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Digital Cultural Heritage

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Augmenting Network Analysis with Linked Data for Humanities Research

Jörn Kreutel

Abstract We will outline the motivation of a web based software tool for social network analysis that particularly aims at enriching the exploration of network visualisations by linking them back to the original data from which networks have been created. We will identify three aspects of enrichment, present the architecture of an existing prototypical implementation and compare its scope with the one of an exemplary tool for SNA that is widely used within the digital humanities. With respect to the latter, we see evident advantages of our solution when it comes to supporting a seamless workflow of network creation, analysis and exploration based on parameterisable queries of the underlying data sources.

Keywords Social network analysis · Digital humanities · Semantic web

1 Introduction

Social network analysis (SNA, see, e.g., [6, 22]) has been found to be a promising quantitative approach offering various fields of application in the area of humanities and cultural studies [10, 16]. Complementing concepts like, e.g, Bourdieu's idea of *field* [8] SNA can be employed for reconstructing the mechanisms that underlie particular actors' careers within a given discipline [7, 11], and thus may contribute to understanding processes of reception like an actor's canonisation or decanonisation, which appear relevant from the point of view of the emergence of cultural heritage. In fact, applications of SNA range beyond its original focus on relationships between social actors towards a coverage of any phenomena that can be represented by graphs and analysed in terms of the formal properties of a graph's nodes and edges [21].

However, actually employing SNA for particular research objectives requires appropriate technical tools for creating and analysing networks and visualising analysis results, which should allow for a seamless workflow at the level of the employed user interfaces. Here, we will present and discuss the prototype of a software sys-

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tem und user interface supporting SNA and associated statistical analyses on the underlying data, which has been developed in the course of ongoing research on bio-bibliographical data, dealing with GDR literature, on the one hand, and the history of German literature studies, on the other. Considering the current state of our system, the objective of this paper is to raise the question of how SNA can be integrated within a wider scope of applying quantitative methods in the humanities and what tools are required for this purpose.[1]

In particular, our prototyping efforts addressed the question how an integrated workflow can be supported for SNA and the exploration of analysis results on the basis of various types of linkable data, including databases and web pages. As we will argue below, this requires appropriate expressive means that go beyond the scope of tools for mere network analysis and visualisation (see [1] for an overview and [2] as a prominent example) and provide enhancements both at the level of data evaluation and the user interface. Adhering to the idea of a widely accessible platform for supporting augmented SNA as a *Software as a Service* solution [17], our prototype is based on standard web technologies and can be accessed by any state-of-the-art web browser, rather than requiring individual installations.

In the following sections, we will outline the rationale for augmenting network analysis and enhancing analysis tools, looking at how networks to be analysed may be created as abstractions from arbitrarily rich underlying data. We will then describe three aspects of enhancements that are currently supported by our prototype and exemplify their usage with examples from bibliographical and co-occurrence networks. After a brief outline of the software architecture of the system, we will compare its functionality and expressive means with what could be achieved using *Gephi* [2] as one of the most prominent and established SNA tools in the area of digital humanities. [13, 24].

[1]Starting point of system development was the attempt to create a proof-of-concept implementation for integrating network creation based on SPARQL [12] queries, network analysis and network visualisation, using co-occurrence networks of drama characters as an example case (see Sect. 3). The requirements of the system then have been iteratively extended based on the author's cooperation with domain experts, and functionality has been verified by intense system usage of the author himself and within joint workshops with the experts. However, the system is prototypical in the sense that it has not been used by the latter experts independently of the author. In addition to DCH 2017, the ideas outlined here have been discussed with SNA experts from the digital humanities community, see *A Web Based Workbench for Augmenting Network Analysis with Linked Data Evaluations*, presented by Jörn Kreutel at *Potsdamer Arbeitstreffen zur digitalen Literaturwissenschaft No. 2*, December 4, 2017 (https://www.uni-potsdam.de/lit-19-jhd/digitale-literaturwissenschaft/potsdamer-arbeitstreffen/no2-2017.html). First findings from co-publication analyses on a corpus of works on German literature studies have been presented by Steffen Martus and Fotis Jannidis in *Was verändert sich eigentlich? Korpusanalytisch basierte Wissenschaftsgeschichte der germanistischen Praxis* at *DFG-Symposium 'Digitale Literaturwissenschaft'* on October 10, 2017 (http://www.germanistik.uni-wuerzburg.de/en/lehrstuehle/computerphilologie/aktuelles/veranstaltungen/dfg-symposium-digitale-literaturwissenschaft/).

2 Network Creation as Data Abstraction

As outlined in, e.g. [6, 22], SNA is usually done on networks the nodes of which either represent entities of a single type—e.g. persons—or, in the case of *bipartite* networks, belong to two different types of entities, whose affiliation with each other is modelled by the network—as in a network that models people's attendance to events or their association with institutions. In any case, the connecting edges of the network represent a single type of, possibly weighted and either directed or undirected, relation with respect to which the quantitative properties of the network may be determined.[2] These relations might be concrete relations or abstractions from the latter, e.g. the two fairly concrete relations of persons being friends or colleagues might be abstracted to the relation of persons knowing each other which could be assigned a weight depending on the number and type of its underlying concrete relations.

Hence, in order to employ SNA for some given domain, the networks to be analysed may not necessarily be represented by the primary data available, but might need to be constructed from the latter, which might involve the assumption of abstract relations like the ones mentioned above. In particular, this is the case if SNA shall be applied on data the model of which has not been designed with the idea of applying SNA in mind, but that, nevertheless, can be interpreted in terms of relations between associated entities from a given research perspective. An example for this is bibliographical data, a possible structure of which is exemplified in Fig. 1. In order to analyse, e.g., the relationships between authors that are constituted on the basis of the common appearance of authors' contributions in collections or anthologies, the actual relations that will be represented by the network's edges need to be extracted from the bibliographical data and be weighted, e.g., depending on the number of joint appearances. At the level of the network, the detail information on the associated entities and the grounds of their associations will then not be present anymore. However, both for exploring the network at the level of an interactive visualisation and for quantitatively analysing the network, additional information on the associated and associating entities—like an author's name, age and their affiliation with institutions, or the collections' titles, publishers and years of appearance, respectively—might be necessary for a holistic understanding of the phenomena to be investigated. For bibliographical analyses, this holds, for example, if different networks of the same type, different partitions of an overall network or networks for different time intervals shall be compared to each other in terms of domain specific 'key performance indi-

[2]For example, the relevance of a node within a network may be measured applying different concepts of *centrality* like *degree*, *eigenvector* or *betweenness* centrality. Using methods of *community detection*, on the other hand, nodes can be classified as belonging to different groups or 'cliques' [6, 22].

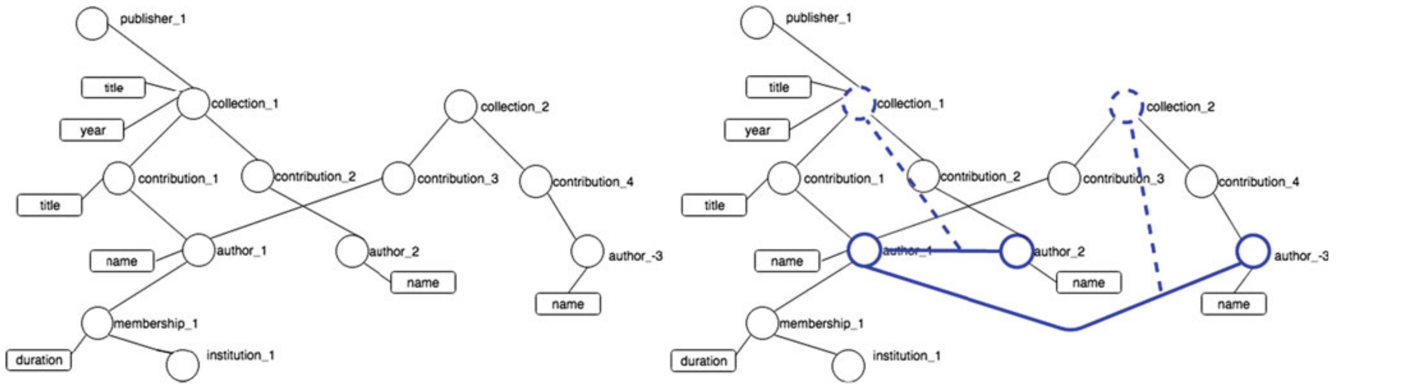

Fig. 1 Bibliographic sample data (left) and abstraction of network relations based on authors' contributions to collections (right). Here, co-publication relations can be assumed between *author_1* and *author_2*, and *author_1* and *author_3*, on the basis of their contributions to *collection_1* and *collection_2*, respectively

cators' like the network authors' overall publication output or their association with publishers and other publishing media than the ones that constitute the network.[3]

As for the user interfaces employed for SNA studies in some particular domain and the expressive means for quantitative analyses, tools therefore need to allow for a certain degree of re-concretisation of abstracted network data, the extent of which will depend on the given overall research interests and the possibly iteratively refined proceeding of the investigation. For the particular case of bibliographic analyses, Klink et al. [14] propose a powerful tool that provides advanced browsing capabilities for the DBLP computer science bibliography (http://dblp.uni-trier.de/), including the creation and visualisation of network analyses on the basis of the bibliographic data. However, the *DBL Browser* is a standalone software solution to be run locally on each user's machine, and it is restricted to the domain of bibliographic analyses, which is a relevant, but yet not the only domain where advanced capabilities for network analyses are desirable. Hence, we find it worthwhile to conceive of a domain independent tool, which rather than being a complete, but monolithic solution provides a comparably thin integration layer that mediates between the primary data sources for SNA, the execution and visualisation of SNA and enhanced statistical analyses, and the exploration of analysis results linking back to the original data and other linkable data sources. The latter does not imply the provision of full-fledged browsing capabilities on the part of the integration layer, but may at least partially rely on existing web based solutions for browsing content like the viewers provided by the databases themselves.[4]

3 Enhancements for Network Exploration and Analysis

For the desired re-integration of primary data and the further integration of associated data sources, we identified three major 'extension points' at the level of a user interface for SNA, further described below. The extension points *network manipulation* and *network browsing* are related to the level of the visualisation of a single network as a graph and the interactive exploration of its content. *network statistics*, on its part, may apply to the creation of statistical analyses to sets of networks, which may represent, e.g., sequences of stages of a network at different time intervals, different partitions of a single network, or different networks representing different relations of actors, which shall be compared to each other:

1. **Network Manipulation**: When exploring a network starting from a visual representation, it is desirable to be able to manipulate this visualisation not only on the basis of genuine SNA measures like the *centrality* of nodes, the partitioning

[3]These requirements are based on a synopsis of work on scientific networks and the types of analyses employed therein, e.g. [9, 20, 26], as well as on desiderata that were raised in the course of carrying out our own analyses on bibliographical data.

[4]See, e.g., the RDF content browsing facilities of the *GraphDB* database (http://graphdb.ontotext.com/), which we employ for data storage.

of nodes in different *communities* or the strength of edges [6, 22], but also with respect to other attributes of nodes and edges that might not have been themselves subject of SNA measurements. For example, in a co-publication network, the size of nodes might be modified, as shown in Fig. 2, depending on the overall publication output of the author represented by the node, and edges might be subject to applying measures considering, e.g., the seniority of related authors in terms of age or status [20]. Hence, the user interface for graph visualisation should allow for domain specific extensions[5] that support the consideration of such additional criteria in order for domain experts to gain a more wholistic view of a network, and to be able to interactively identify sub-networks, which may then, on their part, be subject to dedicated SNA measurements.
2. **Network Browsing**: In addition to network manipulation, which operates with domain specific measurements as quantitative abstractions over concrete data associated with nodes and edges, network exploration might also involve the insight into the concrete and more complete data underlying the latter. For example, co-publication networks might be linked to structured or unstructured data related to their nodes and edges such that, e.g., the available database content on authors or content from additional data sources like online encyclopediae will be displayed when interacting with their visualisations. As for another prominent field of applying SNA in the humanities, edges of co-occurrence networks of actors extractable from literary works [15, 25] might be linked to the actual text fragments within the respective works that are constitutive for the edges. For this purpose, the user interface must support the domain specific creation of views that will display the associated information and integrate them within the overall navigation structure for network exploration. Figures 2 and 3 show how these requirements are currently dealt with by our prototype.
3. **Network Statistics**: Particularly when dealing not only with a single network, but with several networks or several partitions of a network, it is desirable to gain an overview both of the SNA core measures, in the sense of [22], of the respective networks or sub-networks, and of associated domain specific measurements applicable to the networks' nodes and edges. For example, if bibliographical data is enriched by additional biographical data, age profiles or seniority profiles for the authors of co-publication networks can be calculated and analysed, e.g., in terms of temporal development or with respect to different sub-networks of authors, as shown in Fig. 4. Likewise, the overall publication output of network authors beyond a given network of co-publications can be made subject to comparative evaluation by applying appropriate calculations. Considering not only aspects like the quantity of output, but also, e.g., publishers or journals in which contributions appear, might help to identify network partitions as, e.g., 'mainstream' versus 'elite' versus 'niche' sub-networks. Hence, the tools employed for network analysis need to support the creation and visualisation of such additional

[5] As we will argue in Sect. 5, this does not require that the additional information on nodes and edges is represented by the network itself, but only that it is retrievable based on the given representation of the network.

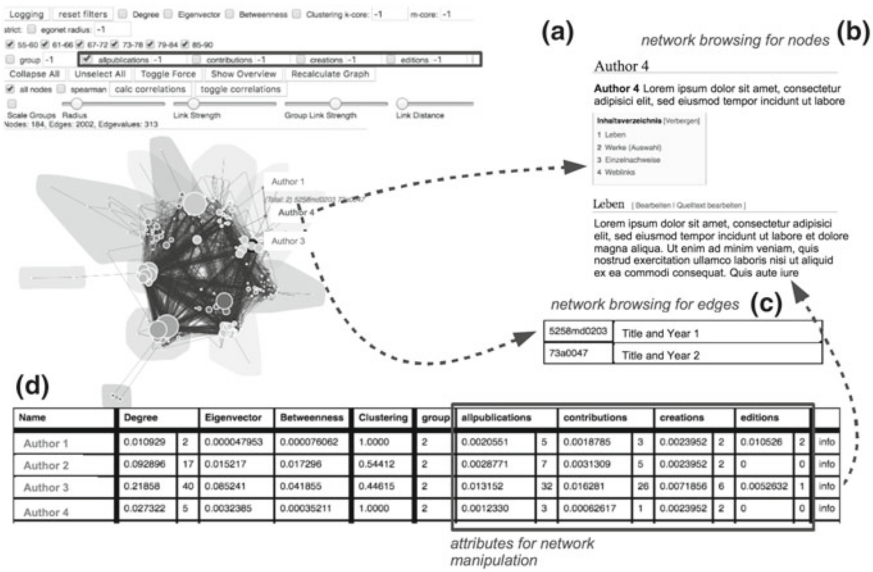

Fig. 2 Examples for domain specific *network manipulation* and *network browsing* on the basis of a co-publication network. Size of network nodes can be manipulated, and nodes can be filtered on the basis of the highlighted domain specific attributes, where control elements are provided in addition to the elements for base SNA measures (**a**, **d**). Selecting a node will navigate the user to an online encyclopedia entry of the respective author, if available (**b**). On selection of an edge, the list of collections to which the associated authors have contributed will be displayed (**c**)

measurements, which like the other two extension cases enrich the means for core network analysis, in order for researchers to gain wider quantitative insight into a given domain.

In addition to these functional requirements on enhanced network analysis, which are formulated from a domain expert's perspective, both for sustainable continuous work within particular research projects and for transparently disclosing the methods underlying their outcomes, analysis tools should support a modular organisation of the technical artifacts, e.g. queries and processing scripts, to be created for domain specific analyses, aiming at seamless reusability and extendibility. The following sections will give a brief overview of how these technical requirements are addressed by our current prototype.

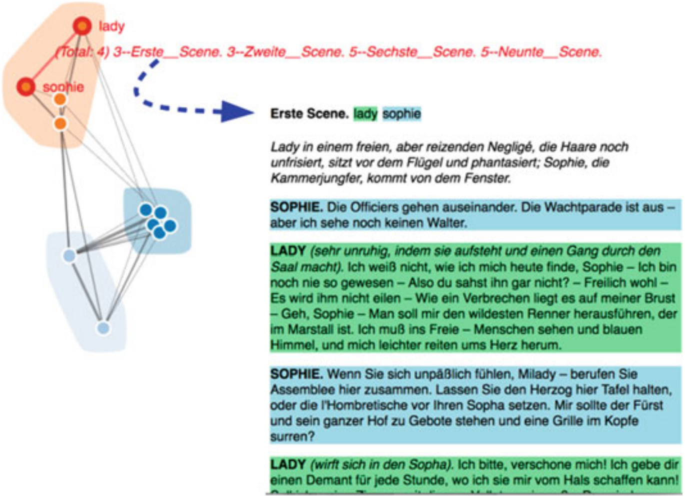

Fig. 3 Example for *network browsing* of a co-occurrence network. Selection of an edge value will navigate the user to the selected scene in which the two characters appear. Texts are taken from an online corpus made available through the *Project Gutenberg* initiative (e.g. http://gutenberg.spiegel.de/), which also serves as the basis for identifying co-occurrence

4 System Architecture

The realisation of the overall system architecture shown in Fig. 5 comprises a rich client user interface using state-of-the-art web technologies[6] and a JavaScript backend provided by a *Node.js* (https://nodejs.org) server for managing domain specific configuration settings and extensions, and for executing the overall workflows for network analysis and enhanced network statistics in the above sense. Adhering to the overall idea of the semantic web [3] and the support of technologies compatible with linked open data [5] infrastructures, primary data from which analysable networks are extracted are stored in an RDF [19] repository, read and write access to which is mediated by a web service that uses the Java *rdf2j* library (http://rdf4j.org/) for processing SPARQL [12] queries. For the core network analysis employing SNA measurements, we run the *NetworKit* toolkit [23] within a thin server layer written in Python.

The support for domain specific enhancements of network exploration and analysis is based on the employment of dynamic JavaScript execution of custom implementation artifacts both within the browser and the Node.js backend. Both environments provide support for executing queries on the underlying data and ex-

[6]In particular, we use the *D3.js* framework (https://d3js.org/) for visualising graphs and statistical analyses, and *CodeMirror* (https://codemirror.net/) for displaying and editing implementation artifacts within the web browser. Starting point for the concrete graph visualisation was the open source solution proposed on http://bl.ocks.org/GerHobbelt/3071239.

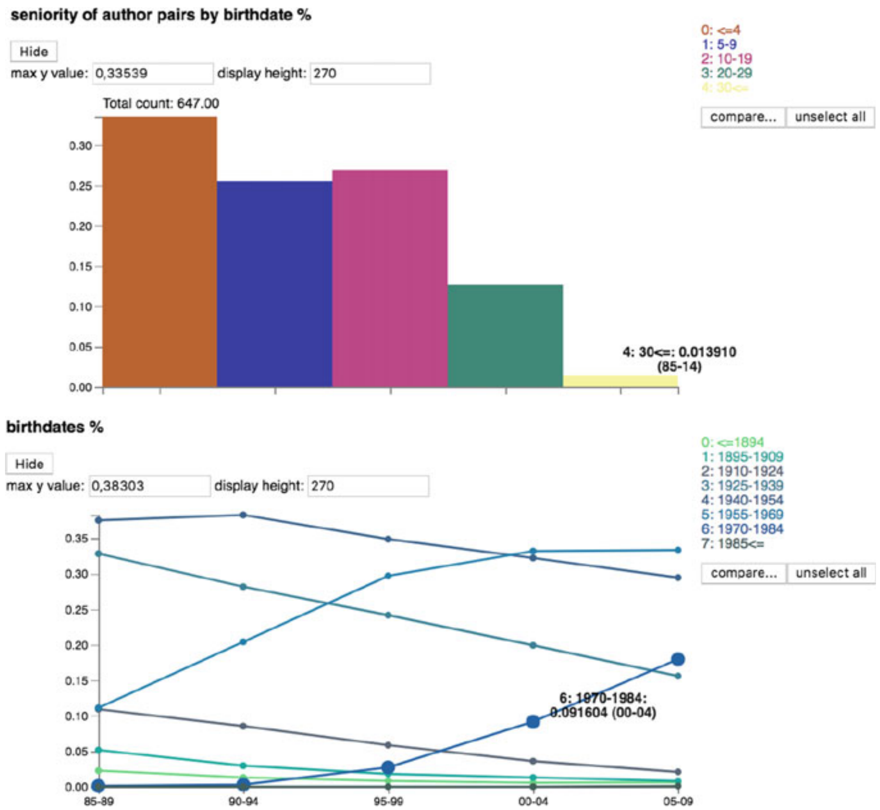

Fig. 4 Examples for *network statistics*. The bar chart (top) shows the age difference, as one aspect of seniority, of author pairs in a co-publication network, whose underlying data has been enriched with biographical information. The line chart (bottom) displays, for a complete bibliography, the shares of authors' age groups with respect to all publishing authors over a sequence of time intervals. Here, one can observe, e.g., a fairly parallel development of the age groups 1955–1969 and 1970–1984 with regard to their positioning within the overall field

ternal data sources, including access to web pages, and offer a library of data types and operations on the latter for processing query results. In particular, results may be represented as sets of tuples or interpreted as graphs, and operations comprise, among others, set operations like intersections and unions, as well as filtering and partitioning operations on these types, and the application of statistical operations like correlation analysis.[7]

For implementing domain specific artifacts that realise one or more of the extension points outlined in the previous section, users create JavaScript components,

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[7]Using these means, for example, a set of publications can be filtered on the basis of the nodes of a co-publication network in order to determine publication output, publishers, journals, etc. for the authors of the particular network. Additional statistical analyses can be done using the JavaScript *jstat* library (https://github.com/jstat/jstat).

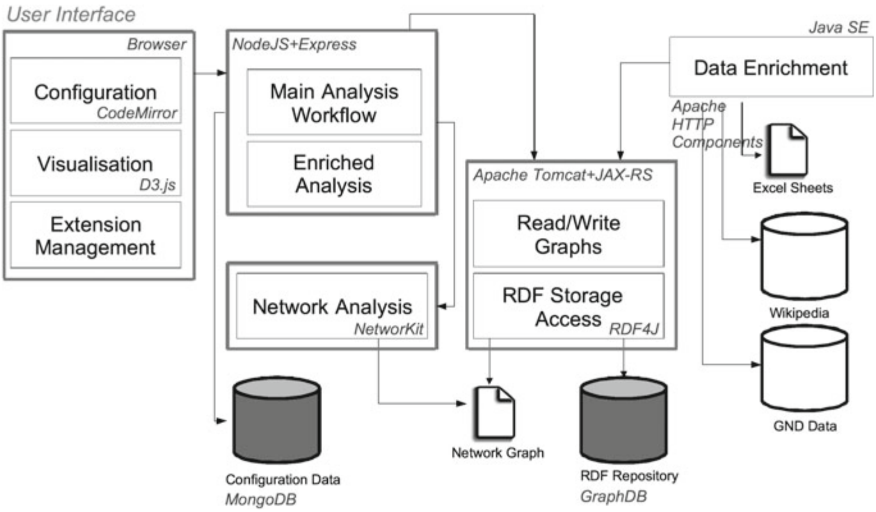

Fig. 5 System architecture and technologies used for realisation. On the right hand, different examples for enriching primary data using content from linkable structured or unstructured data sources like the GND authority file (http://www.dnb.de/EN/Standardisierung/GND/gnd_node.html) or Wikipedia, respectively, are shown

which can be either uploaded and imported via the user interface or edited within the latter. These components are named and can be reused for analysing any networks that have a common structure and are based on structurally compatible primary data, for example co-publication networks that are created from data sources with shared RDF vocabulary. Additionally, components are subject to an inheritance mechanism inspired by object oriented programming languages and can extend and override each other's functionality.

Apart from these possibilities to create domain specific extensions for network analyses, the prototype allows for the, even more fundamental, creation of networks based on 'query patterns' for the underlying primary data. In our particular case, we use SPARQL queries that contain variables which are filled by the system before executing the query. This way, it is possible, e.g., to create a set of temporal 'snapshots' of a network for different subsequent or overlapping time intervals, each of which will be subject to core SNA and possibly further measurements. At the level of network visualisation, snapshots can be integrated into a single view. Filtering capabilities will then allow to visualise the dynamic evolution of a network over time, including the application of enhancements for network manipulation and browsing mentioned above.

Given this overall functionality, the system does not only support a seamless workflow for network creation, analysis, visualisation and exploration, and the creation of network statistics from a single web based user interface. It also allows for a clear division of labour between domain experts using the system for getting insight into a particular data set, and research engineers who create domain specific implementation resources based on the experts' requirements and make them available using the system's extension points.[8] Here, modularisation and extension capabilities at the level of the domain specific programming artifacts themselves are important features for ensuring maintenance and extendability of artifacts for longer running research with, expectedly, iteratively refined perspectives on the data to be investigated.

5 Related Work

Particularly within the digital humanities community as a our primary field of application, Gephi [2] seems a widely used tool for network analysis, visualisation and exploration.[9] For comparing the existing and envisaged functionality of our prototype, Gephi therefore appears to be an appropriate benchmark. See [1] for a wider comparison of existing tools, which, however, only focusses on the mere SNA related functionality, rather than the enhancements to SNA in the sense of the re-concretisation of abstract networks that has been a main motivation of our own development efforts.[10]

To mention, at the beginning, a major drawback of our own solution, our web based prototype currently is by far less powerful than Gephi and the other tools analysed in [1] with regard to the performance of rendering network visualisations and interactively exploring a network. It runs into trouble if networks with more than 10,000 nodes and/or 30,000 edges shall be visualised in an expanded way, i.e. not only at the macroscopic level of a network's communities.[11] In such cases, filters need to be applied in order to obtain a sub-network with handleable size. For improving performance it appears feasible to change the underlying framework for graph visualisation from SVG based *D3.js* (https://d3js.org/) to a more powerful alterna-

[8] A systematic reflection on these roles and their respective contribution to the joint research effort of digital humanities projects has only started recently. See, e.g., the working group on *research software engineering in the digital humanities* (http://dig-hum.de/ag-research-software-engineering-den-digital-humanities) that dedicates itself to this purpose.

[9] This judgement is based on the author's impression gained from research literature and blog posts on concrete SNA usage (see, e.g. https://dlina.github.io/Mayakovsky-Klop/) and has been confirmed by members of the digital humanities community. For a public, yet informal, source see https://en.wikipedia.org/wiki/Gephi.

[10] As for SNA itself, our architecture is designed in a modular way such that NetworKit, which is currently used, could be replaced with any other tool offering an API that can be integrated and exposed by a web service, see, e.g., the SNA package for the R statistical computing environment (https://cran.r-project.org/web/packages/sna/index.html). Likewise, at the level of the user interface, the setting of parameters for SNA has been designed as an extension point on its own and, hence, would be replaceable by tool-specific settings. Finally, access to the actual network data and the results of network analysis is mediated by the Java backend service, which could be extended to cover alternative graph representations if necessary, or be replaced with an alternative service adhering to the latter's API.

[11] In contrast, the comparative analysis in [1] uses a network with 77,317 nodes and 982,787 edges.

tive, e.g. *sigma.js* (http://sigmajs.org/) that uses WebGL.[12] However, particularly if both quantitative and qualitative perspectives are meant to be applied, network visualisation in the humanities might not necessarily deal with large amounts of data,[13] but strongly requires user interfaces that are able to mediate between the two perspectives.

Gephi, on its part, is designed as an extendable infrastructure that offers a plugin mechanism for domain specific customisation and extensions of the tool's core functionality. As for the three aspects of re-concretisation mentioned in Sect. 3, it mainly supports domain specific extension points for network manipulation and network statistics. For example, it allows to implement customised filters that run on the graph data itself or on external data and modify the visualisation (see, e.g., https://github.com/gephi/gephi/wiki/How-to-use-filters). It is also possible to execute customised statistic evaluations, primarily on the graph data itself, but also here, external data could be included (see https://github.com/gephi/gephi/wiki/Statistics). As Gephi is built on top of the Java *NetBeans* platform (https://netbeans.org) and allows to capture interaction events at the level of graph visualisation, extensions for *network navigation* in the sense described above, also appear possible. However, even though installation and update of custom plugins can use an integrated distribution mechanism, usage of plugins will always be bound to concrete Gephi execution environments, rather than being independent of any workplace as in the case of a web based platform like ours.

Principally, Gephi supports domain specific data enrichment either at the level of the network graphs themselves at the time of graph creation, by allowing to enhance a graph's nodes and edges with domain specific attributes, or at the time of graph exploration by appropriate data access implementations. However, this flexibility may result in monolithic solutions that try to deal with any extensions at the level of the network graph, outside of the working environment provided by Gephi. In this case, repeated graph creation would be required as research proceeds and new perspectives on the network's actors and relations arise without the network itself being changed.[14] In contrast to this, our approach to network enrichment, be it for the purpose of manipulation, navigation or statistics, is consequently modular by separating network data from data used for network enrichment and integrating the two aspects dynamically at runtime, where caching mechanisms are employed to avoid processing overhead. This way, enrichments of any type can be reused for analysing and exploring all networks whose nodes and edges have a common type, regardless of the initial research perspective and interests at the time of their creation.

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[12] See https://www.w3.org/TR/SVG2/ and https://www.khronos.org/registry/webgl/specs/latest/2.0/ for the specifications of SVG and WebGL, respectively.

[13] See, e.g., the case of co-occurrence analysis [25] or the analysis of particular circles of actors and their interrelations [4, 20].

[14] This assumption is not based on empirical grounds, but on the author's view of the range of possibilities to employ the expressive means provided by the Gephi infrastructure. However, a random overview of respective tutorials and forums on the latter does et least not strongly hint at a wide spread usage of exploration time data enrichment.

Considering network graph creation, finally, our prototype originated from the attempt to integrate graph creation from primary data in RDF, accessed via SPARQL queries that can be formulated as query patterns, as mentioned above.[15] This way, it is not only possible to easily create sequences of network 'snapshots', e.g. for subsequent time intervals that can be integrated to a joined graph, but also to make the snapshots' parameters available to all extensions that need to take them into consideration. Hence, there is a built-in mechanism for parameterising data enrichment to the given scope from which a network is being viewed and analysed. For Gephi, there also exists a plugin for creating Graphs using SPARQL (https://github.com/gephi/gephi/wiki/SemanticWebImport). Yet, it does not come with dedicated expressive means for pattern based dynamic graph creation and enrichment. Hence, for network graph creation itself external tools would need to be employed. However, from the point of view of our own research and other research interests in the humanities, the evolution of networks will always be an important aspect of the domains to be analysed and should therefore be supported in a seamless way by an integrated platform for network creation, analysis and exploration.

6 Summary

Starting from the observation that the application of SNA on a given data set may require the creation of network graphs that abstract away from many details of that data, we identified three generalisable aspects of re-concretisation that may be provided by software tools for graph analysis and exploration. We then outlined the software architecture of a our own prototypical tool, which particularly addresses these requirements, and compared its functionality and overall approach with the one of Gephi as a prominent solution in the area of digital humanities. We see clear advantages of our solution not only by providing a web based environment, but also considering its support of a seamless workflow for graph creation, analysis and exploration based on a modular organisation of reusable domain specific extensions. Further work will focus on improving graph visualisation performance, on the one hand, and on further enhancing the functionality of the tool's user interface, on the other. In terms of [18], we thus aim at further supporting a seamless mediation between the aspects of *distant reading* and *close reading* with regard to a particular research objective, by linking networks and statistical analyses as abstractions to the concrete data and content from which they originated.

[15] As data access via SPARQL is encapsulated into dedicated components, alternative data sources and query languages like SQL could be integrated into the system infrastructure without any changes to the overall system architecture.

References

1. Akhtar, Nadeem: Social network analysis tools. In: 2014 Fourth International Conference on Communication Systems and Network Technologies (CSNT), pp. 388–392. IEEE (2014)
2. Bastian, M., Heymann, S., Jacomy, M., et al.: Gephi: an open source software for exploring and manipulating networks. In: International AAAI Conference on Weblogs and Social Media. (2009)
3. Berners-Lee, T., Hendler, J., Lassila, O., et al.: The semantic web. Scientific american **284**(5), 28–37 (2001)
4. Biehl, T., Lorenz, A., Osierenski, D.: Exilnetz33. Ein Forschungsportal als Such- und Visualisierungsinstrument. In: C. Baum, T. Stäcker (eds.) Grenzen und Möglichkeiten der Digital Humanities (Zeitschrift für digitale Geisteswissenschaften, Sonderband 1) (2015)
5. Bizer, C., Heath, T., Tim, B.L.: Linked data – the story so far. International Journal on Semantic Web and Information Systems **5**, 1–22 (2009)
6. Borgatti, S.P., Everett, M.G., Johnson, J.C.: Analyzing social networks. SAGE Publications Limited (2013)
7. Bottero, W., Crossley, N.: Worlds, fields and networks: Becker, Bourdieu and the structures of social relations. Cultural Sociology **5**(1) (2011)
8. Bourdieu, P.: Die Regeln der Kunst. Genese und Struktur des literarischen Feldes. Suhrkamp (1999)
9. Burckhardt, D.: Comparing disciplinary patterns: Exploring the humanities through the lens of scholarly communication. digital humanities quarterly **11**(2) (2017)
10. Comsa, M.T., Conroy, M., Edelstein, D., Edmondson, C.S., Willan, C.: The french enlightenment network. The Journal of Modern History **88**(3), 495–534 (2016)
11. De Nooy, W.: Fields and networks: correspondence analysis and social network analysis in the framework of field theory. Poetics **31**(5-6), 305–327 (2003)
12. Harris, Steve and Seaborne, Andy: SPARQL 1.1 Query Language. https://www.w3.org/TR/sparql11-query/ (last accessed on March 21, 2018) (2013)
13. Jannidis, F., Kohle, H., Rehbein, M. (eds.): Digital Humanities. Metzler (2017)
14. Klink, S., Reuther, P., Weber, A., Walter, B., Ley, M.: Analysing social networks within bibliographical data. In: S. Bressan, J. Küng, R. Wagner (eds.) Database and Expert Systems Applications, pp. 234–243. Springer Berlin Heidelberg, Berlin, Heidelberg (2006)
15. Knuth, D.E.: The Stanford GraphBase: a platform for combinatorial computing, vol. 37. Addison-Wesley Reading (1993)
16. Meirelles, I., Schich, M., Malina, R.: Arts, humanities, and complex networks. In: R. Alhajj, J. Rokne (eds.) Encyclopedia of Social Network Analysis and Mining. Springer (2014)
17. Mell, P., Grance, T.: The NIST definition of cloud computing. Special Publication 800-145, National Institute of Standards and Technology (2011)
18. Moretti, F.: Graphs, maps, trees: abstract models for a literary history. Verso (2005)
19. RDF Working Group: Resource Description Framework (RDF). http://www.w3.org/RDF/ (last accessed on March 21, 2018) (2104)
20. Rehrl, M., Palonen, T., Gruber, H.: Professionelle Vernetzung in der Wissenschaft. Unterrichtswissenschaft **38**(4), 334–353 (2010)
21. Sarv, Mari and Laineste, Liisi: Network Analysis in Humanities – Session at the Second European Conference on Social Networks. https://eusn2016.sciencesconf.org/89668/document (last accessed on March 21, 2018) (2016)
22. Scott, J.: Social Network Analysis, 3 edn. Sage (2012)
23. Staudt, C., Sazonovs, A., Meyerhenke, H.: NetworKit: An interactive tool suite for high-performance network analysis. CoRR, abs/1403.3005 (2014)
24. Svensson, P.: The landscape of digital humanities. digital humanities quarterly **4**(1) (2010)
25. Trilcke, Peer and Fischer, Frank and Göbel, Mathias and Kampkaspar, Dario: Digital Literary Network Analysis. http://dlina.github.io/ (last accessed on March 21, 2018) (2015)
26. Wellmon, C., Piper, A.: Publication, power, and patronage: On inequality and academic publishing. Critial Enquiry (forthcoming) (2017)

A Memorial Design Pattern Catalogue for Commemorative Digital Culture

Susanne Haake, Wolfgang Müller and Marc Wolf

Abstract Approaches to remembrance and commemorative culture require most sensitive approaches. This is especially true when developments relate to the digital domain, where the effects and the forms of usage of corresponding offers and artefacts are much harder to control. "Best practices" collections, which might provide guidance to the development of novel products and services linked commemorative culture, are so far missing. In this paper, we present the concept of a catalogue and knowledge base for smart contextualized practices for multimedia applications and products in the field of memorial and culture based on design patterns. We present a comprehensive discussion on corresponding theoretical background, especially with respect to commemorative culture as well as best practice research and design patterns. Further, we present our approach for the identification of patterns and a set of selected examples of design patterns in digital-media based commemorative culture. Finally, the paper provides a discussion on further uses of catalogue and design pattern repository for research.

Keywords Digital heritage · Commemorative culture · Design pattern · Pattern mining

1 Introduction

Each generation and nation has its own way to remember and the commemorative culture is discussed constantly. At least since the 1980s, the Holocaust has been an important part of our memoria, particularly in Germany [1]. The American televi-

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sion series HOLOCAUST (USA, 1979) initiated one of the most important media debates of this decade, initiating a rethinking in the commemorative culture of the Holocaust [2]. Memorials and reminders were created in historical places, literature and movies deal with the topic of Shoah, and eye witnesses tell the story of their life in commemorative events. For just as long, appropriate and contemporary aesthetic expressions of memory have been continuously discussed. With the heyday of commemorative culture, memory studies also receive increased attention [3]. This interdisciplinary research field focuses on the forms and expressions of collective memory with respect to this emotional discussed discourse.

Memory of the Holocaust reached digital media long ago, in which technical progress is reflected in the design of digital products. Up to now numberless digital memorial products can be found: web offerings, but also applications (apps), virtual exhibitions, up to databases of interviews with witnesses provided as video clips. However, the introduction of digital media in a memorial context not always took place without problems and complications. For instance, there have been heated discussions on whether it is appropriate to use smartphones with multimedia apps and games like YOLOCAUST [4] and POKEMON Go! [5] at memorial places, such as former concentration camps. Jewish artist Shapira accused tourists doing funny selfies on the memorial by publishing his project YOLOCAUST online. For him, these people didn't behave correctly or respect the victims and their families in an adequate way [4]. In his web art project he combined these selfies with pictures from extermination camps to show how disturbing the behaviour of doing selfies from his perspective is. One further debate focused on playing augmented reality games on memorial places. The developers of the smartphone games POKEMON Go! and also INGRESS had to delete game areas in former concentration camps due to the heated public debate [5].

These examples once again underline that remembrance and commemorative culture require most sensitive approaches. This is especially true when corresponding approaches are mapped into the digital domain, where the effects and the forms of usage of corresponding offers and artefacts are much harder to control, due to the virtual distance to users, the lack of knowledge on the context, where they access the media products, and the variety of technologies they may use. The examples above show clearly that design decisions, especially in the development of new digital memorial products, may easily result in unforeseen and unwanted effects, which should be clearly avoided in this sensitive domain. On the other hand, positive examples and good practices should be disseminated, to foster the development of most successful applications that avoid pitfalls and render most effective. This is especially important since developments in this field are usually pursued with limited resources at hand, making it most important these as effectively as possible.

While remembrance culture represents a well-studied research field, studies on digital media based approaches have been mostly neglected for long. Corresponding research started in the last years, yet, mostly restricted to the analysis of effects of specific forms of digital media in this context, on commemorative recollection in the social media, and to detailed analysis of individual websites [6]. More general research on the various effects of digital media in this field, and especially on "best practices" is mostly missing, with the exception to applications in the educational field [7]. In specific, there is a lack of comprehensive references to good practices that may provide guidance in the development of new forms of digital memorial products.

Against this background, our research targets to extract and gather practice knowledge in terms of smart practices, as well as to induce general principles. The objective is to provide identified smart practices in the field of digital memorial and culture in an online repository, to be furthered and managed in virtual collaborations with international experts in the field. We foresee that the corresponding catalogue will provide a comprehensive reference of smart, contextualized practices for products and media-related artefacts in the field of memorial and culture in field of practise, that it will serve as a knowledge base providing a standard vocabulary to support design debates between experts, and that it may set the ground for a lingua franca in discussion between different stakeholders involved in the design, development and evaluation of artefacts.

Important contributions of this paper are a concept to document smart practices in the field of commemorative culture based on an adaptation of design patterns, a methodology to identify and collect such patterns based on a deductive approach, and a set of examples for corresponding design patterns, linked to design patterns from HCI.

The remainder of this paper is structured as follows: First, we discuss related work, specifically on remembrance in commemorative culture in a media context, and on "best practice" research in general, as well as in the field of commemorative culture. Thereafter, we present approach to identify and document smart practices in the field based on a design pattern approach, followed by a presentation and brief discussion of selected patterns from commemorative culture. A discussion and a sketch of further work completes our contribution.

2 State of the Art

2.1 Digital Remembrance in Commemorative Culture Studies

Memoria represents on the most important topic in defining cultural identity [8]. The knowledge of mankind is transported from one generation to the next. Collective memory, in this context, is typified as a repository of knowledge and information in the memories of social groups or nations. This goes back to the theory of so called “cadres sociaux”, inside them collective memory can be generated [9]. Firstly recorded in oral narrations, later media is used to save memories. For this, commemorative culture produces recollections, that are stored in collective memory. Media plays an important role in this field, particularly in saving cultural heritage. According to this, the term of collective memory is translated into media aspects, transformed in “cadres mediaux” [1].

Public memory is often linked to places and enshrined in memorials such as the Holocaust memorial in Berlin (Germany) or Yad Vashem in Jerusalem (Israel). This refers directly to Nora’s “lieux de memoire” (places of memory), which collect artifacts that where collective memory crystallizes and secretes itself [10]. Firstly developed in case of France, places of memory were adapted in other countries, for example in Germany. This refers to the spatial turn in cultural studies with respect to the understanding of space as a cultural dimension [11].

Inside this discourse, remembering the Holocaust represents a well-studied research field from different disciplines: historical science, literature, photography, film and art [12]. These fields are described as a commemorative medium, but also as an instrument to communicate memorial aspects. Both parts represent describing forms of collective memory of the Holocaust. The discourse also concentrates on debates, if a commemorative culture is still needed [13]. Analysing remembrance culture in digital media was initially neglected. In the last few years, however, first investigations have emerged in this area, in particular on digital media related topics, on commemorative recollection in the social media and with regards to individual websites [6]. These studies can be integrate into a bigger discourse about how collective memory can be defined inside new media age in general [14]. From this, first studies about forms of new media Holocaust remembrance are published. They focus on how a global memory can be defined in the context of a new memory community [15].

In this context, best practises of using new media in commemorative context can be added in the field of Holocaust education [7]. Memorial websites, forms of remembrance in social media and applications in a memorial context are described for teaching aspects. There exist different studies with best practises in teaching about the Holocaust in several countries, mainly in the USA and Germany [16]. They include empirical studies to measure the impact of teaching about the Holocaust with digital media in school context.

In summary, there are rarely described best practises in a non-pedagogical context [17]. Corresponding studies stress pedagogical, or general media aspects without comparing non-digital commemorative practises with digital forms. An interdisciplinary view on the object of the investigation is missing so far. One main challenge concentrates on the exponential increasing number of web offerings, applications and digital learning objects including new technologies. Hence, a compendium of single studies about the topic was published. What is still missing is an overview with the respect to national and international best practises, extracting the ideas and structures behind single examples.

2.2 Learning from Practice

In this paper we refer to research related to work targeted to learn from practice and proven concepts from the field. Corresponding approaches are often linked with the notions of "best practice" or "good practice". Best practices research is an approach to extract and gather practice knowledge, as well as to induce principles. It can be defined as "the selective observation of a set of exemplars across different contexts in order to derive more generalizable principles and theories" [18]. Best practice research has its roots in strategic management and in the analysis of business processes, but corresponding concepts have been adopted in other domains, such as medicine [19], and education [20]. Best practice research can be considered as a way of thinking, oriented on constant learning, feedback and reflection of what works and why, or even what does not work [21]. As such, best practice collections may provide benefits with respect to encourage critical reflection and rethinking of own approaches, also providing a scaffold for corresponding developments.

While the general approach to learn from practice appears obvious and initially promising, best practice research and corresponding methodologies have been criticized for methodological and practical reasons [21]. Arguments include aspects such as a lack of grounding theory, a lack of validity regarding the selection of practices, and a lack of proven transferability [21]. Still, certain approaches on the collection and use of well-proven practices have documented their value in practice. At this point, it makes sense to follow Bardach [21, 22], who proposes a change of terminology, considering the term "best practice" misleading and rather arguing for the use of the term "smart practices", suggesting that given practices include a smart or interesting idea that deserves attention and which possibly could be mapped to a different problem domain [21]. Ambler [23] proposes to focus on contextual practices instead, stressing the analysis of context and corresponding factors, which may render a solution successful in one situation and less successful in another. Following the arguments of Bardach [22] and Ambler [23], we will refer to "smart, contextualized" practices in the remainder of this paper, whenever a clear reference to general best practice research is not required.

Practices in the field of best practice research include best practice benchmarking [24] and lessons learned [25]. In the field of knowledge management, recently storytelling has found wider acceptance, rather targeting to capture individual, often implicit good practice knowledge in terms of narratives [26].

Design Patterns [27] represent another recent and very successful approach to the documentation of good practices. Originally developed in the field of architecture to cover elements of environmental design at various levels of scale, design patterns describe re-usable forms of solutions to design problems based on a semi-formal approach. Based on a defined pattern structure (see following chapter for a more detailed discussion), corresponding solutions are analyzed with respect to a number of aspects and perspectives. The pattern structure thereby provides both a scaffold for the analysis and a support for the comparison of patterns.

Alexander's design patterns approach thereby recognizes critique expressed especially by Overman and Boyd [18] with respect to limitations in terms of validity of typical best practice research approaches. He also recognizes Bardach's general critique [22], requesting for abstraction, targeting to characterize the basic general aspects and links between them, already highlighting ways for adaptation, rather than to provide a detailed, prescriptive description of approach and elements.

Alexander also describes a formal process for detecting patterns, which involves the identification of distinguishing characteristics accounting for the success of the selected design solution and seeking key elements and invariants common to all good solutions to a specific design problem, not present in corresponding poor solutions [27]. This process thereby includes inductive and deductive elements.

Today, identification of good practice as a source for patterns is usually linked with the metaphor of mining [28]. This involves capturing solutions that are both good and significant [29], while not stating obvious solutions to trivial problems or covering every possible design decision [28]. For pattern mining, two principal approaches can be distinguished: inductive and deductive [30]. Inductive approaches can be considered the most manifest based on the definition of a design pattern as given above, inferring a pattern from the successful use at multiple instances, if possible also related to the agreement of a number of experts in this analysis. However, in practice design patterns have been extracted applying deductive thinking methods in a large number of cases, for instance based on a transfer of attributes and functions of an artefact to another based on a metaphoric perspective (from metaphor to pattern), an expert's analysis of a specific concept and its implications, or based on an expert's analysis of a problem (from experience to pattern) [30].

Alexander already provided the extended view of pattern language that can be created by relating design patterns, thus providing an expressive means to design solutions to a more complex problem based on appropriate combinations of such patterns. Not all types of relations will result in an expressive pattern language. An obvious approach proposed by Alexander [27] proposed and applied a hierarchical approach from high-level to low-level design problems, which represents a universal approach that can be transferred to other domains easily. However, other forms of domain-specific relations are possible and have been applied successfully

The Design Patterns approach was successfully adapted to different domains, such as software development, providing descriptions of good practices in context of software design [31], human-computer interaction [32], web programming [33], and education [34]. Design Patterns nowadays are widely accepted to identify, describe, manage and analyze design problems in a structured way.

Research on design patterns in these fields also resulted in more precise definitions of Design Patterns and their characteristics. The following ingredients are commonly regarded essential to Design Patterns [28]:

- A design pattern implies an artefact;
- A design pattern bridges several levels of abstraction;
- A design pattern includes its rationale;
- A design pattern is manifest in its solution;
- A design pattern captures system hot spots;
- A design pattern is part of a language;
- A design pattern is validated by its use;
- A design pattern is grounded by in a domain;
- A design pattern captures a big idea;
- Design patterns capture a "lingua franca";
- Different design patterns deal with problems at a different scale;
- Design patterns reflect design values;
- Design patterns capture design practice.

Atomic design [35], a novel methodology from web design and development, clearly connects to the concept of Alexander's pattern language. It suggests to break down complex user interfaces into sets of composing elements. Hence, a design process consists of building hierarchies of nested patterns starting with a finite set of basic elements (atoms), which cannot be broken down any further without losing their functionality, and combining these to lead to more complex structures (molecules, organisms and pages). Hence, the atomic design metaphor allows to introduce the modular logic to the design of complex user interfaces. The atomic design approach thereby not only eases and accelerates the design of multimedia applications, it also allows for the tight integration of different stakeholders into the design process. Pattern libraries are today an integral part of world-wide used development framework such as Bootstrap or Google material. Despite the fundamental critique on best practices research, it depicts the influence to and the practical value of corresponding approaches in the field, in particular for those approaches based on the design pattern concept.

3 Approach

In this project we target to develop a catalogue and repository for smart contextualized practices for multimedia applications and products in the field of memorial and culture. This knowledge base will service the following purposes:

- It will provide providers and developers in the field with a comprehensive reference of smart, contextualized practices for products and media-related artefacts in the field of memorial and culture, potentially easing and providing a scaffold to the design and development of new solutions and avoiding pitfalls;

– It will serve as a technical lexicon [28] providing a standard vocabulary to support design debates between experts, allowing them to document, discuss and reason systematically about concepts in the context of media-based approaches in commemorative culture;
– It may serve as a basis for a lingua franca [28] in discussion between different stakeholders involved in the design, development and evaluation of artefacts, services and products in the field of commemorative culture: designers, experts and practitioners from commemorative culture, users and participants, as well as promoters and sponsors; in such discussions, design patterns may also serve to suggest options for a design, which may be accepted, modified or rejected.

From the theoretical perspective, it may serve to summarize and harmonize "best practice" documentation in commemorative culture in general. A systematic and integrative approach with such an objective is required, since commemorative culture is a highly interdisciplinary topic, with many related research fields, and, hence, smart practice documentations are rather spread and fragmented. We expect that the collection of design patterns will provide us novel means for analysis and research, following up on research questions such as:

– In how far do the extracted patterns represent a pattern language?
– What classes of design patterns can be distinguished in the field of commemorative culture? What types of relationships exist between different digital memorial design patterns? What kind of structures of meta-patterns can observed based on these patterns and relations?
– While design patterns represent frequent practice in the design and implementation what are their measurable effects on commemorative culture?
– Is it possible to utilize design patterns' to represent "organization memory" [28] also to model and represent the collective memory in commemorative culture [1]?

In our approach, we collect and present smart contextualized practices in terms of Design Patterns, thus providing a Memorial Design Pattern Catalogue for Cultural History. Here, we draw primarily from the work of Alexander [27], but also from subsequent applications and extensions of this approach, especially in the fields of computer science, human-computer interaction, and education.

While there exist various variations of design pattern descriptions in these fields, there are similarities in the approaches and there exist commonalities in the structural elements. We draw from typical approaches in the field, and our structure provides for the following elements;

- A pattern name: A descriptive name identifying the pattern, also indicating its context and purpose;
- A problem description: A description of the concrete problem or challenge requesting for the solution the pattern provides; this is usually written in a brief and user-oriented way;
- Context: A thorough description of the specific context where the problem is arising and where the provided solution has proven to be smart and effective; In our case, all patterns are all related to the general context of commemorative culture; In addition, we foresee a discussion on the regional, since rites in commemorative culture often depict a distribution in local contexts, only;
- Solution: A description of the general solution strategy and its elements applied to solve the problem based on this pattern;
- Rationale: A reasoning why the pattern works, reinforcing the solution; This section provides a separation of rationale information from the proposed solution to make the solution easier to scan and consume;
- Discussion: A brief discussion of the pattern, also allowing for a critical analysis;
- References: A list of references to related work and approaches, also providing for a relation to theory in the field;
- Examples: A brief description of examples depicting this pattern, to illustrate and to substantiate the pattern;
- Related Patterns: A list of related design patterns, also from other domains (e.g., human-computer interaction, web-technology, education) and also from non-digital backgrounds, with a short description and reasoning of the specific relation.

Our pattern structure has been extended by necessary elements for managing patterns in a repository, including names and affiliations of authors, the date of the latest version of the pattern, a pattern version history, and a section for general comments on the pattern. These elements have been omitted in the presentation and discussion of pattern examples in the following sections for clarity and space reasons.

Elements have been arranged in a tabular form, to further increase clarity of the presentation, to provide quick access to descriptive elements, to foster comparison of patterns and also to ease the development of new design patterns. Figure 1 depicts the applied design pattern template. We consider the design pattern structure not set in stone: in the case upcoming evaluations with domain experts and users will depict a demand to make specific information on the patterns more explicit (e.g., regional scope).

The applied pattern mining process is based initially on a deductive approach. However, different from described approaches in this context [30] our work is more clearly based on theory in related fields to commemorative culture. In specific, we reviewed work related to general and well-known "best practices" in these fields, not necessarily related to information technology and media. Areas covered include memory studies [36], oral history, especially related to contemporary witnesses and the utilization of such material, as well as communicative memory [37], spatial turn with respect to the understanding of space as a cultural dimension [11], memorial places as authentic environments that include artefacts and references to local history

Author:	
Date:	
Pattern name:	
Problem description:	
Context:	
Solution:	
Rationale:	
Discussion:	
References:	
Examples:	
Related Patterns:	
Comments:	

Fig. 1 Design pattern template

[38], and also on research in history on the depiction of chronological relationships [39]. Based on the extracted good practices, we analyzed how those practices have been mapped to applications in the web and other types of multimedia applications, thereby introducing an inductive element to avoid collecting patterns just by academic invention, but allowing for a more focused analysis of existing solutions. At this point, we also utilized existing expertise in the fields on HCI patterns, media education and visualization [40], targeting to relate corresponding smart practices in commemorative culture to existing design patterns in those fields.

As mentioned above, approaches in the field of design patterns are often linked with the objective of designing a pattern language that furthers the design of complex solutions and products by providing means to combine and integrate existing patterns. While tempting, we postponed this for the moment to rather concentrate on the extraction of first design patterns in commemorative culture, to investigate the various relations with related domains, and to better understand design issues for a pattern language in this field.

4 Examples of Memorial Design Patterns

In the following, we present and discuss design patterns from the field of commemorative culture. Three patterns were selected to illustrate our use of the pattern approach in the field, to point out and discuss specifics of the adaption. For this, the pattern table structure is included to each example emphasising important items, but for lack of space don't represent the whole structure, defined in Chap. 3.

4.1 Pattern "Digital Eyewitness Memories"

Eyewitness testimonies are well known in commemorative culture, particularly in Holocaust education [7]. Their individual stories have a high rate of authenticity and liveness. This accompany the increasing attention on oral history that focuses on the individual oral narrations [41]. In particular, the fact that in foreseeable future there will be no eyewitnesses of the Holocaust left to share the memory of their destiny, new ways of conveyance and preserving story of their life have to be found.

This pattern "Digital Eyewitnesses Memories" focuses on this problem. According to this, eyewitness memories are collected in form of digital media, mainly in form of audiovisual media. The solution contains a web based database to present survivor's stories in an adequate way. An impressive example related to the high number of eyewitness narrations is certainly the database of the Shoah Foundation, initiated by Steven Spielberg, which has conducted interviews with over 50,000 people in more than 30 languages since the early 1990s [42].

Such a solution can't replace an eyewitness narration in a face-to-face situation, but, arranged in a adequate way, web based eyewitness database offers great opportunities: Firstly, an individual access. According to users needs and interests, clips can be chosen. This goes with no time or place limit to access. For this, more people can be reached. Further, it is easy to compare different testimonies on one topic. But particularly the form of presentation is essential to increase involvement. We have to consider the design aspects of medium in which they are presented and the context of watching the clips. This goes with finding good lengths and shots of each clip and adequate forms of cross media storytelling in a well designed web offering.

In case of this pattern there exist an often used related pattern: "Register Of Deaths". There are some similarities, but the objective is different. This database is utilised to search for names of victims murdered in the former concentration camps. The register in general exists also in original documents. The digital version of the register of deaths puts all lists together in one database. One important example of the digital memorial pattern register of deaths can be found on the webpage of the memorial place of the former concentration camp Auschwitz, with more than 1.6 million victims of the National Socialists [43].

In the following table important aspects of the pattern “Digital Eyewitness Memories” are presented (Fig. 2).

In the following, two examples of eyewitness databases are presented:

Centropa.org

The website of the organisation centropa is entitled with: “Where jewish history has a name, a face, story.” [44]. Between 2000 and 2010, 1200 Jewish Holocaust survivors were interviewed, living in Central and Eastern Europe, the former Soviet Union and the Balkans. Interview transcripts and more than 20,000 of photographs can be searched through a database. Search options are names and places. Via icons and hyperlinks the user reach further informations about the biography and also film documentary clips. Teaseboxes with a portrait shots foreground the eyewitnesses and his personality (Fig. 3).

Zeitzeugen-Portal.de

A German example is the website “Zeitzeugen-Portal” [45]. A good solution for a smaller number of videos is provided by web portals, which still require a database in the background, but do not make it visible to the user in the interface. In the foreground big pictures of eyewitnesses are presented, which cause a high closeness to the viewer. Also big quotations increase users attention for the presented testimonies. In this example three search options are offered: people, time periods and themes. The selection of the clips takes place by clicking on navigation elements, teaser boxes and buttons (Fig. 4).

4.2 Pattern “Timeline Based Memories”

The second Memorial Design Pattern “Timeline Based Memories” includes the classification of historical events in a dynamic and interactive timeline. In memorial context data plays an important role to collect historical knowledge. For better understanding of historical events a chronological order and contextualisation is used. This pattern provides a solution for individual access to historical events presented by interacting the system. For this, the timeline supports the comprehension of the impact of single events inside a greater historical coherence.

All pattern examples share graphical arrangement along a horizontal line. This line put all mentioned events into one chronological relationship. Possibly inspired by the vertical timeline of facebook there are recent productions in vertical form, which also works well on mobile devices and scrolling with fingertips. Visualisations of different time periods by colours, pictures and titles support the needed contextualisation. Hyperlinks and navigation bars help to navigate and explore the presented digital heritage. Further, presenting content in multimedia context support learning effects.

Pattern name:	Digital Eyewitness Memories
Problem description:	In near future there will be no eyewitnesses of the Holocaust left to narrate their story. Finding new ways of conveyance and preserving eyewitness testimonies are an important part of the current discourse.
Context:	Eyewitness testimonies play an important role in Holocaust education. Nothing is more impressive than to hear about the Holocaust from someone who has survived it. This accompany the increasing attention on oral history that focuses on the individual narrations. Eyewitness testimonies represent a significant part of our cultural heritage.
Solution:	The solution contains a web based database to present survivor's stories in an adequate way. This happens in form of portrait shots to foreground the eyewitnesses and his personality. Further, main search options are names, time periods and places. Via icons and hyperlinks the user reach further textual informations about the biography and also film documentary clips and pictures.
Rationale:	The web based eyewitness database offers great opportunities to increase access to cultural heritage in the form of eyewitness testimonies. At first, an individual access: For example, the user can choose themes and time periods referring to his interests. This goes with no time or place limits. Further, it is easy to compare different testimonies on one topic. Particularly, audio visual media can be impressive and increase audience involvement.
Discussion:	Of course, such a web based eyewitness database can't replace an eyewitness narration in a face-to-face situation. We have to consider the medium in which they are presented and the context of watching the clips. This goes with finding good shots and lengths of each clip and adequate forms of cross media storytelling inside a well designed web offering. Further, a good usability is needed according to searching for eyewitness testimonies.
References:	https://www.domradio.de/themen/kultur/2017-02-02/haus-der-geschichte-arbeitet-neuer-zeitzeugen-datenbank Lange, Britta: Ein "Archiv der Erinnerungen" zwischen Geschichte und Fiktion. Zeitzeugenvideos auf www.gedaechtnis -der-nation.de. In: Ballhausen/Strunz/Krenn (2014): geschichte erzählen: Medienarchive zwischen Historiographie und Fiktion. LIT Münster. Sabrow, M. (1945). Der Zeitzeuge als Wanderer zwischen den Welten. *Die Geburt des Zeitzeugen nach* 1945 Müller, Claudia; Ostermann, Patrick; Rehberg, Karl-Siegbert; Heber, Meike (Hg.) (2015): Die Shoah in Geschichte und Erinnerung. Perspektiven medialer Vermittlung in Italien und Deutschland. Bielefeld: transcript. (Histoire, 66). ISBN 9783837627947 Darin: Liepach, Martin: Zeitzeugenvideos am Ende der Zeitzeugenschaft. S. 157-168 Thompson, P. (2017). *The voice of the past: Oral history*. Oxford university press.
Examples:	vhaonline.usc.edu www.zeitzeugen-portal.de www.centropa.org iwitness.usc.edu
Related Patterns:	Register of Deaths

Fig. 2 Pattern "Digital Eyewitness Memories" (The pattern was created by Susanne Haake, Wolfgang Müller and Marc Wolf, last update on 12.4.2019.)

Fig. 3 The eyewitness web database Centropa.org

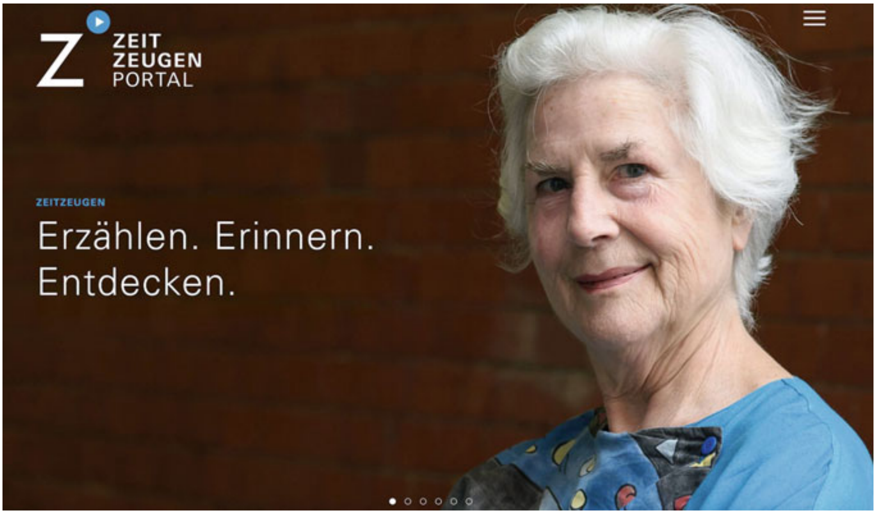

Fig. 4 The eyewitness web database Zeitzeugen-portal.de

The following table describes important items of the pattern "Timeline Based Memories", referring to the presented structure (Fig. 5).

There can be found many examples of interactive timelines in web offerings. Below, two examples in the context of Holocaust memory are presented.

German Historical Museum

The timeline of the German Historical Museum [46] is in line with current web design trends using large pictures and teaser boxes. They are arranged like a slideshow, using arrows to go back or forward. Each teaser box contains a large picture added by a subtitle. The user recognizes that the teaser box is clickable additionally by an arrow. Colors guide through the representations of individual decades. The user interaction is supported by hover effects. This example for a timeline uses a vertical alignment which is still the most common layout to visualize information. This is also a good example to show difficulties in the arrangement of information architecture. Several subnavigations may disorient users and should be avoided (Fig. 6).

The interactive timeline of the Montreal Holocaust Museum

The interactive timeline of the Montreal Holocaust Museum is titled as "War, Persecutions and Mass Killings" [47]. In this example the interactive timeline is accompanied by a historical map illustrating the german expansion path during the Second World War. By navigating through the timeline the user gets directly feedback about changing areas of occupied countries. The legend contains four items: Greater Germany and Occupied Countries, German Allies or Dependent States, Allied Countries and Neutral Countries. Different colors help to distinguish between the different status of the countries. In addition to this a info box explains important dates of the chosen year (Fig. 7).

4.3 Pattern "Location Based Memories"

Memorial places play an important role in the context of commemorative culture [11]. The historical place represents an authentic environment including artefacts and references of the local history. A common practise is to add some further background information about the history of the place to such memorial places, like information signs or sign posts.

If one wants to examine digital remembrance solutions in this context, it must be emphasized that digital memoria go far beyond static web sites. Memory also happens on smartphones and other mobile devices. In this pattern the role of digital location based memories is presented. The name refers to a form of mobile applications that provide information to the user's smartphone or tablet which is tied to a certain historical place. The special feature of this pattern is that the user moves actively in the area. The real memory of the historical place is accompanied by an app. For this a tracking of users position is necessary to localise his position, mainly done by GPS or QR-codes.

Pattern name:	Timeline Based Memories
Problem description:	Historical information needs a chronical order to understand the bigger meaning behind single data, their impacts and relationships. They have to be arranged in an clear order and added by context informations.
Context:	Timelines represent a common way of teaching history, in school or museum context. Their main aim is giving a context and a classification in dependence of a chronological events.
Solution:	This pattern solves the stressed problems above by the utilization of an interactive timeline element (Manfra, 2008/ Riley, 2002). All pattern examples share graphical arrangement along a horizontal or vertical line. Underlying web technologies may render the timeline dynamic, reacting to users' interactions. An interactive timeline may include multimedia content, connected by hyperlinks and navigation bar.
Rationale:	Particular interactive digital forms of timelines contain many possibilities, because the interactive timeline react on users activity, give him feedback by giving information and offers context corresponding to his needs. Hyperlinks and navigation bars supplement context information. Current web trends like titled teaser boxes support the understanding of historical connections. Further, multimedia elements support learning effects.
Discussion:	Arranging historical events on an interactive timeline means also to gather important issues. Historians have to decide which event has to be included and in which way.
References:	Riley, K. L., & Totten, S. (2002). Understanding matters: Holocaust curricula and the social studies classroom. *Theory & Research in Social Education*, *30*(4), 541-562. Manfra, M. M., & Stoddard, J. D. (2008). Powerful and authentic digital media and strategies for teaching about genocide and the Holocaust. *The Social Studies*, *99*(6), 260-264. Ital, H. (2008). Neue Medien zum jüdischen Widerstand im Nationalsozialismus. *International Journal of Foreign Studies*, *1*(1), 179-202. Berson, I., & Berson, M. (2010). Webby Award Winners: Interactive Media for the Social Studies. *Social Education*, *74*(2), 107-110. Godulla, A., & Wolf, C. (2017). Digitales Storytelling mit digitalen Langformen. In *Digitale Langformen im Journalismus und Corporate Publishing* (pp. 45-84). Springer VS, Wiesbaden.
Examples:	www.dhm.de/lemo/kapitel.html www.kz-gedenkstaette-sandhofen.de www.renaspromise.com/education-interactive-timeline.php www.ushmm.org/learn/timeline-of-events/before-1933 histoire.museeholocauste.ca/en/map/war-persecutions-mass-killings
Related Patterns:	A chronological order can also be installed by using a slideshow or picture gallery. Further, historical dates can also be searched by a database in form of a encyclopaedia.

Fig. 5 Pattern "Timeline Based Memories" (The pattern was created by Susanne Haake, Wolfgang Müller and Marc Wolf, last update on 12.4.2019.)

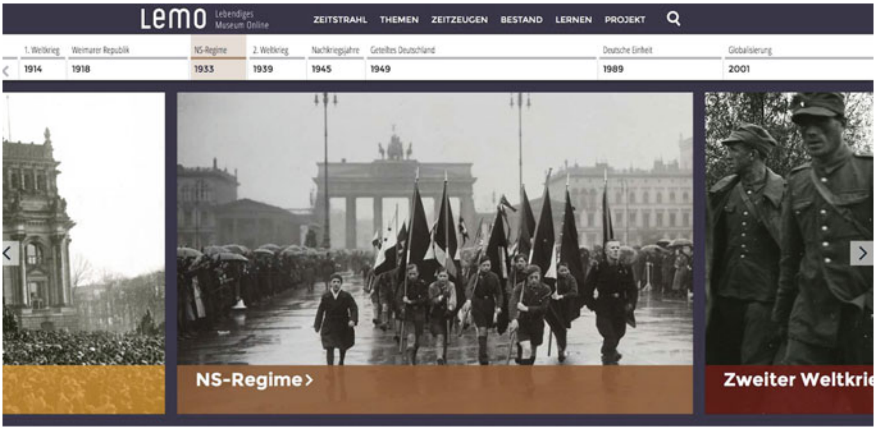

Fig. 6 Lemo - The timeline of the German Historical Museum

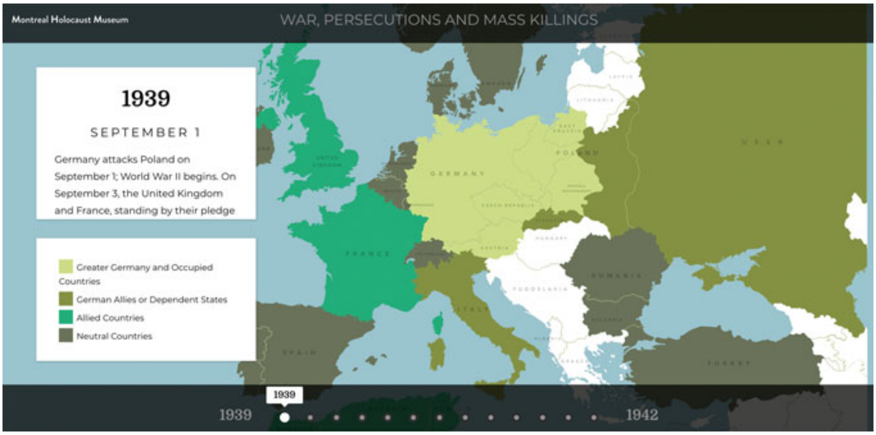

Fig. 7 The timeline of the Montreal Holocaust Museum [47]

In the following table the pattern "Location Based Memories" is introduced in detail (Fig. 8).

The pattern "Location Based Memories" is used in several conditions, in the context of memorial places, but also in an urban area. In the following two examples are presented:

Pattern name:	Location Based Memories
Problem description:	Commemorative culture happens at historical places. The visitor need some further background information to understand the historical meaning of the place. These informations have to give on several locations according to visitor's position.
Context:	Establishing memorial places represents one of the most important aim of commemorative culture. Visiting a memorial is part of a recollection ritus. These memorial places offer areas of remembering the victims and explain the historical incidents that had taken place.
Solution:	Location based services guide a visitor through a memorial place. This apps offer further informations (text, pictures and other historical materials) at particular places. Often a tracking method supports the system to localise the visitors position, mainly by GPS or QR-Code. An interactive map helps to orientate and find other places accompanied by further informations.
Rationale:	This solution represents a good relationship between the historical place and the digital product of remembrance. They complement one another and synergetic effects can be used. Besides other non-digital products location based memories contain more interactive and technological possibilities. For examples location based memories using augmented reality presents a very good solution to built a connection between the memorial place today and in the past.
Discussion:	Of course not every visitor would like to use his smartphone at memorial places, but the great acceptance of audio guides shows that location based memories represent a good solution in this context as well. One main challenge contains to establish a good usability.
References:	RÖDER, D. (2016). SMARTPHONE APPS: THEIR USE OF HISTORY AND USE FOR HISTORY TEACHING. *E-teaching History*, 141. Blaschitz, E. (2017). Mediale Zeugenschaft und Authentizität: Zeitgeschichtliche Vermittlungsarbeit im augmentierten Alltagsraum. *Hamburger Journal für Kulturanthropologie (HJK)*, *1*(5), 51-67. Stäbler, W. (2016). Historische Orte. In *Handbuch Museum* (pp. 133-136). JB Metzler, Stuttgart. Apel, L. (2014). Stumbling blocks in Germany. *Rethinking History*, *18*(2), 181-194.
Examples:	www.mauthausen-memorial.org/de/Aktuell/Die-App-der-KZ-Gedenkstaette-Mauthausen-der-Audioguide-am-Smartphone www.sueddeutsche.de/digital/virtuelle-realitaet-auf-zeitreise-1.3522125 www.stolpersteine-guide.de www.virtuelleskonzert.com/index_de.html
Related Patterns:	Interactive floorplans and maps

Fig. 8 Pattern "Location Based Memories" (The pattern was created by Susanne Haake, Wolfgang Müller and Marc Wolf, last update on 12.4.2019.)

Location based memories offered by the Bergen-Belsen Memorial

The Bergen-Belsen memorial do experiments with using the AR technology to integrate buildings that are no longer visible on the display into the real picture [48]. This was established mainly for educational issues during workshops with young people. The memorial center deliberately refrained from a realistic depiction of the buildings, although this was technically possible. A clear sober aesthetic counters a fascination for the horrors which happened there. But it also consciously dissociates from a computer game aesthetic. Further, a map helps with orientation. Besides the AR-version, the memorial offers also an official audio guide app for visitors.

Urban location based memories offered by the "Stolperstein-Guide"

The app "Stolperstein-Guide" [49] offers the possibility to find so called "stumbling blocks" (Stolperstein) near the user's location and to access additional information about the Holocaust victims. The user's position is tracked by GPS and showed inside a map where the "stumbling blocks" are marked. There exist several apps in a similar context, but this application represents a good example according to usability criterias. The information about the victims are given by pictures and audio files. A database opens further research possibilities.

5 Discussion

5.1 Digital Memorial Design Pattern in Commemorative Culture

The presented pattern deal with the problem how to present individual stories, locations and chronological aspects in digital memorial context. The pattern "Eyewitnesses Memories" contains the solution of a web based eyewitness database. Interactive timelines deal with the problem of putting historical events in a chronological order. Lastly the pattern "Location based Memories" offers a solution guiding visitors through a memorial place. All presented pattern are connected with common practises of commemorative culture. In case of our research aim, memorial design pattern are useful to describe best practises. One reason for this is the clear structure. So, it is quite simple so get an overview other main aspects of the described solution. Furthermore, the categories are closely connected to user's needs and, because of this the presented pattern are useful to find solutions for problems in similar context.

In the following paragraphs, first theses are presented, reflecting structural perspectives on pattern language.

Memorial website and applications contain often more than one memorial design pattern.

There exist relationships between these patterns. They supplement each other and form new environments of digital memorial. For example an location based memories can be added by eyewitness testimonies, as shown in the example "Stolperstein-Guide" [49]. In the example of the web presentation of the former concentration camp Mauthausen the used pattern solutions create an individual form of digital place of memory [50]. By integrating the presented pattern, the visitor is enabled to interact and remember individually according to his needs. This refers to Pierre Nora's "places of memory" [10]. In dependence of Nora collective memory arises at virtual nodes by visiting and interacting with such digital places.

The used pattern has to be considered in context of non digital memorial design pattern.

There is also a connection that influences the impact and focus of a memorial place. According to the importance of eyewitness testimonies, their stories can be found in different context, from media towers in exhibitions to audio files on location based smartphone apps.

These theses shows that describing memorial design pattern and developing a structural model of relationship between such pattern represents an important contribution to the research community. For this, the structural analysis has to be expanded in this field according to our research aim.

5.2 *Further Work*

Work on a repository of design patterns may never be considered finished, since new smart practices constantly arise and, as a result, new good practices evolve. On the other hand, practices once considered be good and advisable may render obsolete over time. This is especially true within media-related contexts, since developments in the technological area give rise to novel technologies, services, and products, and replacing established approaches in ever shorter time-spans. Still, we consider the design pattern approach as valuable for the field of commemorative culture, as guidance or the development of new products, but also as a means to provide a more expressive and clearer depiction of smart practices in the domain. As such, we target to maintain work on our design pattern base for media-related approaches in commemorative culture, extending the repository whenever appropriate and reviewing existing design patterns on a regular basis. In this context, we intend to open the project to involve other interested researchers in the field.

There are some open research fields, for example memorial design pattern with a connection to web 2.0. technologies. Further, the developed pattern are going to be validated by qualitative interviews with memorial experts.

All extracted memorial design pattern are going to be collected and exchanged in form of a wiki, going online in the second step of our research project. This Memorial Design Pattern catalogue helps to preserve and communicate successful solutions which the memorial community and can used to design digital heritage. The defined pattern language, including the interferences, hierarchies and frequencies, opens the opportunity to develop new solutions in the memorial context, combining or diversifying patterns.

The catalog which originated from the project is to be made accessible by means of a dedicated website to research, but also to memorials and web designers, who are active in this field. In doing so, the primarily theoretical issues are finally combined with a practical assistance for the design of new digital memorials about the Holocaust.

References

1. Erll, A. (2005). Kollektives Gedächtnis und Erinnerungskulturen. Eine Einführung, 2, 21.
2. Uhl, H. (2005). Von „Endlösung “zu „Holocaust “. Die TV-Ausstrahlung von „Holocaust “und die Transformationen des österreichischen Gedächtnisses. *Historical Social Research/Historische Sozialforschung*, 29–52.
3. Young, S. (2008). Cultural memory studies: an international and interdisciplinary handbook (Vol. 8). Walter de Gruyter.
4. Shapira, S. (2017). Yolocaust/Szewczak-Harris, E. (2017). YOLOCAUST Project, Shahak Shapira, Berlin, 2017. JAWS: Journal of Arts Writing by Students, 3(1–2), 149–154.
5. Krüger, J., Möllers, F., & Vogelgesang, S. (2016). Pokémon GO. Informatik-Spektrum, 39(6), 427–435.
6. Meyer, E. (Ed.). (2009). *Erinnerungskultur 2.0: kommemorative Kommunikation in digitalen Medien* (Vol. 6). Campus Verlag. Hein, D. (2005). Mediale Darstellungen des Holocaust: Zum World Wide Web und zu seiner Disposition als Gedächtnismedium. *Jahrbuch für Kommunikationsgeschichte*, 176–196.
7. Short, G., & Reed, C. A. (2017). *Issues in Holocaust education*. Taylor & Francis. Manfra, M. M., & Stoddard, J. D. (2008). Powerful and authentic digital media and strategies for teaching about genocide and the Holocaust. *The Social Studies*, *99*(6), 260–264. Riley, K. L., & Totten, S. (2002). Understanding matters: Holocaust curricula and the social studies classroom. *Theory & Research in Social Education*, *30*(4), 541–562.
8. Assmann, J., & Czaplicka, J. (1995). Collective memory and cultural identity. *New german critique*, (65), 125–133.
9. Halbwachs, M. (1992). On collective memory. La mémoire collective (1950). University of Chicago Press.
10. Nora, P. (1989). Between memory and history: Les lieux de mémoire. *Representations*, 7–24. François, E., & Schulze, H. (Eds.). (2009). *Deutsche Erinnerungsorte* (Vol. 1). CH Beck.
11. Döring, J., & Thielmann, T. (Eds.). (2015). *Spatial turn: das Raumparadigma in den Kultur-und Sozialwissenschaften*. transcript Verlag.
12. von Keitz, U., & Weber, T. (2013). Mediale Transformationen des Holocausts. Avinus.
13. Assmann, A. (2013). Das neue Unbehagen an der Erinnerungskultur: eine Intervention (Vol. 6098). CH Beck.
14. Neiger, M., Meyers, O., & Zandberg, E. (Eds.). (2011). *On media memory: Collective memory in a new media age*. Springer.
15. Assmann, A. (2010). The Holocaust—A global memory? Extensions and limits of a new memory community. In Memory in a Global Age (pp. 97–117). Palgrave Macmillan, London.).

