interests of their own domestic banks. As presented in Sect. 3, the largest banks are supervized by JSTs, while smaller, mainly regional banks, are overseen by the national supervisory authorities. As a result, the competent national supervisor might be incentivized to be laxer at some points taking into account the specific national characteristics to protect the own system. For example, Brown and Dinç (2011) find that regulatory forbearance is more likely in weaker banking systems. Hence, prudential supervision might be affected by local political and economic considerations. A laxer oversight of domestic banks finally results in a biased competitive environment among large and small institutions in a specific country.

As a conclusion, it is particularly difficult to establish an adequate Single Rulebook to address all specific national conditions of the EU member states. The consequence is that small, locally oriented and less risky banks are currently regulated too strictly at EU level, but might be less stringently monitored by national supervisors. This unequal treatment finally leads to a biased competitive environment within a country. However, going back to a pure national supervision is not suitable when establishing a European Banking Union, whereas a Small Banking Box could be a step in the right direction. Resulting from this key challenge, the intended European level playing field might be affected, too. We discuss this in further detail in the following.

4.3 Limitations of the European Level Playing Field

Directly linked to the challenges regarding national banking competition, we observe further problems with respect to distortions of competition at a European level. One major objective of the European Banking Union is to create a level playing field (European Parliament, 2009, p. 1). This might be harmed due to the specific structure of banking supervision in Europe.

As stated above, a "one size fits all" mentality is problematic because banking systems substantially differ across countries. In Germany, the three pillar system is relatively less concentrated compared to other systems (European Central Bank (ECB), 2016). The large number of small banks requires a different regulatory treatment. Hence, prudential supervision needs discretion at the national level. However, several studies find that national differences in supervisory practices significantly affect banks' balance sheets and risks (González, 2005). As one of many examples, overseeing and verifying the implementation of internal risk models, which are recently strongly criticized, is a national task for all less significant institutions. Mariathasan and Merrouche (2014) find significant variations of internally estimated risk-weights across jurisdictions depending on the stringency of national supervisors. Hence, banks in less strict supervisory regimes can engage in regulatory capital arbitrage more easily by using the leeway provided by internal risk models to minimize their own funds requirements. Thus, the level playing field might be affected by different regulatory treatments across EU member states.

In conclusion, not only the national competitive environment, but the level playing field at the European level is harmed by the current supervisory structure. A uniform supervision at the European level without any national discretion would be a structural approach alleviating both conflicts at the national level as well as at the European level. Such a solution might increase overall welfare, however discriminating specific bank types at the same time since banking systems are not fully homogeneous. Thus, there may be no overarching structural solution at all.

Instead, it might be reasonable to "correct" incentives for bank owners and management. The recent financial crisis required several bank bail-outs underlining the need for banking regulation and leading to the assumption of implicit state guarantees most of all for large, systemically important banks (so-called too-big-to-fail-phenomenon) (Kaufman, 2014). It seems to be necessary to make it credible that equity as well as debt investors will participate in the loss in case of bankruptcy. The recent Minimum Requirement for Own Funds and Eligible Liabilities (MREL) aims to provide an alternative by establishing a bail-in procedure where holders of non-subordinated debt instruments are exposed to bank losses, too. This procedure purposes a resolution of all banks, including systemically important banks, without endangering the overall financial soundness or the need to finance bail-outs by taxes (Deutsche Bundesbank, 2016, pp. 63). Such a resolution does not systematically discriminate a specific bank type and simultaneously re-establishes effective market discipline (Mikosek, 2016). Therefore, a credible bail-in tool might mitigate agency problems and conflicts of interest.

5 Conclusion

This paper examines the structure of banking regulation and supervision, focusing on the European banking market. In particular, we present the objectives and current structure at three levels, namely at the international level, at the European level and at the national level. Due to the integration of the European banking market, European supervisory tasks and national authorities are strongly interconnected. As a result, certain conflicts of interests and agency problems arise from the specific structure of the European Banking Union. This paper discusses three key challenges in more detail.

First of all, new conflicts of interests arise from a missing separation between the monetary policy function and the supervisory function of the ECB. In this double role, the ECB might adjust interest rates according to supervisory objectives and may violate price stability. However, changing the structure of European banking supervision by withdrawing the ECB's supervisory task might not be reasonable either. Instead, a clear separation of tasks between supervisory and monetary policy divisions is necessary. Secondly, the Single Rulebook might systematically disadvantage smaller, only locally active and less risky banks by imposing too strict requirements on such banks. However, taking this into account, national supervisors might be less strict in overseeing domestic banks, leading to a biased competitive environment between large and small banks. Establishing a Small Banking Box as recently suggested by German supervisory authorities could therefore be useful. Directly connected to this issue, thirdly, is the main objective of the European Banking Union, namely to establish a European level playing field, which might be affected by diverging national supervisory practices. The characteristics of each banking system can differ significantly among EU member states justifying certain discretions for national authorities. However, several studies find that differences in supervisory stringency across countries affect banks' balance sheets and risks. Primarily, when banking markets are weak, regulatory forbearance seems to be higher. However, an overarching structural solution might not be possible either. It is rather necessary to adjust incentives such that investors participate in losses in case of bankruptcy. The recently introduced bank recovery and resolution regime might be a step in the right direction.

It remains to be seen whether agency problems in the banking market are reduced through the new bank recovery and resolution regime introduced in Europe in 2015. Future research is necessary to analyze whether this bail-in procedure is credible and therefore changes the behaviour of bank owners and management. A credible bail-in procedure should enhance the incentives for debt holders to monitor banks. Working as a complement to state regulation, an effective market discipline could mitigate some of the key problems arising from conflicts of interest and agency problems in the European banking market, too.

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The Attention Pattern Emerging from Information Technology: A Structural Perspective

Isabel Ramos

1 Introduction

The pattern of organizational attention is set by the strategy continuously disseminated through the communication channels of the organization (Ocasio & Joseph, 2017; Pettigrew, 1977). The strategic plans aim at realizing a vision of the organization's future. Then the organization's design must be clearly linked to the defined strategy to ensure that the strategic objectives are met. The architectural dispositions in the design define what the organization pays attention to, how the organization interacts with the environment, and how the attention, decision and action are distributed in the organization. The application of the best practices of strategic planning and organizational design results in the engagement of collective attention to a set of issues and alternatives of action; this engagement will contribute to maximize the success of the organization and minimize the cognitive effort of the collective of its members. This is achieved by establishing the routines that govern work, equipping individuals to carry out their activities effectively and coordinate their efforts with other organizational actors.

The organizational structure and communication channels provide the basis for the distribution of attention in the organization but do not account for the quality of the resulting attention. The quality of attention depends on (i) the correct identification of information that is relevant to implement the organization's mission, (ii) the sustaining of the collective attention for the time needed to interpret all relevant information, (iii) the degree of alertness to unexpected events, and (iv) the integration of the various insights produced at the various levels of the organizational structure. IT artefacts extend the collective attention to events and information by automatically gathering, processing and delivering information at different levels of complexity.

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In the remainder of this paper I discuss the problems of alignment between the overall strategy, processes and technology, based on the theory that explains collective attention in organizations. I end by presenting the research venues that are opened to the IS field when studying IT adoption and use in the context of organizational attention.

2 Routinized Engagement of Collective Attention: Enacting Stability

The definition of business processes is intended to formalizing and sequencing the tasks required to deliver a product or a service to an internal or external client. The execution of the tasks is in charge of people, machinery and tools, which operate according to specific techniques and methods and use resources. The processes are managed in order to ensure efficiency, effectiveness and adaptability to internal and external changes.

Organizational processes are specialized attention centres. Organizational actors focus their attention on events and information that they consider relevant for the execution and management of tasks. The used IT artefacts have embedded the ability to detect, collect and process information that contributes to the execution of those tasks. For example, in the process "order management", the attention of actors, human and automatic, is engaged in the management of incoming orders and the tasks involved in responding to those orders.

The formalization of processes stabilizes the attention of actors, protects them from the distraction caused by stimuli considered irrelevant to the execution of their daily tasks, supports continuous improvement efforts and facilitates the integration of new actors. The coordination of the various organizational processes ensures that attention efforts in the various processes are complementary and, together, realize the business vision embodied in the organizational strategy.

The organizational information systems help objectify and institutionalize routines and procedures, therefore further promoting the stabilization of human attention around a well-defined set of issues and action alternatives. A large part of the IT capability management effort is focused on its continuous alignment with the organizational strategy, understood here as the pattern of organizational attention.

It might be thought that a deeply stabilized attention would bring immediate efficiency and effectiveness in meeting the challenges posed by the organization's environment. This is not, however, the case. On the one hand, the stability of organizational attention promotes a deeper understanding about the aspects relevant to achieve the goals of the organization, on the other it induces an unwillingness to do more or different from what is pre-defined in the working procedures, which can lead to an excessive and rigid performance. IT artefacts can aggravate this collective inability to pay attention to (i) unexpected results, (ii) challenges for which the organization did not develop appropriate responses, (iii) local perspectives not aligned with the organizational strategy (Table 1).

Table 1 The style name for this kind of paragraph is "Figure title"

	High level	Low level
Stability of organizational attention	Deep and undistracted attention to issues and relevant responses	Superficial attention to issues
	Disciplined scanning of issues over time	Poor time management; Difficulty prioritizing tasks
	Accurate analysis of situations	Difficulty understanding situations
	NEGATIVE EFFECT: Unwillingness to do more or different from what is pre-defined in the working procedures: excessive and rigid performance	

It being understood that an unstable collective attention poses serious difficulties to communication and decision, the stability of collective attention must be balanced by the monitoring of the periphery of the focus of attention, and beyond, into the areas of collective ignorance.

3 Mindful Engagement of Attention: Adding Vividness and Coherence

Vividness of attention implies a rich and relatively broad understanding of situations. An organization displaying a vivid collective attention is able to analyse various aspects at the same time and inter-relate them in order to generate complex interpretations of situations, even when contradictions are found in the available information. Vivid engagement with the organization's environment is important for its adaptability and resilience. It empowers organizations to create their future without falling prey to the habit or third-party perspective steeped in "best practices" of the sector.

The defined organizational strategy usually integrates some concerns regarding the enactment of attention vividness; moreover, some of the processes implemented by the organizations aim to ensure it. Concerns about innovation, procurement, competitive intelligence, development of organizational competencies and risk management are clear indicators of an effort to maintain collective attention vivid.

The vividness of attention is also attained by integrating local experiences in order to form comprehensive understandings of problems and opportunities. For example, this is evident when the sales, production and human resources experience are linked to define and manage the organization's innovation initiatives.

The formalization of processes to assure a certain level of vividness of attention ends up forcing its stabilization in the pattern of monitoring and aggregating/analysing information induced by the designed routines and supporting technology. The ongoing tension between the approaches implemented to ensure greater

Table 2 Effects of attention vividness and coherence on its extremes. At levels too high vividness and coherence become harmful

	High level	Low level
Vividness of organizational attention	Enhanced ability to detect problems and opportunities in the periphery of the main focus of attention	Inability to detect unexpected information
	Freedom from existing schemes and conceptual labels	Tendency to develop simplistic understandings;
	High capacity to create complex understandings and a clear insight into the situations	Difficulty in generating new answers
	NEGATIVE EFFECT: Vulnerability to distraction. Too complex understandings that preclude effective action	
Coherence of organizational attention	Good balance between top-down enacted attention (strategy/planning) and bottom-up enacted attention (local experience)	Inability to define a common set of problems and responses
	Collective and distributed capacity to maintain the balance between external and internal focuses	Duplication of time and effort in analyzing (potentially not relevant) aspects
	Increased ability to maintain motivation and cooperation	Conflicting/uncoordinated perspectives leading to widespread demotivation
	NEGATIVE EFFECT: Difficulty in nurturing diversity of perspectives	

stability of attention and the ones promoting vivid attention is an inevitable characteristic of organizational design. This tension, and the consequences of giving priority to stability or vividness, have not received attention of research in the IS field.

As in the case of stability, too high attention vividness can have harmful effects. A too vivid attention can hold organizational actors hostage of non-actionable insights due to their high complexity and detail. This may reduce the organization's ability to define an effective course of action; it can also make organizational actors vulnerable to distraction.

In addition to the vividness and stability of attention, the organization needs to ensure that the various organizational units, functions and processes display similar, complementary and compatible attention to allow for consistent responses to challenges and opportunities. The coherence of organizational attention is achieved by a good balance between top-down enacted attention (strategy/planning) and bottom-up enacted attention (locally defined strategies). Too much coherence, however, leads to difficulty in nurturing diversity of perspectives. A certain degree of conflict between local perspectives, together with the effective negotiation of local agendas, is important to maintain the coherence and vividness of attention within adequate levels (Table 2).

Research is needed to determine what can be considered as an adequate level for each of the dimensions of organizational attention. The impact of the IT artefacts on each of the attentional dimensions, and their relationship, is also not known.

4 The Focused Organization: Challenges and Promises for the IS Research

A focused organization is able to mobilize the collective attention to where it needs to go at the right time. It is able to locate trends and emerging challenges as well as to take advantage of opportunities. The organizational attention is the basis of the collective ability to shape the future and act in a coordinated manner to make it happen.

The organizational attention, like the human attention, has a limited capacity so it is necessary to select what to focus on and what to ignore. The organization's strategy integrates a top-down choice over what should be focused. The strategy, the organizational design and the organizational structure guide and integrate local foci at units, functions and processes. A change of strategy implies a change in orientation of the collective focus, and therefore of the various local foci; it has to be accompanied by a reassessment of the organizational design and structure as they are responsible for the stabilization of attention on issues and action alternatives.

The daily routine in the organization provides numerous opportunities for informal learning, identification of new problems and creation of innovative solutions. This local learning creates small local misalignments with the strategic plans. These misalignments are needed to maintain the vividness of the organizational attention, fed by the collective creativity and the experience of organizational actors. When organizational communication channels allow for the negotiation of emerging local perspectives, the misalignments considered most important for the success of the organization are detected and integrated into the organization's design. When such negotiation is not possible, conflict and widespread demotivation may impair decision-making.

The use of IT in organizations has been studied primarily as a factor in stabilizing the collective attention. IS research has focused on the understanding and management of technology acceptance (Stein et al., 2016), identifying the factors that facilitate that acceptance to maximize the success of the adopted technology. The process of technology transfer, the governance of IT and the alignment of the IT infrastructure with the organization's strategy are also popular topics of the IS research (Bernroider, Pilkington, & Córdoba, 2015; Dwivedi et al., 2015).

The impact of IT artefacts on organizational attention has not been studied in a structured way. Researching this impact emerges ever more important due to the growing interest on technologies such as robots and drones, Internet of Things, data analytics, blockchain, social media and other, and on their integration using concepts such as the digitization of the economy, smart cities and cybersecurity.

These technologies and concepts carry with them the production and consumption of huge amounts of structured and unstructured information and, thus, a high potential for cognitive overload.

Well-known cases of political manipulation, security breach of private information and inability to survive crises of various natures call attention to the problem of inadequate organizational attention to warning signals from the environment. The large volumes of information that organizations are exposed to require an increasingly sophisticated effort of selection, evaluation and disposal of information. An impoverished and fragmented attention makes individuals and organizations vulnerable to informational noise, thus rendering them unable to make sense of events and undermining their self-determination capacity. In an increasingly interdependent and connected world, attention to attention is urgent and the IS field can make a very important contribution to undertand the role of IT artefacts in expanding or fragmenting collective attention.

5 Studying the Impact of IT on the Organizational Attention

In this section I present some of the topics that I consider relevant to research the impact of IT artefacts on organizational attention. It is not my intention to be exhaustive about the many research opportunities that are offered to the IS research. This is just one contribution aiming at inspiring the exploration of this fascinating dimension of the use of IT in organizations.

A first research topic is related with clarifying the impact of technology on the stability of collective attention. How are the IT artefacts engaging the attention in organizations? Which are the issues and action alternatives being focused and ignored because of the adopted technology? How this funnelling of attention is impacting organizational success?

Another important aspect to study is the support provided by these artefacts to the concentration effort required to understand the situations. In particular, it is relevant to know how the artefacts help distributing the collective effort of attention, how automatic analysis of information is shaping the interpretation of situations, and how IT artefacts help selecting the relevant information from the over-abundance of information that the organization is exposed to.

Concerning the impact of IT artefacts in the vividness of the attention, it is important to clarify to what extent they amplify the human attention in organizations, both at the individual and the group levels. How do artefacts interconnect information pieces to produce visualizations and sophisticated automatic analyses to support the organization's decision-making? How are artefacts helping to detect contradictory or false information? How are artefacts used to detect non-salient issues?

The various functions and processes are pockets of attention on specific issues and action alternatives. In order to display a consistent behaviour, organizations need to

Table 3 Researching the impact of IT artefacts on the organizational attention

Quality of org. attention	IS research topics
Stability	Role of IT artefacts on the engagement of collective attention; Distribution of the attention effort in organizations supported by IT; IT support to the development of deep understandings of situations
Vividness	Role of IT in interconnecting human experience; IT support to multi-disciplinary interpretation of challenges and opportunities; IT role in detecting contradictory or false information
Coherence	IT role in forming a big picture of what is happening internally and externally to the organization; IT support to the communication and negotiation of emerging local perspectives/strategies
Mindfulness	Impact of IT on the overall quality of collective attention; IT role in enacting organizational reliability

connect these pockets of attention to form a big picture of what is happening internally and externally. Therefore, it is important to study how IT artefacts interconnect the human experience and support multi-disciplinary interpretation of the challenges and opportunities facing the organization.

According to Rerup (2009), vividness, stability and coherence of attention in organizations must be triangulated to maintain a balance between them. Triangulation of attentional dimensions is thus a mindful like state. Organizational mindfulness describes a collective alertness to unexpected events, supporting a high degree of organizational reliability (Gärtner, 2013). Dernbecher and Beck (2017) offer a general perspective on research in information systems addressing the concept of mindfulness. I will add the need to study whether the knowledge embedded in IT artefacts reveal (support the construction of) the reality of the organization; it is also important to study how IT artefacts are involved in the spreading of misinformation or the manipulation of collective perception. Table 3 summarizes the research topics.

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Hybrid Project Management in Digitalization Projects at the University of Applied Sciences Münster

Tobias Rieke

Dear Jörg, I wish you all the best for your 60th birthday.