16. Fallace, T. (2008). *The emergence of Holocaust education in American schools*. Springer. Meseth, W., & Proske, M. (2010). Mind the gap: Holocaust education in Germany, between pedagogical intentions and classroom interactions. *Prospects*, *40*(2), 201–222.
17. Hein, D. (2009). Erinnerungskulturen online. *Angebote, Kommunikatoren und Nutzer von Websites zu Nationalsozialismus und Holocaust. Konstanz: UVK*.
18. Overman, E. S. & Boyd, K. J. Best practice research and postbureaucratic reform. Journal of Public Administration Research and Theory. 4(1). (1994) 67–84.
19. Stenström, M.-L. and Laine, K. (Eds.) (2006). Towards good practices for practice-oriented assessment in European vocational education. Jyväsklyä, FI: Institute for Educational Research, University of Jyväsklyä.
20. Mold, J. W. and Gregory, M. E. Best practices research. FAMILY MEDICINE-KANSAS CITY. 35(2). (2003) 131–134.
21. Veselỳ, A. Theory and methodology of best practice research: a critical review of the current state. Central European Journal of Public Policy. 5(2). (2011). 98–117.
22. Bardach, E. Comment: The Problem of "Best Practice" Research. Journal of Policy Analysis and Management. 13(2). (1994). 260–268.
23. Ambler, S. Questioning "Best Practices" for Software Development: Practices are Contextual, Never Best. Ambysoft Inc. (2014) Online: http://www.ambysoft.com/essays/bestPractices.html. Last accessed 2.4.2018.
24. Zairi, M. Benchmarking for Best Practice: Continuous learning through sustainable innovation. London: Routledge. (1996).
25. Patton, M. Q. Evaluation, knowledge management, best practices, and high quality lessons learned. American Journal of Evaluation, 22(3), 329–336. (2001).
26. Sole, D. & Wilson, D. G. (2002). Storytelling in organizations: The power and traps of using stories to share knowledge in organizations. LILA, Harvard, Graduate School of Education, 1–12. http://www.providersedge.com/docs/km_articles/Storytelling_in_Organizations.pdf.
27. Alexander, C. A Pattern Language. Towns, Buildings, Construction. New York: Oxford University Press. (1977).
28. Dearden, A. & Finlay, J. Pattern languages in HCI: A critical review. Human–Computer Interaction, 21(1), 49–102. (2006).
29. Fincher, S. & Utting, I. (2002). Pedagogical patterns: their place in the genre. In ACM SIGCSE Bulletin (pp. 199–202).
30. Baggetun, R., Rusman, E., & Poggi, C. (2004). Design patterns for collaborative learning: From practice to theory and back. In Proc. ED-MEDIA 2004.
31. Gamma, E., Helm, R., Johnson, R., & Vilissides, J. Design Patterns: Elements of Reusable Object-Oriented Software. Reading, Massachusetts: Addison-Wesley. (1995).
32. Tidwell, J. Designing Interfaces - Patterns for Effective Interaction Design. O'Reilly Media. (2011).
33. Vora, P. Web Application Design Patterns (Interactive Technologies). Burlington, MA: Morgan Kaufmann Pub. (2009).
34. J. Bergin, J. Eckstein, M. Völter, M. Sipos, E. Wallingford, K. Marquardt, J. Chandler, H. Sharp, & M. L. Manns (Eds.) (2012). Pedagogical Patterns: Advice for Educators. Joseph Bergin Software Tools. (2012).
35. Brad Frost (2016). Atomic Design. Publisher: Brad Frost.
36. Erll, A., Nünning, A., & Young, S. B. (Eds.). (2008). *Cultural memory studies: An international and interdisciplinary handbook* (Vol. 8). de Gruyter.
37. Welzer, H. (2008). *Das kommunikative Gedächtnis: Eine Theorie der Erinnerung*. CH Beck.
38. Stäbler, W. (2016). Historische Orte. In *Handbuch Museum* (pp. 133–136). JB Metzler, Stuttgart.
39. Graf, R. (2012). Zeit und Zeitkonzeptionen in der Zeitgeschichte.
40. Aigner, W., Miksch, S., Müller, W., Schumann, H., & Tominski, C. (2008). Visual Methods for Analyzing Time-Oriented Data. IEEE Transactions on Visualization and Computer Graphics, 14(1), 47–60. Müller, W. & Schumann, H. (2003). Visualization for modeling and simulation: visualization methods for time-dependent data-an overview. In Proceedings of the 35th

conference on Winter simulation: driving innovation (pp. 737–745). Weber, M., Alexa, M., & Müller, W. (2001). Visualizing Time-Series on Spirals. In K. Andrews, S. F. Roth, & P. C. Wong (Eds.), Proceedings IEEE Symposium on Information Visualization 2001 (InfoVis01) (pp. 7–14). IEEE Computer Society.
41. Thompson, P. (2017). *The voice of the past: Oral history*. Oxford University Press.
42. Online: http://vhaonline.usc.edu. Last accessed 12.4.2019.
43. Online: http://auschwitz.org/en/museum/auschwitz-prisoners/. Last accessed: 12.4.2019.
44. Online: www.centropa.org. Last accessed: 12.4.2019.
45. Online: www.zeitzeugen-portal.de. Last accessed: 12.4.2019.
46. Online: http://www.dhm.de/lemo/kapitel.html. Last accessed 12.4.2019.
47. Online: http://histoire.museeholocauste.ca/en/map/war-persecutions-mass-killings. Last accessed 12.4.2019.
48. Online: http://www.sueddeutsche.de/digital/virtuelle-realitaet-auf-zeitreise-1.3522125. Last accessed: 12.4.2019.
49. Online: http://www.stolperstein-guide.de. Last accessed 12.4.2019.
50. https://www.mauthausen-memorial.org/en/Visit/Exhibitions-and-Room-of-Names/The-Room-of-Names

Annotation in Digital Humanities

Federico Caria and Brigitte Mathiak

Abstract In previous studies on user behavior with Digital Scholarly Editions (DSE), we found that annotating the text is a key technique for working with the text. In this follow-up study, we invited volunteers to perform open research tasks on a DSE by Lope de Vega, providing the annotation tool hypothes.is to support their tasks. What we found is that none of the participants used the tool extensively, yet, it was clear that annotation of text was a major part of their workflow. During a focus discussion after the experiment, the participants gave examples of how they would compensate for a lack of appropriate tools, often at the cost of considerable extra work and overhead. More research is needed to discover why the users were not accepting the tools provided. So, we propose a human-centered structured longitudinal approach to design an annotation tool that would actually be usable.

Keywords Annotation · Digital editions · User study · Usability · Research behavior

1 Introduction

During the three-year period 2014–2017, we explored the usefulness of digital editions in a typical research context, where users interact with digital collections of textual artifacts for research purposes. Our method has been adapted to the evaluation of these environments using best practices in user-centered design [1]. It is based on the capture of mixed data through several in lab testing sessions with a limited number of testers from various universities and humanities departments.

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1.1 Functionality for Digital Editions

In 2000, John Unsworth introduced a list of seven ‘scholarly primitives’ which are ‘self-understood’ functions forming the basis for ‘higher-level scholarly projects, arguments, statements and interpretations’ [2]. His list summarized activities that were ‘basic to scholarship across eras and across media’, and went on to say that an analysis of these scholarly primitives might result in a clearer sense of how computing tools could support the scholarly endeavour. He also pointed out that comparison and annotation were the most important, yet poorly supported in digital scholarship projects. In valuable user studies on Digital Scholarly Editions (DSEs) we had similar results: the key techniques for working with the text are search, comparison and annotation. However, of these three, only search and comparison have a sound technological basis.

Although Mosaic, the first graphical Web browser, was intended to permit annotation, good tools for marking up what you read or hear, or view online have been slow to develop, observes Schacht [3]. Today, after seventeen years of digital scholarship, annotation tools are available in abundance, yet we have to wonder why most people still prefer to use papers and pens for annotating [4]. Although there are sophisticated computer-based annotation systems available, there is no prevalent service, rather people tend to misuse those, using bookmarks, writing emails, posting forums or creating wiki pages [5]. Moreover, most annotation tools are aimed at implementing collaborative reading or public annotation [6], while personal annotation (what we believe is the necessity expressed by our testers), has played a relatively minor role in the history of computer-based annotation systems.

Annotation in digital editions. In order to better understand how annotation can be integrated into digital editions, we asked volunteers to perform open tasks on a digital edition, which had installed an easy-to-use web annotation tool, hypothes.is. Twelve volunteers were invited to the CAYCIT Buenos Aires lab to sit in front of their laptop and perform open research tasks on a digital edition of Lope de Vega, using the annotation tool to support their task performance.

2 Related Literature

2.1 Annotation Is a High-Reward Technique for Professional Readers

Cognitive science highlights the role of annotation as an information-processing aid. Previous literature suggests that the strenuous attentiveness required by close-reading particularly challenges the information-processing ability of the individual [7], who will find that annotation improves the appropriation of a given text. In this context, annotation is better described by the notion of external cognition, a phrase that refers to ways that people augment their normal cognitive processes with external aids, such as external notes, visualizations, and work spaces. “External cognition is human or cognitive information processing that combines internal cognition with perception and manipulation of external representations of information.”[1] Previous literature suggests a relationship between the ability of note-taking and academic achievement, and one’s ability to hold and manipulate propositional information in working memory.

Ubiquitous annotation in the history of the book. All those who have some familiarity with the history of the book know that annotation is fundamental for scholarship. Jardine’s [8] study of the reading habits of Gabriel Harvey sheds light on the early press era, observing that critical reading was already “synonym of skillful annotation”. According to all the advice books, reading for study or to acquire information or knowledge was supposed to include note-taking [9]. “Otiosa, vana, nugatoria est lectio, cui nulla miscetur scriptio” says a famous manual on note-taking dating back to 1638 [10]. Annotations are a key component of manuscripts as well, as anybody who has had the opportunity to examine them can testify. Notably, the thirteenth century gave birth to two particularly intelligent book designs that accommodated precisely annotation. Both types were connected to the emerging universities, which makes sense as this has been a note-taking environment par excellence—both then and now [11].The massive use of annotation makes us consider a direct link between text, annotation and information processing regardless of the media. In essence, it seems that a professional reader—whose reading activity is always goal oriented—produces annotations by necessity. This seems to reinforce the link with annotation as an information-processing aid.

Effectiveness of different materialities. As far as we are concerned, there are interesting studies, which go into the details of the physical movements and the materials that might determine a more or less successful learning performance. Many of these studies arise from the introduction of tablets in everyday life, especially in education, where stakeholders have felt, more than others, the need of evaluating the impact of new technologies, writing and reading habits on the student’s performance. In this context, we are particularly interested in those who have analyzed the effectiveness of note-taking of typing compared to handwriting, discovering that the latter is more effective, due to the greater slowness and deliberation with which the act of external cognition takes place [12]. Curiously, the lesser ease of handwriting forces the annotator to economize and summarize, which means extracting main ideas from environmental information, summarizing, paraphrasing—contrary to typing on a keyboard, where people tend to write verbatim due to the quickness of the operation. The result of the former is a much better appropriation of the content.

[1] Glossary of Sensemaking Terms, Parc, 2007 (MET).

2.2 Annotation from Print to Digital

We have seen that there is a deep link between annotation, professional reading, academic achievement, and knowledge construction and transmission, to which Vannevar Bush, in theorizing the Memex, alludes. Marshall [8] reminds us of the annotative principle that characterizes the Web, from Bush to Ted Nelson.

Annotative principle behind the Web. Bush's Memo machine focuses on annotation through trail-blazing [9]; Xanadu takes an approach in which new hypertext seamlessly assimilates portions of older writings [13], etc. The research of the pioneers are all motivated by the objective of elaborating data structures closer to the functioning of the brain. Bush, in particular, discusses the potential for greater efficiency of association (one with annotation) compared to current indexing methods, emphasizing once again, the deeper link between the act of annotation and information processing that we have discussed briefly.

Digital annotation tools, collaborative versus personal annotation. Regarding the link between annotation and computing, we found two main research strands, the first one is closer to our topic, and it is found in the work of Marshall [6, 14, 15], the second is related to the W3C and the focus on semantic annotation. Throughout history, many tools have been developed, so that a systematic review of each system would require a separate paper. It is enough to say that their' functions are as varied as annotations can be, e.g. annotations as mnemonic, interlinking, highlighting important parts, commenting for understanding, etc. [5] Another important thing to note is that annotation tools for collaborative reading and writing outnumber those for personal annotation. The difference between personal and public annotation is described by Marshall, who in the late Nineties devoted several papers to the issue. The author analysed 410 marked-up textbooks from a university bookstore. The examination of these textbooks resulted in the distinction of several properties, describing several dimensions of annotations: formal or informal, explicit or tacit, permanent or transient, and published or private.

Private/personal annotation. While we might think of collaborative or public annotations as subsuming personal or individual annotations, especially from an architectural or system design perspective, the practice that leads to their creation is quite different, as observes Marshall. We shall focus on annotation as a personal device, one that plays into reading as a visible trace of human attention on the page, to gain an insight into the typical work of the scholar, who might not necessarily want to share annotations with others. These markings are not always intelligible by third parties, telegraphic, incomplete, and tacit. A highlighted sentence, a cryptic marginal "No!", an unexplained link, a reading history, or a bookmark, all pose interpretive difficulties for anyone other than the original annotator (and the passing of time sometimes erodes that privilege) [15]. These semi-intelligible signs are the traces (Kirsch's communication device) [16], of the inner dialogue of a reader (with the self) better known as close-reading, which very much typifies the type of scholarship that we are dealing with.

3 Design of the Experiment

In the following sections, we will give an overview of the general experimental design, the setting, the editions we studied, and why we selected them, and finally, the demographics of our focus group participants.

3.1 Hybrid Focus Group

In a focus group, a small group of test subjects discusses their experience with the product and shares their opinion, beliefs, and attitudes, while the moderator keeps the discussion on track. In our hybrid approach, we also give the participants questionnaires before and after the tests, to collect both qualitative and quantitative data. The experiment's design is inspired by Nielsen's discount usability [17] and guerrilla techniques for what concerns the recruiting of a limited number of participants, and the low time/cost of realisation; it can be potentially replicated more or less in any research context. Tasks are designed to let the users explore the media, retrieve content, compare records and interrelate information. The task scenarios are meant to reproduce a goal-oriented context of interaction and are left open.

3.2 Setting

The experimental setting consists of a usability lab, personal computers equipped with an open source tool to screen-record the performance of the tasks, an audio recorder to capture the final debriefing, paper and pen. We gathered 12 participants in a usability lab, asked them to perform research tasks in a given amount of time and to give their feedback. An example of a task was to retrieve various kinds of information and compare the records. The feedback collected was of different kinds: (a) a usability questionnaire, filled for each edition after completing a series of tasks; and (b) an audio-taped discussion the focus group. These data were coded together with demographics, the screen capture of the performance of the tasks, and the participants' answers to the tasks, to provide insight into design, usability issues and behavioral information.

3.3 Digital Edition and Annotation Tool

We tested one digital edition (1) *La Dama Boba,* Marco Presotto (ed.) 20xx, which had the Web annotation tool (2) hypothes.is installed. After surveying the online catalogues of digital editions curated by Sahle (v 3.0, 2008–2011) and Franzini

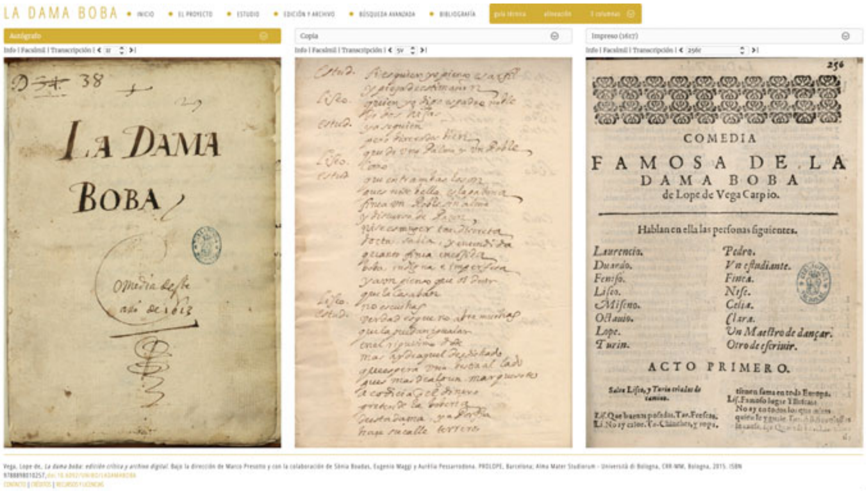


Fig. 1 Main interface of La Dama Boba

(2015), we used a resource we believed was more appropriate to the background of our MA and Ph.D. testers from the University of Buenos Aires.

La Dama Boba http://damaboba.unibo.it. A project developed by Dott. Marco Presotto from Bologna University. The edition reconstructs the text, analyzing the tradition, that according to the editor represents one of the most interesting and significant ecdotic problems of Golden Age theater literature.The editor uses the main witnesses to suggest a reconstruction of the text based on the analysis of the textual transmission of particular specimens. The functions of the site allow you to compare the different witnesses, align the texts, admire the original writing, do research by keyword (Fig. 1).

Hypothes hypothes.is. Open-source annotation tool developed by a non-profit organization funded by Knight, Mellon, Shuttleworth, Sloan, Helmsley, and Omidyar Foundations. The tool enables sentence-level note taking or critique on news, blogs, scientific articles, books, terms of service, ballot initiatives, legislation and more. We found this tool to be one of the easiest available to use. Above all, installing hypthes.is is straightforward, which given the experimental setting, was necessary (Fig. 2).

3.4 Participants

Our testers ranged from 20 to 50 years old and were all enrolled in humanities programs, the majority in the second year of their Ph.D., and two of them were teachers. Their computer skills were medium-high to high, as judged from their self-evaluations on a scale from 1 to 7 (Table 1).

Fig. 2 A screenshot of Hypothes.is annotation tool interface on la Dama Boba

Table 1 Demographics

ID	Department	Level	Web sills
p1	Philology	Ph.D.	6
p2	Philology	Ph.D.	6
p3	Literature	MA	7
p4	Literature	Ph.D.	6
p5	History	Ph.D.	5
p6	History	Ph.D.	5
p7	Literature	MA	4
p8	Literature	Ph.D.	6
p9	History	Ph.D.	5
p10	Philology	MA	6

3.5 *The Tasks*

The tasks were left open and were designed to push testers to put together several pieces of information, located in different parts of the site. This involved opening and closing various windows, and going through more than one screen—with the result that the information was difficult to record. On the sheets that we normally provided to testers before starting the task exercise, we asked them to respond at the end, that is, to use the time for retrieving the needed information only, since additional time was provided to write down the answers. An example of task is:

Example. There is a significant number of interventions in the manuscript—as in any Lope’s autograph—that must be ascribed to the author. These are words or phrases crossed out and replaced by others or reorganized on the flow. Lope’s tendency to what critics defined *intervention in itinere* is well known, also in the case of La Dama Boba, it can be said that the work, or a good part of it, was created directly on the paper that has been preserved for us. Identify at least two examples of this phenomenon in the text. Indicate only alternative examples to those described by the editor. Then, compare at least two of the interventions identified by you with the copy and the printed text and indicate if, and where, there are changes when passing from one witness to another.

4 Findings

This time, the data collected were related to the edition and the annotation tool. The data on the use of the edition are secondary to this paper, but we decided to collect them anyway in order to give feedback to the editor, who was very kind to answer all our questions about the project.

4.1 Satisfaction Questionnaire

Participants were asked to fill in a satisfaction questionnaire for each DSE after completing the tasks. The instrument is adapted from WAMMI (http://www.wammi.com), and Koohang [18], focusing on the need to capture participants' immediate felt experience right after performing the tasks. The main results of the study, as far as we are concerned, are that (a) 100% of our testers finds annotation useful (b) 100% of our testers annotate in their research activity; (c) 50% of testers were not satisfied with how the tool allowed them to access and manipulate their notes (Table 2).

4.2 Suggested Features

In the questionnaire is a section where participants were asked to comment on the functions they thought were the best and to suggest improvements. We went to look at their responses in order to see if any of those who felt unhappy with the annotation tool wrote more specific complains, but we didn't find relevant information on annotation.

4.3 Screen Capture

We went to see the screen capture in order to understand how the testers, at what time in the workflow, had used the annotation tool. We saw that most of them, after having installed and tried it, had just opened it during the reading of the essay, often

Table 2 Some data from the satisfaction questionnaire

Questions	Agree	Disagree
I’d like my workflow to be more supported	xxxxxxxxxx	xx
This website is a precious resource	xxxxxxxxxxxx	
I can quickly find what I want on this website	xxxxx	xxxxxxx
Annotation is useful	xxxxxxxxxxx	x
I rarely take notes when I work with texts		xxxxxxxxxxxx
Synoptic comparison is what I do in my job with texts	xxxxxx	xxxxxx
This website has some annoying features	xxxxxxxx	xxxx
I am happy about how the system gives access to my notes	x	xxxxxxxxxxx

not more than twice. 3/12 only tested it once after installing it, 7/12 opened it during the essay and took up three annotations, only two tried out the instrument during all the tasks, mostly in underlining.

Highlight, comment, tag. The tool gives the ability to mark portions of texts in three ways: highlight, comment and tag. Most users highlighted, comments and tags were very little used.

4.4 Final Discussion

The final group discussions of the panel were audio-taped, transcribed and coded. Their aim was to expand issues relating to note-taking habits, based on a set of open questions, where participants were asked to draw on their experience. The discussion was structured according to the following lineup and then consequently coded.

Confidence with digital or web-based research. We always ask for more information regarding the use of print resources and the web, in order to warm the group up and introduce it to the central topics. This time, the major trends were: (1) advanced use of the Web, at least where possible; (2) predominant use of the print books, libraries, and/or traditional paper resources; (3) lack of digital resources related to authors or themes studied by the participants; (4) general preference for pdf, (or journal’s articles to download) when it comes to using a digital resource (Fig. 3).

Confidence with tasks/usefulness of Lope de Vega. In this way we tried to understand if the tasks were suitable for the sample’s background, engaging in a

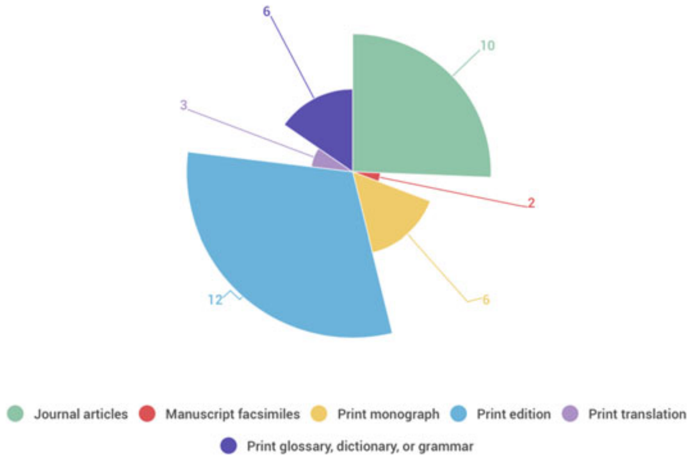
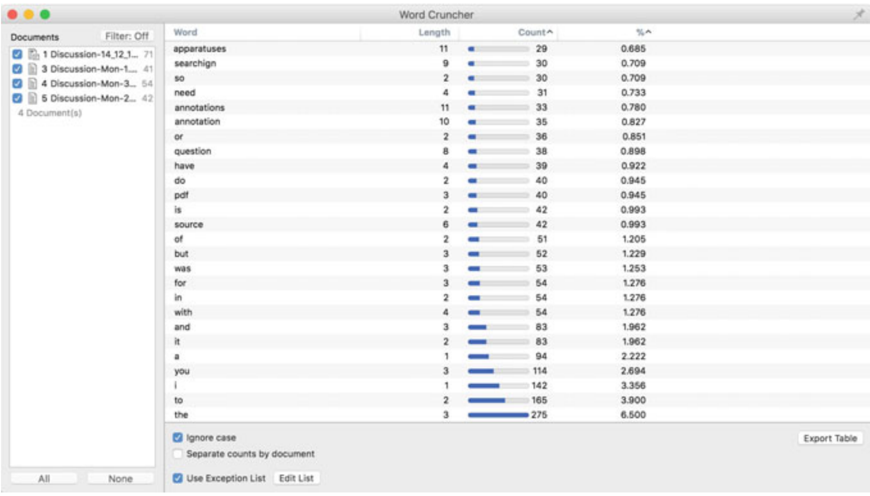


Fig. 3 A chart showing the most used resources by our testers



Word	Length	Count	%
apparatuses	11	29	0.685
searchign	9	30	0.709
so	2	30	0.709
need	4	31	0.733
annotations	11	33	0.780
annotation	10	35	0.827
or	2	36	0.851
question	8	38	0.898
have	4	39	0.922
do	2	40	0.945
pdf	3	40	0.945
is	2	42	0.993
source	6	42	0.993
of	2	51	1.205
but	3	52	1.229
was	3	53	1.253
for	3	54	1.276
in	2	54	1.276
with	4	54	1.276
and	3	83	1.962
it	2	83	1.962
a	1	94	2.222
you	3	114	2.694
i	1	142	3.356
to	2	165	3.900
the	3	275	6.500

Fig. 4 A screenshot from Atlas.ti showing the most frequent terms in the final discussion

quick discussion about the edition and the satisfaction with the exercises. Testers were all experts—we have no BA student, this time—belonging to departments of literature, philology and history. They said they were confident with text comparison tasks, although we expected the opposite. Analysis of the discussion shows that the two words most frequently pronounced by the participants (excluding the semantic field of the annotation, which we come to later), are search, and apparatus (Fig. 4).

4.5 Annotation

"What about hypothes.is? did you use it?" we asked at this point. We were about to discuss the most problematic result of the experiment, as most of the users did not used it at all. "I opened it, but I didn't take any notes" was the most common answer. Thus we tried to investigate further, asking if there were particular reasons or usability barriers that discouraged them from using it, but we did not get any useful insight. In general, our testers were not able to articulate detailed explanations of why they did not use the tool, let alone able to say why it did not satisfy them. We have not received sensible answers on this subject that go beyond various comments, like not being accustomed to taking notes online, etc. "I highlighted a bit, then I was not able to find my highlights" answered one of the participants (P3). "I did not find it useful here", (P10) said another. Another has claimed to have used it to look at the underlining of others, and then passed on to the exercises (P11), etc.

Annotation in user workflow. Those who used hypthes.is more frequently did it in the exercises that involved the reading of the introductory essay (P5): in general the essay was much more annotated that the texts, although most of the exercises required to navigating the texts themselves, using the search engine, and expanding on information derived from the essay. Highlights were the most common type of annotation in the essay.

Annotation techniques on print. Testers declared marking extensively, as we discovered in our previous study. Also in this case we recorded comments regarding the felt experience of a better learning performance. "I always note," said one, "my books are full of notes," said another. "Without writing down I seem to read for nothing", said another, etc. Highlighting, underlining, paraphrasing, summarizing, or using simple keywords whose function is to link to other resources are the most frequent types of marks made by our testers. Among the stratagems to visually organize the notes is the use of different colors.

Annotation techniques on digital. The majority of users said they do not annotate when working on digital. A small number of testers, precisely 4, said they can not do without annotating, and in the absence of tools use a notebook, where they manually report the references from screen to paper, often using screenshots organized in a folder. Curiously, two of these four, before the session began, sat in front of the laptop with a notepad and a pen next to it.

5 Observations

The study confirms that users need annotation tools, which seems to further validate including annotation in the edition's functionality. Regarding the fact that users did not use the tool we provided, nor were able to explain why they did so, there can be two explanations. On the one hand, there is the fact of not being accustomed to note-taking on the digital, as more than one has reported, on the other there is the possibility that the tool's usefulness was not immediately clear, as was suggested by some testers who, for example, hinted at the partial usefulness that it would have for them to access or search notes via keyword. This is definitely too little to derive conclusions. More research is needed as to why the users were not accepting the tools provided. So, we propose a structured longitudinal approach based on human-centered design to design and annotation tool that would actually be usable for scholars.

References

1. Cooper, A. et al.: About Face 3. The essential of interaction design. Wiley Publishing Inc., Indianapolis (2007).
2. Unsworth, J.: Scholarly Primitives: What Methods do Humanities Researchers Have in Common, and How Might our tools reflect this? part of a symposium on "Humanities Computing: formal methods, experimental practice" sponsored by King's College, London (2000), http://www.people.virginia.edu/~jmu2m/Kings.5-00/primitives.html, last accessed 03/10/2017.
3. Schacht, P. Annotation, MLA Modern Language Association Journal. https://digitalpedagogy.mla.hcommons.org/keywords/annotation/.
4. Bargeron D. & Moscovich T.: Reflowing digital ink annotations, CHI '03. In Proceedings of the SIGC Conference on Human factors in Computing Systems (eds G. Cockton & P. Korhonen), pp. 385–393. ACM Press, New York, NY, 2003.
5. Hoff, C., Wehling, U., Rothkugel, S.: From paper-and-pen annotations to artefact-based mobile learning, in Journal of Computer Assisted Learning (2009), 25, 219–237.
6. Marshall, C. C.: The Future of Annotation in a Digital (Paper) World). in Proc 35th GSLIS Clinic, Success and Failures of Digital Libraries, University of Illinois Urbana-Champaign 98.
7. Kiewra, K. A., The Relationship between Information Processing Ability and Note-Taking, in Contemporary Educational Psychology, 13, (1988) 33–44.
8. Jardine, L., Grafton, A.: "Studied for Action": How Gabriel Harvey Read His Livy, in Past and Present, Volume 0, Issue 129 (Nov., 1990), 30–78.
9. Bruce, Blair, A. 2003. Reading strategies for coping with information overload, ca.1550–1700, in Journal of the History of Ideas 64, no. 1: 11–28.
10. Drexel, J. S., Aurifodina artium et scientiarum omnium; excerpendi sollertia, omnibus litterarum amantibus monstrata, Antwerp, 1638.
11. Kwakkel, E.: Medieval Books, blog. https://medievalbooks.nl/author/erikkwakkel/.
12. Mueller, P., Oppenheimer, D.: The pen is mightier than the keyboard. Psychological Science 6(25) pp. 1159–1168 (2014).
13. Nelson, T. Literary Machines. South Bend, Indiana: The Distributors. Edition 87.1. Also 6th Edition, 1984.
14. Marshall, C. C.: Towards an Ecology of Hypertext Annotation. 98.
15. Marshall, C. C.: Annotation: from paper books to the digital library. in Proc DL 97, Philadelphia, PA (July 23–26, 1997), pp. 131–140.
16. Prié, Y.: Lecture Active et Annotation de documents. Slide presentation. http://pagesperso.lina.univ-nantes.fr/~prie-y/ens/04-05/MasterRecherche/lecture-active.pdf.
17. Nielsen, Jakob. "Guerrilla HCI: Using Discount Usability Engineering to Penetrate the Intimidation Barrier", 1994. [Accessed at http://www.nngroup.com/articles/guerrilla-hci/].
18. Koohang, Alex. "Expanding the Concept of Usability." Informing Science Journal, vol. 7, 2004, pp. 129–141. [Accessed at https://pdfs.semanticscholar.org/524f/7dc44ca12f79074bd3064ca3887bcb938218.pdf].

Establishment of a Complex Database for the Study of Cultural Heritage Through the Reading and Analysis of the Traditional Architecture of Upper Kama

Sandro Parrinello and Federico Cioli

Abstract The Upper Kama Region, located north of the city of Perm in the Volga Federal District of Russia, represents a frontier territory between the East and the West and an important crossroad for trade. The numerous religious complexes and industrial settlements scattered throughout the entire territory, buildings of considerable architectural interest, are often left in poor conditions and in a state of neglect. The aim of the research is to implement integrated digital survey methodologies in order to create tools for the management and enhancement of the cultural heritage of the Upper Kama Region. The research, which takes place in the three district of Usolye, Solikamsk and Cherdyn', was carried out thanks to the collaboration between the DAda Lab of the University of Pavia and the Perm National Research Polytechnic University - Scientific Board headed by Prof. Sandro Parrinello and Prof. Svetlana V. Maximova - and is still ongoing.

Keywords Heritage Informatics · Culture Big Data · Cultural Heritage Risk · 3D Survey · Stroganov Architecture

1 Introduction (SP)

The documentation of a cultural heritage, as dispersed as that of Upper Kama traditional architecture, requires the elaboration of a new way of understanding the meaning of the target sites. Upper Kama Region has always attracted the interest of historians and researchers, representing a border territory between East and West and a meeting point between European and Asian culture. The region preserves several

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Fig. 1 Panoramic view of the surrounding landscape around Cherdyn and the Kolva River, a tributary of the Višera River

examples of a peculiar architecture, (rich) in orthodox complexes and neoclassical industrial settlements of the eighteen century. The Upper Kama heritage is currently experiencing a period of decay and abandonment, concentrated on the rural landscape, the last stronghold of the tradition of provincial Russian architecture. The aim of the research is to integrate different digital documentation methodologies, in order to create an instrument of analysis and evaluation of the condition of the cultural heritage for the development of territorial renewal plans [11]. The importance of Upper Kama documentation is due particularly to the lack of a detailed census archive from survey analyses that provides precise information on the quantity and quality of monuments and environment. During the 20th century, numerous historians and researchers have attempted to document the wide phenomenon of these religious buildings combined with industrial archeology complexes.[1] Nevertheless, these researches do not provide a global heritage census and the technical basis for preservation processes, which are necessary to maintain and promote the cultural tradition of the region (Fig. 1).

2 Territory, History and Architecture of Upper Kama (SP)

The Upper Kama Region is an emblematic site where monumental architectures and widespread criticalities coexist: heterogeneity of architectural features, stylistic and constructive variety, multiplicity of construction materials and related pathologies of degradation and conservation. This characterizes Upper Kama basin as a dispersed

[1] A. S. Teryohin, G. D. Kantorovich, I. V. Makovetskiy and V. A. Tsypushtanov provided the most important contribution to this research, presenting their work regarding culture and architecture of Upper Kama settlements in ‘Monuments of stone architecture of XVI–XVIII in Solikamsk (1970). In 1988, Kostochkin [5] wrote a monograph entitled “Cherdyn, Solikamsk, Usolye”, a work that integrates all the previous research activities on the Region. The Perm Scientific Restoration Atelier carried out several activities of inventory, documentation, survey, and developing conservation and restoration projects for the Upper Kama region and in 1986 provide reliable data regarding the majority of existing monuments. Recently, a study about the Upper Kama architecture was conducted by W. Brumfield in form of photographic surveys “Solikamsk: Architectural Heritage in Photographs” (2007), “Cherdyn: Architectural Heritage in Photographs” (2007), “Usolye: Architectural Heritage in Photographs” (2012). Today, the Perm Krai Center for Monuments Protection is in charge of the Upper Kama heritage preservation, establishing projects for the definition of “Protection zones”, as the one regarding the Old Town of Usolye.

system of potential cultural value added to the territorial context, explicable through a targeted system of knowledge, intervention and promotion. The territory extends in the north of Perm Krai, west of Ural Mountains, bounded by Komi region in the North. Mineral resources and the role of commercial crossroads of imperial period has led the territory to an intense cultural and architectural development focused between the 15th century, with first industrial settlements, and the 18th century, till the rapid decline of Russian October Revolution (1917).

The founding of saltpans by merchant families, such as Stroganovs or Golitsyns, led to the development of urban settlements with residential buildings and orthodox complexes, churches, bell towers and family chapels. Salt trading business, that through Urals reached Siberia and, then, China, led to the spread of numerous urban centers, associated to current districts; Solikamsk (1430), Cherdyn (1535) and Usolye (1606).[2] The comparative study of sites highlights stylistic coherence and unitary shapes and themes, related to each other. Masonry buildings, characterized by a mixed style between Muscovite baroque and European influences, gradually replaced the typical wooden architecture of industrial settlements. Monumental sites and isolated religious architectures enriched the landscape along the river basin, characterized by stylistic uniformity in decorative brick elements, such as frames with "*zuchkov*" motif and majolica theme of "sirens". Many churches have a main space covered by onion domes with a large entrance refectory, while bell towers have an octagonal plan section, surmounted by thin pinnacles, with semi-circular "*zakomary*" covered in colored ceramic tiles. Residential buildings are divided into two main types: winter residences, characterized by wooden roofs with trusses, separated entrance compartments and decorated stoves; and summer residences, with similar constructive technologies but stylistically simpler and more contained (Figs. 2 and 3).

Architectural heritage of Upper Kama derives by a localized cultural development contained in a limited historical duration, with European influences in constructive and stylistic characteristics, spread through cultural exchanges along commercial routes. The region consisted in numerous sites interconnected by a unified historical, architectural and stylistic language that distinguishes the territory as a unique cultural basin, requiring equally unified practices of study, expression and communication [9].

The abandon of Upper Kama region, due to the collapse of middle-class society, at the beginning of the 20th century, lefts its architectural heritage to decay. The opening of railway lines decentralized the districts with respect to new commercial routes, and

[2]Brumfield [2]. In his contribution the author provides an overview of the historical and territorial evolution in the districts of Cherdyn and Solikamsk. "*Among the earliest Russian settlement in the area was Solikamsk, apparently founded around 1430 by the Kalinnikovs, a wealthy merchant family from the northern town of Vologda who were intent on developing the ample salt springs in the vicinity of the middle Kama River*" (pg. 318). "*In the 1450s and 1460s a new wave of Orthodox missionary activity accompanied this move, which resulted in the construction of the first churches in the middle Urals and the establishment in Cherdyn' of the area's first monastery, dedicated to Saint John the Divine […]. After a fire destroyed Pokcha's log fort in 1535, Cherdyn' was officially designated a town and became the administrative center of the large Perm territory*" (pp. 319–320).

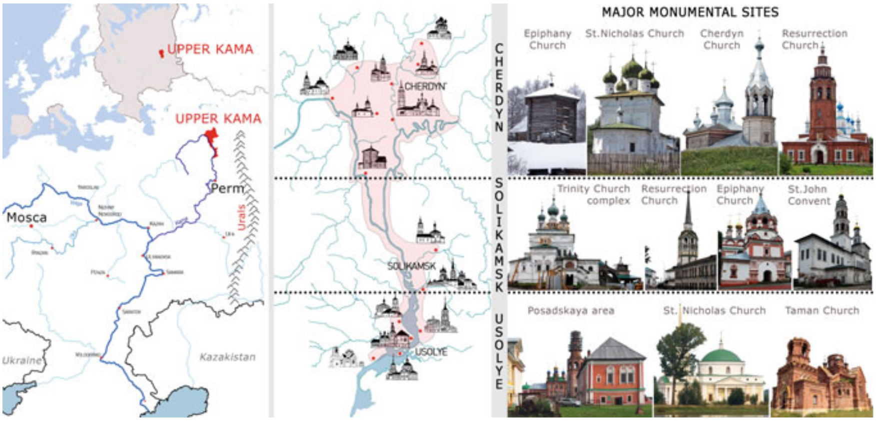

Fig. 2 Upper Kama basin and its contest; Upper Kama districts; monumental sites and examples of architectural complexes. Picture from H2020-MSCA-RISE-2018: PROMETHEUS

Fig. 3 Decorative and constructive apparatus, materials and technical solutions applied in Upper Kama architectural heritage

development plans of Kama River involved widespread flooding of many settlements and sites, reducing to one third of the original the existing heritage. The need of a unified digital documentation, in support of administrative management and conservation practices, reflects the definition of complex databases reach in information models libraries on constructive elements typical of Upper Kama architecture.

3 The Case Study of Usolye (SP)

The research aimed at the creation of a digital database that describes the features of Upper Kama architectural and environmental heritage. For the acquisition of precise information about the current image of the place are developed innovative methods to survey and geo-reference data. The integrated methodology of research, combining traditional and modern methods, perceptive investigations and precise digital measurements, want to assess the state and condition of historic complexes and sites. The documentation of Usolye as case study, conducted during three years of research, is the starting point of a more ambitious project aimed at the analysis and representation of the architectural and environmental features of the entire Upper Kama region. The variety of monuments and the complexity of the environmental system led to the choice of Usolye as a pilot project [3]. The city, founded by the Stroganov Family in 1606 as an important industrial settlement on the Kama River, was a commercial outpost for the production of salt in Urals (Brumfield [1]. The historical center contains a couple dozen buildings, some residential and others related to the former industrial and commercial function of the complex. The Stroganov Ensemble, consisting of the Chamber, the bell tower, and the Transfiguration Cathedral, has been the main subject of the research. The three buildings, built in the XVIII century by the family, represent a rare and one of the most important examples of Stroganov art, mixed with local workers. Their image has changed over the centuries, modifying the prospect along the river, due to numerous fires and floods that have periodically affected the territory. Furthermore, the analysis moved from the architectural complex to the environmental system, in order to understand the interaction between the landscape and the urban settlement. The key element that characterizes the landscape of Usolye is the river and its relationship with the banks. The site consists into four smaller islands, connected to one another by bridges or highways. The vegetation of the islands is characterized by the diversity of wild marshes, meadows, medium height hygrophilous trees, such as birches, willows and wild cherries, dominated by tall black poplars, which stand as solitary rulers. The elements, both architectural and natural, interact with each other creating a unique system.

The organization of two summer schools, set in the Historic Centre, reach with remarkable examples of religious, residential and industrial architecture, aims to the experimentation of different methodologies of analysis in order to develop renewal proposals also valid for similar isolated complexes in the north of Upper Kama. The notoriety of Usolye guaranteed visibility to the project, feeding the debate between citizens and administrative bodies about the preservation of local cultural heritage. The survey conducted with 3D laser scanning and photogrammetric methodology (Structure from Motion) aimed at the development of three-dimensional database, which makes possible to integrate and improve information from other investigation, such as structural inspections and thermographic surveys. A detailed census of the existing buildings, through the filling out of a specific data sheet, supports the three-dimensional data in order to provide precise information about the state of preservation and the architectural features of each building.

4 Methodologies for Investigation (FC)

Through the digital representation, the project is going to re-establish the cultural value of the place, helping the development of a concept for the preservation of the authentic image of the architectural environment, planning processes for its transformation and valorization. Accurate surveying operations constitute the fundamental basis for the critical analyses of architectural elements, settlements or territories. Furthermore, they are necessary to plan and manage conservation, restoration and valorization activities. The more advanced models of laser scanners, together with photogrammetry and Structure from Motion (SfM) methodologies [7], create a global overview of the surveyed object, useful to plan the post-production processes. They concern the creation of digital drawings and 3D models, representing plans, sections and facades, integrated by detailed texture in order to return an accurate and realistic image of the current condition.

The three campaigns of laser-scanner survey, conducted with the use of a Leica ScanStation C10, concerned the Stroganov Chambers (2014), the Stroganov Ensemble, with particular attention to the Steeple and the Transfiguration Church (2015) and the residential complex along the river (2016). The acquisition of data were implemented by a photographic campaigns close range, aim at the built of 3D models (SfM) through which extrapolate metrical reliable textures, containing useful information about the morphology and preservation of constructive elements. These models, which refer to the coordinate system of the laser scanner survey, enriched the archive, constituting a significant part of the complex database together with the information provided by the data sheet census [8].

The interpretation of historical maps allows the detection of the traces of the past, such as ruins and foundations, reconstructing the memory of the place. Cartography and drawings, owned by the municipality archive and the Stroganov Centre, were the starting point for the Old Town analysis. They provide a useful documentation for the creation of thematic maps, in order to identify the main types, functional features and remaining signs of the disappeared architectures. The census activities concern the cataloguing of constructive systems and technological details through a data sheet divided in three main sections: the first, 'general information', provides a framework of the building related with its surrounding; the second, 'visual description', highlights stylistic features, such as dominant colors, visibility and interaction with the urban fabric. The last section, 'architectural-constructional analysis' shows preliminary surveys, 3D models and pictures, representing plans, prospect and sketches, focusing on the constructive system, materials and typology [6].

The data collected during the investigation process served to create detailed two-dimensional documents that faithfully represent plants, elevations and sections of the Stroganov complex and 3D models of the decorative elements, which became integrated instruments of the digital database. All the data contribute to establish the digital archives, structured as a cascade system, which connects the territory with the single architectures and its constructive elements. The georeferenced database is a unique archive, which allow a smart usability and interpretation of data, enabling to deepen the knowledge about the complex. This led to the creation of an atlas of architectural elements that allows a comparison between the various settlements, which is necessary in order to develop an integrated renewal plan on a territorial scale (Figs. 4 and 5).

Fig. 4 3D point cloud of the Stroganov Complex of Usolye, derived from the laser-scanner survey. The figure shows the Transfiguration Church, the Bell tower and the Stroganov Chamber in the background

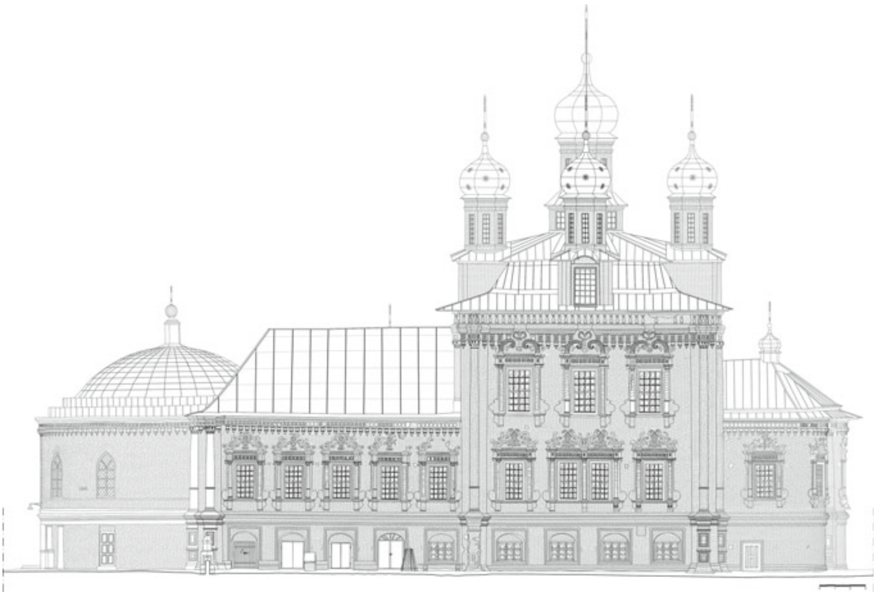

Fig. 5 CAD Wireframe drawing of the Transfiguration Church in Usolye

5 The Development of a Complex Database (FC)

The documentation of the disperse heritage of Upper Kama, connected by a unique databases obtained by the digital survey, as advanced instruments for the managing of the restoration measures on a regional scale, is the aim of the project PROMETHEUS, proposed for the Horizon 2020.[3] The databases consists in informatics containers, as digital archives reach on cultural and scientific information, constantly updatable and strictly connected with the physical reality. Databases are potentially a new generation of instruments, able to establish an interaction between interdisciplinary fields.

The identification of categories of typological and identifying constructive features of Upper Kama Region has been necessary in order to develop the structure of digital archives, managed as "libraries". Through them, it is possible to define and manage information models, unified and classified in architectural building families, with a geometric "shell" implemented through the informative content of historical, material, constructive, technological and estimative data. Each unit will constitute a typological module applicable for the definition of architectural models, both directly and duplicated with partial variations of conformity to the specific context, developing a "modeling mitosis" process and expanding the digital archive. "Digital Modeling" thus finding a concrete application as "Procedural Modeling", developing a grammar of shapes based on the identification of variants and invariants that define archetypes of the architectural elements, which can be summarized in descriptors belonging to different information fields. The definition of a library of Upper Kama heritage thus becoming a necessary phase and a fundamental input, in virtue of constructive and material richness found in its architectural sites, in order to define a database management system (*H2020-MSCA-RISE-2018: PROMETHEUS*) (Figs. 6 and 7).

Actually, there is a gap between three-dimensional databases and design instruments (e.g., 3D models and 2D drawings), that the application of BIM processes is trying to bridge [10]. The project, working from territorial to detailed scale, allows to estimate the efficiency of the parametric models and offers the possibility to optimize the database, integrating data with parametric digital drawings, representing the quality of the place. The myth of a global database for the preservation of cultural heritage is a matter of international concern (as confirmed by several European

[3]The project PROMETHEUS, proposed for the Horizon 2020, Marie Skłodowska-Curie Research and Innovation Staff Exchange (MSCA-RISE-2018), started from the collaboration between the universities of Pavia, Valencia, Florence, Granada, Perm and the two small businesses SIΣMA S.r.l.s. and EBIME S.L. In particular: the Department of Civil Engineering and Architecture – DAda Laboratory of UNIPV—University of Pavia (Team: Prof. Sandro Parinello, Dr. Francesca Picchio, Ph.D.s Raffaella De Marco, PhDs Federico Cioli); the Department of Architectural Constructions—I + D+i Laboratory of UPV—Polytechnic University of Valencia; the Architecture and Urban Studies Department—DSLab of PNRPU—Perm National Research Polytechnic University. The aim of the project is the documentation of the complexity of Upper Kama architecture and the development of strategies for the analysis and management of data applicable to European Cultural Heritage Routes.

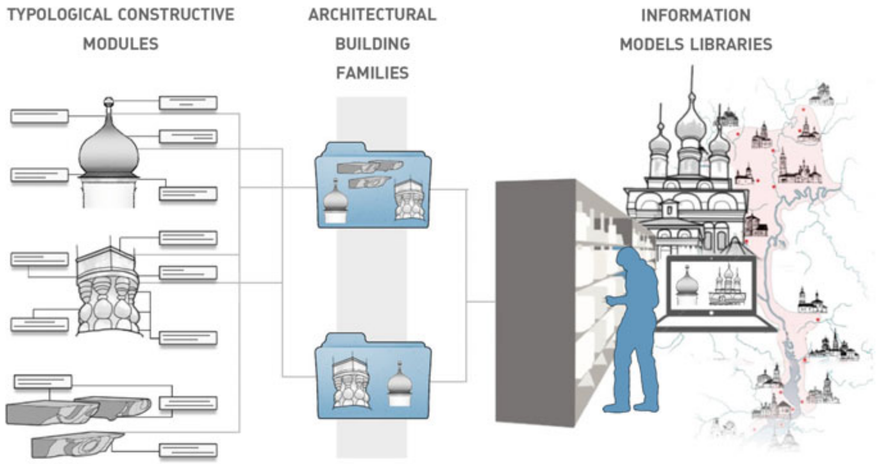

Fig. 6 The schema shows the structure of the work in order to organize the digital database. The aim of the project is to develop Typological Constructive Models and to define Architectural Building Families with a high level of details and accuracy in geometry. Picture from H2020-MSCA-RISE-2018: PROMETHEUS. Graphics by R. De Marco

Fig. 7 Some examples of religious architecture dispersed in the Upper Kama Region and 3D model of the Taman church obtained with SfM detection

projects). The main problem of this type of archives is the usability, which often do not permit to appreciate the cultural background of the place concerned. The flank of databases with an appropriate representation is a challenge, necessary to improve the functionality of digital systems. The relationship between information content and drawings seems to be the only way to develop strategies for the promotion of virtual systems aimed at the documentation.

6 Conclusions (FC)

The analysis highlights several issues, regarding architectonic and structural conditions of the buildings, which are in danger to disappear and require restoration and consolidation works. The documentation produced is the base to start a preservation and renovation project and allows to analyze the issues involving the site, from the landscape to the single architectural elements, understanding materials and degradations. These conditions, reflected all around the Upper Kama Region, led to the development of thematic maps, connected with the digital database, in order to highlight the main issues that cross the territory all along the Kama River. The methodology, developed during the application at the case study of Usolye, is replicable to the other architectural complexes. Furthermore, could be experimented to other cases of dispersed heritage, which concerns a system of relationships, features and cultural values disseminated at the territorial level. It makes the vast amount of information, deriving from such heritage complexes, accessible and usable in order to manage and develop informatics system and touristic thematic routes. The importance of preservation and documentation involves both tangible and intangible features:

> As a monument and a centre of high culture, the Lavra is infinitely necessary for Russia, and in its entirety, what's more, with its day-ta-day existence, its very special life that has long since disappeared into the realm of the distant past. The whole distinctive organisation of this vanished life, this island of the fourteenth-seventeenth centuries, should be protected by the state with at the very least no less care than the last bison were protected in the Belovezh Forest [4].
>
> Florenskij P. Il rito ortodosso come sintesi delle arti, pg. 110

References

Brumfield W.C.: *Usolye: Stroganov outpost in the Urals*. Russia and India Report (2011), in: http://in.rbth.com/articles/2011/08/11/usolye_stroganov_outpost_in_the_urals_12850.html

Brumfield W.C.: *The Architectural Heritage of Solikamsk and the Northern Districts of Perm Province*. In: *Cahiers slaves*, n°10, 2008. Routes et chemins slaves, sous la direction de Laure Troubetzkoy et Francis Conte (2008) 317–355

Cioli F.: *The district of Usolye in the territory of Perm (Russia). Experience of documentation for the valorization of cultural heritage*. In 2da Convención Internacional de Ciencias Sociales y Ambientales (2017)

Florenskij P.: *Il rito ortodosso come sintesi delle arti*. In La prospettiva rovesciata e altri scritti, Gangemi Editore, Roma (2005)

Kostochkin V.V.: *Cherdyn, Solikamsk, Usolye.* Moscow, Stroiizdat, (1988)

Mezenina K.: *Study of the Phenomenon of Upper Kama Architecture: Rehabilitation of Usolye Historic Site*. In: Amoruso G. (eds) Putting Tradition into Practice: Heritage, Place and Design. INTBAU 2017. Lecture Notes in Civil Engineering, vol 3. Springer, Cham (2018)

Parrinello S., Picchio F.: *Dalla fotografia digitale al modello 3D dell'architettura storica*. In: DISEGNARE CONF., vol. 6 (2013) 1–14

Parrinello S., Maksimova S., Mezenina K.: *Historic Environment Architectural Survey with the Use of Digital Technology,* Urbanistika, vol. 17 (2015) 102–117

Parrinello S., Mezenina K., Shamarina A.: *Holistic architectural survey for documenting heritage sites: the case of Usolye architectural complex in Urals, Russia*. In: Nature Culture Heritage in Context. vol. 7th, p. 36, Prague:Center for Heritage & Society - University of Massachusetts Amherst; Faculty of Environmental Sciences - Czezh University of Life Sciences, Prague, May 16–19, (2016)

Parrinello S., Picchio F.: *Databases and complexity. Remote use of the data in the virtual space of reliable 3D models*. In: ARCHITECTURE AND ENGINEERING, vol. 2 (2017) 27–36

Parrinello S., Cioli F.: *Un progetto di recupero per il complesso monumentale di Usolye nella regione della Kama Superiore*. In: Restauro Archeologico, vol. 1/2018 92-111

Urban History Research and Discovery in the Age of Digital Repositories. A Report About Users and Requirements

Sander Münster, Florian Niebling, Jonas Bruschke, Kristina Barthel, Kristina Friedrichs, Cindy Kröber and Ferdinand Maiwald

Abstract The research group on four-dimensional research and communication of urban history (HistStadt4D) investigates and develops methods and technologies to transfer extensive repositories of historical photographs and their contextual information into a three-dimensional spatial model, with an additional temporal component. This will make content accessible to researchers and the public, via a 4D browser as well as a location-dependent augmented reality representation. Against this background, this article highlights users and requirements of both scholarly and touristic usage of digital information about urban history, in particular historical photographs.

Keywords Urban history · Photogrammetry · Augmented reality · 3D · User studies

1 Introduction

Imagine you're exploring the historic center of a city with its impressive town houses, churches and monuments. What if you could just use your mobile device to find out about the historic buildings around you, with detailed visual information about how they were built and the story behind them, making history come alive before your eyes? Photographs and plans are an essential source for historical research [1–4] and key objects in the digital humanities [5]. Numerous digital image archives, containing vast numbers of photographs, have been set up in the context of digitization projects. These extensive repositories of image media are still difficult to search. It is not easy to identify sources relevant for research, analyze and contextualize them, or compare them with the historical original. The research group HistStadt4D, funded by the German Federal Ministry of Education and Research (BMBF), is investigating and developing methods and technologies for this. Historical media and their

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contextual information are being transferred into a 4D–3D spatially and temporally scaled—model to support research and education on urban history. Content will be made accessible in two ways; via a 4D browser and a location-dependent augmented reality representation. The prototype database consists of about 200,000 digitized historical photographs and plans of Dresden from the Deutsche Fotothek (German photographic collection) [6] .

Within former articles we highlighted the prospected research agenda [7] as well as technological venues for virtual tourism support [8] and information habits and requirements of art and architectural historians as scholarly image repository users [9, 10]. The main purpose of this article is to subsume users and requirements of both scholarly and touristic usage of digital information about urban history and in particular historical photographs. This means:

- Identify focus groups and user requirements for scholarly users of image repositories: While there is much research about information behavior of scholars in the humanities, there are only few investigations about how art and architectural historians use image repositories for complex research tasks [10, 11]. For this reason we investigate the information and search behavior as well as image-based research methods of scholarly users on the basis of research literature, by an observational study as well as by a review of extant repositories. Outcome will be a set of implications for repository design.
- Determine recommendations for employing mobile technologies for learning about urban history: Since previous investigations on that topic focus primarily on technical or content quality [e.g. 12, 13], it is our interest to add an educational perspective and investigate how knowledge transfers take place by using mobile devices and in particular augmented reality for urban tourism. Based on a literature review outcome will be application scenarios as well as design implications to enhance urban tourism.
- Introducing technological pathways to enhance accessibility of photography repositories according to these requirements: A technical pipeline starts with the processing of large-scale photo repositories by using photogrammetry to enhance metadata quality as well as to gather spatial-temporal information about depicted objects. These information as well as implications and scenarios from the previous sections build ground for an augmented reality application for urban tourism as well as a 4D browser interface for scholarly users. Within this article basic principles and technological venues will be sketched.

2 Scholarly Users and Usage of Image Repositories[1]

Digital image repositories meet a wide range of needs, from research in humanities and information technologies, through museum contexts and library studies to tourist

[1] An extended version was previously published in [9].

applications [14]. The actual benefit of applications for users highly depends on usability, suitability and efficiency of the technical solutions [8]. In order to develop and improve tools and applications when researching visual media, the demands of the stakeholders need to be identified and distinguished. Therefore, an identification of the target group that relies on images for research is the first step. They will give the relevant insight to e.g. their research abilities, habits and needs as well as the actual motivation, i.e. their research questions and what they value as useful.

Archives and image repositories are usually accessible by everyone for a variety of purposes. Sweetnam provides a general overview of the users of archives which serves as the first narrowing of the target group: (a) professional researchers, (b) apprentice investigators, (c) informed users and (d) general public [15]. The dedicated purposes for accessing archives and repositories are (a) scientific research, (b) pedagogical application and (c) study of historical sites [16]. Our focus for this article is solely on professional researchers, in particular scholars who put a high emphasis on media, e.g. images for their work [10].

What else do we know about scholars in the field of art and architectural heritage research? As investigated via a survey involving contributors of major international conference series on digital cultural heritage between 1990 and 2015 [17], a majority of survey participants are humanists. The high rate of researchers in that field stood in contrast to our former investigations, where especially the rate of researchers in computing was much higher [18]. Within the humanities cohort, a majority of around 90% are archaeologists, followed by art historians (cf. Fig. 1). The low number of art and architectural historians found by this survey may be caused by the fact that they rarely publish on international podia [cf. 19]. With regards to methods used by participants of the survey, in particular statistical analysis, computer vision or 3D modelling are of relevance. Vice versa, data of relevance is primarily image and large scale point or polygon data as well as geo-located data and shapes (by GIS) and textual data.

2.1 Information Search & Retrieval Behavior in Art and Architectural History

How do scholars cope with information and in particular media repositories? Beside the multidisciplinary nature of a community dealing with art and architectural heritage research, many investigations on this topic focus on scholars from arts, architecture and humanities. The meta-analysis by Tenopier on the informational behavior of scholars maintains that an informational behavior [20], and thus also a research process, clearly differs between scholars in different disciplines. While visual elements and images are important sources for ideation and reflection both in fine arts & architecture and art & architectural history studies, a specific question is about differences between these fields. In the arts, images are used for inspiration, to know materials and techniques as well as to strive for starting trends" [21: p. 683]. For

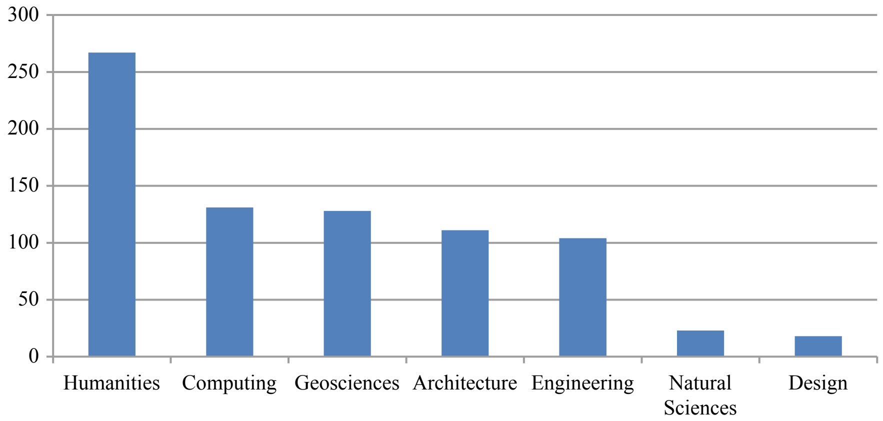

Fig. 1 Disciplinary background of scholars participating in international conferences on Digital Cultural Heritage since 1990 (Online Survey, n = 782) [17]

art and architectural histories, the main focus is on the discussion of the historical source, while a main characteristic is the development of a personal "information topography" [22, p. 49].

Art and architectural historians' research processes may have two different focuses: First, an inspirational one, in which the art historian tries to get a first impression of the topic. Online resources like Google have become a major start-up point in this sector [10]. The second focus is much more structured and thus differs from the lay access to image repositories. Art historians are trained to use a very precise language which helps to narrow down the search results. Instead of generally describing the contents perceived in a photograph they use search terms derived from the typology (e.g. special building type, name of the epoch, etc.) or from the iconography (e.g. sculptures are not described as "woman with a child", but as "Maria and the Christ Child"). Art historians' search behaviour thus already involves an interpretative effort at a quite early stage, which evolves during the following research process. This observation is reflected by the classical three-stage-concept of Erwin Panofsky [23], who—contrary to formalistic approaches—concentrated on an iconographic or interpretative method. Thus, the first strata of meaning comprises the description of what can be seen, for example a woman and a child on her knees. In a second step or strata, the art historian should interpret the work of art by using his accumulated knowledge: The woman becomes Maria, the child can be understood as Christ. The deepest level of understanding, reached by means of the so-called iconology, gathers more information on the topic, historic circumstances of the piece of work, its artist or the ordering party. Within the process of searching sources in image repositories, art historians tend to already start at the second level in order to manage the search more efficiently [24].

In digital art history other approaches are still developing that may support the research process and the search of historical sources. The Google reverse image search or Tineye offer the possibility to start from the photo itself in order to get suggestions about the depicted building etc. [25–31].

2.2 Creating Targeted Tools for Working with Image Repositories

What are recommendations for a creation of targeted tools for image repository users?

Many scholars relying on visual media note that currently online search for images and information is "counter-productive" due to the big amount of irrelevant data they come across or their limited technical abilities [32]. The degree of search expertise certainly has an influence on research progress and results [33] as well as the implementation of suitable applications and tools for filtering and handling. A lot of the existing tools for research platforms and applications stem from computer science and neither meet the needs of scholars from humanities [34] nor consider their behavior and skills. Several issues with solutions have been identified that drive users away. Confusing interfaces, difficulties with navigating or searching as well as unsatisfactory content due to e.g. incompleteness or poor quality have been named by users [35]—not only in visual domains but also for textual humanities [36]. Unnecessarily high numbers of mouse clicks or downloads of browser plugins in order to access information from online media repositories were also noted to be annoying [37].

Further common requirements of the users may be an ease of understanding concerning the data and knowledge, the development and improvement of tools for accurate search/research as well as an intuitive navigation and interface [16]. Someone vaguely familiar is usually in need of a straightforward introduction to the data and topic [38] as well as possibilities to select further material without getting discouraged by an overload of information. Whereas scholars will put emphasis on adherence of scientific standards, a thorough documentation through the supply of metadata and the possibility for collaboration and cross disciplinary work through e.g. annotation. A closer look at research behavior reveals a distinct difference between scientists as well as engineers and scholars from humanities. The first two rely heavily on recent studies and findings whereas the scholars from humanities often reinterpret old sources and revise findings of other scholars [37]. Therefore, sources for humanities research keep their relevance even after years.

Search and Retrieval

Information seeking behavior of humanities scholars has been investigated within several studies [cf. 39]. Two different cases of usage are significant for humanities scholars in e.g. art history who carry out a search for digital content within a repository. Either, they are looking for certain content (e.g. a painting usually searched for through the title or artist) for display purposes [40] so they know very well what they need, or they are looking for material connected to their research topic and are not aware of what they will come across.

The search and retrieval step is an essential part of the research process by providing evidence and sometimes revealing new insights. Several different search approaches support the access for repositories. Most notable are browsing of the content as well as keyword-based or content-based search. Browsing through pictures represented by thumbnails is acknowledged as a thorough way of accessing an image database [41], and people like to use it for inspiration as well as research [40]. It is very time-consuming considering the amount of digitized pictures image repositories offer today, but is close to the natural search behavior within humanities, where cross-referencing and following footnotes is standard [35]. A more strict and systematic access to image repositories is carried out through a keyword-based search. This calls for the translation of visual needs into text [42]. Some name keyword-based systems as the only successful ones [43] but a search with multiple terms quickly becomes challenging [15]. The keywords for the search have to correspond with the metadata of the content. Hence, a good metadata account and knowledge of it is essential for the success. Also, a structured vocabulary and thesaurus is beneficial [44]. There are different information the metadata can cover: descriptive, structural, administrative, and information of preservation as well as rights management [45]. A content-based image retrieval relies on the automated analysis of features (e.g. color, texture, shape) and the comparison of image data itself [46]. Automated lower-level feature-based image content analysis can be carried out by a machine but the higher-level semantic content of images still requires human interaction [47] and is usually more of interest for humanities scholars.

In general, a search query addresses two issues: irrelevant items have to be left out in order to maintain a considerably quick review of the results, and relevant items need to be pointed out to ensure an undistorted perception of the data [25]. In computer science, this is referred to as precision and recall, and it becomes even more relevant with the growing amount of digital content.

In order to further narrow down search results, many digital archives offer advanced search functions. Studies have shown that these filter options do not get much attention [26] and a simple Google-like search box is much preferred [35]. However, additional information like a connection to time and location may be used to access media repositories in a GoogleEarth or GoogleMaps-like way [15]. Cognitive load may be reduced by presenting related material in space and time [27], and the context can be grasped more easily [28]. Additionally, a search resembles a content browsing that does not necessarily need keywords.

2.3 *Empirical Investigations*

To verify the findings from literature, we conducted a review of more than 100 digital image repositories. It shows that existing online archives do not necessarily meet the requirements of art and architectural history scholars [10]. The review was done by probing image search tasks and protocolling results. Since this step was intended to get feedback about a current situation, a workshop held at the Digital

Humanities Deutschland conference in February 2018 took place to receive feedback about prospects. The workshop involved about 25 participants who, among others, were asked to reflect on their own experiences when using image repositories [48]. The workshop group named the following problems they encounter when searching for historic images:

- *Lack of quality of metadata and especially* inconsistency and incompleteness
- *Lack of standardized terms*
- *Limited possibilities to perform complex queries*
- *Insufficient filter options, such as time, motif, object type,* etc.
- *Unclear property rights*.

Some participants also named the reverse image search, but in the practical part of the workshop this approach was rarely used, even by this very technical group. With regard to the geospatial prototype presented, the group agreed that it was a sensible addition to the usual language-based search. Still, the possibility to carry out a faceted search was very much appreciated. Other opinions expressed the wish to label e.g. different buildings in the model, and to compare different images to each other – even more than only two, by juxtaposition or by superimposition. In general, the reactions were very positive towards the introduced approach, and most reactions mainly concerned the usability of the tool.

2.4 Implications

How to design image repositories suitable for scholars in the humanities and particularly art and architectural history? Out of both, the literature review as well as the empirical investigations, we condensed a set of high level implications for repository design:

- *Multilinguality*: Implications derived from our investigation are that a community locates especially in European countries—against this background, the provision of tools in the mother tongue language of addressed researchers is of relevance [49, p. 6].
- *Multidisciplinarity*: Since a community dealing with art and architectural research includes many different disciplines and approaches, varying epistemic demands, skills and habits as well as terminologies have to be obeyed [cf. 50, 51].
- *Differing levels of expertise*: since tools are often developed with the expert user in mind, usability issues may be another hurdle for those with less advanced ICT skills, who want to use specific "academic" tools [35].
- *Enhance accessibility and findability*: As named by many reports [49: p. 7, 52: p. 294], findability and accessibility of resources as well as the digitization of objects are the most critical challenges for media repository users.
- *Raise content quantity*: Recent studies stated a heavy use of generic search engines such as Google [33, 53], even if various repositories exist that are specifically

addressed to scholars in art and architectural heritage [54]. The limited depth and width of content was named as a major obstacle in the use of media repositories such as image databases [52: p. 301].

3 Education

A second path of interest for our investigations is to employ mobile technologies for a touristic exploration of urban history by using mobile augmented reality (AR) applications.

3.1 Augmented Reality Tour Guides—A Survey

In the last decade, various mobile AR applications have been developed for cultural heritage sites especially in Europe [12, 13, 55]. The increasing availability of smartphones and mobile gadgets has changed the tourism sector and will continue to enhance the ways in which tourists access information while traveling [56]. AR information systems can help tourists to get access to valuable information and improving their knowledge regarding a touristic attraction or a destination, while enhancing the tourist experience and offering increased levels of entertainment throughout the process [57]. Although previous research has shown the potential of mobile AR in tourism and the impact on tourists' experiences [58], the learning experience of mobile AR in the context of urban history and cultural heritage needs further research.

Tour guides are amongst the key front-line players in the tourism industry. Through their knowledge and interpretation of a destination's attractions and culture, and their communication and service skills, they have the ability to transform the tourists' visit from a tour into an experience [59]. A tour guide provides assistance, information and cultural, historical and contemporary heritage interpretation to people on organized tours and individual clients at educational establishments, religious and historical sites, museums, and at venues of other significant interest. Considering the research on general mobile augmented-reality tourist guides, which do not have the focus on mediating urban history, gives a broader perspective in that field. There are a few overviews [60, 61] which describe some applications and frameworks which classify mobile tourism applications in certain taxonomies by using different categories [62]. These studies concentrate on service-oriented instead of knowledge-mediating applications. Kennedy-Eden and Gretzel [63] worked out a taxonomy of mobile applications in tourism to provide insights into application development trends as well as gaps in the mobile application landscape. They laid down seven categories for tourism applications: Navigation, Social, Mobile Marketing, Security/Emergency, Transactional, Entertainment, and Information. In addition, they investigated user interactivity. A survey by Grün et al. [64] selected four mobile tourist guides and classified various service categories. Furthermore, a study by Yovcheva et al. [65]

Table 1 Criteria to assess Learning strategies in AR applications (based on [55])

Criteria	Description
Guidance	What kinds of user guidance are offered? (Self-guidance, themed Tour-guiding, Avatar)
Content	What are the characteristic pedagogical and motivational strategies used for content presentation or which ones can be realized? (e.g. storytelling or gamification)
Interactivity	What kinds of interactivity exist or can be realized? (Using movements of digital device, create content, Adventure games, quiz)
Collaboration	What are used approaches for collaboration among users? (Share information, find other users in your surrounding)

includes an inventory of 22 smartphone AR applications that where selected by several criteria to examine the benefits and drawbacks for the use of smartphone AR tourist applications. This research helps to get an overview of different mobile tourism applications, to determine necessary services for future interventions and to situate knowledge-mediating applications within a taxonomy. Another recent research work pointed out the factors which encourage tourists to actively use AR applications by performing a field study with 145 people in Deoksugung Palace, South Korea [66]. In addition to the technological acceptance, tourists' desires and needs were investigated by scientists, too [55, 67]. An updated Technology Acceptance Model, including external dimensions that are explicitly applicable to the AR urban heritage tourism context, was published recently [68].

Learning with new media and especially with augmented reality applications is another related field to this research. Radu [69] conducted a meta-study of 26 academic publications about human learning in AR and non-AR environments. The paper describes positive and negative effects, which are enabled through AR experiences. It highlights various technological and psychological factors, which influence the educational effectiveness of AR experiences. Research on learning experience and outcomes through mobile tourism applications is limited. A recent work presents a study on visitors' learning experience in an art gallery using portable/hand-held devices [70]. Furthermore, results of a study which investigates the increase of learning and sense of place for heritage places by using an AR mobile guidance system indicates significant effects on learning and sense of place through the AR application [71]. Kysela and Storkova investigated the use of AR as a medium for teaching history and tourism by discussing the use of AR for knowledge-mediating purposes [72].

A conceptual model of mobile AR for cultural heritage sites (cf. Table 1) is presented by Zaibon et al. [55], which is based on the theory of informal learning.

3.2 Recommendations for Application Design

The traditional tasks of tour guides should be implemented in mobile augmented tourism applications, which present location-based information about a cultural heritage site. Current AR applications provide a variety of different functionalities to meet these tasks. They give access to multimedia-rich environment through the use of various multimedia formats. Such formats range from sound and image to video clips, 3D models and hyperlinks that may direct the user outside the application [31]. They assist the tourist through navigation functionalities, for different services like tickets, reservations and shopping, and a few implement a creating, sharing, collaboration, communication or social component [27]. According to their functionalities, mobile AR applications in tourism can focus on service-oriented or knowledge-mediating issues. For providing a user-friendly and sustainable mobile tourism application a mixture of both is recommended to strengthen user acceptance. Providing assistance and information are well implemented tasks. One of the main problems within mobile AR applications is the missing interpretation of cultural, historical and contemporary heritage to people and missing pedagogical approaches to connect different disciplines like geography, architecture, art, history as well as cultural, economic, social facts related to a destination.

3.3 Pedagogical Approaches to Enhance Visitors' Experience and Knowledge Transfer

There are different approaches to give visitors a unique experience in real-life city tours. A few of them are implemented in AR tourism applications, but there is still a huge potential in using pedagogical approaches to enrich AR applications for mediating knowledge about urban history or cultural heritage. Themed tours are amongst the most common approaches, which are already adopted for AR tourism applications as the Chicago00 [73] or Timetraveler-App [74]. These applications give access to guided or self-guided tours under the aspect of a certain themes: The St. Valentine's Day, Massacre or The History of the Berlin Wall. Another approach used in real-life scenarios are scenic walks or theatre walks, which are combined with drama. The guide slips into a role and leads the visitors to special places where other actors may bring the events of earlier times to life. This kind is very similar to so-called Ghost-Walks, with ghost stories and legends in the foreground. These elaborately staged scenarios could be a model to implement in AR tourism applications. The development of mobile technology makes it possible to create digital scenarios, which make history become alive at certain locations. Living History at Union Station in Kansas City is a tourist application, which uses the principle of a theatre walk. This is a mobile augmented reality application using story telling. It takes users on a journey back through time as they take self-guided history tours that play out on their phones, as they explore the Union Station their own way. The application provides in-depth story telling within an augmented reality experience, before users can go deeper through written stories, images and artefacts [15]. To explore pedagogical and motivational approaches to enhance tourism experience and foster learning about a destination is one important issue for upcoming research. To investigate tourist responses to different pedagogical strategies within AR tourism applications and to illuminate motivational aspects and learning effects are an important part of this research. To unfold the potential of AR technology for the communication of urban history or cultural heritage it is indispensable to translate real-life approaches into digital scenarios, which can be implemented in mobile augmented tourism applications.

3.4 Implications

Based on a literature review outcome will be application scenarios as well as design implications to enhance urban tourism.

- *Scenarios*: Currently especially user guidance is supported by virtual tourism and in particular AR applications. Related purposes are for instance navigation, social interaction, marketing, security or emergency, entertainment, and information. With the rise of Pokemon Go also exploration may be added [75].
- *Motivational design*: The use of avatars as well as stories may enhance the intensity of as well as the motivation for learning. In contrast and as investigated in previous research, gamification elements may be limitedly useful, too [76].
- *Knowledge transfer*: In contrast to other media and technologies [e.g. 77] there are no proven pedagogical strategies for touristic and AR based learning available yet. A general suggestion is to build digital applications on real-life approaches and challenges and substitute or enhance for instance travel guides or maps.

4 Technological Prospects

The findings gained formed the basis for the conception and prototypical development of a 4D browser interface for a spatially and temporally located search in media repositories as well as a mobile augmented reality application. A special challenge of a first development phase was the semantic linking of the data and the visualization of temporally and spatially located information. Thus, the desired 4D browser application must be able to handle large, transient city models. With a view to further development, there are currently strategies for presenting a large number of data sets [78], interfaces for automatic data retrieval from repositories as well as options for user-controlled, interactive information linking on a development agenda.

4.1 Photogrammetric Methods of Visual Knowledge Generation

A possible technological basis for creating access to large scale image repositories is the spatial and temporal aggregation of data, in this case historical photographs in a 4D model. The span of technologies used reaches from content based image retrieval of image data bases and temporal and spatial orientation of images in virtual environments through to the generation of complex historical 3D models. The potential of historical images lies especially in the documentation but also in the reconstruction of already destroyed cultural objects [79, 80]. For about 20 years the classical analytical photogrammetry has been supported by digital image processing tools. An increasing level in automation is to be seen in all of the technologies. In case of big repositories the methods and algorithms are most often used for recent images [81]. But also single buildings or cities are modelled using historical data [82, 83]. Working with historical images is difficult due to missing information to inner and exterior orientation of the camera. In other words, the camera type and metadata for the location and point in time are missing. Since historical images show very strong radiometric differences even if the images are from the same epoch, the classical approaches tested in the research group fail or are not completely automatable [84]. Methods that were tested in a first instance are the direct linear transformation algorithm for the absolute orientation of images and the Structure-from-Motion (SfM) method for a relative orientation of more than 10 images. Even a sparse 3D model could be created with a high manual effort (cf. Fig. 2).

The work in the research group will now be focusing on how to achieve a relative orientation automatically without using gradient-based matching techniques. Other studies as well as our researches on historical images show that the classical approaches like the Scale-Invariant Feature Transform (SIFT) [85] fail due to huge image differences [86, 87]. Geometric feature descriptors show better results especially in man-made environments [88]. Historical façades descriptors show mostly a lot of straight lines and rectilinear structures that can be used as features to be found in two or more images. Consequently, our approach focuses on the detection, description and matching of quadrilaterals in historical images [89]. It is planned to study other exclusively geometric methods such as line or line segment matchers [73, 75, 90] and compare or even combine them with our approach.

4.2 Augmented Reality

AR applications in cultural heritage aim at presenting additional digital information about situations and artefacts in a spatial context. In historical settings, the viewer is able to interactively capture visual as well as aural information about objects in their historical spatial reference system [91]. AR environments allow the user to combine the virtual data to the real world (in place), using mobile platforms. In this way they

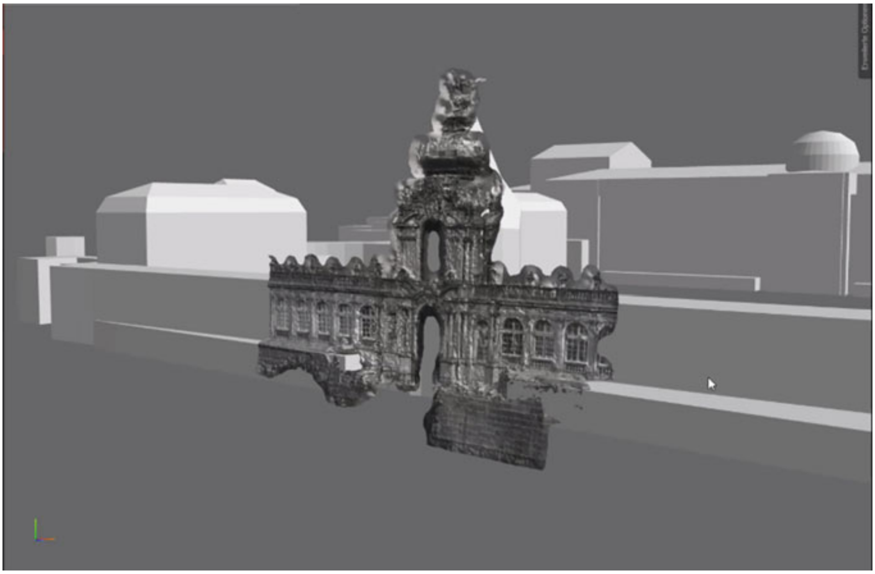

Fig. 2 3D model based on current photographs and historical photographs (proof-of-concept)

allow for a better understanding of the elements of visible and non-visible cultural heritage, not only in the present, but also in the past and future (re-present) [92].

Augmented Reality devices have been used in cultural heritage extensively. Even early research has focused on creating mobile applications combining portable devices with optical or video-see-through glasses [93]. With the advent and eventual ubiquity of hand-held devices [94], AR has made a breakthrough into the domain, spurring innovation in navigation, communication and cultural heritage education as outlined in Sect. 3.

Our investigation focuses on the accessibility of historical data: How can interaction with virtual buildings be designed? Which metaphors can be used? How can augmented reality support educational and research settings? How can spatial photography be apprehended in AR environments? According to Azuma, a general approach toward achieving compelling experiences will be to realize the potential inherent in the medium to see the world around you through the eyes, viewpoint and mindset of another person [95].

Towards this goal, spatial and temporal arrangement of historical photography in a modern building situation will be made available in several different modes of visualization and interaction:

- Map- and location-based visualization and browsing of cultural heritage resources, especially photography along with textual information about these photos as well as the depicted buildings.

Fig. 3 Exploration of spatial photography in an AR environment

- A spatial display of historical photography in the coordinate frame of the real setting, based on the methods described in Bruschke et al. [96] and depicted in Fig. 3.
- Applying historical photographs as textures to buildings to partially augment the modern building situation with historical architecture.

Fidas et al. find the main challenge in AR authoring tools to define a set of primitive elements which can be used by cultural heritage experts as abstract building blocks with the aim of supporting the creation of various cultural heritage experiences [...] without the help of professional developers [97]. We are integrating tools made available to cultural heritage researchers (cf. Section 4.3) with our AR framework to provide an effortless transition between research, research results and dissemination of knowledge for educational as well as for touristic purposes.

4.3 4D Browser

Keyword-based and faceted search [98] are common and powerful features in digital media repositories and other database applications for browsing and narrowing down results. Due to the above-mentioned issues concerning incomplete or imprecise metadata and annotation, the search process can become challenging in finding the desired content. In our approach, established search functionalities will not be replaced, but extended by a 4D viewport enabling spatially and temporally located searches (Fig. 4). A spatial search can enhance the process of finding images, espe-

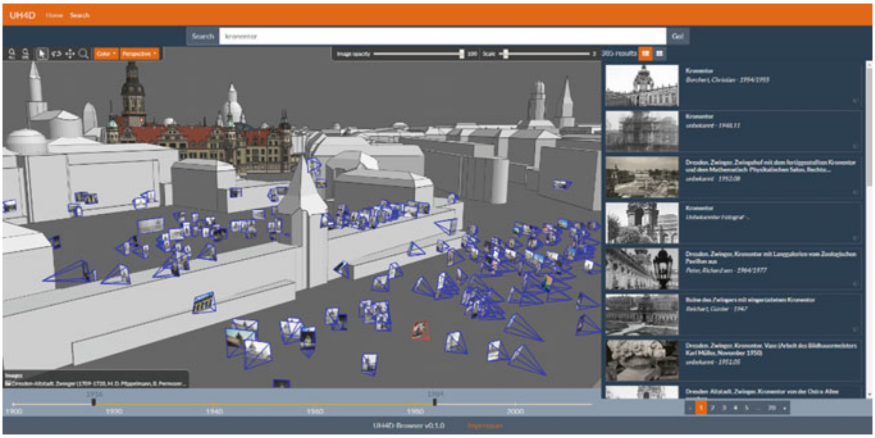

Fig. 4 Spatially oriented images in 3D city model (prototype)

cially those where users have less knowledge about the depicted object or only a vague idea of what they are looking for.

Simple approaches on a 2D map basis implementing Google Maps or Open-StreetMap are already available, also for historical images (e.g. www.historypin.org, www.phillyhistory.org). In this spatial context, information like the distribution of images becomes visible. Deeper information becomes available in a 3D perspective. The orientation of the image and the situation of the photographer within the context of the surrounding buildings gets clearer [82]. The user can take up the position and orientation of the camera, respectively the photographer, and blend between the image and the 3D city model. The combination with various historic states of a 3D city model, i.e. 4D city model, allows comparisons between different buildings' situations.

Users might be interested in images that are similar to the one they are currently looking at. Traditional image retrieval systems rely on annotation or low-level features such as color, shape, and texture, i.e. content-based image retrieval (CBIR), to recommend those images [99]. However, these methods are not always very accurate due to imprecise keywords or lacking color features of historic, monochrome images. In spatial search, users are able to browse groups of images taken from a similar viewpoint in close range.

Due to the spatial relation between the image and the virtual 3D representatives of the buildings, it is determinable, which object is depicted in which image. This allows an additional interaction method by the user. By choosing a building, i.e. 3D object, search results can be either limited to relevant images, or those images are excluded. A timeline enables temporal filtering of the images and choosing a historic building situation.

The spatial search approach, however, yields some challenges: The navigation within a 3D environment is more complex than in 2D applications and requires good skills by the user [100]. Proper navigation tools and support is indispensable. Due to the overload of images at some places, the visualization becomes cluttered, which results in confused users and a disadvantageous search process. To overcome this shortcoming, the images can be clustered and filtered according to discriminative features [101] and summarized by representative images [102]. In addition, search results can be hidden behind 3D geometry. While the exact position is not important when looking from afar, images can float above the 3D city model [103], so users can spot them. Depending on the user's view, a smooth, interpolated transition between different presentation modes at certain distances is reasonable.

In general, as advanced browsing methods and more features are available, the application evolves to be more complex with different layers of information. Hence, it is very important to provide a smooth and easy introduction.

5 Conclusions

What are implications for making image repositories accessible for both scholarly users and citizens? Even if a scholarly use is widely driven by the humanities and in particular art and architectural history, archaeology and museology, several other disciplines like architecture, building engineering or design as well as geo sciences are stakeholders. Major challenges for image repositories are caused by lacking data quality and indexing, findability and usability. Furthermore, Google—virtually the monopolist—sets pace and its functionalities are expected and accustomed by users.

In contrast, most applications for immersive mixed or virtual reality tourism are mostly still experimental. Due to the high level of complexity and technical recommendations AR is challenging. Issues may be for instance availability of applications and services, compatibility to a broad range of user devices as well as the need for users to install native applications on their devices. Beside this, there are various knowledge-mediating issues. While there is much research about AR interaction or technologies, proven pedagogical approaches to make cultural, historical and contemporary heritage available for tourists and to motivate them to interact with urban history are still missing.

Against this background, it is our next objective to further develop and test in particular photogrammetric approaches in order to enrich metadata information about positions and orientations to historical photographs as well as a both 4D-browser interface to browse repositories for historical images in a spatiotemporal way and AR applications to enhance urban tourism.

References

1. Burke P (2003) Augenzeugenschaft. Bilder als historische Quellen. Wagenbachs Taschenbuch 631. Berlin
2. Paul G (2006) Von der Historischen Bildkunde zur Visual History. In: Visual History. Ein Studienbuch. Vandenhoeck & Ruprecht, Göttingen, pp 7–36
3. Wohlfeil R (1986) Das Bild als Geschichtsquelle. Historische Zeitschrift 243:91–100
4. Pérez-Gómez A, Pelletier L (1997) Architectural Representation and the Perspective Hinge. University Press, Cambridge, London
5. Kwastek K (2014) Vom Bild zum Bild. Digital Humanities jenseits des Texts (Keynote). Paper presented at the 1. Jahrestagung der Digital Humanities im deutschsprachigen Raum (DHd 2014), Passau
6. Jensen P (2012) Event-based Archaeological Registration Principles. In: Zhou M, Romanowska I, Wu Z, Xu P, Verhagen P (eds) Revive the Past. Computer Applications and Quantitative Methods in Archaeology (CAA). Proceedings of the 39th International Conference, Beijing, April 12-16. Pallas Publications, Amsterdam, pp. 209–216.
7. Münster S, Kröber C, Friedrichs K, Bruschke J, Maiwald F, Niebling F (2017) Urban History in 4 Dimensions - Supporting Research and Education. Int Arch Photogramm Remote Sens Spatial Inf Sci XLII-2/W5:525–530. https://doi.org/10.5194/isprs-archives-XLII-2-W5-525-2017
8. Niebling F, Maiwald F, Barthel K, Latoschik ME (2018) 4D Augmented City Models, Photogrammetric Creation and Dissemination. In: Münster S, Friedrichs K, Niebling N, Seidel-Grzesińska A (eds) Digital Research and Education in Architectural Heritage. UHDL 2017, DECH 2017. Springer International Publishing, Cham, pp 196–214. https://doi.org/10.1007/978-3-319-76992-9_12
9. Friedrichs K, Kröber C, Bruschke J, Münster S (2018) Creating Suitable Tools for Art and Architectural Research with Historic Media Repositories. In: Münster S, Friedrichs K, Niebling N, Seidel-Grzesińska A (eds) Digital Research and Education in Architectural Heritage. UHDL 2017, DECH 2017. Springer International Publishing, Cham, pp 117–138. https://doi.org/10.1007/978-3-319-76992-9_8
10. Münster S, Kamposiori C, Friedrichs K, Kröber C (2018) Image Libraries and their Scholarly Use in the Field of Art and Architectural History. International Journal on Digital Libraries 19(4):367–383. https://doi.org/10.1007/s00799-018-0250-1
11. Kamposiori C, Benardou A (2011) Collaboration in Art Historical Research: Looking at primitives. Kunstgeschichte, Open Peer Reviewed Journal
12. ViMM WG 2.2 (2017) Meaningful Content connected to the Real World (Report)
13. Bekele M, Pierdicca R, Frontoni E, Malinverni E, Gain J (2018) A Survey of Augmented, Virtual, and Mixed Reality for Cultural Heritage. Journal on Computing and Cultural Heritage 11:1–36. https://doi.org/10.1145/3145534
14. Münster S (2011) Entstehungs- und Verwendungskontexte von 3D-CAD-Modellen in den Geschichtswissenschaften. In: Meissner K, Engelien M (eds) Virtual Enterprises, Communities & Social Networks. TUDpress, Dresden, pp 99–108
15. Sweetnam MS, Agosti M, Orio N, Ponchia C, Steiner CM, Hillemann E-C, Siochrú MÓ, Lawless S (2012) User Needs for Enhanced Engagement with Cultural Heritage Collections. In: Zaphiris P, Buchanan G, Rasmussen E, Loizides F (eds) Theory and Practice of Digital Libraries, 2012. Springer, Berlin, Heidelberg, pp 64–75. https://doi.org/10.1007/978-3-642-33290-6_8
16. Barreau J-B, Gaugne R, Bernard Y, Le Cloirec G, Gouranton V (2014) Virtual Reality Tools for the West Digital Conservatory of Archaeological Heritage. In: Proceedings of the 2014 Virtual Reality International Conference. ACM, pp 1–4. https://doi.org/10.1145/2617841.2617845
17. Münster S (2017) A Survey on Topics, Researchers and Cultures in the Field of Digital Heritage. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences IV-2/W2:157–162. https://doi.org/10.5194/isprs-annals-iv-2-w2-157-2017

18. Münster S, Ioannides M (2015) The scientific community of digital heritage in time and space. In: Guidi G, Scopigno R, Torres JC, Graf H (eds) 2nd International Congress on Digital Heritage 2015. IEEE, Granada, pp 267–274. https://doi.org/10.1109/DigitalHeritage.2015.7419507
19. Hicks D (2006) The Four Literatures of Social Science. In: Moed HF, Glänzel W, Schmoch U (eds) Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of S&T Systems. Springer Science & Business Media, pp 473–496
20. Tenopir C, King DW (2008) Electronic Journals and Changes in Scholarly Article Seeking and Reading Patterns. D-Lib Magazine 14 (11/12):1–13. https://dx.doi.org/10.1045/november2008-tenopir
21. Hemmig W (2009) An empirical study of the information-seeking behavior of practicing visual artists. Journal of Documentation 65 (4):682–703. https://doi.org/10.1108/00220410910970302
22. Bakewell E, Beeman WO, Reese CM, Schmitt M (1988) Object, Image, Inquiry: The Art Historian at Work. Getty Art History Information Program, Santa Monica
23. Panofsky E (1939) Studies in Iconology. Humanistic Themes In the Art of the Renaissance. Oxford University Press, Oxford
24. Commare L (2011) Social tagging als Methode zur Optimierung kunsthistorischer Bilddatenbanken – eine empirische Analyse des ARTigo-Projekts. Kunstgeschichte Open Peer Reviewed Journal
25. Datta R, Joshi D, Li J, Wang JZ (2008) Image retrieval: Ideas, influences, and trends of the new age. ACM Comput Surv 40 (2):1–60. https://doi.org/10.1145/1348246.1348248
26. Rieger OY (2009) Search engine use behavior of students and faculty: User perceptions and implications for future research. First Monday 14 (12). http://dx.doi.org/10.5210/fm.v14i12.2716
27. Cook MP (2006) Visual representations in science education: The influence of prior knowledge and cognitive load theory on instructional design principles. Science Education 90 (6):1073–1091. https://doi.org/10.1002/sce.20164
28. Chandler P, Sweller J (1992) The split-attention effect as a factor in the design of instruction. British Journal of Educational Psychology 62 (2):233–246. https://dx.doi.org/10.1111/j.2044-8279.1992.tb01017.x
29. Avancini H, Straccia U (2005) User recommendation for collaborative and personalised digital archives. International Journal of Web Based Communities 1 (2):163–175. https://dx.doi.org/10.1504/IJWBC.2005.006061
30. Normore LF, Tebo ME (2011) Assessing user requirements for a small scientific data repository. Proceedings of the Association for Information Science and Technology 48 (1):1–4. http://dx.doi.org/10.1002/meet.2011.14504801286
31. Kohle H (2013) Digitale Bildwissenschaft. Hülsbusch, Glückstadt
32. Beaudoin JE, Brady JE (2011) Finding Visual Information: A Study of Image Resources Used by Archaeologists, Architects, Art Historians, and Artists. Art Documentation: Journal of the Art Libraries Society of North America 30 (2):24–36. http://dx.doi.org/10.1086/adx.30.2.41244062
33. Kemman M, Kleppe M, Scagliola S (2014) Just Google It. Digital Research Practices of Humanities Scholars. In: Mills C, Pidd M, Ward E (eds) Proceedings of the Digital Humanities Congress 2012. Studies in the Digital Humanities. HRI Online Publications, Sheffield
34. Dudek I, Blaise J-Y, De Luca L, Bergerot L, Renaudin N (2015) How was this done? An attempt at formalising and memorising a digital asset's making of. In: Digital Heritage, 2015. IEEE, pp 343–346. https://doi.org/10.1109/DigitalHeritage.2015.7419519
35. Warwick C (2012) Studying users in digital humanities. In: Warwick C, Terras M, Nyhan J (eds) Digital Humanities in Practice. Facet Publishing, London, pp 1–21. https://dx.doi.org/10.29085 /9781856049054.002
36. Given LM, Willson R (2018) Information Technology and the Humanities Scholar: Documenting Digital Research Practices. Journal of the Association for Information Science and Technology 69:807–819. https://doi.org/10.1002/asi.24008

37. Maxwell A (2010) Digital archives and history research: feedback from an end-user. Library Review 59 (1):24–39. http://dx.doi.org/10.1108/00242531011014664
38. Maina JKo, Suleman H (2015) Enhancing Digital Heritage Archives Using Gamified Annotations. In: Allen RB, Hunter J, Zeng ML (eds) Digital Libraries: Providing Quality Information. ICADL, 2015. Springer International Publishing, Cham, pp 169–179. https://doi.org/10.1007/978-3-319-27974-9_17
39. Given LM, Willson R (2015) Collaboration, Information Seeking, and Technology Use: A Critical Examination of Humanities Scholars' Research Practices. In: Hansen P, Shah C, Klas C-P (eds) Collaborative Information Seeking: Best Practices, New Domains and New Thoughts. Springer International Publishing, Cham, pp 138–164. https://doi.org/10.1007/978-3-319-18988-8_8
40. Hastings SK (1999) Evaluation of image retrieval systems: Role of user feedback. Library trends 48 (2):438
41. Besser H (1990) Visual access to visual images: the UC Berkeley Image Database Project. Library trends 38 (4):787–798
42. Pisciotta H, Brisson R, Ferrin E, Dooris M, Spink A (2001) Penn State visual image user study. D-Lib Magazine 7 (7/8):169–196. http://dx.doi.org/10.1045/july2001-pisciotta
43. Elgammal A (2006) Human-centered Multimedia: Representations and Challenges. In: Proceedings of the 1st ACM International Workshop on Human-centered Multimedia. ACM, pp 11–18. https://doi.org/10.1145/1178745.1178751
44. Giral A (1998) Digital image libraries and the teaching of art and architectural history. Art Libraries Journal 23 (04):18–25. http://dx.doi.org/10.1017/S0307472200011251
45. Lopatin L (2006) Library digitization projects, issues and guidelines: A survey of the literature. Library hi tech 24 (2):273–289. http://dx.doi.org/10.1108/07378830610669637
46. Terras M (2012) Image Processing in the Digital Humanities. In: Warwick C, Terras M, Nyhan J (eds) Digital Humanities in Practice. Facet Publishing, London, pp 71–90
47. Tikka P (2006) Image Retrieval: Theory and Research. MIT Press Leonardo 39 (3):268–269. http://dx.doi.org/10.1162/leon.2006.39.3.268a
48. Münster S, Barthel K, Bruschke J, Friedrichs K, Kröber C, Maiwald F, Niebling F (2018) Stadtgeschichtliche Forschung und Vermittlung anhand historischer Fotos als Forschungsgegenstand – Ein Zwischenbericht der Nachwuchsgruppe HistStadt4D. Paper presented at the 5. Jahrestagung der Digital Humanities im deutschsprachigen Raum (DHd 2018), Cologne
49. Digital Methods and Practices Observatory Working Group DARIAH-EU European Research Infrastructure Consortium (2016) European survey on scholarly practices and digital needs in the arts and humanities
50. Cetina KK, Reichmann W (2015) Epistemic Cultures.In: Wright JD (eds) International Encyclopedia of the Social & Behavioral Sciences (Second Edition). Elsevier, Oxford, pp 873–880. https://doi.org/10.1016/b978-0-08-097086-8.10454-4
51. Knorr-Cetina K (1982) Scientific Communities or Transepistemic Arenas of Research. A Critique of Quasi-Economic Models of Science. Social Studies of Science 12:101–130. https://dx.doi.org /10.1177/030631282012001005
52. Beaudoin JE (2009) An Investigation of Image Users across Professions: A Framework of Their Image Needs, Retrieval and Use. Drexel University
53. Gregory TR (2007) Under-Served or Under-Surveyed: The Information Needs of Studio Art Faculty in the Southwestern United States. Art Documentation: Journal of the Art Libraries Society of North America 26 (2):57–66. doi:https://doi.org/10.1086/adx.26.2.27949470
54. Chen CJ (2009) Art history: a guide to basic research resources. Collection Building 28 (3):122–125. https://doi.org/10.1108/01604950910971152
55. Zaibon SB, Pendit UC, Aida J, Abu Bakar JA (2015) User Requirements on Mobile AR for Cultural Heritage Site towards Enjoyable Informal Learning. In: 2015 Asia Pacific Conference on Multimedia and Broadcasting. IEEE, pp 61–67. https://doi.org/10.1109/APMediaCast.2015.7210289
56. Jung T, Chung N, Leue MC (2015) The determinants of recommendations to use augmented reality technologies: The case of a Korean theme park. Tourism Management 49:75–86

57. Kounavis CD, Kasimati AE, Zamani ED (2012) Enhancing the Tourism Experience through Mobile Augmented Reality: Challenges and Prospects. International Journal of Engineering Business Management 4:10. https://doi.org/10.5772/51644
58. Kounavis CD, Kasimati AE, Zamani ED (2012) Enhancing the tourism experience through mobile augmented reality: Challenges and prospects. Int J Eng Bus Manag 4 (1):1–6
59. Ap J, Wong KKF (2001) Case study on tour guiding: Professionalism, issues and problems. Tourism Management 22 (5):551–563
60. Smirnov A, Kashevnik A, Shilov N, Teslya N, Shabaev A (2014) Mobile application for guiding tourist activities: Tourist assistant - TAIS. Conference of Open Innovation Association, FRUCT, 2014:95–100
61. Yovcheva Z, Buhalis D, Gatzidis C (2012) Overview of smartphone augmented reality applications for tourism. e-Review of Tourism Research 10 (2):63–66
62. Karanasios S, Burgess S, Sellitto C (2011) A Classification of Mobile Tourism Applications. Global Hospitality and Tourism Management Technologies:165–177. doi:https://doi.org/10.4018/978-1-61350-041-5
63. Kennedy-Eden H, Gretzel U (2012) A taxonomy of mobile applications in tourism. E-Review of Tourism Research 10 (2):47–50
64. Grün C, Werthner H, Pröll B, Retschitzegger W, Schwinger (2008) Assisting Tourists on the Move- An Evaluation of Mobile Tourist Guides. In: 7th International Conference on Mobile Business. IEEE, pp 171–180. https://doi.org/10.1109/ICMB.2008.28
65. Yovcheva Z, Buhalis D, Gatzidis C (2012) Smartphone Augmented Reality Applications for Tourism. E-Review of Tourism Research 10 (2):63–66
66. Chung N, Han H, Joun Y (2015) Tourists' intention to visit a destination: The role of augmented reality (AR) application for a heritage site. Computers in Human Behavior 50:588–599. https://doi.org/10.1016/j.chb.2015
67. Goh DH, Ang RP, Lee CK (2010) Determining Services for the Mobile Tourist. Journal of Computer Information Systems 51 (1):31
68. Tom Dieck MC, Jung T (2015) A theoretical model of mobile augmented reality acceptance in urban heritage tourism. Current Issues in Tourism 21 (2):154–174
69. Radu I (2014) Augmented reality in education: a meta-review and cross-media analysis. Personal Ubiquitous Comput 18 (6):1533–1543. https://doi.org/10.1007/s00779-013-0747-y
70. tom Dieck MC, Jung TH, tom Dieck D (2016) Enhancing art gallery visitors' learning experience using wearable augmented reality: generic learning outcomes perspective. Curr Issues Tour:1–21
71. Chang Y-L, Hou H, Pan C, Sung Y, Chang K (2015) Apply an Augmented Reality in a Mobile Guidance to Increase Sense of Place for Heritage Places. J Educ Technol Soc 18 (2):166–178
72. Kysela J, Štorková P (2015) Using Augmented Reality as a Medium for Teaching History and Tourism. Procedia - Soc Behav Sci 175:926–931
73. von Gioi RG, Jakubowicz J, Morel JM, Randall G (2012) LSD: a Line Segment Detector. Image Processing On Line 2:35–55. https://doi.org/10.5201/ipol.2012.gjmr-lsd
74. Donovan J (2014) Timetraveler App Allows You To See The Berlin Wall Story In Augmented Reality. Tech Crunch
75. Wang L, Neumann U, You S (2009) Wide-baseline image matching using Line Signatures. In: IEEE 12th International Conference on Computer Vision. IEEE, pp 1311–1318. https://doi.org/10.1109/ICCV.2009.5459316
76. Klamert K, Münster S (2017) Child's play - A literature based survey on gamified tools and methods for fostering public participation in urban planning. In: Electronic Participation. Springer, Heidelberg, pp 24–33
77. Eilam B, Gilbert JK (2014) The Significance of Visual Representations in the Teaching of Science. In: Eilam B, Gilbert JK (eds) Science Teachers' Use of Visual Representations. Springer International Publishing, Cham, pp 3–28. https://doi.org/10.1007/978-3-319-06526-7_1
78. Samuel J, Périnaud C, Servigne S, Georges G, Gesquière G (2016) Representation and Visualization of Urban Fabric through Historical Documents. In: Catalano CE, De Luca L

(eds) 14th Eurographics Workshop on Graphics and Cultural Heritage, Genova, Italy, 2016. The Eurographics Association
79. Grün A, Remondino F, Zhang L (2004) Photogrammetric Reconstruction of the Great Buddha of Bamiyan, Afghanistan. The Photogrammetric Record 19:177–199
80. Falkingham P, L., Bates K, T., Farlow J, O. (2014) Historical Photogrammetry: Bird's Paluxy River Dinosaur Chase Sequence Digitally Reconstructed as It Was prior to Excavation 70 Years Ago. PLoS ONE 9 (4):e93247
81. Agarwal S, Furukawa Y, Snavely N, Simon I, Curless B, Seitz SM, Szeliski R (2011) Building Rome in a Day. Communications of the ACM 54 (10):105–112. https://doi.org/10.1145/2001269.2001293
82. Schindler G, Dellaert F (2012) 4D Cities: Analyzing, Visualizing, and Interacting with Historical Urban Photo Collections. Journal of Multimedia 7 (2):124–131
83. Bitelli G, Dellapasqua M, Girelli VA, Sbaraglia S, Tinia MA (2017) Historical Photogrammetry and Terrestrial Laser Scanning for the 3d Virtual Reconstruction of Destroyed Structures: a Case Study in Italy. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences 42:113
84. Maiwald F, Vietze T, Schneider D, Henze F, Münster S, Niebling F (2017) Photogrammetric analysis of historical image repositories for virtual reconstruction in the field of digital humanities. Int Arch Photogramm Remote Sens Spatial Inf Sci XLII-2/W3:447–452. https://doi.org/10.5194/isprs-archivesXLII-2-W3-447-2017
85. Lowe DG (2004) Distinctive image features from scale-invariant keypoints. International journal of computer vision 60 (2):91–110
86. Wolfe R (2015) Modern to historical image feature matching
87. Ali HK, Whitehead A (2014) Feature Matching for Aligning Historical and Modern Images. International Journal of Computer Applications 21 (3):188–201
88. Micusik B, Wildenauer H, Kosecka J (2008) Detection and matching of rectilinear structures. In: IEEE Conference on Computer Vision and Pattern Recognition. IEEE, pp 1–7
89. Maiwald F, Schneider D, Henze F, Niebling F, Münster S (2018) Feature Matching of Historical Images Based on Geometry of Quadrilaterals. Int Arch Photogramm Remote Sens Spatial Inf Sci XLII-2:643–650. https://doi.org/10.5194/isprs-archives-XLII-2-643-2018
90. Zhang L, Koch R (2013) An efficient and robust line segment matching approach based on LBD descriptor and pairwise geometric consistency. Journal of Visual Communication and Image Representation 24 (7):794–805
91. Ridel B, Reuter P, Laviole J, Mellado N, Couture N, Granier X (2014) The Revealing Flashlight: Interactive Spatial Augmented Reality for Detail Exploration of Cultural Heritage Artifacts. J Comput Cult Herit 7 (2):1–18. https://doi.org/10.1145/2611376
92. Marques L, António Tenedório J, Burns M, Romão T, Birra F, Marques J, Pires A, António J (2017) Cultural Heritage 3D Modelling and visualisation within an Augmented Reality Environment, based on Geographic Information Technologies and mobile platforms. Architecture, City and Environment 11 (33):117–136. https://doi.org/10.5821/ace.11.33.4686
93. Vlahakis V, Karigiannis J, Tsotros M, Gounaris M, Almeida L, Stricker D, Gleue T, Christou IT, Carlucci R, Ioannidis N (2001) Archeoguide: First Results of an Augmented Reality, Mobile Computing System in Cultural Heritage Sites. In: Proceedings of the 2001 Conference on Virtual Reality, Archeology, and Cultural Heritage, New York, NY, USA, 2001. VAST '01. ACM, pp 131–140
94. Schmalstieg D, Wagner D (2007) Experiences with Handheld Augmented Reality. In: Proceedings of the 2007 6th IEEE and ACM International Symposium on Mixed and Augmented Reality (ISMAR '07). IEEE Computer Society, Washington, DC, USA, 1-13. https://doi.org/10.1109/ISMAR.2007.4538819
95. Azuma R (2015) Location-Based Mixed and Augmented Reality Storytelling. 2nd edition of Fundamentals of Wearable Computers and Augmented Reality Location-Based Mixed and Augmented Reality Storytelling:259–276

96. Bruschke J, Niebling F, Maiwald F, Friedrichs K, Wacker M, Latoschik ME (2017) Towards Browsing Repositories of Spatially Oriented Historic Photographic Images in 3D Web Environments. In: Proceedings of the 22nd International Conference on 3D Web Technology, Brisbane, Australia, 2017. ACM, pp 18:1–18:6. https://doi.org/10.1145/3055624.3075947
97. Fidas C, Sintoris C, Yiannoutsou N, Avouris N (2016) A survey on tools for end user authoring of mobile applications for cultural heritage. 2015 6th International Conference on Information, Intelligence, Systems and Applications (IISA). IEEE. https://doi.org/10.1109/iisa.2015.7388029
98. Yee K-P, Swearingen K, Li K, Hearst M (2003) Faceted Metadata for Image Search and Browsing. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Ft. Lauderdale, Florida, USA, 2003. ACM, 642681, pp 401–408. https://doi.org/10.1145/642611.642681
99. Ji Z, Yao W, Pi H, Lu W, He J, Wang H (2017) A Survey of Personalised Image Retrieval and Recommendation. In: Du D, Li L, Zhu E, He K (eds) Theoretical Computer Science. NCTCS 2017. Springer Singapore, Singapore, pp 233–247. https://doi.org/10.1007/978-981-10-6893-5_18
100. Fitzmaurice G, Matejka J, Mordatch I, Khan A, Kurtenbach G (2008) Safe 3D Navigation. In: Proceedings of the 2008 Symposium on Interactive 3D Graphics and Games, Redwood City, California, 2008. ACM, pp 7–15. https://doi.org/10.1145/1342250.1342252
101. van Leuken RH, Garcia L, Olivares X, van Zwol R (2009) Visual Diversification of Image Search Results. In: Proceedings of the 18th International Conference on World Wide Web, Madrid, Spain, 2009. ACM, pp 341–350. https://doi.org/10.1145/1526709.1526756
102. Jaffe A, Naaman M, Tassa T, Davis M (2006) Generating Summaries and Visualization for Large Collections of Geo-Referenced Photographs. In: Proceedings of the 8th ACM international workshop on Multimedia information retrieval, Santa Barbara, California, USA, 2006. ACM, pp 89–98. https://doi.org/10.1145/1178677.1178692
103. Chagnaud C, Samuel J, Servigne S, Gesquière G (2016) Visualization of Documented 3D Cities. In: Eurographics Workshop on Urban Data Modelling and Visualisation, Liège, Belgium, 2016. The Eurographics Association. https://doi.org/10.2312/udmv.20161425

Digital Infrastructures for Digital Humanities in International Textbook Research

Ernesto William De Luca and Christian Scheel

Abstract As a non-university research institution, the Georg Eckert Institute for International Textbook Research (GEI) conducts and facilitates fundamental research into textbooks and educational media primarily informed by history and cultural studies. For this purpose, the GEI provides research infrastructures such as its renowned research library and various dedicated digital information services. Hence, the institute develops and manages both digital and social research infrastructures. As such, the GEI realizes a unique position in the international field of textbook research. In the digital humanities (DH), the investigation of research questions is supported by a range of increasingly sophisticated digital methods such as automatic image and text analysis, linguistic text annotation, or data visualization. Digital tools and services combined with the increasing amount of resources available through digital libraries such as the German Digital Library, the Deutsches Textarchiv, Europeana and research infrastructures such as CLARIN or DARIAH provide digital support for textbook analysis. In this work, we present the actual state of the art of the development of digital infrastructures for digital humanities in international textbook research.

Keywords Textbook research · Digital humanities · Digital infrastructures

1 Introduction

The *Georg Eckert Institute*[1] (GEI) for International Textbook Research, a key institution in the field of textbook research, hosts the largest international textbook collection worldwide. The GEI has a track record spanning over 40 years of conducting

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[1] http://www.gei.de/en/.

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research projects, working with international partners in bodies such as international textbook commissions, and publishing its research. Over the last 20 years, the institute has digitalised a large proportion of its library holdings and initiated field-specific data collections and open-access publications. As a member of the German Leibniz Association and as a leading research institution in the field, the GEI regards the development and maintenance of research infrastructure for international textbook and educational media research as a core part of its mission.

Textbooks, as carriers of the knowledge and information that one generation wishes to pass on to the next, frequently find themselves at the center of political controversy. As such, their importance as an object of investigation in historical and cultural research has gained significant traction in recent decades. However, textbook research has not yet found dedicated representation as a main subject at universities.

An important role is played by the provision of digital services, which are based on data from the library catalogues and the developed digital systems. Furthermore, most services provide access to this data by standardized interfaces.

These services are in charge of the *Digital Information and Research Infrastructures department*[2] (DIRI) at the GEI, which works in close and continuous collaboration with the Research Library, and the other departments, providing research infrastructure services, which are of central importance for the institute and the research discipline as a whole. The department also conducts autonomous research into the development, improvement and application of digital research infrastructures and methods.

The collection of all digital services is referred to as "the middleware", regardless of the type of service or its place of execution. This abstract term helps to support communication about technical aspects to non-technical departments of the GEI without going into detail.

The department DIRI therefore upholds the GEI's "circular model" and simultaneously benefits from it, focusing on the following fields:

1. Provision of the *information technology infrastructure* for institute staff and for external users who use these IT services on site, such as library users or research fellows, and those that access internet-based research infrastructures hosted by the GEI.
2. Conceptual development, provision and maintenance of *digital information services*, in particular the GEI's internet services. Research findings and data from the other departments, including the library always form the backbone of this online content.
3. Creation and expansion of *Digital Humanities* processes to further develop new digital capture tools and methods derived from discipline-specific issues and based upon the large digital inventories of the GEI and its partners, which the department was instrumental in creating. Such processes are tested in close collaboration with the experienced historians leading the projects, and within the

[2] http://www.gei.de/en/departments/digital-information-and-research-infrastructures.html.

other departments, and are evaluated as the projects progress. The department enables the effective application of digital research infrastructure as well as allowing users to carry out independent research regarding improvements to services in terms of inventory and semantics.

An example of the shift towards more digitally oriented research has resulted in a range of digital information services specifically tailored to textbook research, such as:

- EurViews[3]: a multilingual digital platform containing primary sources from twentieth and twenty-first century history textbooks from around the world that manifest particular concepts of Europe and Europeanness (for example, see [2, 3, 11]).
- GEI-Digital: a digital library focusing on out-of-copyright works published between the inception of textbooks in the seventeenth century and the demise of imperial Germany in 1918.
- edu.data: an information service that provides information about textbook systems in individual countries, and a library catalogue that contains bibliographic meta data about textbooks from around the globe.

While these services all contain resources and information that are relevant to textbook research, their content is frequently stored in isolated data silos that lack appropriate interfaces or standardized data models and which prevent convenient use or exchange of data within the GEI or with external services. Furthermore, the data in these digital information services lack semantic contextualization completely.

2 Digital Infrastructures at the GEI

At the moment we are integrating all our data and meta data formats into one repository and cooperating with international partners to incorporate global data on textbook research from other institutions. Our aim is to create an interoperable, standardized, multilingual access to all available data on textbook research across formats. The data include, but are not limited to, open-access texts, web pages, databases, library data, curricula, TEI-tagged textbooks, textbook reviews, research project descriptions, and data on institutions and researchers in the field.

The GEI is currently pursuing a three-way approach, effectively building three ‘roads’ which will eventually merge into one wider road. The project “WorldViews” [12] is integrating data available via GEI applications and websites, while “GLOTREC” (Global Textbook Resource Centre) is creating an international, multilingual reference and information architecture for textbooks. Finally, the project “Children and their World” develops novel, reusable instruments for the access and analysis of large digital corpora, namely textbook contents. Concluding these projects, the three ‘roads’ will merge to become a system which will be integrating all available data on textbooks and textbook research worldwide.

[3]http://www.eurviews.eu/nc/start.html.

The increasing internationalisation of databases calls for multilingual and even multiple-alphabet accessibility. This challenging task is part of the GLOTREC project, which has recently reached the milestone of completion of the International TextbookCat [14], serving as a multilingual hub to data on textbooks from three different library catalogues, held decentrally (GEI OPAC,[4] Edisco[5] and MANES).[6] We are currently working on the integration of more data, more languages, more alphabets and more data types.

While our principal focus is data integration and representation at present, we are committed throughout the process to two fundamental principles:

Usability. Simply collecting and providing the data would not meet the needs of our target group.

(a) We wish to represent the data in a way that is helpful to users with multiple needs. Our aim in this context is to present the data in an 'integrated but separate' state and show users what kind of data they have found and what is the source of it.
(b) We will enable multiple points of entry. Further, all existing applications, such as databases and document repositories, will be maintained. The Repository of Textbook Research will serve as a hub to these applications as well as to their data.
(c) We are attempting to create meta data schemata that are simultaneously as coherent as possible and as specific as necessary for the various included datasets. The Challenge is to present datasets as diverse as textbook data, research articles and digitalised textbooks.

Openness. We believe we have reached at least the two-star level of Tim Berners-Lee's (2006) 5-star deployment scheme for Open Data [1].

(d) We are working on making at least the GEI-owned data in the repository available in non-proprietary formats.
(e) Furthermore, we are using URI wherever possible and linking the data with our own and other datasets.
(f) As well as creating and maintaining our repository, we are mirroring our data to repositories of a wider thematic scope. The texts contained within our own academic repository are delivered to other repositories, for example Leibniz Open, via OAI-PMH [17].

At the moment, we have already created "the middleware" for GEI-generated data, which deals with data standardisation and homogenisation, and are hosting a multilingual catalogue, named International TextbookCat, within which we integrate three international textbook catalogues from Italy, Spain and Germany. Furthermore, in the project "Children and their World", we are creating Natural Language Processing methods such as Topic Modeling [13] for the analysis of large digitalised historical textbook corpora.

[4] http://bibliothek.gei.de/en/online-catalogues.html.

[5] http://www.edisco.unito.it.

[6] http://www.centromanes.org.

Even though the basic services are implemented, the Georg Eckert Institute's path to the integration of all available data on textbooks and textbook research within a single repository is still challenging. The data are in various formats and stem from international and multilingual sources. We aim to integrate the documents through automatic techniques which analyse the ambiguous terms [6] and the related relations [4] in the documents, and integrate different collections using standardization processes (mapping functionalities) of international library catalogues analysing the meta data included [14, 15] presenting the results adapted for different devices [5] with a responsive design.

Our goal is to spread our idea of sustainable, integrated and linked open data in textbook research to other fields and international research communities and to provide a role model for the gradual implementation of long-term projects. In the following we present novel technical approaches for multilingualism and user centred design in digital humanities as well as the representation of diverse data sets of multiple formats, scope, and (qualitative and quantitative) depth in one repository (see Fig. 1).

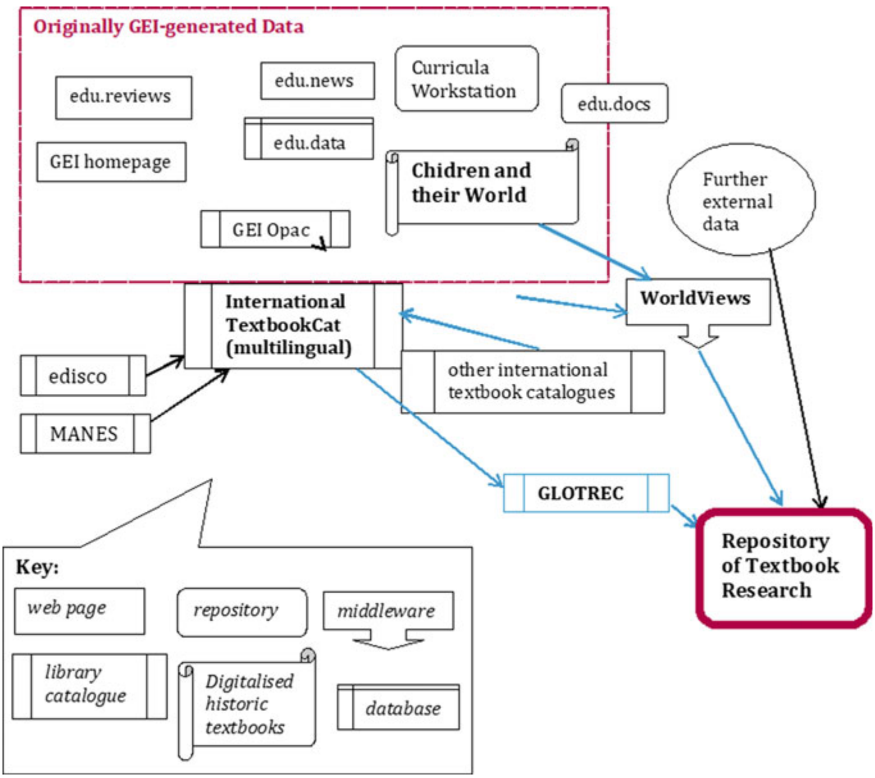

Fig. 1 Digital Infrastructures at the GEI

Moreover, semantic technologies can be used and adapted for helping humanists in analysing and processing digital content. Related challenges and problems can be shown within the use of some tools and use cases. Whereas the classic methodology shows limitations in scalability, the new tools often do not adequately reflect the intended semantics and thus deliver unreliable results. Another important issue to be aware of is the communication and understanding between disciplines. Different possibilities will be shown as a first proof of concept for humanities, information science and computer science to overcome the method mismatch and let researchers from different disciplines work 'on a par' with another.

3 Visualizing and Integrating Data Collections for Digital Humanities

As a cultural institution, the GEI digitizes and interlinks its collections providing new opportunities of navigation and search. However, it is comprehensive that the data is sparse, complex and difficult to interact with, so that a good design and support of the systems is indispensable. Moreover, it is difficult to grasp their distribution and extent across a variety of dimensions.

An important promise in connection with the digitization efforts of many institutions of cultural heritage is increased access to our cultural heritage. [16]. Aggregators, such as the Digital Public Library of America[7] and Europeana,[8] expand this ambition by integrating contents from many collecting institutions so as to let people search through millions of artifacts of varied origins. Due to the size and diversity of such composite collections, it can be difficult to get a sense of the patterns and relationships hidden in the aggregated data and the overall extent of the collection [7].

Therefore, new ways of interaction and visualization possibilities can help in finding relevant information more easily than before. Hereby we developed different tools and visualizations for accessing our data in various project.

In the following, we discuss three prototypical implementations of visualizations and data analysis tools, each one focusing on different facets of the collections: 1. *"GEI-Digital visualized"* presents a new concept of accessing information through combinations of visualizations and data analysis, 2. "Children and their world" Explorer shows how topic modeling approaches can help researchers in finding relations between documents that apparently do not belong to the same topic and 3. *"International TextbookCat"* presents statistics about the collection, which can help users in better understanding the development of a given topic during the years.

Visualization—GEI-Digital Visualized
The Internet platform GEI-Digital provides more than 4300 digitalized historical

[7]Digital Public Library of America: http://dp.la.
[8]Europeana: http://www.europeana.eu.

German textbooks in the fields of history, geography and politics, as well as books on the content of more than one million pages. Both textbooks from the Georg Eckert Institute and textbooks from other partner libraries were digitized and integrated. GEI-Digital aggregates the entire collection of German textbooks until 1918. In the course of digitization, a total of 250,000 meta data were recorded, whereby the indexing follows the specific needs of textbook research. Thus, in addition to information about the publisher and year of publication, subjects and grades were recorded as meta data.

The prototypical visualizations of "GEI-Digital visualized"[9] have been developed in cooperation with the Potsdam University of Applied Sciences in the Urban Complexity Lab as part of a research commission from the Georg Eckert Institute for International Textbook Research.

Through the visualization of the meta data and interactive combination possibilities, developments on the historical textbook market with its actors and products can be made visible. In this project, we present the prerequisites and possibilities of data visualization. Using the example of GEI-Digital visualized, we analysed which are the added value given by data visualizations in combination with library content, on the one hand, and with research purposes and on the other (see Fig. 2).

Data Exploration—"Children and their world" Explorer

Within the "Children and their world" Explorer[10] we implemented a tool, which shows how texts, included in the corpus, can be exported and used in other Digital Humanities Tools for further detailed analysis (see Fig. 3). Researchers can work

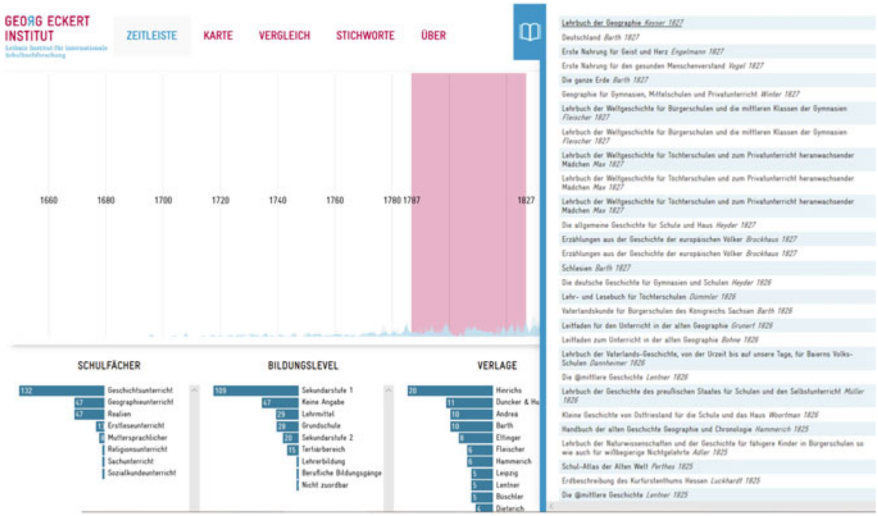

Fig. 2 Screenshot of the GEI-Digital-Visualized Tool

[9] http://gei-digital.gei.de/visualized/.

[10] http://wdk.gei.de.

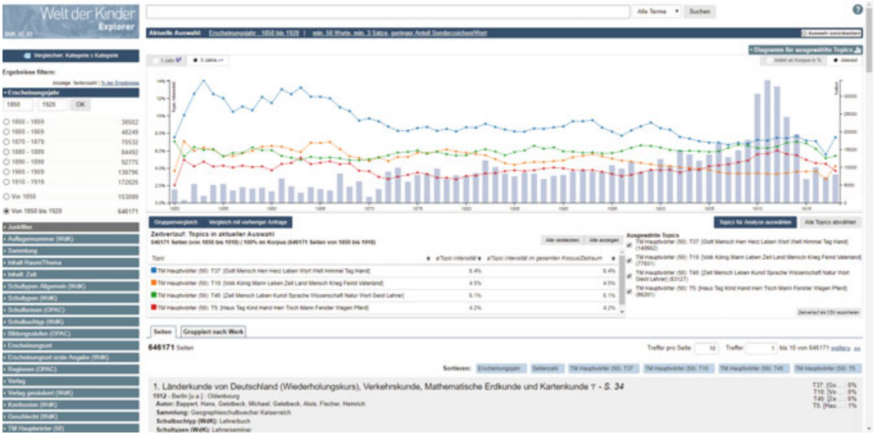

Fig. 3 Screenshot of the Digital Humanities Tool "Children and their world" Explorer

with a set of texts and look for ways to reveal structural patterns in their sources, which were, until now, impossible to analyze within a classical hermeneutical way.

This interdisciplinary Digital Humanities project deals with world knowledge of the 19th-century textbooks and children's books. This digital information (as a sub corpus of the GEI digital collection) has been combined to implement specific tools for semantic search and statistical text analysis, which can support researchers to better formulate their research questions and to support the serendipity effect, which can be given by the use of digital tools.

To this end, approximately 4000 digitized and curated 19th-century historical textbooks have been annotated at the page level using topic modeling and automatic enrichment with additional meta data. These extensions enable a free browsing possibility and a complex content and meta data driven search process on textbooks.

Research—International TexbookCat

The International TextbookCat[11] research instrument (see Fig. 4) provides a welcome extension to the library OPAC system and is a search tool that dramatically improves the search possibilities within the textbook collection. It employs an internal classification system in order to categorize textbooks according to applicable country, education level and subject. Additional categories of federal state and school type are provided for German textbooks and international textbooks can be filtered according to language.

Furthermore, the project extends the textbook collection with the inventories of international partners, combining the textbook databases of three institutions: the Georg Eckert Institute, the University of Turin and the National Distance Education University in Spain, in order to create a joint reference tool.

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[11] http://itbc.gei.de.

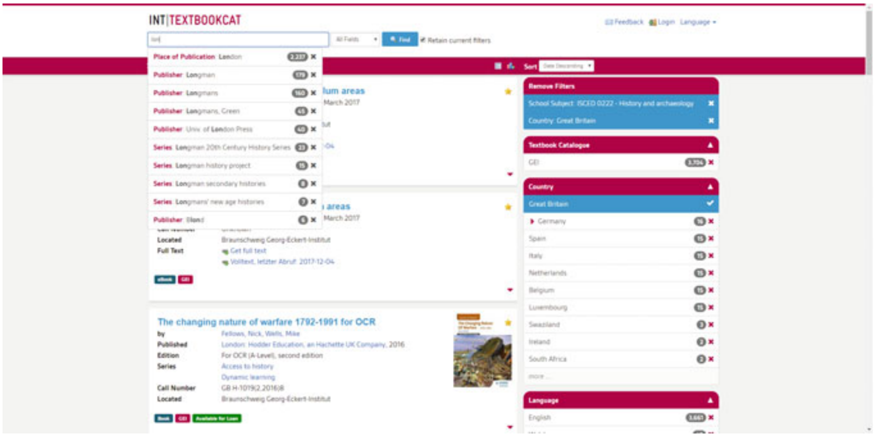

Fig. 4 Screenshot of the International TexbookCat Research Tool

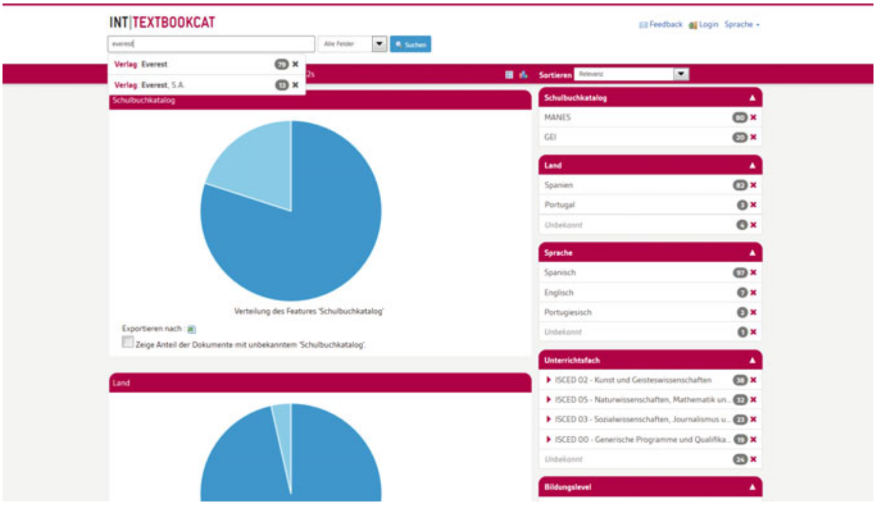

Fig. 5 Presentation of the statistics given a query in the International TexbookCat Research Tool

Workflows and system architecture are being developed that in the long-term will enable further institutions to participate with relatively little effort on their part. The research, the textbook collection and hence the local classification scheme of the Georg Eckert Institute are primarily focused on educational sciences, history, geography, political science and religious sciences [8–10].

An additional function is given by the statistics about the collection (see Fig. 5). Here the researchers can use them for the development or verification of their hypothesis and research questions given a desired request (query).

4 Building Digital Infrastructures for Digital Humanities in International Textbook Research

A variety of digital offers have been implemented during the years, so that researchers which were interested in cross-search possibilities had to find a way themselves to get the most relevant information related to their research questions, if they wanted to use different services. Currently they have to search all current and completed projects on the institute website or use the platform *Edumeres*[12] as the virtual network for international textbook research, which has been bundled since its relaunch in 2016 in the form of modules. Edumeres summarizes projects that do not overlap thematically or only slightly. The presentation remains so far product-oriented and is tailored to the German- and partially English-speaking audience. The content is currently stored as recent news from educational media research ("edu.news"), or as a platform for textbook reviews ("edu.reviews"), a database on education systems and textbook use worldwide ("edu.data") as well as a repository for the Open Access publications of the institute ("edu.docs"). On the other hand, there are different other library services, such as the digital curriculum workstation ("curricula workstation"), the database of approved textbooks in Germany ("GEI.DZS") and the already described digital historical textbook library ("GEI-Digital").

Analysing the available digital infrastructure of the GEI, we can say that the implemented Digital Humanities tools can be used for different purposes. Depending on the specific questions and internal criteria of their home projects, the GEI datasets (some of which are under construction, some of which have been completed or are being continually expanded) will be harmonized to one meta-search tool with regard to defined user groups (see below). However, the emergence of data silos presented side by side is not an undesirable development, but can be seen as an additional service, which is not intended to replace the offers mentioned, but gives the possibility to better access data through standardization, preparation and centralization, leading to the desired respective user interfaces.

In the near future, we plan to realize a GEI global search engine, which allows a direct access to all services and tools of the institute, presenting all relevant results at first glance. Researchers will be supported in performing cross-research questions, analyzing the data from different perspectives (as shown in Fig. 6) and analyzing found results in their original services in detail.

Another challenge is represented by the different formats and different annotations available in the institute's digital information systems and services. For example, projects with individual search services (realized by Solr index servers) do not have yet uniformed internal field identifiers. Additionally, not all the information of the associated databases is included in these indices. Internally, the technical diversity results in maintenance effort through updates (partly proprietary) and the missing harmonization of all services. This fundamental sustainability at the technical level does not yet fulfill the ideal of data openness supported by the GEI and cannot

[12] http://edumeres.net.

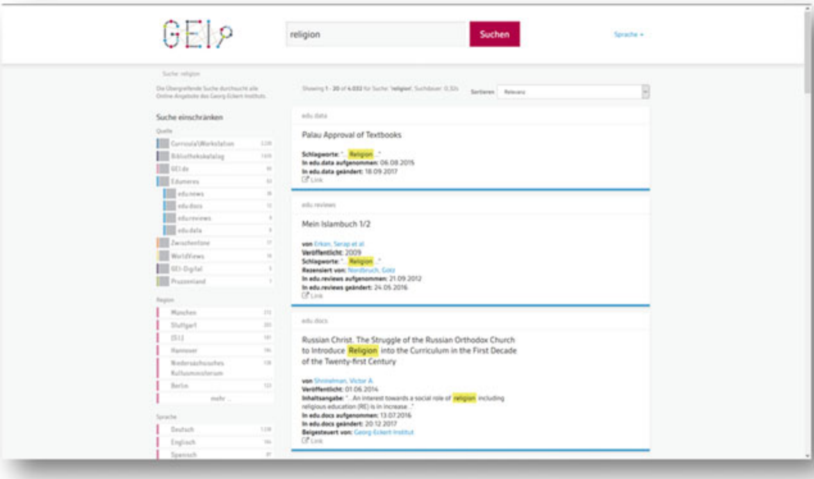

Fig. 6 Meta search of data collections (http://search.gei.de)

yet offer many user groups attractive incentives for reuse. Although recent projects provide APIs that allow the data to be processed in other contexts, this option is in fact only open to technically savvy users.

5 Conclusion and Future Work

Tools of the Digital Humanities have shown to be successful in supporting research on books. For instance, our institute provides several tools for doing research on textbooks and curricula. Unfortunately, not all institutes have the possibilities and the qualified staff to set up their own Digital Humanities architecture. Hence, we enhanced our successfully applied tools to be ready to cover additional data from all around the world.

Thus, the individual information infrastructures offer different search, analysis and visualization options for the subsets of the GEI digital collections, or the digital data collected in projects.

Moreover, the differences are based on the different quality and amount of collected meta data, but also on the decisions taken for their evaluation and presentation. In this work, we presented different digital services for Digital Humanities resulting in:

- The digital edition WorldViews[13] including selected excerpts from textbooks in different languages, coming from different publication periods. These data are

[13] http://worldviews.gei.de/.

enriched with additional translations, comments, and TEI annotations which are made available and are fully searchable as well as having CMDI meta data profiles, allowing them to be accessed within the European research network, CLARIN.

- The "GEI-Digital" Portal, allowing a faceted search, where researchers can filter the various sub-corpora using the available meta data, as e.g. to display books of certain publishers in certain publishing locations—however, a combination of certain queries is not always possible. For this purpose, a prototype was developed with "GEI-Digital Visualized", which uses the same meta data to create volumes of books, e.g. displaying their appearance data in a timeline and the publishing locations in a map.
- The "Children and their World" Project, where additional meta data has been retrieved to support more detailed research needs. In addition to the GEI-Digital meta data, the confession or the denomination, the targeted gender of the scholars and the historical school types have been made available for faceted browsing in the research interface "Children and their World" Explorer, which also allows to work with Topic Models.
- The International TextbookCat Project, dealing with data standardisation and homogenisation, and hosting a multilingual catalogue, within which we integrate three international textbook catalogues from Italy, Spain and Germany (GEI OPAC, Edisco and MANES). We are currently working on the integration of more data, more languages, more alphabets and more data types.

In conclusion, our objective is to create a multilingual, multi-alphabet, multi-dataset five-star-openness repository on textbook-related data whose content is available via multinational and multi-thematic applications. We presented the GEI digital infrastructure and the related services, which can be used for data integration and representation in the 21st century, covering the milestones already achieved and those still ahead of us. In the near focus, we will have to focus on the user perspective; in this way, we hope to demonstrate the uniqueness and novelty of our digital systems and the importance of scope and scale for the Repository of Textbook Research.

References

1. Berners-Lee, T. (2006, last updated 2009). Linked Data. <online> https://www.w3.org/DesignIssues/LinkedData.html, last accessed 21st November 2017.
2. Best, H., Lengyel, G. and Verzichelli, L. (Eds) (2012). The Europe of Elites. A Study into the Europeanness of Europe's Political and Economic Elites, Oxford/ New York 2012.
3. Chakrabarty, D. (2000) Provincializing Europe. Postcolonial Thought and Historical Difference, Princeton, New Jersey.
4. De Luca, E. W. and Nürnberger A. Rebuilding Lexical Resources for Information Retrieval using Sense Folder Detection and Merging Methods, In: Proceedings of the 5th International Conference on Language Resources and Evaluation (LREC 2006). Genova, Italien, 2006b.
5. De Luca, E. W. and Nürnberger A. Supporting Information Retrieval on Mobile Devices, In: Proceedings of MOBILE HCI 2005: 7th International Conference on Human-Computer Interaction with Mobile Devices and Services, ACM Press. New York, 2005.

6. De Luca, E. W. and Nürnberger A. Using Clustering Methods to Improve Ontology-Based Query Term Disambiguation, In: International Journal of Intelligent Systems, 21:7, John Wiley & Sons, pp. 693–709, 2006a.
7. Dörk, M., Pietsch C. and Credico G. One view is not enough. High-level visualizations of a large cultural collection. In: Information Design Journal 23(1). John Benjamins Publishing Company. 2017. Link: http://dx.doi.org/10.1075/idj.23.1.06dor.
8. Fiedler, M., Scheel, C., Weiß, A., De Luca, E.: „Welt der Kinder. Semantisches Information Retrieval als Zugang zu Wissensbeständen des 19. Jahrhunderts", FVWG und GCDH Workshop für Wissenschaftsgeschichte und Digital Humanities in Forschung und Lehre, 2016.
9. Fuchs, E., Niehaus, I., Stoletzki, A.: Das Schulbuch in der Forschung: Analysen und Empfehlungen für die Bildungspraxis. V&R Unipress, 2014. URL: http://www.gei.de/publikationen/eckert-expertise/.
10. Fuchs, E., Kahlert, J., Sandfuchs, U.: Schulbuch konkret: Kontexte - Produktion - Unterricht. Klinkhardt, 2010.
11. Gehler, M., and Vietta, S. (Eds). (2010). Europa –Europäisierung –Europäistik, Wien.
12. Hennicke, S., Stahn, L.-L., De Luca, E.W., Schwedes, S. and Witt, A. WorldViews: Access to International Textbooks for Digital Humanities. In: Digital Humanities 2017. The Alliance of Digital Humanities Organizations (ADHO). Montreal, Canada, August 8–11, 2017.
13. Hennig, L., De Luca, E. W. and Albayrak S. Learning Summary Content Units with Topic Modeling, In: Proceedings of the 23rd International Conference on Computational Linguistics (COLING 2010). Beijing, China, August 23–27, 2010.
14. Scheel, C., Schmitz C. and De Luca E.W. Fusing International Textbook Collections for Textbook Research. Interdisciplinary Conference on Digital Cultural Heritage (DCH 2017). Berlin, August 30–September 01, 2017 Staatsbibliothek Berlin.
15. Scheel, C., Schmitz C. and De Luca E.W. Vereinheitlichung internationaler Bibliothekskataloge. In: Conference on Learning, Knowledge, Data and Analysis - Lernen. Wissen. Daten. Analysen. (LWDA 2016). Workshop "Information Retrieval 2016" held by the Special Interest Group on Information Retrieval of the Gesellschaft für Informatik (German Computing Society), pp. 271–282. Hasso Plattner Institute, Potsdam, Germany. September 12–14, 2016.
16. Smith, A. (2002). Strategies for building digitized collections. Microform & imaging review, 31(1):8–30.
17. The Open Archives Initiative Protocol for Metadata Harvesting. Protocol Version 2.0 of 2002-06-14. Document Version 2015-01-08. URL http://www.openarchives.org/OAI/openarchivesprotocol.html.

Fusing International Textbook Collections for Textbook Research

Christian Scheel and Ernesto William De Luca

Abstract The investigation of sanctioned knowledge for the formation of the young generation is a subject of textbook research. Additionally, textbooks are gaining importance for historical research in other disciplines, in the search for "popular knowledge", as they reflect worldviews, thought flows and desired knowledge. Therefore, it is important to have knowledge of textbooks from around the world. This work describes the fusion of international textbook collections and the usage of classification schemes, covering textbook specific characteristics. The resulting research tool for international textbook research is a prototype for fusing any other metadata-based web databases to raise research from national to international level.

Keywords Textbook research · Digital archives · Fusing web databases

1 Introduction

Although the field of textbook research is relatively new, there are many independent textbook collections available dating back to the year 1979, covering textbooks from the 18th to the 21st century [1]. Those researchers who were interested in investigating knowledge and culture found in textbooks created their own archives or databases. Besides containing textbooks and because of different areas of interest, these collections are very diverse in size and quality of information. Some collections are physical available and others are just bibliographies. These textbook researchers have not been librarians; they often did not follow any standards or created their own standards, but the collections have in common that the textbook specific characteristics have been documented very well. Such information as "country of use", "school subject", "type of school", or "level of education" is crucial for textbook research.

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Usually, no library is annotating textbooks at this level of detail, because textbooks are treated like any other book. Hence, to support international textbook research, these textbook collections had to be analyzed, cleaned, unified and made available to the public.

As starting point to unify these collections, we have chosen the international textbook collection, which is physically available at the research library of the Georg Eckert Institute, Brunswick, Germany. For describing 180,000 textbooks, the librarians created a classification scheme for textbook specific characteristics. Unfortunately, this classification was partly focused on the national level, so that "type of school" was only annotated for German textbooks and "periods" covered only periods in time that have been important to German history. In addition, "federal state of use" was only used for textbooks where "country of use" was Germany. The research, the textbook collection and hence the local classification scheme of the Georg Eckert Institute are primarily focused on educational sciences, history, geography, political science and religious sciences [2–4], where other collections also include math or even cooking.

In this work, we present results of the analyzation of international textbook collections and generalize found problems. We go on, proposing how to create a classification scheme covering all textbook specific characteristics on international level with as much reuse of existing schemes and standards. We show how information in textbook collections are mapped to codes of the new classification scheme and how these codes are the foundation of a language independent research tool for textbook research.

2 Textbook Collections

To guarantee that the young generation will follow the rules and views of their leaders, knowledge is often sanctioned. This happened in the past and certainly happens now. Besides other areas of research, textbook researchers are analyzing the worldviews, thought flows and desired knowledge found in textbooks, providing additional information to questions like "How and why have historical events been supported by the people?" The youth is not questioning the knowledge in textbooks, which makes them particularly vulnerable. By comparing textbooks over time and internationally, sanctioned knowledge can be revealed. Therefore, textbook researchers started collecting textbooks in their area of interest.

International textbook collections have emerged mostly as an initiative of individual researchers (groups), and from the need to catalog textbooks because there was no explicit indexing of textbooks by the libraries. Unlike the Georg Eckert Institute, where all textbooks are also part of the research library, the databases of international textbook researchers are usually only bibliographies. However, this is not a disadvantage, otherwise information about textbooks, e.g. when books are deposited in monastic libraries, are simply unknown. In addition, the quality of the information can be regarded as high, especially for textbook specific characteristics.

Besides the textbook collection of the research library of the Georg Eckert Institute, three other collections are referenced in this work: EDISCO, MANES and the Emmanuelle Textbook project. Analyzing and comparing these collections have played a major part for fusing these databases. The University of Turin's Research Center for Digitization and Creation of Digital Libraries for the Humanities hosts the EDISCO database, which has around 30,000 records of Italian textbooks from the 19th and 20th centuries. The Department of History of Education and Comparative Education hosts the MANES database, which has approximately 35,000 records of Spanish, Portuguese and Latin American textbooks from the 19th and 20th centuries. The metadata in MANES is recorded according to its cataloging guidelines [7]. In 1979, Alain Choppin, a pioneer of textbook research, started to create the "Emmanuelle Textbook Project". This collection includes French textbooks dating back to 1789 [8, 9].

3 Fusing Web Databases

Before the International TextbookCat was implemented, a great part of textbook research was networking. Researchers needed to know each other personally to gain access to textbook collections from other countries. However, for researchers interested in the field of textbook analysis, finding textbook collections was not even the biggest hurdle. Because textbook researchers usually have not been librarians, textbook collections have not been standardized, resulting in frustrating observations. In the following, some of these observations are listed:

- Although books are described, common fields for describing books are missing.
- For accessing the data, logins are needed.
- Accessing the data is only possible within the corresponding institute.
- The user interface is not intuitive and needs training or supervision.
- The user interface is monolingual.
- The metadata is monolingual.
- The metadata is not limited and contains spelling errors.
- The data can not be retrieved via interfaces.

Hence, even when having access to another textbook collection, the results have not been comparable. The problems can be divided into three fields: access, user interface and data. While the whole idea of fusing these web databases is about unrestricted access and a common user interface, there is still the need to retrieve and fuse the collections automatically. Therefore, interfaces and standards are needed.

3.1 The Need for Access

To break the existing structures, we encourage those who maintain a textbook collection, to also offer open access to everyone. Hence, when starting to fuse these web databases, we made clear that anybody joining the project would have to migrate to a common library system. Library systems not only provide access for users, but also enable automated data collection through the standardized OAI-PMH interface [5].

3.2 The Need for Standards

Before fusing international web databases, there is the need for common classification schemes. While all characteristics of books should be covered by the used library system. All other metadata must be represented in a consistent format or at least must be mappable into such presentation.

The textbook collection of the research library of the Georg Eckert Institute contains over 180,000 textbooks. Although about 100,000 of these textbooks are written in German, the collection contains textbooks from 181 countries. To better describe these textbooks, the librarians developed a local notation, a classification system that could be used to describe every book in the collection in detail (see Table 1 ↓). The "country of usage" is a textbook specific feature, because the country where a book was printed is not necessarily the country where the book is used. Hence, country of usage is very important to estimate the impact of a textbook. In this collection, the class "state" contains only codes for the German states. Due to the limited research focus, only subjects such as history, social studies, geography and religion, as well as language lessons, can be found in "school subject". Textbooks for mathematics are therefore not part of the collection (and the local notation), as their significance for the historical and cultural studies of (international) textbook research is considered to be comparatively low. The class "level of education" corresponds almost exclusively to the classification of the International Standard Classification of Education (ISCED) of UNESCO [6]. The notation for "school type" only covers the German school system, even if approximately 100,000 textbooks in this collection have not Germany as "country of usage". The Germany-centric view is continued in the class "period". This class is redundant to the publication year, but allows a classification according to 15 historically relevant and Germany related epochs. The textbook specific class "document type" distinguishes between textbook, syllabus, teaching material, teacher's manual, collection of exercises, etc. Therefore, it may not be confused with the general type, covering book, e-book or video.

Ideally, the collections of the international partners could have been one-to-one mapped to the data structure of the Georg Eckert Institute. That this could not be the case was foreseeable in advance, since the school systems differ from one country to another and thus there is often no corresponding code in this classification scheme. Further reasons have been revealed when analyzing the international collections.

Table 1 Local notation for textbook specific characteristics of the Georg Eckert Institute, where _ represents the placeholder for numbers or letters

Code(s)	Class	Expressions
l_ _ _	Country (of usage)	181
b_ _ / b_bz	State (Germany)	16/4
u_ _ _	School subject	15
k_ _	Level of education	7
s_ _	School type (Germany)	11
z_ _ _	Period	15
d_ _	Document type	12

Individual fields in the collections. Since the creators of the collections were not librarians, in some cases only those characteristics were recorded that are important for textbooks in particular, but not books in general. For example, titles, subtitles, and title additions are recorded separately according to library standards, whereas a "layman" would collect that information as a whole.

Interpretation of individual fields. A further challenge were fields whose names were ambiguous, so that they have been interpreted differently by different people. For example, the field "usage" was interpreted by MANES creators both as "usage for" and as "usage as", even though there are cataloging guidelines [7]. Hence, this field contained individuals and groups, as well as document types.

Differences in the degree of detail. When looking at the collections, the disadvantage of free text fields could be seen. The absence of mandatory expressions for certain attributes, for example, was reflected in 155 different expressions for school subjects in EDISCO and 85 school subjects in MANES, which contrasted with the 15 school subjects of the GEI classification system. Even though a large part of the variants was due to spelling errors, after the adjustment, 86 new school subjects remained, which had to be taken into account in the international classification system. This made a fundamental decision necessary on whether to generalize properties (fewer options), specialize (all options) or simply ignore non-mappable properties. Generalizing or ignoring would lead to the loss of information, while specializing has the disadvantage that one has to (unambiguously) translate each expression (including future ones) into each supported language.

Different understanding of matter. Can cookbooks be seen as textbooks? Should math books be considered, even when there is no use of application in textbook research?

Entries are difficult to map. Due to different education systems in different countries, fields such as the "school type" can not be mapped. In the research tool, filtering on such a field would usually only lead to results from a specific country, which is not wanted.

3.3 The Need for Multi-lingual User Interfaces

In the past, there were many limiting factors for textbooks as a source of the humanities. One of them are the languages. When working with a textbook collection in another language, the researcher had to have at least a basic understanding of that language in order to navigate through this catalogue and additional effort was needed to translate the metadata by hand. When fusing international catalogues, there is the need to present metadata in the researcher's mother tongue.

4 Fusing Metadata

The task of fusing web databases can be broken down to the task of fusing metadata. Each possible expression for any feature (like "school subject", "level of education", etc.) coming from any web database needs to be annotated language independently.

4.1 Classification Schemes and Norms

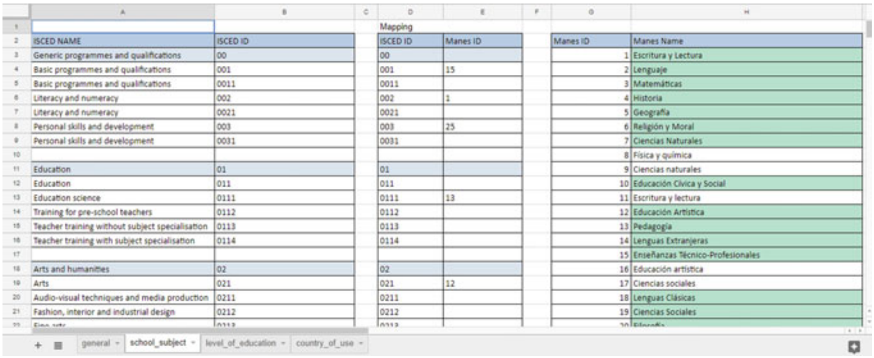
When "country of usage" is "Germany" in an English database and "Deutschland" in a German database, then both expression have to be mapped to the same code. While there are established norms for representing countries (ISO 3166-1), there might be missing norms for individual features like "school type". The first task for fusing metadata is too search for classification schemes which can be reused.

One of the most convenient detail about classification schemes and standards is the usage of codes. When representing "Germany" with "de", this code can easily be mapped back to "Germany" or "Allemagne", if French is you mother tongue. Hence, the need for multi-lingual interfaces is actually satisfied on the way.

There often are no norms for representing individual features. For instance, there are no codes for representing cities. In such cases, we are using the English translation as code and collected the necessary translations from knowledge sources like DBpedia [10] (see owl:sameAs relation[1]).

In the field of textbooks, we were happy to find standards for "school subject" and "level of education". The International Standard Classification of Education (ISCED [6]) provides hierarchical schemes for both features. Hence, we only had the task of translating all codes into other languages. When applying these hierarchical schemes, another convenient detail was revealed. While there are 120 codes for representing school subjects, there are only 10 top-level codes (like "Fine arts"or "Natural sciences, mathematics and statistics"). The most specific codes can be found in the third level. Therefore, there was no need to decide whether we want to represent a feature specifically or generally. The specific expression "Math" is implicitly part of

[1] http://de.dbpedia.org/page/Berlin.



Mapping

ISCED NAME	ISCED ID	ISCED ID	Manes ID	Manes ID	Manes Name
Generic programmes and qualifications	00	00		1	Escritura y Lectura
Basic programmes and qualifications	001	001	15	2	Lenguaje
Basic programmes and qualifications	0011	0011		3	Matemáticas
Literacy and numeracy	002	002	1	4	Historia
Literacy and numeracy	0021	0021		5	Geografía
Personal skills and development	003	003	25	6	Religión y Moral
Personal skills and development	0031	0031		7	Ciencias Naturales
				8	Física y química
Education	01	01		9	Ciencias naturales
Education	011	011		10	Educación Cívica y Social
Education science	0111	0111	13	11	Escritura y lectura
Training for pre-school teachers	0112	0112		12	Educación Artística
Teacher training without subject specialisation	0113	0113		13	Pedagogía
Teacher training with subject specialisation	0114	0114		14	Lenguas Extranjeras
				15	Enseñanzas Técnico-Profesionales
Arts and humanities	02	02		16	Educación artística
Arts	021	021	12	17	Ciencias sociales
Audio-visual techniques and media production	0211	0211		18	Lenguas Clásicas
Fashion, interior and industrial design	0212	0212		19	Ciencias Sociales

Fig. 1 Example for mapping Spanish data into the ISCED classification for school subjects. On the left, the target classification can be seen. On the right, all found expressions for school subjects (including spelling mistakes) are listed. The mapping is defined in the middle of this spreadsheet

"Mathematics and statistics" and the most general representation "Natural sciences, mathematics and statistics".

4.2 Mapping

The most time consuming part of fusing metadata is defining the mapping for each web database. An expert is needed to link each expression from the data to one or more codes in the classification scheme. The best expert is always the owner of the data, because this person knows the real meaning of expressions and will not make assumptions based on translations.

We experienced, that using spreadsheets (like Google Spreadsheets; see Fig. 1) for defining the mapping was a good choice, because of the intuitive nature of tables.

After retrieving a dataset (through OAI-PMH interface [5]), we automatically collected all expressions for each feature, gave each expression a unique identifier, created the spreadsheet and asked to link these identifiers to the codes of the respective classification scheme. These files can be revised at any time, because the tools do not manipulate the original data, but the representations in the search index.

4.3 The Used Tools

Besides having developed tools for creating, filling and reading the spreadsheets automatically and observing all databased for new or changed entries, most of the tools used are open source tools.

For reading the textbook collections, applying the mapping and writing the results to a search index, the tool MARC4J[2] is used. The search index, which is the only storage where the fused data is kept, is part of a Solr[3] server.

The user interface is based on VuFind.[4] Besides being already translated for several languages, this discovery system supports saving searches or bookmarking books in individual list. This has shown to be very helpful for managing books for specific research questions.

5 The International TextbookCat

In the field of textbook research, there have been many textbook collections, which were hard to access. First, it was difficult to find these collections, and secondly, the textbooks were usually annotated in the language in which they have been written.

For creating the International TextbookCat,[5] a research tool, which covers international textbook collections, these catalogues had to be analyzed and fused on metadata level. The most important part was to find classification schemes for each feature (like "school subject") and to define mapping rules to map the expressions found in the catalogues into these schemes.