1 Preamble

Structuring is one main ability of people who are professionals in information systems (IS). IS tasks often deal with complex business scenarios combined with information needs and software systems. The abilities of identifying and sorting the elements, constructing descriptive information models and deriving necessary actions have their origin in structuring operations. Today, these scenarios have become more complex due to new technologies and increased connections between the system's components. Reference models (e.g. Becker & Schütte, 2004, 77ff.) and standards like the Business Process Model and Notation (BPMN) (https://www.omg.org/bpmn/) were designed to structure their distinct topic and to provide an easier access to the inherent complexity. Project management also tries to deal with complexity, risks and change while pursuing a certain goal. Multiple institutions have published reference models or standards in this topic (like the PMI, AXELOS and IPMA). The penetration of reference model usages in university administration projects is increasing as well as the introduction of project management offices (PMO) in universities (Wehnes, 2014).

Remembering my good time at the chair of information systems of Prof. Becker, who has been also prorector for "Strategic Planning and Quality Assurance" (10/2008–09/2016), I would like to present an approach used in a software introduction project of an enterprise content management system at the University of Applied Sciences Münster (UAS Münster). This approach addresses the demands of a concrete planning and the necessary flexibility on the user's needs.

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2 Agile and Classic Project Management in Universities

2.1 Project Management in University Administration

Universities like enterprises are strongly influenced by projects. Two types of projects can be differentiated in universities: On the one hand research projects are performed within the faculties in cooperation with a set of external partners. On the other hand, there are many projects in the administration dealing with optimizing the IT-Systems, organizational structures and processes. In addition, various kinds of projects in the university administration can be differentiated: e.g. construction projects, reorganization projects and digitalization projects. These kinds do usually have a different basic structure. Construction projects in Germany are usually oriented at work phases of the HOAI (German Fee Structure for Architects and Engineers (HOAI: Honorarordnung für Architekten und Ingenieure, 2013). Reorganization projects usually describes the As-is and develop the To-be (Becker, Kugeler, & Rosemann, 2012). Project management in IT-projects has developed within the last 30 years. In the 80th projects are oriented at the waterfall model (or V-model). With the agile manifest (Beck et al., 2001) the development process evolved and became more iterative and user-oriented. Digitalization projects does not focus only on the IT-side, organizational aspects are always a part—often even a major part of it. Due to planned fixed budgets and controlling reasons project were structures in classic manner with stages and milestones.

The organization culture at the UAS Münster is very consent-oriented. Changes will be discussed with the users and affected employees in a constructive and trustful manner. In this way solutions are designed that have a positive sustainable effect.

Classic project management methods have mainly a hierarchical structure. Decisions are made by the project manager or the project board. Stakeholder management, which deals with the different opinions and attitudes towards the project's goals, categorizes the stakeholder in terms of interest (positive/negative) and influence (high/low). This also shows that this is driven more by a risk/cautiousness-oriented view than a positive and trustful cooperation.

2.2 Project Management Standards in Universities

The use of reference models and standards for project management are still spreading in universities. One option is to use a popular reference model (like PRINCE2, IPMA and PMI). The adaptation of these reference models is sometimes difficult, due to a mainly enterprise orientation in these standards. (e.g. Business plan as in PRINCE2, which is does not fit well in the university context).

Maybe for this reason some universities started to define their own standards for project management (Der Präsident der Leibnitz-Universität Hannover, 2009; Peters). Some even has implemented a systematic approach by implementing a project management office (PMO) and concentrating certain supporting and controlling tasks in this organization unit. Considering a high number of projects in big organization portfolio management is also an issue for universities and discussed in the literature (Bünten et al., 2016).

Other universities like the UAS Münster are using one of the mentioned reference models and adapt them. But even with an adapted or university-specific standard, acting consequent is another challenge.

2.3 Flexibility and Involvement Versus Rigid Environment

Project outcomes should be fully accepted by their users. This can be supported by involving the users during the project, so they are part of the designing and developing process.

But it can also be expected, that these users are not very experienced in designing new processes and digitalized solutions. Within the ECMS introduction process it could be observed that workshop participants redesign already agreed intermediate results several times. The development of the projects outcomes can be regarded as a maturity process. Thus, the project management process must be aligned in a way, that changes and new findings can be easily integrated. Agile project management puts the user in the center and can easily handle changes.

At the same time expectation of classic project management method in terms of planning, quality, budget and formality are expected. These stand in contrast to an agile approach.

A possible solution can be found by combining classic and agile aspects in hybrid project management.

3 An Approach for Hybrid Project Management in University Management Projects

The UAS Münster started in 2017 implementing an enterprise content management system (ECMS). With the introduction of the ECMS the UAS Münster pursues the following goals:

- increasing the efficiency and quality in the focused application areas,
- accelerate the processes,
- simplifying the processes,
- creating free space in daily work for other tasks,
- strengthen the cooperation between the single organization units,
- creating a location-independent possibility of working on the processes,
- increasing the satisfaction of all process participants,
- optimizing the document storage und decreasing redundancies,

- ensure information security, and
- standardize file and folder structure, processes and solutions.

This list contains possible goals, not all goals have to be achieved in every application area.

At the beginning of the project the question arouses how the project organization can be set, how subprojects (focusing on one applications area) can be prioritized and how the development process can be standardized. With the introduction of the new campus management system, started in 2015, the project management standard PRINCE2 has been set as default for project management at the UAS Münster. Thus, this refence model have been tailored for the ECMS introduction.

3.1 PRINCE2 Reference Model

PRINCE2 is an acronym for "PRojects IN Controlled Environments" (Axelos, 2017 and in the following). PRINCE2 defines seven processes, seven principles, seven themes and 26 management products. Projects deliverables are called products. PRINCE2 differs management products (e.g. as a result of project management activities) and specialist products (project goal-oriented interims and end deliverables).

PRINCE2 defines a project board, consisting of three roles with different perspectives on the project: the executive, the senior user and the senior supplier. The seven processes correspond to seven different types of stages performed in every project. These are:

- **Starting Up a Project (SU)**: This is not regarded as a stage, rather as a set of preparing activities, like the project mandate (explains the purpose of the project and other basic settings). It also defines the project team.
- **Initiating a Project (IP)**: This is the first real stage where the project is planned in detail, like the time, cost, quality, risks and benefits and structure.
- **Directing a Project (DP)**: This process is performed by the project board. It assesses the performed stages, initiate the next stage and accepts or decline the project result and closure. This is an ongoing task, closing at the end of the project.
- **Controlling a stage (CS)**: The project manager authorizes work packages and controls the progress of the product development that should be delivered within this stage. It contains activities for communication with and coordination of the team.
- **Managing Product Delivery (MP)**: This stage describes the communication of the project manager with his team. Therefore, the project manager or a team manger accepts and executes work packages. The project deliverables are developed within this stage.
- **Managing Stage Boundaries (SB)**: This stage describes the transition from one stage to the next one (Fig. 1).

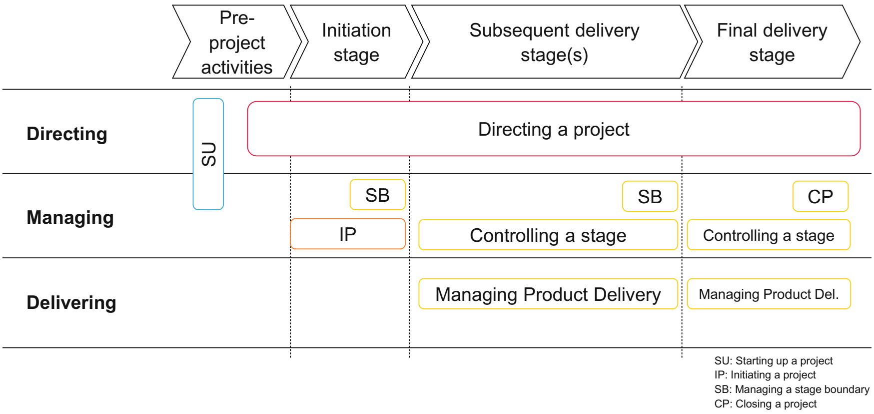

Fig. 1 Project management stages in PRINCE2 (derived from Axelos, 2017)

3.2 Tailoring PRINCE2 for an ECMS Introduction in the University Context

Reference models cannot be used directly, the must be adapted to the user's specific context. PRINCE2 calls this step *tailoring* and means the adaption for a specific project.

The three roles in the project board have been filled with five persons. The chancellor has taken the role as executive. The role of senior customer has been filled with twice, with an administration member and a faculty member. The role of senior supplier has been also filled twice, with the superior of the project manager and with an executive of the external supporting consulting company. Additionally, a user committee has been established, mainly consisting of representatives from administration units and faculty members. It also includes the staff representatives and the data protection officer. Within the user committee ideas e.g. for new subprojects were prioritized and recommended to the project board, which accepts or declines this suggestion.

The ECMS introduction process consists of many application areas. Each application area has their own requirements. They can therefore be regarded as single subprojects within the whole introduction process. The goal of the whole ECMS introduction project is to develop necessary processes and setting up an environment for continues introduction to further application areas. This aims at switching the task of new area-specific ECMS-introductions to a responsible business unit. Within the introduction project solutions for the first application areas should be developed and launched. Every subproject is focusing on one application area and should also be compliant to the PRINCE2 method. Therefore, the seven PRINCE2 processes were also adapted. This is depicted in the following Fig. 2.

In the following the main processes are described.

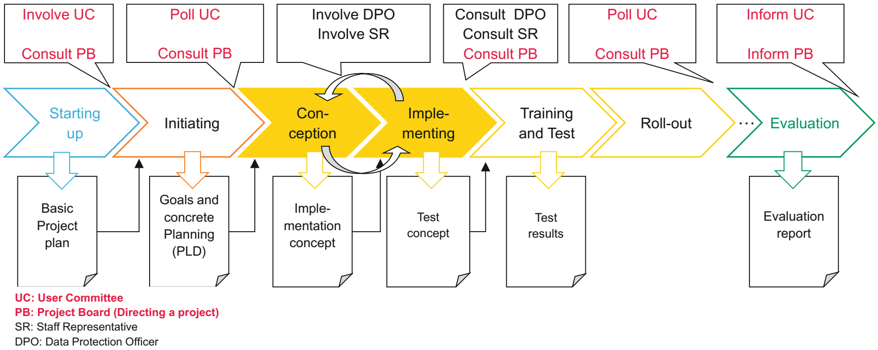

Fig. 2 Project stages in the ECMS introduction process (for one application area)

3.3 Starting Up and Initiating

This pre-stage is used to describe the subproject in brief. Since there are various aspects to describe, we decided to use a project canvas. A project canvas is one great tableau, which comprises all necessary aspects to describe the subproject and thereby structure the start of the subproject. Habermann and Schmidt (2018) developed this instrument especially for this reason, to ease the beginning of a project (Fig. 3).

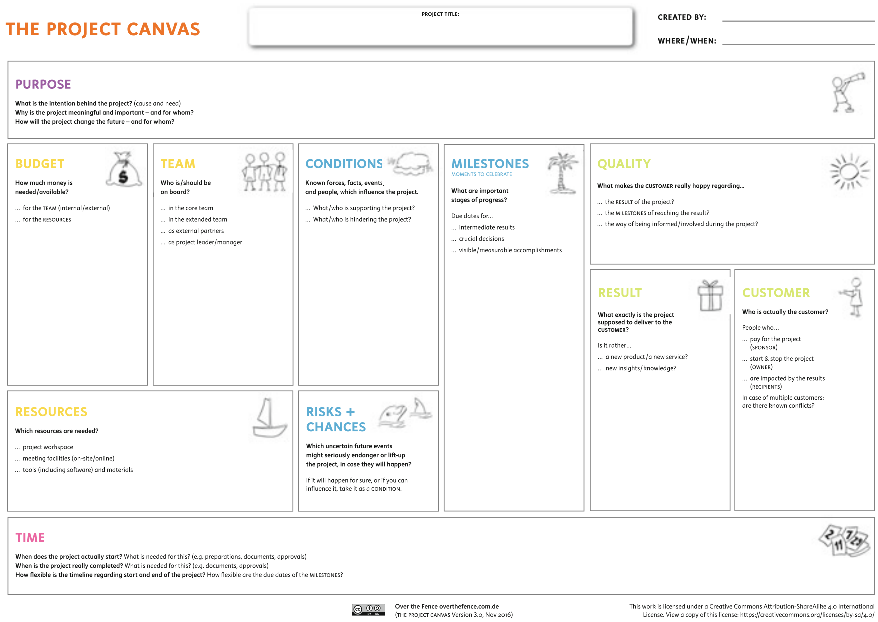

Fig. 3 Project canvas (Habermann & Schmidt, 2018)

Within the subproject we usually start with a workshop with representatives from all concerned organizational units. Then each canvas field will be discussed. The result will be depicted on sticky notes and placed on the corresponding field. Usually, a two-hour time frame is sufficient to develop one canvas. This pragmatic approach helps to describe the whole subproject on one page. The result is transformed to a PowerPoint-slide for the next board or user committee meeting. With this input the project board is able to set free the initiating stage.

Within the initiating stage, the subproject will be described in more detail. In some cases, a separate workshop for defining the subproject outcome is necessary. This step becomes important, if the representatives of the organizational units have no clear and identical picture from the target system, which should be planned and implemented within the subproject.

A project plan, a risk register, a project diary and some other documents will be managed at the project level (not subproject level).

3.4 Agile Delivering and Controlling

After setting the goal for the subproject the upcoming stages will be performed iteratively. It consists of the step defining the requirements, prototyping and evaluating. These steps follow an agile mindset according to the agile values (Beck et al., 2001):

- Individuals and interactions over processes and tools
- Working software over comprehensive documentation
- Customer collaboration over contract negotiation
- Responding to change over following a plan

During the conception step requirements will be defined with the user group. Then these concepts and requirements will be implemented in the ECMS. The result will be presented back to the user group. Afterwards changes and extensions can be performed in the next iteration.

Especially in early phases of implementation it also supports the developers, who are not very experienced in ECMS customization. Different options how to implement the requirements can be evaluated.

Within these iterations the staff representatives will be informed for evaluating the consequences for the users. If a suitable system has been developed the data protection officer will also be informed to give a first statement about the compliance with the General Data Protection Regulation.

The formal stage transition between conception and implementing will be omitted within these two phases.

3.5 Managing Stage Boundaries

Stage boundaries become a more important part after presenting the final prototype. The next steps must be concretized. The prototype is presented within the customer committee and the project board. Maybe some last changes will be identified.

3.6 Stage: Closing Up a (Sub)Project

This is the last stage. Within this stage lessons learned are saved and communicated. Within this subproject an evaluation is planned which will performed by an independent team. The results of this evaluation are very valuable for adapting the introduction process. After analyzing these evaluation results and deriving some additional learnings the subproject is closed.

4 Conclusion

The challenge for those ECMS projects lies in the different expectations on the project management process in terms of classic characteristics and an agile outcome designing process. Thus, the project management process has integrated agile stages, that are iterated until the outcomes meet the expectations in behavior and functionality. Due to the agile development process, the users are fully integrated and are designing their future working environment. A high acceptance for the results can be expected. But to fulfil the external expectation in time, ideas and new requirements must be documented in an application area specific product backlog. Every single feature must be assessed and assigned if this feature is required in the first release or if it can be considered in a future release. This responsibility lies within the project manager to balance the user satisfaction and time and cost goals.

Tailoring the PRINCE2 reference model is a question of rigor versus relevance: Keeping the intended process requirements vs. gaining additional benefits like increasing user experience and acceptance by switching to an agile approach. In terms of structuring the project management process it is a decision of how much variance should be allowed. Thereby the project manager must be able

- to structure the requirements to the reference model adaptation,
- to structure the requirements to the project outcome and
- to structure the project management issues to meet the project expectations.

Hence, it is about "Strukturieren, Strukturieren, Strukturieren".

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Structuring in the Digital Age

Michael Rosemann

1 The Implications of the Digital Age

Technology and conceptual modeling always had a close relationship. Initially, conceptual modelling helped to comprehend and develop technology solutions. For example, the ability to design an Entity-Relationship-Model (Chen, 1976) was an important step towards the development of a database management system or a Petri Net (Petri, 1966) allowed understanding the processes, i.e. states and activities of a well-defined system. Unsurprisingly, these early modelling grammars were often called mathematical modelling languages, had an initial home in fields such as Computer Science, Automatic Control or Operations Research before moving into domains such as software development or information systems design. They set new modelling paradigms and led to a comprehensive space of formalisms (Chen, 2002; Silva, 2012).

In a subsequent stage, technology was seen as an enabler of new solutions for problems that used to be the focus of Industrial Engineering (Davenport & Short, 1990). For example, Business Process Reengineering (Champy & Hammer, 1993) and Lean Management (Womack, Jones, & Roos, 1991) both raised the appetite to design process models as a way to identify non-value adding activities and other forms of weaknesses. In this phase, technology helped to automate existing corporate activities and was one way to resolve problems caused by design flaws, manual labour and internal process complexities. In summary, automation empowered corporations to achieve new levels of previously unseen operational efficiency, and it continuous to do so. After a wave of enterprise systems implementations that helped automating the activities within a process, workflow management systems, or process-aware information systems in more general, streamlined the transitions along a control flow.

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Nowadays, Robotic Workflow Automation aims to automate the human interactions along a process by replicating well-structured behavioural patterns.

While automation has empowered organizations, digital technologies are empowering people in their multiple roles as students, passengers, customers, citizens, etc. Facilitated and accelerated by consumer-oriented smart devices, the ubiquitisation of computing capabilities, growing digital literacy, a data-rich environment, long tail platform economics and low cost development to name just a few essential trends, citizens have taken control of many value chains or have created entire new customer-to-customer trading patterns as part of the rising sharing economy (Botsman & Rogers, 2010). No longer are people passive participants of business processes or records in a corporate CRM system. Rather they start to own their data, experience hyper-personalised processes (e.g., in healthcare) and receive integrated services across sectorial borders. The rise of digital capabilities, informed citizens undergoing attitudinal changes in their relationship with technology and the emergence of entire new options in form of innovative business models, have drastically increased the possible design space. No longer is the act of re-designing, i.e. converting as-is models into to-be models, the main focus of structuring.

Rather, the emergence of the digital phenomenon has brought with it an increased spectrum of how future realities could look. This is largely due to the fact that technologies at the interface of data, artificial intelligence, sensors, advanced manufacturing, limitless scalability and other digital technologies have provided a new set of design variables. Subsequently, in such an opportunity-rich environment the focus of the unit of analysis has shifted from studying as-is models in search of failure to the conscious design of feasible, desired and viable to-be models. Industry boundaries start to disappear in the speed in which the sectorial view of providers is replaced with the solution-driven demands of consumers.