In the resulting research tool, the classification schemes are reflected as facets. These facets allow to search for textbooks that have certain attributes, independent from the language each attribute was formulated in its original database. Representing attributes as codes also helped to present every metadata in the researcher's mother tongue.

The problems to be solved before fusing textbook collections are also found in similar areas. In any research field, there are historically grown collections (of any items) which are important to the field, but can not be accessed properly. The process of analyzing, refining and mapping can surly be applied to any of these collections, while also helping to preserve them.

References

1. Ossenbach, G.: „Textbook databases and their contribution to international research on the history of school culture", History of Education & Children's Literature, pp. 163–174, 2014.
2. Fiedler, M., Scheel, C., Weiß, A., De Luca, E.: „Welt der Kinder. Semantisches Information Retrieval als Zugang zu Wissensbeständen des 19. Jahrhunderts", FVWG und GCDH Workshop für Wissenschaftsgeschichte und Digital Humanities in Forschung und Lehre, 2016.

[2] https://github.com/marc4j/marc4j.

[3] http://lucene.apache.org/solr/.

[4] https://vufind.org.

[5] http://itbc.gei.de.

3. Fuchs, E., Kahlert, J., Sandfuchs, U.: Schulbuch konkret: Kontexte - Produktion - Unterricht. Klinkhardt, 2010.
4. Fuchs, E., Niehaus, I., Stoletzki, A.: Das Schulbuch in der Forschung: Analysen und Empfehlungen für die Bildungspraxis. V&R Unipress, 2014. URL http://www.gei.de/publikationen/eckert-expertise/.
5. The Open Archives Initiative Protocol for Metadata Harvesting. Protocol Version 2.0 of 2002-06-14. Document Version 2015-01-08. URL http://www.openarchives.org/OAI/openarchivesprotocol.html.
6. Silke L. Schneider, (2013), The International Standard Classification of Education 2011, in Gunn Elisabeth Birkelund (ed.) Class and Stratification Analysis (Comparative Social Research, Volume 30) Emerald Group Publishing Limited, pp. 365–379.
7. Gabriela Ossenbach: „Research about school handbooks in Latin America: The project MANES contribution", Historia de la Educación, 2013. URL http://revistas.usal.es/index.php/0212-0267/article/view/10797.
8. Alain Choppin: „EMMANUELLE: a data base for textbooks' history in Europe", Historical Social Research, pp. 52–58, 1989. URL http://nbn-resolving.de/urn:nbn:de:0168-ssoar-51666.
9. Alain Choppin: „The Emmanuelle Textbook Project", Journal of Curriculum Studies, pp. 345–356, 1992. URL http://dx.doi.org/10.1080/0022027920240404.
10. Auer, Sören & Bizer, Christian & Kobilarov, Georgi & Lehmann, Jens & Cyganiak, Richard & Ives, Zachary. (2007). DBpedia: A Nucleus for a Web of Open Data. Lecture Notes in Computer Science. 6. 722–735.

Digital Preservation of Cultural Heritage for Small Institutions

Rolf Däßler and Ulf Preuß

Abstract In this article we describe a concept for the digital preservation of the cultural heritage of smaller cultural institutions without their own infrastructure, in order to preserve and use digital objects in the long term. For this purpose, a digital archive will be extended by a pre-ingest component, which will aggregate the digital objects of the cultural institutions and provide access to the archived information. The proposed system for distributed digital preservation can be described by an extended Open Archive Information System (OAIS) reference model—the Outer-Inner OAIS (OO-IO) model. In the Federal state of Brandenburg there are about 340 archives, museums and libraries. Most of them are rather small but of great significance for cultural heritage. The digital preservation of data and information is therefore one of the biggest challenges. Unfortunately, smaller institutions often lack the knowledge and the resources to meet this challenge. The described approach supports these cultural and research institutions in their efforts to preserve cultural heritage.

Keywords Digital preservation · Aggregation of content · Use case · Pre-ingest · Inner-Outer OAIS reference model

1 Introduction

The growing demand for digital preservation is a global phenomenon. Especially cultural heritage institutions face this task. It requires sustainable solutions, in order to provide long-term access and usability. Out of the digital nature of digital objects arise new cooperative ideas and pragmatic solutions.

In this article, we focus exemplary on the Federal state of Brandenburg with its hundreds of mostly smaller archives, libraries and museums. They hold the responsibility for preserving cultural heritage. About 340 of them are operated by a small fixed

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staff, while many more are run by volunteers. The monument list of Brandenburg contains more than 24,000 objects [8].

During the last five years more than 60 of these institutions participated in government funded projects to digitize some of their cultural heritage. As a side effect, institutions face a growing demand for digital preservation. However, almost all institutions lack the knowledge for digital preservation and the necessary resources for own systems [9]. While in recent years, based on the OAIS Reference Model [2], a series of practical digital archive solutions have been developed, it is now necessary—in analogy to the research data management—to establish sustainable organizational and technical infrastructures for the digital preservation of the cultural heritage [6]. Furthermore, there is a need for cooperation between organizations to address this challenge. The same holds true for any other cultural heritage communities with smaller institutions and a demand for digital preservation.

Development of cooperative digital services and infrastructures is part of the digitalization strategy of the state Brandenburg [5] and is described in detail in a Framework for preservation of digital cultural heritage [10].

All cultural institutions have a common task: The reliable building of the cultural heritage with the aim of a long-term availability and access. In spite of different working methods, all cultural heritage institutions are responsible for the specific tasks of collection building, cataloging/indexing, presentation, education and knowledge transfer as well as preservation of their content (see Fig. 1). For the purpose of preservation, they usually have an on-site or local depot for physical objects. In the near future, they need a digital depot for their digital objects too. Because of its digital character, it can be organized as a central compound solution.

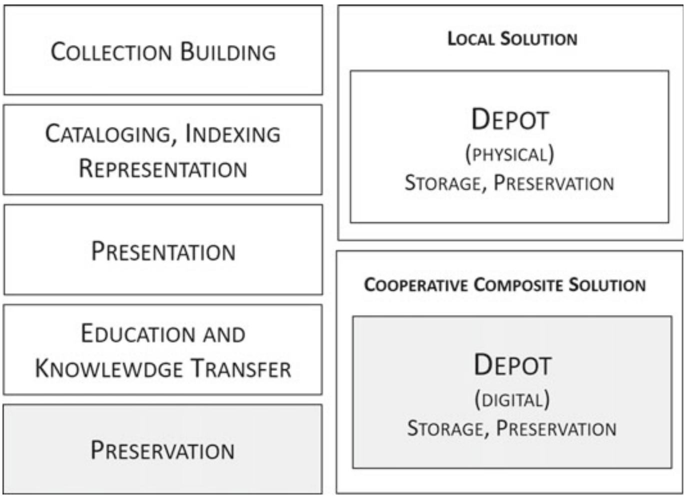

Fig. 1 Main Tasks of Cultural Heritage Institutions, including preservation of their physical and/or digital collections [10: p. 10]

2 Technical Model

2.1 Aggregator

Cross-division digital preservation should have an universal character. For this purpose, an OAIS-compliant digital archive with ingest-, access and preservation modules as well as a powerful archival storage is required [2]. For a largely automated and standardized ingest, a pre-ingest process is additionally required to aggregate, prepare and transform heterogeneous primary data and metadata.

The management of the archival packages is based on a minimal set of descriptive metadata. The service provider of the digital depot is responsible for long-term format migration as well as for maintaining the authenticity and integrity of the digital objects. To do this, preservation metadata are largely automatically extracted. However, responsibility for the maintenance of the interpretability (performance) of the digital objects remains with the cultural institutions. This eliminates the need for complex indexing and metadata mapping.

For a largely automated and standardized ingest, a pre-ingest component, the so called aggregator, is required. This component aggregates, prepares and transforms the heterogeneous primary data and metadata, delivered by the institutions (Fig. 2). The aggregator allows institutions to deliver content, to manage their deliveries independently and to access copies of the archived information stored in the archival system over the long term. The aggregator then supplies standard submission

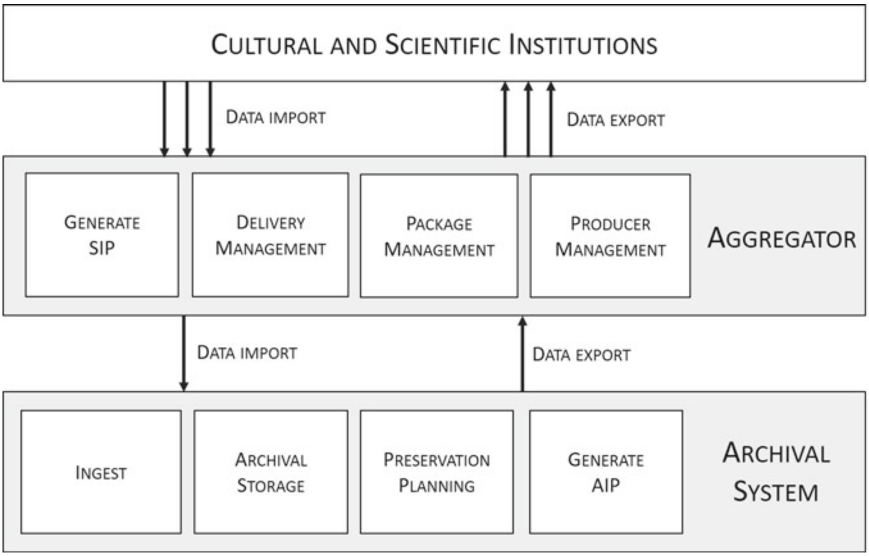

Fig. 2 Aggregator as a coordination and support unit between institutions and the provider of the archival system (digital depot) [10: p. 29]

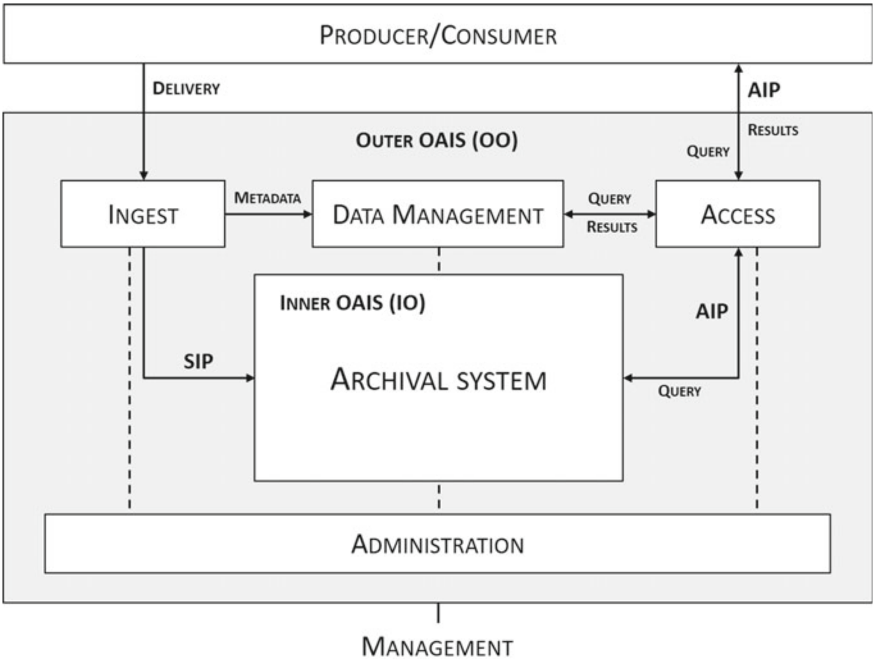

Fig. 3 Inner-Outer OAIS Reference Model (IO/OO) for distributed preservation

packages as a single producer to the archival system. The advantage of this method is, that the ingest process can be largely automated and manual processes can be performed in advance by the pre-ingest process.

The digital depot solution is modularly interchangeable and the digital depot is thus independent of a specific digital archival system. For example, the archival system, developed by the Zuse Institute in Berlin, could be used within such a framework of a cooperative composite solution Berlin-Brandenburg [4].

The proposed system for distributed digital preservation, which is shown in Fig. 3 can be described by an extended Open Archival Information System (OAIS) Reference Model—the Outer-Inner OAIS (OO-IO) Model [11]. The Outer OAIS Model describes the main functional entities of the Aggregator: Ingest, Data Management, Administration and Access. Cultural and scientific institutions act both, as producers of the digital objects and as consumers of the archival information packages. Preservation Planning is not a task of the Outer OAIS system. In contrast to the original OAIS model the Ingest process of the Outer OAIS generates Submission Information Packages (SIPs), which are transferred to the Archival System (Inner OAIS). It represents an independent external OAIS system with all functional entities of the original OAIS Reference Model including the Preservation Planning. The data management includes the metadata management of the information packages, producers and deliveries. The institutions retrieve and access their stored Archival Information Packages (AIP) of the Inner OAIS via database queries.

2.2 System Architecture

According to the OAIS reference model, the system architecture of the aggregator (see Fig. 4) consists of the functional units Pre-Ingest, Data Management and Access [1]. The functional units recording, archiving and retention planning are part of an external digital archive. The data exchange takes place via OAIS-compliant information packages. The aggregator generates SIPs (Template Information Packages) for the digital archive and receives AIPs (Archive Information Packages) from the digital archive. In this way, the archived information packets can again be made available to the cultural institutions (consumers). The cultural institutions themselves provide their digital content, e.g. digital copies (data objects) and available object descriptive metadata (presentation information). This information is transferred to the SIP in the pre-ingest process of the aggregator and later during the digital archive capture process (after format transformations and adding metadata) to the SIP. To manage the archive packages for later access, the package description information is maintained in the aggregator data management database. This includes metadata about the supplying institution, the delivery itself and the archiving packages. The scope, nature and significance of this metadata are set by a submission agreement. This metadata

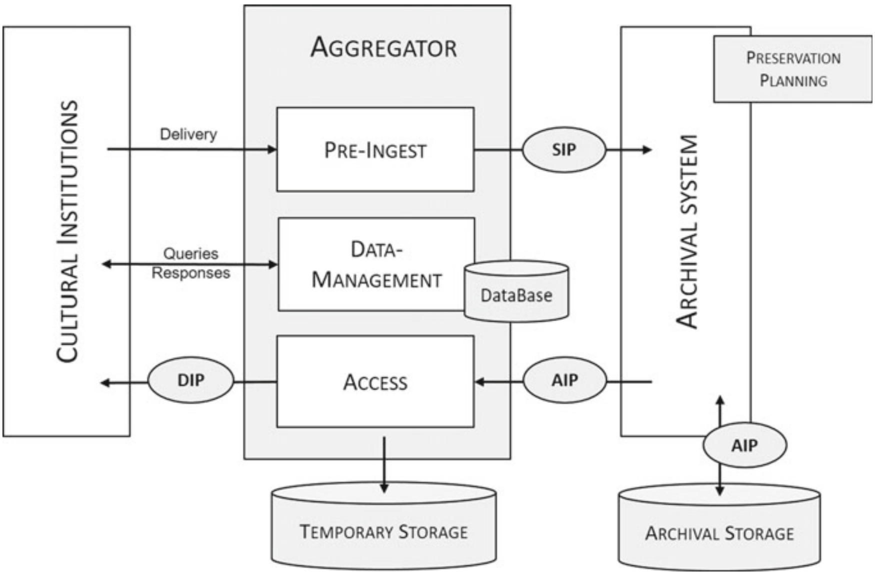

Fig. 4 Digital preservation system architecture

can be added web-based through a graphical user interface during the pre-ingest process. The aggregator's pre-ingest module generates a SIP that can be adapted to the transmission specifications of the digital archive, regardless of the cultural institutions (producers). The digital archive generates AIPs from the SIPs by extending the existing metadata and executing format transformations as needed. In addition, the digital archive is responsible for the digital preservation of file formats and the maintenance of the authenticity and integrity of the information objects. Through the data management of the aggregator, each cultural institution can receive copies of its archive packages via search queries.

2.3 Metadata Model

The data exchange takes place via OAIS-compliant information packages (see Fig. 5). The aggregator generates submission information packages (SIP) for the archival system and obtains archival information packages (AIP) from it. In this way the archived information packages can be made available to the cultural institutions. The cultural institutions themselves supply their data objects and if available the object-describing representation information. Data and Metadata are transferred within the pre-ingest process to the Submission Package and later on during the ingest process of the archival system—after format trans-formations and the addition of preservation metadata—to the archival package.

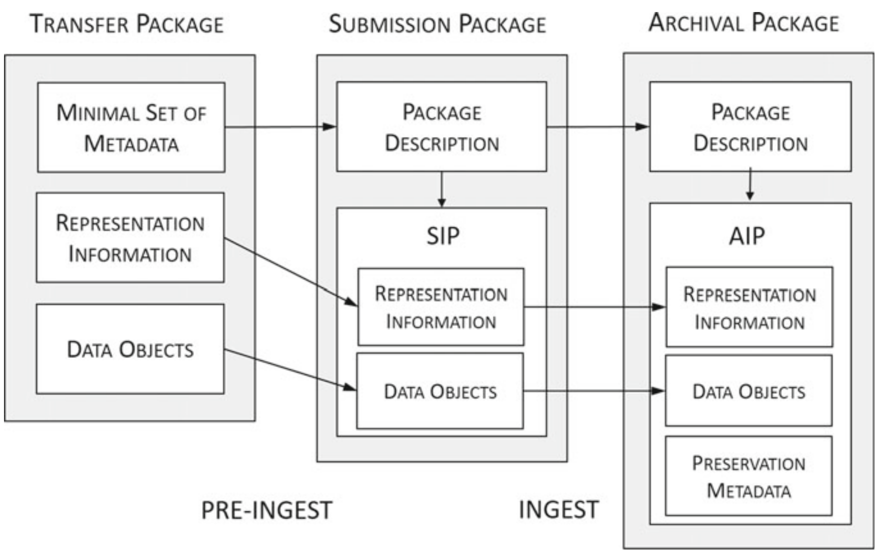

Fig. 5 Digital preservation metadata model

The database management of the archival packages is based on a minimal set of descriptive metadata. The database model includes certain information categories: information about the institutions and the participants, information about the archival packages, the type of project funding and information about the submission process and the processing status.

2.4 User Interface

The aggregator, which is currently in an experimental phase, successfully demonstrates the complete delivery process. Producer management involves registering producers with a defined minimum set of metadata. Each institution is identified by the International standard identifier for libraries and related organizations (ISIL) [3]. Further information about the institution can be found in the ISIL database of the Berlin State Library. The aggregator database allows you to search for specific institutions and their submissions. Once registered, each institution can provide content and manage those deliveries independently. The data organization is the following: Each producer has a collection. The collection consists of several projects and each project can contain several contributions. Each submission consists of one or more files. It is possible to add a new project to each existing project. After a successful submission, the aggregator automatically generates a submission package that is copied to the submission folder. The package is then transferred to the archive system. After a successful inclusion of the submission package and the generation of an archive information package, the aggregator receives status information. From then on, every cultural institution can receive copies of their archive packages through search queries. A demonstrator of data aggregation has already been successfully tested in a bachelor thesis of 2017 [7].

3 Organization Model

The structure, operation and further development of the cooperation network require different functional levels (see Fig. 6). The core level is the legal and organizational level. It is responsible for legal agreements and coordination and monitoring of the agreed services. At this level is also the development department, which oversees and develops the collaborative approach and related processes. The second level consists of the participating institutions (users). The aggregator is the support level located between them and the provider of the preservation service. Here, the institutions are supported in data preparation, data transfer and later data requirements. The last level is the service provider (digital depot) and is as such subject to a potential change of vendor over time. The organizational model is described in more detail in a strategic framework for the preservation of Brandenburg's digital cultural heritage [10].

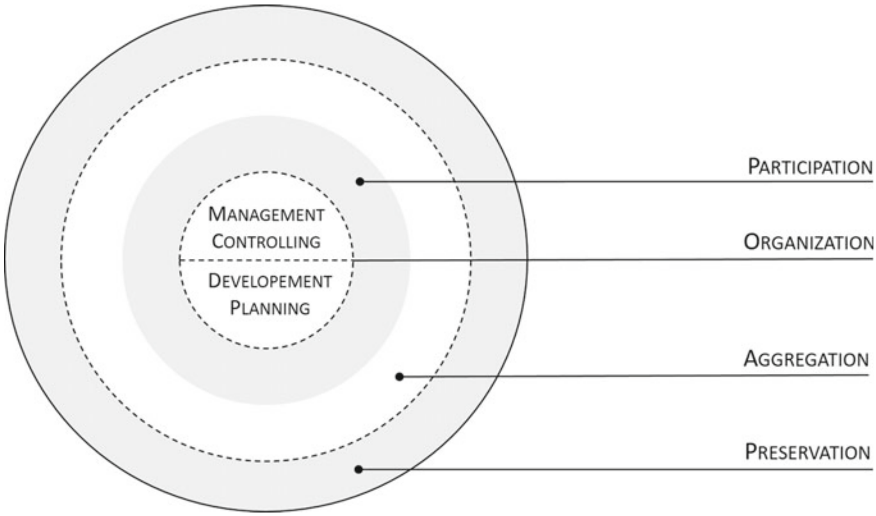

Fig. 6 Organization model [9: p. 27]

4 Discussion

The described approach supports cultural heritage and research institutions in their efforts to sustain digital collections. The focus of our solution is on the demand within Brandenburg. Because of the community based conceptual model, it should be adaptable to communities in other states or regions with similar infrastructural shortcomings. At the moment, the project is in an experimental proof of concept phase. Not yet implemented is an error handling in case of non-valid SIPs during the ingest process of the archival system.

Our next step is the pragmatic test of an exemplary preservation cycle. For that, we will start with the preservation of digitized large format glass plate film negatives, which come from different cultural institutions.

The proposed concept and system architecture for the data aggregation might be useful for a wide range of distributed preservation applications. The aggregator is in this regard an essential tool for a fully standardized and automated ingest process and the development of cooperative digital archiving services [7].

In conclusion, there are limited alternatives for digital preservation, especially for smaller institutions. The general idea of an interdisciplinary approach relies on the openness and determination of institutions, organizations and individuals. Institutions such as archives, libraries and museums should be able to participate in the digital turn in order to provide and sustain valuable, authentic and genuine information to our society [9].

References

1. Daessler, R. Digitale Archivierung im Wandel – Von der Einzellösung zur kooperativen Verbundlösung, In: Proceedings of the 86th Archivtag, Koblenz 28.09. - 01.10.2016, in preparation.
2. ISO 14721:2012 (en). (2012). Space data and information systems - Open archival information system (OAIS) – Reference model. Retrieved from ISO.org website: https://www.iso.org/obp/ui/#iso:std:iso:14721:ed-2:v1:en.
3. ISO 15511:2011. (2011). Information and documentation – International standard identifier for libraries and related organizations (ISIL). Retrieved from ISO.org website: https://www.iso.org/standard/57332.html.
4. Klindt, M.; Amrhein, K. (2016). One Core Preservation System for All your Data. No Exceptions! In: Proceedings of the 12th International Conference on Digital Preservation, Chapel Hill, NC, USA, 2–6 November 2015; School of Information and Library Science, University of North Carolina at Chapel Hill: Chapel Hill, NC, USA, 2016. pp. 101–108. Retrieved from University of Vienna website: http://phaidra.univie.ac.at/o:429524.
5. Land Brandenburg state chancellery. (2017). Brandenburg Digital. Distanzen überwinden. Statusbericht zur Zukunftsstrategie Digitales Brandenburg. (Report) Retrieved from the Land Brandenburg website: http://www.brandenburg.de/media_fast/1167/Statusbericht_zur_Zukunftsstrategie_Digitales_Brandenburg__20170829.pdf.
6. Ludwig, J. (2013). Summary and Interpretation. In: Digital Curation of Research Data. Experiences of a Baseline Study in Germany. Neuroth, H., Strathmann, A., Osswald, A., Ludwig, J. (Eds.); Göttingen: Vwh / Universitaetsverlag Göttingen. pp. 55–69. Retrieved from Universitaetsverlag Göttingen website: http://resolver.sub.uni-goettingen.de/purl?isbn-978-3-86488-054-4.
7. Neudhoefer E. (2017). Pre-Ingest-Werkzeug für Digitalisate aus Kulturerbe-Einrichtungen des Landes Brandenburg. Bachelor Theses. Retrieved from University of Applied Sciences Potsdam website: https://opus4.kobv.de/opus4-fhpotsdam/frontdoor/index/index/docId/1765.
8. Preuss U. (2016). Brandeburg.digital. In: Förderale Vielfalt – Globale Vernetzung. Euler E.; Klimpel P. (Eds.). Hamburg: Hamburg University Press. pp. 52–69. Retrieved from Hamburg University Press website: http://hup.sub.uni-hamburg.de/purl/HamburgUP_DDB2_Vielfalt.
9. Preuss, U. (2016). Sustainable Digitalization of Cultural Heritage - Report on Initiatives and Projects in Brandenburg, Germany. In: Sustainability 2016, 8(9), 891. Basel: MDPI. Retrieved from MDPI website: https://doi.org/10.3390/su8090891.
10. Preuss U., et al. (2017). Rahmenkonzept zum Erhalt des digitalen kulturellen Erbes im Land Brandenburg. (Report). Retrieved from University of Applied Sciences Potsdam website: https://opus4.kobv.de/opus4-fhpotsdam/frontdoor/index/index/docId/1777.
11. Zierau, E. (2017). OAIS and Distributed Digital Preservation in Practice. In: Proceedings of the 14th International Conference on Digital Preservation, Kyoto, Japan, September 25–29, 2017. Retrieved from iPRRES2017 website: https://ipres2017.jp/wp-content/uploads/14Eld-Zierau.pdf.

Body as Echoes: Cyber Archiving of Buddhist Deities in the Cave Temples of China

Wu-Wei Chen

Abstract In this on-going project entitled "Body As Echoes" (BAE), literature review, field research, and interviews of the practitioners are utilized to examine the iconography, conservation and digital heritage imaging of Buddhist deities in the cave-temple complexes of China. Archives, image sequences, point cloud visualizations, 3D models and web-based interactive navigations are accumulated from the various cave-temple complexes in China (Dazu Rock Carvings, Maijishan cliff grottos, Huang Ze Temple, Thousand-Buddha Cliff, Dun Huang Cave paintings) to conduct the researches. The intangible aspect of the project includes the cultural meaning, interconnections between the depicted deities, accentuation of the dynamism of time and change, and the new media narrative in the digital space nowadays. Buddhism and its path from India, China to Japan symbolize the dissemination of intercultural activities along the Silk Road. Different geo-locations in China, on the other hand, are connected by cave art, religion, and culture. The existence and preservation of cultural heritage transcend the echoes of the digital humanities.

Keywords Digital heritage imaging · Cultural heritage · Digital sculpting · Photogrammetry · Dazu rock carvings · Silk Road · Buddhist deities · Research capacity

1 Digital Heritage: Definition and Application

Digital heritage refers to the technology to preserve, revitalize and narrate the cultural heritage—tangible (paper, textile, ceramic, sculptures, architecture, site) or intangible (dialects, craft, performance) legacy, on the land or underwater. By narrative, messaging, and education, digital techniques also assist to revitalize the ancient wisdom inherited from those cultural legacies. Optical technology such as remote sensing, GIS(Geographic Information System), laser scanning, photogrammetry,

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UAV(Unmanned Aerial Vehicles) provides non-intrusive methods to get access, analyze, document and preserve the cultural heritage. Drone footages captured at the ancient ruins also help to reestablish the all-around spatial information for the needs of rescue teams and conservators.

In recent years, cultural heritage faces tremendous challenges from the natural environment (breaking, buckling, cracking, deteriorations, disfiguration, delamination, dust, earth movement, flood, fire risks, humidification, insects, open stitches, redeposition, solubilization) and human activities (theft, vandalism, terrorist attacks). Human activity is one of the major factors jeopardizing the sustainability of heritage objects and sites—Bamiyan, Mossul and others are the recent examples of raising our awareness. Academia and multinational delegations arrive at those demolished locations to collect evidence, document and digitally reconstruct the site and objects. The virtual objects are visualized by crowd-sourcing travel images to compile into the 3D models. CAVE (Cave Automatic Virtual Environment) and other mixed reality methods are also used to narrate, educate and interact with public audiences. Case studies of successful projects can transform into pedagogic materials. Cyber-archiving and monitoring become preventive conservation to extend the life cycle of heritage objects and sites. The knowledge accumulated from the real-world projects echo and pass on through education and narration to consolidate the understanding of cultural heritage and raise the awareness to protect them through joint efforts.

2 Digital Heritage Documentation and Restoration

Most cave temple complexes in China contain sculpted deities or narrative relieves. In terms of sculptured heritage, the traditional sculpting methods to carve, polish and replicate the physical materials are transformed into digital brushes and strokes on the software platform. From the digital humanities perspective, the digital sculpting techniques inherit and challenge the very definition of sculpture or sculpting. If the body scheme and the motion of sculpting are captured, the ontological/phenomenological reflections towards the virtual/tangible heritage objects also lead to the intriguing dialogues between technology and philosophy.

Digital sculpting, inspired by the traditional sculpting methods, cleans up the raw data collected from the multiple sources in the heritage data collection workflow. The noise reduction process, for example, assists in cleaning up the modern facilities that do not belong to the original heritage in the point cloud data, such as monitoring devices or fences onsite. The 3D-printing techniques also apply to the visualization of the damaged or lost parts from the cultural objects. Compared to the traditional sculpting, digital techniques enable data collections from the authentic objects, analyze the complex forms of the whole or damaged parts, and replicate them in the virtual world. The earlier digitization project led by the Virtual World Heritage Laboratory (http://www.vwhl.org, 2009–2013) marks the milestone of utilizing optical imaging techniques to compile the 3D models from the sculptures. The project focuses on the complexity of famous sculptures and strives to recollect the "neglected area of the digital humanities" and the cultural significance of the selected sculptures.

Traditional conservation principles such as authenticity, reversibility, and non-invasiveness apply to the digital heritage workflow as well. Looking back to the conventional methods towards the wooden deities sculptures, we can get the sense of how dissembling and photo-documentation still apply in the process. The ancient records of restoration reveal themselves by finding the carved texts or documents sealed inside the sculptures. When we utilize the optical technologies (CT, MRI, Inferred and X-Ray scanning) to diagnose the same cultural objects, the goals remain the same. Optical imaging assists to achieve the non-invasive principle and the reversibility enable the following researchers to track down the possible issues in the future.

2.1 Challenges of Digital Documentation for Cave-Temple Complexes in China

The quintessential workflow of the digital documentation for heritage sites in China is as follows: the multi-stations laser scanned data and photogrammetry results are integrated to get the accurate topology and rich textures of the site and objects; GIS and satellite photos are further used to monitor the changes of terrain and earthwork. The seemingly straightforward workflow still confronts unexpected challenges while working at the site. In the case of Cave Temples, for example, we need to find solutions to ensure the stability and accessibility of power supply for the equipment and lighting to work smoothly at the site. The noninvasive lighting equipment, as the significant factor for the documentation in the caves, also contributes to the success of the project. After the point cloud data is generated and exported as the polygonal model, digital sculpting assists with the polishing of the model and fix the holes of the model (usually at the back of the deity, or the conjunction between the Halo and the cave).

Fang He (Fig. 1), the Beijing-based practitioner in the field, dedicates his sculpting and storytelling expertise to the site of Maijishan Cave-Temple Complex. Like other peers, Fang utilizes the heritage imaging and filmmaking to depict the aesthetics of the deities, caves, and niches. Proposed to Palace Museum of Beijing to initiate the Maijishan Maijishan Cave-Temple Complex documentations back in early 2009, Fang's project set the milestone of digital heritage imaging in China. Marker-free optical scanning (scan range among 30–40 cm^2) was developed by the Beijing-based company to fulfill the needs for cave and clay deity scanning (average height of the deities between 80 and 150 cm). Laser scanning data and photo documentation provide references to rebuilding the clay-sculpted deities and scene, then transform the caves and deities into VR film. Full view of the Maijisha Cave-Temple Complex is accomplished by 3d modeling, and the reference photos are obtained by climbing to the mountaintop nearby to get the accurate shots (Fig. 2).

Fig. 1 Mr. Fang He (with the spectacle at the left) and the crew to scan and document the deities at Majishan

Challenges of the Maijishan digital documentation not only come from the technical aspects but also the natural environment and human activities. In the 1980s, due to the usage of shotcrete to reinforce the cliff from collapsing, the Maijishan World Heritage Site got affected; The narrow boardwalks along the caves on the cliff make the caves and niches even more unreachable.[1] Back then the East cliff was open to the public, while admission fee was charged to enter the West cliff. As Fang recalled, "When getting into the cave, the excrements and scratches from the birds were all over the clay sculpture." After arriving at the cave, further challenges come from color management (e.g., check card, white balance…, etc.). For unifying the color temperature throughout the shooting, Fang needed to manually adjust the white balance of the camera multiple times throughout the day, utilized color check card in the shots for the reference of color correction, adapted to the changes of color temperature due to the heat caused by the lights…, etc. The ever-changing weather in the mountain brings uncertainty for the color temperature and lighting. Then there are obstacles deployed at the entrance of the cave, and the security devices (e.g., surveillance cameras, power supply, … etc.), steel cages are to prevent theft and vandalism. The entrance of the caves and niches

[1]UNESCO World Heritage Convention. Maijishan Scenic Spots. https://whc.unesco.org/en/tentativelists/1631/.

Fig. 2 Majishan VR film opening sequence and the infographics of the cave-temple complex

are set up with wires and gears, which deter audiences from getting closer. These contemporary facilities need to remove during the noise reduction process or digital sculpting process to get closer to the authentic look (Figs. 3 and 4).

2.2 *Overseas Heritage of China and Digital Restoration*

One of the most significant motivations of digital technology for Chinese cultural heritage is the digital restoration of overseas cultural objects. Theft, vandalism, and

Fig. 3 Laser scanned deity and wireframe view of the Majishan cave-temple complex

Fig. 4 Deities at the temples of Kyoto and Nara by digital sculpting

demolishment make the field research tremendously difficult at the heritage sites. Private collectors make it even harder to get the missing parts back to where they belong. Some of the stolen cultural objects become overseas collections in museums and galleries, and those objects begin the return-home trip through digital documentation and restoration projects. Successful projects of overseas heritage restoration rely on joint efforts of multi-institution, cross-continent collaborations participated by interdisciplinary practitioners, such as the digital restoration projects of Xiangtanshan Grotto and Tianlongshan Grotto. Through field research and digital heritage imaging, the feasible module of interdisciplinary cultural heritage research can further expand to other world heritage sites in China.

2.3 Working Progress of Cyber-Archiving Dazu Rock Carvings

The earlier study of the author since 2011 establishes the research interests towards the religious deities and gradually leads to the full focus to the religious heritage sites in China. Karma Mandala—the wooden deities deployed in the Lecture Hall of To-Ji Temple in Kyoto inspires the author's interests to further investigate the relationships between the sculptures, mandala, the structure of the site, and the civil engineering of the ancient Kyoto.[2] The author further documents the private collection of deities, narrative relief and objects with Gandhara style in Hong Kong (Figs. 5 and 6)

The 2016 field research to the Dazu Rock Carvings marks another crucial stage in the author's academic work. This World Heritage Site inherits the rock carving styles from the caves of Northern China, meanwhile developed its unique look to represent the diversity of this cave temple complex. During the research period, Dazu Rock Carvings Institute grants the permission and the supports for the author to get access to the chosen caves. The Dazu studies continue to inspire the author's research focus at southern China and further, expand to the surrounding areas of Sichuan. The author then investigates and documents the various sites of Sichuan Province in China—Big Budda Cave (Fig. 7) of Huang Ze Temple, Lotus Cave and Da Yun Cave at the Thousand-Buddha Cliff, the Potalaka Bodhisattva Avalokiteśvara (Fig. 8) with relaxation gesture at the Vairocana Cave, and Dazu Rock Carvings. The documentation includes the Guanyuang area (North Sichuan) as well as Anyue to Dazu (East Sichuan).

The Cave-temple complexes in Dazu, Guanyuang, and Anyue are diverse regarding terrains, weather, and forms. Yuanjue Cave at the Dazu Rock Carvings, for example, is easy to walk. The single, natural light source coming from the rectangle hole on top of the entrance makes it hard to see the whole cave clearly at first sight. Human eyes need to digest to the dark environment for a while, then the twelve deities along the cave start to get visible; Da Yun Cave and other niches at the Thousand-Buddha Cliff in Guanyuang, are the opposite. Caves and niches of Thousand-Buddha Cliff

[2] P.281, Bogel, Cynthea J. With a Single Glance.

Fig. 5 Photogrammetry documentation of Gandhāra-style, carved grey schist Shakyamuni, Bodhisattva (gilt), Standing Maitreya and narrative relief

are facing the open view of the Jialing River, and the sunlight gets in the cave directly during the day. The challenge within the Thousand-Buddha Cliff in Guanyuang is the accessibility: The majority of the caves is situated meters above the ground level. Without the scaffolding outside, the only way to get in and document the caves is by climbing up the narrow boardwalks along the cliff which only allows one man to pass each time. Regarding the accessibility for digital heritage imaging, different caves do have diverse challenges to overcome.

Guanyang, as the gateway to enter Sichuan from the North, also becomes the path to inherit the deity carving style and the cave forms of Northern China. The Da Yun Cave of Thousand-Buddha Cliff and the Big Buddha Cave in the Huang Ze Temple mark the clear evidence of the cave carving style from the late Tang Dynasty. On the other hand, Potalaka Bodhisattva Avalokiteśvara at the Vairocana Cave of Anyue symbolizes the transformation of styles in the Song Dynasty: the slim feminine appearance、relaxation posture、accessary、and the tender expression looking down from the lotus seat…, etc. The Water-Moon form is evident on this deity, and witnesses the transformation of the visual style of the Bodhisattva in China.

Fig. 6 Digital documentation of the deities (Bodhisattva, Ksitigarbha, and Peacock Radiant Wisdom King) at Dazu Rock Carvings in Sichuan Province, China

3 Innovative Technologies for Narrative and Messaging

The wanton damages and destructions of the World Heritage Sites ironically become the inspirations for the innovative technology: Standing Buddha statue of Bamiyan that was destroyed by the Taliban in 2002 signifies the massive loss of joint assets for mankind. The site and object used to be recorded in the sutras to symbolize the fertility and activeness of the area. To restore the cultural memories, innovative technologies are applied in the research of RWTH Aachen Center in Germany. Professor Michael Jansen, the director of the center, addresses the significance of adopting innovative techniques in the process. Specifically, he discusses the utilization of the archive images as the references of the 3D model reconstruction, the comparison of before and after the incident, and the Caves Automatic Virtual Environment (CAVE) for VR display. Besides the techniques adopted by RWTH, projection mapping, panoramic site view, 360-degree dome shader are also frequently utilized to disseminate the messages of heritage conservation.

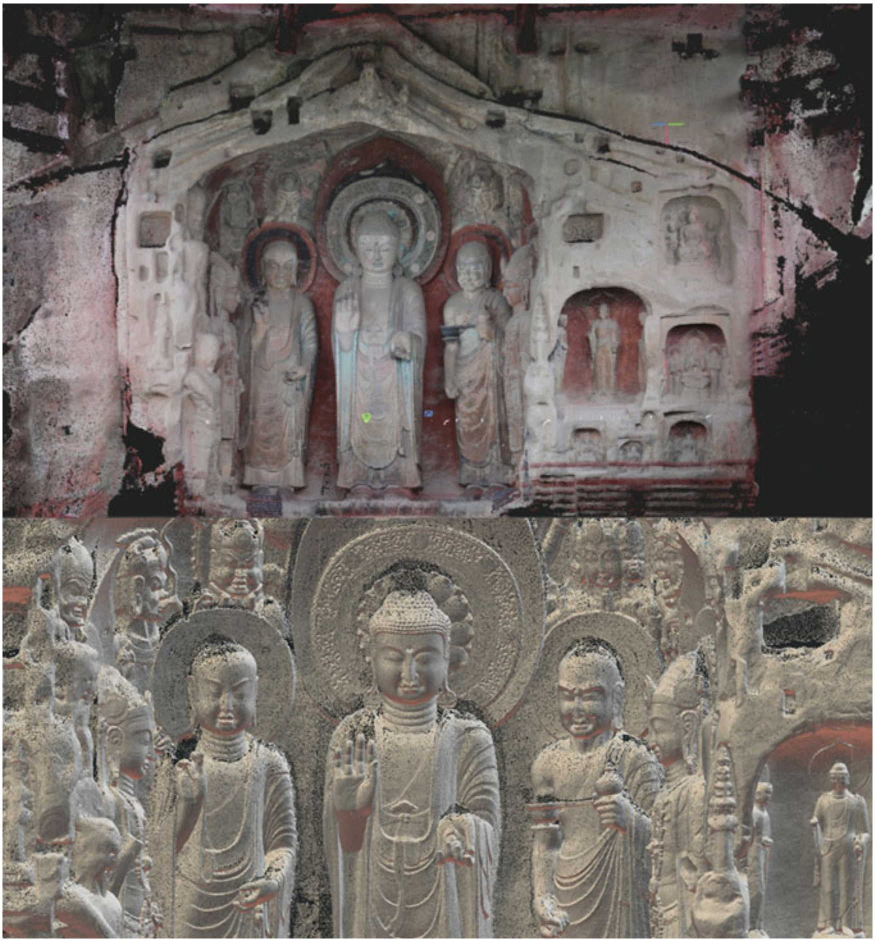

Fig. 7 Digital documentation of the Big Buddha Cave at Huang Ze Temple (Texture and point cloud view)

3.1 Digital Narrative as the Metamorphosis of the Sutra

The Buddhist art reflects the ideas of the sutras, and are often treated as the metamorphosis from the Buddhism texts—stories of Jataka to depict the before life, sutras as the metaphors to symbolize the present life, and the Pure Land to represent the afterlife, … etc. To be free from the reincarnation and karma, the sentient beings need to see through the impermanent nature of life and strive to the path of enlightenment. The iconography with rich contexts is frequently deployed in the site as the mural paintings, sculptures (Fig. 9), and site structures. The mudras, postures, accessories, dharma, seed syllables and mandala compose the cosmic universe for the sentient

Fig. 8 Digital documentation of the Potalaka Bodhisattva Avalokiteśvara at the Vairocana Cave

beings. The Mikaeri Amida (Amitabha Looking Back) deity at Zenrin-Ji in Kyoto for example, "looks back to the sentient beings with mercy, and interprets the attitudes of thinking back on his position, waiting for the people behind and leading them to the way of salvation together."[3] (Fig. 10).

For the author's research in the Dazu Rock Carvings, the documentation of the Peacock Radiant Wisdom Kings at Shimenshan (Cave No.8) (Fig. 11) preserves the tender look of the deity in the digital form. Point cloud data and polygonal model are converted for comparison with the actual cave. The web-based viewer enables the spectators to look into the cave, observe the low relief storytelling, and navigate to the back of the halo to see the structure of the deity. The earlier results of the author's documentation towards the Gandhara-style Bodhisattva in the 2nd Century (Fig. 12), and the Counting Beads Avalokiteśvara (aka Charming Avalokiteśvara) at the niche No. 125 (Fig. 13) of Dazu Rock Carvings reveals the distinct look of Bodhisattva in male and female forms. The other unique example is the niche of Avalokite uniq and Ksitigarbha (No. 253) where the two deities appear together (Fig. 14). The phenomenon of more than ten similar niches like this spread at Beishan area reflects the mundane wishes for prosperity, auspiciousness and the Pure Land. The web-based viewer also allows the users to embed, juxtapose, and compare the digital visualizations into their webpages. In terms of reinterpretation, the privilege and freedom of the digital narrative on the web platform emerge.

[3]Introduction of Mikaei Amida at Eikando.

Fig. 9 Shakyamuni deity carved grey schist of the ancient region of Gandhara circa 2nd century. Cyber-archive by Photogrammetry

Fig. 10 The Mikaeri Amida (Amitabha Looking Back) deity at Zenrin-Ji in Kyoto

Fig. 11 Point cloud view (L) and low-polygonal view of Peacock Radiant Wisdom King at Cave No.8 in Shemenshan, Dazu Rock Carvings

Fig. 12 Gilt grey schist Bodhisattva from the ancient region of Gandhara circa 2nd—3rd Century, H 15.5 cm. Cyber Archive by photogrammetry

3.2 Digital Humanities in Cultural Heritage Conservation

To raise humanity care towards the mutual assets of the human being, multi-national collaborations on optical imaging strive to bring back the overseas legacy to where they belong: Xiantangshan grotto, Shuilu'an, … etc. Earlier success on the digital documentation and 3D visualization of Shuilu'an Temple clay sculptures mark the efforts between North-Western University and Beijing University. The Xiantangshan project further demonstrates the humanistic spirit in the digital realm—assists the overseas heritage in returning to where it belongs on the digital platform, and further enhance the awareness of heritage protection. On the other hand, the crowdsourcing projects such as Project Mossul strives to bring back the collective memories of demolished heritage sites. The joint efforts of the image donors assist in restoring

Fig. 13 Expression, posture and full view of the niche No.125 Charming Avalokteśvara deity. 92 cm in height. Point cloud visualization

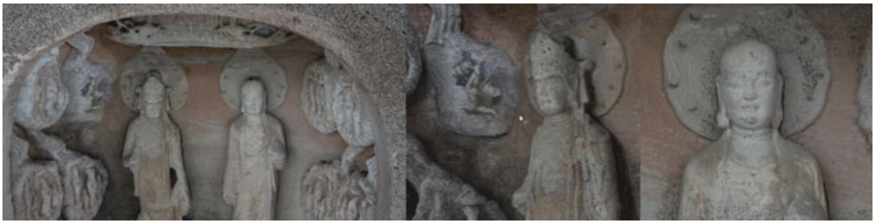

Fig. 14 Niche No. 253 Bodhisattva and Ksitigarbha deities. Point cloud visualization

the heritage objects and sites in the digital realm. The once destroyed humanistic spirit gets to resurrect in the digital realm.

4 Digital Conservation and Research Capacity Environment in China

Regarding the academia in China, institutions carry the missions to cultivate the next generation of conservators and the research for heritage studies. Digital heritage technologies enable students and researchers to get access to remote sites from the digital platform. State key laboratories, national institutions, and universities lead to establishing the database through photogrammetry, laser scanning, UAV survey, and GIS mapping. Equipped with practical experiences in the field research and large-scale projects, those institutions play the key roles to cultivate and raise awareness of heritage preservation. "With the joint efforts of academia, governmental organizations and industry, the finalized projects can transform into education plans. These real-world projects provide insights and practice to enhance students' awareness of cultural heritage and global issues."[4]

Through the teaching position at the New York University Shanghai, the author participates in the international platform of research capacity environment that provides the collaborations between the community, industry, and GLAM (Gallery, Library, Academia, Museum) institutions. Workshops, keynote presentations, and field researches are conducted in China and overseas to broaden students' visions towards digital heritage imaging and application. The public lectures at the local libraries of Shanghai and the industry connections of the digital heritage imaging companies further benefit the communities in China.

4.1 Mellon Buddhist Workshop at the Sackler Gallery

The author participated in the Graduate Research Workshop for the Study of Buddhist Art in Asia (https://wp.nyu.edu/buddhistartworkshop/), jointly organized by the Institute of Fine Arts at NYU, Freer Gallery of Art and Arthur M. Sackler Gallery in Washington D.C. The workshop included the visions from the art historians, curators, conservators, and digital heritage imaging. Through the week-long period, students get to visit multiple exhibitions ("Encountering the Buddha: Art and Practice Across Asia," "Buddhist Art In Japan: In the Shadow of an Apocalypse," "Secrets of the Lacquer Buddha") related to Buddhist artworks, and get the introductions of the contents by the curators, conservators and scholars onsite.

The author presented the research progress at the World Heritage Sites in China and further demonstrated the digital sculpting techniques for restoration. The Cosmic Buddha scanning and digitization exhibition of the FreerSackler Gallery became the main point of the discussion. Through the open data of the Digitization Program Office (DPO) of Smithsonian Institution, the 3D model of the Cosmic Buddha can be downloaded and utilized to examine the hand-rubbing process and texture extraction.

[4] Wu Wei, Chen. "Crafting for spirituality - a pedagogic project for digital heritage".

The 3D viewer provided by the DPO also allowed the students to observe the details of the cultural objects. The curator of the Cosmic Buddha exhibition further utilized the digital model to add annotations from the curatorial review, art historian inputs, and conservation records to augment the viewer experiences.

4.2 Dun Huang Study Trip for Field Research

The author joined with colleagues from the field of Global China Studies, Humanities and Visual Arts to lead the study trip for field research of Mogao Grottoes in the Dunhuang City of Gansu Province, China. Through the literature reviews and digital caves navigations on the Digital Dunhuang website led by the colleague of Global China Studies, students get familiar with the historical contexts, forms of the caves, and sculpture styles from the different period within one thousand years of history of the site. The author instructed the students to document the outlooks of the site and digitally and assists the students to compile the imageries into point cloud visualizations. The preliminary results of pint cloud visualizations can be viewed from the web-based platform, and further compiled into VR view, polygonal models for further applications.

5 The Future Perspectives of Digital Heritage

The Chinese practitioners of the last century investigated and preserved fragile cultural properties under the crossfire of war zones and hostile areas, such as Mr. Liang Sicheng and Ms. Lin Huiyin during World War II. The efforts that they dedicated towards the hand-drawn documentations, texts, and photographs towards the numerous sites and objects, still inspire the Chinese practitioners nowadays. As the student of Mr. Liang Sicheng and also the award-winning architect for his revitalization project of Beijing Ju'er Hutong in 1993, Mr. Wu Liang Yong expressed his idea of "genius loci in general" between culture, history and living condition:

> The culture of architecture comes from a local accumulation of history. It manifests itself among the built forms and in day-to-day living, exerting a voiceless influence on the experience and behavior of the inhabitants. In a sense, it is the soul of our cities, towns, and villages.[5]

Nowadays, conservations techniques enable the practitioners to observe and research up-close on the digital platform, and the practitioners' journeys are still on the road. With the daily evolving of innovative technologies, practitioners in the field are obliged to understand the trends, adapt the suitable techniques and apply to the collection, visualization, dissemination and education for the digital heritage contents.

[5] Wu Wei, Chen. "Crafting for spirituality - a pedagogic project for digital heritage".

5.1 Integrations and Conservations of the Digitized Heritage Data

In the online exhibition (neonsigns.hk) held by M + Museum in Hong Kong, the collections of oversized neons signs which inherit the memories of the city are exhibited online along with the photos, videos, and crowdsourcing page. The juxtaposition of neon signs design archives, interviews of the hand-craft masters, collages of Hong Kong films with neon signs scenes composes the intertextuality between the analog and digital data. The online exhibition is still live, and able to bring the concepts of sustainability to the digital realm.

Collected data from the heritage sites and objects can be further transformed into digital narrations and artworks for exhibitions and educational materials, yet the tasks of maintaining and restoring the analog/digital heritage data challenge the next generation of conservators. Besides the understanding of the materiality and hands-on restoration, the knowledge to conserve the digital heritage contents and revitalize the heritage data remains the goals for perfection. Especially when A.I., machine learning, and mixed reality are frequently utilized in the heritage data application, the understanding of the technology assists to restore and maintain the functioning of the contents. For the analog data or earlier digital data which is collected or generated by out-dated techniques, the conservation of those contents is equally important as the restoration work for the sites and objects.

5.2 Envision the Digital Heritage Studies Over Religious Sites of Asia

The author's on-going project focuses on the abundant, exquisite rock carvings and cave temples widely spread in China. The locations of the cave temple complexes indicate the historical bunds of the Silk Road and document the intercultural activities along the routes. To further investigate the cross-influences and diversity, it is obliged to study the religious sites over Asia—iconography, art history, conservation records, development of digital heritage contents, … etc. Meanwhile, the intangible heritage around the sites including the literature works, rituals, and craft work, also become the unseparated parts of the tangible site. Through the paths to the existed civilization, the resonance of wisdom unfolds itself on the road.

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References

1. Bogel, Cynthea J. With a Single Glance: Buddhist Icons and Early Mikkyō Vision. University of Washington Press (2010), 278–337.
2. Bringing the Ancient Theater of the Silk Road to Los Angeles. East West Bank. https://www.eastwestbank.com/ReachFurther/News/Article/Bringing-the-Ancient-Theater-of-the-Silk-Road-to-Los-Angeles.
3. Cultural Heritage Conservation in Pakistan: Conversation with Dr Richard A. Engelhardt. https://www.youtube.com/watch?v=BWYUO0nciss.
4. Dazu Rock Carvings Institute. Dazu Rock Carvings. Chongqing Publishing Group. Chongqing, China (2010), 36–51.
5. Gandhara - Das buddhistische Erbe Pakistans. https://www.youtube.com/watch?v=Su2zCRIMFv8.
6. Introduction of Mikaei Amida. http://www.eikando.or.jp/English/mikaeri_amida_e.html.
7. Introducing Open Access at The Met. https://www.metmuseum.org/blogs/digital-underground/2017/open-access-at-the-met.
8. Jansen, Michael. Virtual reality for a physical reconstruction? The Bamiyan Buddhas in Afghanistan. Archaeologising Heritage. Panel 3: The Virtualisation of Archaeological Heritage. International Workshop on Angkor/ Cambodia. Heidelberg, Germany (2010).
9. Kibi Conservation Studio for Cultural Objects. http://www.kibibunn.info/.
10. Liang Yong, Wu. LOOKING FORWARD TO ARCHITECTURE OF THE NEW MILLENNIUM. http://newurbanquestion.ifou.org/proceedings/1%20The%20New%20Urban%20Question/Wu%20Liangyong.pdf.
11. Opening ceremony of The Cave Temples of Dunhuang, Buddhist Art on China's Silk Road. http://www.yucolab.com/news/108-opening-ceremony-of-the-at-the-j-paul-getty-museum-la.html#.V_R4u2V6yGk.
12. Park, David. Art of Merit: Studies in Buddhist Art and Its Conservation. Wappingers Falls: Antique Collectors Club (2014), 362–394.
13. The Digital Sculpture Project. Virtual World Heritage Laboratory. http://www.digitalsculpture.org.
14. The International Dunhuang Project. http://idp.bl.uk/idp.a4d.
15. The Vajracchedika-prajna-paramita Sutra. http://big5.xuefo.net/nr/article1/7446.html.
16. TNM and TOPPAN Museum Theater. http://www.toppan-vr.jp/mt/.
17. TNM & TOPPAN MT. VR作品「三蔵法師の十一面観音」(VR work of Xuanzang's eleven-faced Avalokiteshvara). https://youtu.be/rQvhzuzZGJQ.
18. TOPPAN VR. http://www.toppan-vr.jp/bunka/.
19. UNESCO World Heritage Convention. Majijshan Scenic Spots. http://whc.unesco.org/en/tentativelists/1631/.
20. Wu Wei, Chen. "Crafting for spirituality - a pedagogic project for digital heritage", SIGGRAPH ASIA 2016 Crafting Spirituality: A Pedagogic Project for Digital heritage: Digital Sculpting, Projection Mapping and Beyond on - SA '16, 2016
21. Wuzhi, Yi and Xiangui, Lang. Techniques for Reinforcement of the Maijishan Grottoes. Conservation of Ancient Sites on the Silk Road conference proceedings, The Getty Conservation Institute, 187–193.
22. 三维技术再现紫禁城 虚拟世界中建起太和殿 (3D technology to represent the Forbidden City and establish the Tai He Dian in the virtual world). http://news.sina.com.cn/c/2002–11-29/1231823365.html?from=wap.
23. 日本鉴真坐像接受3D测量将数字化保留文物原貌 (3D documentation of Japanese deity to preserve the look of cultural relics by digitization). http://www.pusa123.com/pusa/news/fo/201231261.shtml.
24. 故宮Open Data專區 (National Palace Museum Open Data).http://theme.npm.edu.tw/opendata/.
25. Chongqing Dazu Rock Carvings Museum. Dazu Rcok Carvings Research, Vol.4. China Federation of Literary and Art Circles Publishing House. Beijing, China:2002, 358–377.

26. 凸版印刷、TBSと共同でマチュピチュ遺跡全域をバーチャルリアリティ映像化、国立科学博物館『インカ帝国展　マチュピチュ「発見」100年』で3月10日より初公開~遺跡全域を三次元計測し、空中都市マチュピチュを精緻に再現~. http://www.toppan.co.jp/news/2012/03/newsrelease1330.html.
27. 凸版印刷、興福寺「三重塔」内を彩色再現~ヘッドマウントディスプレイで塔内を360度鑑賞するVRコンテンツを製作、「興福寺国宝特春公開2016 五重塔・三重塔」にて初公開~. http://www.toppan.co.jp/news/2016/08/newsrelease160823.html.
28. トッパンVR関連ニュースリリース. http://www.toppan-vr.jp/bunka/vr/release.shtml.
29. トッパンVRコンテンツラインナップ. http://www.toppan-vr.jp/bunka/vr/contents.shtml.

A Multivariate Use of Digital Cultural Heritage: Online Resources for Archaeology in the DBAS—MUSINT Websites (University of Florence, Italy)

Maria Emanuela Alberti, Cristian Faralli and Anna Margherita Jasink

Abstract Since many years the Aegean Laboratory of the SAGAS Department of the University of Florence, Italy, is building two flexible containers of online resources, the Data Bases about Aegean Subjects (http://dbas.sciant.unifi.it/) and the Aegean Museum (http://www.aegean-museum.it/) websites. The contents are related to the archaeology of the Bronze Age Aegean (Greece, 3000–1000 BCE). Together, they are a good example of the multiple potential of Digital Cultural Heritage. Their various parts aim to different targets and audiences, including tools for scholarly research, teaching materials for University classes, and dissemination and interaction contents for a wider public. An overview of the websites is presented here, to stress the connection between the various levels and especially between academic contents and wider dissemination. The main aim of the Aegean Laboratory (@egean-Lab) is indeed to provide a way to explore various aspects of the Bronze Age Aegean that work for both an academic user and a young pupil. In addition, the cooperation between University and Museums offers access to various collections that otherwise would not be available for the wider public. All this is something that only the Digital Cultural Heritage can ensure. The present paper focuses on the relevant elements of the two websites: the presence of specialized Data Bases, that are therefore freely searchable from anyone, whilst used at the same time for scholarly purposes; 3D representations of the archaeological materials, embedded in the Data Bases and explorable; study tools of various types, from University lessons to didactic panels; contents aimed at the younger visitors, with attractive drawings, reconstructions, videos, games and an interactive tale to complete. All this is the result of the cooperation of various institutions and of a wide range of specialists, from archaeologists to architects and designers to computer scientists and primary school teachers. In the

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DBAS—Databases about Aegean Subjects, databases span from the Cretan Hieroglyphic Seals and Aegean Cushion Seals to the Ahhiyawa Question and Mycenaeans in the Amarnian Egypt, passing by the Textile Work Areas in Bronze Age Crete (the latter still under construction). In the two main sections of the Aegean Museum website, MUSINT I and II, a larger range of the Digital Cultural Heritage potentials are exploited. MUSINT I gathers in a virtual interactive museum the Aegean materials from various Museums in Tuscany, combining 3D representations of the objects, technical reports and databases. Somehow similar is MUSINT II, that presents in various ways some particular findings from Minoan Crete, the sealings from Haghia Triada. Those stored in Italy are searchable through a database that links once again the scientific records of the Museums of Florence and Rome with 3D representation and scholarly comments. The didactic and interactive part is particularly developed here. The paper will present in detail some databases and an interactive tale that are presently being implemented, to foster the discussion on methodological issues and best practices. Though the Aegean Museum is still under development, it can provide a good example of the Digital Cultural Heritage potential in combining various kinds of tools, expertise, builders and users, bringing together the specialized scholar and the curious pupil, research work and dissemination, and creating a substantial impact in the way we study and perceive antiquity.

Keywords Databases · Interactive museums · Story-telling · Bronze Age Crete · Archaeology

1 Introduction

DBAS—@*egeanLab* (http://dbas.sciant.unifi.it/) starts in 2005 as the web-portal of the Laboratory of Aegean Civilisations of the University of Florence.[1] With the name of ‘Data Bases about Aegean Subjects’, it was initially created as an online resource containing tools for scientific consultation, such as highly specialized Databases [14, 15, 16]. Along the years it developed in something more complex and includes now a wider range of contents, especially digitalization of museum collections and excavation materials, with scientific and educational aim [17, 19–21]. Consequently, we decided to maintain the same acronym while changing the whole name in ‘Digital Bank on Aegean Subjects’ (Fig. 1).

Actually, the visitor may also start from a second portal, **MUSINT** (http://www.aegean-museum.it/) (Fig. 2), especially devoted to create interactive Aegean museums, where objects coming from different sites and collections are often presented as 3/dimensional models.

[1] M. E. Alberti and A. M. Jasink contributed to the arguments, the structure and the organization of the present article. The first author wrote paragraphs 3. 4. 5; the second wrote paragraphs 1. 2a. 5; C. Faralli wrote 2b and the other digital contents. The authors warmly thank Giulia Dionisio for her help in the editing process.

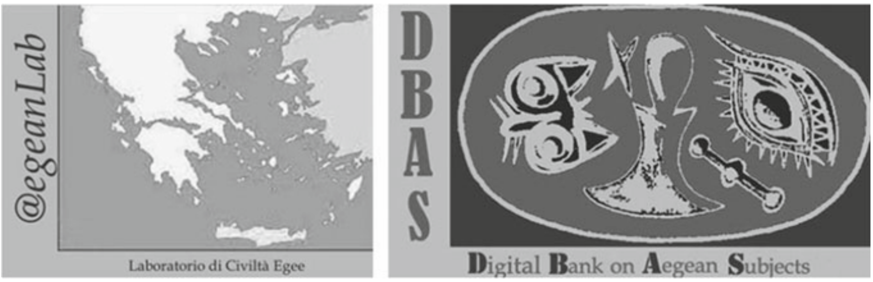

Fig. 1 The Homepage logotype of DBAS—@egeanLab

Fig. 2 The Homepage of MUSINT

Both these containers are good examples of the multiple potential of Digital Cultural Heritage. The on-line resources created by DBAS-MUSINT about the societies of the Bronze Age Greece, Crete and Aegean in general (3000–1000 BCE/from the third to the beginning of the first millennium BCE) open a field of research, but the specialists of Bronze Age Aegean, though largely using the new technologies, remained substantially out of the main stream of the discussion. Actually, despite the debate on the complex link between digitization and archaeology/ancient history is presently quite extended, involving various branches of the antiquities, the Aegean field is only marginally affected.

The main aim of DBAS-MUSINT is to present together and connect resources for academic research and resources for a wider public, covering educational contents. Research, didactics and interaction are the key-words. The sites actually include tools for scholarly research, teaching materials for University classes, and dissemination and interaction contents for a wider public and school pupils [18]. Most of the resources are conceived for an active use by the audience: interrogating databases, performing games, answering questions and choosing pathways in the tale.

In addition, they illustrate in the best way how University and Museums can cooperate within the Digital Cultural Heritage. They provide various online resources

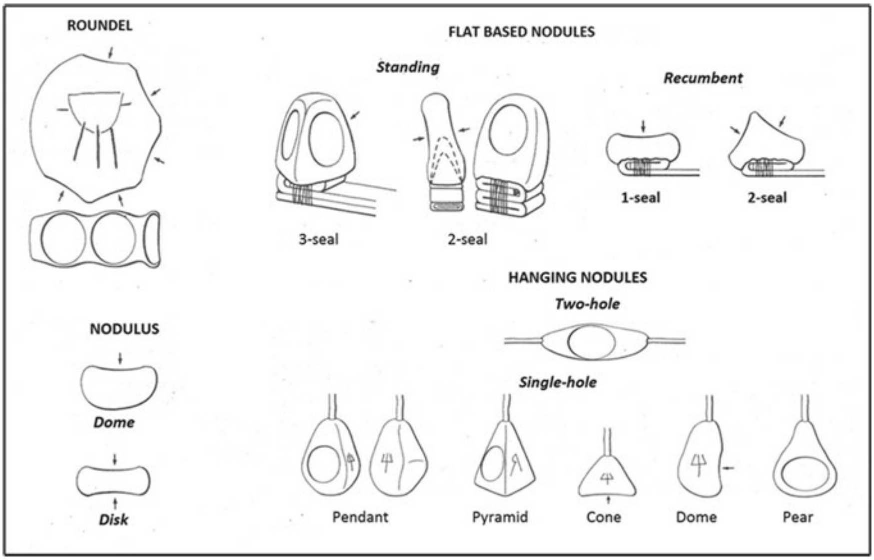

Fig. 3 *Cretulae* from Haghia Triada and other Minoan sites

to explore contextually the materials of various Museums that could not be seen together otherwise.

In this paper we decided to focus on three sections chosen from the two websites, that are in our opinion good examples as for methodology and best practice. The first is a database on the *cretulae* from the Villa of Haghia Triada (Fig. 3), that puts together all these small objects discovered in this site.

This database is included in DBAS (in the English version) and in MUSINT II (in both English and Italian versions). The second is a database on textile work areas which will soon appear on DBAS. The third is an interactive story-telling concerning the reconstruction of a 'special' day and events occurred at HaghiaTriada, and is included in MUSINT II.

2 DB-*HTS* (Acronym for Database on Haghia Triada Sealings)

DB-*HTS* is the new database on the DBAS web-portal and improves considerably the study of the Haghia Triada sealed documents: it concerns not only the *cretulae* collected in two Italian Museums, the Archaeological Museum of Florence and the Pigorini Museum of Rome, where many objects have been transferred from Haghia Triada and Phaistos during the excavations of the Italian Expeditions in Crete at the beginning of the twentieth century, but also the whole of the *cretulae* which remained

No. Cat. A	117	SEAL IMPRESSION
No. CMS II,6	117	
Occurrences	38	
Museum	HMs 461/1-24, 462/1-6, 463/1-2. 579 MAF 94759. 94760 RMP 71964. 71975. 71966	
No. AT / Levi	19	
No. Cat. B	81, 101, 110	
Shape	Single-hole hanging nodule	18 *pendant*, 1 *cone*
Motif	Animal - bird	A standing water bird to left, surrounded by vegetal motifs.
Seal's shape	Convex lentoid soft stone pierced along the vertical axis	
Inscriptions	*AB 81* KU (Wa 1471-1622) *AB 77* KA (Wa 1322-1470)	HMs 461/1-24, 462/1-6 (Wa 1562-1591), 463/2 (Wa 1593),579 (Wa 1614), MAF 94759. 94760 (Wa 1557-1558), RMP 71964-71966 (Wa 1559-1561) HMs 463/1(Wa 1422)
Notes	The engraved symbol AB 81 *KU* presents several "variants", some of which could been interpreted as different signs rather than variants. The impression is of the same hand as No. 73 (monkey) and No. 132 (fish)	

Fig. 4 Example of a Cat. A number

in Crete and may be found in the Heraklion Museum.[2] This is a unique possibility for scholars to see all these materials together and we will illustrate it better in a while.

2.1 *The Content*

The *cretulae* are one of the main Aegean administrative systems used by the Minoan Palaces. They are small clay nodules bearing the impression of a seal and, in most cases, an inscribed sign of the Cretan script, the Linear A.

We have gathered in two correlated catalogues all the information concerning the various aspects of these objects. The 175 numbers of **Cat. A** (Nrs. 1-175) focus each one on a different seal (Fig. 4) which may be impressed on different *cretulae*,[3] but give further information, many of which we may find also in **Cat. B**. This latter Catalogue is based on the carved symbols[4]: the single numbers (Nrs. 1-179) concern the whole of the *cretulae* which have the same sign and the same impressed seal (Fig. 5).

As to the *cretulae* discussed in MUSINT II (i.e. the sealed documents kept in the two Italian Museums) we have the opportunity to present not only the images kindly offered by ARACHNE/CMS, but also 3/D models that our team created with laser scanner acquisition and uploaded on the Sketchfab platform (see next paragraph on technical devices).

[2]The references on this subject are extremely extensive. We limit quotations to some of the most inclusive works on *cretulae* and for an exhaustive bibliography we refer to the work in press by Montecchi [33].

[3]The text of reference is the Corpus der Minoischen und Mykenischen Siegel, Band II, Teil 6 [34]; for a revised version of the whole Corpus, the website ARACHNE (http://arachne.uni-koeln.de/), with a part devoted to the Aegean seals and sealings (http://arachne.uni-koeln.de/drupal/?q=it/node/271), is now available online.

[4]The point of reference for the signs incised on the *cretulae* remains GORILA 2 [12]. It is also important to consider the more recent work by Hallager [13] specifically devoted to the "roundel" shape, but with major references to the other sealed documents.

No. Cat. B	101	CARVED LINEAR A SIGN
No. GORILA	Wa 1557-1592	
Linear AB sign(s)	*AB 81* KU	
Occurrences	35	
Scribe	Wa 90 (MAF, HMs 461/1-17) Wa 86 (RMP) Wa 91 (HMs 461/18-19. 21) Wa 84 (HMs 461/20) Wa 92 (HMs 462/1-6) Wa 93 (HMs 463/2)	
Shape	single-hole hanging nodule	
No. AT/Levi (HT)	HT 19	
Museums	MAF 94759. 94760; RMP 71964.71966.71965; HMS 461/1-24; HMS 462/1-6; HMs 463/2	
No. CMS II,6	117	
No. Cat. A	117	
Sealing motif	Animal - bird	A standing water bird to left, surrounded by vegetal motifs.
Notes	In GORILA 2 the cretula MAF 94759 is catalogued as "Firenze 3" and the MAF 94760 as "Firenze 4"; the cretula RMP 71964 as "Pigorini 2", the RMP 71966 as "Pigorini 18" and the RMP 71965 as "Pigorini 21".	

Fig. 5 Example of a Cat. B number

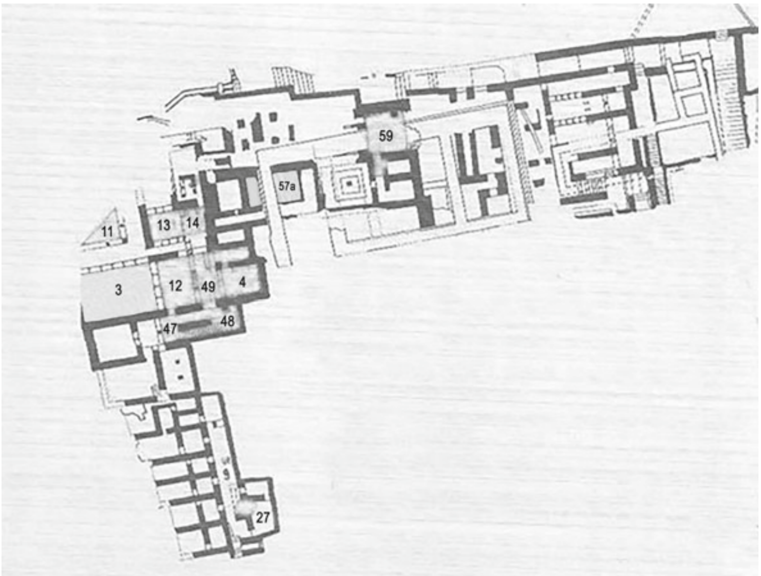

Fig. 6 The Villa of Haghia Triada

These objects were found in different parts of the Villa (Fig. 6). We shall limit to describe three areas where *cretulae* have been found, since the exact localization of the documents is still under discussion ([33], with exhaustive bibliography), apart from a very limited portion whose original position has been reconstructed:

(1) SW Quarter. This is the only area inside which an exact placing may be given: on the threshold or window-sill between room 27 and corridor 9, 45 dome *noduli*, without inscription but stamped by the same seal (Cat. A No. 20) have been found.

(2) NW Quarter. In this exclusive quarter various groups of *cretulae* have been found, but a reconstruction of their original location, partly at the first floor and partly at the ground floor, is difficult because the layout of the rooms was not clear since the beginning of the excavations. A more general differentiation has been made on the basis of the discovery of the objects on smaller distinguished areas: one of them includes rooms 4-49-12 and 47-48, where likely the objects had fallen down from above or slipped from near areas; a second area includes room 13 (the so-called 'stanza dei sigilli') and the adjacent corridor 50; a third area, not well distinguished from the previous one, includes porch 11.

(3) N Quarter. In the area of northern magazines, where the major group of Linear A tablets has been found, also some nodules and/or *noduli* have been discovered. The identification of a specific room (room 59) remains uncertain since the same structure of the room, mostly destroyed by the following construction of the Mycenaean *megaron*, is not clearly defined.

These Catalogues and the related Database represent the starting point to enter new and diversified routes by means of distinct but connected queries, which try to answer as many questions as possible. This relational database gives information about shape, motifs, inscriptions and so on of single objects; offers queries to correlate such information from both files of stamped and incised motifs, and gives also statistical data (percentages, recurrences, etc.). In this way, it allows extensive and overlapping cross-correlations that can lead to new interpretations of both seals and written signs. In the next paragraph the technical aspect will be briefly described.

2.2 Technical Devices

The first step of elaboration from these two distinct data sets, which differ from each other in some entries, is the creation of a table that gathers the information for all the items. Each string corresponds to a single object and is the union of the information from both the data sets/catalogues (seal impression and carved sign). Each object has been identified with a couple of identification numbers (IDs): the first represents the number of the objects inside each catalogue and the second represents the number of the catalogue itself. In this way, it is possible to make a query to identify only the information for this object from one or the other data set.

The second step is the creation of tables to be used to implement direct queries, or first-level queries. A table has been constructed for every search parameter. The tables relate the search parameter and the objects of the catalogues. Each parameter has been associated to a number and the iconographies have been associated to each object through this list of numbers (Fig. 7).

Fig. 7 Example of numbers associated to iconographic motifs

id	db1_icon_name_IT	db1_icon_name_EN
32	-	-
5	animali	animals
34	animali - animali marini	animals - sea animals
35	animali - animali marini - pesci, altro	animals - sea animals - fishes, others
37	animali - animali marini e insetti	animals - sea animals and insects
15	animali - insetti	animals - four-footed animals - insects
13	animali - pesci	animals - four-footed animals - fishes
6	animali - quadrupedi	animals - four-footed animals
8	animali - quadrupedi - bovini	animals - four-footed animals - bovines
11	animali - quadrupedi - cani	animals - four-footed animals - dogs
9	animali - quadrupedi - capridi	animals - four-footed animals - caprids
12	animali - quadrupedi - cavalli	animals - four-footed animals - horses
10	animali - quadrupedi - cervidi	animals - four-footed animals - cervids
7	animali - quadrupedi - leoni	animals - four-footed animals - lions
33	animali - quadrupedi - suini	animals - four-footed animals - boars
16	animali - scimmie	animals - four-footed animals - monkeys
14	animali - uccelli	animals - four-footed animals - birds
18	creature immaginarie	imaginary creatures
20	creature immaginarie - donna uccello	imaginary creatures - bird-woman
19	creature immaginarie - genio minoico	imaginary creatures - Minoan genuis
22	creature immaginarie - grifone	imaginary creatures - griffin
21	creature immaginarie - sfinge	imaginary creatures - sphinx
1	esseri umani	humans
3	esseri umani - figura femminile	humans - woman
2	esseri umani - figura maschile	humans - man

The example here is about iconography of the impressed seal: to the left, the structure of the table, and to the right the associated research form. As one can see, in the table each motif has a different number.

This is the basis for a further step.

The third step is the creation of correlation tables, to be used for the crossed queries or second-level queries. These tables allow the crossed correlation of data, so that multiple research options can be combined (Fig. 8).

In the correlation table each ID can appear various times, since it aims to allow all the possible variations of a certain element, or to combine different characteristics of the same object.

Particularly, the figure shows the correlations of the iconographies where information about their distribution among the objects in both catalogues may be obtained.

The general behaviour of the database is managed by the programming language. The suffix _IT or _EN to the table names allows the automatic selection of the language by PHP scripts (postprocessing hypertext protocol). This is one of the most used programming language and has been selected as the most suited interface with the SQL structure of the database.

Fig. 8 Example of correlation tables

id	ncat	tcat	nicon
1	1	1	3
2	1	1	29
3	2	1	29
4	2	1	3
5	3	1	3
6	3	1	29
7	4	1	3
8	4	1	29
9	5	1	3
10	5	1	29
11	6	1	3
12	6	1	29
13	7	1	2
14	7	1	29
15	8	1	2
16	8	1	3
17	8	1	29
18	9	1	3
19	9	1	2
20	9	1	29
21	10	1	2
22	10	1	3
23	10	1	29
24	11	1	2
25	11	1	29

Some data sheets embed link to interactive 3D images, coming from the platform SketchFab (https://sketchfab.com/). HTML/PHP code has been embedded into the web pages in order to retrieve information from SketchFab remote archives. Meanwhile SQL queries have been written to read information from SketchFab and some tables have been customized for this aim. The database has been connected to the 3D model in SketchFab to give flexibility to the content of the web pages, the carved signs and the seal impressions. SketchFab is perfectly inserted in the context of Musint II for the interactive experience it offers.

3 DB-TWC (Acronym for Textile Work Areas in Bronze Age Crete)

Other data bases have been already realised in DBAS and have been already presented in press. Some more are still under construction and we hope to implement the range of addressed topics in the future. Presently, another quite complex data base that is still in progress is the DBAS-*TWC*, on textile work areas of Bronze Age Crete. The aim of the work is to move a step further beyond current scholarship, that is mainly concerned with the technical details of tools and craftsmanship to reconstruct the actual textiles being produced then. This is a quite developed domain and our understanding of the Minoan textile techniques has considerably improved in the last decade [1–3, 6, 7, 9, 10, 22, 31, 36]. However, a comprehension of the wider organisation of textile production is still missing, as it is a reappraisal of the interconnections among various production cycles of the agricultural and domestic economies within their own setting.

One of the main obstacles is that the evidence is widespread throughout the many and dispersed sites of the island, that are investigated and published in a variety of ways and languages. The lack of uniformity is thus the main scientific issue. How can we compare things that are not homogeneous? That is why the data base has been created. It aims to provide an unified and homogeneous data set of the evidence related to textile activities from Bronze Age Crete, re-organising the information from a variety of publications and languages. The effort has been made to create a grid of indicators to be applied to every context taken into account.

Actually, one of the most important factor to be considered is that in a number of the relevant contexts indicators of various activities are found together: liquid processing, food processing and cooking, storage and textile production. Many tools are multi-purpose, other very specialised. This suggests a real mixed use of spaces in antiquity [3, 8, 11, 41]. The documented textile activities are only part of the productive processes carried on the examined work areas. One of the aim of the DB is to explore the way all these implements overlap, what can mirror the different types of activity organisation in the various considered contexts. We also intend to propose a preliminary typological classification of the analysed contexts and a first differentiation between various scales of production (Figs. 9 and 10).