The problem-centric focus of corporate modelling was largely grounded in a known design space (e.g., one could imagine that the majority of problems within a business process can be identified based on current process analysis methods). The design space of an opportunity-rich environment, however, remains unknown. Rather than focusing on conscious incompetence (dealing with identified issues) designers now face unconscious incompetence, i.e. they lack awareness for the majority of design options.

Thomas Friedman described this as follows in his book *'Thank you for being late'*, which is dedicated to how to cope with the accelerating pace of change (Fig. 1). In his view, we have entered the point where technology is now ahead of human adaptability. As a new type of competence, digital intelligence might be best placed to summarise the skills and capabilities needed to be aware of, comprehend and assess the potential of a fast growing set of digital affordances. As long as the human adaptability was ahead of technology, i.e. the area to the left in Fig. 1, modellers could articulate the desired conceptual solution and then select (search for) the most appropriate technologies. Beyond the intersection point, however, modellers simply lack the awareness for those technologies that provide relevant affordances.

Conceptual modelling in this environment is more an exploration of what is possible as opposed to what is broken. This explains the emergence of Design-led Busi-

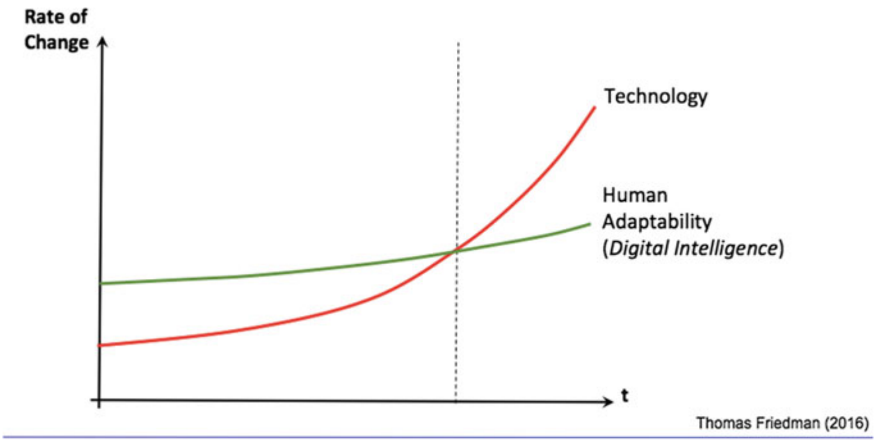

Fig. 1 Technology > Digital intelligence

ness Process Management or the ambidextrous design approach NESTT (Rosemann, 2017), in which a strong focus is put on the active support for modelling when design capabilites and not analysis skills are the key succes factor. Furthermore, the design rationale is often no longer the incremental improvement of artefacts, but the search for more disruptive ways to create new feasible, desired and viable solutions.

The impact of digital technologies, however, goes beyond the search for desired, feasible and viable solutions within an increasingly unknown context. No longer is it sufficient to take a customer-centric view on the firm. An additional societal view is needed. Failures across various industries (oil and gas, automotive, technology, finance, etc). have dissolved large parts of the societal trust in institutions (Botsman, 2017). Furthermore, new levels of responsibility (the absence of harm) and aspirations are required, i.e. value propositions that go beyond a profit/investor driven narrative.

This article unpacks these four stages with a focus on the new impact that the digital age has on the requirements of modelers across all four stages.

2 The Four Stages of Modelling Requirements

2.1 The Age of Engineering Excellence

The requirement to develop sound visualizations of relevant artefacts characterized by syntactical rigor and semantic quality for decision-making purposes motivated the birth of conceptual modelling. For example, the focus of ER-diagrams was to conceptualize database schema and to be able to translate these into database tables driven by the relational model. In a similar way, Petri Nets were developed to facilitate an exact graphical depiction of the behaviour of a system. In this context, conceptual modelling techniques have been designed to facilitate the early stage of requirements gathering as part of development activities. The primary motivation was to provide approaches to conceptual modelling guided by assessments such as process models free of livelocks and deadlocks or tables derived from ER-diagrams complying to the Codd's concepts of normalisation.

The latter points to an essential feature of engineering excellence; conceptual models need to convert into executable artefacts along defined staged models. The automated conversion of conceptual artefacts is still an area of research and professional interest. This includes converting textual descriptions of processes into conceptual models, the design of executable workflows or the reverse engineering of workflow models from event files (so called process mining). The latter will increasingly lead to machine-made models making the manual design of as-is models for high volume process models obsolete over time.

Engineering excellence captures all those modelling activities that are driven by improving intrinsic model qualities (e.g., syntactic quality) and modelling qualities (e.g., low cost-to-model). The related research is largely grounded in Computer Science and CASE tools have been the dominating support systems for modelling professionals striving for engineering excellence.

Besides the development of model attributes that contributed to the syntactical attributes of a model, a range of proposals has been made to design a set of model qualities, and related normative recommendations, in order to improve engineering excellence.

In our very own work to nurture engineering excellence, i.e. improving the quality of conceptual models, we developed a set of so-called *'Guidelines of Modelling'* (Becker, Rosemann, & Schütte, 1995) including recommendations for how to improve the correctness, relevance, economic efficiency, clarity, comparability and systemic design. All of this work has been dedicated to creating models that comply with intrinsic requirements (e.g., rules for their syntactical correctness or their compliance with an underlying meta model).

2.2 The Age of Corporate Excellence

The ongoing demand for organizations to improve operational performance required the ability to comprehend current systems and processes and to reflect across stakeholders on better ways to deliver products and services. Iconic for this stage has been the emergence of Business Process Re-engineering (Champy & Hammer, 1993). The related demand to discuss business requirements with stakeholders who are domain experts rather than technical experts required the development of more intuitive conceptual models than those that were given birth within the age of engineering excellence. While the intention to translate conceptual models into executable models was still of relevance, the ability to initiate conversations, shared reflections and joint explorations of how to improve a process became often more important than quality features postulated as engineering excellence. In particular, process modelling in this age was driven by the requirements of the *time-cost-quality* triangle, i.e. a stronger economic view needed to be considered when designing a process model.

No longer were the characteristics of the model (e.g., conformance with naming conventions), but those of the real-world artefact captured in these models the centre of the attention. As a result, a move towards process improvement and optimisation accelerated the design of conceptual models capturing various facets of time (e.g., in support of simulation), cost (e.g., in support of activity-based costing or simulation) or quality (e.g., in support of Lean Management, Six Sigma). This development largely initiated a focus on using conceptual models in search of flaws (e.g., non-value adding activities) in existing processes. This positioning of conceptual models also increased the relevance of models as they helped to improve the quality of various business decisions (Dietzsch, Kluge, & Rosemann, 2006).

In summary, the demands for corporate excellence led to the development of conceptual models that were formal enough, but also more intuitive (e.g., Event-driven Process Chains, PICTURE (Becker, Pfeiffer, & Räckers, 2007)) than those model types that supported engineering excellence. This created a class of model types that were closer to what had been used in the context of Industrial Engineering for a long time.

2.3 The Age of Customer Excellence

Though customers are, of course, fundamental to the existence and operation of a corporation, it took a surprisingly long time to make customers and their end-to-end experiences the focus of conceptual modelling. The primary concern und unit of analysis of enterprise modelling in stage two (corporate excellence) has been the one of the company with customers being regarded as the bookends of processes. In this worldview, customers are the entity that initiates a process (e.g., via an order) and receives the ultimate service or product. Along the interaction, customers might be involved which led to constructs such as ‘the voice-of-the-customer’ (aka moments of truth) in the context of quality management (e.g., Six Sigma).

The transition towards the third stage (customer excellence) is best described as moving the attention of conceptual modelling from the supply side to the demand side. The dominating approach to simply depict customer touch points has been increasingly enhanced or in some cases even being replaced with capturing actual or desired customer experiences. Evidence for this can be seen in the growing popularity of customer journey maps that capture customer experiences. Business processes tend to focus on the sequence of internal activities, i.e. activities that are often behind the line of visibility for the customer. Customer journey maps, on the other hand, abstract from company-internal procedures as they capture what is visible to customers. As a consequence, they model more of the activities occurring before the first touch-point with the corporation occurs (e.g., what motivated the customer demand in the first place?) and past the delivery of the product or service, i.e. the actual usage stage.

The shift from corporate to customer excellence did not only change *what* is modelled, but also *how* modelling occurs. The domain of business process modelling was largely characterised by modelling and domain experts sourced from the inside of the organization. With the focus being on operational efficiency, many of the artefacts that were subject of conceptual modelling were internal to the organization. This is very different to conceptual modelling in the age of customer excellence. The semantic quality of these models significantly correlates with the quality of the engagement with external stakeholders in the act of modelling. Similar to the impact Business Process Reengineering had on conceptual modelling in the age of corporate excellence (problem-centred, reactive, cost focused, analytical), Design Thinking (Brown, 2008) and Design-led Innovation can been seen as equally influential on conceptual modelling in the age of customer excellence. Rather than the act of re-designing an existing artefact, the focus is more on the design of a new artefact. This requires the proactive capitalisation on a richer design space with the result that the design of entire new customer experiences, and subsequent revenue, has become the focus of conceptual modelling. As a result, the dominating focus on analytical skills has been expanded by an increased demand for design skills. This is evidenced by organizations who are re-skilling their business analysts with design skills leading in many cases to actual role changes, i.e. business analysts in fact becoming business designers.

Design thinking and corresponding agile approaches have also changed the nature and the ambition related to the conceptual artefacts produced. Rather than aiming for artefacts that comply with certain criteria (e.g., degree of normalisation, soundness, cost efficiency, minimal processing time) and the search for 'optimised processes' in the age of engineering and corporate excellence, artefacts in the age of customer excellence are increasingly minimum viable artefacts. A *minimum viable process model*, for example, facilitates all the requirements of a process (e.g., it can be executed), but also recognises that it is in a continuous stage of flux. This is very different paradigm to the rather dichotomic as-is/to-be narrative. However, unlike minimum viable products, a corresponding, entrepreneurial view in the domain of business process modelling is still in its infancy.

The increased *customer centricity* correlated with the emergence of a more advanced understanding of cost and revenue models for which the simplified cost-minimization paradigm of the previous age was no longer sufficient. This lead to the emergence of *business models* as a way to reflect on available variables for the monetization of processes, products and services. However, while the notion of cost-aware process design is by now well understood, the revenue-sensitivities of process design are still poorly researched.

Finally, entire new technology solutions created previously unknown affordances as the democratization of IT allowed light asset models facilitating ubiquitous access and low cost products launched on platforms. Labelled digital technologies, this development provided a much more comprehensive design space and made previously unimagined services feasible. It is characterized by a fundamental difference to the previous age. While the corporate age was largely driven by capturing and resolving well structured shortcomings (so-called pain points), the digital stage is creating an over-supply of opportunities. However, this outside-in view on conceptual modelling (e.g., what new process designs are possible due to Blockchain?) is largely unexplored in current modelling approaches for two reasons. First, there is no consensus on the affordances of these digital technologies (e.g., what are the general affordances of location-sensitive services?). Second, even if these affordances are known (e.g., Blockchain provides trusted services), it is impossible to identify the artefacts (e.g., processes) that would benefit from such trusted service provision. This dilemma motivated the modelling of new meta data in the form of capabilities required, e.g. the requirements of a process to provide trusted services. The better and faster an organization can absorb digital technologies, the higher is its capability and as a consequence its pool of strategic options as well as the shorter is its *digital latency*, i.e. its time to react to new action possibilities.

As a consequence, the age of customer excellence can be best summarized in the feasibility-desirability-viability triangle (Brown, 2008), i.e.

- structuring what is *feasible* in a fast moving field of digital technologies
- structuring what business models are available and applicable in the relevant corporate context to ensure *viability*
- structuring what constitutes *desirability*

There are substantial modeling challenges related to these three attributes.

As opposed to technology that was reactively selected to address an identified issue (e.g., enterprise system, RPA), feasibility assessments require a comprehensive understanding of the design space. How to model the design space that is to the disposal of a process designer, however, is still unknown. A main reason is that there is no correlation between the modelling artefacts and external options. For example, one could imagine that for a well defined activity (e.g., payment in a B2C context) access to a design repository points to contemporary payment options (e.g., crypto, voice-enabled, location sensitive payments, etc.). This example shows that models in the age of customer excellence can no longer be designed by a domain and a modelling expert only, but also require (human or machine) expertise in terms of opportunities available.

In a similar way, the modelling of viability is far more complex than the design of cost-centred processes. As long as modelling had the purpose of facilitating cost efficiency, the data required could be largely derived from the models themselves (e.g. as part of activity-based costing based on activities, resource consumption per cost driver, etc.). Viability, however, goes beyond the cost dimension and in particular covers the revenue dimension. How to model revenue-sensitive processes is still poorly understood as the correlation between process design and revenue implications is often not captured. One could image that conjoint analyses which are used to capture how customer value attributes of a product or a service are also extended to the space of processes and other system artefacts.

Finally, modelling desirability poses new design challenges. Previously, 'quality' has been a main proxy used to capture the attractiveness in the eyes of the consumer.

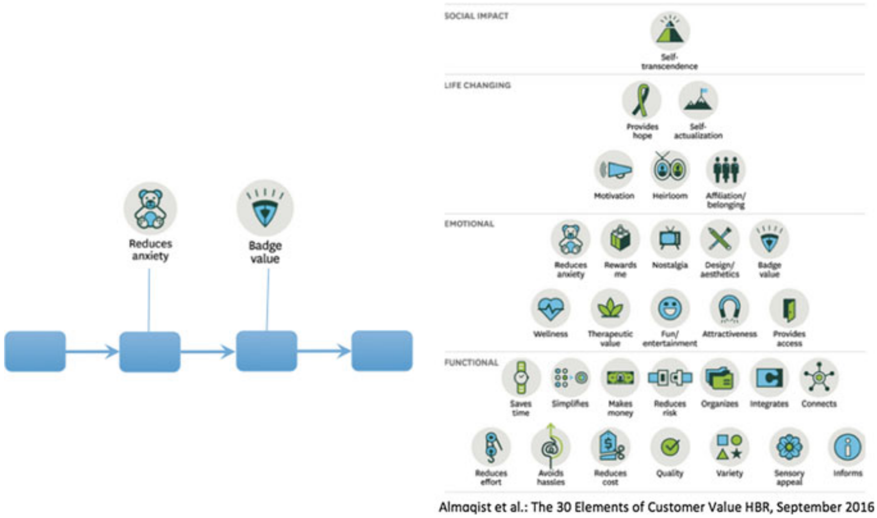

Fig. 2 Modelling elements of customer value in a business process

Desirability, however, is a much more nuanced construct. In our own experiences in the context of Design-led Business Process Management with a large Australian financial service provider, we borrowed a published set of sources of customer value to derive inspirations for what design choices in the context of process, service and product modelling could create customer value from a framework proposed by Almquist et al. (2016) see Fig. 2.

2.4 The Age of Societal Excellence

The ambidextrous organization improves its internal efficiency addressing classical time-cost-quality requirements (corporate excellence) and at the same time innovates by exploring new desired outcomes while considering new business models and digital affordances (customer excellence). In addition to these two substantial requirements, a new challenge has emerged which is related to the disappearance of institutional trust (Botsman, 2017).

No longer are companies reduced to the role of being providers of products and services in exchange for money, but they are increasingly judged by higher requirements. Customers expect that the company they purchase from also addresses societal requirements. These can be decomposed into the following three requirements (Rosemann & Kowalkiewicz, 2018).

- First, the systems and processes must be *trusted*, i.e. the customer expects an experience according to promise. For example, a technical system might be secure

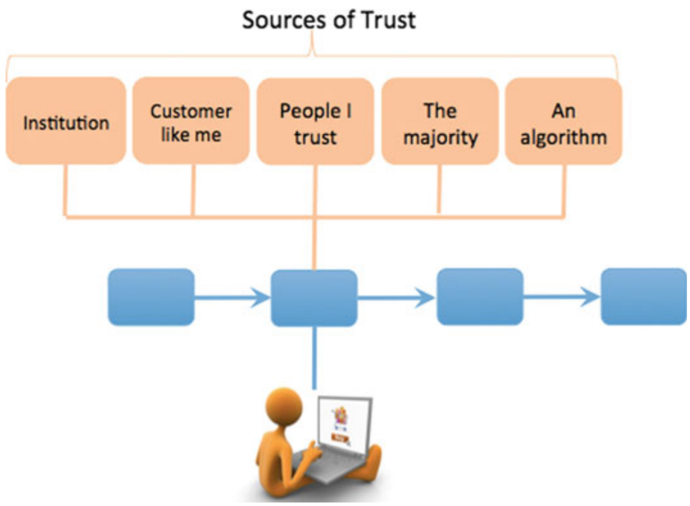

Fig. 3 Alternative sources of trust within a business process

or a car might have all the features to be autonomous, however, a customer still might not be willing to trust this capability. Previous notions such as feasibility have ensured that a system or process works or risk-aware processes were well understood in terms of their risk exposure and related mitigations. Trusted processes, require capturing the subjective, behavioral elements related to trust assessments. Unlike an assessment of risk (or security) levels, trust is a highly subjective construct and different stakeholders derive trust from different sources. This is visualized in Fig. 3 showing an abstract customer interaction with a business process. In order to proceed (e.g., with a purchase decision), a customer might trust the institution (e.g., the retailer's description of the quality characteristics of the item), similar customers (see patientslikeme.com), people known to her (e.g., how many of my friends rated the restaurant highly?), the majority of customers (see Amazon's book recommendations) or an algorithm (e.g., an AI-algorithm might be more trusted than a radiologist when assessing an X-ray). Which of these, or other sources of trust, should be deployed for which cohort of customers is an essential design challenge as the lack of trust (despite engineering and corporate excellence) will prevent customers from engaging with the organization.

- Second, and in addition to the ability to deliver, systems and processes need to be *responsible*. This requirement is best described by Google's 'Don't be evil'. For example, the expectation is that there is a *responsible* treatment of all data that is handled in increasingly data-intensive processes. Europe's General Data Protection Regulation (GDPR) is a good example for a regulation that aims to ensure the responsible use of data.
- Third and finally, organizations are expected to have a purpose that goes beyond stakeholder's expectations. Credible *aspirations* are desired, i.e. what is the cor-

poration's contribution to mankind beyond satisfying the interests of its investors and broader stakeholder community?

These societal requirements form entire new challenges for the conceptual modelling community. We are only at the infancy to understand what trust, responsibility and aspiration means, let along how to model these constructs in the context of conceptual models. For example, at this stage there is no accepted approach for how to model different types of trusted or responsible processes.

3 Conclusion

The emergence of digital technologies has led to an environment in which the design options and challenges are growing faster than our ability to structure these in the context of conceptual models. This so-called *model latency* materialises itself in the delayed availability of appropriate modelling techniques (e.g., to capture viability or trust), scarcity of relevant skills within conceptual modellers and ultimately in a delayed availability of conceptual models that could facilitate decision making in a world that has moved from the notion of 'optimised' to recognising a state of ongoing flow and early release (minimum viability).

This article proposed four stages to consolidate different classes of requirements. Though they emerged over time, the requirements across all four stages still all exists. Engineering excellence captures all the rather formal, model-intrinsic attributes and is nowadays of high relevance in the context of solutions that support round-trip-engineering. Further activity can be expected in the area of more intuitive ways of visualising conceptual models (e.g., augmented model environments) and the conversion of models into natural (or even spoken) language (voice-controlled modelling).

Corporate excellence has been the traditional (time-cost-quality) focus of process modelling for operational efficiency gains. Further improvements in this space will lead to a stronger merger of analytical approaches such as process mining being used for more cost-effective ways of conducting Six Sigma or activity-based costing assessments. Another area of further development will be to deepen our understanding in the design of *entrepreneurial processes* and complementary artefacts, i.e. fast changing models. Finally, predictive models will allow the use Artificial Intelligence to provide earlier insights into what types of processes might emerge in the future (Poll, Polyvyanyy, Rosemann, Röglinger, & Rupprecht, 2018).

Customer excellence has been defined as modelling with the purpose of achieving desirability, feasibility and viability. Its essential challenge is how to model in a fast growing, often unknown design space. Subscription systems might facilitate proactively finding possible design options based on correlating available technological affordances (e.g., Blockchain) with new meta data (e.g., high demand for trust).

Finally, societal requirements go beyond the immediate economic value proposition and demand the design of trusted, responsible and aspirational systems and processes. This is the space, where conceptual modelling is still in its infancy, but where also in light of recent events and the overall disappearance of institutional trust, the maybe most significant demand for the development of new modelling techniques exists.

The need to structure complex systems and processes with conceptual models will remain of high popularity and an ongoing base for decision-making. However, new criteria for what constitutes the quality of such models and what needs to be captured in these models is growing quickly. A significant model latency could be a threat to the perceived usefulness of conceptual modelling.

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Managing a Network

Reima Suomi

1 The Problem Setting

Jörg (just a made-up name) loves structures, but he runs a network of several universities. This network is dynamic, complex and performs critical functions in an unstructured way and at various uncoordinated times. Jörg would really like to see some structure in the network. How can Jörg manage this?

1.1 Defining Structure

The world rests on structures. Structures can be natural or man-made. Almost nothing in the world is permanent, but structures are meant to be and understood as long lasting, if not permanent. Nature itself is a master at making structures: Take the very small unit of the atom, and work your way up to larger plant, animal and human body structures and then on to ideas about the structure of the universe—all of these things point to the diversity and beauty of natural structures. Of course, we must understand that our conceptions of these structures are man-made representations; the real structures might be something totally different than we understand, no matter how much we believe in science.

Human-made structures are everywhere. They might be physical such as houses, machines or infrastructure, or conceptual, such as the whole of mathematics (Shapiro, 1997) or any language (Gernsbacher, 2013).

In information and computer sciences, we are very good at inventing and building structures. In this field, the concept most often related to structure is infrastructure (Hanseth & Lyytinen, 2016). For a long time, computers have had a well-defined

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structure (Watson & Gurd, 1982). Computer programs, as instantiations of artificial language, all have well-defined structure and implement algorithms that are structured. A rich research tradition has concentrated on business process structures (Becker, Kugeler, & Rosemann, 2012; vom Brocke et al., 2011).

A more contemporary concept related to structure is governance, often implemented in the term "governance structure". Governance is all of the processes of governing, whether undertaken by a government, a market, a network, or a social system (family, tribe, formal or informal organization, a territory or across territories), applied through the laws, norms, power or language of an organized society (Bevir, 2012).

1.2 Defining Network

Networks are studied in network science[1]: *Network science is an academic field which studies complex networks such as telecommunication networks, computer networks, biological networks, cognitive and semantic networks, and social networks, considering distinct elements or actors represented by nodes (or vertices) and the connections between the elements or actors as links (or edges).* As can be seen from the definition, networks consist of nodes and the connections (links, sometimes humans) between nodes. Further, we can see that computer science is well represented in network science, but also belonging to the field are social networks important in human sciences. In general, the study of network representations of physical, biological, and social phenomena lead to predictive models of these phenomena (National Research Council. Committee on Network Science for Future Army Applications, 2006).

Networks are mainly human made, but nature also exhibits networks. The best example is maybe the human brain, which is a network of neurons, alongside many other things. The adult human brain contains about 85–86 billion neurons (Williams & Herrup, 1988).

Regarding human-made networks, they can be physical or conceptual, meaning that they can have visible physical links or not. An example of a physical network is in railroading: Railway stations are connected by physical links (rails). By contrast, aviation airport networks, while they are physical networks, are not connected by physical links. Conceptual networks are, by definition, not visible, and do not have physical links. A prime example of a conceptual network is the periodic table of the elements or, more recently, the human genome (again human interpretations of real natural entities).

Humans form networks. They are naturally dynamic ones, and they are formed for different purposes. A university can be interpreted as a network and as a platform for forming social networks (Mayer & Puller, 2008). It is well know that the currently dominant social media network Facebook was born in a university context.

[1] https://en.wikipedia.org/wiki/Network_science.

A human network usually aims to provide some meaningful action, business or other service. A typical concept regarding such human networks is virtual organization. Gristock (1997) lists typical characteristics of a virtual organization:

- Mediated interactions
- Geographical dispersion
- Mobility
- Diversity of actors
- Asynchronous work time
- Temporary structure.

1.3 Defining Complexity

There are many nice definitions of complexity in the literature. Below are three such definitions for how to view complexity, starting from the least complex definition and ending with the most complex one:

According to Schneberger & McLean (2003), *complexity is dependent on the*

- *number of different types of components*
- *number of types of links*
- *speed of change of the system.*

Cilliers (1998) sees complexity in the following conditions:

> A complex system is one that is made up of a number of elements interacting in a dynamic and nonlinear fashion, forming loops and recurrent patterns involving both positive and negative feedback, it is open in the sense that it is difficult to define the borders between it and other systems: it has history (i.e., its past is coresponsible for its present as well as its future); and each element is ignorant of the system as a whole, responding only to information available locally.

Finally, Smith & Weintraub (2002) define complexity: *There is complexity if things relate but don't add up, if events occur but not within the process of linear time, and if phenomena share a space but cannot be mapped in terms of a single set of three-dimensional coordinates.*

Complexity is added by the fact that people live and act in different cultures that do not always have similar characteristics. Thomas (2011) defines culture: *[c]ulture is a universally spread, for a nation, society, organisation, group, thus for every social formation, that humans feel a sense of belonging towards, very specific, typical and identity giving orientation system. This orientation system is manifested in specific symbols (e.g., language, norms, behavioral rules, behavioral scripts) and is traditionalised in every social formation through the process of socialisation and enculturation. The culture specific orientation system influences cognition, thinking, evaluating, judging, emotional and motivational processes and action of all members of any social formation. It thus defines the belonging of the members (function of constituting identity).*

2 The ERCIS Network Structure

There is also a real Jörg, Professor Jörg Becker, and he is the manager of a real network, the European Research Center for Information Systems, consisting of currently 27 universities in different countries. Needless to say, the ERCIS network is a complex and dynamic network, and it is not easy to manage. Let us relate the concepts from in Sect. 1 to the ERCIS case, and to this, we will add still a few more elements.

ERCIS does not occur naturally, but it is invented by man. So, its operation and maintenance needs human energy and intervention. Its main purpose might be interpreted as being a network-based governance structure for academic activity, including research, teaching and other academic activities.

As mentioned above, maintaining ERCIS requires constant energy. We can interpret that the central formal entities of the network are the universities involved, and individuals act as links between these central nodes. An alternative interpretation could be that individuals are the central nodes of the network, and that universities just function as platforms where the individuals can operate. As ERCIS is a human artefact and needs a formal or at least a semi-permanent structure, the first interpretation is more appropriate. In either case, individuals occupy a very central position in the network.

ERCIS clearly displays the characteristics of a virtual organization. It is geographically dispersed (it includes many more continents than the name suggests!) and celebrates a diversity of actors, including different individuals (professors, students, other types of academics) and organizations (business partners, various public organizations associated as regulators or financiers, such as the host universities and the ministries governing them). Mobility of individuals is a goal for ERCIS, and activities must be performed at asynchronous times between the actors and the temporary structure.

Complexity is deeply built into ERCIS. For example, its regulatory environment is a major challenge, as it must take into consideration the different national regulatory frameworks in addition to the jungle of EU bureaucracy. Further adding to complexity, ERCIS acts at the intersection of different cultures. Different national cultures are involved on a daily basis, the activities take place within the scope of different academic cultures. Beyond the complexities due to culture, ERCIS involves diverse fields: as is the case for information systems (IS) science in general, ERCIS also works at the intersection of computer science, natural sciences, technical sciences, (as the goal is often to build working real systems in the spirit of design science March & Smith, 1995), management science, and many other human sciences, including economics (ultimately, all human activity involves some economic aspect). Further, social sciences are also involved, as information systems are very often conceptualized as socio-technical entities (Cherns, 1976). Social and even medical sciences come into play, as welfare and health and medical systems are often the topic of IS research (Sawyer, 2005).

According to (Camarinha-Matos, 2005), The design and development of a transparent, easy to use, and affordable ICT infrastructure is a key prerequisite for the effective large-scale implementation of collaborative network organizations such as virtual organizations, professional virtual communities, e-science communities, etc. The key ICT infrastructure of ERCIS is its website www.ercis.org, which offers various services, including well-functioning posting list services. In the future, ERCIS could still extend its ICT infrastructure by creating e.g. more social media presence.

Important in networks are the concepts of bridging and bonding. These concepts are defined as follows (Newell, Tansley, & Huang, 2004): The bridging view sees social capital as a resource inhering in a social network that can be appropriated by a focal actor based on relations with others in the network. Individuals who provide a "bridge" across divided social communities (structural holes) are important, since they play a brokerage role. The bonding view focuses on the collective relations between a defined group, where social capital relates to the internal structure and relations within a collective. ERCIS, like any network, is about building bridges and bonds. Key individuals of ERCIS such as Jörg Becker are the key bridges between different organizations (for example, Jörg holds an honorary doctoral degree from the University of Turku). The social actions that could be called bonding are, for example, the ERCIS annual meetings and the presence of ERCIS at different conferences (ICIS, ECIS). A key bonding activity is that of forming research projects, often with EU funding, as the EU is a natural platform for ERCIS to work in.

Interestingly, the first defined use of the term "social capital" happened in the context of an educational institution (a school rather than a university) (Hanifan, 1916). Social capital is nowadays defined as a form of economic and cultural capital in which social networks are central; transactions are marked by reciprocity, trust, and cooperation, and market agents produce goods and services not mainly for themselves, but for a common good. Since then, the term has been used widely in contemporary research (see for example Widen-Wulff & Suomi, 2007). Individuals and even organizations surely take part in ERCIS activities because they feel that ERCIS grows their social capital. Everyone is proud to be a part of the ERCIS network, especially as access is mainly limited to one university partner in every country. Officially, ERCIS does not have a limited set of individual members. ERCIS activities are usually not described by complex transactions and contracts, but by mutual trust. Reciprocity is deeply appreciated in ERCIS activity, as is cooperation in all of its forms. As in science in general, outputs are not for the authors themselves, but for the common good of the scientific and other relevant audiences.

3 Conclusions

ERCIS is a complex dynamic network that surely benefits from structure, as any man-made artefact. Jörg Becker has been the main architect of ERCIS, and he has succeeded in his design and management work in an awe-inspiring, excellent way.

The whole ERCIS community would like to congratulate Jörg Becker on his 60th Birthday, not just as a head of our community, but also as a friend whom we can always trust and count on.

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Structuring the Boundaries of the Firm

Theresia Theurl and Eric Meyer

1 Introduction

Firms are the basis for almost any economic analysis. In economics we analyse how these firms interact on markets and how they attempt to maximize their profits or minimize their costs. On the other hand business administration deals with the interior organisation of the firm and how firms should design and implement their processes in order to be successful in the markets. There seems to be a dichotomy between these two different approaches. On the one hand economic analysis focusses on the activities of firms on markets disregarding their interior life, on the other hand there is business analysis that addresses the problems of organising the processes within a company and how to procure pre-products and sell the company's output on the markets which are subject to the economic analysis. But the boundaries of the firm have been a rather neglected topic in economic analysis. They have been perceived as given without asking what the determinants and the characteristics of these boundaries are. This is even more surprising, as economists usually assume that the basis of all economic progress is the entrepreneur who creates and produces new products, but then refuse to further integrate this activity into the economic analysis.

Thus, there was an elephant in the room, which no one had really seen until Ronald Coase raised the question of the boundaries of the firm (Coase, 1937). Coase asked why there are firms at all, if we assume that markets work so efficiently. Economics explain that markets are the most efficient way to carry out transactions, i.e. selling or forwarding a product or any kind of output. Unfortunately, these transactions also occur within firms, which organise processes in order to forward a product from one step of production to another. But if markets are so efficient why aren't these efficient

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instruments used for these transactions within firms. If internal production was an inefficient way of production, these inefficient companies should disappear from markets, because smarter entrepreneurs will realize that there are more efficient ways of manufacturing these goods and they will consequently outperform the inefficient competitors relying on the internal organization of processes. Since this reasoning could be applied to any transaction, there is no reason why firms should exist at all. Coase concluded that there must be additional effects that have been disregarded in the analysis. He identified different costs for using the pricing mechanisms of markets and for using the internal organisation of a firm. If firms now try to minimize these costs, they will end up in a cost-minimizing extent of the firm, i.e. they use internal organization for a transaction whenever internal costs are lower and they use market mechanisms whenever the costs of using markets are lower.

Although—or maybe because—Coase's question seems to be so trivial it remains one of the most fascinating topics in economics and we are still lacking a comprehensive theory of the firm. Similar to physics there still is no "grand unifying theory" of firms, which constitute the atoms of economic and business analysis. In this contribution we will structure the theoretical explanations for the determinants of the boundaries of the firm. It will emerge that the concept of a boundary (line) for the firm is inappropriate in today's economy, because it ignores the collaboration of companies and therefore the boundaries become increasingly blurred and companies' activities are starting to overlap. A well-structured understanding of the boundaries (or "boundary areas") of the firm are necessary for structuring and managing the processes of companies, which will be the final part of this article.

2 Structuring the Explanations for the Boundaries of the Firm

2.1 The Structure of Economic Production

In order to analyse the boundaries of the firm we need a common framework encompassing the activities within a firm and the activities of a firm on markets. Such a common framework is constituted by the economic activities within the production processes, which are depicted in Fig. 1. Such processes consist of economic activities that enhance the value of the ingredients of the production process (depicted as small circles) and the transfer or sale to another economic activity (depicted as lines).

The first term "economic activity" is intentionally very general. It can be described as any kind of transformation of pre-products and other resources (like energy, services or information) into new outputs by using capital goods like machines and human capital (workers). Again this sounds trivial, because it is exactly what companies are supposed to do. But identifying these activities or process steps is the basis for thoroughly determining the boundaries of the firm. Consider a company producing cars and the management's process idea is to take some metal, plastic

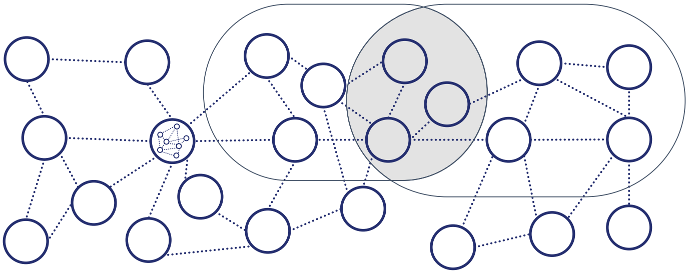

Fig. 1 The production process network

and electronics that are assembled by some workers using some robots. This would be one big process step and the company will know its boundaries but it will have significant problems in efficiently designing its boundaries, because due to a lacking analysis of separable activities within their one giant process step they are not able to sort out activities which could be done more efficiently by other companies. Therefore, a refined and detailed process analysis is the starting point for determining the appropriate boundaries of a firm. The process analysis is a consequence of Porter's value chain of a firm (Porter, 1985), who roughly distinguished a sequence of process steps and supporting activities within the firm. It is worth noting that Porter's supporting activities also consist of separable process steps and therefore they are part of the determination of the appropriate boundaries of the firm, too. Some companies have evaluated the processes of the supporting activities and decided to buy these activities from specialised market partners (e.g. assessment centre selection in HR or technological development processes). Moreover, the process analysis has to identify which workers and which capital goods have to be allocated to these process steps and—quite important—which information the activities in these steps need and which information they produce that could also be forwarded to the next process steps.

The second term is the "transfer" or "sale" of a product, service and/or information from one process step to another. Within a company the term "transfer" is more appropriate, between companies on markets the term "sale" is a suitable choice. In both cases the product is moved from one process step (economic activity) to another. But while the transfer within the firm does not change the ownership of the transferred product, the sale usually includes a change of ownership and an exchange, i.e. there is a corresponding transfer from the buyer to the seller (usually a money transfer). The theories of the firm try to identify whether such a transfer should be carried out within a firm or over the market.

Up to now we assumed that it is possible to easily separate the economic activities (i.e. the circles in Fig. 1) by drawing a boundary line between different companies. But assigning these activities and process steps to a distinct company is much harder than it seems. From a legal perspective all goods that are owned by the firm belong to the firm and define the boundaries of the firm. But as we have seen above, the economic activities involve also employees of a company, which turns the definition of the company's boundaries into a much more complicated question as some examples will illustrate.