As result, the record for each single entry/context is quite complex, since it contains not only the information related to textiles, but also those connected to the other spheres of activity. It includes:

(a) Site identification: name, chronology, exact context (if a room or a group of rooms, and not a whole structure, are concerned), bibliography and special notes.
(b) Functional specialisation: presence or absence of the following indicators:
    (1) dye-stuffs; mordents or other chemical substances;
    (2) liquid processing installations and tools: considerable variations are possible;

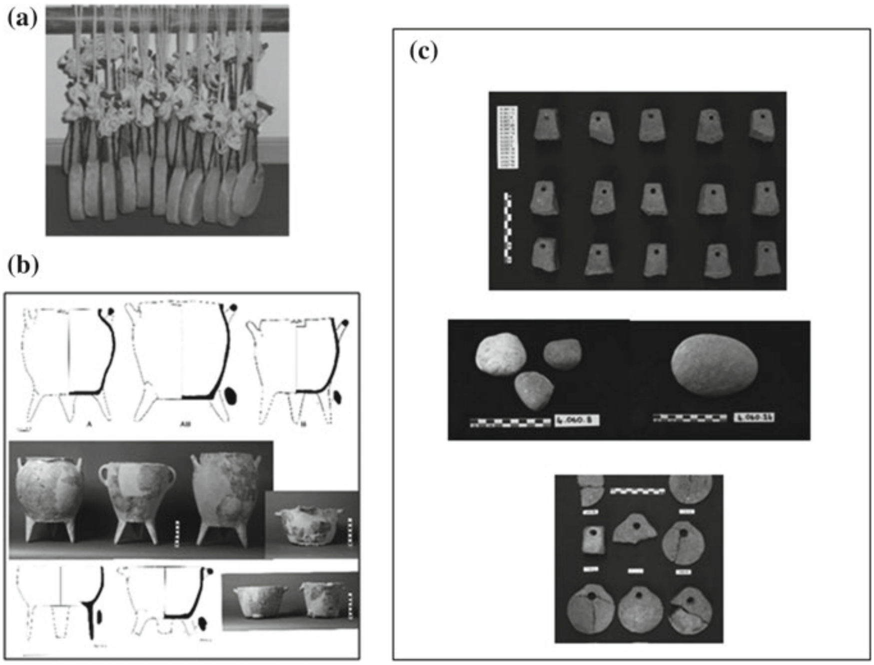

Fig. 9 **a** Experimental loom set up with replicas of Minoan loomweights (modified from Andersson Strand—Nosch [6, Fig. 4.1.17, p. 90]); **b** cooking pots from Petras, Crete, LMI (Alberti [4, Fig. 1]); **c** loomweights and stone tools from Sector Pi, Malia, Crete (courtesy of Efa, M. Pomadère)

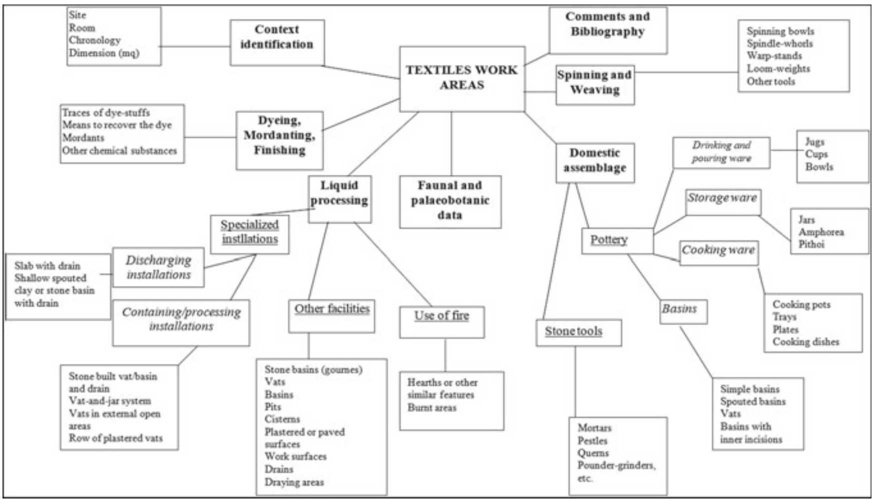

Fig. 10 DBAS-*TWC*—sectors of activity and relevant archaeological indicators to be considered

Context identification
MO.B.A - *Site:* Mochlos. *Building* : Coastside, Building A. *Group:* IV. *Chronology:* LMIB. *Dimension:* 220 (mq).
Dyeing, mordanting, finishing
Dye: attested, ochre. *Means to recover the dye:/ Mordants: / Other chemical substances: /*
Stone tools:
Many 15++
Liquid processing:
Specialised installations: *Row of plastered vats: / Slab with drain: / Vat and jar system: /*
Other facilities: *Gournes:*inside. *Vats:/ Basins:* inside. *Pits:* attested. *Cisterns:/ Plastered or paved surfaces:* inside. *Work surfaces:* many. *Drains: / Drying areas: /*
Use of fire:
Hearths or other similar features: / Burnt areas: attested.
Pottery:
Basins. *Simple basins:* 1 *Spouted basins:* 1 *Base spouted vats:* 1 *Basins with inner incisions:* 2 Cooking ware: *Cooking pots:* many, in the whole house *Trays: /*
Storage ware: *Amphorae:* attested *Jars:* attested *Pithoi:*attested
Drinking and pouring ware: *Jugs:* attested *Bowls:* attested *Cups:* attested
Other pots
Lamps:
Spinning and weaving:
Loom weights: 14 *Spindle whorls: / Spinning bowls:/*
Other informations:
Faune:
Tablets, nodules, etc.:
Other: pumice; evidence of metalworking and stone vase industry
Notes:
Bibliography:
Mochlos I A, p. 12-40; Soles 2003a; pottery: *Mochlos I.B*; small finds: *Mochlos IC*.

Fig. 11 DBAS-TWC—example of the various fields of a single context/file

(3) typical domestic assemblage (cooking and storage vessels, stone tools, hearths, etc.);
(4) textile tools proper (spindles, spinning bowls, spindle-whorls, loom-weights);
(5) other.

The search to be implemented in this DB will be then quite complex. It would be necessary to intersect every indicator with the others, to see how implements of the various activity sectors overlap. Are always liquid processing and textile tools together? Are large pots and dye-stuff in the same spot, as to suggest dyeing operations? What can we say about the organisation of craftwork? Are there larger and more specialised areas than the others?

We are still at the very beginning, but we hope that the experience we are making with the DB-*HTS* on *cretulae* will help us to reach the desired result (Fig. 11).

4 The Tale *La Mattina Di Zuzù* (Zuzù's Morning)

The last example we would like to illustrate here is the tale *La mattina di Zuzù* (Zuzù's morning). It is an interactive tale for children and has been planned as educational device linked to MUSINT II, where the Minoan *cretulae* are the main focus. The tale takes place in Haghia Triada, Crete, during the Bronze Age and features as main characters the joung girl Zuzù, her friends Bri Bri and Pim and the Secretary of the

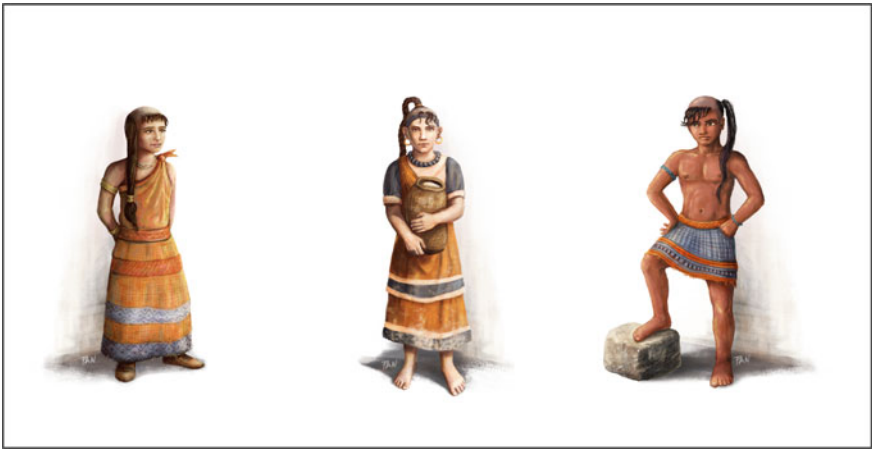

Fig. 12 The main character of the tale: from left, Zuzù, Bri Bri and Pim (P. Kruklidis)

'Villa'. During the morning, Zuzù and her friends help weavers and grinders, admire frescoes, interact with the Secretary, store-keepers and other administrators, and, last but not least, discover various *cretulae* that have been lost, helping in this way the Secretary and the Lord of the 'Villa' to solve a mystery [5]. The tale could give some hints on the 'best practices' for Digital Cultural Heritage (Fig. 12).

The first point to stress is the strict connection among the tale and the databases presented in our sites. The idea is to take the various items that are part of the scientific DBs in our websites and to represent them in use, to show the audience a possible slice of ancient life. In this way, the somehow inert material culture so often quite aridly recorded acquires vitality and scope, and inscribes the more abstract informatics tools within a framework of practices and sense.

This process is grounded on the extreme accuracy of the scientific documentation: each step of Zuzù and his friends has precise archaeological references, both in the archaeological remains and in specialised publications. The frescoes they admire are exactly those found in the "Villa", and the wool-store is exactly where some administrative documents concerning wool have been found [23–32, 35, 37–40]. However, and this is the great challenge for the archaeologist/narrator, the tale goes on as a tale, with no scientific details or footnotes: all the relevant information has been embedded in the narration (Fig. 13).

Interaction is the key for a good "edutainment" result. The users must act and be stimulated by the story, assimilating in the meanwhile the various details on the ancient life. That is why the tale is interactive. It has four sections, three linked to different seal imprints and having Zuzù as main character, and a fourth one for the Secretary. Each section can be read independently. The reader can move from one section to the other, answer questions, follow links to educational materials and play games. Last but not least, the end of the tale is open: it is up to the reader to decide the finale.

Fig. 13 The most famous fresco from Haghia Triada, the cat chasing a bird, as appears in the online tale (P. Kruklidis)

These features have been achieved by a smart use of links. They allow the characters to make decisions and the reader may hop through several points of the story. The way we choose to present the tale and the archaeological and historical contents are multi-media graphics: hand-drawing, vector images, virtual reconstructions and others, 2D and 3D reconstructions, pictures and reproductions of remains and archaeological materials. Thanks to this, the story is more attractive and educational sections are more informative and complete (Fig. 14).

Collaboration is obviously the key-word to achieve such a complex result. The tale as it is online now is the outcome of the work of the archaeologist/narrator, the illustrator, the IT specialist and the game-makers. Each page has been reworked many times, especially to tune illustrations and the various links to educational materials. We had discussions on the hair-style of children, on the age of characters, on the right clothes for a scribe and for a Lord. We actually learned a lot, building a learning resource.

Fig. 14 The beginning of the tale. Zuzù on the left and the Secretary on the right. Above, the reconstruction of the 'Villa' of Haghia Triada (P. Kruklidis)

5 Conclusions

These three examples of our work to implement the DBAS and MUSINT websites underline the role that new technologies can play even for the study of these remote ages and societies. Three aspects are worth of note:

1. strict connection between academic research and the creation of online contents
2. interaction between research and didactic issues
3. cooperation of various institutions and different specialists, such as archaeologists, philologists, school teachers, illustrators, IT specialists and game-makers. Cooperation is indeed, in our opinion, one of the best asset of the Digital Cultural Heritage.

References

1. Alberti, M.E.: The Minoan Textile Industry and the Territory from Neopalatial to Mycenaean Times: some First Thoughts. Creta Antica 8 (2007) 243–263
2. Alberti, M.E.: Textile Industry Indicators in Minoan Work Areas: Problems of Typology and Interpretation. In: Alfaro, C., Karali, L. (eds): Vestidos. textiles y tintes. Estudios sobre la producción de bienes de consumo en la Antigüedad. Actas del II Symposium Internacional sobre Textiles y Tintes del Mediterráneo en el mundo antiguo (Atenas. 24 al 26 de noviembre. 2005). Purpureae Vestes II. Universitàt de València: València (2008) 25–36
3. Alberti, M.E.: La casa., la villa, il palazzo. Organizzazione produttiva a Creta in età neopalaziale e micenea (vino, olio, cereali e tessuti). Anicia: Roma (2012a)
4. Alberti, M.E.: Vessels in Cooking Fabrics from Petras House I (LMIA): Overview and Capacity Measures. In: Tsipopoulou, M. (ed.): Petras, 25 Years of excavations and studies. Acts of a two-days conference held at the Danish Institute at Athens, 9–10 October 2010. Monographs of the Danish Institute in Athens 16. The Danish Institute in Athens: Athens (2012b) 235–254
5. Alberti, M.E.: L'impatto del 'racconto' interattivo sull'insegnamento della storia. In: Jasink, A.M., Dionisio, G. (eds): MUSINT II. Nuove esperienze di ricerca e didattica nella museologia interattiva. Periploi 8. Firenze University Press: Firenze (2016) 53–66
6. Andresson Strand, E., Nosch, M.-L. (eds): Tools. Textiles and Contexts. Investigating Textile Production in the Aegean and Eastern Mediterranean Bronze Age. Ancient Textiles Series, vol. 21. Oxbow Books: Oxford - Philadelphia (2015)
7. Burke, B.: From Minos to Midas: Ancient Cloth Production in the Aegean and the Anatolia. Ancient Textiles Series, vol. 7. Oxbow Books: Oxford - Oakville, Conn (2010)
8. Costin, C.L.: Craft Specialization: Issues in Defining, Documenting and Explaining the Organization of Production. In: Schiffer, M.B. (ed.): Archaeological Method and Theory, vol. 3. University of Arizona Press: Tucson (1991) 1–56
9. Cutler, J.: Ariadne's Thread: the Adoption of Cretan Weaving Technology in the Wider Southern Aegean in the Mid-Second Millennium BC. In: Nosch, M.L., Laffineur, R. (eds): KOSMOS. Jewellery, Adornment and Textiles in the Aegean Bronze Age, Proceedings of the 13th International Aegean Conference, University of Copenhagen, Danish National Research Foundation's Centre for Textile Research, 21–26 April 2010. Aegaeum 33. Peeters: Leuven and Liège (2012) 145–154
10. Cutler,. J., Andersson Strand, E., Nosch, M.-L.: Textile production. In: Poursat, J.-C.: Vie quotidienne et techniques au Minoen Moyen II. Outils lithiques. poids de tissage. lampes. divers. Faune marine et terrestre. Fouilles exécutées à Malia. Le Quartier Mu V. Études crétoises, vol. XXXIV. Ecole française d'Athènes: Athènes (2013) 95–120
11. Evely, R.D.G.. Minoan Crafts: Tools and Techniques. An Introduction. Studies in Mediterranean Archaeology, vol. 92. P. Åströms Förlag: Göteborg and Jonsered (1993–2000)
12. Godart, L., Olivier, J.-P.: GORILA 2 - Recueil des Inscriptions en Linear A. Vol. 2. Nodules, scellés et rondelles édités avant 1970. Études Crétoises, vol. XXI,2. Paul Geuthner: Paris (1979)
13. Hallager, E.: The Minoan Roundel and other Sealed Documents in the Neopalatial Linear A Administration, Vols II. Aegaeum 14. Peeters: Liège et UT-PASP (1996)
14. Jasink, A.M., Baldi, M., Bombardieri, L., Carminati, F., Gonzato,F.: Collecting Databases about Aegean Subjects on-line (DBAS Project). Kadmos XLI (2006) 173–186
15. Jasink, A.M., Bombardieri, L., Gonzato, F.: New reaserch tools for the Aegean Studies. The DBAS project on-line. DO-SO-MO. Fascicula Mycenologica Polona 7 (2007) 81–92
16. Jasink, A.M., Bombardieri, L., Marino, M.: The Ahhiyawa Question and the Cretan Hieroglyphic Seals: two Databases in the DBAS project. In Pecchioli Daddi, F., Torri, G., Corti, C. (eds): Central-north Anatolia in the Hittite period: New Perspectives in light of recent Research, Acts of the International Conference held at the University of Florence (7–9 February 2007). Herder: Roma (2009) 249–257, pl. XXX–XXXII
17. Jasink, A.M., Dionisio, G. (eds.): MUSINT 2. Nuove esperienze di ricerca e didattica nella museologia interattiva. Periploi 8. Firenze: Firenze University Press (2016)

18. Jasink, A.M., Dionisio, G.: Teaching New Technological Methodologies Applied to Ancient History: the Profitable Example of the Municipal Archaeological Museum and the Primary School of Montelupo Fiorentino, Italy. In: Proceedings of the 20th International Conference on Cultural Heritage and New Technologies (CHNT 20), November 4–6 2015 Wien, Wien (2015)
19. Jasink, A.M., Faralli, C., Kruklidis, P.: MUSINT II: A Complex Project on a Virtual and Interactive Museum Involving Institutions in Florence, Rome and Heraklion. Studies in Digital Heritage, Vol. 1, No. 2. Wien (2017) 283–297
20. Jasink, A.M., Tucci, G., Bombardieri, L. (eds): MUSINT. Periploi 3. Firenze University Press: Firenze (2011)
21. Jasink, A.M., Tucci, G., Cini, D.: MUSINT: A Virtual Habitat for Relocated Archaeological Artifacts. In Borner, W., Uhlirz, S., Dollhofer, L. (eds): Proceedings of the 16th International Conference on Cultural Heritage and New Technologies, November 14–16 2011 Wien (CHNT 16). Wien (2012) 185–200
22. Jones, B.: Ariadnes's Threads. The Construction and Significance of Clothes in the Aegean Bronze Age. Aegaeum 38. Peeters: Leuven-Lièges (2015)
23. La Rosa, V.: La Villa Royale de Haghia Triada. In: Hägg, R. (ed.): The Function of the 'Minoan Villa': Proceedings of the Eighth International Symposium at the Swedish Institute of Athens. 6–8 June. 1992. Skrifter utgivna av Svenska Institutet i Athen 4°. Svenska Institutet i Athen and Jonsered: Stockholm. Distributor P. Åströms Förlag (1997) 79–89
24. La Rosa, V.: "Il colle sul quale sorge la chiesa ad ovest è tutto seminato di cocci". Haghia Triada. Vicende e temi di uno scavo di lungo corso. Creta Antica 4 (2003) 11–68
25. La Rosa, V.: La fornace da vasaio TM IB di Haghia Triada. Introduzione. Creta Antica 12 (2011) 127–130
26. La Rosa, V.: La conclusione dei lavori ad Haghia Triada. Creta Antica 15 (2014) 129–241
27. Militello, P.: Haghia Triada I. Gli affreschi. Monografie della Scuola Archeologica di Atene e delle missioni italiane in Oriente IX. Bottega d'Erasmo: Padova (1998)
28. Militello, P.: Ayia Triada Tablets, Findspots and Scribes. A Reappraisal. Pasiphae Rivista di filologia e antichità egee 5 (2011) 59–69
29. Militello, P.: La fornace da vasaio TM IB di Haghia Triada. Una riconsiderazione della tavoletta HT 31. Creta Antica 12 (2011) 273–288
30. Militello, P.: Impianti di lavorazione a Festòs ed Haghia Triada in età palaziale: per una rassegna delle evidenze. Creta Antica 13 (2012) 109–138
31. Militello, P. Festòs e Haghia Triada: i rinvenimenti minori I. Materiali per la tessitura. Studi di archeologia cretese, vol. 11. Bottega d'Erasmo A. Ausilio: Padova (2014)
32. Montecchi, B.: Planning a Feast in Neopalatial Crete: A Look at the Linear A Evidence. Annuario della Scuola Archeologica di Atene e delle missioni italiane in Oriente LXXXIX.1 (2011) 111–133
33. Montecchi, B.: Contare a Haghia Triada. Le tavolette in Lineare A, i documenti sigillati e il sistema amministrativo nel TM IB (in press)
34. Müller, W., Pini, I.: CMS II,6 - Corpus der Minoischen und Mykenischen Siegel. Die Siegelabdrücke von Aj. Triada und anderen zentral-und ostkretischen fundorten. Gebr. Mann Verlag. Berlin (1999)
35. Palio, O.: Le Case del Lebete e la Case delle Sfere Fittili ad Haghia Triada. Creta Antica 3 (2002) 121–132
36. Peterson Murray, S.: Patterned Textiles as Costume in Aegean Art. In: Shaw, M.C., Chapin, A.: Woven Threads. Patterned Textiles of the Aegean Bronze Age. Ancient Textiles Series, vol. 22. Oxbow Books: Oxford and Havertown, PA (2016) 43–104
37. Procopiou, H., Treuil, R. (eds): Moudre et broyer. L'interprétation fonctionnelle de l'outillage de mouture et de broyage dans la Préhistoire et l'Antiquité I-II. CTHS: Paris (2002)
38. Puglisi, D.: L'organizzazione a terrazze nel "villaggio" TM I di Haghia Triada.Creta Antica 8 (2007) 169–200
39. Puglisi, D.: La fornace da vasaio TM IB di Haghia Triada. Le ceramiche e il sistema di produzione. distribuzione e consumo. Creta Antica 12 (2011) 199–272

40. Tomasello, F.: La fornace da vasaio TM IB di Haghia Triada. L'impianto. Creta Antica 12 (2011) 131–198
41. Tournavitou, I.: Towards an Identification of a Workshop Space. In: French, E.B., Wardle, K.A. (eds): Problems in Greek Prehistory. Papers presented at the Centenary Conference of the British School of Archaeology at Athens. Manchester April 1986. Bristol Classical Press: Bedminster, Bristol (1988) 447–468

Rebuilding the Past: 3D Reconstruction and BIM Analysis of a Neolithic House at La Draga (Girona, Spain)

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Abstract The 3D reconstruction and the BIM analysis of the prehistoric house architecture of the Neolithic settlement of la Draga (Girona, Spain) will be illustrated in this paper. La Draga is an Early Neolithic pile-dwelling settlement (ca. 5.300–4.800 cal BC) located in the NE of the Iberian Peninsula, on the eastern shore of Lake Banyoles (Girona, Spain). The excavations revealed that the settlement was one of the earliest open-air Neolithic occupations in NE Iberia, and it is particular for bearing an exceptional conservation and preservation of the archaeological organic remains. The archaeological surveys shown that the area occupied by the settlement was of 8000 m^2 ca. (ca. 100 m along the shoreline and ca. 80 m of width inland Tarrus in La Draga (Banyoles, Catalonia), an Early Neolithic Lakeside Village in Mediterranean Eu-rope. Catalan Hist Rev (1):17–33, [1], Bosch et al. in El jaciment-neolític lacus-tre de La Draga (Banyoles-Pla de l'Estany). Quaderns de Banyoles, 13, [2]). Of the four sector excavated one is today sub-merged (Sector C) and other two are in the phreatic level (Sector B and D) (Palomo et al. Prehistoric Occupation of Banyoles Lakeshore: Results of Recent Excavations at La Draga Site, Girona, Spain. J Wet Ar-chaeol 4(1):58–73, [3]). This is the reason why perishable material has been recovered, among which a relevant amount of well-preserved wooden artifact, the majority of whom are architectural parts. The presence of these parts

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and the need to better understand the ancient architecture are the base of this work. To do so we decided to use a new approach, combining 3D reconstruction (using Rhinocer-os 5) and BIM (Building information Modeling) structural analysis. In the prior excavations the wooden elements have been 3D scanned giving us accurate information about shape, geometry and material properties (Li et al. in Coordination between understanding historic buildings and BIM modelling: a 3D-output oriented and typological data capture method. ISPRS, Proc 25th Int CIPA Symp 40:283–288 [4]). In addition to that, all these elements have been accurately georeferenced and based spatial analysis have been taken into account. This two studies combined, allow us distinguish between those wooden parts with a clear, or almost, architectonical function and those parts that, even being part of the house, had no evident structural function. The 3D model created on the base of these data showed that, even though very complete, these data were not enough to re-construct the house and there were many "gaps" to fill because many important architectonic parts have left no traces. A clear example is the roof: even we had identified the parts that composed it, we have no information about the roof covering. In cases like this, to fill these gaps, we have sought help from history, ethnology and anthropology to elaborate solutions suitable with our case taking into account all the information about the ancient Draga (available resources, and technologies known by the human group, the landscape etc.). To analyse the viability of the resulting model, it has been elaborated using a custom-made BIM for modelling prehistoric timber structures: it is based on the use the modern and vernacular architecture definitions and procedures to analyse the functional of different parts. The house, as a complex, forms a unique object but it is formed by several other individual or conglomerated elements. The identification of these elements, through the use of the BIM technique, allowed us to individuate the structural parts of the building and to work with them. Following modern architectural practices, the house has been divided into blocks (base block, elevated block, overhead block, etc.) identifying, for each one, independent or composite elements, linear elements, opening and connection. Each parts of the blocks has been defined with a specific terminology (ridge beam, tie beam etc.) and described in its characteristics. Then, the architectural analysis has been used to determine relations and hierarchies between these elements, in the house as a whole and inside the individual blocks. Starting from the description of these key elements, we added general characteristics to them managing to elaborate a descriptive model suitable for all kind of house. Finally, all the information gathered with the archaeological, ethno-anthropological, architectonical and BIM analysis has been synthesized to create an accurate, even hypothetical, 3D model of one of the ancient house of la Draga.

Keywords BIM · 3D archaeology · Neolithic · Architecture · Pile-dwelling

1 Introduction

Over the past 20 years, advances in computing have allowed archaeologists to visualize their data sets in increasingly sophisticated ways. An evident result of this tendency is the broad use of 3D technologies. One of the reason behind the great success of these technologies, is that cultural features such as houses and other buildings are defined by a volumetric region of physical space that should be represented using a minimum of 3-dimensional (henceforth 3D) space [5], while 2D representations limited the analysis of architectural data in a 2-dimensional space [6]. Only a 3D representation of built spaces allow the detailed study of such factors as wall sloping, roof height and the distribution of light and shadow, playing a role in mediating the organization of domestic space [7–12]. More than that, within a high-dimensional representation (even 5D in certain circumstances), archaeological features can be explored from many different perspectives. This has the potential to provide new insights into the functional analysis of past objects, houses and spaces: how they were built, how they were used in the past, how they have been preserved in the present. This implies investigating their function, their form and shape, and the social-cultural processes behind their creation, and so on [13, 14]. Creating a model of an archaeological artefact, or simulating it, and then placing it inside a high-dimensional environment could also help in the study about the built space and its relations with the natural environment [15–17]. Despite the huge diffusion of these new technologies and their potential, virtual reconstruction, as a field of archaeological research, is a yet undefined discipline, one that is still largely fragmented when it comes to methodology, both in terms of data transparency and common standards [18–20]. In this paper we will illustrate our efforts to build and validate a high-dimensional visual model of one of the pile-dwellings from the Early Neolithic site of La Draga (Girona, Spain), built to explain the archaeological remains and to understand the logic of built spaces in a remote past. In addition, we will present our results in implementing the conceptual model of the prehistoric timber house into a Building Information Model (BIM), providing a blocks definition for expanding the explanatory model and generalize our initial findings with the additional goal of setting the base for a functional BIM that would fit not only with the site of la Draga but also with all the archaeological sites in general.

1.1 The Site

The Early Neolithic settlement of la Draga was discovered in 1990 on the eastern shore of Lake of Banyoles (Catalonia, Spain). What make this site unique is that it is the only pile-dwelling settlement found, so far, in the entire Iberian Peninsula. The survey shown that the settlement covered an area on 8000 m^2. The stratigraphy dates the site from the end of the sixth millennium BC [21–23]. In topographical terms, the area where the village was built was a peninsula and the ground sloped steadily from east to west and from north to south. The original village stretched for over 100 m along the Neolithic shoreline, in a north-south direction, and approximately 80 m inland towards the east. One part, comprising the Neolithic shoreline, lies beneath the waters of the lake, but the most extensive area of the village is still on dry land. In Neolithic times, the whole settlement was out of the water, though the huts that stood right on the edge of the lake must have been subject to frequent flooding. So far four areas has been excavated (A, B, C and D) for a total of 970 m^2. In sector B, the archaeological level was under the phreatic layer. In this area, the archaeologists found the largest concentration of organic elements and the most relevant ones: large concentrations of cereals and fauna, bone tools, flints and large quantities of vegetal remains, wooden tools, architectonical wooden elements, baskets and so on [24]. The excavations undertaken so far, allowed identifying two main settlement phases, without any clear interruption in the stratigraphy but with two settlement patterns clearly differentiable. The first phase is characterized by the wooden structures built directly on the top of the natural layer made of lacustrine clay. The radiocarbon dating place this first phase among 5324 and 5000 cal. BC [25]. The second phase is placed among 5210 and 4800 cal. BC. Since the majority of the site was submerged in water a large quantity of perishable materials have been preserved, amongst which: architectonical elements, hunting tools (arrows and bows) [26], carpentry tools, household utensils (vessels, baskets, etc.) and tools related with farm works like sickles and digging sticks [27].

1.2 Architectonical Wooden Elements

All the architectonic wooden elements studied so far [28] came from the sectors B, C, D. From 1991 to 2017, 1271 vertical wooden elements have been found. In sector D the study of the wooden elements has been direct (and not based on previous publications) which is why our study is focused on the finds of this specific sector. The architectonical elements has been divided among vertical elements, horizontal elements and tilted elements. The vertical elements include vertical poles, short forks and long forks. The diameter these elements ranges between 11–20 and 211–220 mm. The horizontal elements include planks, trunks, and horizontal poles. The diameter of these elements ranges between 7 and 210 mm. Only in few cases it has been possible to measure the total length of the artefacts. The tilted elements include all those artefacts artificially tilted and still inserted into the soil. The first analysis seems to indicate that these elements were in connection with the vertical poles and the short forks. The majority of these tilted poles has a diameter between 21 and 70 mm. In addition to these elements, the excavation revealed evidences of two horizontal wooden structures, or part of them. A plank, longer more than 3 m and joined to a short fork, composes the first structure. The other structure, instead, is composed by three horizontal elements, connected to form a rectangle.

2 Reconstructing the House

In order to carry out our reconstruction, the first step has been to analyse the building elements of la Draga taking into consideration the basic architectural planes composing a house, in order to find a location to all the architectural wooden elements found so far. The main architectural element of the house is what the theory of architecture identify as "plane" [7, 11]. Planes define three-dimensional volumes of mass and space. A plane could be horizontal or vertical. Architecture works mainly with three generic types of planes: overhead plane, elevated plane and base plane, and relationships between them [7, 11].

2.1 Base Plane

Our hypothesis for the base plane is based, first of all, on the presence of forks, beams and boards that have been interpreted as its components. The characteristics of the floor, the structure meant to support it and the rest of the house are proposed according to their spatial localizations, main features and deductions made by using the data coming from the physics analysis and the data obtained from the analogy with both ancient and modern pile-dwelling sites. Following these data, we were able to reconstruct the house base plane as consisting of several short forks (inserted into the natural soil) and the flooring system (framing and floor itself). The positioning of the forks on the ground was rather imprecise, without apparent traces of any rectilinear alignments. They had an average length of 1.37 m of which 30 cm jutting out from the soil. The rest of the forks is inserted into the ground for about 1 m, that is just enough to ensure their bearing capacity [29]. The space between soil and house floor also prevented water and moisture to get inside the structure. The forks acted as friction/cohesion piles meaning that their carrying capacity was derived mainly from the adhesion or friction of the soil in contact with the shaft of the pile. These types of pile foundations are commonly known as floating pile foundations. The forks were meant to hold the framing (consisting of crossed logs, beams and boards and acting like joists and girts) which, in turn, held the platform/floor. About the horizontal wooden elements interpreted as part of the framing there is few information. The longest of these elements was longer than 6 m. Its length (6.27 m) has been used as maximum length for both framing and platform. The floor hypothesis consists of several boards some of which had a triangular section having been obtained cutting a log into "wedges". Possible gaps between the boards were probably closed with branches. Both framing and flooring acted as a pile cap, distributing the applied load to the individual piles. Evidences of this arrangement has been found in Sector D, where the archaeologists indeed discovered a fork connected with a board. The board was stuck in the fork's V-shape extremity and laying parallel to the soil. Four planks lied on this board, perpendicularly, probably keeping their original location. As regard the overall width of the house base plane we have no direct information. However, the high of the forks and the slope angle of the roof pitches seems to indicate that the interior house width was of about 2.74 m. As regard the overall width, since both archaeological and ethnographical data shown that usually the platform composing the base plane is just a little bigger than the house itself, we have established that the overall width was to be about 3.50 m.

2.2 Vertical Plane

The archaeological data found so far at la Draga, seems to indicate that the roof pitches acted both as roof and lateral/main walls. This particular arrangement implies that the vertical plane was composed only of two vertical walls, one the front and one on the back. In our reconstruction, these two walls consisted of a framing made of beams, horizontally and vertically placed, standing against the main rafters that acted as corner posts. No direct evidences of openings have been identified at la Draga, however, at least the presence of an opening acting as an entry can be expected. As regard the presence of any other aperture acting as windows one hypothesis is that there might be two small openings at the top of the frontal and rear walls, at the junction with the roof, with the function of providing both ventilation and light. The other hypothesis is that there were no windows at all. Ethnographical comparison, in fact, has shown that in many cases simple houses with walls made of vegetal elements have no needs of openings since the smoke simply goes out through the wall framing. We have no direct information about the dimension on the vertical plane of the house. However, using the data about the base plane and the slope angle degree of the roof pitches we deduced a width of 2.74 m and a high of 2.30 m.

2.3 Overhead Plane

The overhead plane of the houses of la Draga corresponds with the roof, without any direct evidence of ceiling. The roof was composed of a ridge beam, held by two main forks, one on the front and one on the back of the house, forming its main vertical axis. They were probably inserted into the soil, passing through the floor. The presence of wooden elements acting as purlins and rafters can also be suggested with the latter probably prolonged up to the soil in which they were insert, improving their structural function. According to the size of the architectonical elements of la Draga, four rafters are suggested acting as principals ones (two in the fore side of the house and two in the rear side). These elements were inserted into the natural soil, passing through the floor, in order to make the house more solid. The other rafters were shorter and probably leaning on the wooden floor. As said before we reconstructed the roof pitches as acting both as roof and lateral/main walls. We have opted for this peculiar architectonic form since usually in pile-dwelling sites there are traces, more or less clear, of vertical walls (like posts in pairs or threes) but at la Draga they found no such evidences. On the contrary, they found rows of posts artificially tilted that seems to be in connection with the short forks. This, and the slope degree of some of these elements (e.g. 58.030°), seems to indicate that for the construction of the lateral walls/roof the solution presented in our model was used. Even if at la Draga there is no direct data about the walls/roof framing, archaeological and ethnographical comparison suggest that probably consisted of horizontal posts tied together with the tilted elements. In our reconstruction, the overhead plane had no openings: light and smoke just trespass through the vegetal material that composed the covering of the roof pitches. The only direct data that we have about the overhead plane size are the dimensions of the long forks, the longest of which measure 3.12 m. Even if they have been found lying on the soil, the archaeological team of la Draga was able to detect traces that seems to indicate that these forks were plunged into the soil for 52 cm while the remaining 2.30 m were jutting out from the soil. As regard the roof pitches, we know that the average slope angle degree of the tilted elements composing them is about 50.830°. The measurements taken by the archaeological team seems also indicate that the longest tilted element measured 3.83 m. Connecting

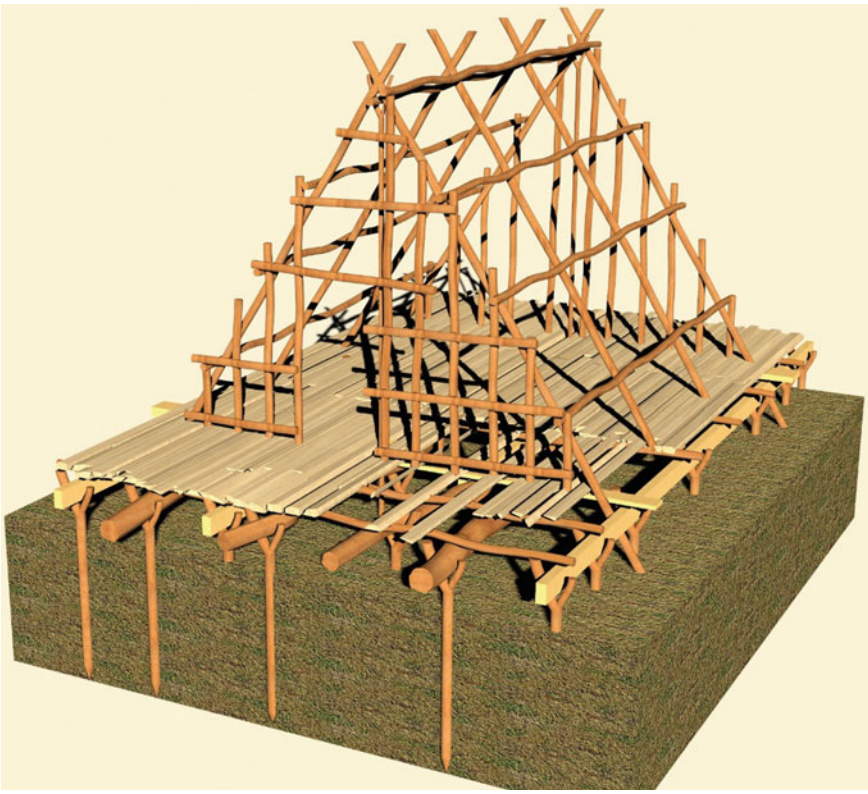

Fig. 1 The 3D model showing the structure of one of the pile-dwelling of la Draga

all these measurements with those taken for the other planes, we deduced that the internal high of the house was about 2.30 m for a width of 2.74 m (Fig. 1).

The elements composing the different planes were probably connected by using ropes/and or lianas made of vegetal fibres, for example nettle [30]. Other ancient lake dwellings in circumalpine region, but also modern pile-dwelling settlements, have provided evidences of ropes, lianas or simple vegetable fibres used for this purpose [31]. No direct traces of the material composing the walls/roof has been found, so far at la Draga. However, a huge quantity of oak's branches has been found during the excavation, some of them intertwined. They have been interpreted as part of the covering, probably completed by the use of other local materials as fresh/dry aquatic/terrestrial plants and/or leafs [3].

3 Constructing the BIM

In the last years, the use in archaeology of BIM process has increase. However, its use is still in an "embryonic stage" and a unified process does not yet exist. In this chapter, we will illustrate our effort in this direction, to create a BIM process that can be handle all the different archaeological situations. Usually the BIM process is used to manage the information about a standing structure, to describe its characteristics, its needs and the information about it [32]. At la Draga we faced the problem of not having any standing structures but only parts of probable structures. Because this is a common problem in archaeology, we decide to plan a BIM process meant to compensate that. The solution was creating a process showing both the material data, the archaeological evidences, both the reconstruction and the hypothesis about the lost elements. The result would be a BIM that, beside the "common" information, could displaying a 3D model showing the "certain" elements and the "hypothesized" ones. To generate our BIM process we decided to use Rhinoceros 5, Grasshopper and VisualArq. The objective of this case study is to design a procedure to build a parametric and informed 3D model of a Neolithic pile-dwelling. The following section describe the procedures undertaken so far to construct the BIM process. The first step of the constructive process has been drawing, on the XY plane, the polylines representing the overall size of those architectonical objects forming the architecture. These three lines are: the line representing the perimeter of the elevated platform (the outer line); the line deifying the boundary of the posts and the connected grid (or framing) (central line); and the line representing the perimeter of the walls (inner line). The following step has been, starting the definition of the algorithm. This process begins with the construction of primitive lines to which the architectonical objects "posts" and "beams" will be linked. Then we built a surface starting from a closed plane curve and we move this surface upwards respect the variable parameter *h_pillars*. The surface in eighth is divided with variable parameters alongside the parametric direction *u* and *v* generating a points matrix identifying the positions of the cabin posts. The element SDivide, used to create unidimensional geometrical entities, determines a points matrix whose data structure offer the clear distinction of rows and columns. The structure rows/columns could be inverted using a Boolean switch that using the transition from true to false, and vice versa, allows a data filter to select one of the two possible built. Through the points sequence we built the polylines that are the structural joists axes. The pile-dwelling posts went through the water and the soil. This detail is expressed by the definition with a negative offset in the horizontal plane, that from height 0 descend about a variable value *d_pillars*. On the moved horizontal plane, the points matrix is projected; projected points and quoted points began the extremes of vertical lines and structural posts that will held the pile-dwelling platform.

3.1 Architectonic Object Style Definition (Family)

The external geometries and the definition illustrated above represent the forms on which lean the architectonical objects. In first place, the style of those architectonical objects that will be inserted into the model for its characterization should be defined. To do so we used VisualARQ. The next step is the compilation of the graphic attributes of views and sections, the selection of shapes and dimensional characteristics and the definition of numeral and textual metadata, handled by the tool "Parameters". In this way is it possible to create families made of architectonical objects to link to the primitive forms/shapes. The next step is a series of settings, which in some cases reiterate the actions just described, about the architectonical object Style: in the section "Attributes" we can set the starting layers, the visibility and the materials; in the same window we found the graphical variables to handle the representation of the projection and of the architectonical object section. In the section "Geometry", we have to choose the kind of section outline to be used in the style section and an object default height. Once we have defined the shape, in "Size" we can introduce lists of dimensional variables in order to be able to define the family "Post", using pre-determined dimensions. In "Blocks", you can replace no-parametrized blocks in the 3D and 2D visualization. "Parameters" is where we can set the metadata characterizing the style that we are creating. The metadata can be textual or numerical and are shown/presented in a window were we have to define: Name, Category, Data type and Description [33].

Once we have defined the style of the architectonical object we have to create it and link it with the geometries defined at the beginning of the parametrical procedure. To do so we get again the posts axes and we extract the end points from them; the distance between the two ends defines the high of the post, the value of which is a variable to be included in the component that collects the options with which determine the architectonical object being created. Another input data of this component is the style that was previously created from which extract one of the dimension set during the style building phase. The options then will characterize the object "post", the position of which is defined by the end point of the line representing the axe. The next component allows to recall the metadata set during the style definition phase (Place of discovery) and to give it a value that will be upload directly into the final architectonical object. For the construction of the objects “beams” the procedure is the same but, in this case, we decide to create the style using Grasshopper using VisualARQ components devoted to building the style. The visual programming allows defining a section using custom measures (e.g. A, B, C) and metadata directly set in the definition (e.g. Place of discovery). Also for the beam, the component Beam Option will have as input the Style just defined and one of the components of the profile (e.g. B). The component Beam will be then connected to the options and to the primitive geometries accordingly edited for a technical adaptation; the component Beam, like the component Column, could be informed with defining metadata (e.g. Latitude, longitude etc.). The platform is characterised by a surface placed at the desire quota and divided in order to represent the random juxtaposition of the wooden tables. The walls are placed on the platform by connecting them to a component that allow us to modify the form in the plan (or top view). It is also possible to switch easily from a curved from to a polygonal form without interruptions, guarantying infinite shapes and increasing the number of architectures included in the definition. The covering (roof) follows the form drawn in the plan and, thanks to an open parameter, is possible to change, automatically or by input, the slope of the pitches.

4 Conclusions

According to the features documented and the architectonical elements found so far, our hypothesis is that the cabins al la Draga would be similar to which is known in architecture as A-Frame house. The main characteristic of this typology of houses is that that the roof pitches work as well as lateral walls, giving to them the peculiar shape of an A. The only vertical walls are the frontal and the rear ones. The outcome was an A-Frame cabin, with pitched walls, standing on short forks holding a framing of horizontal elements supporting the house flooring made of planks, which was not too much raised from the natural soil (0.30 cm ca.). The front wall and the back wall were vertical. The other main goal achieved in this investigation, and that has gone beyond all expectation, has been the development of a BIM (Building Information Module) process. We start with the idea of creating a BIM process to handle and display both the archaeological data and the reconstructive hypothesis about the lost elements of the houses of La Draga. However, during the design phase, we soon realized that we could go beyond, that we could create a BIM process not only for our specific case but also for all the archaeological sites in general. We have been able to design a procedure (currently in alpha test) to build a parametric and informed 3D model of an archaeological structure. Following the architectonical definitions we used for our site, we were able to define general groups, families and objects capable of handle any situation. The structures are divided on the base of the architectonic planes (base plane, vertical plane and overhead plane) each of which has his families and object. We created a library of object but because we know that each site is different from the other, new elements can be also easily added. Moreover, families allow connecting elements meaning that if I change a value all the connected elements change their values as one. This is a very important aspect because especially in the reconstructive phase because one can easily see how a hypothesis would affect the rest of the structure. Other important aspect is that, being an open process, each time I have a new data I can add it and be able to see how the rest of the model react to the new information. I can also link all the information I have about a specific object (photos, diagrams etc.) and I can easily recall them whenever I want. Moreover, I can run physical stress test on a single object or on the entire model, or undertake tests about the lightening of the interior of the heat dispersal patterns.

References

1. Tarrus, J. "La Draga (Banyoles, Catalonia), an Early Neolithic Lakeside Village in Mediterranean Eu-rope," Catalan Hist. Rev., no. 1, pp. 17–33 (2008)
2. Bosch, A., Buxó, R., Chinchilla, J., Palomo, A., Piqué, R., Saña, M., Tarrús. "El jacimentneolític lacus-tre de La Draga (Banyoles-Pla de l'Estany)", Quaderns de Banyoles, no. 13 (2012)
3. A. Palomo, R. Piqué, X. Terradas, À. Bosch, R. Buxó, J. Chinchilla, J. Tarrús, "Prehistoric Occupation of Banyoles Lakeshore: Results of Recent Excavations at La Draga Site, Girona, Spain," J. Wet. Ar-chaeol, vol. 4, no. 1, pp. 58–73 (2014)
4. Li, K., Li, S. J., Liu, Y., Wang, W., & Wu, C. "Coordination between Understanding Historic Buildings and BIM Modelling: A 3D-Output Oriented and typological Data Capture Method," ISPRS, Proc. 25th Int. CIPA Symp., vol. 40, pp. 283–288 (2015)
5. Barceló, J. A. "3D Modeling and Shape Analysis in Archaeology". In Remondino, F., Campana, S., 2014: 3D Recording and Modelling in Archaeology and Cultural Heritage—Theory and Best Practices. Archaeopress BAR Publication Series 2598, 9:15–23 (2014)
6. Levy, R. and Dawson, P. Reconstructing a Thule whalebone house using 3D imaging. IEEE MultiMedia, 13(2):78–83 (2006)
7. Pramar, V.S. Design Fundamentals in Architecture. Somaiya Publications, New Delhi (1973)
8. Lourenço, P. B. Analysis of historical constructions: from thrust-lines to advanced simulations. Historical constructions, 7–9 (2001)
9. Papadopoulos, C. and Earl, G. P. Structural and lighting models for the Minoan cemetery at Phourni, crete. In Proceedings of the 10th International conference on Virtual Reality, Archaeology and Cultural Heritage, pp. 57–64. Eurographics Association (2009)
10. Papadopoulos, C. and Earl, G. Formal three-dimensional computational analyses of archaeological spaces. Spatial analysis and social spaces: interdisciplinary approaches to the interpretation prehistoric and historic built environments (Eds. E. Paliou, U. Lieberwirth, S. Polla). De Gruyter, Berlin, pp. 135–165 (2014)
11. Ching, F.D.K. Architecture: Form, space, and order. John Wiley & Sons Inc. Inc., Hoboken, New Jersey (2014)
12. Brughmans, T., Keay, S. and Earl, G. Understanding inter-settlement visibility in Iron Age and Roman Southern Spain with exponential random graph models for visibility networks. *Journal of Archaeological Method and Theory*, 22(1), 58–143 (2015)
13. Barceló, J. A., and Moitinho, V. M. Functional analysis from visual and non-visual data. An artificial intelligence approach. Mediterranean Archaeology and Archaeometry, 12(2):273–321 (2012)
14. Papadopoulos C. and Sakellarakis Y. Virtual windows to the past: reconstructing the 'ceramics workshop' at Zominthos, Crete, in Melero J., Cano P. & Revelles J. (ed.) CAA 2010 Proceedings of Computer Applications & Quantitative Methods in Archaeology. Pp.47–54. (British Archaeological Reports British series 2949). Oxford: Archaeopress (2013)

15. Kantner, J. and Hobgood, R. Digital technologies and prehistoric landscapes in the American Southwest. BAR International Series, 1151: 117–124 (2003)
16. Robertson E.C., Seibert J, Fernandez D, Zender M. Space and Spatial Analysis in Archaeology. UNM Press (2006)
17. Kantner, J. Implications Of Human Behavioral Ecology For Understandign Complex Human Behavior: Resource Monopolization, Package Size, and Turquoise. Journal of Anthropological Research, 66(2), 231–257 (2010)
18. Beacham, R., Denard, H. and Niccolucci, F. An introduction to the London charter. Joint Event CIPA/VAST/EG/EuroMed (2006)
19. Denard, H. Implementing best practice in cultural heritage visualisation: the London charter. In Good Practice in Archaeological Diagnostics (pp. 255–268). Springer International Publishing (2013)
20. Demetrescu, E. Archaeological stratigraphy as a formal language for virtual reconstruction. Theory and practice. Journal of Archaeological Science, 57:42–55 (2015).
21. Bosch, A., Chinchilla, J., Tarrús, J. El poblat lacustre neolític de La Draga. Excavacions 1990 a 1998. Girona, Museud'Arqueologia de Catalunya: Centre d'ArqueologiaSubaquàtica de Catalunya. (Monografies del CASC; 2) (2000)
22. Bosch, A., Chinchilla, J., Tarrús, J. Elsobjectes de fusta del poblatneolític de La Draga. Excavacions 1995–2005. Girona: Museud'Arqueologia de Catalunya: Centre d'ArqueologiaSubaquàtica de Catalunya. (Monografies del CASC; 6) (2006)
23. Bosch, A., Chinchilla, J., Tarrús, J. El poblat lacustre neolíticantic de La Draga. Excavacions 2000 a 2005. Girona: Museud'Arqueologia de Catalunya: Centre d'ArqueologiaSubaquàtica de Catalunya. (Monografies del CASC; 9) (2011)
24. Bosch, A., Chinchilla, J., Tarrús, J. Elsobjectes de fusta del poblatneolític de La Draga. Excavacions 1995–2005. Girona: Museud'Arqueologia de Catalunya: Centre d'ArqueologiaSubaquàtica de Catalunya. (Monografies del CASC; 6) (2006)
25. Palomo, A., Piqué, R., Terradas, X., Bosch, À.,Buxó, R., Chinchilla, J., Saña, M., Tarrús, J. Prehistoric occupation of Banyoles lakeshore: results of recent excavations at La Draga site, Girona, Spain. Journal of Wetland Archaeology, 14 1:58–73 (2014)
26. Piqué, R.; Palomo, A.; Terradas, X.; Tarrús, J.; Bosch, A.; Chinchilla, J.; Bodganovic, I.; López, O., Saña, M. Characterizing prehistoric archery: technical and functional analyses of the Neolithic bows from La Draga (NE Iberian Peninsula). Journal of Archaeological Science 55, 166–173 (2015)
27. Palomo, A., Piqué, R., Terradas, X., López, O., Clemente, I., Gibaja, J.F. Woodworking technology in the Early Neolithic site of la Draga (Banyoles, Spain) in Anderson, P.C., Cheval, C., Durand, A. (eds.), An interdisciplinary focus on plant-working tools, Antibes: Éditions APDCA, 383–396. [ISBN 2-904110-53-4] (2013)
28. López, O. Processosd'obtenció, transformació i ús de la fusta en l'assentamentneolíticantic de la Draga (5320–4800 cal BC). Ph.D. dissertation, Dep. Archeol. Prehist. Univ. Autònoma de Barcelona (2015)
29. Sabbe, K. Serruys F. Vakwerkstructuuralsalternatievefunderingvoor offshore windturbines, KHBO, Oostende (2008)
30. Piqué, R., Romero, S., Palomo, A., Tarrús, J., Terradas, X. and Bogdanovic, I. The production and use of cordage at the early Neolithic site of La Draga (Banyoles, Spain). Quaternary International (2016)
31. Pétrequin, P. L'architecture lacustre duNéolithiquemoyen II au Nord-Ouestdes Alpes: lescontraintesdu milieu, de l'organisation sociale et desmodes de faire-valoiragricoles. Bulletin de la Société préhistoriquefrançaise, 367–389 (1988)
32. Calvano, M. and Sacco, M. Dalla Forma Al Bim. Progettare Con I Modelli Informati - From The Form To Bim. Designing With Informed Models. In 3D Modeling&Bim, Empler, T. (Eds.), pp. 362–374. Sapienza University of Rome (2016)
33. Calvano, M. and Casale, A. Il modello integrato e la conservazione dell'immagine della città. In 17th CIRIAF National Congress (2017)

3D Modeling Applications to Terracotta Figurines from Plakomenos, Greece

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Abstract In the last ten years, 3D technologies have proliferated in archaeology with multiple applications, both in the field and the lab. The pace of development is very rapid and constitutes a paradigm shift. 3D modeling is becoming an indispensable tool and is transforming the field. So far, analysis of artifacts has relied on direct physical access to objects, 2D representations (photographs and drawings), and written descriptions. However, the growing popularity of 3D technology has established that a 3D model of an artifact provides a superior record, compared to 2D products. The 3D model closely approximates the experience of the original (Payne in Necrocorinthia. A study of Corinthian Art in the Archaic period, Oxford, [1]). High-fidelity 3D digital artifacts can bridge the gap in quality of data available to researchers. Also, they can be disseminated widely, which facilitates and encourages scholarly collaboration. Here, we will explore the application of 3D modeling to a particular category of artifacts, terracotta figurines of the Archaic period (7th–6th centuries BCE) from the site of Plakomenos, in Greece.

Keywords 3D modeling · Terracotta figurines · Archaic period · Plakomenos · Greece

1 The Site of Plakomenos

The site of Plakomenos is located in southern Greece, in the NE Peloponnese, in Corinthia, in an olive grove (Fig. 1). The olive grove is on a hillside, in the foot of the mountain Koukougeras, on the south side of the Phliasian plain. Several archaeological sites are nearby, including: Phlious, a classical city state where excavations have

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Fig. 1 Location of the site of Plakomenos in NE Peloponnese

revealed part of the acropolis; the site of Aidonia, where a cemetery of Mycenaean chamber tombs is currently under excavation; Petri, an Early Helladic settlement, which has been partially excavated; Agia Eirini, a site dating to the Middle Helladic and Mycenaean periods. Further away, to the East, is Archaia Nemea, the site of a Panhellenic sanctuary dedicated to Zeus. There, athletic competitions, similar to the Olympics, were taking place every two years. Overall, the Phliasian plain is rich in archaeological sites dating back to the prehistoric period (Fig. 2). The reasons for the wealth of archaeological remains is twofold: (1) The area is of strategic importance because the main routes of communications pass through the region, connecting the Argolid and Corinthia with the central Peloponnese. (2) It is a fertile valley, especially suitable for vineyard cultivation, which predominate in this region today.

This is an agricultural area, so, cultivation and related activities often lead to the disturbance of archaeological strata and discovery of new sites. This is what happened at the site of Plakomenos. In 1998, during an archaeological surface survey carried out by the University of Heidelberg, a field was identified which produced rich surface finds, primarily fragments of terracotta figurines and pottery. Subsequently, the Archaeological Ephoreia of Corinthia was notified and a small scale rescue excavation was carried out. The rescue excavation was limited to the collection of the archaeological finds which had been brought to the surface. In 2003, the rescue excavation continued, in the northwestern part of the field, where the density of archaeological finds was very high. The excavation yielded a large number of terracotta votive figurines and miniature votive vessels. The finds were not in situ, they were found in a compacted layer, in a channel, formed by water flow (Figs. 3 and 4). The channel followed the meandering flow of water; thus, it became apparent that the original location of the finds was higher up. Unfortunately, it was not possible to identify their original position, due to the limited scale of the excavation. We

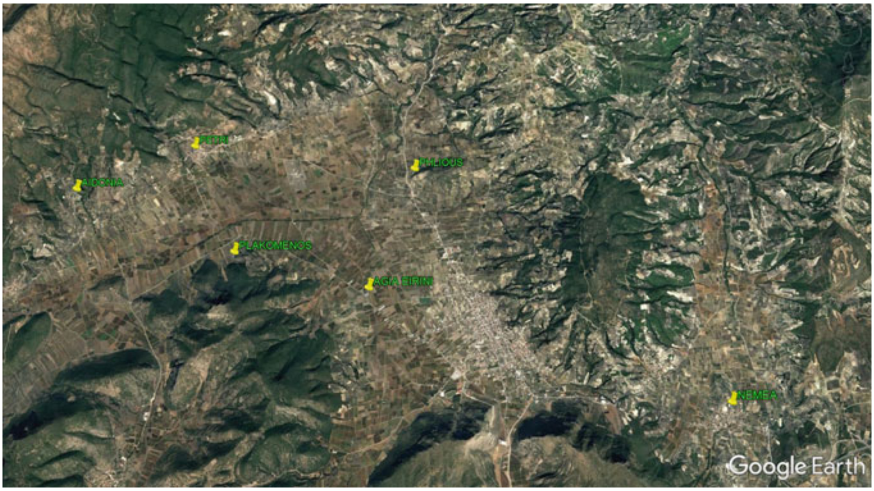

Fig. 2 Location of the site of Plakomenos in relation to other archaeological sites in the area

Fig. 3 Female terracotta figurine in situ

hope that future excavations will provide more information. The field had undergone significant modifications in order to build a terrace, using mechanical means, and the deposits (fill) had been seriously disturbed.

Fig. 4 The compacted layer of the finds

2 Brief Presentation of the Finds—Main Types of Figurines

It is clear that the finds came from a sanctuary votive deposit. There is a large number of terracotta votive figurines and miniature votive vessels which date to the Archaic period, from the end of the 7th century to the middle of the 5th century BCE. The majority of the finds date to the 6th century BCE. Since the artifacts were not found in situ, but had been carried down by water flow, they were found in a compacted layer, mixed and often stuck together, the one inside the other, while parts of the same object were found in different locations. In spite of this, it was possible to collect and salvage a large number of artifacts. The ceramics consist of miniature votive vessels, with very few fragments of large vessels. The most common shapes are: *kotylai*, small *skyphoi*, *kalathiskoi*, and *pyxides* [1]. Many of these are preserved complete. A unique find is a fragment of a black-glazed *skyphos* with a votive graffito to Aphrodite, which indicates that the sanctuary was dedicated to the goddess. The graffito has been inscribed from left to right on the black glaze, underneath a hunting scene (Fig. 5). Unfortunately, the graffito does not preserve the name of the dedicant.

The figurines form the largest group of the finds and belong to a variety of types. More than 1500 figurines are preserved nearly complete. An additional 3000 fragments were collected. The majority represent female figures, most in sitting but also in standing position. There are figurines that represent males, mainly horse riders (Fig. 6), a few standing naked male figures (Fig. 7), dancers forming a circle, animals such as rams and turtle, furniture, boats, kilns and armor/weapons. Several figurines preserve remnants of a white slip and occasionally traces of red and black colors. A

Fig. 5 Skyphos with the votive graffito to Aphrodite

unique find is a miniature apsidal building (temple?) which is nearly complete. Its back side is apsidal while the front is open with a column supporting the roof. In its interior, there are two hand-made standing figurines with bird-shaped heads and long dresses. In front of them are two sitting lions which are depicted in simplified form.

The majority of the female figurines are hand-made. Some are made in a mold. A number of them combine a hand-made body with a mold-made head. The seated figures have thrones whose back legs consist of two cylindrically shaped protrusions from the body. The lower edges of the figure's long dress form part of the throne's support. The body is flat without much detail. The arms, which probably were extended toward the front, are rarely preserved. There are two common types, one with hand-made head and a second with molded head. The hand-made figurines have bird-shaped faces; their facial features are given without much detail. The eyes are added separately, along with the top of the head and the area behind the shoulders. The head is embellished with a *polos* (cylindrical crown) and the chest with one or two breast-bands, fastened with disc-shaped pins. The waist is pinched in (Fig. 8). The mixed type of figurines shows greater variety (Fig. 9). They have similarities with the bird-faced figurines (one or two breast-bands) but overall they have a wider variety of decorative elements. They are embellished with earrings, and necklaces with one or three pendants; they have more breast-bands across the chest, some in wavy form, and others rope-like. The dress is fastened on the shoulder with decorative pins, in a variety of shapes, which in some cases appear as floral decoration. The hair is more elaborate and depicted in relief, with braids of hair falling behind the shoulders (Fig. 11) [2].

The figurines from Plakomenos are similar to figurines from major sites in the NE Peloponnese, such as Argos, Tiryns [3] and Perachora [4]. They may represent imports from these areas, where figurine production was well-established, or they

Fig. 6 Terracotta figurine of a horse rider

may be products of a local workshop that imitates these well-known types. The seated goddess type, known as Tirynthian Argive, is widespread in the Peloponnese, and although there are some typological differences, it is common in many areas. The closest area with similar finds is a votive deposit from Phlious, excavated in 1924 by the American School of Classical Studies [5]. The main difference is that the Phlious deposit yielded fewer female figurines; the most common type is that of the horseman, along with male naked figurines with bird-faces and/or molded-heads. In addition, in Nemea, at a distance of approximately 700 m east of the temple of Zeus, a deposit which is known as the Rawson deposit was excavated by Oscar Broneer in 1925. It contained 10 Tirynthian Argive terracotta figurines, along with 1000 miniature votive vessels [6]. Terracotta figurines were used for cultic purposes. They were frequently offered by worshippers in shrines and sanctuaries of various deities, seeking health and fertility or to thank the gods [7]. They are among the earliest and most abundant figural symbols used in ancient Greece going back to the Neolithic period.

The majority of the Plakomenos figurines belong to the seated female type. It is believed that this type, at first, was representing goddess Hera, since it has been found in the Argive Heraion and in shrines close to Argos. Later, the type spread to the northeastern Peloponnese and became a generic representation of a female deity. Argos and Corinth were well-known for the production of terracotta figurines

Fig. 7 Terracotta figurine of a naked male figure

[8]. However, the figurines were produced in several locations in the broader region, as local workshops started imitating these well-known types, using similar manufacturing techniques. In Plakomenos we know from the graffito that the shrine was dedicated to Aphrodite, the goddess of Love (Eros) and nature, who also has many different characteristics as *Ourania* (Heavenly) or *Pandeimos* (for all the people) [9]. However, the large number of horses and riders found at Plakomenos indicates that, probably, a male deity or hero was worshipped there as well. There are no written references mentioning this sanctuary, so it is through archaeological research that we will be able to establish the identities of the worshipped deities. The ongoing study of this well-preserved and varied material will provide us with information about local ritual practices and evolving religious beliefs. Furthermore, it will allow us to reconstruct the interaction of local communities and their participation in economic and social networks throughout the region.

Fig. 8 Female figurine with bird-shaped face

2.1 3D Modeling

After an overview of the archaeological context and the finds, we report next on the ongoing experimentation with a 3D modeling method, laser scanning, and its application to the archaeological collection from Plakomenos. This is a pilot study of a small selection of figurines, in order to explore the value of 3D modeling to the study and dissemination of this material. The 3D models were created with a NextEngine 3D laser scanner. It is a portable, affordable scanner, suitable for small to medium-sized artifacts. The NextEngine projects laser stripes onto an object. A triangulation technique is used to calculate the distance of each point, generating a 3D model. This method is faster compared to others, as the four twin laser arrays allow multiple points to be scanned at once [10, 11]. The scanner generates 3D point clouds and records texture as well. It is equipped with twin 3.0 Megapixel CMOS image sensors for texture recording in color mode [12]. The texture is not high resolution, it is inferior to the texture that image-based methods such as photogrammetry provide.

Fig. 9 Female figurine of mixed-type

However, this equipment produces high-fidelity models in a fraction of the time required for photogrammetric processing.

Multiple views are needed to create a complete model. The model requires editing (trimming, aligning, fusing) and, depending on the complexity of the object, it can take from half hour to two hours for a complete edited model (Fig. 10). The models are accurate, with a precision of 0.13–1.66 mm [12]. The 3D laser scanner records surface lines, indentations, breaks, imperfections, etc. that may facilitate many different types of analysis (e.g., manufacturing methods, hand-made vs. mold-made parts). Thus, the specific traits of the NextEngine 3D desktop laser scanner make it very useful to archaeological research, since it is lightweight, affordable, easy to operate and relatively accurate. Furthermore, the laser scanner produces models that capture all the detail of the figurines. The details in the rendering of the facial features, the clothes, and hair-style are clearly visible (Fig. 11). We find that the Matcap rendering provides the most detailed view/information about the figurines.

Because of the considerable variability, the detailed features are important for the classification and dating of the figurines. The 3D models allow full rotation, which

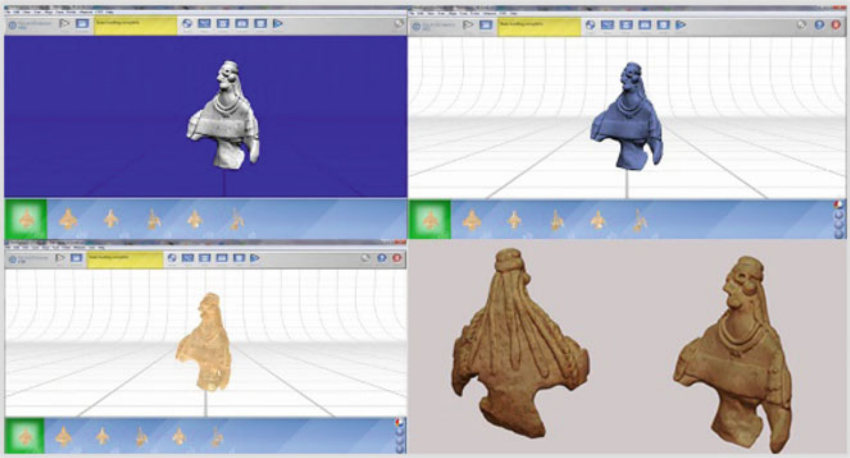

Fig. 10 Viewing options in 3D Scanning software (ScanStudio) and Matcap rendering in Sketchfab

offers an advantage in examining the features in the front, back and side views. This is a superior form of visualization that cannot be achieved to the same extent through photographs and drawings. The 3D models can also assist in reconstructing partially preserved figurines through digital restoration of fragmented specimens. Thus, the 3D models represent high-fidelity depictions of the figurines and allow detailed inspection and study. Another significant advantage is that they offer the opportunity to study the material remotely, without the limitations associated with a visit to the local museum where the finds are stored. In addition, the digital versions of the figurines can be studied without handling the real artifacts, which prevents further deterioration, especially because many of them are fragile. Thus, the act of creating a 3D model is a step towards digital preservation [13]. A 3D model can potentially serve as an enduring record of an artifact. Furthermore, the 3D models allow us to accomplish more effectively the documentation of variability in this archaeological collection; they facilitate typological classification, development of a database, and comparison with similar finds from other areas. The 3D models presented here are currently available on sketchfab (sketchfab.com/search term: plakomenos) (Fig. 12).

As the collection of 3D models from Plakomenos expands, we plan to develop a digital library that will make this material widely available. Similar digitization efforts are being undertaken for collections of figurines from Cypriot excavations [14–16]. Future directions may include the development of dedicated applications for further exploration/interaction with the digitized figurines. Clearly, the analysis of artifacts, their digital preservation, and dissemination are benefiting substantially from 3D technology. Accurate 3D models of artifacts are becoming an invaluable resource. These technologies enable us to present the material in an engaging manner, they facilitate analysis, interpretation, and sharing of results. They are generating

Fig. 11 3D models views

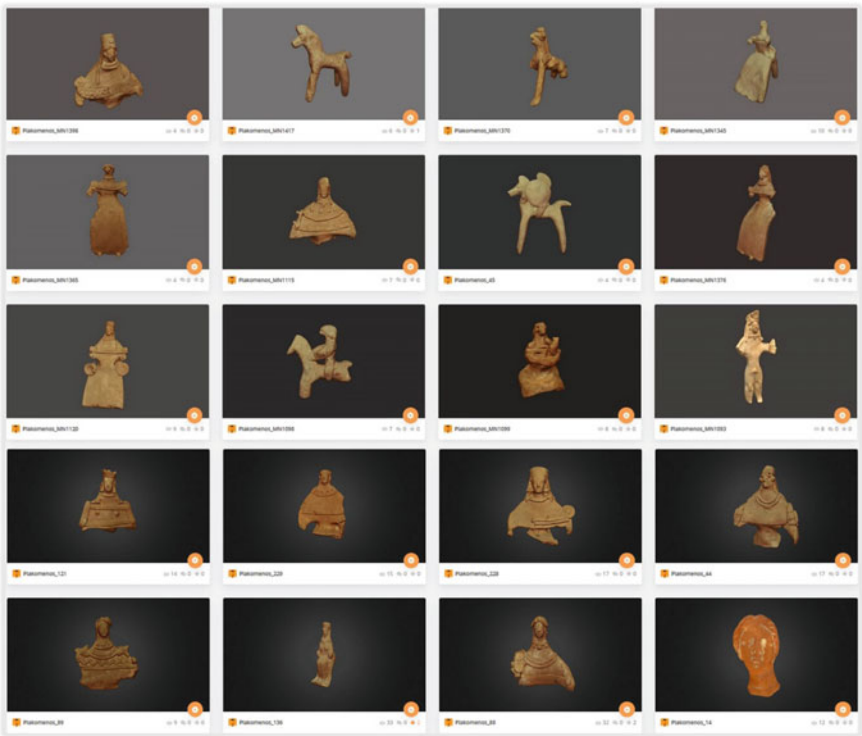

Fig. 12 Group view of Plakomenos 3D models

novel kinds of datasets and are rapidly altering well-established archaeological practices relying on 2D documentation.

These technologies are creating a new category of objects, "digital surrogates" which have their own independent reality, and require their own documentation and explanation. "Digital surrogate" is a term used in libraries and archives to refer to any digital representation of a work that exists in the physical world (a thumbnail, a metadata record, a digital image). More commonly, however, the term indicates a faithful digital copy that seeks to represent an analogue original as accurately and in as much detail as possible [17].

Many questions remain, as we are still assessing the impact of digital technologies. For example, the longevity of these datasets remains uncertain, as storage space requirements, support of current digital infrastructure, and long-term data accessibility and preservation are matters that do not have standardized solutions, yet, rather require extensive ongoing dialogue and collaboration. Laser scanners and other 3D modeling methods can facilitate a wide variety of tasks in archaeology, such as the digital reconstruction of artifacts, the creation of virtual typologies, digital extensions of museum exhibits, or the creation and use of replicas in preservation and teaching [18], [19]. We hope that the application of these methods to the material at hand will assist in the documentation of representative types of figurines from Plakomenos with visually effective means, the identification of local workshops, and the reconstruction of patterns of circulation in NE Peloponnese. Furthermore, these digital tools will enhance the study, presentation, preservation and sharing of this significant archaeological collection.

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References

1. Payne H.: Necrocorinthia. A Study of Corinthian Art in the Archaic Period, Oxford (1931)
2. Waldstein, C.: The Argive Heraeum II, Boston, (1905) 16–37
3. Frickenhaus A., Tiryns-Die Ergebnisse der Ausgrabungen des Instituts I. Die Hera von Tiryns, Athens (1912)
4. Payne, H. et al.: Perachora. The Sanctuaries of Hera Akraia and Limenia. Excavations of the British School of Archaeology at Athens, 1930–1933, I. Architecture, Bronzes, Terracottas, Oxford, (1940) 191–255
5. Biers W.R.: Excavations at Phlius, 1924: The Votive Deposit, Hesperia 40, (1971) 397–423
6. Barfoed, S.: The Mystery of the Seated Goddess: Archaic Terracotta Figurines of the Northeastern Peloponnese. In Thomasen, H., A. Rathje and K. Bøggild Johannsen (eds.): Vessels and Variety: New Aspects of Ancient Pottery, Danish Studies in Classical Archaeology, Acta Hyperborea 13, Museum Tusculanum Press, University of Copenhagen, (2013) 85–105
7. Croissant F.: Identication d'une déesse: questions sur l'Aphrodite argienne, In C. Prétre, Le donateur, l' offrande et la déesse: systèmes votifs dans les sanctuaries de déesses du monde grec: actes du 31e colloque international organize par l' UMR Halma-Ipel (Université Charles-de-Gaulle/Lille 3 décembre 2007) Liège, 181–202
8. Stillwell, A.N.: The Potters' Quarter: the Terracottas, Corinth XV2, Princeton, NJ, 1952
9. Williams, C. II: Corinth and the Cult of Aphrodite, In M.A. Del Chiaro- W.R. Biers, Corinthiaca. Studies in Honor of Darrell A. Amyx, Columbia (1986) 12–24
10. Brown, J. Innovation at home – Inside a 3-D desktop scanner. Electronic Engineering Times, 27 September (2010) 48–49
11. White, S. Virtual Archaeology – The NextEngine Desktop Laser Scanner. Archaeology International 18 (2015) 41–44. DOI:http://dx.doi.org/10.5334/ai.1804
12. Polo, M E and Felicísimo, A. M. Analysis of Uncertainty and Repeatability of a Low-Cost 3D Laser Scanner. Sensors 12 (2012): 9046–9054. DOI:http://dx.doi.org/10.3390/s120709046
13. Olson B. R. and Placchetti, R. A.: A Discussion of the Analytical Benefits of Image Based Modeling in Archaeology. In: Olson B. R. and Caraher W. (eds.): Visions of Substance: 3D Imaging in Mediterranean Archaeology, The Digital Press @ the University of North Dakota (2015) 17–26
14. Counts, D., Averett, E., and Garstki, K.: A fragmented past: (re)constructing antiquity through 3D artefact modelling and customised structured light scanning at Athienou-Malloura, Cyprus. Antiquity 90 (2016) 206–218
15. Papantoniou, G., Loizides, F., Lanitis, A., and Michaelides, D.: Digitization, Restoration and Visualization of Terracotta Figurines from the 'House of Orpheus', Nea Paphos, Cyprus. In: Ioannides M. et al. (eds.): EuroMed 2012, LNCS 7616, Springer-Verlag Berlin Heidelberg, (2012) 543–550

16. Vassallo, V.: A 3D Digital Approach to Study, Analyse and (Re) Interpret Cultural Heritage: the Case Study of Ayia Irini (Cyprus and Sweden). In Campana, S., Scopigno, R., Carpentiero, G. and Cirillo, M. (eds.): Proceedings of the 43rd Annual Conference on Computer Applications and Quantitative Methods in Archaeology (2016) 227–232
17. Rabinowitz, A. The Work of Archaeology in the Age of Digital Surrogacy. In Olson, B R and Caraher W R Visions of Substance: 3D Imaging in Mediterranean Archaeology. The Digital Press @ The University of North Dakota (2015) 27–42
18. Kaneda, A. Application of a Low Cost Laser Scanner for Archaeology in Japan. 22nd CIPA Symposium, Kyoto, Japan, October 11–15, 2009
19. Simon, K. M., Payne, A. M., Cole, K., Smallood, C. S., Goodmaster, C. and Limp, F. Close-Range 3D Laser Scanning and Virtual Museums: Beyond Wonder Chambers and Cabinets of Curiosity? Computer Applications and Quantitative Methods in Archaeology (CAA), Williamsburg, Virginia, March 22–26, 2009

Virtual Collection of Cuneiform Tablets as a Complex Multilevel System with Interdisciplinary Content

Petr Zemánek, Jana Mynářová, Petra Štefcová and Jaroslav Valach

Abstract The contribution deals with the architecture of a virtual collection of cuneiform tablets, conceived as a complex system combining and integrating several domains of information obtained from various types of analyses. The collection, containing some 400 Old Assyrian tablets from the excavations of Bedřich Hrozný in Kültepe (Turkey, ancient Kanesh) and originating in a narrow chronological window (ca. 20th–19th century BCE), is a special type of pottery with additional layer of textual information in cuneiform script. The digitization of the collection includes the digital models of the artifacts (3D models, stereometric and standard photographs, Structure-from-Motion), but also additional data on individual objects (physical properties, such as dimensions, colour, shapes, composition). The textual part is made available via standard methods of corpus linguistics and philological data is grouped together for some important attributes (persons, goods, links). The data stemming from the collection is connected with external data, placing the database in the context of cultural and historical development.

Keywords Cuneiform tablet · Virtual collection · Multi-disciplinary database · 3D digital models · Old assyria

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1 Introduction

A cuneiform tablet is an object made of clay on which textual information is present, and they are in general ancient, very roughly dating from the late fourth millennium BCE to the second century CE. As such, they represent a special type of pottery, where the most precious information is rendered on their surface in a rather subtle manner easily undergoing damage, not only due to the age of the artifacts, but also due to improper handling. The layer bringing most information on the past is the most vulnerable one.

The collection consists of ca. 400 cuneiform tablets from the Old Assyrian period (level II) excavated in Kültepe (ancient Kanesh, Turkey) by Bedřich Hrozný and is almost entirely homogeneous in the sense that it comes from one location and a rather narrow chronological layer (ca. 20th–19th century BCE). From the point of view of the content, the majority of the tablets represent correspondence among the members of the ancient Assyrian society, connected with the Old Assyrian trading network [1, 2]. Personal memoranda (contracts) among members of the society represent another important genre, in this case the tablets may exhibit some additional features, namely an envelope and seals.[1] The textual edition of the collection is accessible in [4],[2] 2D photographs are available at https://cdli.ucla.edu/collections/prague/prague_en.html. The collection is part of the Inscriptions cunéiformes du Kultépé (ICK) series; the number of Old Assyrian tablets altogether reaches ca. 23,000 tablets.

The priority aim of the virtualization of the collection is to preserve the physical collection in digital form in order to diminish to an absolute minimum direct contact, which might cause their wear-out. The second aim is to offer a powerful tool for both administration and further analysis of the collection as a whole, and its internal and external relations, as well as to enhance the research by making the collection available to the public and introducing elements of the digital humanities approach. This tool should help both in preserving the collection and in positioning it within a broader context. Thus, the task can be understood as an effort to bring together (and interconnect) as much relevant information on the collection and its position in a wider frame as possible.

When compared with other initiatives in the digitization of cuneiform tablets,[3] our focus is not just on the creation of digital models or a creation of textual corpus, but also the possibility to offer data useful for the maintenance of the collection,

[1]The contracts in this collection are written on a clay tablet which is folded in a plate of clay (envelope); on its surface the type of the contract is mentioned, and the two contractual sides add an imprint of their personal seals [3]. An example can be found at [https://cdli.ucla.edu/dl/photo/P359969.jpg] for the tablet and [https://cdli.ucla.edu/dl/photo/P359969_e.jpg] for the envelope of the same tablet.

[2]The editors have omitted some of the tablets, cf. [4: XXIV]. Some of them can be found in [3].