- In the computer industry the producers of computer chips send some of their programmers to the producer of the operating system in order to contribute code that is close to the processor in order to make the operating system work seamlessly on these processors. Do these activities belong to the producer of computer chips or the producer of operating systems?
- BMW cooperates with PSA in producing engines for their small cars. These engines have been developed jointly but are produced in factories owned by PSA. To which company do the production activities belong? Legally they are produced with capital goods owned by PSA, which are employed by PSA workers. But BMW reasonably will try to keep influence on the production and its quality, because they are used in their cars and contain their development activities.
- IBM invites smaller companies to develop products and customer solutions using IBM products at IBM facilities. These companies may sell these products without any rent they have to pay to IBM, but customers will have to use the IBM products for these purposes. To which company do these development activities belong? Is it IBM, because they are using IBM-owned facilities and because they create new value for IBM products by developing complementary software solutions? Or is it the smaller companies because they develop new products and sell these products without further feedback to IBM?

From a business perspective the legal ownership of goods or a contractual relationship is not the most relevant question. For managing economic activities control and influence are relevant parameters and in today's value creating networks production constellations emerge where activities that are legally assigned to one company need to be influenced by another company. Therefore, it is a reasonable step to move away from the binary perception of firm boundaries to a more business-focussed view of the boundaries. Such an approach could use the methodology of fuzzy logic (Zadeh, 1965) for assigning the economic activities to one company or another. Fuzzy logic defines a degree of membership to a certain group or property ranging between 0 and 1. In the case of economic activity such degrees of belonging to a company could be derived from economic characteristics including especially the extent of control or influence that is desirable for economic activities or that is actually implemented in the relationships with other companies. These degrees will not necessarily coincide with legal ownership e.g. capital shares in a joint venture, although capital shares will influence these degrees. Such concept will also allow a better analysis of cooperative arrangements that do not include capital investments, but operate on a pure contractual base that allow companies to jointly use capital goods or form teams for joint developments. They create such overlapping areas of company activities that are hard to reconcile with the idea of distinct boundaries but rather resemble boundary areas of companies (shaded area in Fig. 1).

2.2 Explaining the Boundaries of the Firm

There are numerous approaches to explain the boundaries of the firm of which five will be briefly introduced in this chapter. The focus will be on the basic mechanisms of each theory and how these mechanisms help to identify the boundaries of the firm. Therefore, each theory will be described by highlighting the theoretical basis, its contribution to explaining the boundaries of the firm and its shortcomings.

Transaction cost theory: As mentioned in the introduction Coase was the first one to systematically analyse the question of boundaries of the firm (Coase, 1937). His focus was on the costs of the transfers or sales that have been introduced in the previous paragraph. The process steps themselves or value creating economic activities have been neglected by Coase. He compared the costs of transactions in markets and the costs that arise for transfers within a company. The main costs he identified for market transactions are the costs of finding the right partner and the right price, which we would call screening costs today, and the costs of negotiating and contracting with the partner (Coase, 1937, p. 390–392). These costs clearly correlate to the complexity of the transaction. Standardized transactions (e.g. in commodities) neither require extensive screening, nor is the contracting costly, because these transactions are carried out so often, that market standards have been established which significantly reduce these costs. Rare and complex transactions (e.g. for customized solutions) need a more intensive search and are less transparent, so that retrieving the right transaction partner and the appropriate price is much more cumbersome. For transactions within a company these screening and contracting costs do not occur, because the transaction partners are given by the prescribed processes within the company. Therefore, Coase identified the costs of organising these processes (Coase, 1937, p. 394–397). Although Coase's focus is on the organisation of processes, he also refers to the tasks of allocating resources to the right uses, what we would assign to the design of economic activities. He outlines, that entrepreneurs in larger companies will experience problems in correctly allocating the resources in the production processes.

Coase's work has been a starting point for the analysis of transaction costs. He identified some of these costs, but fell short in explaining what the economic reasons for these costs are. Williamson (1978, 1985) explored these economic reasons for transaction costs and identified relationship-specific investments, uncertainty and the frequency of transactions as determinants of the transaction costs. Most relevant is Williamson's analysis of relationship-specific investments that cause a special type of transaction costs for the participating transaction partners and lead to governance implications. Transactions can be differentiated with respect to the *investments* that have to be made *before the transaction* takes place in order to carry out these transactions with *one particular partner*. In this case the investment can only be used in this particular relationship and transaction with the selected transaction partner giving the transaction partner a powerful position. Knowing that his partner has invested in this relationship the other partner may try to exploit this dependency and may want to renegotiate the terms of the transaction and thus reallocate the gains from the transaction to his favour. The invested partner will recognize the possible exploitation and might refuse to do the required investment and thus the transaction will not take place, which would be detrimental for both parties. There are several suggestions for solving the two parties' dilemma. First, one option is to sign contracts that try to avoid the exploitation, but these contracts are necessarily incomplete, i.e. it is impossible to account for all future states of the world and therefore there will remain loopholes that can be used by the more powerful party. Moreover, it remains unclear what exactly should be part of such a contract and how the contract (and its obscured contents) will work in an environment of behavioural opportunism. Second, the partners may agree on some profit-sharing agreements that help to realign the partners' interests. Third, the partners could agree to bring the relevant economic activities into a joint venture to which both parties will contribute equity and therefore will share the profits from the joint venture. Finally, the powerful partner could do the relationship-specific investment and lend the capital to the partner company for the production and subsequent execution of the transaction, i.e. the dependent partner's employees would work with capital goods owned by the company. Notice, that in the first two options the firms remain rather separated, while for the last two options the firms' activities overlap and it will be harder to discern their boundaries.

Coase's and Williamson's work was path-breaking by discovering a new category of costs that occur for every economic transaction. These transaction costs could be compared to the friction in physics. They are disturbing the pure theoretical analysis of processes, but they are also necessary to understand in order to explain the real world. Nevertheless, Coase's and Williamson's work has some shortcomings. Coase's observation that there are information needs in market transactions while neglecting them within companies is far from realistic. Therefore, information asymmetries had to be further analysed and classified. Williamson on the other hand developed a governance theory of the companies' transactions, but remained rather imprecise what exactly the governance elements of markets and of companies are that should be part of the contracts to be concluded between the companies.

Principal agent theory: Information asymmetries occur for market transactions and for transactions within the firm and economic theory as developed different types of information asymmetries that can be applied to market and internal transactions: characteristics (quality), efforts, and intention. Nevertheless these categories have different expressions in market and internal transactions and therefore may cause different costs. Coase neglected the information asymmetries within companies. Alchian and Demsetz analysed the information asymmetries within firms (Alchian & Demsetz, 1972) and thus contributed further cost categories for carrying out transactions within a firm. When organising the processes of a company the entrepreneur has to select the workers and monitor their efforts, i.e. there are similar costs due to information asymmetries. And similar to the relationship with a market partner the management creates employment contracts with the employees in order to govern these relationships. For governing the internal transaction they suggest four relevant governance mechanisms. First the entrepreneur receives all the residual rewards after compensation the employees, second the entrepreneur must be willing and able to observe the input behaviour of the employees working the companies' processes and their compliance to the processing rules, third the entrepreneur is the central party to all contracts with employees in these processes, and fourth the entrepreneur may change the composition of the workers employed in each process step and may also recompose the process steps (Alchian & Demsetz, 1972, p. 783). Principal agent theory is not a theory of the firm itself, but it helps to identify information and governance costs within the firm and in market transactions. Moreover, in contrast to the transaction cost approach it focusses on the human capital of companies and how to govern the human resources of a firm.

Contract theory: The two approaches above already indicated that contracts are relevant for governing transactions. In consequence the firm can also be perceived as a nexus of contracts (Jensen & Meckling, 1976, p. 310).[1] The idea of contracts basically reflects the structure of economic production outlined in Sect. 2.1, where the transfers correspond to contracts governing the transfers or sales. In addition contracts may also cover the relationship of the company or entrepreneur to the employees working in the economic activities. Accordingly, Reve (1990) differentiates internal and external contracts depending on the contract partners. Unfortunately, the contributions of the contract theory basically focus on the internal organization of the firm and the incentives within the firm.[2] But as has been seen above contracts and the ability to write appropriate contracts is highly relevant for determining the boundaries of the firm. Therefore, more information on the contents of such contracts and how these contents interact with the economic and legal environment could significantly contribute to the management of the boundaries of the firm.

Property rights theory: In contrast to the approaches of contract theory, which addresses relations between human beings (esp. within the firm) and the contractual regulation of their relationships, the focus of the property rights approach is on the ownership of the (physical) assets of the firm. It also draws on the incompleteness of contracts, as they have been described in the transaction cost theory. If contracts involving assets are incomplete, then a situation may occur, where the assets are used or changed in a way that is not covered by the contract. Hart (1995) assigns these residual rights for changing goods beyond the contract contents to the owner of the property (i.e. the assets). Considering the ownership allows him to draw conclusions on the extent of vertical integration and on the direction of the vertical integration. Beyond Hart's formal description of the property rights and its integration implications the practical applications are rather limited. First, by the nature of the approach it excludes all relevant effects that originate from human behaviour and the contracts between these humans. Second, the property rights approach would offer a much

[1] Aoki, Gustafsson & Williamson (1990) is a collection of articles in the same spirit of reconstructing the firm as a simple collection of countless small contracts.

[2] Jensen and Meckling admit in their catalogue of questions they intend to answer and by describing the purpose of their work that they are focussing on the inner life of the firm and not on its boundaries (Jensen & Meckling, 1976, p. 306). Their objective is to fill the "black box" of the firm.

wider perspective on the boundaries of the firm, if we allowed for a more differentiated approach to property rights. By differentiating property rights (e.g. right to use, right to change the good, right to make profit with the good, right to transfer the good, right to exclude from use) more complex structures of boundaries of the firm could emerge. Third, assigning the residual rights to an owner of an asset solves a legal problem, but to a lesser extent helps to cope with the real management challenges especially in overlapping boundary areas and cooperative arrangements. From the perspective of game theory, this legal ownership installs a threat point, that from a business perspective of managing such a cooperation with shared property rights should better not be applied.

Resource-based theory: The resource-based theory is a very general approach to the characteristics of a firm. Wernerfelt defines the general term “resource” as “anything which could be thought of as a strength or weakness of a given firm” (Wernerfelt, 1984, p. 172). It encompasses everything that could be attributed to the production process of a firm: machines, staff, management, brands, knowledge etc. Thus, the resource-based theory addresses the ingredients to the production process and especially the individual production steps but leaves out the transactions from one economic activity to another. The very broad approach reduces the explanatory power of the theory, since almost everything could belong to a firm and it is therefore hard to identify its contribution to explaining the boundaries of the firm. Barney (1995) suggests four criteria for deciding whether a resource is valuable and necessary for a company. First, does the resource add value to the production process? This refers especially to the combination of resources that jointly create new products or new technologies. Second, is the resource rare? A resource that is readily available to all market participants loses its value for a company and reduces the probability that it will give it a competitive edge. Third, is the resource inimitable? Resources that are easy to imitate by competitors will hardly be able to give the company an enduring competitive advantage. Fourth, is the company able to organize its resources and capabilities in order to make use of their valuable, rare and inimitable resources? This question mainly addresses the process organization of the resources in the company. Often the answers to these questions are not unambiguous and they require further operationalization. But resources that only fulfil selected criteria and therefore are not part of the strategic core of the company may be used in cooperation with other companies and therefore create more complex boundary structures of the firm.

The theories presented above focus on different aspects of the organisation of the production process and provide different criteria to the determination of the boundaries of the firm. These results are summarised in Table 1.

3 Managing the Boundaries of the Firm

The management of a firm cannot be restricted to managing the processes and activities within the firm. Actively determining and managing the boundaries of the firm

Table 1 Theoretical foundations for criteria determining the boundaries of the firm

Theory	Focus	Criteria for determining the boundaries of the firm
Transaction cost theory	Transaction	Relative costs of market use and internal transactions • Bureaucracy costs • Organization costs (organizing processes) • Negotiation costs • Costs of partner selection • Costs resulting from incomplete contracts
Principal agent theory	Transaction • Focus on information asymmetries • Human relationships	Information costs (internal vs. external) • Monitoring employee compliance to internal processes • Monitoring partner company/quality of partner output
Contract theory	Transaction • Governance of transaction • Human relationships	Contract design • Capability of creating external contracts • Capability of managing the effects of incomplete contracts
Property rights theory	Transaction and assets used in economic activities	Assigning property rights • Capability to identify property rights
Resource-based theory	Assets and economic activities	Identifying relevant company resources • Vale creation • Rareness • Inimitability • Organisation

is a necessary part of a successful management and therefore structuring the boundaries of the firm is a valuable input for managing the firm. The theoretical insights from Sect. 2 show the way to identify the boundaries and present some instruments how the boundaries should be managed. First, a thorough process analysis is the basis for the decision of the boundaries of the firm, because only for the identified process steps decisions on internal production or external procurement or sales are possible. Second, on the basis of the insights from Sect. 2.2 the management has to decide whether process steps are carried out within or outside the firm and for which process steps hybrid arrangements are recommended. Third, after deciding on these boundaries they have to be part of the management, i.e. they have to be monitored and operated according to the results of the preceding steps.

Designing and analysing a company's processes sounds like a trivial task, because it should be done in every company, but is not or not accurately done in many firms. Moreover, a process analysis for the purpose of determining the boundaries of the firm has additional requirements. Describing the economic activities includes the analysis which capital stocks (physical capital, human capital) are employed and whether there are any indications of specificities for these assets. Transfers have to be structured along the three transfer objects "products", "services" and "information". While a detailed process map for the flow of the (physical) products usually exists, a similarly detailed analysis is missing for the information flows. Mapping the information flows is also the more challenging task, since much information is implicitly forwarded from one process step to another, because it is either stored in the transferred products or in employees who work in more than one step (particularly in smaller companies). Making the information needs and information produced visible is a necessary requirement for installing and managing a company boundary. Missing information after dividing process steps between firms will result in production interrupts or in lower production quality.

After creating a suitable process map the process steps and the transactions have to be analysed whether they should be within or outside the company or whether they should be part of a hybrid arrangement. From the theoretical insights we can derive questions that are to be answered in such an analysis:

- What is the relevance of the resources used in the process steps? Strategically valuable resources are to be kept within the firm according to the resource based theory.
- Are assets used in the process steps specific? Depending on the exploitability created by such specificities integrated solutions or hybrid solutions are recommended.
- Which information costs occur? The costs of the internal monitoring of processes and with external information requirements (defining information, monitoring external partners, establishing information interfaces etc.) have to be analyzed and compared.
- Which property rights are available and have to be defined? The identification of property rights is particularly relevant for cooperative (or hybrid) arrangements at the boundary of the firm.

It should be noticed that the conclusions reached for the boundaries of the firm also depend on the management capabilities and the economic and political environment of the firm. A management that is more experienced in managing outside information flows or in containing the risks of incomplete contracts has much lower costs of cooperating or of using the market mechanisms than a company that is not able to manage these risks. Similarly, uncertain political environments with reduced scope for contracting solutions will increase the costs of market use. Thus, even identical firms with identical processes may come to different integration solutions and therefore have to apply different management tools, if they differ in their capabilities of managing their boundaries or if they are operating in different countries.

Finally, the boundaries have to be operationally managed by monitoring the product, service and information flows and by adapting the boundaries if the costs for managing these boundaries change. Especially hybrid boundaries, i.e. economic activities that cannot be assigned to one company but where two or even more partners claim to partially control or influence the activities require different management approaches, since the usual instruments of command and control applied within companies are incompatible with the requirements for influencing an independent partner company.[3] For these cooperative arrangements incentive-based mechanisms, trust (to compensate for contract incompleteness) and conflict resolution mechanisms and competences are necessary management instruments.

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[3]Malone (2004) coined the idea of moving from command and control to a management of "cultivation and coordination".

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Bringing Structure to Research Data Management Through a Pervasive, Scalable and Sustainable Research Data Infrastructure

Raimund Vogl, Dominik Rudolph and Anne Thoring

1 Introduction

The advancing digitization of research poses major challenges for universities in providing the infrastructure for the processing, analysis, storage and accessibility of digital research data appropriate to the rapidly growing needs. University leaders are also committed to creating these infrastructures for researchers through research data policies (WWU Münster, 2017).

In this context, the IT service facilities of the five universities Bielefeld, Bonn, Münster, Paderborn, and Siegen in the German state of North-Rhine Westphalia (NRW) form a consortium to jointly develop a synergetic and sustainable, cost-efficient research data infrastructure using standardized hardware components (×86 servers with large-volume hard drives in JBOD configuration) and free open-source software (community versions of Ceph and OpenStack on a Linux platform). The operational management is to be made efficient by inter-university cooperation—this operating group was already established in advance.

In addition to the storage of research data (Ceph), an integrated platform for virtual machines and containers (OpenStack), which enables very fast access to the extensive data sets for processing and analysis, is of central importance based on the collected user requirements.

Since only cost-/maintenance-free community versions of Ceph and OpenStack are used, only hardware is the subject of a grant application to finance this infrastructure. A standardized hardware configuration for all five sites consisting of uni-

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fied server building blocks, which both provide Software Defined Storage via Ceph and serve as hosts for the OpenStack managed virtual machines (hyper-converged approach), represents this platform.

On this platform, the software systems for data processing, analysis and management are used as virtual machines or containers—thus the specific requirements for the respective research fields for the handling of research data are mapped—e.g. through GitLab instances, private ownClouds, bioinformatics packages, digital humanities desktops, etc.

Also one or possibly several repositories for the long-term availability of data are provided. Data storage takes place as Ceph object data. Securing against hardware obsolescence through Ceph's intrinsic data migration capabilities to new hardware is an essential element of long-term availability. Using self-serviceable open source software is another key element in ensuring long-term availability by minimizing the risk of software obsolescence.

The platform is based on the ideas of the European Open Science Cloud (Mons & Tochtermann, 2016) and represents a development for the participating universities towards the National Research Data Infrastructure planned for Germany (López, Vogl, & Roller, 2017).

The requirements of the research groups of the participating universities were collected in detail—the necessary hardware platform for the implementation was determined with a total of 116 hyper-converged Ceph/OpenStack server systems and a total gross disk capacity of 30 petabytes. An application to finance the project was submitted to the NRW Ministry of Science.