[3]The most important being Cuneiform Digital Library Initiative [https://cdli.ucla.edu/], Open Richly Annotated Cuneiform Corpus [http://oracc.museum.upenn.edu/], Digital Hammurabi Project [http://pages.jh.edu/~dighamm/index.html]. Cf. also [http://www.cuneiform.de/]. Other projects concern with analysis issues, such as Cuneiform Analyzer [5] or GigaMesh [6]. For an advanced employment of 3D visualization cf. [7].

as well as for the study of its position in the Old Assyrian society, and the creation of possible links to other similar collections. The binding of the database with the material artifacts is also a pivotal difference from other types of databases used in humanities, such as D-Place [8] or Seshat databank [9]; another difference lies in the focus on the concentration of various types of information in the tablets and making this data as explicit as possible. In this sense, the project aims both at museological and research utilization of the resulting database, and the basic aim of the project is to offer a complex rendering of the tablets with new technologies to help the preservation of the collection and open it to (further) research. Another important aim is to provide metainformation on the tablets as well as their position in the Old Assyrian society and its position in today's study of the Ancient Near East. The resulting system is supposed to enable the administration of the collection, enhance its preservation and open access to the further exploitation of the collection in a variety of ways by non-invasive methods. A basic overview of the architecture of the database is available in [10].

2 Domains of Description

The basic unit of analysis is the tablet itself as the constituting element of the collection and as a material object with many possible information layers connected to it. The data consists of several layers of description, where information from various types of research are brought together. As the information on the past is necessarily fragmentary (the objects are ca. 4000 years old) and the tablets are very often damaged,[4] the combination of various types of data is supposed to overcome at least some of the problems of incompleteness. This is also connected with the need of fields of comments for each data item in the database, and strict distinguishing between acquired data and interpretations.

The database represents an interplay of several domains of the analysis of the collection. Although the division into domains is somewhat artificial from the point of view of the final shape of the database (in which there should be no significant obstacles for combinations of various types of information from various domains), in the analytical stage, it reflects roles assigned to the teams within the project. The basic domain includes data that identify the object together with the description of its physical properties. The second domain offers the digital models of the object and can be seen as the principal level enabling the digitization of the collection, providing graphical information on the object. The next domain comprises the description of the layer provided by textual/visual information; in case of the cuneiform tablets, this means the level of the text, sometimes extended by seal impression(s) contained on the tablet's surface. This layer can be compared to e.g. collections of coins,

[4] An example of a well-preserved tablet from our collection is [https://cdli.ucla.edu/dl/photo/P359935.jpg]; a severely damaged one can be found at [https://cdli.ucla.edu/dl/photo/P359958_e.jpg].

inscriptions or manuscripts, but it can also cover various types of decorations on the objects, etc. The last domain brings the information on the position of the object within the society that created the artifact, its purpose, function, etc.

2.1 Domain of Basic Information and Physical Properties

The first domain in our list is the one dealing with typical information necessary for a museological praxis. Its role is twofold: the unique identification of the object within the sample, but possibly also within a greater set of similar collections. The next task is the provision of the basic types of the object's properties, such as weight, measures, colour, volume, etc. Another part of this domain involves methods of non-destructive analysis, such as optical microscopy or X-ray fluorescence, and both methods have their further usage in the analysis of the collection.

As opposed to traditional types of such analyses of other collections of cuneiform tablets, we follow rather strict procedures that are supposed to ensure that the resulting data is reliable and transferable to other databases. The selected measurement procedures are supposed to meet high standards of precision within reasonable effort. Such methods are briefly described below.

Colour characterization. The typical way of subjective decision based on some colour scheme was replaced by a more precise way of colour definition. For measuring the colour, a spectrophotometric method has been chosen. We use a mobile spectrophotometer (X-Rite RM200QC) that measures the object under eight different light sources and one UV LED source with nine wave-bands, which ensures a higher precision as opposed to models working only with the RGB spectrum. In order to obtain a relevant number of data, 6–8 or 8–12 measurements are taken (in accordance with the tablet size). As a base, the RAL K7 Classic colour guide has been used, and the results of the measurement are expressed by the values of ΔL, Δa, Δb (deviation from colour standard); the average values are visualized in the CIE 1976 standard. This data is then stored in the database, both in the form of a diagram of chromaticity and the base values (L, a, b). Although the collection is supposed to be rather homogeneous (correspondence and contracts within limited time and space), the variation of colour within the collection is rather high. From the measurements concluded until now, there are seven groups of colouring identified so far, consisting of various types of grey, beige and yellow.

Composition of the tablets. The application of XRF methods in order to reveal the element structure of the objects yields interesting results even on a rather small sample (ca one quarter) of the collection. We use a micro X-ray fluorescence spectrometer Artax 400 (by Bruker), which is a mobile μXRF spectrometer for in situ measurements without the limitations of the size of the object. It is possible to focus the analyzed spot by means of CCD camera and a laser beam. The results are evaluated by means of several methods (mathematical/statistical analysis: multivariate analysis, cluster analysis, discriminant analysis [11, 12]; corresponding analysis: analysis of two variables arranged in a contingency table, resulting in a correspondence map

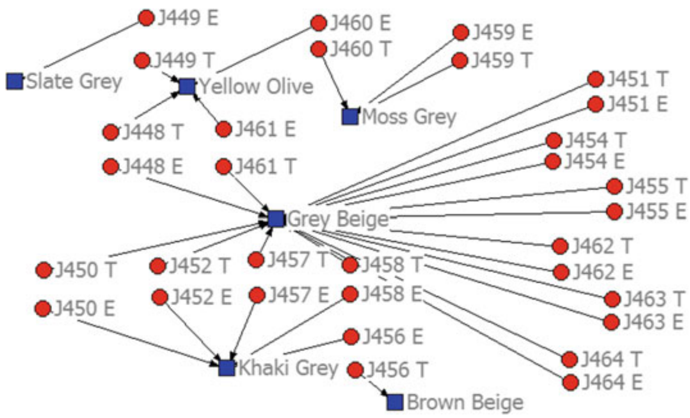

Fig. 1 Scheme of the colour correspondence of tablets (labelled with *T*) and their envelopes (*E*). In the sample of 16 tablets, in 9 cases the colour of the tablet and its envelope is not shared, although a strong correlation is in this case expected

representing the relations of the variables [13]. Several proprietary programs have been produced by team members for processing the results [14]. The comparison of data for individual tablets shows that the collection consists of several groups characterized by common properties of clay composition (Fig. 1).

These methods are supposed to reveal the element structure of the clay and by themselves, they constitute an independent branch of investigation. The usage of the results is manifold—from purely museological purposes, such as storage requirements, to various types of analysis purposes (e.g., links among clay types, locality, scribe, actors).

2.2 *Domain of Digital Models*

The production of digital models is nowadays very widespread. The models produced within this project include several types of the rendering of graphical information. It can be said that without this type of information, the current way of digitization of collections would not exist, and it has additional importance in case of the cuneiform tablets, where proper visualization is crucial.

The photographs of the tablets (available also within the CDLI project, https://cdli.ucla.edu/collections/prague/prague_en.html) represent the traditional part. These offer the basic and traditional type of graphical information. Another type of graphical information are the autographs, i.e. drawings of the tablet surface produced by specialists (in our case, the autographs come from [4: Tafel I—CLX]). As the digital photos of the tablets can be completely superseded by the higher types of models

Fig. 2 Digital model of surface topography of cuneiform tablet separated from its colour is rendered in a simulated illumination enhancing shapes of signs (left part of figure). The 3D model is acquired by photometric stereo technique. The same area of the same tablet captured by focus stacking technique of digital photographs is shown for comparison on the right. Such a visualization is capable of substituting a direct contact with the tablet

(2.5D, 3D), the autographs retain their importance as they carry also the interpretational level—an opinion of an expert who had the tablets physically available.

Within the project, new models are produced, and all of them bring spatial information. These models can be divided into two types. The first one is represented by models based on laser triangulation, photometric stereo (PS) and Structure from Motion (SfM), i.e. models sometimes described as 2.5D. True 3D models (i.e., including the image of the inside of the object) are obtained by means of fine-grained Computer Tomography (CT) methods with extreme resolution[5]; all of these models (2.5D and 3D) can be combined. The PS and SfM models bring a smoother and more detailed picture of the surface together with colour information, while the CT models offer information on the inner structure of the object (tablet). This scanner can be used in digitization of other similar collections (Fig. 2).

It is worth mentioning that the CT-based models do not function as mere digital objects used in the representation of the collection but are very useful for both the collection maintenance and research. The true 3D modelling reveals the inner structure of the tablets and enables a better choice of the best measures for the correct conservation of the artifacts within the collection. The research purposes

[5]For the models, we currently use the equipment called TORATOM [15, 16]. Within the project, a mobile version of the equipment is being developed.

include especially palaeographic utilization, where the interaction of the shape of the tablet's surface (in any rate of magnification) and variable simulated lightning of the object offers new possibilities in the analysis of the cuneiform writing; e.g., the sequence of the individual wedges within a sign can be traced.

The possibility of the re-arrangement of the graphical information in a variety of ways adds significantly to the use of this information in the research, as the combination of various types of representation can significantly help with various types of tasks.

2.3 Domain of Linguistic and Philological Description

The textual information available on the tablets is dealt with basically within the tradition of cuneiform studies and corpus linguistics. The importance of philology in case of ancient languages is crucial, as the data is available only directly from the texts and no feedback from native speakers is possible. This requires space for various types of notes and alternative analyses, especially in damaged contexts. The aim of the analysis is to meet the demands of the discipline, but also to provide the texts in various formats used by today's linguists and philologists.

The intention is to provide an accessible representation of the text in all its details. The representation must be readable both for humans and machines and must allow for a detailed (linguistic and philological) analysis of the text, the graphemic system used, the reconstruction of damaged parts (both on the level of a single grapheme and the whole text), and to offer an analysis of the content of the texts (Fig. 3).

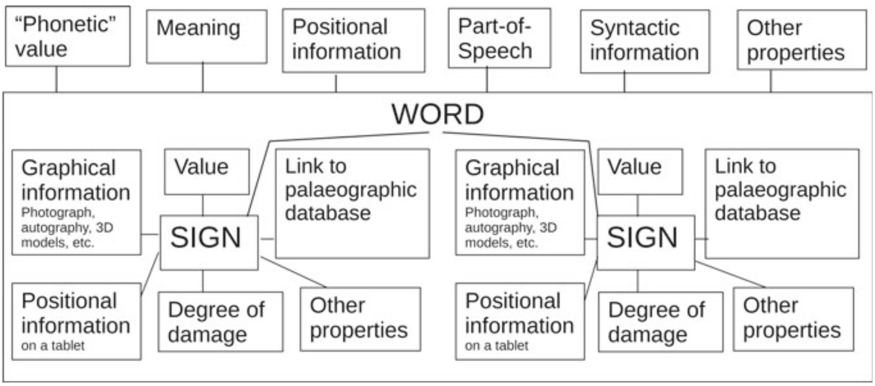

Fig. 3 Example of the sign-oriented architecture of the linguistic description. The *sign* is the basic element at which the description starts and the *graphical information* is most usable, as well as the *degree of damage* or *link to palaeographic database*. Joining of signs into *words* creates a new level of description. E.g., in case of the word for 'silver', the *values* of individual *signs* are KÙ and BABBAR, brought together they form a word with a different "*phonetic*" *value* (*kaspu*). Standard linguistic description starts only at this level

The focal point of this domain is a text written on a tablet. The text is coded in the Unicode standard (UTF range 1200-123FF for cuneiform, 12,400-1247F for cuneiform numbers and punctuation) and in transliteration into Latin script according to the ORACC project [http://oracc.museum.upenn.edu/]. Although the two renderings of the text (cuneiform and transliteration) should be equivalent, for the purposes of the analysis, the sign-oriented approach is preferred. In this sense, parallels with Chinese or Japanese corpus linguistics can be drawn [17–19]. As the texts are mostly of a unique character (correspondence and contracts that were issued in one or two copies), any damage to the text is difficult to recover, in addition to the fact that the texts are written in an ancient and fragmentarily attested language. This means that substantial portions of the texts can be damaged (partially or completely missing), and some parts of existing texts can be understood differently by today's scholars. As a result, the transfer from the cuneiform script to current systems must offer the possibility of alternative interpretations.

The linguistic analysis includes both morphological information (parts of speech) and syntactical ones. Syntax is treated according to the Universal Dependency standard [20], which enables a comparison with other languages. Translation of the original text is of great importance with ancient languages. These are organized by means of parallel corpora techniques.

The analysis of the palaeography will result in a palaeographic database. The variability of signs within the collection is rather high, in spite of the fact that the sample is otherwise homogeneous (archives of several tradesmen). Every sign, including its individual variants, in the collection is described, with a concordance of its appearances. The numbering of signs follows a standard sign list provided by [21] and contains also a definition of the position of the signs on individual tablets, as well as information on their diagnostic features.

The philological part of this domain will cover various types of other information, mostly derived from the collection (corpus) itself. One of the most important tasks is the identification of the persons that took part in the relations reflected by the tablets (correspondence or contracts), as well as the definition of their roles. The flow of goods between geographical locations as well as their prices can be mapped. At the same time, it is clear that such tasks might demand external information as well.

2.4 Domain of Cultural Context

This domain gathers information from external sources. Currently, we have identified several areas where the connection of the database with external data sources is desirable.

From the point of view of the textual information, the connection with other sets of Old Assyrian documents presently studied is crucial. Such a connection could offer important comparisons regarding the content, but also the style of the letters and contracts (personal memoranda), which could further aid to obtain a more structured view of life in the Assyrian trading centres. There are many textual editions of such sources; unfortunately, the corpus of Old Assyrian texts (The Old Assyrian Text Project [http://oatp.ku.dk/].) that used to join them, is currently not accessible, and one of our aims is to help revive this activity.

A similar type of connection is the palaeographic database.[6] A detailed analysis could shed more light on the use of the script in the colonies, but alternatively also bring important information on the possible link between the Old Assyrian texts and the later cuneiform tradition of the Hittites. Preliminary investigation seems to point to an extensive variability of individual signs reflecting possible individual preferences and/or traditions of the respective tradesmen writing their messages on their own.

There is also historical information available. The concept of the Assyrian trade network has been mentioned above [1, 2], which means that the integration of this database with other sources of information on this network is important. The network derived from the collection can help in comparing the flow of goods, price level and types of contacts.

Geographical information contained in the letters (and contracts) needs to be completed with a map of locations in Anatolia. Such a map can also contain additional data, such as demographic information, communications between the cities, etc.

This part of the database is the most open one. It can be expected that many new possibilities of connections will appear in the future, as the process of digitization of other collections will progress.

3 Integrated Multi-disciplinary Database

The resulting database intends to bring together the types of data mentioned above. It is certainly necessary to distinguish data, metadata and analyses, but on the other hand, there should be no technical obstacles in joining the data from multiple domains. It should allow to pose multi-disciplinary queries combining knowledge gathered in separate domains. The database will also provide a user interface for the research community in order to access the accumulated information. As much data as possible will be made available via an internet browser.

It is to be hoped that such an approach will lead to new discoveries on the collection and its position within society, as well as to provide a tool for a more reliable solution of complex tasks that were so far solved only within a single discipline. The added value can be seen in several examples offered below.

The identification of fakes: several tablets from the collection have been labeled as fakes by some scholars [4: XXIV], based on the analysis of the handwriting. However, other attributes of a given tablet may be in line with the attributes of the other tablets (e.g., clay composition, tablet shape, or stylistic characteristics). This might point in a different direction, showing that the (somewhat peripheral) community developed a complex specific style, formed from diverse (family?) traditions.

[6] For a general overview of the current state of the art in cuneiform palaeography, cf. [22].

The identification of a scribe is traditionally based on palaeography (cf. the example above), but there are several other attributes that can be expected as characterizing. It can be surmised that a (professional) scribe will be defined not only by his handwriting style. Other attributes that can be taken into consideration in connection with this type of craft may include: the technique of tablet preparation (processing of clay, shape, measures in relation to the amount of text, etc.); the clay composition (well-tried source of clay); the linguistic style characteristics, but also a certain circle of persons that used the service of the scribe, and possibly other features.

Many other similar examples of possible analyses based on cross correlation of the data could be added. In our opinion, such types of analyses are in line with the current turn to the exploitation of digitized data. The connection with other types of databases created in the field (in its broad understanding) ensures the usability of the database in the future.

4 Conclusion and Future Work

The project dealing with the collection of cuneiform tablets shows that the integration of data coming from various fields can be useful in several ways, starting from the maintenance of the collection itself to various ways of publishing the content of the collection and opening it to scholarly research.

Already in a rather early stage, it can be seen that the data from various fields bring interesting correlations usable in the research. New hypotheses can be supported by a number of data that were not combined together before, and old hypotheses can be re-examined on the basis of cross-related data.

For future work, the primary aim is to fill in the whole database: currently, about one fourth of the collection is processed. However, the most important and possibly the most difficult task will be to ensure that the combination of a number of data will work smoothly together. This is inevitably connected with existing standards, which in some cases may mean that we will strictly follow a certain standard, or, in other cases, that the system is able to export the data in the desired format. The choice is sometimes driven by the given task (e.g., generation of data for EUROPEANA [23], the specification of Universal Dependencies or parallel corpora), sometimes the project brings its own way of data acquisition (e.g., colour characterization) and the creation of interfaces is important. Another task in this direction is the merger of data acquired within the project with data from other, external sources, especially within cultural context domain.

The digitization of the collection means also the possibility of creating links to other such collections, especially the ones from Old Assyria. Such links among related collections could lead to a virtual space concentrating knowledge on some particular place or period in history and could bring a better understanding of the past. Apart from purely technical sustainability (which is in our case guaranteed by Charles University and the National Museum in Prague and by adherence to standards), this is another opportunity to keep the information derived from the collection being used within the scholarly discourse on the Old Assyrian society.

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References

1. Larsen, M.T.: Ancient Kanesh: A Merchant Colony in Bronze Age Anatolia. Cambridge University Press, New York (2015)
2. Barjamović, G.: The Geography of Trade. Assyrian Colonies in Anatolia c. 1975–1725 BC and the Study of Early Interregional Networks of Exchange. In: Dercksen, J.G. (ed.), Anatolia and the Jazira during the Old Assyrian Period, Old Assyrian Archives, Studies 3, PIHANS 111. Nederlands Instituut voor Het Nabije Oosten, Leiden (2008), 87–100
3. Matouš, L., Matoušová-Rajmová, M.: Kappadokische Keilschrifttafeln mit Siegeln aus den Sammlungen der Karlsuniversität in Prag. Karlsuniversität in Prag, Praha (1984)
4. Hecker, K., Kryszat, G., Matouš, L.: Kappadokische Keilschrifttafeln aus den Sammlungen der Karlsuniversität Prag. Univerzita Karlova, Filozofická fakulta, Praha (1998)
5. Fisseler, D., Weichert, F., Müller, G., Cammarosano, M. Extending Philological Research with Methods of 3D Computer Graphics Applied to Analysis of Cultural Heritage. 12th Eurographics Workshop on Graphics and Cultural Heritage (GCH) (2014), 165–172
6. Mara, H., Krömker, S., Jakob, S., Breuckmann, B. GigaMesh and Gilgamesh – 3D Multiscale Integral Invariant Cuneiform Character Extraction. Proceedings of the 11th International Symposium on Virtual Reality, Archaeology and Cultural Heritage (2010), 131–138
7. Fisseler, D., Müller, G.W., Weichert, F. Web-based Scientific Exploration and Analysis of 3D Scanned Cuneiform Datasets for Collaborative Research. Informatics 4.44 (2017)
8. Kirby, K.R., Gray, R.D., Greenhill, S.J., Jordan, F.M., Gomes-Ng, S., Bibiko, H.-J. et al. D-PLACE: A Global Database of Cultural, Linguistic and Environmental Diversity. PLoS ONE 11(7) (2017): e0158391
9. Turchin, P., Currie, T.E., Whitehouse, H., François, P., Feeney, K., Mullins, D. et al. Quantitative historical analysis uncovers a single dimension of complexity that structures global variation in human social organization. Proc. of the National Academy of Sciences December (2017)
10. Valach, J., Štefcová, P., Brůna, R., Zemánek, P. Multidisciplinary Information System of Assyrian Cuneiform Tablets Enhancing New Research Possibilities via Heterogeneous Data in Records. Int. Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLII-2/W5 (2017), 703–706
11. Uchida, E., Niikuma E., Watanabe, R. Regional Differences in the Chemical Composition of Cuneiform Clay Tablets. Archaeological Discovery 3 (2015) 179–207
12. Goren, Y., Mommsen, H., Klinger, J. Non-destructive provenance study of cuneiform tablets using portable X-ray fluorescence (pXRF). J. of Archaeological Science 38.3 (2011), 684–689
13. Pillay, A.E., Punyadeera, C., Jacobson, L., Eriksen, J. Analysis of Ancient Pottery and Ceramic Objects using X-Ray Fluorescence Spectrometry. X-Ray Spectrometry 29 (2000) 53–62
14. Brůna, R. Tablet analysis support software. https://github.com/KyomaHooin/Kanesh
15. Fíla, T., Vavřík, D. A multi-axial apparatus for carrying out X-ray measurements, particularly computed tomography. European patent EP2835631. Granted 24.02.2016
16. Fíla, T. et al. Dual energy X-ray micro-CT imaging of hybrid Ni/Al open cell foam. Journal of Instrumentation 11 (2016), C01005

17. Bond, F., Baldwin, T. Introduction to Japanese Computational Linguistics. In: Bond, F., Baldwin, T., Inui, K., et al. (eds.). Readings in Japanese Natural Language Processing. CSLI Publications, Stanford (2016), 1–28
18. Zoe, B., Smith, S., Hoey, M. Corpus Linguistics in Chinese Context. Palgrave Macmillan, London (2015)
19. Bramanti, A. Rethinking the Writing Space: Anatomy of Some Early Dynastic Signs. In: Devecchi, E., Müller, G.G.W., Mynářová, J. (eds.): Current Research in Cuneiform Palaeography. Proceedings of a Workshop organised at the 60th Rencontre Assyriologique Internationale, Warsaw 2014. PeWe Verlag, Gladbeck (2015), 31–47
20. Nivre, J., Agić, Ž. et al. Universal Dependencies 2.1. LINDAT/CLARIN digital library at the Institute of Formal and Applied Linguistics (ÚFAL), Faculty of Mathematics and Physics, Charles University (2017) (available online, https://lindat.mff.cuni.cz/repository/xmlui/handle/11234/1-2515, 9.4.2018)
21. Borger, R. Mesopotamisches Zeichenlexikon. Zweite, revidierte und aktualisierte Auflage. Ugarit Verlag, Münster 2010
22. Devecchi, E., Müller, G.G.W., Mynářová, J. (eds.): Current Research in Cuneiform Palaeography. Proceedings of a Workshop organised at the 60th Rencontre Assyriologique Internationale, Warsaw 2014. PeWe Verlag, Gladbeck (2015)
23. Doerr, M. et al.: The EUROPEANA data model (EDM). In: Proceedings of the 76th IFLA General Conference and Assembly, Gothenburg, Sweden (2010), 9 (https://www.ifla.org/past-wlic/2010/149-doerr-en.pdf)

The Potentials of the Digital Cultural Heritage: A Best Practice Example of Presentation and Use. The Digital Representation of the Hans Gross Kriminalmuseum

Bernadette Biedermann

Abstract The project Repository of Styrian cultural heritage (Wissenschaftserbe website) studied aspects of museum documentation and presentation by asking how digital methods can strengthen the use of digitisation of tangible cultural heritage. One of the participating partners was the Hans-Gross-Kriminalmuseum, a collection within the cross-faculty platform university museums (überfakultärer Leistungsbereich Universitätsmuseen) at University of Graz (university museum website). The project was realized in cooperation with the Center for information modelling offering the technical knowledge and undertaking the implementation to provide (meta)data online. In this context, this paper addresses the question of the significance of digital technologies for presentation and use of tangible cultural heritage by the example of a special case study. It acts on the assumption that presentations of museum objects in the virtual space cannot compete with real museum exhibitions, as they cannot replace an encounter with the original object. Therefore virtually represented collection complexes are also tools for expert users to research and for non-expertusers to browse through the collection. This paper demonstrates these presuppositions using the example of the physical museum collection of Hans-Gross -Kriminalmuseum at the University of Graz.

Keywords Potential of digital cultural heritage · Digital museology · Museum documentation standards · Museum presentation museum database · Use cases

1 Introduction

Digitization of *Hans-Gross-Kriminalmuseum* [1], a collection which is part of the complex *University Museums* at *University of Graz, Austria* [2], studied in the context of the cross-faculty project *Repository of Styrian Cultural Heritage* [3] aspects of museum documentation and presentation by asking how digital methods can be applied and enlarged by museological theory and vice versa. The digitization process

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of the *Hans Gross Kriminalmuseum* should thus serve as best practice example for presentation and use of the digital cultural heritage.

This is why in the context of this cooperation project between the *University Museums* and the *Center for Information Modelling* [4] at *University of Graz* museological theory [5] was combined with the methods of the digital humanities [6].

In the context of the conference *Digital Cultural Heritage* held in Berlin, Germany, from 30th of August till 1st of September 2017 (*DCH2017*) [7] the lecture presented with the same title as this paper primarily addressed the question of the significance and the potential of digital technologies for presentation and use of tangible cultural heritage by using the example of museum collections respectively the digitization process of *Hans Gross Kriminalmuseum*.

This paper enlarges on the presentation in Berlin with the addition of the theoretical background referring both to the theory of museology and to the research paradigm of digital humanities. Against this background it focuses in detail on the digitization and documentation process also within the project workflow of the project *Repository of Styrian Cultural Heritage* of which *Hans Gross Kriminalmuseum* was part and the outcome of which was a cross-organizational database [8] with the title *Webportal Cultural and Scientific Heritage of Styria* (in German *Kultur- und Wissenschaftserbe Steiermark*) [9] This paper also focuses on its digital presentation and use respectively on forms of online presentations of digital cultural heritage by integrating discussions taken place in the context of the presented lecture at the international conference *DCH2017* in Berlin.

To achieve this aim, an overview on museological theory and the methods of digital humanities first provides insights into the theoretical background, and the paper then continues by referring to the history of the *Hans Gross Kriminalmuseum* in the context of the project *Repository of Styrian Cultural Heritage*; furthermore, it presents the documentation process and workflow in detail and this is followed by a description of the forms of digital (re-)presentation in virtual space. These forms also go hand in hand with aspects of using the collection as a best practice example for presentation and use of digital cultural heritage. Finally, the paper concludes with the potentials of digital cultural heritage for museums and users which are also extending beyond the presented project.

2 Theoretical Background

Within the workflow and corresponding to museological theory various museum presentations serve various objects and also the needs of their visitors. Displaying objects in physical space is generally diametrically opposed to the key objective of preserving important historical material for a very long time. In the context of this proposition classic and virtual presentations have specific characteristics and can serve various purposes. Since virtually open access presentations have the potential to address users independent of time and place they clearly provide an answer to specific visitor needs. Furthermore, virtually represented collection complexes can be especially useful when employed as tools for expert user research, while they are also valuable in allowing non-expert users to browse through collections which for various reasons cannot be displayed in physical space. Digital presentation can as a result thus also help to extend the physical preservation lifetime of many frail or easily damaged objects. This is why the paper basically proceeds from the assumption that presentations of museum objects in virtual space are not in competition with classic museum exhibitions in physical space, since they cannot replace nor bring an encounter with the original object [10].

To serve visitor needs and also to reach visitors in a specific manner objects have to correspond to specific visitor interests and attitudes on objects. As a consequence the approach of general museology is derived from and acts in accordance with the theory of museality which is defined as a "relation between man and his reality by which he realizes and decides in accordance with society which parts of the surrounding natural and arranged world are able to act as witnesses to this reality and are thus worthy to be systematized, researched, mediated and traded as bearers of this relation" [11]. According to this theory, an object can stand witness for several events, persons or circumstances which are proven within a scientific hermeneutical and inter-subjective process [12]. Additionally objects can also have relations to several dates and places. Because of the attributed quality museality, the object becomes a *nouophor* and therefore a bearer of sense and meaning for a special society in the context of a special historical period [13]. Of course, objects are also significant in terms of their materiality [14] or symbolic meaning [15].

Of special importance is the act of the object's musealization [16] which goes hand in hand with its documentation as well as the object's context information respectively its history or biography. According to this museological point of view the value of an object is intrinsically linked to its context information and dependent on its documentation status. Thereby, the significance of museum documentation standards lies in the support given systematically to structural information by logical structures. Such standards also emphasize the significance of the need for objects being intrinsically linked to their contextual information, which in a further consequence is especially important for museum presentations [17].

Since the presented project was realized in cooperation between the *University Museums* and the *Center for Information Modelling* at *University of Graz*, in terms of digital standards and technologies methods of digital humanities it appeared appropriate to apply to this workflow. In the course of the presented museum digitization project museological theory was linked to the methods and the research paradigm of digital humanities. This research paradigm is focused on modelling information content and describing, managing and visualizing metadata primarily to humanistic texts sources. Digital methods use mostly XML-based standards to model, transform and visualize information and in a further consequence to exchange and intercommunicate information [18]. In doing so they annotate data semantically, process data and analyze texts, which are mostly based on XML-standards. Controlled vocabulary serves to structure information by knowledge systems and enrich as "open linked data" the semantic web [19]. By this means digital humanities provide metadata online for presentation and use almost open access which is corresponding to the open GLAM initiative [20]. They also provide data for digital long-term preservation either by databases or repositories. The digital humanities are able to enlarge their research focus ever more fully from text sources and also to museum objects for which this project example has a leading role.

3 Hans Gross Kriminalmuseum Within the Context of University Museums and the Project Styrian Cultural Heritage

The *Hans Gross Kriminalmuseum* founded in 1896 by Hans Gross [21] was one of the participating project partners within the cross-faculty and cross-organizational project R*epository of Styrian Cultural Heritage* [22], and a collection housed by the C*ross-Faculty Platform University Museums* (*überfakultärer Leistungsbereich Universitätsmuseen*) at *University of Graz* [23]. The group known as the *University Museums* also include both the *UniGraz@Museum*, housing a collection of historical-physical objects and also providing space for temporary exhibitions on current themes [24] and an exhibition center, the *Haus der Wissenschaft*, which presents exhibitions on various science-related topics [25].

The founder of the *Hans Gross Kriminalmuseum*, Hans Gross, who was a coroner and a professor of criminal law, began to collect criminological objects as *corpora delicti*. He believed that these objects provide significant and tangible evidence for special crime facts and that objects can act as real evidence, for instance in specific criminal cases [26]. In his opinion objects were more reliable evidence than witness statements. Based on this study students were trained on items documenting criminal cases. In addition to weapons, projectiles and toxins, animal and human specimens (such as shattered bones and blood stains) completed the fundus.

This approach corresponds with the museological theory based on museality. In the context of this object-theory Hans Gross was one of the pioneers at the beginning of the 20th century, although this theory was first established in the context museology more than half a century later in the 1960s and first published by the Czech philosopher Zbynék Z. Stránský in 1971 [27].

The merit of Gross is especially linked to the significance he established in the field of scientific criminology. This is why he is also known as the *father of criminology* [28]. An installation in the context of the *Austrian Conference on Contemporary History* at *University of Graz* in 2016 [29] pointed out that the adoption of Hans Gross' at the *University of Graz* was for long linked to the tradition of German nationalist thinking. The installation was thus titled *Bitte umhängen* (please, put on) and intended to both move visitors and to make them reflect on the issue of German nationalism [30].

Within the project workflow objects and parts of the archival material of *Hans Gross Kriminalmuseum* underwent a musealization and a documentation process. In this context the objects were documented and digitalized. The *Center for Informa-*

tion Modelling of *University* at *University of Graz* offered the necessary technical infrastructure and undertook the implementation to provide (meta-) data (online). The implemented infrastructure is an asset management system for the humanities known as *GAMS* [31], a repository for the long-term preservation and presentation of digital cultural heritage.

The workflow was also part of and coordinated in the context of the cross-faculty project *Repository Styrian Cultural Heritage*. Several Styrian (university) collections were documented and digitalized within this project [32] and one of the project aims was to present object data open access and for this reason to install an online platform with the title *Webportal Cultural and Scientific Heritage of Styria* (in German: *Kultur- und Wissenschaftserbe Steiermark*) [33]. This portal gives open access to an online repository where users can browse through the digitized collections. It is also hosted by the *Center for Information Modelling* of *University of Graz* [34].

The stakeholders involved in the *Hans Gross Kriminalmuseum* digitization project consisted on the one hand of the museum staff [35] handling the objects and collecting data. In cooperation with the responsible persons employed at the *Center for Information Modelling* [36] data were transformed and prepared for online presentation. A group of students [37] was also involved and these were participants in the joint degree Master Program in the study year 2015/16 with the title *EuroMACHS* which stands for *European Digital Media and Cultural Heritage Studies* [38]. This Master Program was also offered by the *Center for Information Modelling* of *University of Graz* and since the winter term 2017/18 has been raised to the status of a Master Degree of Digital Humanities [39].

4 Digital Documentation and Data Collection

Within the documentation and data collection process of *Hans Gross Kriminalmuseum* respectively the project workflow around 2300 objects and additionally 700 photographs and glass slides were documented. As additional source material, about 2000 historical index cards and about 1000 documents have been compiled and written. These documents are originally archival material from the criminological institute and encompass court documents and portfolios of statements of facts which complement, at least partially, the object inventory and show that objects were originally evidence for special criminal cases.

On the basis of this source material and the encountered documentation status of the collection it was challenging from a museological point of view to develop a structure consisting of a consistent data model and template. Added to this, the objects and the source material had not been registered uniformly until then. To edit the data, a specific approach to structure and formalize information had to be developed within the framework of data standards [40] and the characteristics of the existing documented sources.

The project work flow thereby encompassed the documentation process by implementing a multi-perspective view on the objects. According to this, to the approach of Hans Gross as well as to museality, the digital *Hans Gross Kriminalmuseum* should serve also the purpose to represent object relations to events by linking representatives of objects, sources, metadata and standardized vocabulary to each other [41].

To implement the workflow the objects were on first site treated by a conservator who also packed them for the transport into a storage magazine. In a second step data fields were established referring to already existing data and also to data which was possible to gather within the workflow. Subsequently the primary data were gathered consisting of object name, material, dates, measurements, condition (damages), short object description, cleaning and packing dates. Within this workflow every object was linked to a unique and ongoing inventory number whereby historical inventory numbers—if available—were also stored. The same procedure was established for the names of objects. A special category installed by Hans Gross, structuring objects into 32 aspects concerning their relation to crime cases respectively their original use in relation to a criminal case was also integrated into the process of data collection [42]. For the other mentioned categories such as the object name, dates, condition, damages, packing, cleaning and notes free text input was first used. Additionally a special category referring to the condition of the object in terms of their exhibition capability was established.

Additionally, every object was linked to material and object categories, for which two thesauri [43] were established referring to already existing thesauri which is for English speaking regions the *Getty Arts and Architecture Thesaurus* [44] and for German speaking regions the *Oberbegriffsdatei* established in cooperation with *Deutscher Museumsbund* [45].

After the process of data collection and object manipulation, the data was structured and organized in a formal manner. At the same time the objects had to be allocated and kept in a museum storage facility. This was necessary, because large-scale renovation of *University of Graz*. Related to the content this meant to especially formalize object data referring to the established categories and also to the developed thesauri to be presented as a further consequence in a formalized way by the methods of digital humanities. The process of formalizing object data was managed on first sight by means of an excel-style spreadsheet in which a special column was set for every data category. This style spreadsheet provided the basis for transforming data into XML-based standards, like *LIDO*, *SKOS* and *TEI*. *LIDO* which stands for *Lightweight Information Describing Objects* [46] is a standard for describing museum objects as also a data harvesting format to exchange museum object data. Both thesauri were designated in *SKOS* which stands for *Simple Knowledge Organization System* [47]. Every concept was first referenced in German and English by a specific identifier and also reference is given—if it was possible in terms of translation—to the mentioned already existing *Getty* thesauri. A special reference was also given to the *CIDOC-CRM* [48] by defining the objects as biological or man-made. The index cards were referenced with the standard *TEI—Text Encoding Initiative* [49]. In this way complete project data is based on XML (standards). Of course high resolution digital images in *III-F* [50] built a project standard in terms of visual object representations.

If objects could be contextualized, and if a relation to other objects could have been made in the order of their history or narration referring to a specific scene of crime, the objects were linked to additional source material like index cards, photographs and glass slides. By this means a multi-perspective view on objects was established to be presented in a further consequence on the webpage. This multi-perspective view refers not only to the concept of museology but is also reflected in the mentioned *Conceptual Reference Model* (*CRM*) [51], developed by *CIDOC*, the *International Committee for Documentation* respectively the *Documentation Standard Working Group* [52] of ICOM, the *International Council of Museums* [53]. This shows that every object can have many different relations to persons, dates and circumstances.

This multi-perspective object view established by data collection and followed by linking objects also determines in further consequence the interoperability of the webpage. This view is also supported by the mentioned controlled vocabulary [54] which was also integrated into the web page *Cultural and Scientific Heritage of Styria* of the project *Repository of Styrian Cultural Heritage*. In this way a multi-layered perspective of objects could be offered for users, which at the same time is significant for a best practice example for presentation and use of digital cultural heritage. This aspect overlaps with the claim that objects consist of multiple meanings and polysemic entities [55].

In addition to the process of data collection and preparation for presentation a special group of objects formed the basis for a storytelling narrative, or respectively for the presentation of a curatorial view of the objects. For this reason a special group of objects was selected: Archival, source material and secondary literature should be available and it should be a more or less clear and closed group of objects. Concerning these aspects, a group of objects related to poaching was selected by the curator. This group of objects served as example to be researched by the group of students of the EuroMACHS Master Program referred to above, during the study year 2015/16 [38].

In this context a kind of a virtual tour on the history of poaching in Styria was developed with the students. Beginning with object data, archival material and also secondary literature concerned with poaching in Styria was reflected on and a concept for a virtual tour was developed. Objects were linked to additional materials and presented in form of a storytelling or narration on the webpage. Thereby texts and images together with additional materials had to be prepared.

The object data was documented and recorded by this means for purposes of long-term data preservation, which is also hosted by the repository *GAMS*. The project has recently ensured adequate storing and preservation of the material as well the context information related to the collection. It was thus necessary to design the content and the outline of the webpage and also to write the texts and prepare the necessary images. But it was not only the contents that had to be developed, the data also had to be transformed. For these purposes XSL-transformations stylesheets and templates were developed, transforming data managed by excel into the XML-standards *LIDO* and *SKOS*. All data is presented on the webpage on the basis of *CSS-Bootstrap* [56]. The virtual tour is presented by *Storymap-JS*, a javascript-based open source software [57].

5 Digital (Re-)Presentation

Based on the documentation and digitization process, the webpage of the *Hans Gross Kriminalmuseum* guides users through the virtual collection space respectively the digital representation of the collection complex. Therefore, a gallery of tiles [58] gives a short overview on the navigation on the webpage where users find short labels about the objects [59], the project on poaching [60], the history of the museum [61] and the categories defined by Hans Gross [62]. This presents a very special object which is the scene of crime suitcase made and used by Hans Gross on scenes of crimes [63], as well as the virtual tour on poaching [64].

The slides within the header section also give detailed information about the collection [65]. The slide history of the collections gives insights into the museum, the virtual collection, the biography of Hans Gross, the categories defined by Hans Gross, the crime scene suitcase as very special object again as well as an overview on literature about the history of the museum and the significance of Hans Gross especially in the context of criminology. The next slide gives insights into the poaching project by presenting a short description, listing the objects and the index cards related to poaching, giving a *Resource Discovery* on the example of index cards [66] together with a link to the virtual tour of poaching. This curatorial view or storytelling on poaching can be compared with a temporary exhibition in physical space [67]. The last slide presents the inventory by structuring objects into groups of chemicals, photographs, index cards, graphic training aids, objects and the pornographic collection [59]. Users can also browse through the collection by the 32 categories established by Hans Gross, also called *Hans Gross Categories* [59].

Not all of the gathered data is presented on the webpage, however, and users can see the inventory number, the object description, the object type and the material—both linked to the mentioned thesauri—the measurements, a permalink, Handle-Link and the licenses for further use and presentation of the data. A special object viewer presents the high resolution images to give users special insights of the object surface, which would not be possible in classic museum presentations. Users do not have insights into internal museum data, which is due to security requirements for the place of storage and also the detailed condition, packing and exhibition capacity dates.

A multi-layered perspective on objects is offered by hyperlinking objects with each other respectively with the various object types. Thus for example a fishing rod with the inventory number 490 [68] is linked to an index card which simultaneously documents the history of the fishing rod [69]. Each of these objects is also presented in open access by XML-standards such as LIDO [70] when there is either an object description or respectively TEI [71] appropriate text sources.

In full awareness of the fact that for installing a virtual museum it would for example require 3D-models and 3D-virtual tours through the physical collections the project team decided to name the digital representation *Virtual Collection* (in German *Virtuelle Sammlung*). This is why the name should represent primarily the multi-perspective view on objects which is in this special way only possible to achieve in the virtual space and which is enlarged by a virtual representation on poaching.

All object data is freely available for users open access via the web on GAMS since spring 2017 [65]. Additionally some object data was integrated into the web portal *Cultural and Scientific Heritage of Styria* (*Kultur und Wissenschaftserbe Steiermark*) [72]. This web portal presents an image and selected object data such as description, material, institution, collection, inventory number and a permalink. To see the full record a link to the virtual collection on GAMS is offered. The advantage of this web portal is that users can query all the represented collections.

6 Using the Virtual Collection

The presented forms of digital online representation of objects concerning *Hans Gross Kriminalmuseum* attempt to address several visitor needs. On the one hand expert users should find insights into the collection. Also non-expert users should find the information respectively the narration they are searching for. For more context information and depending on the various research questions users have of course the possibility to contact the museum staff. Therefore the digital presentation tries to address the needs of expert as well as of non-expert users.

According to types of museum presentation in the physical space which are especially temporary as well as permanent exhibitions this digital representations offers (meta-) data of the inventory (comparable with permanent exhibitions) as well as a virtual tour (comparable with a temporary exhibition) giving a curatorial view on the objects. This is why several perspectives of presentation are integrated into the digital representation.

Data is freely available independent of opening hours and space, since this is implicit for open access versions. Users can therefore consume information focused on own interests and browse through the context information, object data and storytelling. Thereby users can participate depending on the information level they want to achieve. Controlled structured vocabulary serves the purpose to give a special semantic structure in advance.

7 Conclusion

The *Virtual Collection* of *Hans Gross Kriminalmuseum* represents the inventories open access online. Its purpose is to browse through the collection on own interests. Structured and controlled vocabulary thereby attempts to provide a possibility for knowledge organization. A multi-perspective view is offered by linking objects to each other and to other object types. The virtual tour gives a curatorial view in narrative form by telling a story, a method which is comparable with a temporary exhibition in physical space. Of course the images offered in high resolution by a viewer with a special zoom factor give special insights into object surfaces which cannot be offered in the context of physical displays. Additionally 3D-representations could also address extended visitor interests as well as multimedia offers like film and audio files related to the objects or the collection complex. The *Virtual Collection* of *Hans Gross Kriminalmuseum* thus shows a best-practice example of presentation and use of Digital Cultural Heritage in the virtual space.

Further potentials of the digital cultural heritage lie in the possibilities offered by the virtual space in the context for example, of turning the tables and studying the visitors or the users themselves. User behavior of online collections could be compared to visitors of physical collections to give new insights into the use of online presentations. Moreover, extended controlled vocabulary by integrating museological aspects has potential not only within the context of documentation but also of presenting and structuring information for users respectively visitors. The *University Museum* of *University of Graz* is thus establishing cooperation with the CIDOC working group on the topic of controlled vocabulary and thesauri.

Potentials for physical presentations respectively classic museums are also given by integrating digitization and hyperlinking objects into classic museums.

References

1. See Hans Gross Kriminalmuseum website: https://kriminalmuseum.uni-graz.at/de/ [16.3.2018].
2. See University Museum website: https://universitaetsmuseen.uni-graz.at/de/ [16.3.2018].
3. See Project website: https://wissenschaftserbe.uni-graz.at/de/zum-projekt/ [16.3.2018].
4. Centre for Information modelling website: https://informationsmodellierung.uni-graz.at/ [16.3.2018].
5. For museological theory see: Waidacher, F.: Handbuch der Allgemeinen Museologie. 3rd edn. Böhlau, Wien Köln Weimar (1999); Stránský, Z.Z., Museology as a Science. In: Museologia, vol. XI, no. 15 (1980), pp. 33–40; in differentiation to other museological approaches see: Desvallées, A. and Mairesse, F. (eds.): Key Concepts of Museology, Paris (2010), pp. 53–56, see online: http://icom.museum/fileadmin/user_upload/pdf/Key_Concepts_of_Museology/Museologie_Anglais_BD.pdf [19.3.2018].
6. For digital humanities see for example: Cartner, B.: Digital humanities. Current perspectives, practices and research. Emerald, Bingley (2013); Kurz, S.: Digital Humanities: Grundlagen und Technologien für die Praxis. Springer-Verlag, Wiesbaden (2015); Schreibmann, S. and Siemens, R. G.: A new companion to digital humanities. Wiley Blackwell, Chichester West Sussex UK (2016); Jannidis, F., Kohle, H. and Rehbein, M.: Digital Humanities. Eine Einführung. J. B. Metzler, Stuttgart (2017).
7. The conference with the title “Digital Cultural Heritage International Conference took place in Berlin (Germany) from 30th August till 1st September. See online: http://interdch.net/DCH2017/ [16.3.2018].
8. See Cultural and Scientific Heritage of Styria website online: http://gams.uni-graz.at/archive/objects/context:pardus/methods/sdef:Context/get?locale=en [15.3.2018].
9. See online: http://gams.uni-graz.at/archive/objects/context:pardus/methods/sdef:Context/get?mode=&locale=en [17.3.2018].
10. For this thesis see in detail: Biedermann, B.: ‘Virtual museums’ as digital collection complexes. A museological perspective using the example of Hans-Gross-Kriminalmuseum (University of Graz), in: Museum, Management and Curatorship, Vol 32, No 3, 2017, pp. 281–297, Routledge/

Taylor and Francis (2017), online: http://dx.doi.org/10.1080/09647775.2017.1322916 (https://doi.org/10.1080/09647775.2017.1322916).
11. Waidacher, F.: Handbuch der Allgemeinen Museologie. Böhlau, Wien Köln Weimar (1999), p. 723.
12. Stránský Z.Z.: Der Begriff der Museologie, In: Muzeologické sešity, supplementum 1. Einführung in die Museologie. Brno (1971), pp. 14–39; See also: Reisinger, N.: Musealisierung als Theorem der Museologie. Zur Musealisierung von Großobjekten und Landschaften am Beispiel der Eisenbahn und des 'Südbahnmuseums Mürzzuschlag'. In: Curiositas. Jahrbuch für Museologie und museale Quellenkunde, Bd. 12–13, Leipzig and Langenweißbach (2013), pp. 55–68.
13. Waidacher, F.: Sachen oder Wörter oder von der Mühe, Erinnerung zu bewahren. In: Geldner, G. (ed.), Der milde Knabe oder die Natur eines Berufenen. Ein wissenschaftlicher Ausblick. Oskar Pausch zum Eintritt in den Ruhestand gewidmet. Böhlau, Wien (1997), pp. 19–29, here p. 20.
14. Pearce, S. M.: Museum Studies in Material Culture. Leicester University Press, London (1989), pp. 1–10; Buchli, V. (ed.): The Material Culture Reader. Berg, Oxford (2002).
15. Pearce, S. M.: Museums, Objects and Collections. A Cultural Study. Leicester University Press, Leicester (1992); Marstine, J.: Introduction. In: Marstine, J. (ed.), New Museum Theory and Practice. An Introduction. Blackwell, Malden MA (2006); pp. 1–36; Carbonell, B. M. (ed.): Museum Studies: An Anthology of Contexts. Wiley, New York (2012).
16. Reisinger, N.: Musealisierung als Theorem der Museologie. Zur Musealisierung von Großobjekten und Landschaften am Beispiel der Eisenbahn und des 'Südbahnmuseums Mürzzuschlag'. Iin: Curiositas. Jahrbuch für Museologie und museale Quellenkunde, Bd. 12–13, Leipzig und Langenweißbach (2013), pp. 55–68.
17. Waidacher, F.: Museologische Grundlagen der Objektdokumentation. In: Institut für Museumskunde (ed.), Mitteilungen und Berichte aus dem Institut für Museumskunde, vol. 15, Berlin (1999); Deutscher Museumsbund (ed.): Leitfaden für die Dokumentation von Museumsobjekten – von der Eingangsdokumentation bis zur wissenschaftlichen Erschließung. Berlin (2011), see online: http://www.smb.museum/fileadmin/website/Institute/Institut_fuer_Museumsforschung/Publikationen/Materialien/LeitfadenDokumentation.pdf [19.3.2017]; see also LIDO (Lightweight Information Describing Objects) website: network.icom.museum/cidoc/working-groups/lido/what-is-lido/ [19.3.2018]; see also the Conceptual Reference Model (CRM) developed by the International Committee for Documentation (CIDOC) in the context of the International Council for Museums (ICOM): www.cidoc-crm.org/ [19.3.2018].
18. For digital humanities see basically: Cartner, B.: Digital humanities: current perspective, practices and research. Emerald, Bingley (2013); Terras, M., Nyhan, J. and Vanhoutte, E. (eds.): Defining digital humanities: a reader. Ashgate, Farnham (2013); Arthur, P. L. and Bode, K.: Advancing digital humanities: research, methods, theories. Palgrave Macmillan, Basingstoke (2014); Kurz, S.: Digital Humanities: Grundlagen und Technologien für die Praxis. Springer-Verlag, Wiesbaden (2015); Büttcher, S., Clarke, Ch. and La Cormack, G.V.: Information retrieval: Implementing and evaluating search engines. MIT Press, Cambridge MA (2016); Schreibmann, S. and R. G. Siemens: A new companion to digital humanities. Wiley Blackwell, Chichester West Sussex UK (2016); Jannidis, F., H. Kohle and M. Rehbein: Digital Humanities. Eine Einführung. J. B. Metzler, Stuttgart (2017).
19. Berners-Lee, T.: Linked Data (2006), see online: https://www.w3.org/DesignIssues/LinkedData [19.3.2018].
20. See Open GLAM website: https://openglam.org/ [19.3.2018].
21. Hans Gross Kriminalmuseum: https://kriminalmuseum.uni-graz.at/de/gruendung/die-sammlung/ [15.3.2018].
22. Head of the project was Vice-Rector Peter Scherrer, see online: https://wissenschaftserbe.uni-graz.at/de/zum-projekt/ [16.3.2018].
23. See Unigraz@Museum website: https://unigraz-at-museum.uni-graz.at/de/ [16.3.2018].

24. See website University Museums website: https://universitaetsmuseen.uni-graz.at/# [22.3.2018].
25. See Haus der Wissenschaft website: https://haus-der-wissenschaft.uni-graz.at/de/ [16.3.2018].
26. Bachhiesl, Ch.: Notizen zur Wiedereröffnung des Hans-Gross-Kriminalmuseums der Karl-Franzens-Universität Graz. In Historisches Jahrbuch der Stadt Graz, Vol 33, edited by Bouvier, F. and Reisinger, N. Medienfabrik, Graz (2003), 191–208.
27. Stránský, Z.Z.: Der Begriff der Museologie. In Muzeologické sešity, supplementum 1. Einführung in die Museologie, Brno (1971), pp. 14–39.
28. About Hans Gross see for example: Bachhisel, Ch., Kocher, G., Mühlbacher, Th. (ed.), Hans Gross - ein „Vater" der Kriminalwissenschaft. Zur 100. Wiederkehr seines Todestages. Austria: Forschung und Wissenschaft interdisziplinär, Vol. 12. LIT, Wien (2015); for additional literature see also: https://gams.uni-graz.at/archive/objects/context:km/methods/sdef:Context/get?mode=bibl [19.3.2018].
29. See Zeitgeschichtetag website: https://zeitgeschichtetag.uni-graz.at/en/ [16.3.2018].
30. See online: https://gams.uni-graz.at/archive/objects/context:km/methods/sdef:Context/get?mode=gross [16.3.2018].
31. See: Steiner, E. and Stigler, J.: GAMS and Cirilo Client. Policies, documentation and tutorial Graz (2017), online: http://gams.uni-graz.at/docs [15.3.2018].
32. See online: http://gams.uni-graz.at/archive/objects/context:pardus/methods/sdef:Context/get?mode=collections&locale=en [16.3.2018]; see also: https://static.uni-graz.at/fileadmin/veranstaltungen/zeitgeschichtetag/Zeitgeschichtetagfotos/DSC_0042.JPG [16.3.2018].
33. See online: https://informationsmodellierung.uni-graz.at/en/research/completed-projects/webportal-cultural-and-scientific-heritage-of-styria/ or http://gams.uni-graz.at/context:pardus [16.3.2018].
34. See Center for Information modelling website: https://informationsmodellierung.uni-graz.at/ [16.3.2018].
35. Head of University Museums: Nikolaus Reisinger; curator of Hans Gross Kriminalmuseum: Christian Bachhiesl, museological competence: Bernadette Biedermann, data collection: Stefan Köchel, Conservator: Barbara Schönhart.
36. Head of Centre for Information Modelling: Johannes Stigler, project coordinator: Elisabeth Steiner, Data Management: Carina Koch.
37. The project with the students was coordinated by Bernadette Biedermann. The participating students were: Anja Grabuschnig, Christian Höserle, Kerstin Hummelbrunner, Jonas Kerschner, Christopher Pollin, Elisabeth Pressl, Ana Reisman and Nijole Ukelyte.
38. See online: https://euromachs.uni-graz.at/de/ [16.3.2018].
39. See online: https://informationsmodellierung.uni-graz.at/en/studying/master-degree-digital-humanities/ [16.3.2018].
40. The project was especially referring to data standards LIDO and CIDOC-CRM; see online: http://network.icom.museum/cidoc/working-groups/lido/what-is-lido/ and http://www.cidoc-crm.org/ [20.3.2018].
41. Multi-perspective object view and objects as polysemic entities see Cameron, F.: Museum Collections, Documentation and Shifting Knowledge Paradigms (2005). In Perry, R. (ed.), Museums in a Digital Age. Routledge, London New York (2010), pp. 80–95; Cameron, F. R.: Digital Futures I: Museum Collections, Digital Technologies and the Cultural Construction of Knowledge. In: Curator: The Museum Journal 46 (3) 2003, pp. 325–340.
42. These categories are only available in German at the moment. See online: https://gams.uni-graz.at/archive/objects/context:km/methods/sdef:Context/get?mode=categories [16.3.2018].
43. Biedermann, B. (et. al.): Thesaurus for Materials, see online: http://gams.uni-graz.at/archive/objects/o:mth/methods/sdef:SKOS/get [15.3.2018]; Biedermann, B. (et al.): Thesaurus für Objektklassifikation| Thesaurus for object classification, see online: http://gams.uni-graz.at/archive/objects/o:oth/methods/sdef:SKOS/get [15.3.2018].
44. See website Getty Arts and Architecture Thesaurus: http://www.getty.edu/research/tools/vocabularies/aat/ [15.3.2018].

45. See Oberbegriffsdatei: http://museum.zib.de/museumsvokabular/index.php?main=download&ls=9&co=we&ln=de [15.3.2018].
46. See LIDO-Website online: http://network.icom.museum/cidoc/working-groups/lido/what-is-lido/ [16.3.2018]; for LIDO schema see online: www.lido-schema.org/schema/v1.0/lido-v1.0-specification.pdf [16.3.2018]; for XML-definition see: http://www.lido-schema.org/schema/v1.0/lido-v1.0.xsd [16.3.2018].
47. For SKOS see the W3C introduction: http://www.w3.org/2004/02/skos/ [16.3.2018] and the primer: http://www.w3.org/TR/skos-primer/ [16.3.2018].
48. See CIDOC-CRM website: http://www.cidoc-crm.org/Version/version-6.2 and http://www.cidoc-crm.org/technicalpapersPage [16.3.2018].
49. See online: www.tei-c.org/index.xml [16.3.2018].
50. See online: http://iiif.io/ [16.3.2016].
51. See online: www.cidoc-crm.org/ [16.3.2018].
52. See online: http://network.icom.museum/cidoc/ [16.3.2018].
53. See online: http://icom.museum/ [16.3.2018].
54. Biedermann, B. (et. al.): Thesaurus for Materials, see online: http://gams.uni-graz.at/archive/objects/o:mth/methods/sdef:SKOS/get [15.3.2018]; Biedermann, B. (et al.): Thesaurus für Objektklassifikation | Thesaurus for object classification, see online: http://gams.uni-graz.at/archive/objects/o:oth/methods/sdef:SKOS/get [15.3.2018].
55. Cameron, F.: Museum Collections, Documentation and Shifting Knowledge Paradigms. In Parry, R. (ed.): Museums in a Digital Age. Routledge, London New York (2010), pp. 80–95.
56. See online: https://www.w3schools.com/bootstrap/bootstrap_ref_all_classes.asp [16.3.2018].
57. See online: https://storymap.knightlab.com/ [16.3.2018].
58. Webpage and "Gallery of Tiles" on GAMS http://gams.uni-graz.at/context:km [16.3.2018].
59. See online: https://gams.uni-graz.at/archive/objects/context:km/methods/sdef:Context/get?mode=collection [16.3.2018].
60. See online: https://gams.uni-graz.at/archive/objects/context:km/methods/sdef:Context/get?mode=wilderer [16.3.2018].
61. See online: https://gams.uni-graz.at/archive/objects/context:km/methods/sdef:Context/get?mode=about [16.3.2018].
62. See online: https://gams.uni-graz.at/archive/objects/context:km/methods/sdef:Context/get?mode=categories [16.3.2018].
63. See online: https://gams.uni-graz.at/archive/objects/context:km/methods/sdef:Context/get?mode=case [16.3.2018].
64. See online: https://gams.uni-graz.at/o:km.story [16.3.2018].
65. See online: https://gams.uni-graz.at/context:km [16.3.2018].
66. See online: https://gams.uni-graz.at/archive/objects/query:km.wildererkk/methods/sdef:Query/get?mode=query [16.3.2018]. See especially: Christopher Pollin, Vom Suchen, Stöbern und Finden. Information Retrieval am Beispiel der Digitalen Sammlung des Hans Gross Kriminalmuseums. Master Thesis, Graz 2017.
67. For the virtual tour see: http://gams.uni-graz.at/o:km.story [16.3.2018].
68. See online: http://gams.uni-graz.at/o:km.8434 [16.3.2018].
69. See online: http://gams.uni-graz.at/o:km.1608 [16.3.2018].
70. See online: http://gams.uni-graz.at/o:km.8434/LIDO_SOURCE [16.3.2018].
71. See online: http://gams.uni-graz.at/o:km.1608/TEI_SOURCE [16.3.2018].
72. See online: http://gams.uni-graz.at/context:pardus [16.3.2018]; for objects data of Hans Gross Kriminalmuseum see: http://gams.uni-graz.at/archive/objects/context:pardus/methods/sdef:Context/get?mode=search&locale=en#!/?q=*&dct_isPartOf%5B%5D=Hans%20Gross%20Kriminalmuseum&x=0 [16.3.2018].

Planning for the End from the Start: An Argument for Digital Stewardship, Long-Term Thinking and Alternative Capture Approaches for Digital Content

Somaya Langley

Abstract Sustainability and continued access to digital cultural heritage, digital humanities content and research materials can be challenging. For any research project, available resources and dependencies set the limits for what is possible. In the digital environment, consideration of these limitations can tend to focus on the technological aspect. However, it is not just technology that ensures the success of a project or long-term access to digital content. Using the Three-Legged Stool Model for Digital Preservation (Kenney and McGovern in Digital Preservation Management: Implementing Short-term Strategies for Long-term Problems, 2003 [38]) (and other relevant models) provides an important foundation to ensure that any digital cultural heritage or digital humanities project is approached holistically. In addition, digital stewardship (Lazorschak in The Signal, 2011 [44]) should also be considered as an essential building block for digital cultural heritage and the digital humanities. Historically, questions of sustainability and ongoing access are often brought to the fore only as funding streams near their end, or as research project champions retire. Sustainability of digital content has been a topic of debate for many years (Bodleian Libraries in Digital Humanities Archives for Research Materials, Oxford, [2], Cantara in Longterm Preservation of digital humanities in OCLC Systems and Services 22:38–42, 2006 [10]). In recent years, the importance of sustainability is being further recognised, with research funding bodies requiring plans for long-term preservation and access as a part of applications for project funding, such as requiring the inclusion of this information in Data Management Plans (DMP) (UK Research and Innovation—Arts and Humanities Research Council in Research Funding Guide, 2019 [61]). The author advocates for creating specific technical information necessary for long-term preservation, as well as borrowing and adapting from other disciplines. While long-term preservation and access may have been considered from the outset, the author also argues that not enough is done to establish a digital stewardship framework approach. The Digital Preservation at Oxford and Cambridge (DPOC) project (2006–2018) (Digital Preservation at Oxford and Cambridge, 2016 [21]), provides the opportunity to look more holistically at how digitised and born-digital content is created, acquired, preserved and made available.

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At Cambridge University Library (CUL), a case study approach has been adopted, in order to better understand the needs of different ‘classes’ of digital content. Examples discussed include digitised fragments from the Taylor-Schechter Cairo Genizah Collection and the interactive data in the Kymata Atlas, illustrating two very different challenges of stewarding digital content. Through the case study research, the author and colleagues have identified that digital cultural heritage and digital humanities projects often develop a website or online resource as a mechanism for providing access to digital content project outputs. If not adequate planned for, digital content is at risk of becoming inaccessible after a project ends. Migration of files and various web archiving approaches are examined as possible preservation techniques, as well as other digital capture and documentation approaches more commonly used in contemporary art, time-based media and multi-platform archiving domains (Langley et al. in Proceedings of the 19th International Symposium on Electronic Art, ISEA 2013, 2013 [43]). Considering how to preserve and provide access to digital content right from the beginning of a project is essential. Taking a holistic digital stewardship approach—while learning from the lessons of past projects and borrowing from similar disciplines—can assist in better preparing for the end of a digital cultural heritage or digital humanities project.

Keywords Digital stewardship · Digital preservation · Digital humanities · Digital cultural heritage · Digital Preservation at Oxford and Cambridge · DPOC · Cambridge University Library · Migration · Web archiving · Video screen capture · Data management plans · Performing arts · Technical riders · Three-Legged Stool Model for Digital Preservation · Taylor-Schechter Cairo Genizah Collection · Kymata Atlas

1 Introduction

Long-term management of digital content, whether from the digital cultural heritage, digital humanities or another discipline, presents a variety of challenges. As is the nature of research funding, the ability to plan for the long-term is often hampered by short-term project-based funding. Given the rapid churn of technology, inbuilt obsolescence (in devices, computer hardware and operating systems etc.) and interdependencies between software, operating systems, hardware and peripherals, keeping digital content accessible in the long-term is both non-trivial and time-consuming. Without ongoing funding resources or planning that is established early on, digital content outputs can be at the receiving end of rapid, pragmatic decisions when a project draws to a close. A website may be taken offline or left to languish, quickly become ‘technologically frozen’ until further resources can be secured [35]. Digital content that is left unmaintained is at risk of losing functionality, potentially becoming completely inaccessible. In other words, neglecting digital content will not work [17]. Online resources can also become a risk to wider technological infrastructure if they are hosted or they operate within the framework of a larger organisation. Without timely system upgrades and ongoing active management, the platforms established to provide access to digital content can become a significant security risk.

While the digital preservation discipline has been recognised internationally for over two decades,[1] for many organisations, in-depth operational digital preservation activities are only just commencing. The field of digital curation (which emerged out of eScience) appeared in the mid-2000s, in order to support reuse of digital content [28]. It was recognised that not only was the preservation of digital content necessary, the selective curation of it was also essential. While digital preservation efforts have been typically focused within the library and archive sectors, digital curation developed within the academic and research domains. While these two highly related disciplines have developed in parallel, there has not yet been enough crossover between both disciplies. An area of work that warrants a far better collaborative approach is between born-digital archival practices and Research Data Management (RDM). At times, it is not easy to identify the difference between, or to be able to separate born-digital archival materials from research data. Indeed, relationships between individual items may mean that the digital content could be classed as either. Pathways for transfer of digital content into a collecting institution's custody may be the determining factor as to whether digital content is classified as an archival collection or as research data.

Now is the time to better conceptualise and act on the management of digital content more holistically. Considering the overall stewardship of digital content, rather than allowing digital content to be pigeonholed by one discipline or another (particularly due to the limitations of either the digital curation or digital preservation disciplines), is critical. Taking a holistic approach to preserving and managing digital content allows for mitigating issues that otherwise may not be apparent until further down the line, where future necessary interventions may prove costly, time-consuming or simply not possible. Efforts can begin by planning early on. Long-term thinking regarding digital content that may be output from a digital cultural heritage, digital humanities or other research project is essential to consider from the outset. In other words, commence planning the project's 'funeral' during its conception.

2 Digital Preservation at Oxford and Cambridge

The Digital Preservation at Oxford and Cambridge (DPOC) project [21]—a two-year collaboration between Cambridge University Library (CUL) and the Bodleian

[1]Digital preservation efforts at CUL began in 1998, or earlier. The Consortium of University Research Libraries (CURL) Exemplars for Digital ARchiveS (CEDARS) digital preservation project collaboration between the Universities of Cambridge, Leeds and Oxford, which commenced in April 1998, put Cambridge 'on the map' in terms of international digital preservation activities. Another organisation who was an early adopter of both digital preservation and web archiving practices was the National Library of Australia (NLA). The NLA's web archiving service, PANDORA, was launched in January 1996, while the NLA's first digital preservation policy was published in July 2001.

Libraries, Oxford—provides the opportunity to look more holistically at how digitised and born-digital content is created, acquired, preserved and made available. Based on the Three-Legged Stool Model for Digital Preservation [38], three Digital Preservation Fellows have been employed at each institution. A Policy and Planning, Outreach and Training, and Technical Fellow in each location allows for a more encompassing approach to be taken during the lifespan of the project. The DPOC project examines digital content from previous digital humanities projects as well as born-digital acquisitions and research data. While the vast majority of items being examined in this project are in digital form (with the exception of selected analogue audiovisual carriers), there may be considerably different approaches to how digital content is acquired, captured and access provided in the long-term. Amongst a range of other project deliverables, a series of case studies are being undertaken by CUL, illustrating several different approaches for acquiring, capturing and preserving digital content.

2.1 Digital Content Classes

Six 'classes' of digital content were identified as being held within CUL's collections (illustrated in Table 1). These classes represent the types of digital content commonly held in academic library collections around the world. The classes were determined by the typical 'collecting area' functions of academic research libraries, including published digital content (Class 4), Special Collections (Classes 1 and 2), research publications and research data (Class 3) and digitised content (Class 5), including both still image and audiovisual digitisation. Commonly found in Galleries, Libraries, Archives and Museums (GLAM) sector collections is also a considerable amount of digital content that has been created internally, within an organisation (Class 6). Digital content created by an organisation is often documentation (typically photographs and/or videos) of public events, or even digital promotional materials. Class 6 content also covers documentation of physical collection items, such as photographs of a collection item undergoing conservation treatment. These images are typically created before (and sometimes after) repairs are carried out by conservators.

These six classes are used to guide the implementation of CUL's Digital Preservation Policy [4] and other emerging digital acquisition and preservation plans.

2.2 Case Studies

As part of the DPOC project, CUL has been undertaking three separate case studies: digitised image content (Case Study 1), a born-digital acquisition (Case Study 2) and a research data project (Case Study 3). The three case studies were selected from 40

Table 1 Classes of digital content held in Cambridge University Library's collections

Class	Type	Description
1	Born-digital personal and corporate records	Digital archives of significant individuals or institutions
2	Born-digital university records	Selected digital records of the University of Cambridge
3	Research outputs	Research data, research publications, electronic and digitised theses, scholarly digital editions, supplementary research relating to digitised content and associated materials[a]
4	Published born-digital content	Web archives, eBooks, born-digital maps, born-digital music, digital ephemera, published born-digital content held on physical format carriers[b] and copies of electronic subscription materials (archival and/or access copies, as permitted by agreements) etc.
5	Digitised content	Digitised image content: Two-dimensional (2D) photography and three-dimensional (3D) imaging etc. Digitised audiovisual content: Moving image (film and video) and sound recordings etc.
6	In-house created content	Photography and videography of events and lectures, photos of conservation treatments etc.

[a]Associated materials are considered to be data that provides context and assists in the interpretation of digital content. It may also refer to files that are essential for rendering digital content. Associated materials may include algorithms, code, diagrams, documentation, sidecar files, scripts, transcripts etc.
[b]Physical format carriers include magnetic tape (carrying analogue or digital audio and/or video content), motion picture film (carrying optical moving image and may include audio content), disks (zip disks, $3\frac{1}{2}$ inch and $5\frac{1}{4}$ inch floppy disks, carrying data), optical media (such as Compact Discs, Digital Versatile Discs and Blu-ray discs, carrying data, audiovisual or multimedia content) portable hard disk drives or USB flash drives (carrying data)

potential candidates, that represented a broad range of digital collection items, from each of the six digital content classes.

It was essential that each case study represented a different class of digital content. In addition, the case studies were chosen based on a range of criteria including: complexity, frequency and/or volume, significance, urgency, uniqueness and value to end users and/or stakeholders [40]. Each case study was ranked against seven key 'stages' that digital content passes through when being transferred to a collecting institution, and as it is managed and preserved. The stages selected included: 'Appraise', 'Acquire', 'Pre-Ingest', 'Ingest', 'Store & Manage', 'Preserve'[2] and 'Deliver and/or Provide Access'. These stages were loosely based on the Digital Curation Centre's Curation Lifecycle Model [18] and the author's previous experience in handling born-digital content.[3] Given the strong driver to address digital content holistically, as part of Case Study 2, the Digital Stewardship End-to-End Workflow Model was developed. This workflow model outlines a total of 14 different stages—from conceptualisation through to use and reuse [41]. Coupled with the Digital Stewardship End-to-End Workflow Model, the Digital Streams Matrix [42] was developed by the author, to aid decision-making when identifying and selecting actions and processes needing to be carried out on the different classes of digital content. For example, the Acquire stage of the Digital Streams Matrix outlines several ways of capturing web-based content.

Many digital cultural heritage and digital humanities projects provide their project outputs online. Two of the three CUL case studies (Case Studies 2 and 3) contained websites. In their simplest form, these websites may be the only location for digitised images created as part of a digital humanities project.[4] While web archiving was not the main focus of the case study work, some initial explorations into how these websites—which were critical to both Case Study 2 and 3—could be archived, was attempted. The approaches investigated are based on several common use cases found as a result of surveying CUL's digital collections. During the Bodleian Libraries collection surveying activities, DPOC counterparts at Oxford discovered that many projects containing digital content were also created in the online environment, often as websites. Based on a number of identified risks, Bodleian Libraries concluded that the digital content held in these websites would need to be 'rehoused' in the near-future. As a result of exploring the various approaches for small-scale capture of websites (as part of a larger digital acquisition process), a selection of available tools were identified, suitable for use in a range of different scenarios. These tools and approaches are discussed further on in this paper.

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[2]While digital preservation considerations should be addressed at each stage, typically 'preserve' in this sense refers to in-depth digital preservation activities, such as 'preservation actions'. A preservation action may consist of a number of tasks, from a simple checksum verification, through to migrating a batch of files from one file format to another.

[3]Previous experience handling born-digital acquisitions was obtained through acquiring, managing and preserving born-digital collections while employed at several significant Australian cultural institutions including the NLA, the National Film and Sound Archive of Australia and the State Library of New South Wales.

[4]As part of the DPOC, the Digital Preservation Fellows at the Bodleian Libraries, Oxford found in excess of 40 websites at the University of Oxford, containing mainly digitised image outputs. Bodleian Libraries are in the process of consolidation; extracting digital content from identified websites and storing the files in one of the two Bodleian Libraries' digital repositories: Digital.Bodleian or the Oxford University Research Archive (ORA).

3 Digital Stewardship

Digital heritage, as defined by the United Nations Educational, Scientific and Cultural Organization (UNESCO), encompasses digital content from a range of 'different communities, industries, sectors and regions' [59]. When digital content is transferred into the custody of a collecting institution, it is managed alongside other digital content from a vast array of professional fields. In order to retain the original meaning and intent of the digital content, context is critical. For digital content to be adequately archived and preserved in the long-term—particularly if custody is transferred to a collecting institution—comprehensively organising and maintaining digital content should not be the final step taken by a content creator or producer, just prior to transfer. Steps towards preservation should have already taken place during the digital content's lifespan. Digital preservation must be 'baked in' throughout the lifecycle of the digital content [58]. As active management should occur right from the start, 'stewardship' is a better way to conceive of managing digital content. For this reason, it would be wise for any digital cultural heritage or digital humanities project to adopt a 'digital stewardship' approach.

Digital stewardship brings together the concepts of both digital preservation and digital curation. In 2010, the National Digital Stewardship Alliance (NDSA) [49] was launched, as an initiative of the Library of Congress' National Digital Information Infrastructure and Preservation Program (NDIIPP) [46]. National Digital Stewardship Residency recipient Jaime McCurry, defined digital stewardship as encompassing [45]: "…all activities related to the care and management of digital objects over time. Proper digital stewardship addresses all phases of the digital object lifecycle: from digital asset conception, creation, appraisal, description, and preservation, to accessibility, reuse, and beyond." [48]. Digital stewardship provides a framework for long-term thinking to ensure that preserving and managing digital content for the long-term is not merely an afterthought.

4 Digital Curation and Preservation Models

There are a wide variety of models for conceptualising and guiding the management of digital content. Three models considered useful to the fields of digital cultural heritage and the digital humanities are briefly discussed.[5]

The Three-Legged Stool Model for Digital Preservation [38] considers the 'Organizational Infrastructure' (the 'what'), the 'Technological Infrastructure' (the 'how') and the 'Resources Framework' (the 'how much') as equally important parts necessary for undertaking digital preservation activities. It is common to consider digital preservation only as a technical problem with a technological solution. The

[5]Two of these models have already been referenced in the paper thus far. The author's newly developed alpha release Digital Stewardship End-to-End Workflow Model has been mentioned in the context of CUL's Case Study 2. It is not discussed further in this paper.

Three-Legged Stool Model tries to dispel this myth; identifying that the Technological Infrastructure—the 'equipment, software, hardware, a secure environment, and skills to establish and maintain the digital preservation program'—is just one of three essential aspects. The 'Organizational Infrastructure' includes 'policies, procedures, practices and people' and the 'Resources Framework' that encompasses 'start-up, ongoing, and contingency funding' are equally critical. Without addressing each of the three areas, successful digital preservation efforts are not possible. For digital cultural heritage and digital humanities projects, identifying and addressing the 'what', 'how' and 'how much' right from the start, will assist in improved sustainability of digital content in the long-term.

The Digital Curation Centre's Curation Lifecycle Model [18], first published in draft in 2007 [29], comprises several layers of 'actions': Full Lifecycle Actions,[6] Sequential Actions and Occasional Actions. The model is most useful for its eight Sequential Actions: 'Conceptualise', 'Create or Receive', 'Appraise and Select', 'Ingest', 'Preservation Action', 'Store', 'Access, Use and Reuse' and 'Transform'. These are the sequential actions that digital content typically passes through, with the latter seven of these actions being cyclical. Digital content can continue to be managed via this sequence of actions throughout its entire lifecycle. The Occasional Actions of 'Reappraise', 'Migrate' and 'Dispose' may become relevant to some digital content, depending on the circumstances. This decade-old model continues to be enhanced, as the field of digital curation matures and evolves.

The CLOCKSS [12] Threats Model and Mitigation Strategy [13] is another holistic (risk managed) approach to digital preservation. The model outlines various disasters, errors, failures, and obsolescence that could occur, which would put digital content at risk. These include commonly thought of failures of media, hardware, software and network services, as well as economic and organisational failure. Obsolescence (of media, hardware and software) can also play a part in placing digital content at risk. Communication and operator errors are considered a risk, as are natural disasters, internal and external attacks. All are factors that should be risk managed. This Threats Model underlies the Lots of Copies Keeps Stuff Safe (LOCKSS) [47] technology, and was formalised in 2005 as a 'bottom-up' approach to developing digital preservation system requirements [55]. Considering, at least briefly, each of these risks at the start of a digital cultural heritage or digital humanities project will better equip the project to manage problems as they arise. This would also aid in planning for long-term preservation of, and access to, any digital content created. Not only relevant to digital cultural heritage and digital humanities researchers, these models should also be considered by digital content creators and producers, as well as staff working in collecting institutions.

[6]The Full Lifecycle Actions are higher-level considerations centred around 'Description and Representation Information', 'Preservation Planning', 'Community Watch and Participation', and 'Curate and Preserve'. For reasons of brevity, they are not discussed in this paper.

5 Migration

For the past decade, CUL has been digitising items in its collections and making these images available via the Cambridge University Digital Library (CUDL) [5]; a delivery system with an embedded digital image viewer and other functionality.[7] While the focus has been on the digitisation process and provision of access, CUL has realised that digital image files need to be preserved in sustainable ways, hence the digital preservation scoping work being undertaken as part of the DPOC project. The DPOC project has drawn attention to the fact that CUL's digitised image collections are held in multiple locations. This means that not all digitised images are managed in Extensis Portfolio, the current Digital Asset Management System (DAMS) in use at CUL.

For smaller digital cultural heritage or digital humanities projects where a DAMS is not available, it is more likely that the output of digital content has been published via an online mechanism or resource. Digital content that is made available via a website (where the website is built utilising a back-end database), may ultimately be easier to migrate into a digital preservation system or digital repository, than digital content embedded into individual webpages. With the vast array of web technologies used to create a website, managing a migration process must ultimately be handled on a case-by-case basis. (It should be noted that for digital content embedded in a website that does not have an underlying database, 'screen scraping' may be the only option.)

For digital content held in a database of some form, migration is usually the best approach. Migration refers to the process whereby digital content (and associated metadata) is transferred—typically in large 'batches'—from one environment, system or repository (such as database or website) to another (such as a DAMS or digital preservation system). Several basic stages as part of a migration process include analysis, preparation, assessing and undertaking the migration [63]. Any migration process must be well planned. Some necessary steps include (but are not limited to):

- Analyse the digital content that is held in the environment, system, repository or location you wish to migrate from[8];

[7]The CUDL provides zooming functionality to view digital images, using OpenSeadragon technology. The delivery system is also going through a redevelopment to improve functionality for digital images—such as implementing the International Image Interoperability Framework (IIIF)—and to provide mechanisms for accessing digital content in other formats. The development of the CUDL was generously funded by The Polonsky Foundation and the Andrew W. Mellon Foundation.

[8]For proper analysis of digital content prior to a migration process, identifying the variety of files is essential. Running digital preservation software tools such as DROID (which utilises The National Archives of the UK's PRONOM file format registry), Siegfried, the Open Preservation Foundation's JHOVE, or FITS across all of the digital content will assist in identifying the formats of the files, and potentially also characterise and validate the files (depending on which tools are used). Undertaking this type of in-depth analysis will pre-empt ingest issues or failures as part of a migration process, particularly when migrating digital content into a digital preservation system.