Going beyond the scope of the mere infrastructure platform for storage and execution environments, the sciebo. RDS project aims to create easy-to-use, integrated research data management workflows for scientists. Based on the established cloud storage service "sciebo—the Campuscloud", tools and interfaces will be developed. In concrete terms, tools for creating data management plans, analysis tools and repositories for long-time archiving are to be connected and integrated. The project is oriented towards specific use cases, especially from the humanities, and is always closely aligned with user needs.

2 EOSC and Research Data Infrastructures

Digitalization in research and, in particular, the massive increase in the volume of digital primary research data are currently the focus of discussion not only at a national but also at a European level. The EU grouped its strategies for promoting digital infrastructures around the concept of the European Open Science Cloud (EOSC).

From the preamble to the EOSC Strategy Paper (Mons & Tochtermann, 2016):

This report approaches the EOSC as a federated environment for scientific data sharing and re-use, based on existing and emerging elements in the Member States, with lightweight international guidance and governance and a large degree of freedom regarding practical implementation. The EOSC is indeed a European infrastruc-

ture, but it should be globally interoperable and accessible. It includes the required human expertise, resources, standards, best practices as well as the underpinning technical infrastructures. An important aspect of the EOSC is systematic and professional data management and long-term stewardship of scientific data assets and services in Europe and globally. However, data stewardship is not a goal in itself and the final realm of the EOSC is the frontier of science and innovation in Europe. […]

Ever larger distributed data sets are increasingly immobile (e.g. for sheer size and privacy reasons) and centralised HPC alone is insufficient to support critically federated and distributed meta-analysis and learning.

This clarifies which challenges, but also potentials, are associated with an emerging environment of federated infrastructures for the exchange and reusability of scientific data.

In the EU call EINFRA-12-2017, the main elements of this infrastructure are structured as follows:

(1) Data and Distributed Computing e-infrastructures for Open Science
(2) Secure and agile data and distributed computing e-infrastructure
(3) Access and preservation platforms for scientific information

In particular, in the context of EOSC, reference is always made to existing or emerging infrastructures in the EU Member States as fundamental elements.

The German initiative for the National Research Data Infrastructure (NFDI) can be understood as such an element (López et al., 2017).

Following the currently available papers on NFDI, the aim is to establish sustainable, interoperable research data services through multiple thematically focussed consortia organized on a Germany-wide scale. The timeframe for this is 15–20 years (depending on the source).

However, here we present a regional consortium, focussed on immediately addressing the identified short-term needs for research data infrastructure (both for storage, processing and analysis of large-volume research data) in numerous disciplines at the participating universities with a cooperative, sustainable and transferable approach. For certain disciplines, it may be quite possible to develop this infrastructure to suit institutions beyond those connected in this consortium over the next 5–10 years.

The concept we are pursuing is based on the movement, which is currently strongly represented in the US Life Science environment, for the establishment of "data commons". The vision of these Data Commons is summarized as follows (Open Commons Consortium, 2018): Infrastructure where data can live as a searchable, discoverable, computable, reusable resource. The concrete Mission is articulated as follows: To aid researchers in creating, managing, curating, publishing, discovering, and reusing data throughout the data life cycle. This is in line with the FAIR (Findable, Accessible, Interoperable, Reusable) principles (Apel, 2018), which are also central to the EOSC concept.

Examples for the adoption of the Data Commons concept are found for example in biomedical research (Paten, 2017), genomics,[1] or environmental monitoring.[2] For the "long tail of science", NSF has established Jetstream[3] as a "national research and education cloud". The underlying concepts of Jetstream (federated system at several universities, use of open source software—especially OpenStack and Ceph) are closely related to the concept presented in the project described here.

3 Research Data Infrastructure for North Rhine-Westphalia

The effects of digitization on science, especially with regard to the handling of increasingly digital research data, are currently being discussed in many contexts and addressed in numerous initiatives, position papers, conferences and funding programs. Research funding organizations require compliance with standards and guidelines when dealing with research data for granting funding. Increasingly, on the part of university managements, research data policies are providing researchers with standards to assess the steps to be taken to comply with good research practices in this context (WWU Münster, 2017). However, requiring researchers to commit to the careful and sustainable use of digital research data also places university authorities in the position to be responsible to provide the required support services and infrastructures.

Among the central IT service providers, especially at research universities, the impact of the explosive (practically exponential) growth of digital data has already arrived—the capacities of storage systems designed and build on the requirements of some five years ago are often exhausted, the retrofitting and maintenance by means of established technologies is very cost-intensive and the migration to new platforms is extremely time-consuming—and still the overwhelming demands of the research groups for the next few years are not yet addressed.

The purpose of this project is to create a future-proof, cost-effective and synergistic research data infrastructure for the five participating universities that will provide both an environment for data manipulation and analysis (using OpenStack as a powerful private cloud platform for virtual computing environments with self-service provisioning) as well as for long-term preservation (Ceph Open Source Software Defined Storage). The use of widely established open source products, which are a de facto standard, in line with a multidisciplinary operational concept, which bundles the competence and performance of numerous people, make this infrastructure future-proof (in the worst case, the necessary adjustments to the source code can be done inhouse). The exclusive use of free community versions of the software also minimizes the costs. Instead of costly service offers, the joint university-wide

[1]Genomic Data Commons Data Pool (https://portal.gdc.cancer.gov).

[2]The OCC Environmental Data Commons (http://edc.occ-data.org).

[3]Jetstream (http://jetstream-cloud.org).

operating team ensures the support. This paves the way for the establishment of a sustainable infrastructure for research data, which can be operated in the long term and flexibly expanded by its modular structure consisting of standard components (both software and hardware)—and this on an affordable financial scale.

The demands that have been submitted to the requesting university IT centers for the next few years can not be met in the cost structure of proprietary storage and virtualization products. Large-scale facilities such as CERN, which faced similar challenges in handling exploding data a long time ago, have taken this very path and massively fostered the development of these open source products, helping to provide the proven and stable functionality that we can build on today.

In the state of North Rhine-Westphalia, the universities have formed three consortia that address the respective infrastructure requirements for research data management with joint large-device applications—whereby different technical approaches, focal points and functional areas are pursued (depending on past experience and established environments of the respective consortium members).

This project focussing on a Ceph and OpenStack based infrastructure is one of these. Its technical and operational concepts are now stable, mature, and verified in some quite extensive pilot environments after lengthy discussion processes and preliminary work in the consortium. The hyper-converged solution approach for a combined Ceph/OpenStack cluster per site is very flexible, highly scalable, cost-efficient—and elegant.

The versions released by Ceph since mid-2017 (in particular Luminous) have brought along a breakthrough in terms of functionality, stability and performance, so that the very extensive needs of the research groups within the framework of the requested research data infrastructure can be met very effectively and with a reasonable investment and support effort.

The past few months were not only well used individually by the consortium participants in setting up and testing pilot systems—the inter-university operating group has already been constituted and is in regular exchange.

4 Demand Assessment for Research Data Infrastructures

We start by exemplifying the demand for an efficient (storage) infrastructure for research data by the development of the data volume of Münster University (WWU) in the last 10 years.

The development of the capacity of the hard disk systems operated centrally at Münster University compared to the volume of the backup data in the central tape library shows the explosion of the data volume in the course of digitalization as well as the change in dealing with the data.

While the volume of data in the tape library (with archive data and the backup of decentralized systems/workstations) was still significantly larger than the volume of hard disk systems up to 2009, this was reversed in 2010 with a new generation of storage systems (see Fig. 1). In the course since 2010, several massive leaps in hard

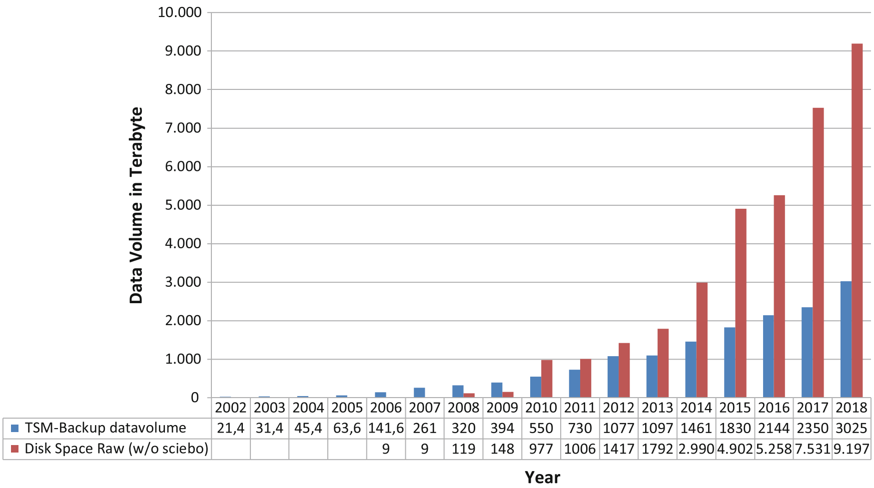

Fig. 1 Evolution of the gross capacity of the WWU disk storage systems compared to net volume of backup data in TSM tape library

disk capacity have been shown by extensions of the central SAN systems as well as completely new systems, such as new parallel storage for HPC or the Ceph pilot system.

It also makes it obvious that not all data is backed-up—partly because it is only temporary (HPC scratch), partly because it is just a local copy of other large-volume archived data (e.g. publicly available geospatial data). However, the concept of general magnetic tape backup is also questioned since the recovery times from a tape library are prohibitive due to the large volumes of data. A backup-to-disk is necessary for a reasonable recovery time, as long as the backup-restore concept is kept. But even the storage of data in file systems causes long-term problems—the migration of file system-based data to a new generation of storage systems turns out to be extremely time-consuming.

A paradigm shift to a new concept of intrinsically resilient storage systems that can guarantee long-term data availability even without backup and time-consuming file system migrations is necessary and sometimes already in progress. In particular, the storage in an object storage system such as Ceph, which allows a considerably simpler migration to new hardware platforms (by means of a smooth migration by gradually adding new storage servers and removing obsolete ones), appears as a working way of ensuring long-term data availability.

For Münster University, the needs of scientific data storage facilities and virtual machines for data processing and data analysis were compiled. The volume of 8 petabytes net in a 5-year time perspective alone for the previously known projects is massive—but in the light of the growth of storage systems in recent years realistic. Covering these cumulative requirements with conventional systems or technologies is not possible—but they can be well addressed with the Ceph and OpenStack approach.

We assume that the demand survey is not exhaustive and that there will be further demands—however, the flexibly scalable nature of this core infrastructure should allow for further expansion to account for this with reasonable use of finance.

5 The Concrete Demand Assessment of Münster University

Based on the infrastructure and scientific projects listed below, WWU will need 1,200 TB net of Tier 1 storage (3 × replica, especially for temporary data and VM images) and 6,800 TB net of Tier 2 storage (8 + 3 Erasure Coding for non-volatile data—the access to the EC pools can be made performant by an upstream NVMe-based cache Tier). This requires approximately 13,000 TB of OSD gross hard disk capacity in the Ceph Cluster. The need for VM capacity is about the equivalent of 32 hosts, each with 40 cores and 512 GB of RAM. Together with the CPU and RAM requirements for Ceph results in the need for 46 hyper-converged hosts each with 24 × 12 TB HDD capacity for Ceph–OSDs (with a total of around 13,000 TB as needed).

List of infrastructure projects:

- Infra 1: Infrastructure for a planned next generation sequencing center (NGS) of the WWU
- Infra 2: Data exchange platform for the WWU Imaging Network (WIN) for optical microscopy
- Infra 3: Storage platform for e-lectures for ZIV and ZHLdigital (center for digital teaching)
- Infra 4: Research data repository of the eScience Service Point of ULB and ZIV
- Infra 5: Piloting of backup-to-disk with S3 connection
- Infra 6: Piloting the purging of the "cold" data from the parallel HPC file system by means of ILM (Information Lifecycle Management) of the GPFS
- Infra 7: VM platform for infrastructure services and research projects
- Infra 8: Pilot installation for sciebo "Next Generation"

The user demand assessment at Münster University resulted in projects from human genetics, medical informatics, hygiene, evolutionary biodiversity, cell biology, landscape ecology, lattice gauge theory, physical chemistry, organic chemistry, geophysics, seismology, applied mathematics, image processing and machine learning, and from the information systems department.

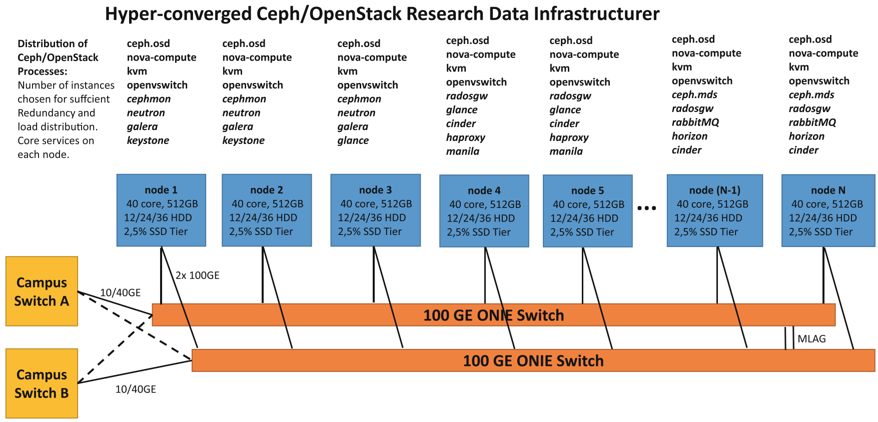

Fig. 2 Schematic of the hyper-converged Ceph/OpenStack platform

6 The Appropriate Solution Architecture—A Hyper-converged Ceph/OpenStack Platform as a Research Data Infrastructure

As stated above, the key ideas in building this research data infrastructure are the following principles:

- Use of low-cost standard hardware (without manufacturer-specific properties)
- Use of free open source software
- Use of community versions without fee-based mandatory maintenance contracts

This will ensure the sustainability of this infrastructure both in terms of affordability and operability (without the risk of software and hardware obsolescence). In accordance with the data commons concept, feedback for user demands shows that not only storage alone is needed in a research data infrastructure, but also host platforms for virtual machines for data manipulation and analysis.

The mapping of these needs, can be accomplished with open source software through a system design that is composed of homogenous nodes as building blocks equipped with disk, RAM and CPU resources for Ceph as well as OpenStack, operated as a private cloud stack. In this hyper-convergent system configuration (Fig. 2), there are no dedicated nodes for individual functions.

In particular, this hyper-converged approach allows very flexible scaling by adding individual building blocks, always increasing memory and computational capacity together. Ceph automatically allocates the data to the new node. A particular advantage of the hyper-converged approach is that the bundling of the Ceph with the OpenStack hosts gives a larger number of nodes for the distribution of Ceph-OSDs—thus making disk space-saving and highly available Erasure Coding (EC) configurations like 8 + 3 possible (host level fault tolerance requires at least 11 hosts).

Since the research data infrastructure will be the primary storage location for actively used (“hot”) research data, and the volume of this data usually requires processing on systems that have very fast connection to the storage, the hyper-convergent approach is also well suitable from this point of view, because here the computing capacity for data processing and analysis is directly integrated with the storage platform. The Ceph/OpenStack platform is essentially a Software Defined Data Center (SDDC), where most of the traffic is in the “east-west” direction (that is, within the SDDC)—the “north-south” traffic to and from the campus network is expected to be much lower. This feature of Ceph also enables a sliding migration to new hardware by gradually adding new and disabling obsolete building blocks. Long-term availability of data can thus be ensured by means of an active “data stewardship” that can be operated over the long term (due to standard hardware and open source software).

Discussions with the prospective users of the research data infrastructure in the course of the needs assessment as well as the application scenarios realized so far in the pilot installation at Münster University have shown that very different usage scenarios can be realized for the storage provided via Ceph. We see application scenarios for block storage (Rados Block Device—RBD) especially for OpenStack cinder, for the provisioning of storage through a NAS protocols (e.g. through OpenStack Manila), for direct access to object storage via radosgw (e.g. with the S3 protocol), for parallel files system access through CephFS or for cloud shares through ownCloud (supplementing the ownCloud based sync and share cloud storage service sciebo for the universities in North Rhine-Westphalia (Vogl et al., 2016)).

By providing various VM templates or containers that are pre-configured for specific use cases, end users can benefit from the use of specific software packages (e.g. ownCloud and GitLab instances, or Moodle for teaching topics) for their work. The sharing these templates within the consortium has great potential for synergistic cross-university collaboration in the operation of this research data infrastructure. The use of such VM templates or containers will be an essential aspect of research data management—in some cases, application containers or VM templates even constitute the “executable” research results in unit with the research data. The demand assessment for scientific projects to use this research data infrastructure consistently shows the need for their own VMs, with a multitude of environments for handling research data. In our understanding, research data management is a multi-faceted combination of all of these domain-specific solutions along with general-purpose services (repository, …) and a sustainable and scalable infrastructure.

The research field Digital Humanities (DH) is gaining momentum at Münster University and has a significant intersection with research data management. In this respect, the same technological basis is used for the realization of services in the field of DH. On the agenda are concrete projects such as the use of preconfigured virtual desktops for the Digital Humanities at Münster University. Among other things, VM images for “Digital Editions (VD Edition)” as a standard workstation for digital editions and “Makerspace for Digital Editions (VD Edition EdIt)” shall be service offerings.

As part of the cross-university cooperation between the five universities, it is also agreed that each partner will open up to 15% of its resources (storage or virtualization) for use by the other partners.

Thus, load peaks or failures of components (for example, by the migration of VMs) can be compensated, but also disaster resilient data storage by replication of selected data pools between universities is possible.

In this context, of course, the question of data protection must be clarified. Currently, the IT center (ZIV) of Münster University, in a project together with the Institute for Telecommunications and Media Law (IMT), is reviewing the effects of the new EU General Data Protection on the contract design of cross-university IT/cloud projects. According to the current state of work, we assume that the GDPR provides a much better instrument than the hitherto applicable contracted data processing with the new legal construct of "common responsibility" (so far missing in German data protection law).

7 Creating Easy-to-Use Research Data Management Workflows—From Data Management Plan to Long-Term Archiving

With the increasing digitalisation of research, the importance of structured research data management (RDM) can hardly be overestimated. In practice, however, these requirements have so far only been implemented unsatisfactorily, as various studies have shown. This is due in particular to the lack of easy-to-use tools. The aim of the sciebo.RDS project (a DFG funded project of the ZIV and University Library (ULB) of Münster University together with the Competence Center Connected Organization of Duisburg-Essen University) is therefore to develop a low-threshold offer for the management of research data, which is clearly designed as a service offer for scientists. The focus is on the development of a management suite for flexible integration and coupling with existing services and systems as well as the exemplary implementation of integrated scientific work processes (workflows) using real use cases. With the established collaboration service "sciebo—the Campuscloud", a productive platform already exists that allows data sharing and collaboration across universities. Sciebo is a cloud storage service currently used at 28 universities by around 100,000 people and around 1,600 research projects. As stated in Sect. 6, one of the use cases for the research data infrastructure will be the future platform for the next generation sciebo system—sciebo will thus become an integrated component of the research data infrastructure. Based on sciebo, tools, workflows and services are to be developed to support researchers in the implementation of structured research data management, including templates for data management plans, the easy building of data packets with metadata and the storage of those data in repositories. The core idea is to collect the researchers by creating bridge functionalities where they already store a large part of their data during the research process and to provide them with easy-to-use tools, e.g. for data preparation, publication and seamless transfer to repositories or long-term archives. The focus is on those subject areas that have not yet developed their own subject-specific research data workflows, especially in the humanities. In addition, we are investigating how blockchain technology can be used for the validation of research data.

8 Conclusion

We have described a project currently underway in NRW to establish a multi-university research data infrastructure. The design principles of cost effectiveness, sustainability and scalability lead us to a hyper-converged system design with Ceph storage and an OpenStack based private cloud. This fits well into the paradigms of data commons and the EOSC. To enable a low-threshold access to this infrastructure for state of the art research data management also for less IT-savy fields in the "long tail of science" or in the humanities, research data services are in development in a DFG funding project.

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Part VI
Technologies

"What turns me on about the digital age, what excited me personally, is that you have closed the gap between dreaming and doing." (Bono)

Creating models, structuring processes and data, and defining organizational structures are all about conceptualization and construction. We can construct whatever we imagine, and ultimately it is our desire to create a solution, maybe a software, which is of value. When dreaming is about defining structures, design, and construction, it is the technology and the implementation which makes it *real* and allows for using, i.e., doing.

Send-Receive Considered Harmful: Toward Structured Parallel Programming

Sergei Gorlatch

1 Introduction

Program development for parallel and distributed systems remains a challenging and difficult task. One of the obvious reasons for this unsatisfactory situation is that today's programmers rely mostly on the programming culture of the 1980s and '90 s, the Message Passing Interface (MPI) (Gropp, Lusk, & Skjellum, 1994) still being the programming tool of choice for demanding applications.

The merit of MPI is that it integrated and standardized parallel constructs that were proven in practice. Designed to enable high performance, MPI's low-level communication management using the primitives *send* and *receive* results in a complicated programming process. Several attempts have been made to overcome this (e.g., HPF and OpenMP). However, despite reported success stories, these approaches have never achieved the popularity of MPI, mostly because they make the performance of parallel programs less understandable for the developer and difficult to predict.

A similar "software crisis" occurred in the sequential setting in the 1960s. The breakthrough was made by Dijkstra in his famous letter "*goto* considered harmful" (Dijkstra, 1968), in which the finger of blame was pointed at the *goto* statement. By that time, (Böhm & Jacopini, 1966) had formally demonstrated that programs could be written without any *goto* statements, in terms of only three control structures—sequence, selection and repetition. Therefore, the notion of *structured programming* (Dahl, Dijkstra, & Hoare, 1975) became almost synonymous with "goto elimination".

If we wish to learn from sequential structured programming, we should answer the question: Which concept or construct plays a similarly negative role to that of *goto* in the parallel setting? As implied in Fig.1 and demonstrated from Sect. 3 onwards, we propose that *send-receive* statements be "considered harmful" and be avoided as far as possible in parallel programs.

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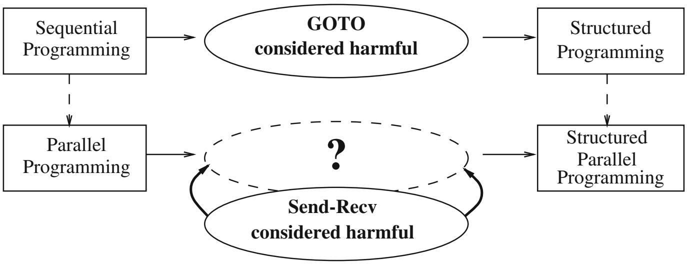

Fig. 1 Similarly as goto complicates sequential programs, using send-receive causes difficulties in parallel programming

The thrust of this paper is:

> Parallel programming based on message passing can be improved by expressing communication in a structured manner, without using send-receive statements.

This paper is a modified version of (Fischer & Gorlatch, 2002). Recently this approach has been significantly extended by numerous researchers in different areas of parallel programming, also beyond the context of message passing. In particular, the novel parallel architectures like multi-core CPUs and many-core GPUs (Graphics Processing Units) require structured programming at probably even higher scale than message passing considered here, as an alternative to the low-level CUDA and OpenCL approaches. For the recent results in the field, we refer the reader to the survey on algorithmic skeletons (Gorlatch & Cole, 2011), the SkelCL library (Steuwer & Gorlatch, 2014), skeleton-based transformations (Hagedorn, Steuwer, & Gorlatch, 2018), and the LIFT approach (Hagedorn, Stoltzfus, Steuwer, Gorlatch, & Dubach, 2018).

2 Collective Operations: An Alternative to Send-Receive

What would be the proper substitute for *send-receive*? In our view, it does not even need to be invented: we propose using *collective operations*, which are already an established part of MPI.

We address the following challenges to prove the benefits of collective operations. *Challenges for collective operations as an alternative to send-receive*:

- *Simplicity*: Are "collective" programs simpler and more comprehensible?
- *Programmability*: Is a systematic process of program design facilitated?
- *Expressiveness*: Can important application classes be conveniently expressed?
- *Performance*: Is performance competitive with that using send-receive?
- *Predictability*: Are program behaviour and performance more predictable?

For the sake of completeness, we show in Fig. 2 the main collective operations of MPI for a group of four processes, P0 to P3. The two upper rows of Fig. 2 contain

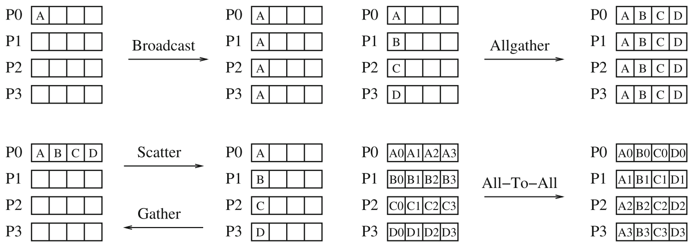

Fig. 2 Collective operations on four processes. Each row of boxes represents data of one process

collective operations that specify pure communication (*broadcast, gather*, etc.); the operations at the bottom of the figure, *reduce* and *scan*, perform both communication and computation. The binary operator specifying computations (+ in Fig. 2) is a parameter of the collective operation: it may be either predefined, like addition, or user-defined. If this operator is associative, the corresponding collective operation can be efficiently implemented in parallel.

Each of the next sections, one per challenge, opens by stating a commonly held, pro-*send-receive* opinion, which we somewhat polemically call a "myth". We proceed by refuting the myth and conclude with a "reality" statement based on the presented facts and arguments. This "myths-and-realities" structure of the paper enables us to draw a clear conclusion about the suitability of collective operations as an alternative to *send-receive*.

3 The Challenge of Simplicity

Myth: Send-receive primitives are a simple way of specifying communication in parallel programs.

To reason effectively about a parallel program comprising hundreds or thousands of processes, one needs a suitable abstraction level. Programmers usually think in terms of how data need to be distributed to allow local computation: there is a stage (phase) of computation followed by a stage of communication, these stages being either synchronized, as in the BSP model, or not. Collective operations neatly describe data redistributions between two stages, while individual sends and receives do not match this natural view, which leads to the following problems:

- There is no simple set of coordinates that describe the progress of a parallel program with individual communication. Such programs are therefore hard to understand and debug.
- If MPI is our language of choice, then we have not just one *send-receive*, but rather eight different kinds of *send* and two different kinds of *receive*. Thus, the programmer has to choose among 16 combinations of *send-receive*, some of them with

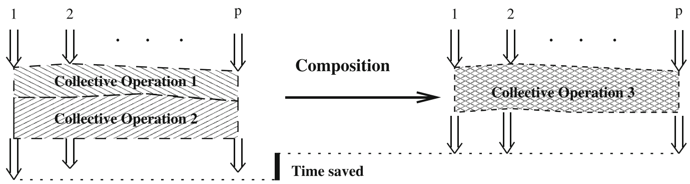

Fig. 3 The idea of fusing two collective operations into one by a transformation like (1)

very different semantics. Of course, this makes message-passing programming very flexible, but even less comprehensible!

- The last but not least problem is the size of programs. For example, a program for data broadcasting using MPI_Bcast may have only three instead of its *send-receive* equivalent's 31 lines of code (Gorlatch, 2001; Pacheco, 1997).

Reality: The apparent simplicity of *send-receive* turns out to be the cause of large program size and complicated communication structure, which makes designing and debugging of parallel programs.

4 The Challenge of Programmability

Myth: The design of parallel programs is so complicated that it will probably always remain an ad hoc activity rather than a systematic process.

The structure of collective programs as a sequence of stages facilitates high-level program transformations. One possible kind of transformations fuses two consecutive collective operations into one. This is illustrated in Fig. 3 for a program with 'p' processes, where each process either follows its own control flow, depicted by a down-arrow, or participates in a collective operation, depicted by a shaded area. Fusing two collective operations into one may imply a considerable saving in execution time; more on that in Sect. 7.

One fusion rule states that, if operators 'op1' and 'op2' are associative and 'op1' distributes over 'op2', then the following transformation of a composition of scan and reduction is applicable:

$$\left[\begin{array}{c}\text{MPI\_Scan(op1)}\\ MPI\_Reduce(op2);\end{array}\right. \Rightarrow \left[\begin{array}{c}\text{Make\_pair;}\\ \text{MPI\_Reduce(f(op1, op2));}\\ \text{if my\_pid == ROOT then Take\_first;}\end{array}\right. \qquad (1)$$

Here, function **Make_pair** duplicates its arguments, thus creating a pair, and **Take_first** yields the first component of a pair. Both functions are executed without interprocessor communication. The binary operator **f(op1, op2)** on the right-hand side works on pairs of values and is built using the operators from the left-hand side of the transformation. The precise definition of **f**, as well as other similar transformations, can be found in (Gorlatch, 2000).

Rule (1) and other rules from (Gorlatch, 2000) have the advantage that they are (a) proved formally as theorems, (b) parameterized by the occurring operators, e.g. **op1** and **op2**, and therefore customizable for a particular application, (c) valid for all possible implementations of collective operations, and (d) applicable independently of the parallel target architecture, and (e) suitable for automation.

Besides fusion rules, there are also transformations that decompose one collective operation into a sequence of smaller operations. Composition and decomposition rules can sometimes be applied in sequence, thus leading to more complex transformations, for example:

$$\left[\begin{array}{c}\text{MPI\_Scan (op1)}\\ MPI\_Allreduce(op2);\end{array}\right. \Rightarrow \left[\begin{array}{c}\text{Make\_pair;}\\ \text{MPI\_Reduce} - \text{scatter}(f(op1, op2));\\ \text{Take\_first;}\\ \text{MPI\_Allgather;}\end{array}\right.$$

Profound results have been achieved with formalisms for the verification of concurrent and message-passing programs (Schneider, 1997). With collective operations, we take a different approach: we design message-passing programs in a stepwise manner (Gorlatch, 2000) by applying semantically sound transformations like (1). In Sect. 7, we show that such design process can be geared to predicting and improving performance.

Reality: Collective operations facilitate high-level program transformations that can be applied in a systematic program-design process.

5 The Challenge of Expressiveness

Myth: Collective operations are too inflexible and unable to express many important applications.

To refute this quite widely held opinion, we present in Table 1 several important applications, which according to the recent literature were implemented using collective operations only, without notable performance loss as compared with their counterparts using *send-receive*.

Here, Map stands for local computations performed in the processes without communication; Shift is a cyclic, unidirectional exchange between all processes; Iter denotes repetitive action; (group) means that the collective operation is applied not to all processes of the program, but rather to an identified subset of processes (in MPI, it can be specified by a communicator).

Additional confirmation of the expressive power of collective operations is provided by the PLAPACK package for linear algebra (van de Geijn, 1997), which was implemented entirely without individual communication primitives, as well as by one

Table 1 Applications expressed using collective operations only

Application	Communication/computation pattern
Polynomial multiplication	$Bcast(group); Map; Reduce; Shift$
Polynomial evaluation	Bcast; Scan; Map; Reduce
Fast fourier transform	Iter(Map; All-to-all; (group))
Molecular simulation	Iter(Scatter; Reduce; Gather)
N-Body simulation	Iter(All-to-all; Map)
Matrix multiplication (SUMMA)	Scatter; Iter (Scatter; Bcast; Map); Gather
Matrix multiplication (3D)	Allgather(group); Map; All-to-all; Map

of the best textbooks on parallel algorithms (Kumar, 1994), where the programming methodology centres on implementing and then composing collective operations.

In (Fischer & Gorlatch, 2002), we proved the Turing universality of a programming language based on just two recursive collective patterns, anamorphisms and catamorphisms. This fact can be viewed as a counterpart to the result of Böhm and Jacopini (Böhm & Jacopini, 1966) for parallel programming.

Reality: A broad class of communication patterns found in important parallel applications is covered by collective operations.

6 The Challenge of Performance

Myth: Programs using *send-receive* are, naturally, faster than their counterparts using collective operations.

The usual performance argument in favour of individual communication is that collective operations are themselves implemented in terms of individual *send-receive* and thus cannot be more efficient than the

latter. However, there are two important aspects here that are often overlooked:

1. The implementations of collective operations are written by the implementers, who are much more familiar with the parallel machine and its network than an application programmer can be. Recent algorithms for collective communication (Park, Choi, Nupairoj, & Ni, 1996) take into account specific characteristics of the interprocessor network, which can then be considered during the compilation phase of the communication library. The MagPIe library is geared to wide-area networks of clusters (Kielmann, Hofman, Bal, Plaat, & Bhoedjang, 1999). In Vadhiyar, Fagg, & Dongarra (2000) the tuning for a given system is achieved by conducting a series of experiments on the system. When using *send-receive*, the communication structure would probably have to be re-implemented for every new kind of network.

2. Very often, collective operations are implemented not via *send-receive*, but rather directly in the hardware, which is simply impossible at the user level. This allows all machine resources to be fully exploited and sometimes leads to rather unexpected results: e.g. a simple bidirectional exchange of data between two processors using *send-receive* on a Cray T3E takes twice as long as a version with two broadcasts (Bernashi, Iannello, & Lauria, 1999). The explanation for this phenomenon is that the broadcast is implemented directly on top of the shared-memory support of the Cray T3E.

Below, we dispute some other commonly held opinions about the performance superiority of *send-receive*, basing our arguments on empirical evidence from recent publications.

- It is not true that non-blocking versions of *send-receive* MPI_Isend and MPI_Irecv, are invariably fast owing to the overlap of communication with computation. As demonstrated by Bernashi et al. (1999), in practice these primitives often lead to slower execution than the blocking version because of the extra synchronization.
- It is not true that the flexibility of *send-receive* allows smarter and faster algorithms than the collective paradigm. Research has shown that many designs using *send-receive* eventually lead to the same high-level algorithms as obtained by the "batch" approach (Goudreau & Rao, 1999). In fact, batch versions often run faster (Hwang & Xu, 1998).
- It is not true that the routing of individual messages over a network offers fundamental performance gains as compared with the routing for collective operations. As shown formally in Valiant (1990), the performance gap in this case becomes, with large probability, arbitrarily small for large problem sizes.

Reality: A broad class of communication patterns found in important parallel applications is covered by collective operations.

7 The Challenge of Predictability

Myth: Reliable performance data for parallel programs can only be obtained a posteriori, i.e. by actually running the program on a particular machine configuration.

Performance predictability is, indeed, often even more difficult to achieve than absolute performance itself. Using collective operations, not only can we design programs by means of the transformations presented in Sect. 4 we can also estimate the impact of every single transformation on the program's performance. Table 2 contains a list of transformations from (Gorlatch, Wedler, & Lengauer, 1999) and (Hagedorn, Steuwer, & Gorlatch, 2018), together with the conditions under which these transformations improve performance.

In the above table, a binomial-tree implementation of collective operations is presumed, our cost model having the following parameters: start-up/latency t_s, transfer time t_w and block size m, with the time of one computation operation assumed as

Table 2 Impact of transformations on performance

Composition rule	Improvement if
Scan_1; Reduce_2 → Reduce	*always*
Scan; Reduce → Reduce	$t_s > m$
Scan_1; Scan_2 → Scan	$t_s > 2m$
Scan; Scan → Scan	$t_s > m(t_w + 4)$
Bcast; Scan → Comcast	*always*
Bcast; Scan_1; Scan_2 → Comcast	$t_s > m/2$
Bcast; Scan; Scan → Comcast	$t_s > m\left(\frac{1}{2}t_w + 4\right)$
Bcast; Reduce → Local	*always*
Bcast; Scan_1; Reduce_2 → Local	*always*
Bcast; Scan; Reduce → Local	$t_w + \frac{1}{m} \cdot t_s > \frac{1}{3}$

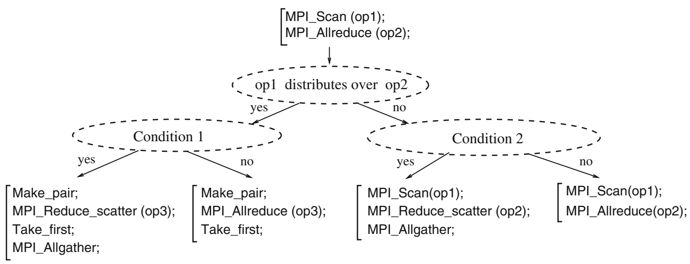

Fig. 4 The tree of design alternatives with decisions made in the nodes

the unit. These parameters are used in the conditions listed in the right column of the table. The estimates were validated in experiments on a Cray T3E and a Parsytec GCel 64 (see Gorlatch, 2000 for details).

Since the performance impact of a particular transformation depends on the parameters of both the application and the machine, there are alternatives to choose from in a particular design. Usually, the design process can be captured as a tree, one example of which is given in Fig. 4.