- Analyse the associated metadata of each file (including for ‘complex digital objects’,[9] where it is necessary to identify the metadata critical for retaining the integrity of the entire ‘digital object’);
- Define both mandatory and optional metadata (and identify what metadata is unnecessary to migrate)[10];
- Document all known ‘edge cases’[11] (for both digital content and metadata), and test the ability to export the digital content and metadata that falls within these edge cases;
- Define what metadata does not exist and must be created as part of a migration process (e.g. preservation metadata, including ‘agent information’[12]);
- Generate checksums for each file[13];
- Create a technical manifest[14];
- Develop a metadata crosswalk to map from the ‘old’ environment, system, repository or location being migrated out of, to the ‘new’ environment, system, repository or location being migrated into—using standards-based metadata schemas[15];
- ‘Data washing’ of any metadata that doesn’t correctly map to the new metadata schema and/or environment, system, repository or location[16];

[9]A complex digital object is a type of digital content that consists of a number of files (often of different formats) that make up the components of a single digital item. eBooks, websites and interactive multimedia works are considered some of the types of complex digital objects.

[10]If in any doubt, retain metadata rather than discard it. This is particularly important if analysis is not comprehensive, or if the function of certain metadata isn’t fully known or understood.

[11]An ‘edge case’ is a less common situation that either does not follow the expected rules within a system or falls at the extreme boundaries of the system. Any systems that have used a ‘Band Aid’ approach to managing digital content or metadata can be expected to contain edge cases. Without analysing and testing for edge cases, it is likely that some digital content and/or metadata will be lost as part of a migration process.

[12]Information about ‘Agents’—as defined in this instance by the PREMIS preservation metadata standard—would refer to information about the software tools and version(s) of the tools used to create or make changes to files.

[13]A checksum is a cryptographic hash, which is typically represented as an alphanumeric code that is unique to each file (with the exception of collisions). There are a range of different checksum algorithms, such as SHA-1, SHA256, SHA512, MD5 etc., that are often used. Once a checksum has been created for a file, this alphanumeric code can be used to verify whether a file has been modified. For as long as the alphanumeric code remains the same, this indicates that the contents of a file has not been altered.

[14]A technical manifest is a record of a group of files. Typically this would be used as information about a ‘complex digital object’, digital collection, or batch of files (as part of a migration process). As a minimum, a technical manifest should include for each file, the checksum, and the corresponding filename and file path.

[15]Metadata standards that may be useful for developing crosswalks, are highly dependent on the system(s) being migrated from and to. These must be developed on a case-by-case basis, and are also influenced by how metadata has been recorded in a database, system or repository. Common metadata standards that may form part of a crosswalk include Dublin Core, EAD, EBUCore, METS, PREMIS, TEI etc., depending on the type of digital content and systems used.

[16]Also known as ‘data cleansing’ or ‘data cleaning’. This may include removing duplicate data or adding in specific metadata that does not already exist within the current database, repository or system.

- Test export of metadata—including metadata in relation to digital content (so relationships between each file and its associated metadata is retained);
- Test export of digital content to ensure the quality of the digital content (including any metadata embedded in files) is maintained during the export process;
- Establish an in-depth understanding of the environment, system, repository or location the digital content is being migrated to (including which metadata standards and file formats it supports);
- Configure the new environment, system, repository or location, including ingest workflows (and other workflows that are supported);
- Fully test ingest workflows in the new system to ensure that content batch-migrated from the old environment, system, repository or location can be successfully ingested.[17]

While similar tasks for each migration are likely to apply, each collection of digital content consists of different elements and may be arranged in vastly different ways. Therefore, each migration process will differ. The order of tasks may switch around and not every step may be necessary. Alternatively, for environments, systems or repositories that have not been used in standardised ways (or importantly, how they have been used has changed over time), additional steps may be required. Hence, analysis of the digital content, metadata and both the old and the new environment, systems, repositories or locations are necessary. A lesser degree of analysis may be acceptable if a comprehensive understanding and documentation already exists.

Once the outlined steps (identified above) and any additional requirements have been determined (and documented), a thorough understanding of the digital content and metadata will have been achieved. It is at this point that developing a migration strategy is possible. The migration strategy should be accompanied by quality control testing and error handling procedures (as issues will arise). Additionally, consider the migration process as not only an export from one system to another, but also an opportunity to improve metadata along the way. While the focus of this exercise may be migration, it is essential to develop an in-depth understanding of how newly created digital content (and its associated metadata) is ingested into the new system, using the new workflows. While this may seem like a considerable amount of work, cutting corners in the analysis and preparation stages may actually cost time and/or resources if issues occur, and have not been adequately planned for.

5.1 The Taylor-Schechter Cairo Genizah Collection

CUL's Taylor-Schechter Cairo Genizah Collection is considered 'the world's largest and most important single collection of medieval Jewish manuscripts' [6]. The almost 193,000 fragments held at CUL were discovered in the Ben Ezra Synagogue in Egypt,

[17]Testing is necessary to ensure that there are no 'show stoppers' when a full migration process takes place. Not undertaking adequate testing may mean that the migration process fails, takes much longer and/or the costs of the migration work increase.

documenting approximately 1000 continuous years of Jewish history in the Middle East and North Africa. The ability to share these digitised fragments with the world, via the CUDL [5], is one of CUL's successes.

CUL's digital image content is stored in several locations. The diversity of storage locations is often dependent on how the digitisation project was funded, or indeed, the department that undertook the digitisation work. While digital image preservation master files are stored in networked file stores, other projects (related to both digitised and born-digital content) have resulted in preservation master files stored in more than one instance of a DSpace repository instance, such as the Taylor-Schechter DSpace.[18] In order to support the Taylor-Schechter DSpace, at the time the DSpace instance was created (in 2009), an 'Operator Manual' was also developed. The Operator Manual includes details on filenaming protocols, workflows and backups. Unfortunately, over time, this manual has not been updated, and so no longer fully reflects the Taylor-Schechter DSpace instance.

As part of the DPOC project, preservation master files (high-resolution images) of fragments from the Taylor-Schechter Cairo Genizah Collection—that are stored in the Taylor-Schechter DSpace—have been identified as being 'at risk'. This is due to the fact that these images have not been actively managed since the completion of the digitisation project. Without project funding, there was no dedicated person or team assigned to actively manage the preservation master files, as CUL do not have a dedicated digital preservation staff member or program at present. In addition, the Taylor-Schechter DSpace has not received scheduled updates of the repository software, and adding new users to access the Taylor-Schechter DSpace content is no longer possible. (This means that only a select number of CUL staff continue to maintain access to this repository.) A variety of issues with the Taylor-Schechter DSpace have manifested over the past decade, resulting in the need to decommission this legacy system and migrate the preservation master files into a digital preservation system.[19] As part of the DPOC project, some analysis has taken place, identifying a range of issues. For example, original filename identifiers[20] are only stored as metadata due to the repository software auto-renaming files on ingest. Additionally, selected preservation master images from the Taylor-Schechter DSpace have been individually migrated to a networked store, when an image is ordered by an external (or internal) client. A brief plan of action to export over 360,000 preservation master files from the Taylor-Schechter DSpace has been drafted. However, this is only one component of a full migration strategy. While there may be a variety of technical challenges to overcome, the main challenge is not technical. It is a resourcing issue. Given the shared responsibilities of this digital content, which currently lies between

[18]This is one of several instances of an internal 'dark' DSpace repository at CUL. CUL also provides the University of Cambridge's Apollo Open Access Repository, which is a publicly available DSpace instance [60].

[19]At the time of authoring this paper, CUL is working towards a business case for the implementation of a digital preservation system.

[20]CUL has developed its file naming 'protocols' based on the Classmark scheme used for physical items in CUL's collections [7]. At present, CUL does not have an organisation-wide Persistent Identification (PI) scheme for file naming.

CUL's Digital Content Unit (DCU), Digital Library Unit (DLU), Digital Initiatives and Strategy (DIS) and the Taylor-Schechter Genizah Research Unit, a small project team must be put together to develop a migration strategy. There are likely to be a range of edge cases and other complexities that must be factored in, requiring input from subject matter experts, digitisation experts and IT staff.

Some lessons can already be garnered from this particular example. Standardisation is essential, and supporting documentation must be created and then adequately resourced, in order to maintain the documentation and keep it up-to-date. Standardisation does not only refer to the creation of the digital content, it also refers to the way in which supporting documentation is created. Rather than 'operator manuals' or 'protocols', a suite of standardised documents including policy, standards, procedures and guidelines (PSPG) as well as strategies and plans are necessary. For digital cultural heritage and digital humanities projects, also establishing standardised documentation right from the start will mean an easier process of managing digital content throughout the lifetime of the project. Standardised documentation will also aid in the long-term, particularly when transferring digital content into the custody of another organisation.

6 Bundling and Bitstream Preservation

One of the simplest ways of archiving digital content—particularly a set of files—is to zip[21] them up into a single 'bundle'. Bundling a set of files ensures that they remain together. This should be coupled with a checksum. Generating a checksum hash and then validating these hashes at regular intervals is the method used to monitor changes to digital content. A wide range of checksum verification tools are available, which range from simple Command-Line Interface (CLI) to Graphical User Interface (GUI) tools with additional features.[22] A single checksum can be generated for the bundle, rather than a checksum generated for each file within the bundle. Once the zip file and its associated checksum have been created, ensuring the 'fixity'[23] of this bundle can be a somewhat trivial exercise. While this may be the simplest approach, this does not provide for any sophisticated methods of managing the digital content, should

[21] A zip file is often a single file that represents a folder (or directory) of a set of files that have been compressed together. Various types of compression can be applied to make the size of the zip file smaller for the purposes of transfer or storage. Compression does not always have to be applied. This paper does not go into the considerations and technicalities of applying compression to zip files and how this may affect preservation of digital content.

[22] A range of tools for generating and verifying checksums are available. These include (but are not limited to) Bagger, bagit-python, checksum+, Exactly, hashcheck, Hashdeep, Fixity and ExactFile. Some are CLI tools, while others are GUI software. It should be kept in mind that specific tools may only be available for particular operating systems and computer platforms.

[23] 'Fixity' is the measure used by the digital preservation discipline to ensure that no unauthorised change to digital content occurs. Fixity refers to the checksum(s), filename and file path—as a minimum—that are generated and/or recorded for a specific file.

a bundle somehow be modified. A checksum for each file in a set of files would provide further granularity and may make troubleshooting easier in the long run. Hence, when a zip bundle is created, sometimes a technical manifest containing the fixity of each of the files in the set is also generated. This is an additional safeguard, should it be needed for any future monitoring or troubleshooting.

The notion of bitstream preservation is to ensure that at least one copy of the data (0s and 1s) is maintained at all times, and to ensure the integrity of this data (the 'bitstream'). Maintaining the fixity of digital content is a core concept of digital preservation, and ensuring the integrity of the data is typically done by 'fixity checking'. The typical method used for fixity checking involves regularly verifying that checksum hashes for each file remain unchanged [22]. Depending on the tool used to generate a checksum hash, unless there is a comprehensive understanding of the formatting of the fixity information, it may be wise to use the same tool to undertake fixity checking (particularly where a researcher has a lower digital or technical literacy). Documentary evidence to prove these requirements have been met is also necessary [1].

Fixity checking by way of monitoring checksums does not prevent intentional or unintentional changes from occurring. It is only a method for detecting change. Whether modification of a file is intentional (potentially malicious) or unintentional, or if the file has been corrupted, this is unable to be determined by fixity checking. While many other approaches to archiving digital content described in this paper require certain infrastructure, fixity checking is the simplest method for managing digital content. This is particularly the case for individual researchers, where institutional data management and storage is not available.

7 Packing Down and Putting on Ice

If a digital cultural heritage or digital humanities project faces a temporary resourcing challenge, one method of archiving the digital content (particularly if there is a good chance the project may recommence at some point in the future point) may be to pack the project down, in a way where it is effectively being 'put on ice'. This could be thought of as the 'cryogenically frozen' approach. At some point in the future—when the necessary resources have been secured—it can be 'brought back to life'. Developing a thorough content model and/or data model at an early stage of a project is crucial in order to utilise this approach.

While somewhat embryonic, one example of this approach is the Australian project, Ozmeka [51]. Based on Omeka [50], the Ozmeka version (of the Omeka code) has been developed with the intention of supporting eResearch projects. It is an attempt at a standardised way of handling the digital outputs of research projects, where they have been presented online. This approach is being trialled with the eResearch project Dharmae, the Data Hub of Australian Research on Marine and Aquatic Ecocultures [14]. It is hoped that over time, being able to 'cryogenically freeze' and bring back to life digital projects will be less cumbersome. At present, one of the challenges faced by the RDM community is the grey area between 'active research data' and 'archival research data'. Digital content can easily switch between being 'active' and needing to be preserved for the long-term. However, the infrastructure and mechanisms available to move digital content between these two states (and often, two different storage environments) is not easily facilitated. Far better methods for allowing the 'spin up' and 'spin down' of digital project environments are needed.

7.1 Databases and Code Repositories

Where archiving and preservation of a database is important—not only preserving the digital content and/or the metadata held in a relational database (including web-based databases), but the database itself—then this can be achieved by using the SIARD (Software Independent Archiving of Relational Databases) format [56] and SIARD Suite [57]. For digital cultural heritage and digital humanities projects that are generating a large amount of data, where the relationships between the data elements are of considerable importance, preserving the whole database may be an approach to consider. Due to the finite nature of the DPOC project, preservation of databases was not considered a priority and so this option was not investigated further.

For code-based projects, a 'good practice' approach should be taken when managing, versioning and sharing code. Where hosting arrangements are part of a digital cultural heritage or digital humanities project—such as working in an academic or another institutional environment—other factors may need to be taken into account. For example, this may include committing code to a local code repositories, rather than using GitHub [26]. Where code is stored, it must be documented. Documentation should include information on dependencies between other aspects of a project, as well as instructions on how to install, configure and run the code. Ideally documentation should be standardised as PSPG. When working in the context of an academic or other institutional environment, be pragmatic and utilise any existing PSPG templates.

8 Alternative Capture Methods

Context is crucially important for digital content. Where the complexity of the digital content doesn't easily facilitate more straightforward digital archiving approaches (such as those that have already been discussed in this paper), documentation methods may be suitable. These documentation methods can help in providing an understanding of how the digital content was used, and are particularly useful for use with interactive digital content.

8.1 Video Screen Capture

A simple time-based method to document a 'single pass' through a complex digital work—whether this is a website, game or an interactive experience—is to record a Video Screen Capture (VSC).[24] A VSC records the image content that appears onscreen (plus associated audio), and produces a single channel video file. If attempting to document an interactive environment (containing an infinite number of pathways and experiences), then it is recommended that several VSCs are recorded. Ideally, each VSC would document a different 'journey' through the interactive environment. Capturing several different journeys—from different perspectives—-may be a suitable approach for documenting a complex environment. This digital archiving approach is already in use for capturing multi-platform content experiences [43]. Together with the original files (such as project files) plus other documentation, VSCs may provide researchers of the future with a better understanding of how the digital content operated, and what the experience was like for a user.

8.2 The Kymata Atlas

An example of where using the VSC approach was considered suitable, was for documenting the user interactivity of the 'Surface Viewer' interface of the Kymata Atlas [39], illustrated in Fig. 1. The Kymata Atlas—a research resource from the MRC Cognition and Brain Sciences Unit at the University of Cambridge—provides a partial set of information processing pathways mapping of the human brain (represented as 'functions'). The Surface Viewer allows for interactive visualisation of the datasets contained within this research resource. Users can move their mouse over the various sectors of the brain, which displays information found at various coordinates.

Using VSC provides a simple mechanism for archiving the interactive interface, and displaying how the Surface Viewer could be used. However, as the Kymata Atlas is a significant and internationally-relied upon resource containing numerous datasets, other approaches would also be required in order to fully archive the entirety of this online resource.

8.3 Documenting in Context

A more advanced approach to archiving websites via VSC is illustrated in Robert Sakrowski and Constant Dullart's netart.database [23]. In addition to recording a VSC, a camera (mounted behind and to one side of the user) records an individual's interaction with a website, and the computer hardware the website is displayed on.

[24] In the Mac environment, QuickTime (version 10.4) is capable of creating a VSC.

Capturing this additional element provides another layer of information for future researchers. The netart.database project focusses on a particular sub-set of media art culture; that of net.art. This additional documentation will allow future researchers to observe how interactive net.art works were experienced, showing a user engaging with the computer hardware and browser software available at the time.

While the netart.database may not be a preferred method for documenting some digital cultural heritage or digital humanities projects, for Human-Computer Interaction (HCI) and Information Communications Technology (ICT) researchers, this approach may provide a simple and straightforward method for capturing the interaction between humans and computers (and/or other devices). The beauty of this method is—compared to motion capture[25] approaches—its simplicity and low-cost.

8.4 *Rhizome's Webrecorder*

Developed for Rhizome, the US media arts organisation (and initially funded by the Andrew W. Mellon Foundation), the Webrecorder tool [54] is another time-based approach to archiving websites. The open-source project allows for the 'recording' of websites, with the output produced as WARC (Web ARChive) files.[26] A user

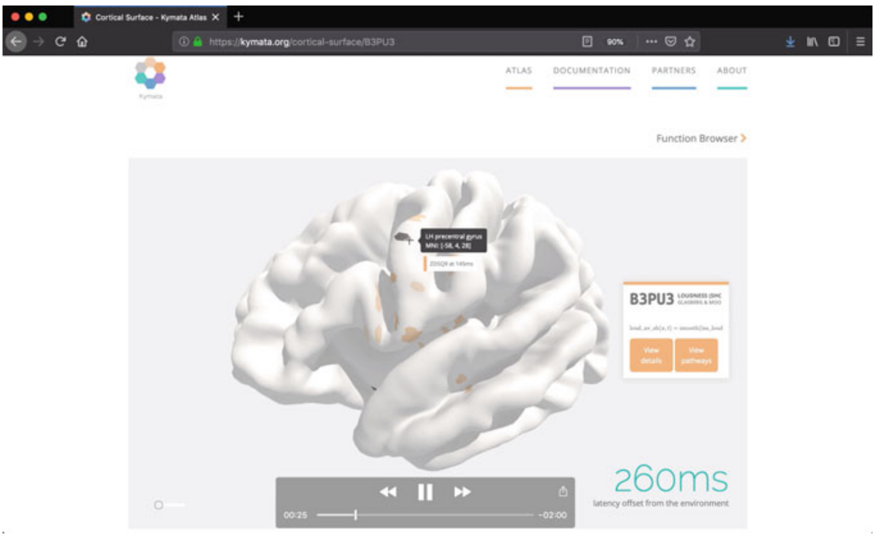

Fig. 1 Still from a Video Screen Capture of the Kymata Atlas Surface Viewer

[25]Motion capture is an approach for capturing the movement of humans or other objects in a three-dimensional space, typically producing a dataset that represents positions in space over a certain time period.

[26]A revised version of the Internet Archive's ARC file format.

wanting to capture a website enters the URL and navigates around the site. All actions are automatically recorded. When the required interaction with the website is complete, all the user needs to do is to stop the 'capture' button. This 'session' is stored for a limited period of time, allowing a user to decide whether to turn the recorded session into a permanent web archive file. Like other web archives stored using the WARC file format, in order to view the contents of the WARC files, 'playback' tools are required.The International Internet Preservation Consortium's (IIPC) OpenWayback software [31] is one tool that can be used for this purpose.

9 Hosted Infrastructure Arrangements

For some digital cultural heritage or digital humanities projects, a hosting arrangement entered into with an organisation may be the best and most cost-effective approach. Organisations, rather than individual research projects may have at their disposal a range of infrastructure that simply cannot be sourced for a single project alone. That said, transferring the hosting of a complex website or online resource to another organisation may be time-consuming. Additionally, some hosting organisations may not support the software the online resource has been developed with, the underlying technical infrastructure that the online resource is dependent on, or the access methods provided to the digital content.

If a hosting arrangement is one of the longer-term possibilities being considered for extending the lifespan of a digital project, discussions with potential hosting organisations should begin as early as possible. Covering the costs of ongoing support and future maintenance—such as system upgrades (including supporting any ICT security compliance)—should be factored into any research grant funding applications, where permitted. If a hosting arrangement is negotiated, establishing a contract or a Memorandum of Understanding (MOU) is considered essential.

9.1 Design & Art Australia Online

One example of a digital humanities project that has established a hosting arrangement is Design & Art Australia Online (DAAO). The DAAO is a collaborative scholarly eResearch tool: an online database providing access to biographical information about Australian visual artists, designers and architects etc. [15]. This project has been running for over a decade, with primary funding from the Australian Research Council (ARC), stretching across a number of different grants. The DAAO—a national partnership of art galleries, libraries and universities—is hosted by the University of New South Wales (UNSW) Library. DAAO is subject to stringent technical and security compliance, with both UNSW ICT and UNSW Library technology infrastructure.

9.2 King's Digital Lab

At King's College London (KCL), the King's Digital Lab (KDL) [36] provides infrastructure for eResearch and digital humanities projects to ensure the foundation of a digital project is established and stable from the get-go. These hosting arrangements allow KDL to spin-up virtual servers for various digital projects as required [37]. The added benefit of these hosting arrangements is that time and research funding is not wasted on setting up and configuring the technical infrastructure and framework for the online resource. This frees up both funding and project time, allowing for efforts to be better directed towards undertaking research activities. This method also mitigates against potential risks regarding the longer-term sustainability of digital content created as part of a project, due to relying on already established and managed technical infrastructure. Pathways are starting to be established between KDL and the KCL Library, in order to transfer digital content to library repositories (where it meets library collection development policies), at the end of the life of a digital humanities project.

9.3 The Casebooks Project

The University of Cambridge has been home to a number of digital humanities projects. One example is the Casebooks Project [11], a collaboration with the Bodleian Libraries at the University of Oxford. The Casebooks Project combines the fields of medicine and astrology, making almost 50,000 'cases' available online. In recent years, the University of Cambridge and CUL has been expanding their digital humanities capabilities [3, 8]. Typically, CUL does not host digital project websites, as access to digital content is provided via the CUDL. Indeed, even the Forman and Napier Casebooks [9] (as part of the Casebooks Project) can be already accessed through the CUDL. However, providing access to the full set of Casebooks via the CUDL is problematic at present. This is due to the fact that there is no 'one-to-one' relationship between a 'case' and a single page (or set of pages). A 'case' may commence midway through a page and run across multiple pages. As an interim arrangement—until such times as other viewer mechanisms are developed—the Casebooks Project is currently being hosted by CUL, having been migrated from its previous location on the Department of History and Philosophy of Science servers. Conceptualising a case is somewhat challenged by the current capabilities of typical image delivery systems and viewers, including the CUDL image viewer. Given the burgeoning of digital humanities projects and/or alternative viewing mechanisms (including other ways of representing and interacting with digital content), other options may become possible in the future.

10 Web Archiving Approaches

There are several freely available tools that can be used for web archiving activities, in addition to the Rhizome's Webrecorder [54]. Some tools, such as Heritrix [33], have larger-scale infrastructure requirements and demand skills that include the ability to set-up, configure and run CLI web crawlers. Other options, such as the Internet Archive's Archive-It web archiving service [32], is provided as an online service and resource. There are over 400 organisations using Archive-It. However, use of this service is restricted to established institutions such as libraries and archives, non-governmental organisations, and historical societies.

Another web archiving tool, HTTrack [30], provides both CLI and GUI options. The HTTrack tool downloads all the HTML and other static content found in a web directory and copies these files—in the same file structure—to another location. While HTTrack can be used by an individual researcher, it is not necessarily successful at capturing all digital content, particularly from dynamic websites. For example, it may miss certain types of digital content, such as audiovisual content, that is only linked (not embedded) within a website. In order to capture linked audiovisual files, these may need to be acquired via alternative methods. One method that has been used is to download the linked video files—using the Video DownloadHelper browser plugin [62]—and manually link these video files into the website files downloaded using HTTrack. This can be an onerous process if more than a handful of files need to be added back in. It is also not an exact replication of the relationship between two or more websites, and may therefore not be considered an authentic archival representation.

Capturing websites is only one part of the web archiving process. Providing access to archived websites is another piece of work entirely. Many tools used in web archiving produce files in the WARC format.[27] For websites that have already been archived into the Internet Archive's Wayback Machine [34], other playback tools are available for enabling users to interact with archived website content. For example, Oldweb.today [53] (also developed by Rhizome), provides an emulation facility, allowing users to see and experience what a website originally looked like, through various legacy web browsers (and browser versions).

For example, using the emulated Netscape 3.04 web browser, which was released in 1997, it is possible to view an instance of the Cambridge University Library website that was captured on the 9th February 1998, illustrated in Fig. 2. Providing todays' users with the opportunity to interact with websites from previous decades—using the browser software that was available at that time—allows for a more comprehensive engagement, as well as contextualisation of the archived web resources.

[27] Due to the focus of the DPOC research (and this paper), tools for the presentation of websites that have been archived in the WARC file format have not been investigated.

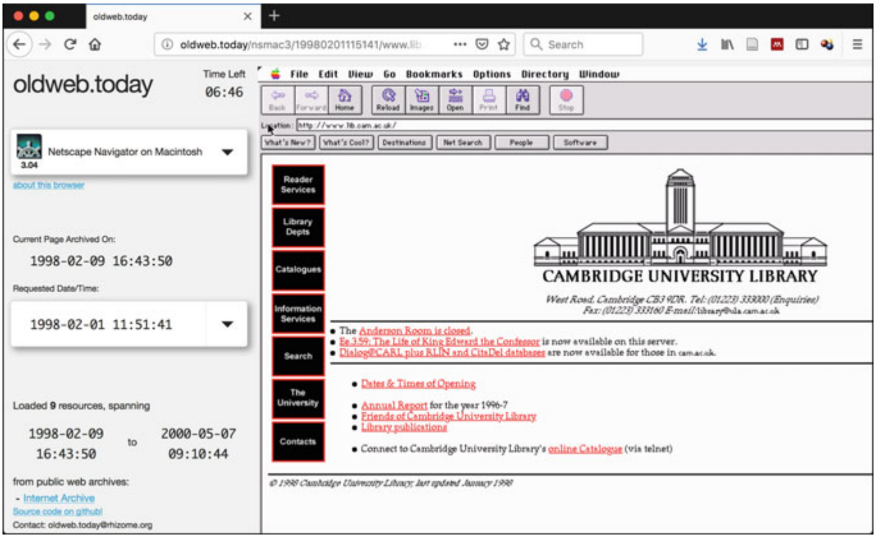

Fig. 2 Cambridge University Library website, captured on 9th February 1998, viewed through Oldweb.today, using the emulated Netscape 3.04 browser

11 Improving the Use of Data Management Plans

Research funding bodies are increasingly stipulating that for the purposes of reproducibility, datasets (that support research publications) should be submitted to appropriate open access repositories, typically those provided by the researcher's institution, or alternatively discipline-specific repositories. Researchers and staff at the University of Cambridge are strongly encouraged to submit their research publications and any associated datasets into the University of Cambridge's Apollo Open Access Repository [60]. While practices surrounding Data Management Plans (DMPs) differs from country to country, in the UK, DMPs are only created as part of the funding application or research grant proposal, and are not required to be submitted into a repository alongside research datasets. As DMPs are developed prior to research commencing, the proposed technological frameworks, software etc., may be a far cry from what is actually implemented. As a result, the initial DMP (often produced years earlier) rarely reflects the final digital outcomes and environments, developed and implemented as part of a digital project.

Taking a digital stewardship approach, DMPs could be harnessed to support digital preservation activities in the longer-term, including forming the basis for a preservation plan. Given the increasing complexity of research data, the importance of DMPs (or a similar record of the technologies used in a project including hardware, software, versions, peripherals, dependencies, standards plus other technical complexities etc.), will become more relevant over time. While it is ideal that there is involvement from subject matter experts, when trialling or undertaking digital preservation activities or actions (particularly when handling complex digital content), the reality is that this is unlikely to occur.

The following recommendations have been developed with the intent of making better use of DMPs for preservation purposes. These include (but are not limited to):

- Consider the DMP as a 'live' document—update it throughout the course of the project (preferably versioning the document);
- Submit the DMP alongside any datasets or digital content being placed in a digital repository;
- Include data citation information;
- Author the DMP for submission in a way that is usable for long-term preservation purposes—including using clear headings (and sub-headings), and write any technical specifications as lists (rather than prose);
- Include a technical questionnaire, detailing the technical specifications (encompassing all aspects of the project)—incorporate information on the code developed, any standards used, software and software versions required to use and/or reuse the digital content, hardware requirements, peripherals and any other dependencies etc.;
- Detail any different versions of digital content produced (such as high-quality or low-quality copies);
- Ensure that a complete description of how to use, reuse and/or reproduce the digital content—(preferably as a set of instructions)—is provided, as this will be critical for long-term preservation.

A good example of a DMP from the University of Cambridge is Dr Laurent Gatto's 'Data Management Plan for a Biotechnology and Biological Sciences Research Council (BBSRC) Tools and Resources Development Fund (TRDF) Grant' [25]. This DMP succinctly outlines information on the data, documentation, software, source code, and reproducible framework. Other examples of DMPs and guidance are available from the Digital Curation Centre [20], including the DMPonline tool [19].

12 Developing Documentation

As part of the transfer of custody of digital content outputs produced as part of a digital cultural heritage or digital humanities project, to a collecting institution or research repository, also supplying any associated materials is also essential. These associated materials will assist in comprehending the digital content's context and functionality. A project that produces an interactive online resource will need to ensure that the specifics of how different components connect is recorded. This may include documenting how any data flows through the system, including inputs and outputs (e.g. how data is entered/ingested, and how data is exported/made available). This information will be crucial for being able to preserve certain types of digital content in the long-term.

For digital content to be made available using future technologies on devices that are yet to be invented, a 'preservation action' may be necessary. This may take the form of a 'migration'[28] from one file format to another. For complex or interactive digital content, where dependencies between files exists, documenting these relationships between individual file components is critical. These relationships can be recorded as technical manifests, as well as other descriptive documentation (including within a DMP). If dependencies are unknown, a preservation action (such as a file format migration) may result in 'broken' digital content. For some complex interactive digital content, it may only be one part of the digital content that no longer works, however this may not be apparent if other aspects are still functioning. Given that preservation actions on digital content may be carried out in batches—without subject matter experts present, and without the ability to test every aspect of the migrated (or normalised) resultant version of the digital content—issues may not be discovered until it is encountered by a user, further down the track. For this reason, any complexities and dependencies should be thoroughly documented.

For example, as part of a transfer of custody for the DAAO eResearch tool, it would be necessary to provide the system diagram(s), information on system dependencies, metadata standards and other standards used, any data dictionaries implemented, controlled lists, metadata crosswalks, and the data model [16] (illustrated in Fig. 3).

This suite of documents form a key resource for managing the DAAO eResearch tool. These documents would be essential for ongoing maintenance, as well as for guiding any future preservation activities.

13 Borrowing from Related Industries

While digital stewardship of large-scale digital cultural heritage and digital humanities data is in its relative infancy, reinventing the wheel is unnecessary. Other disciplines have developed practical methods and methods for handling complex set-ups; borrowing and adapting these approaches to align with various digital preservation activities is recommended. One relevant sector for this purpose is the performing arts.

Mandatory documents produced as part of a performing arts production include (but are not limited to):

- Technical rider—a list of technical requirements for staging the performance;
- Stage plot—the layout of the performers, props, instruments, audiovisual and technical equipment etc.;

[28]In this context, migration—or normalisation—means to change a file from one file format to another (more standardised or commonly used) file format. These types of 'preservation action' migrations are often carried out in batches. Undertaking migrations of this kind can be intensive—-particularly for complex digital content—as ensuring no loss of any data or functionality is of primary concern.

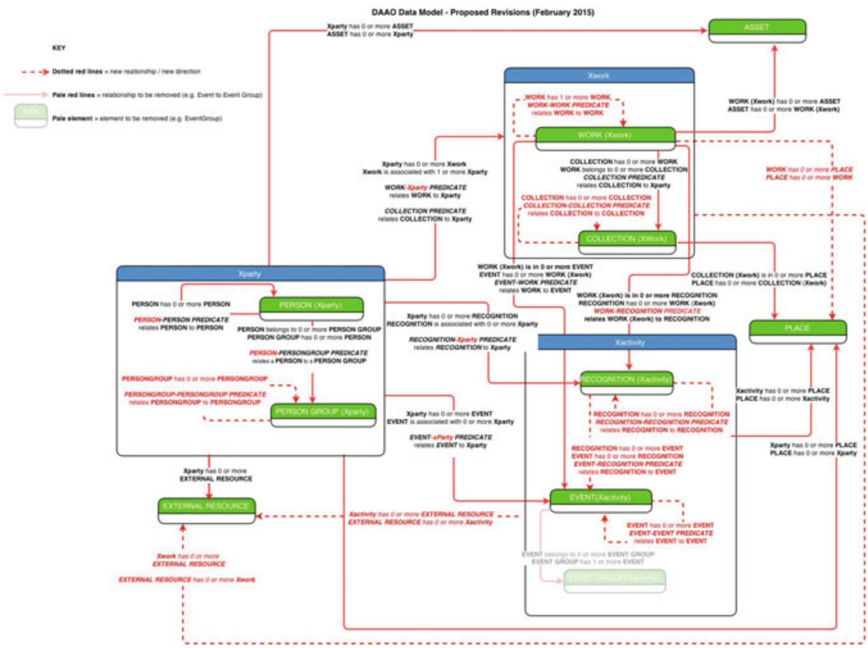

Fig. 3 Design & Art Australia Online, 2015 data model

- Input list—an ordered list of the audio channels sent from microphones, instruments (via 'DI' boxes), computers and other electronic sound-producing devices etc., which are sent to a mixing desk.

These key documents for staging performing arts productions could be borrowed and then 'mapped' into the digital stewardship domain. Table 2 contains a proposed mapping between documents used in the performing arts and documentation required by the digital stewardship domain (incorporating digital curation, digital preservation and RDM).

Staging a professional performance without a tech rider would not occur in the performing arts. To support the digital stewardship of digital cultural heritage and digital humanities projects, when transferring custody of digital content outputs, these equivalent documents should also be considered as mandatory. In order to ensure this documentation is available during transfer of custody, it should be created early on in the project so as to record any complexities.

Some examples of technical riders that may be worthwhile referring to include a rider from the duo comprising American electronic music producer Grey Filastine and Indonesian 'neo-soul' vocalist Nova Ruth. Their 2017 live audiovisual performance, Drapetomania, incorporates traditional and electronic sounds and visuals [24]. Given the range of vocals and instrumentation (electronic and traditional) used in their performance—plus the digital video element—this is a comprehensive yet

Table 2 Comparative proposed alignments between the performing arts and digital stewardship documentation

Performing arts	Digital stewardship
Tech rider	Data Management Plan—laid out in list format, technical requirements etc.
Stage plot	System diagram, system dependencies diagram, data model etc.
Input list	Data flow diagram or list—information on inputs (entered/ingested) and outputs (exported/made available)
Other information held in the tech rider, and other production docs	All other associated documentation—standards used, metadata crosswalks, data dictionaries, controlled lists etc.

condensed setup. Their tech rider clearly outlines the different components required to stage this performance, which may be a useful guide for digital cultural heritage or digital humanities projects that contain a wide range of elements. For complex digital content, the 2009 work, ZEE, by Austrian artist Kurt Hentschläger—who creates immersive audiovisual installations and performances—may prove a useful reference [27]. Hentschläger's tech rider clearly states which components are and are not supplied. Digital cultural heritage or digital humanities projects or outputs that contain multiple dependences will need to clearly identify each of these aspects. The tech rider for ZEE may be a useful documentation model.

Indigenous Australian contemporary dance company, Bangarra Dance Theatre's 2017 performance, Bennelong [52], incorporates a multitrack audio playback file (running out of QLab) with two data projectors 'blended' to create a giant projection on cloth, at the rear of the stage. Figure 4 illustrates the stage plot and input list, which form part of the tech rider for this production. In terms of a model for data flows—including inputs and outputs—a simple visual diagram, similar to the Bennelong tech rider, would be suitable for recording this type of information.

Given the need to capture precise technical information, as part of digital cultural heritage or digital humanities project outputs, or for reproducibility of research data, it is not that great of a leap between documenting technical information in the performing arts, to these domains. For projects that are nearing the end of their lifespans, this method of documentation allows for a meaningful way of detailing information, that will be necessary when undertaking preservation activities in future.

14 Conclusion

Taking a holistic digital stewardship approach allows for greater consideration of the available methods for capturing, managing and preserving digital content outputs,

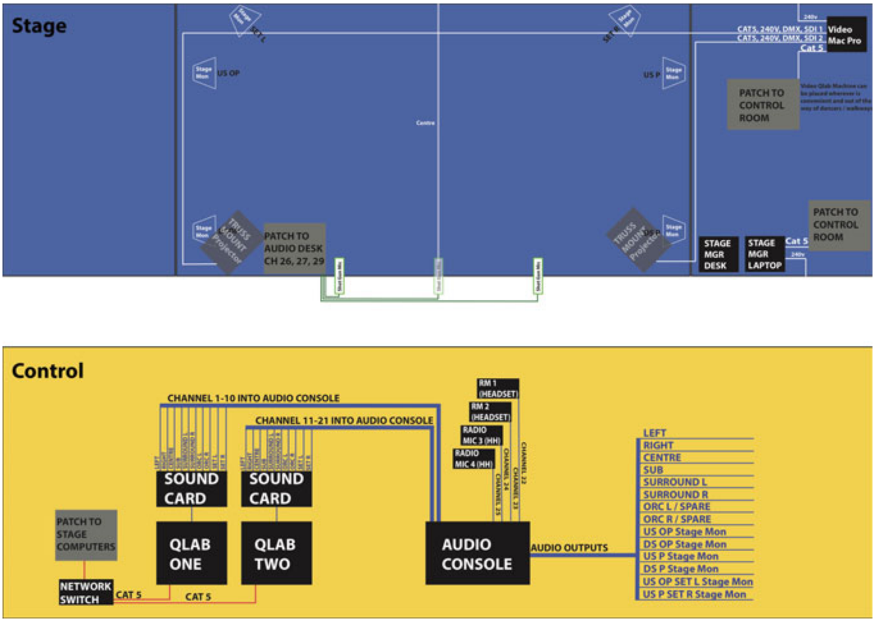

Fig. 4 Stage plot and input list for Bangarra Dance Theatre's 2017 Bennelong production

created as part of digital cultural heritage or digital humanities projects. Developing a comprehensive awareness of the needs of each specific type of digital content, and producing documentation from the get-go, gives the digital content an improved chance of long-term sustainability. Plan the project's funeral early enough—ideally, as it is conceived—so that it allows for as many aspects of the digital content to 'live on'. Utilising several digital curation and digital preservation models—as well as implementing more than one capture approach in order to 'cover a few bases' (acknowledging there are pros and cons to each)—is likely to enable more options for the preservation of and access to digital content in the future. Considering the different ways in which future access to digital content may be offered will influence earlier preservation decisions. This will either provide future flexibility, or possible limitations downstream. Given other disciplines' approaches to capturing and documenting complex interactive digital content, and technical requirements and/or specifications, it would be pertinent for the field of digital stewardship (encompassing digital curation and digital preservation) to borrow and adapt selected approaches in order to record these technical complexities. There is no one perfect solution and the digital content outputs produced from each digital cultural heritage or digital humanities project, must be handled on a case-by-case basis, at least for the foreseeable future.

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References

1. Brown, A.: Practical Digital Preservation: A how-to guide for organizations of any size. Facet Publishing, London (2013) 218
2. Bodleian Libraries, Oxford.: Digital Humanities Archives for Research Materials. (2014). Available at: http://blogs.bodleian.ox.ac.uk/dharma/2015/04/07/dharma-final-report/, accessed 27 March 2017
3. Cambridge Digital Humanities. Available at: https://www.cdh.cam.ac.uk/, accessed 28 May 2018
4. Cambridge University Libraries.: Digital Preservation Policy. Available at: https://doi.org/10.17863/CAM.32927, accessed 6 January 2019
5. Cambridge University Digital Library. Available at: https://cudl.lib.cam.ac.uk/, accessed 3 May 2018
6. Cambridge University Library.: Taylor-Schechter Cairo Genizah Collection. Available at: https://cudl.lib.cam.ac.uk/collections/genizah, accessed 27 March 2017
7. Cambridge University Library.: Classification. Available at: http://www.lib.cam.ac.uk/collections/classification, accessed 30 May 2018
8. Cambridge University Library.: Digital Humanities. Available at: http://www.lib.cam.ac.uk/research/digital-humanities, accessed 27 May 2018
9. Cambridge University Library.: Forman and Napier Casebooks. Available at: https://cudl.lib.cam.ac.uk/collections/casebooks/, accessed 28 May 2018
10. Cantara, L.: Long-term preservation of digital humanities. In: OCLC Systems & Services 22 (1). (2006) 38–42. Available at: https://www.researchgate.net/publication/220418724_Long-term_preservation_of_digital_humanities_scholarship, accessed 27 March 2017
11. The Casebooks Project. Available at: https://casebooks.lib.cam.ac.uk, accessed 2 May 2018
12. The CLOCKSS Archive. (2017). Available at: https://www.clockss.org/clockss/Home, accessed 2 May 2018
13. CLOCKSS.: Threats and Mitigations. Available at: https://documents.clockss.org/index.php?title=CLOCKSS:_Threats_and_Mitigations, accessed 16 June 2017
14. Data Hub of Australian Research on Marine and Aquatic Ecocultures. Available at: https://dharmae.research.uts.edu.au/, accessed 29 May 2018
15. Design & Art Australia Online. Available at: https://www.daao.org.au/, accessed 6 March 2018
16. Design & Art Australia Online Blog.: Schema and Data Model Refinements. (2015). Available at: http://blogs.unsw.edu.au/daao/blog/2015/03/schema-and-data-model-refinements/, accessed 30 May 2018
17. Dietrich, J.S.: E-Journals: Do-It-Yourself Publishing. In: Engineering and Science, Vol. 62 (4). (1999) 26–33. Available at: http://resolver.caltech.edu/CaltechES:62.4.EJournals, accessed 27 March 2017
18. Digital Curation Centre.: DCC Curation Lifecycle Model. Available at: http://www.dcc.ac.uk/resources/curation-lifecycle-model, accessed 29 March 2018
19. Digital Curation Centre.: DMPonline. Available at: https://dmponline.dcc.ac.uk/, accessed 30 May 2018
20. Digital Curation Centre.: Example DMPs and guidance. Available at: http://www.dcc.ac.uk/resources/data-management-plans/guidance-examples, accessed 30 May 2018

21. Digital Preservation at Oxford and Cambridge. (2016). Available at: http://www.dpoc.ac.uk/, accessed 27 March 2017
22. Digital Preservation Coalition.: Fixity and checksums. Available at: https://www.dpconline.org/handbook/technical-solutions-and-tools/fixity-and-checksums, accessed 25 May 2018
23. Dullaart, C, Sakrowski, R.: netart.database. Available at: http://net.artdatabase.org/, accessed 6 March 2018
24. Filastine & Nova.: Drapetomania Technical Rider. (2017). Available at: http://www.filastine.com/images/download/FilastineNova_Drapetomania_TECH_RIDER_15_Drapetomania.pdf, accessed 29 May 2018
25. Gatto, L.: Data Management Plan for a Biotechnology and Biological Sciences Research Council (BBSRC) Tools and Resources Development Fund (TRDF) Grant. (2017). Available at: https://doi.org/10.3897/rio.3.e11624, accessed 30 May 2018
26. GitHub. Available at: https://github.com/, accessed 2 May 2018
27. Hentschläger, K.: ZEE – Technical Rider 2009.1. (2009). Available at: http://www.kurthentschlager.com/portfolio/zee/techrider/Tech_Rider_ZEE_2009.pdf, accessed 28 May 2018
28. Hey, A J G, Trefethen, A E.: The Data Deluge: An e-Science Perspective. In: Berman, F, Fox, G C and Hey, A J G Grid Computing - Making the Global Infrastructure a Reality. (2003). Available at: https://eprints.soton.ac.uk/257648/, accessed 27 May 2018
29. Higgins, S.: Draft DCC Curation Lifecycle Model. (2008). Available at: https://doi.org/10.2218/ijdc.v2i2.30, accessed 2 May 2018
30. HTTrack Website Copier. Available at: https://www.httrack.com/, accessed 2 May 2018
31. International Internet Preservation Consortium.: OpenWayback. Available at: http://netpreserve.org/web-archiving/openwayback/, accessed 2 May 2018
32. Internet Archive.: Archive-It. Available at: https://archive-it.org/, accessed 7 May 2018
33. Internet Archive.: Heritrix. Available at: https://webarchive.jira.com/wiki/spaces/Heritrix, accessed 28 May 2018
34. Internet Archive.: Wayback Machine. Available at: https://archive.org/web/, accessed 17 March 2018
35. Johnston, L.: Digital Humanities and Digital Preservation (2013). In: The Signal. Available at: https://blogs.loc.gov/thesignal/2013/04/digital-humanities-and-digital-preservation/, accessed 27 March 2017
36. King's Digital Lab. Available at: https://www.kdl.kcl.ac.uk/, accessed 28 May 2018
37. King's Digital Lab.: What we do, Web and data hosting. Available at: https://www.kdl.kcl.ac.uk/what-we-do/web-and-data-hosting/, accessed 28 May 2018
38. Kenney A.R., McGovern N.Y.: Digital Preservation Management: Implementing Short-term Strategies for Long-term Problems (2003). Available at: http://dpworkshop.org/dpm-eng/conclusion.html, accessed 27 March 2017
39. The Kymata Atlas.: (2017). Available at: https://kymata.org/, accessed 12 March 2018
40. Langley, S.: An approach to selecting case studies. (2017). Available at: http://www.dpoc.ac.uk/2017/05/26/selecting-case-studies/, accessed 27 March 2017
41. Langley, S.: Digital Preservation Should Be More Holistic: A Digital Stewardship Approach. In: Digital Preservation in Libraries: Preparing for a Sustainable Future. ALA Editions, Chicago (2018) 93–128. Available at: https://doi.org/10.17863/CAM.34317, accessed 6 January 2019
42. Langley, S.: Digital Streams Matrix (alpha release). (2018). Available at: https://doi.org/10.17863/CAM.26363, accessed 13 January 2019
43. Langley, S., Carter T., Davies, M., Gilmour I.: Managing multi-platform materials: selected case studies. In: Proceedings of the 19th International Symposium on Electronic Art, ISEA 2013 (2013). Available at: http://hdl.handle.net/2123/9706, accessed 27 March 2017
44. Lazorschak B.: Digital Preservation, Digital Curation, Digital Stewardship: What's in (Some) Names? In: The Signal. (2011). Available at: https://blogs.loc.gov/thesignal/2011/08/digital-preservation-digital-curation-digital-stewardship-what's-in-some-names/, accessed 27 March 2017

45. The Library of Congress.: Inaugural Class of National Digital Stewardship Residents Selected. (2013). Available at: https://www.loc.gov/item/prn-13-120/, accessed 14 May 2018
46. The Library of Congress.: National Digital Information Infrastructure and Preservation Program. Available at: http://www.digitalpreservation.gov/, accessed 12 March 2018
47. Lots of Copies Keep Stuff Safe. Available at: https://www.lockss.org/, accessed 29 April 2018
48. McCurry, J.: Digital Stewardship: The one with all the definitions. (2014). Available at: https://collation.folger.edu/2014/04/digital-stewardship-the-one-with-all-the-definitions, accessed 20 May 2018
49. National Digital Stewardship Alliance. Available at: https://www.ndsa.org, accessed 27 March 2018
50. Omeka. Available at: https://omeka.org/, accessed 4 May 2018
51. Ozmeka. Available at: https://github.com/ozmeka/ozmeka, accessed 4 May 2018
52. Page, S.: Bennelong.: Bangarra Dance Theatre. (2017). Available at: https://www.bangarra.com.au/whatson/productions/bennelong-2017, accessed 29 May 2018
53. Rhizome.: Oldweb.today. Available at: http://oldweb.today/, accessed 6 March 2018
54. Rhizome.: Webrecorder. Available at: https://webrecorder.io/, accessed 28 April 2018
55. Rosenthal, D S H et al.: Requirements for Digital Preservation Systems: A Bottom-Up Approach. (2005). Available at: http://www.dlib.org/dlib/november05/rosenthal/11rosenthal.html, accessed 24 May 2018
56. Software Independent Archiving of Relational Databases. Available at: https://github.com/DLMArchivalStandardsBoard/SIARD, accessed 30 March 2018
57. Swiss Federal Archives.: SIARD Suite. Available at: https://www.bar.admin.ch/bar/en/home/archiving/tools/siard-suite.html, accessed 28 April 2018
58. Thompson D.: Why digital preservation is or isn't business as usual. (2017). Available at: http://www.dpconline.org/blog/why-digital-preservation-is-or-isn-t-business-as-usual/, accessed 27 March 2017
59. United Nations Educational, Scientific and Cultural Organization.: Concept of Digital Heritage. (2017). Available at: http://www.unesco.org/new/en/communication-and-information/access-to-knowledge/preservation-of-documentary-heritage/digital-heritage/concept-of-digital-heritage/, accessed 2 April 2018
60. University of Cambridge.: Apollo Open Access Repository. Available at: https://www.repository.cam.ac.uk/, accessed 22 May 2018
61. UK Research and Innovation—Arts and Humanities Research Council.: Research Funding Guide. Available at: https://ahrc.ukri.org/funding/research/researchfundingguide/, accessed 6 January 2019
62. Video DownloadHelper. Available at: http://www.downloadhelper.net/, accessed 16 May 2018
63. Yang, H.: Total Cost of Ownership for Application Replatform by Open-source SW. (2016). Available at: https://doi.org/10.1016/j.procs.2016.07.170, accessed 16 April 2018

Semantic Data-Modeling and Long-Term Interpretability of Cultural Heritage Data—Three Case Studies

Laura Albers, Peggy Große and Sarah Wagner

Abstract Research institutions and museums are increasingly initiating projects where large amounts of metadata are collected that describe both the content and the context of the collected data. The use of semantic methods enables their connection. In addition, these data must remain interpretable by man and machine even after the end of funded research projects. Therefore, the data-model used has to enable a mapping of the content and context of the respective research project as well as to develop the digital resources on a sustainable basis. In the following, three different projects with diverse topics are presented, in which domain knowledge is modeled on the basis of an ontology, in this case the CIDOC Conceptual Reference Model (CRM).

Keywords Semantic data-modeling · CIDOC CRM · WissKI · Virtual research environment · Peace representation · Romanesque · Wall painting · Cabinets of curiosities · Research project · Museum · University

1 Introduction

Research institutions and museums are increasingly initiating projects where large amounts of metadata are collected that describe both the content and the context of the collected data. The use of semantic methods enables their connection. In addition,

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these data must remain interpretable by man and machine even after the end of funded research projects. Therefore, the data-model used has to enable a mapping of the content and context of the respective research project as well as to develop the digital resources on a sustainable basis. In the following, three different projects with diverse topics are presented, in which domain knowledge is modeled on the basis of an ontology, in this case the CIDOC Conceptual Reference Model (CRM).

In the information sciences an ontology is used for the description of general and specific knowledge mostly of a certain domain in a digital and formalized form. It enables the representation and persistent storage of one's own knowledge and thus its reinterpretation and reuse. The CIDOC CRM is a formal reference ontology developed by the International Committee for Documentation as part of the International Council of Museums (ICOM) and is the only heavy-weight ontology that has established itself over the last few years in the cultural heritage domain. The current version 6.2 defines 89 concepts and 149 relationships, explained by a short documentation (scope note) and visualized by examples. The event-centric approach of the CIDOC CRM is a unique selling point. This means that every step in the history of a thing or person is connected to an event (e.g. production) and not just described as a state (has producer). The events connect the documented subjects with other objects, acting persons, time and place and further information.

This data-model became through its recognition as an ISO-Standard (ISO 21127:2006) a valid tool for conceptual modelling that provides a semantic structure needed to mediate between different sources of cultural heritage information. The standardization ensures a long-term interpretability of the collected information. Since the CIDOC CRM is a written document and therefore not machine readable, the "Erlangen CRM" based on OWL was developed. In order to meet the specification of a topic of a certain research project, the ontology can be adapted or extended [7, p. 120]. This more specified version is referred to as an application or domain ontology. These ontologies form the semantic back-end for the virtual research environment WissKI.

WissKI was developed in cooperation between the Friedrich-Alexander-Universität (Erlangen), the Germanisches Nationalmuseum (Nuremberg) and the Zoologisches Forschungsmuseum Alexander König (Bonn) from 2011 to 2017. A virtual research environment is defined here as a tool for cross-linked and transdisciplinary projects, that include the collection and the management of complex data-sets as well as the generation of new knowledge.

Based on the content management system Drupal, WissKI meets the necessary prerequisites for web-based, collaborative and location-independent work. The criterion of the reuse and availability of research data is the fact that the Erlangen CRM, Drupal, and the software WissKI are available as open source instruments. The continuous improvement and expansion of the system is supported by the continuous development of the community.

The documentation of information in WissKI can be made form- and text-based. The form-based documentation is suitable for the collection of data and facts, the text-based one offers the possibility to record discursive information that can be annotated. The data edited is saved in a triple store together with the semantic paths underlying each field. By using semantic web technologies such as RDF and Web Ontology Language (OWL) the readability and interoperability of data is ensured. The use of existing authority files contributes to the enrichment and contextualization of the research data. In addition, WissKI supports the creation of local vocabularies, which support the data entry and thus harmonize them. The so-called "pathbuilder" enables the modelling of "paths" consisting of triples (entities and properties in subject-predicate-object-sequence), which proposes only those classes or properties for selection that correspond to the preceding class or property.

2 Case Studies

2.1 Representations of Peace in Early Modern Europe

The international joint research project "Representations of Peace in Early Modern Europe", funded by the Leibniz Association since July 2015, explores representations of peace in the period from the 16th to the 18th century. Peace treaties and truces had to be explained, justified and communicated beyond the mere text of the treaty. Peace representations took on this task, which were a multimedia phenomenon of the early modern period. Consequently, the research project focuses on visual representations, linguistic images and musical forms of expression. This broad approach requires the cooperation of different humanities disciplines with their respective analytical competences and perspectives as well as institutions with suitable holdings.

In order to depict abstract concepts such as peace, justice or prosperity, artists, poets or composers used a canon of motifs that were widely spread and understood throughout Europe. This "vocabulary" of peace needs to be exemplified and analyzed across genre. In addition, common questions on transmedia reception processes, changes in motifs in connection with different peace treaties, on function and perception of visual, linguistic and musical concepts were developed. The starting point, therefore, is the transdisciplinary documentation of corresponding sources, which are mainly comprised of mass media such as books, pamphlets, medals and sermon prints. The collected information relates both to data on a particular physical object as well as its content and form, such as iconography or motif, text genre or instrumentation. In addition, according to the research questions, the contextual correlations between objects, source content and peace events must be documented.

2.1.1 Data-Modelling and Data Scheme

Most of the media researched on are so-called mass media such as prints, books, medals and broadsheets, their contents, i.e. linguistic and visual motifs, need to be standardized as far as possible in relation to the research questions formulated above. Thus, the following facts had to be considered during the design of the data-model:

- Contents in the broadest sense are repeatedly received in printed products over long periods of time, often across genre boundaries.

- Broadsheets consist of texts and images that can come from different contexts and could be reused. The origin of text and image can belong to different times, as well as their reception can be done separately in other genres.
- Medals form a unit as a physical object in terms of content, one can speak of two units, since there are representations on both sides, which in turn either reused or received differently.

Information about the material object and immaterial content must be collected separately so that e.g. different dates of origins can be clearly documented. This must be mapped in the data-model. This led to the decision to distinguish between the physical shape and the content displayed on or in the objects (Fig. 1). The physical shape was modelled as instance of class *E84 Information Carrier* and its content as instance of class *E73 Information Object*. The class *E84 Information Carrier* comprises instances that are explicitly designed to act as persistent physical carriers for instances of *E73 Information Object* and must have been designed for a particular purpose that is given in all examined sources. Instances of class *E73 Information Object* must be identifiable immaterial items, such as poems, images, texts or scores that have a recognizable structure and are documented as single units. An *E73 Information Object* does not depend on a specific physical carrier and it can exist on one or more carriers simultaneously, which is reflected by the following path:

E73 Information Object → P128i is carried by → E84 Information Carrier

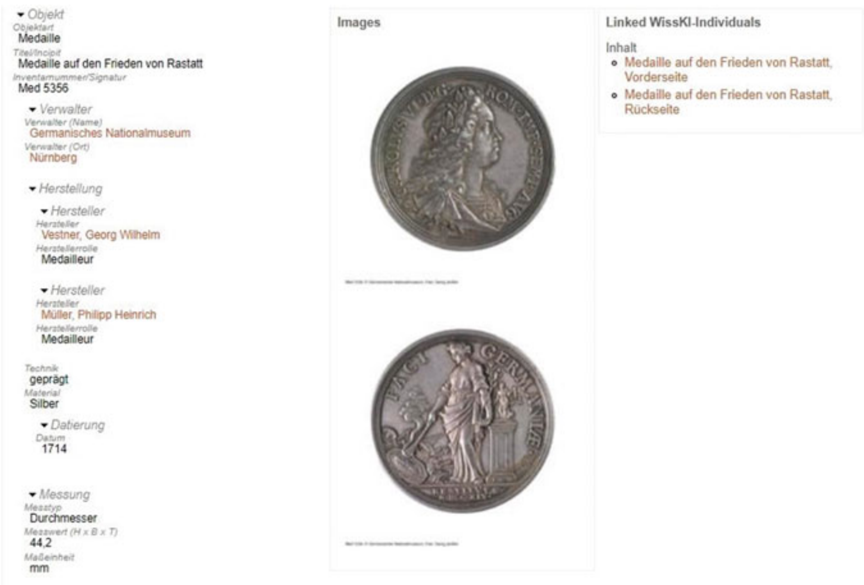

Fig. 1 Excerpt from WissKI, data entry of a medal with the linked information of physical shape (Objekt) and content (Inhalt)

2.1.2 Modelling of Ambiguity and Imprecise Information

Another main research question relates to the correlation between source content, such as motifs or themes, and peace event. In attributing and interpreting themes and contents of visual, linguistic or musical sources, an attempt is made to recognize the attitude of the artist, the client or the contemporary observer with regard to the function and meaning of images, words or notes [3, p. 13]. The modelling of the content must be therefore in line with the analytical methods used in the humanities. The historicity of the sources causes a vagueness of information that is not given objectively but attributable to a knowing subject or group [8, p. 107]. This interpretation process by the researcher has to be reflected in the data-model.

Motifs or themes of the sources are considered to be instances of the class *E55 Type*. This class comprises concepts denoted by terms from thesauri and controlled vocabularies used to characterize and classify instances of CRM classes. For the description of image content Iconclass offers a widely used classification system as Linked Open Data, which has been integrated. The interpretation of the motifs is an act of assignment by the researcher and is expressed in the data-model by the class *E13 Attribute Assignment*, respectively as *E17 Type Assignment*, a subclass of *E13*. The path connecting the assignment and the motif appears as:

E73 Information Object → P140i was attributed by → E17 Type Assignment → P2 has type → E55 Type → P149 is identified by → E75 Conceptual Object Appellation

As a result, the above-mentioned blurring of the information is mapped in the semantic structure of the data, accordingly; moreover, if needed, further details of the classification act could be included later.

2.2 Digital Capturing of Romanesque and Baroque Wall Paintings with CIDOC CRM

The following considerations and proposals for modelling data concerning wall paintings in CIDOC CRM result from two projects: The WissKI-project "Roma—Die digitale Erfassung von romanischen Wandmalereien" (The digital capturing of romanesque wall paintings) had been started as a thesis for a master degree at the Friedrich-Alexander-Universität Erlangen-Nürnberg. It was continued within the DFG-project „Sakralität und Sakralisierung in Mittelalter und Früher Neuzeit" in 2017. After the start of the project the initial idea of capturing primary data of extant romanesque wall paintings was expanded by the focus on medieval wall paintings. The second project "Corpus der barocken Deckenmalerei in Deutschland" (Corpus of baroque ceiling paintings in Germany) aims at the digitisation of extant and reconstructable objects from the time between 1550 and 1800. Funded by the Bayerische Akademie der Wissenschaften, sacral as well as profane objects will be recorded during the project term of henceforth 22 years. Irrespective of how the projects formally differ (thematic scope, time and personal scope, financial resources), congruent basic questions and problems for the data structure can be stated. The similarities as well as modelling proposals are described in the following presenting the actual state of development.

The peculiarity of wall painting lies in its alternating relationship with the architecture in which it is located. The wall surface formally and hierarchically characterized by the architectural element was considered for the painting itself. The architectural part either specified the frame and the format of the painting, or it was 'ignored' on purpose. Either way, the architectural context is constitutive for the painting and has an influence on the image content. Two examples illustrate how this reciprocity of painting and architecture can be understood within the Romanesque and Baroque epochs.

In Romanesque sacral buildings the interior was predominantly covered with mural paintings illustrating figures, scenes and ornaments [10, p. 17]. A very common form in medieval sacral architecture was the basilica. Within this building type the architectural parts did not have the same importance. Its longitudinal shape was about to stimulate the person to move into the direction of the eastern part, the chancel. In this most sacred space the procession and thus the wall painting cycle had its culmination point. In the former monastery basilica of Prüfening, figurative depictions are arranged one above the other in four registers on the northern and southern walls of the presbytery. From bottom to top their biblical-hermeneutic meaning increases. Starting at the bottom with the depiction of the secular and ecclesiastical ruler, monks, apostles and prophets, the image program culminates in a representation of the Virgin Mary in the dome. The physical building is reinterpreted by the murals as the state of theocracy and the Heavenly Jerusalem. The representation of the Virgin has to be seen as the figuration for the community of the faithful as well as for the church as place of assembly. Just as the dome is carried by the single stones, the community of believers is constituted by each one of them, represented on top by Mary as the bride of Christ. Corresponding to the iconological meaning of sacral architecture a representation of Mary in the dome in the chancel has to be interpreted in multiple ways. That means more than one possibility of interpretation to understand the figure of Mary must be considered [11, p. 268]. In comparison to that, a representation of Mary in the longhouse might intend to show the historical woman giving birth to her son, Jesus Christ.

In the Baroque era, ceiling paintings provide a vivid example of the interplay between painting and architecture. Through the architecture-bound painting "the hierarchy of rooms is made clear and meaningful places [are] thematically exaltated" [1, p. 24, translated by the author]. For this exaltation, the ceiling is the ideal culmination point.

In the paintings, the ceiling opens sky-like to the beholder and thus gives the represented scene eternal validity. In the staircase of the Würzburg Residence, the ceiling painting with the four continents placed in heaven opens up to the beholder bit by bit. The stepping up was concretely incorporated into the staging and in the experience of the painting. Only at the end, after the turnaround on the turning platform, the observer sees the civilized Europe as the ruler of the world, represented by the court of Würzburg and the patron of the paintings, the prince-bishop. In this way the principle of meraviglia, the wondering admiration, is taken into account [2, p. 118].

In Baroque as well as Romanesque art, the wall painting is directly related to the use and function of the room, bringing the observer to the insight or movement that the patron or artist has envisaged. Only through the movement in space, the key message of the painting emerges. A work-immanent procedure, without considering the architectural context, would be accompanied by great losses in the exploration of the meaning of the paintings [1, p. 23].

2.2.1 Structuring the Architecture and its Modelling in CIDOC CRM

Since the integration of architectural parts of the building in the content of the painting is a significant characteristic and since the meaning of what is represented does also depend on the exact positioning of the painting inside the building, the crux for digitizing wall paintings is to capture the painting in its building context.

In order to be able to grasp the architectural context and thus the entire informational content of the painting, it must be linked to a wall, not only to a building. In both WissKI-projects a structural subdivision of the architecture into its single parts was undertaken. The central starting point is the building as the largest unit, the wall or ceiling as the smallest unit. The structural parts are linked to each other via part-of-relations (P46i forms part of) (Fig. 2).

The data structure for the locating of the wall painting examples above are as follows (Tables 1 and 2).

Each subunit can be linked directly to the building. For this reason the structure remains flexible and is able to cover a wide range of building shapes. A single-nave church for instance might consist of four walls and a ceiling, which are then linked directly to the building. Intermediate components like compartments or subcompartments are not needed. The terms of the respective architectural components are based inter alia on the Getty Thesaurus for Art and Architecture. As a corresponding class

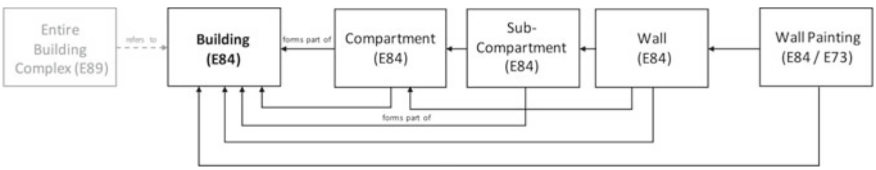

Fig. 2 Architecture structure from Roma with class assignment in CIDOC CRM

Table 1 Example Roma: Locating the wall painting in the dome of the chancel in the basilica in Prüfening

Data structure	(Entire Building Complex >) Building > Compartment > Subcompartment > Wall
Specific data entry	(Monastery of Prüfening >) Basilica > Eastern part > Chancel > Dome

in CIDOC CRM for the architectural units, the *E84 Information Carrier* class is selected in both projects.

2.2.2 Modelling the Relation Between the Painting and Its Physical Carrier

The content of a wall painting represents a conceptual object that can be modelled as an instance of the class *E73 Information Object*. However, the difficulties that arise by linking the painting (as *E73 Information Object*) directly to the wall or ceiling (as *E84 Information Carrier*) are explained in the following examples:

- Sometimes mural paintings are removed from their original spot for conservation reasons and placed in a museum. A conceptual object as it is defined by class *E73* can not have a place on earth. Therefore a wall painting modelled as *E73* cannot be physically moved. That means, information such as a former or current location can only be captured with a class describing physical objects. Only in a few cases the whole wall is transported to the museum. Usually only the painting layer with ground, thus a part of the wall is taken away. The wall or ceiling itself may remain in its original place.
- Often there are several painting layers on top of each other. The different pigments and recognizable painting parts form the basis for dating attempts of the single layers. On one wall several paintings with different physical characteristics must be recorded.
- Wall paintings do not always consist of frescoes that have been applied directly on the wall. There are also paintings stretched on canvas, which were intended as an integral part of the program, even if they are loose. Due to the nature of their attachment they are often subject to a change of location. Thus the physical support of the painting does not necessarily have to be the ceiling or wall, but can consist of another material.

The distinction between the material and immaterial information of a painting is important in order to capture the whole range of information. So how can conceptual painting be modelled in relation to physical painting with CIDOC CRM? Similar to the peace project, the mural painting is considered as an *E84 Information Carrier* and as an *E73 Information Object*. But in contrast to the peace project, the information about the physical and non-physical is not captured in two different forms, but in one

Table 2 Example Corpus: Locating the wall painting at the ceiling of the staircase in the Würzburg Residenz

Data structure	(Ensemble >) Building > Part of the Building > Room Sequence > Room > Wall/Ceiling
Specific data entry	(Prince-bishop's Residence >) Residence > Corps de logis > Room Sequence of Development > Staircase > Ceiling

Wandmalerei	Group [wm:sub84_Wall_Painting]
Titel Wandmalerei	wm:sub84_Wall_Painting -> ecrm:P102_has_title -> wm:sub35_Wall_Painting_Title
Befindet sich in Bauwerk	wm:sub84_Wall_Painting -> ecrm:P46i_forms_part_of -> wm:sub84_Building
Bildinhalt	Group [wm:sub84_Wall_Painting -> ecrm:P128_carries -> wm:sub38_Wall_Painting_Image]
Bildthema / Sujet	wm:sub84_Wall_Painting -> ecrm:P128_carries -> wm:sub38_Wall_Painting_Image -> ecrm:P140i_was_attributed_by -> wm:sub17_Wall_Painting_Type_Assignment -> ecrm:P2_has_type -> wm:sub55_Subject_Type -> ecrm:P149_is_identified_by -> wm:sub75_Subject_Type_Appellation
Figur	wm:sub84_Wall_Painting -> ecrm:P128_carries -> wm:sub38_Wall_Painting_Image -> ecrm:P140i_was_attributed_by -> wm:sub17_Wall_Painting_Type_Assignment -> ecrm:P2_has_type -> wm:sub55_Figure_Type -> ecrm:P149_is_identified_by -> wm:sub75_Figure_Type_Appellation

Fig. 3 Detail from Roma-Pathbuilder: wall painting bundle with subbundle image content

single form. This is due to the fact that the repetition of certain motifs in the wall painting projects is not the main focus. The paintings were not produced serially in a comparable form in that sense. Each painting with its specific support and architectural context should be viewed and recorded individually. So while physical painting (*E84*) is modelled as part of the wall (*E84*), the conceptual painting is linked to a physical painting via the property *P128 carries* (Fig. 3).

In this way several paintings can be attached to one wall (see the example of different layers above). And if a wall painting has been translocated and therefore has a change in its location, it can be registered because it has a physical existence.

2.3 A Data-Model for the Kunst- und Wunderkammer

In the museum sector, the historical collection type of the so called "Kunst- und Wunderkammer" has been experiencing a veritable renaissance, especially since the end of the 20th century. "Kunst- und Wunderkammer" is a German loanword for "Cabinet of Curiosities" or "Cabinet of Wonder" which describes an early modern form of collecting that appeared around the mid of the 16th century north of the Alps and that was built upon traditions and ideas of collections of the classical antique, medieval treasury chambers or Italian study rooms. Today they are seen as early forms of the modern museum. Like today's exhibitions, these collections appeared in very different forms and shapes, but their lowest common denominator was their encyclopaedic character. These collections aimed to form a microcosm of the order of the world (macrocosm) and visualize the universal connection of objects made by man (artificialia) and nature (naturalia) to represent a certain ideology that was mostly linked closely to the individual one of the collector and his background [9, p. 37–39; 5, p. 217]. Besides their representative function, they served as laboratories or places of (scientific) discourse and played an important role in the development and specification of scientific disciplines.

In many places, former bourgeois, courtly or ecclesiastical Kunst- und Wunderkammern are being reconstructed and recreated in regard to their historical roots. Recreations and adaptations of this early modern form of collecting appear in very different forms in contemporary exhibition practice, ranging from historically close reconstructions to fictitious, ideal creations. Nowadays it seems that nearly any museum has a (re-)built "Kunst- und Wunderkammer" on display.

The dissertation project at the Friedrich-Alexander-Universität Erlangen-Nürnberg is dedicated to the documentation, analysis and categorization of Kunst- und Wunderkammern in contemporary permanent exhibitions. The aim is to investigate the different exhibition types, especially in the German-speaking countries, the contemporary context of their genesis and the motivation of museums to (re-)build them. For the documentation and analysis of these exhibitions a virtual research infrastructure based on WissKI was built. In the project a representative selection of permanent exhibitions is being closely examined with regard to their current and historical concept, the history and context of the collection and the museum context of their (re-)creation.

For the documentation of the exhibitions and the semantic description of the connection of historical and contemporary features as well as for the specific questions and assignments of the subject of investigation, a data-model has been developed that builds upon an application-ontology (wunderkammern.owl) based on the CIDOC CRM. It is intended to enable a comparability of the different kinds of Kunst- und Wunderkammer-exhibitions in order to get an overview of their range, but also to draw conclusions about curatorial preferences or temporal and local occurrences. In addition, the current and, if traditional, the historical Kunst- und Wunderkammer will be compared by their arrangement and presentation, the underlying concepts of order, the focus of their content or the location. Furthermore a comparison of the historical and current situation should thus be made possible, at least to cover basic characteristics.

2.3.1 Classifying the Historical Collection and the Current Exhibition in the CIDOC CRM

In the context of the project, the exhibition is understood as a physical totality of the exhibition-room(s), objects and furniture, which are connected by the dimension of meaning (museum-theoretical concept, the order of things, their relations to each other and the multiple layers of meaning of the objects themselves). For this reason, the starting point for the class assignment to the CIDOC CRM had to be something physical and man-made, which led to *E22 Man-Made Object* [4, p. 64]. In order to include the informational level of the subject, instances of Kunst- und Wunderkammern were assigned as *E84 Information Carrier* [4, p. 110]. According to the scope note, "[t]his class comprises all instances of *E22 Man-Made Object* that are explicitly designed to act as persistent physical carriers for instances of *E73 Information*

Object [4, p. 101]. This allows a relationship to be asserted between an *E19 Physical Object* and its immaterial information contents […]".

Although historical Kunst- und Wunderkammern no longer exist in their original form, this group—like the current one—was also modelled as a subclass of *E84 Information Carrier*. The reason for this is the guarantee of direct comparability regarding the historical and current collection or exhibition, whereby not only conceptual aspects play a role, but also the space, the building or the geographical place where they are or were located. Like today's exhibition, they were a physical bearer of information, as they represent the embodiment of a particular view on the world. To treat the historical and current instances on the same level but to distinguish them semantically, the application-ontology lists the *Historical Wunderkammer* and the *Current Wunderkammer* as subclasses of *E84*.

By using the WissKI-Linkblock, a module that was developed to visualize data that was edited in another close context, information, e.g. on the historical Kunst- und Wunderkammer can be displayed in the context of the current one. For example the place of the historical Kunst- und Wunderkammer was modelled as follows:

Historical Wunderkammer → P53 has former or current location → Geographical Place → P87 is identified by → Place Name

The information documented, e.g. the geographical place "Halle", should be displayed in the context of the current situation to enable a comparability, so the starting point for the path is the *Current Wunderkammer*. To connect the historical and the current Kunst- und Wunderkammer, the property *p130 shows features of* is used. The linkblock-path to visualize the information on the geographical place of the historical Kunst- und Wunderkammer in the data-set of the current one is:

Current Wunderkammer → P130 shows features of → Historical Wunderkammer → P53 has former or current location → Geographical Place → P87 is identified by → Place Name

These linkblock-paths were modelled for all aspects of the historical and current situation that need to be compared (Fig. 4).

2.3.2 Types and Type Assignments for the Classification of Collections and Exhibitions

For the definition and description of the various types to be documented, the data-model facilitates the classification of each exhibition by combining various criteria and classification types, which are assigned as *E55 Type* [4, p. 89]. Since numerous types for the classification of properties of these exhibitions are to be defined and distinguished semantically, different subclasses of *E55* were developed in the application-ontology. These different types are connected to instances of Kunst- und Wunderkammern by a subclass of *E17 Type Assignment* [4, p. 60] (Fig. 5).

For example, class *E55 Type* includes the subclass *Exhibition Type*, which refers to the way an exhibition is integrated into the overall exhibition or museum context, e.g.

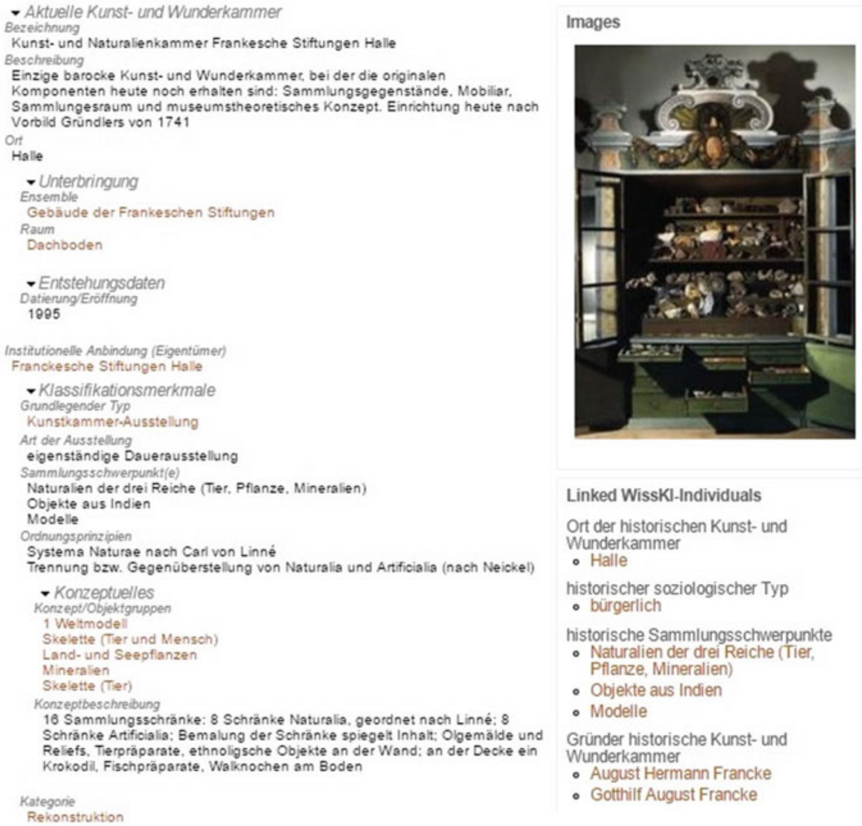

Fig. 4 Current Kunst- und Wunderkammer of the Francke Foundations Halle. The block "Linked WissKI-Individuals" mirrors information on the historical Kunst- und Wunderkammer

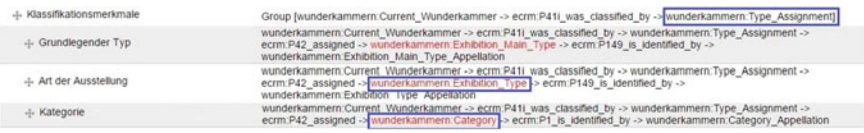

Fig. 5 Detail, WissKI Pathbuider, Semantic paths of the bundle "Type Assignment" and the different subordinate classification features

if a permanent exhibition is standing by itself or if it is a small section integrated in a bigger exhibition-context. For this reason a controlled vocabulary had to be developed in order to describe the exhibitions using headwords, e.g. “Ausstellungssektion” (section exhibition) or “geschlossene Dauerausstellung” (independent permanent exhibition).

Another subgroup of *E55* developed for the project is the class *Category*. Based on the comparison between the historical and current presentation, a distinction is made between three main assignments or exhibition types, which have proved useful from the preliminary analysis of more than 30 exhibitions and that are to be understood as a suggestion: the “reconstruction”, which comes closest to the historical Kunst- und Wunderkammer, that not only contains a large number of the original historical objects, but also the furniture and the former exhibition space. Moreover, the arrangement and presentation of the objects were realized as close as possible to the historical situation. The opposite is the type of exhibition referred to as “construction”, which is often built upon ideal historical concepts, although historical collections were probably never created on this basis and presented in such a strictly classified manner. The most common type is the “modern conception”, in which historical objects with a common provenance are brought together again in a modern display and in which the staging aspects and the construction play a rather subordinate role. In fact, the exhibitions often move between these higher-level categories. The *Category* is one of the core pieces of the project and represents a conclusive assignment of various features of each exhibition (Fig. 6).