The best design decision is obtained by checking the design conditions, which depend either on the problem properties, e.g. the distributivity of operators, or on the characteristics of the target machine (number of processors, latency and bandwidth, etc.). For example, if the distributivity condition holds, it takes us from the root into the left subtree in Fig. 4. If the block size in an application is small, Condition 1 (see Gorlatch, 2000) yields "no", and we thus end up with the second (from left to right) design alternative, where op3 = f(op1, op2) according to rule (1). Note that the conditions in the tree of alternatives may change for a different implementation of the collective operations involved.

Arguably, *send-receive* allows a more accurate performance model than collective operations do. Examples of well-suited models for finding efficient implementations are LogP and LogGP (T. Kielmann, Bal, & Gorlatch, 2000). However, these models are overly detailed and difficult for an application programmer to use, as demonstrated by a comparison with batch-oriented models (Bilardi, Herley, Pietracaprina, Pucci, & Spirakis, 1996; Goudreau, Lang, Rao, Suel, & Tsantilas, n.d.).

Reality: Collective operations contribute to the challenging goal of predicting program characteristics during the design process, i.e. without actually running the program on a machine. The use of *send-receive* obviously makes the program's performance much less predictable. Furthermore, the predictablity of collective operations greatly simplifies the modelling task at the application level, as compared with models like LogP.

8 Conclusion

This short communication proposes—perhaps somewhat polemically—viewing the *send-receive* primitives as harmful and, consequently, trying to avoid them in parallel programming.

We have briefly demonstrated the advantages of collective operations over *send-receive* in five major areas, which we call challenges: simplicity, expressiveness, programmability, performance and predictability. Based on recent publications in the field and our own research, we have presented hard evidence that many widely held opinions about *send-receive* vs. collective operations are mere myths.

Despite the success of structured programming, *goto* has not gone away altogether, but has either been hidden at lower levels of system software or packaged into safe language constructs. Similarly, there are parallel applications where non-determinism and low-level communication are useful, e.g. a taskqueue-based search. This motivates the development of "collective design patterns" or skeletons which should provide more complex combinations of both control and communication than the currently available collective operations of MPI.

We conclude by paraphrasing Dijkstra's famous letter, which originally inspired our work. Applied to message passing, it might read as follows:

> The various kinds and modes of send-receive used in the MPI standard, *buffered, synchronous, ready, (non-)blocking*, etc., are just too primitive; they are too much an invitation to make a mess of one's parallel program.

It is our strong belief that collective operations have good potential for overcoming this problem and enabling the design of well-structured, efficient parallel programs based on message passing.

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Parallel Programming with Algorithmic Skeletons

Herbert Kuchen

1 Introduction

Nowadays, typical high-performance computers consist of a cluster of compute nodes connected by some high-speed network. Each node contains multiple processor cores communicating via a shared memory. Additionally, it often contains accelerators such as Graphics Processing Units (GPUs) with hundreds or thousands of cores, which further increase the computation power. The communication between the different compute nodes is typically implemented by using a communication library such as MPI (Gropp, Lusk, & Skjellum, 2014; MPI Forum). The coordination of the computations on different cores of the same node is typically based on an API such as OpenMP (Chapman, Jost, & van der Pas, 2008; OpenMP). GPUs are programmed using a low-level, architecture-specific framework such as CUDA (Nickolls, Buck, Garland, & Skadron, 2008) or OpenCL (Stone, Gohara, & Shi, 2010). Thus, for exploiting the full computation power of such a machine, the programmer has to master several different frameworks/APIs in combination, which clearly overburdens the application programmer. Especially, GPU programming is currently challenging, due to the complicated memory and thread hierarchies of GPUs. The memory hierarchy (Owens et al., 2008) consists of relatively slow global memory, faster shared memory, and very fast but scarce private memory, which requires explicitly programmed data movements between main memory and GPU memory. In addition, the GPU thread hierarchy requires the programmer to take the logical arrangement of threads (work items) in groups and their physical grouping in warps into account. In order to achieve good performance, the programmer has to make the best use of both—threads and memory hierarchies—and to thoroughly combine them. However, even if good performance has been achieved, it is usually not portable to another model of GPU from a different vendor (e.g., when changing from AMD to NVIDIA

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hardware) the programmer has to re-design and re-implement application software in order to achieve high performance again.

When developing parallel programs, frequently the SPMD (single program multiple data) style is applied, where all processors run the same code on different data. Conceptually, the programmer often has one or more distributed data structures in mind, which are manipulated in parallel. Unfortunately, the mentioned low-level frameworks do not support this view of the computation. The programmer rather has to split the conceptually global data structure into pieces, such that every processor receives one (or more) of them and cares about all computations which correspond to the locally available share of data. In the syntax of the final program, there is no indication that all these pieces belong together. The combined distributed data structure only exists in the programmer's mind. Thus, the programming level is much lower than the conceptual view of the programmer. This causes several disadvantages. First, the programmer often has to fight against low-level communication problems such as deadlocks, starvation, and race conditions, which could be substantially reduced and often eliminated by using a more expressive and structured approach. Moreover, the local view of the computation makes global optimizations very difficult. One reason is that such optimizations require a cost model of the computation which is hard to provide for the complicated interactions of several low-level frameworks.

Many approaches try to increase the level of parallel programming and to overcome the mentioned disadvantages. It is impossible to mention all high-level approaches to parallel programming here. Let us just focus on a few particularly interesting ones.

Bulk synchronous parallel processing (BSP) (Skillicorn, Hill, & McColl, 1997) is a restrictive model where a computation consists of a sequence of *supersteps*, i.e. independent parallel computations followed by a global communication and a barrier synchronization. BSP has been successfully applied to several data-parallel application problems, but owing to its restrictive model it cannot easily be used for irregularly structured problems.

An even higher programming level than BSP is provided by *algorithmic skeletons* (Aldinucci, Danelutto, Kilpatrick, & Torquati, 2017; Bassini, Danelutto, Dazzi, Joubert, & Peters, 2018; Benoit, Cole, Gilmore, & Hillston, 2005; Cole, 2004; Ernstsson, Li, & Kessler, 2018), i.e. typical parallel programming patterns which are efficiently implemented on the available parallel machine and usually offered to the user as higher-order functions, which get the details of the specific application problem as argument functions. Thus, a parallel computation consists of a sequence of calls to such skeletons, possibly interleaved by some local computations. The computation is now much more structured and seen from a global perspective. Several implementations of algorithmic skeletons are available. They differ in the kind of host language used and in the particular set of skeletons offered. Since higher-order functions are taken from functional languages, many approaches use such a language as host language (Darlington et al., 1993; Kuchen, Plasmeijer, & Stoltze, 1994; Skillicorn, 1994). In order to increase the efficiency, imperative languages such as C and C++ have been extended by skeletons, too (Botorog & Kuchen, 1996, 1998; Danelutto, Pasqualetti, & Pelagatti, 1997; Foster, Olson, & Tuecke, 1992).

Depending on the kind of parallelism used, skeletons can be classified into *task parallel* and *data parallel* ones. In the first case, a skeleton (dynamically) creates a system of communicating processes. Some examples are *pipeline*, *farm*, *divide & conquer, and branch & bound* (Cole, 1989; Danelutto et al., 1997; Darlington et al., 1993; Poldner & Kuchen, 2008a, b, c). In the second case, a skeleton works on a distributed data structure, performing the same operations on some or all elements of this structure. Data parallel skeletons, such as *map*, *fold*, and *zip* are used in several approaches (Botorog & Kuchen, 1996, 1998; Danelutto et al., 1997; Darlington et al., 1993; Darlington, Guo, To, & Yang, 1995; Ernsting & Kuchen, 2012; Kuchen et al., 1994).

The approach described in the sequel incorporates the main concepts found in existing skeleton implementations. In particular, it provides task as well as data parallel skeletons, which can be combined based on the *two-tier model* taken from P^3L (Danelutto et al., 1997).

In general, a computation consists of nested task parallel constructs where an atomic task parallel computation maybe sequential or data parallel. Purely data parallel and purely task parallel computations are special cases of this model.

Apart from the lack of standardization, one reason for the missing acceptance of algorithmic skeletons is the fact that they typically are provided in form of a new programming language. However, parallel programmers typically know and use Fortran, C, or C++, and they hesitate to learn new languages in order to try skeletons. Thus, an important aspect of the presented approach is that skeletons are provided in form of a library. Language bindings for the mentioned, frequently used languages will be provided. The C++ binding is particularly elegant, and the present paper will focus on this binding. The reason is that the three important features needed for skeletons, namely higher-order functions (i.e. functions having functions as arguments), partial applications (i.e. the possibility to apply a function to less arguments than it needs and to supply the missing arguments later), and polymorphism, can be implemented elegantly and efficiently in C++ using operator overloading and templates, respectively (Kuchen & Striegnitz, 2002, 2005). Thus, the C++ binding does not cause the skeleton library to have a significant disadvantage compared to a corresponding language extension. The skeleton library can be implemented in various ways. The implementation considered in the present paper is based on MPI, OpenMP, and CUDA.

This paper is organized as follows. In Sect. 2, we present the main concepts of the skeleton library Muesli. Section 3 contains experimental results demonstrating that the structured approach to parallel programming offered by e.g. Muesli can compete with low-level implementations w.r.t. performance and scalability. Finally in Sect. 4, we conclude.

2 The Skeleton Library Muesli

The *Mu*enster *s*keleton *li*brary *Muesli* offers data parallel and task parallel skeletons. Here, we will focus on data parallel skeletons. Data parallelism in Muesli is based on a *distributed data structure* (or several of them). This data structure is manipulated by operations (such as *map* and *fold*, explained below) which process it as a whole and which happen to be implemented in parallel internally. These operations can be interleaved with sequential computations working on non-distributed data.

In fact, the programmer views the computation as a sequence of parallel operations. Conceptually, this is almost as easy as sequential programming. Communication problems like deadlocks and starvation cannot occur. Currently, two distributed data structures are offered by the library, namely:

```
Template <class E> class DistributedArray{…}
Template <class E> class DistributedMatrix{…}
```

where `E` is the type of the elements of the distributed data structure. By instantiating the template parameter `E`, arbitrary element types can be generated. This shows one of the major features of distributed data structures and their operations. They are *polymorphic*. A distributed data structure is split into several partitions, each of which is assigned to one processor participating in the data parallel computation. Currently, only block partitioning is supported. Other schemes like cyclic partitioning may be added later.

Two classes of data parallel skeletons can be distinguished: computation skeletons and communication skeletons. *Computation skeletons* process the elements of a distributed data structure in parallel. Typical examples are the following methods in class `DistributedArray <E>`:

```
void mapIndexInPlace(E (*f)(int,E))
E fold(E (*f)(E,E))
```

`A.mapIndexInPlace(g)` applies a binary function `g` to each index position `i` and the corresponding array element `A[i]` of a distributed array `A` and replaces `A[i]` by `g(i,A[i])`. `A.fold(h)` combines all the elements of `A` successively by an associative binary function `h`. E.g. `A.fold(plus)` computes the sum of all elements of A (provided that `E plus(E,E)` adds two elements). *Communication* consists of the exchange of the partitions of a distributed data structure between all processors participating in the data parallel computation. In order to avoid inefficiency, there is no implicit communication e.g. by accessing elements of remote partitions like in HPF (Kennedy, Koelbel, & Zima, 2007) or Pooma (Crotinger et al., 2000). Since there are no individual messages but only coordinated exchanges of partitions, deadlocks and starvation cannot occur. The most frequently used communication skeleton is

```
void permutePartition(int (*f)(int))
```

A.permutePartition(f) sends every partition A$_i$ (located at processor i) to processor f(i). f needs to be bijective. This is checked at runtime. Some other communication skeletons correspond to MPI collective operations, e.g. allToAll, broadcastPartition, and gather. For instance A.broadcastPartition(i) replaces every partition of A by the one found at processor i.

Moreover, there are operations which allow to access attributes of the local partition of a distributed data structure, e.g. get, getFirstCol, and getFirstRow fetch an element of the local partition and the index of the first locally available row and column, respectively. These operations are no skeletons but frequently used when implementing an argument function of a skeleton.

At first, skeletons such as fold and scan might seem equivalent to the corresponding MPI collective operations MPI_Reduce and MPI_Scan. However, they are more powerful due to the fact that the argument functions of all skeletons can be *partial applications* rather than just C++ functions.

A skeleton essentially defines some *parallel algorithmic structure*, where the details can be determined by appropriate argument functions. With partial applications as argument functions, these details can depend themselves on parameters, which are computed at runtime.

Consider the code fragment for Gaussian elimination in Listing 1.

```
double copyPivot(const DistributedMatrix<double>& A,
                 int k, int i, int j, double Pij){
  return A.isLocal(k,k) ? A.get(k,j)/A.get(k,k) : 0;}

void pivotOp(const DistributedMatrix<double>& Pivot,
             int rows, int firstrow, int k, double** LA){
  for (int l=0; l<rows; l++){
    double Alk = LA[l][k];
    for (int j=k; j<=Problemsize; j++)
      if (firstrow+l == k) LA[l][j] = Pivot.getLocalGlobal(0,j);
      else LA[l][j] -= Alk * Pivot.getLocalGlobal(0,j);}}

void gauss(DistributedMatrix<double>& A){
  DistributedMatrix<double> Pivot(sk_numprocs,n+1,0.0,p,1);
  for (int k=0; k<Problemsize; k++){
    Pivot.mapIndexInPlace(curry(copyPivot)(A)(k));
    Pivot.broadcastRow(k);
    A.mapPartitionInPlace(curry(pivotOp)(Pivot,n/p,
                                          A.getFirstRow(),k));}}
```

Listing 1. Gaussian elimination with data parallel skeletons.

As one expects, the main method gauss consists of a loop, where in every iteration the pivot row is broadcasted and the pivot operation is performed for every element of the considered matrix.

The example in Listing 1 demonstrates that the programmer has a global view of the computation. Distributed data structures are manipulated as a whole. If you compare this to a corresponding program which uses low-level frameworks directly, you will note that the latter is based on a local view of the computation. It just uses the locally available partitions of the global data structures, which only exist in the programmer's mind. This has several consequences. First, the index computations are different. In the low-level implementation, all array indices in every local partition start at 0, while the indices are usually global when using skeletons. For partition `(i,j)`, they start at `(i*m,j*m)` (where `m` is the number of rows and columns in each partition). If the actual computation depends on the global index, the global view is more convenient and typically more efficient. Otherwise the local view is preferable. Without skeletons, there is no choice: only the local view is possible. However for skeletons, we can provide the best of both worlds. We just have to add access operations, which support the local view or a combination of global and local view in order to provide the most convenient operations.

In general, the local view has the advantage that the computation may be more easily optimized to the special needs at each processor. Consider the Gaussian elimination example above. From a global perspective, one would have to apply the pivot operation to every element of the matrix. For the columns to the left of the pivot column this computation would be redundant, and it could be easily avoided based on a local perspective. For such situations, the skeleton library provides specialized versions of the corresponding skeletons, which do not refer to single elements of a distributed data structure but to every partition as a whole. This allows similar optimizations than the local view at the price of lesser elegance. In the above situation the skeleton `mapPartitionInPlace` can be used instead of `mapIndexInPlace` in order to process a partition as a whole.

3 Experimental Results

Since the skeleton library has been implemented on top of MPI, openMP, and CUDA, it will hardly be possible to outperform hand-written C++ code based on these low-level frameworks. Thus, the question is whether the implementation of the skeletons causes some loss of performance and how large this will be. In order to investigate this, we have implemented a couple of example programs in both ways, with skeletons and using low-level frameworks. We have considered the following kernels of parallel applications:

- **Matrix multiplication**: based on the algorithm of Gentleman (Quinn, 2003): this example uses distributed matrices and the skeletons `mapIndexInPlace`, `rotateRows`, and `rotateCols`.
- **All pairs shortest paths**: based on matrix computations: this uses essentially the same skeletons as matrix multiplication.
- **Gaussian elimination**: **t**he matrix is split horizontally into partitions of several rows. Repeatedly, the pivot row is broadcasted to every processor and the pivot operation is executed everywhere. This example mainly uses `mapPartitionInPlace` and `broadcastPartition`.

Table 1 shows the results for the above benchmarks on the PALMA multi-node, multi-core cluster at the University of Münster (Ernsting & Kuchen, 2012). Each

Table 1 Runtimes (in s) for different benchmarks with and without skeletons

Example	Computing nodes	Cores	GPUs	Runtimes (s)	
				Muesli	MPI+(OpenMP or CUDA)
Matrix multiplication (8192 × 8192)	1	1		8633.22	12019.21
	4	4		549.93	505.21
	64	12		7.41	7.66
	1		1	108.11	96.71
	1		4	22.73	22.844
All pairs shortest paths (8192 × 8192)	1	1		115459.21	155617.57
	4	4		7209.63	6799.30
	64	12		98.77	88.49
	1		1	1352.82	1205.97
	1		4	278.27	248.14
Gaussian elimination	1	1		469.35	564.31
	4	4		45.09	53.78
	64	12		6.47	1.51
	1		1	142.48	140.05
	1		4	39.53	40.42

compute node consists of two Intel Xeon Westmere X5650 processors with 6 cores each (12 in total). One node of this cluster has 4 Nvidia Geforce GTX480 GPUs. Columns 2, 3, and 4 show the number of cluster nodes, cores per node, and GPUs used. Columns 5 and 6 show the runtimes in seconds using Muesli and the low-level frameworks, respectively. Obviously, Muesli can compete with the low-level frameworks. Also, the scalability of the skeleton-based implementations is similar to that of the low-level implementations.

4 Conclusions and Future Work

We have presented the skeleton library Muesli, which provides a structured approach to parallel programming and enables the simple development of portable parallel programs. In particular, it provides task parallel skeletons generating a system of communicating processes as well as data parallel skeletons working in parallel on a distributed data structure. Task and data parallelism are combined based on the two-tier model. The C++ binding of the skeleton library has been presented. Moreover, experimental results for some draft implementation based on MPI, OpenMP, and CUDA show that the higher programming level can be gained without a significant performance penalty. Communication problems such as deadlocks, starvation, and race conditions are avoided, since there are no individual messages but coordinated communication operations.

As future work, Muesli has to be applied to a variety of domains in order to find out whether its current design is flexible enough or whether it needs to be extended. Moreover it has to be investigated whether the global view of the computation allows for performance optimizations.

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