2.3.3 Extension to a Virtual Kunst- und Wunderkammer

The data-model developed for the exhibition-analysis has been designed in a way that it can be extended to capture virtual reconstructions of Kunst- und Wunderkammern. It allows a detailed documentation of the spatial structure, the repositories and the objects. As far as the interconnection of objects and their complex level of meaning is concerned, the data-model can easily be adapted. For cases in which the objects that were part of the historical collection cannot be merged physically anymore, virtual reconstructions could be a useful possibility to reconstruct the former situation based on existing sources like inventories or travelogues. Only the virtual depiction can visualize the network of relationships of objects as well as their different levels of meaning through a non-linear, network-like structure. In this way, the virtual mapping of idealistic concepts would be enabled as it was undertaken in an analog way more than 300 years ago by Michael Bernhard Valentini. By using Semantic Web technologies, the multiple meanings of contexts gain a new dimension that is to be explored in future projects.

3 Conclusion—Long-Term Interpretability and Interoperability

The domain ontologies of the three projects have been aligned to the characteristics of each research topic and its research questions. Although the CIDOC CRM is a generic ontology, it allows extensions that can be adapted closely to the needs of a specific case. Given the fact that the application-ontologies are extensions of the ISO-certified top-level ontology, a conformity is given by the abstraction back to the level of each class or property that was specified. To minimize the loss of semantics, each new class and property developed in the application-ontology needs to be documented in a scope note.

The three presented projects are so different in their subject matter and content, thus the data collected is only peripherally overlapping. A merging of their application-ontologies would be possible, but would naturally go hand in hand with abstraction to the reference ontology CIDOC CRM with a considerable loss of domain-specific semantics. Thus, the huge advantage of data-modelling based on CIDOC CRM would be negated: to carry out the modelling on project-related conditions as semantically as accurately as possible and thus to ensure long-term interpretability.

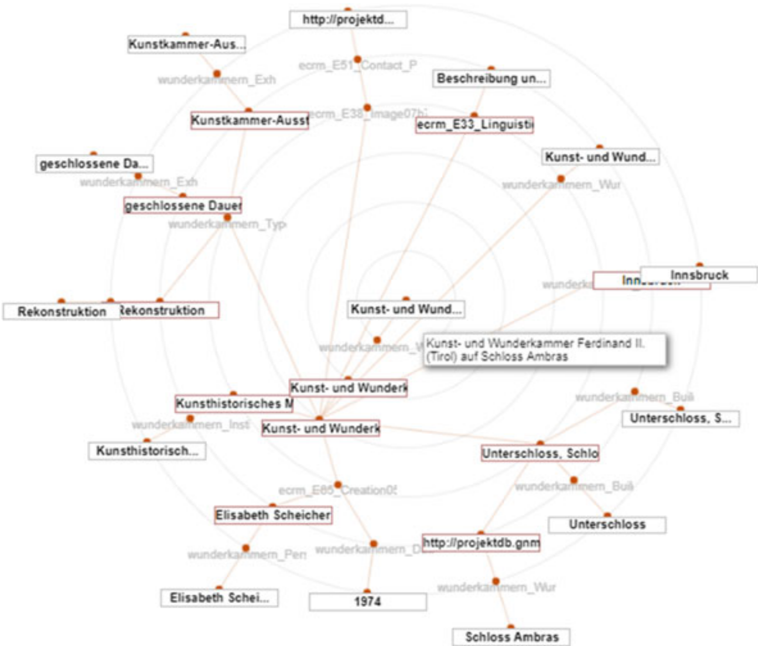

Fig. 6 Graph-view of the current Kunst- und Wunderkammer at Ambras Castle, Tyrol

References

Büttner, F., Gottdang, A.: Sinnstiftungen – das Medium Deckenmalerei. In: Akademie Aktuell. Zeitschrift der Bayerischen Akademie der Wissenschaften (2/2016) 19–25

Büttner, F., Gottdang, A.: Einführung in die Ikonographie. Wege zur Deutung von Bildinhalten. Beck, München (2013)

Büttner, N.: Einführung in die frühneuzeitliche Ikonographie. Wissenschaftliche Buchgesellschaft, Darmstadt (2014)

Doerr, M., Lampe, K., Krause, S.: Definition des CIDOC Conceptual Reference Model Version 5.0.1., autor. durch die CIDOC CRM Special Interest Group (SIG) (Beiträge zur Museologie 1). ICOM Deutschland, Berlin (2010)

Felfe, R.: Die Kunstkammer und ihre Aktualität. Museale Inszenierungen von Naturgeschichte in der Frühen Neuzeit. In: Toellner von, R. et al. (eds.): Die Gründung der Leopoldina- Academia Naturae Curiosum - im historischen Kontext (Acta Historica Leopoldina Nr. 49). Deutsche Akademie der Naturforscher Leopoldina, Halle, Stuttgart (2008) 215–240

Fichtner, M., Ribaud, V.: Paths and shortcuts in an event-oriented ontology. Springer. 6th Metadata and Semantics Research Conference 2012, November 2012, Cadiz, Spain. In: Communications in Computer and Information Science (2012) 214–226. https://doi.org/10.1007/978-3-642-35233-1_22

Hohmann, G., Fichtner, M.: Chancen und Herausforderungen in der praktischen Anwendung von Ontologien für das Kulturerbe. In: Robertson-von Trotta, C., Schneider, R. (eds.): Digitales Kulturerbe. Bewahrung und Zugänglichkeit in der wissenschaftlichen Praxis. KIT Scientific Publishing, Karlsruhe (2015) 115–128

Jannidis, F.: Grundlagen der Datenmodellierung. In: Jannidis, F.; Kohle, H.; Rehbein, M. (eds.): Digital Humanities. Eine Einführung. J.B. Metzler, Stuttgart (2017) 99–108

Roth, H. (ed.): Der Anfang der Museumslehre in Deutschland. Das Traktat „Inscriptiones vel Tituli Theatri Amplissimi“ von Samuel Quiccheberg. De Gruyter, Boston, Berlin (2000)

Stein-Kecks, H.: Romanische Wandmalerei. In: Kunsthistorische Arbeitsblätter (7/8 2003) 19–36

Stein-Kecks, H.: Bilder im Heiligen Raum. “An der Zierde deines Hauses habe ich mich erfreut, Herr”. In: Wittekind, S. (ed.): Romanik. Geschichte der bildenden Kunst in Deutschland. Prestel, München (2009) 265–287

From Classic (Analogue) to Digital Forms of Cultural Heritage Protection in Poland

Barbara Prus, Karol Król, Krzysztof Gawroński, Edward Sankowski and Józef Hernik

Abstract The aim of this article is to present research about some aspects of material entities that are part of the cultural heritage of Poland. The article examines characteristics of protection of this cultural heritage as expressed in activities dating from the early nineteenth century to modern times and indeed extending to the present moment which is much more digitally framed. Such activities now include some use of digital resources. In this article, special attention is paid to the fact that currently in Poland the classic analogue form of monuments registration dominates at the national, regional and local levels. A more developed digital historical monument database has great potential for progress in various ways. Apart from the fundamental function of gathering and recording information about cultural heritage, such a database also has a large information-disseminating, educational, and marketing potential. It can be used to create new digital resources for communication and presentation of cultural heritage, and for planning purposes.

Keywords Preservation of cultural heritage · Monuments information · Protection of monuments in Małopolska · Commune monuments registry

1 Introduction

The common definition of cultural heritage includes the legacy of physical artefacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and often intended to be available for the benefit of future generations. It includes tangible culture such as buildings, monuments, landscapes,

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books, works of art, and artefacts generally. The intangible culture includes folklore, traditions, language, and knowledge. A last element of cultural heritage, though culturally mediated, is defined as natural heritage and includes culturally significant landscapes, and biodiversity [11].

The care and preservation of heritage, formerly known in part as care of monuments, is rooted in the second half of the 19th century [26]. This is a task that for many years has been a subject of interest of European Union law. One of the entries in Agenda 2030 (Goal 11) is devoted to the need to strengthen efforts to protect and safeguard the world's cultural and natural heritage [1]. The Agenda acknowledges the natural and cultural diversity of the world and recognizes that all cultures and civilizations can contribute to, and are crucial enablers of sustainable development, precisely (in part) through attention to culture.

There has been a trend in the ongoing theory and practice of sustainable development to include more attention to culture. Sustainable development theory and practice has from the beginnings of its explicit, relatively recent, most influential formulations always contained a cultural as well as political and economic framework. However, this attention to culture seems to have increased in contemporary development studies. Attention to culture has always been integrated with attention to economic and political (governmental) factors, and this article continues that integrative emphasis [22].

All countries in the world are distinguished by a valuable, unique cultural heritage (evidence of cultural diversity of nations) that has evolved over the centuries. The phenomenon of cultural heritage means that individual countries are recognizable in the world, such as the USA with the oldest National Park Yellowstone, Peru with Inca cities, Egypt with pyramids and the Sphinx, Brazil with its carnival in Rio.

The cultural heritage and natural heritage of each European Union member state is protected under the Convention on the Protection of the World Cultural and Natural Heritage adopted in Paris on November 16, 1972 [12, 18], as well as on the basis of the European Landscape Convention as adopted in Florence on November 20, 2000. These documents contain the statement that the heritage of humanity equally includes cultural heritage as well as natural heritage [30]. However, the very need to protect monuments was recognized by some much earlier.

Over the centuries, the boundaries of countries and the identity of nations have changed, while cultural heritage has often survived through those political changes. Historic objects are not only goods that constitute the world cultural heritage, but sometimes they are, more modestly, valuable small items such as particular family memorabilia. The significant value of historic objects is a result of their rarity, uniqueness and distinctive character [20].

Polish tradition and culture are reflected in numerous monuments scattered all over the country, but also in countless routes stretching thousands of kilometers across the country. The classic, traditional routes of cultural heritage include the Cistercian Route joining the places where the temples of this order survived, the Piast Route or the Eagles' Nests Route, famous for the ruins of medieval strongholds (castles). Hiking routes in the Sudety Mountains, the Beskids, the Świętokrzyskie Mountains and the Gates of the Carpathian Foothills can if this is communicated well publically encourage visitors (and locals) wandering around the Polish mountains. There are also many thematic routes: from the Małopolska Wooden Architecture Route, through the Lower Silesian Route of Extinct Volcanoes, to the Wielkopolska Water Mills Route. An interesting tourist option is canoe routes designated on rivers such as Drawa, Brda, Krutynia or Czarna Hańcza.

Since the 1970s, the following fifteen examples of cultural objects have been inscribed on the UNESCO World Heritage List in Poland (Fig. 1), including: (1) Old Town in Krakow, (2) Royal Salt Mines in Wieliczka and Bochnia, (3) Jungle in Białowieża, (4) Old Town in Warsaw, (5) Old Town in Zamość, (6) the medieval urban complex in Toruń, (7) the Teutonic castle in Malbork, (8) Kalwaria Zebrzydowska: the Mannerist architectural and landscape complex and pilgrimage park, (9) Lower Silesian Churches of Peace in Jawor and Świdnica, (10) wooden churches of southern Małopolska—Binarowa, Blizne, Dębno Podhalańskie, Haczów, Lipnica Murowana, Sękowa, (11) Muskauer Park, (12) Centennial Hall in Wrocław, (13) wooden Ortho-

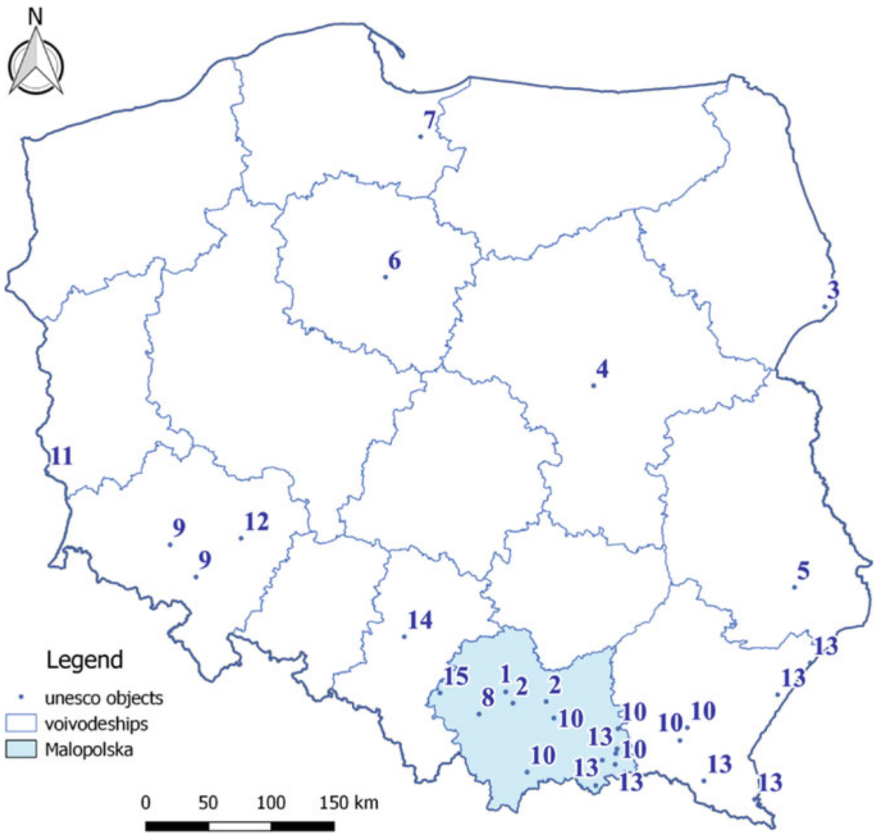


Fig. 1 Location of objects inscribed on the UNESCO World Heritage List about Poland. Numbers in the figure are as in the text above. *Source* Own study

dox churches in the Polish and Ukrainian Carpathian Region, (14) a mine of lead, silver and zinc ores in Tarnowskie Góry and an underground water management system, and (15) German extermination camps: Auschwitz and Birkenau (whc.unesco.org). A specific complement to the UNESCO list is the list of UNESCO Biosphere Reserves, in which nine Polish national parks are listed: Bieszczadzki, Tatrzański, Babiogórski, Karkonoski, Słowiński, Poleski, Kampinoski and Białowieski, Bory Tucholskie as well as Łuknajno Lake.

In Poland, the institution undertaking activities in the field of national heritage protection is the National Heritage Institute operating at the Ministry of Culture and National Heritage. Pursuant to §3 of the statute of the National Heritage Institute, which is annexed to Regulation No. 32 of the Ministry of Culture and National Heritage of 23 December 2010 [33], the Institute performs tasks in the field of sustainable protection of Polish cultural heritage in order to preserve it for future generations. The Institute's tasks include archiving collections of documents related to the protection of monuments and their digitization and dissemination, collecting documentation of the National Monument Records, evaluation and improvement of the system of protection and records of tangible and intangible heritage, creation and dissemination of documentation standards, as well as research on and maintenance of particular categories of monuments.

2 Forms of Monuments Protection in Poland

Cultural heritage encompasses three main forms: tangible, intangible and natural heritage. Tangible forms of cultural heritage are (e.g.) monuments that are the product of the activity of generations. Intangible heritage includes information about, and cultural objects consisting in folklore, traditions of culture, or language. Natural heritage results from the preservation of natural and cultural instances of landscape. All forms of protection of cultural heritage in Poland are subject to legal protection, which is determined by numerous legally generated acts. In the case of material heritage, it is other things being equal easier in some respects to provide legal protection. The protection of intangible heritage is by comparison an exceptionally difficult task and consists in its identification, consolidation of records, preservation and transmission to the next generation.

The awareness of the need to protect national monuments, constituting an important component of cultural heritage, has been growing in Polish society since the 19th century. However, it was not accompanied by any effective legal solutions. To a large extent it resulted from the intentional policy of the invaders—Austro-Hungarian Empire, Prussia and Russia, among whom the Polish lands were divided, at the end of the 18th century. The occupiers sought to eliminate traces of Polish culture. At the same time, however, none of the countries that partitioned Poland at first had a law ensuring proper care of their own monuments of art and that were located within Polish territory.

The first mention of the institutional care of monuments in Poland dates back to the beginning of the 19th century from the Prussian partition. In 1803 King Frederick William III, when he was informed about the devastation of the Teutonic castle in Malbork by the Prussian army, moved the military warehouses to another place, and entrusted the building to the architects' care, because the conservator profession was not known at that time. In 1843, the first state monument conservator was established in the Prussian Kingdom. His name was Ferdinand von Quast (born in 1807). He held the function of monument conservator in the area of Silesia, Pomerania, Prussia and Wielkopolska for life until 1877. Von Quast claimed that *"no destruction is able to change the original character of the monument so much, as many a so-called* "*conservator (maintenance engineer)*" [29].

The lack of institutional care for monuments in Poland resulted in attempts by groups of artists and scholars to compensate for indifference or hostility to cultural heritage. The most deserving of mention was the "Warsaw Society for the Protection of Historical Monuments" founded in 1906. It dealt with the protection and conservation of monuments, as well as research in the field of art history. Activities to protect monuments and associated cultural memory were also undertaken by social activists and enthusiasts. One can count among them Zygmunt Gloger, a Polish ethnographer and archaeologist, who lived at the turn of the 20th centuries. His activity consisted in saving from oblivion instances of the material and spiritual heritage of his homeland, i.e. its history, culture and tradition. He painted wooden cottages, manor houses, treads (machines for grinding grain) and mills, did sketches, took photographs. All those were traditional regional constructions in the Polish region, which at that time did not exist in the state dimension on the world map. We owe to him an inventory of objects that disappeared from the Polish countryside landscape in one century. He published a several-volume, richly illustrated "Encyclopedia Staropolska", and also "Wooden constructions and tree products in old Poland" [8].

The activities of official restorers from the early 20th century were also outstanding. Konstanty Demetrykiewicz submitted reports on official journeys in his district—Galicia [6]. He recorded reports in the field that could be called "monuments inventory" in the work entitled "The conservators group of Western Galicia". In addition, in 1916, i.e., just before Poland regained its independence, there appeared an illustrated, enriching book entitled "Wooden Churches of Western Galicia". It was developed by conservators operating in the service of the Austro-Hungarian Monarchy—Feliks Kopera and A. Lepszy, based on years of inventory research conducted in 1912–1916 (Fig. 2). And at the beginning of the 20th century, Alexander Janowski became famous as a promoter of Polish monuments.

After the country regaining independent existence, monuments in Poland were legislatively protected. Already at the end of the First World War the first Polish legal act on the protection of monuments of art and culture was issued as the decree of the Regency Council of October 31, 1918 [34]. This document, supplemented with a few executive regulations issued shortly thereafter, regulated issues related to the protection of monuments and the organization of state conservation services during the first decade of independent Poland. This decree played an important role in the field of state care of monuments in Poland, but it also had its drawbacks. These include

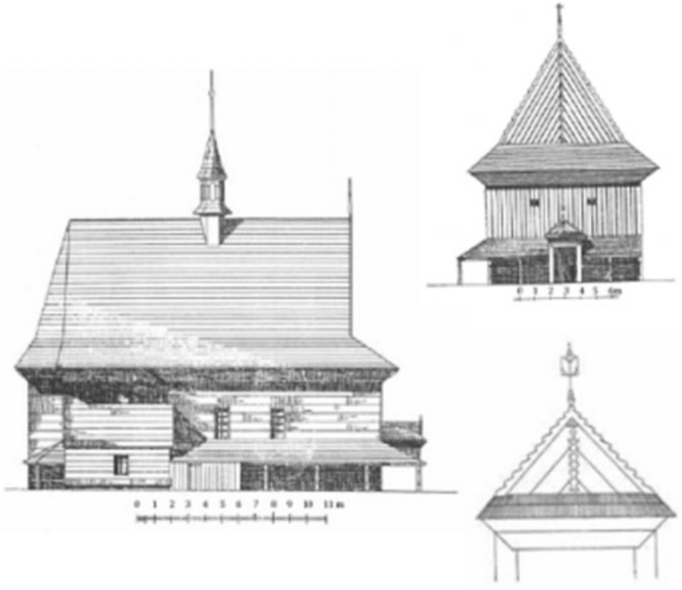


Fig. 2 Sketches of a 17th-century wooden church made in 1912 by Austro-Hungarian Empire. The General Conservator of Monuments in Krakow, Feliks Kopera. *Source* Kopera and Lepszy [13]

the entry contained in the first article, based on which the power of law extended only to the monuments entered into the national inventory, which in practice made it impossible to take quick conservation actions as regards other objects.

The organization of state offices for the care of monuments began from the former Congress Kingdom, divided into nine conservation districts. In December 1918 the first conservator was appointed (in the Warsaw district). Further nominations took place in February and March 1919. The first conservators were directors of subsidiary projects deriving their authoritative endorsement from the Ministry of Art and Culture created on December 5, 1918 [35]. In February 1920, conservation offices were incorporated into provincial offices, as branches of art and culture in the Provincial Administrative Departments. At the same time, a territorial reform was implemented, which consisted in reconciling and rendering equal the area of their activity with the borders of voivodeships, with some new districts being distinguished in some cases. Unfortunately, in the following year, due to the austerity policy of the newly created Polish State, some branches of art were eliminated from consideration, while some surviving projects were expanded. In 1922, the Act of February 17 [31], the Ministry of Art and Culture was liquidated, and its responsibilities were taken over by the Department of Arts, subject to the Ministry of Religious Denominations and Public Education (WRiOP). Even greater changes—caused by the crisis and the austerity policy undertaken by the state authorities—took place in the following years. The largest of them took place in 1923, when the WRiOP minister's order of 17 November divided the state's area into seven large conservation districts. On March 6, 1928 [37], a new act on the protection of monuments came into force, granting large powers to the conservation authorities; thanks to that it had a very innovative nature, considering the limitations of the time period.

The period of World War II brought destruction and devastation of historic buildings. However, thanks to official records and photographic documentation as well as sketches and plans, it was possible to reproduce them partially. In the years after the war there was in Poland a period in which the nature of monuments was recorded through the use of paper cards.

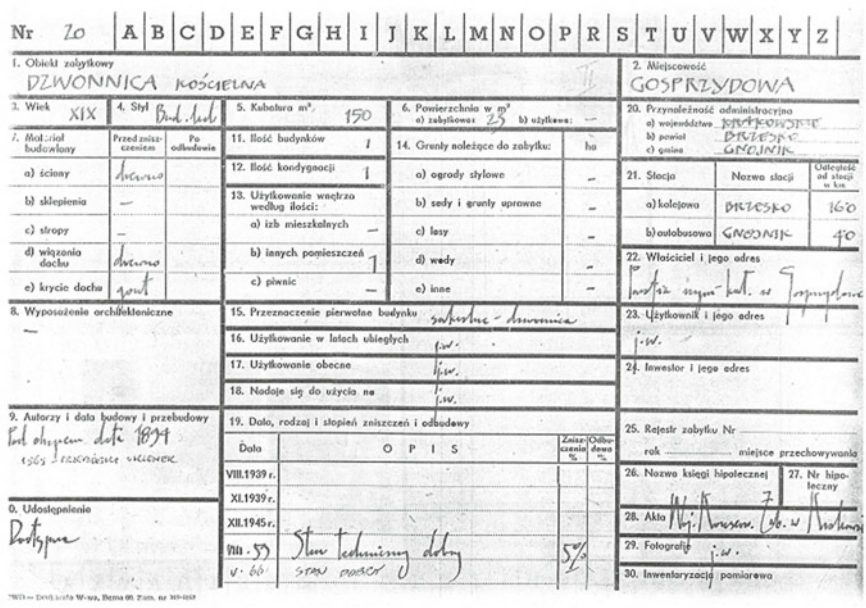
3 Records of Monuments in Poland

Records of monuments are ordered collections of data, made according to uniform patterns of studies, containing basic information about (e.g.) historic buildings. Such records contain administrative and address data, a historical outline, a description of the object, photographs and plans. Such records may include references to individual architecturally relevant objects, construction teams, granges, urban and rural complexes, archaeological sites, and historic parks and cemeteries [32]. Records of monuments are a mandatory activity for the offices of monuments protection, as well as for the municipal authorities. A properly prepared record ensures that a planned conservation policy is in place in the register of monuments, written ideas for the cooperation of the relevant conservators in drawing up spatial development plans, plans for renovation and construction works, subsidizing conservation works, preparing detailed documentation of selected historic buildings and creating a set of monuments in a given area. Examples of consolidation in the documentation of monuments in Poland are registration cards of monuments of architecture and construction. They appeared in the 1960s.

Records of architectural and other constructed monuments

The green card system was created in 1958 as a result of the activities of the Museum Board (Fig. 3). In 37 boxes there were contained basic data about the object, including relevant architectural equipment, related authors, date of construction, reconstruction, type and extent of damage, as well as the owner and date of entry in the register. The card contained and contains valuable information about archival files and measurement inventory, as well as a schematic plan, photographs and description.

The formulary had headings for the conservation work, their costs and the inspections carried out. The main action of record keeping of monuments on green cards was carried out in the years 1959–1964. Cards were also made until the end of the 1960s but became rare in the ’70s. Most of the cards concerned architectural and other constructed monuments erected up to the middle of the 19th century. Green cards were made for more prominent works from a later period, as well as for parks and cemeteries, for urban planning informational purposes. In total, about 50,000 green cards were made in Poland for historic buildings (entered or not in the register of monuments). Currently, they constitute an extremely valuable, archival collection


Nr 20 | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | R | S | T | U | V | W | X | Y | Z

1. Obiekt zabytkowy: DZWONNICA KOŚCIELNA
2. Miejscowość: GOSPRZYDOWA
3. Wiek: XIX
4. Styl
5. Kubatura m³: 150
6. Powierzchnia w m² a) zabytkowa: 25 b) użytkowa: —
7. Materiał budowlany | Przed zniszczeniem | Po odbudowie
a) ściany
b) sklepienia —
c) stropy —
d) wiązania dachu
e) krycie dachu
8. Wyposażenie architektoniczne —
9. Autorzy i data budowy i przebudowy
0. Udostępnienie
11. Ilość budynków: 1
12. Ilość kondygnacji: 1
13. Użytkowanie wnętrza według ilości: a) izb mieszkalnych — b) innych pomieszczeń 1 c) piwnic —
14. Grunty należące do zabytku: ha a) ogrody stylowe – b) sady i grunty uprawne – c) lasy – d) wody – e) inne –
15. Przeznaczenie pierwotne budynku
16. Użytkowanie w latach ubiegłych
17. Użytkowanie obecne
18. Nadaje się do użycia na
19. Data, rodzaj i stopień zniszczeń i odbudowy

Data	O P I S	Zniszczenia %	Odbudowa %
VIII.1939 r.			
XI.1939 r.			
XII.1945 r.			
[illegible]		5%	
[illegible]	STAN DOBRY		

20. Przynależność administracyjna a) województwo KRAKOWSKIE b) powiat BRZESKO c) gmina GNOJNIK
21. Stacja | Nazwa stacji | Odległość od stacji w km
a) kolejowa | BRZESKO | 16
b) autobusowa | GNOJNIK | 4
22. Właściciel i jego adres
23. Użytkownik i jego adres
24. Inwestor i jego adres
25. Rejestr zabytku Nr ... rok ... miejsce przechowywania
26. Nazwa księgi hipotecznej
27. Nr hipoteczny
28. Akta
29. Fotografie
30. Inwentaryzacja pomiarowa

Fig. 3 Part of a green card. *Source* Provincial Office for the Protection of Monuments in Krakow o /Tarnów

of information about historic buildings. The illustrative material contained in them is a unique iconography for transformed, damaged or non-existent objects.

The information Sheet of Monuments of Architecture and Construction—the so-called white card (Fig. 4) was developed in 1975. The conception of its creation was not a mere continuation of the green card. White cards were meant to become the basis for the first central records of architecture and construction for the purpose of protecting monuments in Poland. The white card contained extensive historical, descriptive and conservation information, site plans and projections of facilities as well as extensive photographic documentation, as well as information on bibliography and archives. The cards were made in accordance with a uniform pattern for all types of architectural and construction objects, from sacred and residential architecture, public and defensive buildings, residential, industrial, farm and economic buildings, to small architecture—park buildings, as well as wells and fences. Cards were also created for construction teams, to serve as records with regards to farms, hospital and factory complexes as well as urban and rural complexes. Many of the most valuable objects still do not have a white card, although it is considered the basic form for the registry. Interesting is the fact that the white card form, developed in the mid-1970s, meets or even exceeds the Council of Europe Directive 1992 Data Core Index on Architectural Heritage.

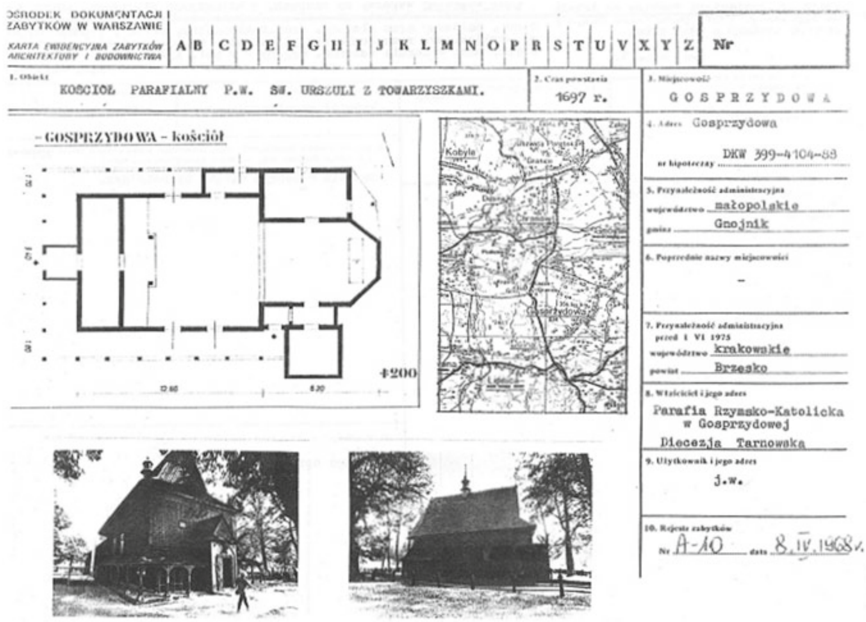


Fig. 4 A part of a white card. *Source* Provincial Office for the Protection of Monuments in Krakow o /Tarnów

4 Contemporary Forms of Monument Protection in Poland

As we can see in the Act on the Protection of Monuments of 23 July 2003, all types of monuments are in Poland a subject of preservation (Article 6.1) such as:

(1) immovable monuments, in particular:
   a. cultural landscapes,
   b. urban and rural layouts and construction sites,
   c. architecture and construction works,
   d. defensive construction works,
   e. technical facilities, including mines, steel mills, power plants and other industrial factories,
   f. cemeteries,
   g. parks, gardens and other forms of greenery designed,
   h. places commemorating historical events or activities of outstanding personalities or institutions,

(2) movable monuments, among which you can find i.e. ethnographic objects (…)

(3) archaeological monuments, in particular:
   a. remnants of prehistoric and historical settlement,
   b. graveyards,
   c. relics of economic, religious and artistic activity.

Protection of monuments, in accordance with the provisions of the Act on the Protection of Monuments, is the task of public administration bodies, as well as the owner of the object. Protective measures are to enable permanent preservation of monuments and their management and maintenance in a good condition, control by the state of preservation and changes in destination, as well as prevention of threats that may reduce their value. Care by the owner if any of the monument consists in allowing for scientific conditions for research, documenting the monument and preventive activities aimed at maintenance, restoration and sometimes carrying out construction work aimed at preserving the monument and sometimes providing for its maintenance (including maintenance of its surroundings) in the best possible condition. The Act on the Protection of Monuments restricts the right to use a monument in a way that may reduce its value, while in the first place it promotes and disseminates knowledge about the monument and its significance for history and culture. The legal forms of protection of monuments in Poland are:

(1) entry into the register of monuments,
(2) recognition as a historical monument,
(3) creation of a cultural park,
(4) determination of protection in the local spatial development plan.

The register of monuments located in the province is maintained by the voivodeship conservator. Entry of an immovable monument in the register takes place on the basis of a decision issued by the voivodeship conservator of monuments from the office or at the request of the owner of the monument. The environs of the monument, or the geographical, historical or traditional name of the monument may also be entered in the register. The register may also include historic urban layout, or accounts by or about rural or historical construction teams. All of this does not exclude the possibility of including reference to individual decisions (within larger group activities) in the register entry that is about immovable monuments.

Entry in the register of immovable property is disclosed in the land and mortgage register at the request of the voivodeship conservator on the basis of a decision to create records about this monument. Such a decision also forms the basis for entry in the real estate cadastre. And information about the entry in the register is announced in the voivodship official journal ([32], Article 9).

The register of monuments in Poland is the basis for drawing up programs of care for monuments by voivodeships, powiats and communes. The national monuments register is maintained by the General Conservator of Monuments in the form of a collection of record cards of monuments in the provincial monuments records. The Voivodeship Inspector of Monuments keeps the voivodeship register of monuments in the form of record cards of monuments located in the voivodeship. Permanent monuments from the area of the commune are subject to the municipal record of monuments, for which the commune head, mayor or city president is responsible. A communal monuments register (GEZ) is kept in the form of a collection of address cards of immovable monuments covered by the voivodeship register of monuments.

5 Monuments Protection in Małopolska

Malopolska lies in the south of Poland, and its capital is Krakow. Monuments, including ancient monuments, can increase the tourist potential of Malopolska. The register of monuments of Malopolska currently contains approximately 3400 objects located in 182 municipalities. The list of numerous, high-class monuments is influenced by the recognized position of Małopolska on the tourist map of Europe. Monuments of the province of Małopolska are characterized by a variety of forms and utility functions as well as states of preservation [9]. The most numerous group of monuments entered into the register are churches (wooden and brick), manors and court estates as well as residential houses and outbuildings.

The largest number of monuments in the registry are concentrated in the city of Krakow (Fig. 5), whilst a large number of monuments are also located in the district of Krakow and the counties located to the south and west of the province. It can also be observed that in Malopolska there is not a single commune which does not have a monument in the register of the conservator office.

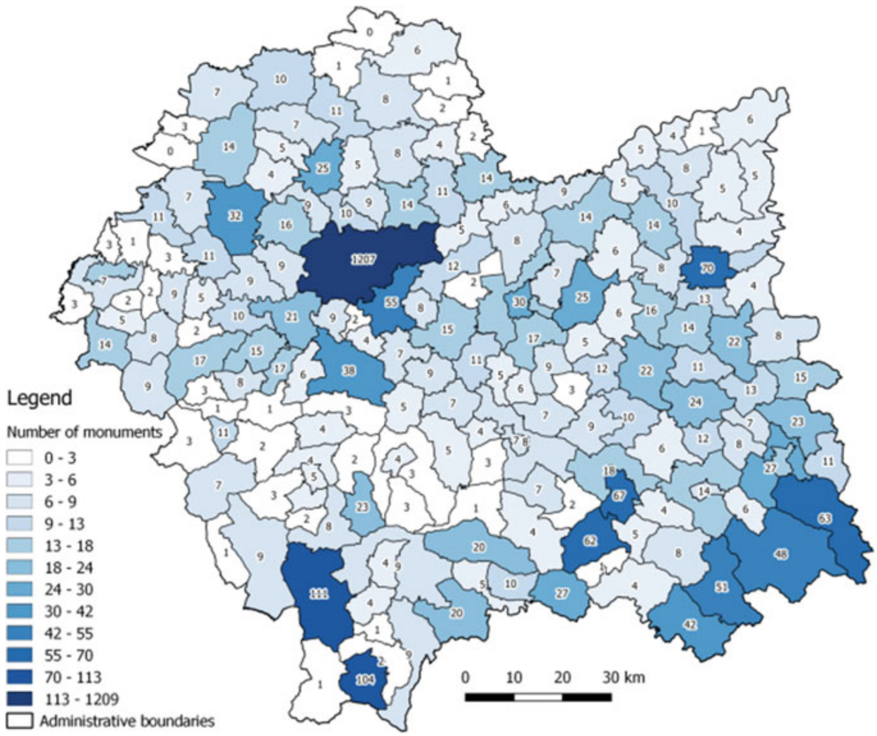


Fig. 5 Malopolska Region—number of monuments in communes as of October 2017. *Source* own study based on the list of objects entered in the register of immovable monuments of the Małopolska conservator office

In Małopolska, a number of activities are carried out aimed at protection and of interest in cultural heritage, dissemination of knowledge about cultural heritage in various forms and furthering various cultural activities (Table 1). Worth mention are e.g. the Małopolska Wooden Architecture Route, Malopolska Gates, and The Music Whispered in Wood or Emanation Festival. The General Conservator of Monuments also organizes a contest for the neatest historic building.

Table 1 Examples of cultivating cultural heritage including traditions, culture and historic objects within programs, routes, competitions, and festivals

Mode of protection—a program or a protection project	Example (photo documentation)
The Małopolska Wooden Architecture Route includes the most valuable and the most interesting wooden monuments in Małopolska. On the route there are picturesque churches, beautiful Orthodox churches, slender belfries, old Polish courts, wooden villas and open-air museums, including some of the most valuable monuments of folk material culture The Wooden Architecture Route was established in 2001 at the initiative of the Małopolska Voivodeship. All objects on the route have been marked with signboards and access to them by road signs. It includes 252 objects, including 125 churches, 49 specifically Orthodox churches, 30 buildings, 23 complexes, 16 museums, and 9 open-air museums	 Photo: Information board next to an object on the Wooden Architecture Route

(continued)

Table 1 (continued)

Mode of protection—a program or a protection project	Example (photo documentation)
The Gates of the Carpathian Foothills concept plays the role of a virtual tourist card, making it possible to get to know the area of the Carpathian Foothills, its traditions and culture, as well as providing an option for collecting stamps related to visited places through a mobile application. The concept of the project consists in gaining "7 Gates Foothills" (by scanning the bar codes at 7 places) which allows the winner to open an important gate after collecting all keys, i.e. after visiting the attractions. It is possible to obtain the keys to the gate after visiting individual places assigned to the seven gates 1. Sweet Gate is a place where sweet products are made, e.g. honey, jams, and fruit products 2. The gates of the past (as they are called) include places related to history 3. Bicycle gates are attractive places from the point of view of cycling tourism 4. The Holy Gate assembles religious places, churches, sanctuaries and chapels 5. Tradition gates are places of folk and traditional crafts displays, sometimes religiously significant 6. Horse gates—these are typically horse stables 7. The gates of recreation and relaxation- connected with places of recreation, active spending of time; or relaxation	 Photo: Plaque near the facility on the Gateway to the Foothills Route—The Holy Gate

(continued)

Table 1 (continued)

Mode of protection—a program or a protection project	Example (photo documentation)
Competition of the General Conservator of Monuments "Well-Tended Monument" Award	 Photo: The winner of the competition of the General Conservator of Monuments "Well-preserved Monument"in 2005 — church in Gosprzydowa, Malopolska, (Jerzy Bakalarz OP,Photographer).
The Music Whispered in Wood is a program supported by the Małopolska Tourist Organization, Malopolska Voivodeship, Wooden Architecture Route. It is a series of concerts on the Wooden Architecture Route, which allows spending summer weekends. The program has been implemented since 2007 for 12 consecutive holiday weeks. Apart from music, the program also offers the opportunity to participate in dance shows and stage mysteries	 Photo:String concert in the wooden church in Gosprzydowa—2009.

(continued)

Table 1 (continued)

Mode of protection—a program or a protection project	Example (photo documentation)
The Emanation Festival includes dozens of music concerts organized by the Krzysztof Penderecki European Center for Music in the space and landscape of Małopolska—Program co-financed by the Ministry of Culture and National Heritage	 Photo: Concert in the church of St. Leonard in Lipnica Murowana (Małopolska) inscribed on the Cultural Heritage List UNESCO, (Michał Urban, Photographer).

6 Municipal Records of Monuments—Statutory Requirement

The Act on the Protection of Monuments and Guardianship of Monuments from 2003 imposed on Polish municipalities the obligation to create and conduct the so-called Communal Register of Monuments in the form of a collection of address cards of monuments located in the area of the commune. The scope of the commune record of monuments was covered [32]:

1. monuments entered into the register of the conservator,
2. other immovable monuments located in the voivodship register of monuments,
3. other immovable monuments designated by the commune head (mayor, president of the city) in agreement with the voivodeship conservator.

In practice, the Communal Register of Monuments covers public facilities, sacral buildings, industrial architecture, technical facilities, villas, necropolises (necropoleis) and parks. The scope of information on immovable monuments, which should constitute the content of the card of the Municipal Monument Records of Monuments (the address card) has been specified in the regulation on keeping a register of national, voivodeship and commune records of monuments [36]. The address card of the monument contains information about the type of the monument, its name and location, giving the town, street name and number, name of the commune and powiat. The address card may contain additional information, e.g. a photograph, a map fragment with a selected monument location or coordinates enabling ascertaining of its location.

Records of monuments are the basis for drawing up programs for the care of monuments by voivodeships, powiats and communes, as well as enabling the protection of monuments in the planning e.g. spatial planning process.

7 Municipal Records of Monuments in Małopolska

The survey carried out in Małopolska by the Provincial Office for Monuments Protection in Kraków on the status of works on the commune record of monuments showed that for 182 communes, 70.1% had a municipal register of monuments drawn up according to the requirements of the 2003 Act. Municipalities that do not have this record are located mainly in the southern part of Małopolska (Fig. 6). This deficit

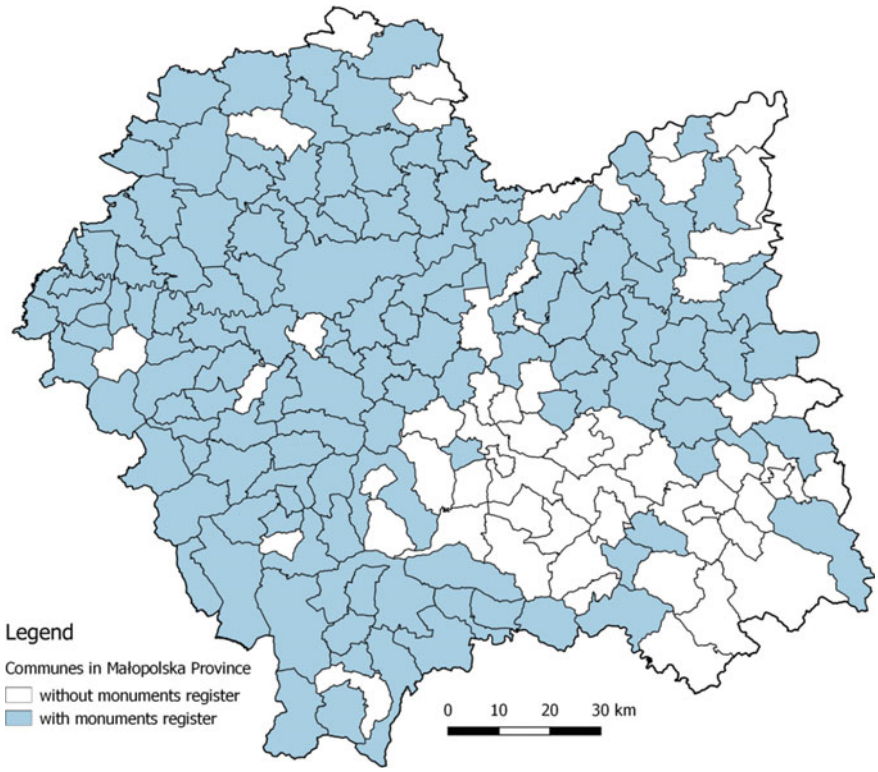


Fig. 6 The state of advancement of work on the Municipal Register of Monuments in Malopolska. *Source* own study based on data obtained from the Provincial Office for the Protection of Monuments in Krakow (Provincial Office…). Status for February [19]

may result in the lack of proper protection of monuments for the purpose of carrying out tasks in the field of planning and spatial development.

8 Digital Substitutes of Municipal Monuments Records

Municipal records of monuments in Małopolska are mainly kept in the form of paper address cards (analogue version). An alternative is the address cards of the commune records of monuments based on digital databases, along with spatial references for inventories. Inventory of monuments can significantly improve GIS spatial information systems. The whole can be presented on digital maps or in the form of web applications that perform various functions, e.g. informational and educational functions [17].

The application presenting the monuments can be prepared in a static form, which is based on raster studies, using selected techniques and programming tools, e.g. jQuery JavaScript [14], or in a dynamic form that uses map data furnished by geodata providers. These applications can be expanded by multimedia materials, including three-dimensional 3D models [3]. In most cases, such applications are a component or fragment of a larger website creating the so-called mashup [28]. The level of application advancement, including the number and form of objects, the spatial extent of the map, the number of functionalities, their usability and the functions to be fulfilled determines the choice of technique.

One of the increasingly popular solutions in the world, and at the same time relatively easy to implement, is the presentation of spatial phenomena on digital maps using the Leaflet programming library. With their help individual layers of the map could organize, mark, describe and present objects in space. The tool is characterized by performance, usability and a relatively simple API. Due to the relatively small size and support of touch panels, the Leaflet library is often used in the design of maps for mobile devices [7].

An example of an application created with the Leaflet library using OpenStreetMap resources, which can be a component of any hypertext document is an interactive map presenting selected historical objects, including churches, basilicas, cemeteries and shrines (Fig. 7).

The application presents a spatial reference for monuments and sacred objects located in the Grybów commune, including: the location and characteristics of the Minor Basilica; St. Catherine of Alexandria, a temple of special liturgical and pastoral significance; and a shrine dedicated to Our Lady of Czestochowa, dating from 1858. The application is characterized by dynamics and interactivity—historical objects presented using thematic icons and grouped into categories can be hidden or shown, and each object on the map is described with text, complemented by photography.

The interactive "Municipal Records of Monuments of the Tomice Commune" is another example of an internet application presenting a register of monuments, including chapels [15, 21]. The Tomice commune is located in the Wadowice powiat in Malopolska. The creation of the application was preceded by an inventory of

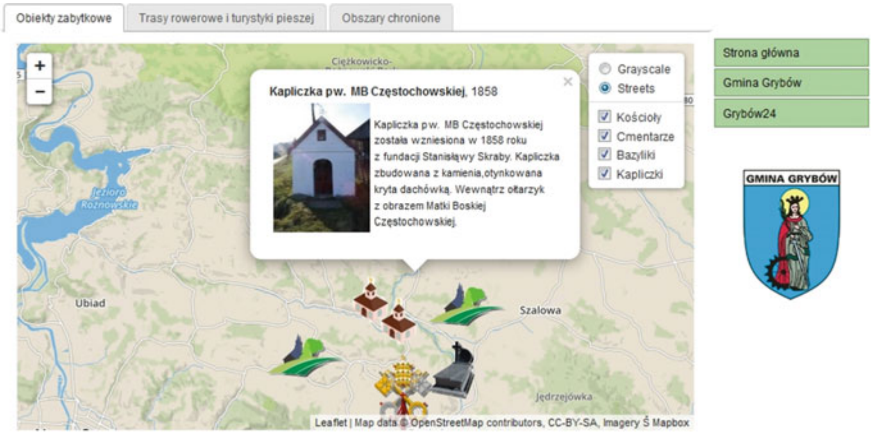


Fig. 7 A view in the browser window of an overview map presenting selected monument objects, including shrines located in the Grybów commune (Małopolska). *Source* Own study using Leaflet library

Fig. 8 Multimedia presentation of monuments records of the Tomice commune. *Source* Own study

monuments carried out using the list provided by the Provincial Conservator of Monuments in Krakow. Immediately in the field, photographs of objects documenting their state of preservation were made. All data were collected in the GIS spatial data system database using the QGIS software and used to create traditional address cards of monuments, but also their digital counterparts (Fig. 8).

The main function of the application is a multimedia presentation of address cards of individual monuments. The application interface design was made by implementing selected jQuery scripts in the structure of the hypertext document. Although the application was created for publication on the internet, it was made so that its use was possible without access to the network (offline).

9 The Concept of Communal Records in the Form of a Vertical Portal and Discussion

A municipal evidence register has a large marketing potential, which can be acted on by creating an internet application, taking into account the strategies and principles of content marketing [10]. In principle, the application created in such a way may constitute a fragment of the commune's internet ecosystem and strengthen its presence on the Internet (Fig. 9). The marketing function can be implemented by supporting the promotion of the commune, shaping its image on the internet and diversifying traffic sources on the municipal portal.

The effectiveness of the web application is conditioned by the usefulness of the content it presents and the high quality of potential use [16]. The design concept of multimedia monuments records assumes that they will be presented using multimedia materials, and the application itself will be prepared in a responsive form—its comfortable browsing will preferably be possible regardless of the size of the device display on which it will be viewed [4]. In addition, it should be possible to develop the application and expand it with new content, which can be achieved through the use of a CMS (Content Management System).

Fig. 9 Design concept of an application presenting the municipal record of monuments. *Source* Own study

According to the design concept, classic address cards of individual monuments will be transformed and prepared in the form of hypertext documents. This transformation will mainly include content that will be extended to include a detailed description of the monument, including its history and location. In addition, the text description will be completed with a photo gallery. The multimedia character of the presentation will be enhanced by video films presenting the object itself and its surroundings. This treatment will fulfil several basic functions. The video material will allow a better presentation of a given object, increase the attractiveness of its presentation and allow for better communication of the content for purposes of the recipient's psychology [27]. In addition, this presentation can encourage users to be active longer on the application pages, which is important when placing the site in search results. Therefore, it indirectly influences the increase of its impact range. In addition, the design concept provides for complementing the description of each monument with the presentation of its location on the web map, and the entire application—a map component, presenting each monument in thematic layers, created based on the type of the monument.

Moving ahead with the project of digitization of monuments records, management, and planning in Poland for the sake of monuments protection potentially represents a far-reaching societal change. Depending on how this is done, it would potentially be a major beneficial step towards promoting one aspect of sustainable development, not only with political and economic but also cultural development as a guiding idea. It should be noted, too, that the digitization project would also be consistent with reasonable conceptions of development that aim to build on but improve on older conceptions of sustainable development [23].

Much additional content and technological as well as organizational invention for the sake of the Polish project will eventually be necessary in addition to the types of activities implied by antecedently expressed notions of sustainable development, such as the canonical UN-originated Brundtland Report of [5].

In this article we have aimed to provide an initial historical narrative about monuments-focused protection efforts in part of the pre-digital era. We have proposed ways of increasing the technological sophistication of monuments protection activities through using information technology. Ongoing technological innovation added to the picture we have presented will undoubtedly require adjustments and new articulations about how to move forward.

There is an opportunity for Poland to move forward in presenting its past but also future identity to the rest of the world (and prior to that, to itself) [2].

On the economic front, one might anticipate more tourism in Poland to result, but also enhanced investment potential (for other types of enterprises) which would require choices by Poland. This would involve intra-national as well as international communications facilitated by digitization.

On the cultural front, the digitization project aiming at enhanced monuments protection would offer opportunities for combining political and economic with aesthetic decision-making and creative activities with regard to spatial planning and related domains.

It can be expected that increasingly, psychological and social scientific inquiry and related professional practice interventions (engineering, management, education, marketing and business generally, etc.) about human learning through individual and group interactions with computers will be integrated into the project. This is already part of the project, and is likely to grow. Both persons engaged in doing the digitization, and persons who are users of the results potentially will learn and improve as digitization is increasingly integrated into social processes. This is an example of what Joseph Stiglitz and Bruce Greenwald have argued is central for societal development: technological innovation and adoption of best organizational practices in a "learning society" [25].

10 Summary

Poland is a country with a rich cultural heritage. This is evidenced by, among other signs, numerous monuments located throughout the country, and constituting the core of this heritage. There is a special place on the cultural and historical map of Poland for Malopolska with its formerly royal city of Krakow.

From the moment of the emergence of awareness of the importance of protection of the cultural identity of Poland manifested by the protection of traditional architectural forms (wooden mansions, churches, buildings), and cultural and historic buildings, projects have been carried out to preserve these elements in the form of descriptions (e.g. albums, dictionaries, guides), documentation, photography, sketches, plans, maps. The registration of monuments, inscribed in the statutory requirement, enabled the unification of this task throughout the country. For the most part, the documentation has an analogue form, which limits its availability. It is therefore worth developing digital forms of records of objects that testify to the cultural identity of regions with valuable or interesting monuments. In the digital form, information can be collected and stored, at national, regional and local levels.

The statutory obligation to protect monuments in the territories of individual communes of Poland requires the creation of a commune record of monuments in the form of address cards. However, the creation of digital forms and presentations of commune records of monuments are not commonly practiced in Poland. Most municipalities do not provide communal records of monuments on the Internet, or their presentation is static, passive. This is related to a number of barriers, including: a barrier of knowledge and skills and a cost barrier. The creation of a commune record of monuments in Poland is still treated as a statutory obligation, and in this respect the records are carried out. The barrier of knowledge is associated with the lack of awareness of the (marketing) potential of commune records of monuments and the skills for its development. In communes, there is also a belief that the creation of an Internet application is associated with high costs, and the municipalities themselves are struggling with the lack of professionals from the marketing and ICT industries who would support the process of creating and managing such an application. The multimedia form of the presentation of the commune record of monuments may therefore bring a number of image, marketing and educational benefits. However, it requires knowledge and work—first at the stage of content creation, then at the stage of promotion and development. It also requires incurring certain expenditures; however, the return on the investment made will be the higher the greater the efficiency of the application itself.

Poland is changing day by day, yet it still retains its individuality and unique identity, which is undoubtedly influenced by the richness of its cultural heritage. About two thirds of Poles currently live in cities. The village to often loses its unique character; however, in many parts of Poland, civilization has not yet come, in a sense. Horses work in the fields; you can come across wooden churches, huts and barns, at the crossroads of chapels and roadside crosses that resemble a living museum. Here we still have the opportunity to get lost in time, among winding paths in the shade of characteristic willows, narrow streets of small towns, ancient oaks and chestnuts forming park avenues. Or you may sit down on the high threshold of a country cottage at the side of an old woman listening to the story of "how it used to be" [24]. Old customs are changing, but Polish tradition is still alive and cultivated. Colourful cultural and natural richness of Poland, manifesting a turbulent history and a promising future, is an invitation for tourists to experience Poland's fusion of cultural tradition and modernity.

References

1. Agenda 2030 – Transforming our world; The 2030 Agenda for Sustainable Development A/RES/70/1. United Nations.
2. Appadurai A. 2013. The Future as Cultural Fact, [In:] A. Appadurai, The Future as Cultural Fact-Essays on the Global Condition, Verso, London, 2013, 285–300.
3. Bac-Bronowicz, J., Wojciechowska, G. (2016). The status of work on development of the database of architectural industrial heritage in Wrocław. Annals of Geomatics, 14(5 (75)), 537–549.
4. Baturay, M. H., Birtane, M. (2013). Responsive web design: a new type of design for web-based instructional content. Procedia-Social and Behavioral Sciences, 106, 2275–2279. https://doi.org/10.1016/j.sbspro.2013.12.259
5. Brundtland Report 1987. Our Common Future, World Commission on Environment and Development, Oxford University Press, Oxford.
6. Demetrykiewicz K. 1900–1916. Teka grona konserwatorów Galicyi Zachodniej. Książka została opatrzona wstępem Sokołowskiego, Biblioteka Jagiellońska, SYGNATURA 72058 IV i III, Tom I, Kraków CMC.
7. Donohue R.G., Sack C.M., Roth R.E. 2014. Time series proportional symbol maps with Leaflet and JQuery. Cartographic Perspectives, 76, 43–66.
8. Gloger Z. 1907–1910. Budownictwo drzewne i wyroby z drzewa w dawnej Polsce. Warszawa.
9. Hernik J., Prus B., Ulman E., Dixon-Gough R. 2015. The Evolution of Małopolskie and Kraków as Destinations for Cultural Tourism. [In:] Hepperle E., Dixon-Gough R., Mansberger R., Paulsson J., Reuter F. and Yimay M. (eds.) Challenges for Governance Structures in Urban and Regional Development. European Academy of Land Use and Development. Vdf Hochschulverlag AG an der ETH Zürich, 59–73.
10. Holliman, G., Rowley, J. (2014). Business to business digital content marketing: marketers' perceptions of best practice. Journal of Research in Interactive Marketing, 8(4), 269–293. https://doi.org/10.1108/JRIM-02-2014-0013

11. Ionita A., Lepadatu C., Dumitrescu G. 2009. Digital Cultural Landscape Content. [In:] Hernik J. (ed.) Cultural Landscape – Across Disciplines, Oficyna Wydawnicza Branta, 255–277.
12. Jones M. 2007. The European Landscape Convention and question of public participation. Landscape Research, 32, 613–633.
13. Kopera F., Lepszy L. 1916. Kościoły drewniane Galicyi Zachodniej. Serya 1. Die Holzkirchen Westgaliziens. I. Serie. Kraków: Wydawnictwo Grona Konserwatorów Galicyi Zachodniej.
14. Król K., Szomorova L. 2015. The possibilities of using chosen jQuery JavaScript components in creating interactive maps. Geomatics, Landmanagement and Landscape (GLL), 2, 45–54.
15. Król, K., Gawroński, K., Gawrońska, G. (2013). Aplikacje multimedialne w zarządzaniu gminną ewidencją zabytków. Infrastruktura i Ekologia Terenów Wiejskich, 1(IV), 31–43.
16. Lin, S. W., Fu, H. P. (2012). Uncovering critical success factors for business-to-customer electronic commerce in travel agencies. Journal of travel & tourism marketing, 29(6), 566–584. https://doi.org/10.1080/10548408.2012.703034
17. Lu, J., Lu, Z. (2004). Development, distribution and evaluation of online tourism services in China. Electronic Commerce Research, 4(3), 221–239. https://doi.org/10.1023/B:ELEC.0000027981.81945.2a
18. Mercado-Alonso I., Fernández-Tabales A. and Muñoz-Yules O. 2018. Perceptions and social valuations of landscape. Objectives and methodology for citizen participation in landscape policies. Landscape Research, 43:1, 95–111, https://doi.org/10.1080/01426397.2017.1302570
19. Provincial Office 2018. Wykaz obiektów wpisanych do rejestru zabytków nieruchomych województwa małopolskiego z uwzględnieniem podziału na powiaty i gminy. Wojewódzki Konserwator Zabtyków w Krakowie.
20. Prus B., Gawroński K. 2010. Krajobrazy kulturowe a ochrona zabytków. [w:] Planowanie i zagospodarowanie przestrzenne jako instrument kształtowania krajobrazów kulturowych, K. Gawroński, J. Hernik (red.), Wyd. Branta, 222–233.
21. Salata T., Prus B., Król K. 2012. Opracowanie i zastosowanie nowoczesnego modelu danych przestrzennych dla stworzenia gminnej ewidencji zabytków (Development and implementation of a modern model of spatial data for the creation of municipal records of monuments). Infrastructure and Ecology of Rural Areas. Polish Academy of Science. No 2/I, 41–52.
22. Sankowski E., Harris B.J., Hernik J., 2016. Some Problems and Possibilities for Sustainable Development, Publishing House of the University of Agriculture in Krakow, Krakow.
23. Sen A. 2009. The Idea of Justice, Section, "Sustainable Development and the Environment". Harvard University Press, Cambridge, Massachusetts, 248–252.
24. Sołtyk K. (eds). 2015. Prawdziwa Polska. The real Poland. Skarby nadwiślańskiej krainy. Marvels from the land of the River Vistula. Multico Oficyna Wydawnicz, Warszawa.
25. Stiglitz J.E. and Greenwald B.C., 2015. Creating a Learning Society-A New Approach to Growth, Development, and Social Progress, Reader's Edition, Columbia University Press, New York, 2015
26. Van der Valk A. 2009. Multiple cultural landscape: research and planning for living heritage in the Netherlands. [In:] Hernik J. (ed.) Cultural Landscape – Across Disciplines, Oficyna Wydawnicza Branta, 31–60.
27. Waters, R. D., Jones, P. M. (2011). Using video to build an organization's identity and brand: A content analysis of nonprofit organizations' YouTube videos. Journal of Nonprofit & Public Sector Marketing, 23(3), 248–268. https://doi.org/10.1080/10495142.2011.594779
28. Wood J., Dykes J., Slingsby A., Clarke K. 2007. Interactive visual exploration of a large spatio-temporal dataset: reflections on a geovisualization mashup. Visualization and Computer Graphics, IEEE Transactions on, 13(6), 1176–1183.
29. Żywicki J. 2010. Officials: architects, builders, civil engineers…Architecture and construction people in the Lublin voivodeship and the Lublin province in the Kingdom of Poland in the years 1815-1915 (Urzędnicy: architekci, budowniczowie, inżynierowie cywilni…Ludzie architektury i budownictwa w województwie lubelskim oraz guberni lubelskiej w Królestwie Polskim w latach 1815–1915). Wyd. UMCS, Lublin.
30. Zeidler K. 2007. Prawo ochrony dziedzictwa kultury. Wyd. Wolters Kluwer, Warszawa.

Legal Acts

31. Act 1922. Ustawa o zniesieniu Ministerstwa Sztuki i Kultury z dnia 17 lutego 1922, [w:] Dziennik Praw Państwa Polskiego (dalej: DPPP) z 6 marca 1922 r., nr 14, poz. 128, s. 238–239.
32. Act 2003. Ustawa z dnia 23 lipca 2003 r. o ochronie zabytków i opiece nad zabytkami [Dz.U.10.76.489].
33. Act 2010. Ustawa z dnia 18 marca 2010 r. o zmianie ustawy o ochronie zabytków i opiece nad zabytkami oraz o zmianie niektórych innych ustaw [Dz.U.10.75.474].
34. Decree 1918a. Dekret o opiece nad zabytkami sztuki i kultury z dnia 31 października 1918, [w:] Dziennik Praw Państwa Polskiego (DPPP) z 8 listopada 1918, nr 16, poz. 36, s. 93–99.
35. Decree 1918b. Dekret o utworzeniu Ministerstwa Sztuki i Kultury z 5 grudnia 1918 r., [w:] DPPP z 14 grudnia 1918 r" nr 19, poz. 52, s. 140–141.
36. Regulation 2004. Rozporządzenie Ministra Kultury z dnia 14 maja 2004 r. w sprawie prowadzenia rejestru zabytków, krajowej, wojewódzkiej i gminnej ewidencji zabytków oraz krajowego wykazu zabytków skradzionych lub wywiezionych za granicę niezgodnie z prawem [Dz.U. 11.113.661]
37. Regulation 1928. Rozporządzenie Prezydenta RP z dnia 6 marca 1928 r. o opiece nad zabytkami, [w:] Dziennik Ustaw Rzeczypospolitej Polskiej z dnia 14 marca 1928 r, nr 29, poz, 265.

Visual Content Analysis and Linked Data for Automatic Enrichment of Architecture-Related Images

Tino Mager, Seyran Khademi, Ronald Siebes, Carola Hein, Victor de Boer and Jan van Gemert

Abstract Built form dominates the urban space where most people live and work and provides a visual reflection of the local, regional and global esthetical, social, cultural, technological and economic factors and values. Street-view images and historical photo archives are therefore an invaluable source for sociological or historical study; however, they often lack metadata to start any comparative analysis. Date and location are two basic annotations often missing from historical images. Depending on the research question other annotations might be useful, that either could be visually derived (e.g. the number or age of cars, the fashion people wear, the amount of street decay) or extracted from other data sources (e.g. crime statistics for the neighborhood where the picture was taken). Recent advances in automatic visual analysis and the increasing amount of linked open data triggered the research described in this paper. We provide an overview of the current status of automated image analysis and linked data technology and present a case study and methodology to automatically enrich a large database of historical images of buildings in the city of Amsterdam.

Keywords Architectural history · Architectural heritage · Computer vision · Linked open data · Automated image analysis

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1 Image Use in Architectural History

The creation of and the research in architecture is closely related to images. From architectural drawing as a cornerstone of design to paintings or photographs, visual representations allow the investigation of not only existent, but also unbuilt, changed or destroyed buildings. Thereby, the images facilitate select insights and eventually allow for contemplating on timely or spatially unreachable objects. In this regard, especially photography plays an important role due to its low grade of abstraction and a relatively trustworthy representation of specific situations.[1] It might be by mere chance that *View from the Window at Le Gras*, the world's first photograph, depicts a building.[2] But the then new technology was soon taken into account for conserving the views of historical buildings. After individual approaches, the Missions Héliographiques was a first large-scale institutional approach: in 1851 Prosper Mérimeée, France's Inspector General of Historical Monuments, initiated the project to photograph France's monuments on a country wide scale. This acknowledgement of photography's possibilities to provide reliable depictions of buildings belongs to an early stage of the modern chapter of the discipline of architectural history, but it has remained its validity ever since.

Much later, in the second half of the 20th century, the pictorial turn established images not only as scientific sources, but also as an object of investigation in its own right. Today in architectural history, research on image content as well as on issues of creation or fake concerning image content is accompanied by considerations on how the digital availability of images changes and challenges the character of research and the notion of pictorality. At the border to art history and computer science, a broad variety of considerations can be observed. At this point, we argue that the definition of the difference between chemical or digital photography as well as questions of originality and materiality might allow for interesting excursions into art theory but will be of lesser relevance than a much more game-changing aspect of digitality: the autonomous processing of image content by machines.

The recent leaps forward in computer science and machine learning, particularly deep learning, have shown astonishing results in applying non-human intelligence to a broad range of purposes. Even if rather trivial tasks for humans, such as driving a car, seem to remain relatively difficult for machines, they outsmart us on more specific tasks like learning chess from scratch and beating the chess champion within a day, or learning a language. Moreover, computers are pretty good at detecting faces—just check e.g. the Fotos app on your phone—and can do so in the millions, that means to an extent much further than human beings would be able to recognize their fellows. This brings us back to architecture: if computers can recognize individual human beings by looking at their face, they should be able to detect specific buildings by looking at their visual representations. In principle, this is the aim of ArchiMediaL,

[1]The authors are aware of the selective and sectional character of photographic images as well as the possibility of manipulative use of photographs and their falsification. However, at this point the important thing is photography's ability to capture a situation closely to reality.

[2]Nicéphore Niépce, *View from the Window at Le Gras*, heliographic image, 1826 or 1827.

an interdisciplinary research project conducted by architectural historians and computer scientists from TU Delft, VU Amsterdam, HafenCity University Hamburg and University Duisburg-Essen. Its general aim is to research computational approaches for the automatic detection of built forms and architectural elements in visual representations. So what's the benefit?

Along with digital photography and mass digitalisation in the recent years, the availability of visual representations of architecture increased exponentially. Unfortunately, in many cases this availability remains theoretical and does not come along with accessibility. To be found and investigated, images of architecture need to be annotated with information concerning the depicted object, otherwise they are unavailable for (re)search. Moreover, images of the same object can hold divergent annotations in different repositories, not to mention mistakes or different languages or spellings [1]. Here, a recognition and identification of the visual content—the depicted object—could overcome the shortcomings of text-based search. If such a vision-based search could be conducted across databases and archives, it would link their repositories and thereby enhance the search for visual sources (once the related legal questions are solved, a serious issue not to be addressed here). However, the interlinking of the repositories requires the advanced approach of linked open data.

2 Linked Open Data

Physical and digital objects and events can be described in various ways and for various purposes. An encyclopedia is one example where natural language is used to describe noteworthy things for historical and educational purposes. A number-plate on a car contains a sequence of numbers and letters used to uniquely identify a vehicle. Humans have a high tolerance to syntactic variations and sloppiness used to describe or identify things by relying on redundancy and common sense to deduce the intended 'meaning' of a sequence of characters. Computers are less flexible and rely on explicit schemas and rigid grammar. For more than two decades, just after the World Wide Web became part of our daily lives, researchers in the domain of Computational Logic came up with the idea to use the Web infrastructure as a vehicle to collaboratively describe and link 'things' in a formal way and create a standard to define an event or object by reusing descriptions made and shared by others. This research domain is called the *Semantic Web* [2] and the resulting formal (in various levels of computational complexity) and interconnected descriptions *Linked Data* [3]. When this data is publicly available, we call it *Linked Open Data (LOD)*, and the whole collection of Linked Open Data sets is called the *Linked Open Data cloud*. Since structured language is grounded in formal logic, computers can automatically reason over this data. For example, if one wants to describe an archaeological finding of a Delftware ceramic plate at a location in Alkmaar, a Dutch city, the place is already been described by the *Geonames Ontology* [4] and the type of artifact, 'Delftware', by the *Art & Architecture Thesaurus* available as Linked Data [5]. Since the computer 'understands' the geographical property of sub-regions, and the hierarchical property of historic artifact classifications, the archaeological finding would be automatically included when searching for: ‘pottery findings in The Netherlands’. The use of Linked Data to represent both data and metadata allows for a flexible data model that is easily updated and extended. Linked Data and the Resource Description Framework (RDF) [6] are the web-standard for publishing heterogeneous data on the Web, making it possible to build interconnected knowledge graphs, enriching original digital collections.

Digital Humanities is one of the earliest adopters and leading contributors to the Linked Open Data cloud, ranging from cultural heritage [7], archaeology [8], history [9] to politics [10] and census data [11]. Architecture is another domain where relevant Linked Data became available. For example, The Netherlands’ Cadastre, Land Registry and Mapping Agency—in short Kadaster—collects and registers administrative and spatial data on property and the rights involved. This also goes for ships, aircraft and telecom networks. Linked Data has been used extensively for knowledge representation and data publishing in the digital Cultural Heritage domain [12]. Europeana [7], the European cultural heritage aggregator is using Linked Open Data to publish information from European museums, archives and libraries on the Web of Data using the Europeana Data Model (EDM), which is defined in RDF and reuses well-known vocabularies such as SKOS and Dublin Core.

Previous Digital History projects that use linked data include *Dutch Ships and Sailors*, where heterogeneous maritime historical datasets are integrated [13], and *BiographyNet* which focused on biographical data [14]. By adhering to Linked Data standards, the project results can easily be integrated in (international) research infrastructures such as Europeana or CLARIAH [15], who also base their data publishing on Linked Data principles.

Apart from inter-linking images by content across repositories, an automatic detection of buildings supports a shift of focus within architectural history. Even though architectural historians began to use images relatively early, the discipline did not sufficiently reconsider its own methodological principles. Architectural historians for a long time mainly looked at the masterpieces of architectural history. As they focused on palaces and temples, they created a skewed understanding of the past. Today, despite the availability of millions of visual representations from around the globe, the consideration to the new possibilities that have arisen is by far insufficient. As a result, our knowledge of working class housing in ancient cities or on suburban developments is more limited than knowledge on the buildings of the elite. If today the flood of images can only be considered fully with the help of computer technology, the new possibilities also entail the obligation to question the established perspectives and to change them in the direction of a holistic view of architecture based on refined theoretical and methodological foundations. It is therefore crucial to critically reflect on the reading and interpretation of these sources and to develop global and balanced approaches to explore the previously unavailable heterogeneous and interconnected datasets. Here again, an automated recognition of image content would help researchers to gain systematic visual access to the rather unknown world of non-capital-a architecture.

3 Visual Content Recognition

Unlike humans, computers are good at memorizing huge amounts of seemingly unrelated images; however, deducing complex semantic relations for these images is among the more challenging tasks in computer vision. There are recent advances on data-driven approaches that impressively improved the later capability of the visual intelligent systems. This could be a benchmark for computer scientists to interact more meaningfully with other disciplines.

In this part, we aim to spot and sketch the joint research directions for visual data processing and humanities researches in urban planning and history of architecture within the scope of the three-year project, with the focus on the state of the art computer vision techniques. We aim for mutual understanding between the two fields that enables true interdisciplinary research. In the following, example areas are highlighted where computer vision can offer an aid in architectural history research, which is further elaborated in our case study at the end of this paper.

3.1 Image Retrieval

There has always been a demand from scholars to locate a research object such as an image in a collection of available objects, for instance in a repository of images. Content Based Image Retrieval (CBIR) is the task of finding a query image in the gallery of a reference image database. This is a timely problem of image based search engines that can be a challenging task once the query image does not have an exact match (same object representation) in the gallery. The most explored research area in CBIR is the representation learning, i.e. to effectively learn the descriptor of the query and the gallery images in order to maximize the distance metric between un-matched objects, and the similarity between the same objects [16, 17]. Another active area of research is distance metric learning that studies the best measure of the similarity and dissimilarity between objects. We refer to the combination of these topics as "matching problem". Unlike the classification and segmentation tasks that deep learning techniques are successful at, the matching problem is not yet impressively excelled by deep nets. This is mostly attributed to the lack of available data to train a network in an end-to-end manner, which is known to be the most crucial setting to achieve the competing results. Given this, there are lots of research opportunities in this area.

4 Location Prediction

Where is the location of a depicted scene in a query image? Firstly, this is to help curators to automatically annotate a given object in the repository. Secondly, the attributes that a computer learns for this task may reveal the discriminative features over location and invariants over time. The latter can be a subject for further analysis by humanities researchers, e.g. to study the dynamics of the appearance in buildings over time or in a specific area. Hence, the research question for humanities is to study the causality of these discrepancies, where the related question for the computer scientist is how to visualize the learned discriminative attributes [18, 19]. Consistently, is it possible to combine these two functionalities to serve both the curators and the humanities researchers? In the following we introduce a case study on Amsterdam and the available and potential databases for the location prediction task and try to address this question.

4.1 Data Visualization

There are vast amounts of digital records in art and heritage that are well-documented, but in general they are far from being sufficiently analysed. Currently, there is a variety of advanced search tools that help humanities researchers to access these resources neatly, surpassing the hassle of old-school library search. In general scale, Google search platforms are among the most popular, that cover wide ranges of publicly available data. Recently, CLARIAH, a specific platform for humanities and art researchers has been developed to facilitate search queries and to unify different databases in the Netherlands, which is anticipated to be scaled at the international level [20]. Despite the improving situation, important questions remain: Where is the bottleneck in information retrieval? Why is it still difficult to analyse all these data? Is there anywhere that pattern recognition and computer visualisation can help researchers to better process these valuable resources? We believe human vision is most powerful to analyse incredible amounts of information in an amazingly efficient way and computer visualisation could be an auxiliary tool to extend this capability. Therefore, data visualisation is one of the most promising computer-aided means that researchers would benefit from. The idea behind the data visualisation is to ease the interaction with data where more relevant information are clustered together.

4.2 Object Detection and Recognition

Moreover, time consuming and relatively tiring tasks like identifying objects of interest for specific research could be conducted by machines. For example, the identification of buildings with brick facades or thatched roofs in a city or region is rather trivial for a computer as the data is available in various street view applications. Specific details of facades could also be investigated in regard to their correlation to other non-architectural phenomena, as long as this information is available in a digital format. These are but a few examples for the benefits of an automatic object recognition, e.g., in buildings and architectural forms. The nature of the task is not trivial and has not been solved in the computer vision community; however, there is a good chance to soon reach a point where the above mentioned aspects become common tasks for trained machines. This will tremendously change the way architectural historians are conducting research. It is rather obvious that the possibility to investigate phenomena of millions of objects and on a global scale will open up new fields of research within the discipline. Be it global networks of oil-related architecture, architecture of power or poverty, informal urbanism or correlations of architecture and economy, politics or culture—a shift to quantity calls for novel theories and a reconsideration of methods. Concerning the latter, we regard it as essential to not only ask computer scientists for help, but to create research projects that understand interdisciplinarity as a type of research that tackles issues for everyone involved. We believe that jointly formulated, common research questions will facilitate a collaboration that provides motivation for the members of all fields involved. This requires the ability to compromise but also results in new views on a disciplines' objects and methods. That aspect should be taken into consideration, when the rising intelligence of machines is regarded as a thread to humanities and humanities' values. The term "intelligence" has been well-disputed and it remains a matter of perspective if algorithms can be considered intelligent or not. The same goes for the term "learning", that is being contested in regard to its application to machines [21]. Machines—or to be more precise: networks—learn basically by adapting their processing to the valuation of their output in regard of a certain input. Much like e.g. a child learns to distinguish animals or a language. Experience results in knowledge. If there's a preference to use the term "training" in regard to deep learning, we should be careful to reserve a specific term to humans just because it seems inadequate for a machine to learn. This could lead to dangerous underestimations. The historian Yuval Harari points out that we are at a changing point in history and that we are coming closer to reconsidering humanism itself as we have no reason to claim several human features, such as consciousness, as exclusive [22]. However, as we have to adapt to new technologies and methods, a core ability of the humanities researcher will remain uncontested, at least for the foreseeable future: critical reflection. Therefore, we should be open for critically adapting new technologies, and need to establish literacy in fields not yet regarded as closely related disciplines.

In the case of ArchiMediaL, the close cooperation quickly revealed that some of the architectural historians' wishes are far less realistic than first assumed. On the other hand, we discovered several possibilities that are rather unrealistic for classical approaches, and thereby slowly brought our naturally divergent research interests insofar together, that there is something for every involved field—architectural history, deep learning and linked data. The aim to use computer technology to improve access to visual representations of e.g. pre-colonial or vernacular architecture turned out to be limited by the data available. Deep learning requires quite large training sets with several images per depicted object and the databases available to us just did not provide this variety.[3] Therefore we decided to step back and to use a well known and

[3]E.g. the TU Delft repository *Colonial Architecture and Town Planning*. URL: http://colonialarchitecture.eu [access: 12 April 2018].

visually well represented environment as a playground to test transdisciplinary cooperation and its opportunities. This does not mean that the tools and knowledge that are under development and already developed are specific to the beeldbank project, but it is a more reliable database to start with due to its completeness. Once the tools have been validated with the beeldbank repository, they will be adjusted and used for other visual historical databases.

4.3 The Beeldbank Case Study

People who are very familiar with a neighborhood often are able to know where a historic picture from some street in that area is taken by recognizing buildings and other visual features, even if some structures are demolished and the businesses, fashion and cars have changed. One of the first challenges that we are dealing with in the ArchiMediaL project is to automatically match the content of historical images with recent “Street View” images (SVIs). SVIs come with various metadata, like a timestamp and geo-data. By visual matching historical images with SVIs successfully, the geo-coordinates from the SVIs will be inherited by the matched images. In order to start this challenging endeavour, a lot of data is required. As mentioned earlier, the artificial neural networks for visual content analysis need to be trained, and they often only perform well when a large amount of training and evaluation data is available. To achieve this goal, we need to find an urban area (e.g. a city) for which both a rich source of SVIs and historical images are available and where we can find people who are familiar with the area and who can be incentivised to manually create training and evaluation data.

For this reason we selected Amsterdam in The Netherlands, since: (1) the city archives provide access to beeldbank [23], a large publicly available online database of historical images of streets and buildings, (2) the area of the city is widely covered by various Street View approaches (e.g. Google Street View and Mapillary) and (3) the authors of this article are geographically closely connected to organisations that can help with finding people for manual annotation and curation. To find the locations of the buildings in the historic photographs, a two-stage approach is pursued: firstly, linking and comparing any available metadata accompanied with the respective historical image to narrow down the geographical area where the image is taken. Secondly, applying automatic visual content analysis on the sets above to find the exact matches.

4.4 Annotating Historical Images with Linked Open Data

If we are able to derive the exact geo-location and the timestamp of a historical image, we will need to transform it into URI’s to match the Linked Open Data used by e.g. the Dutch National SDI (PDOK)—a central facility for unlocking geo-datasets of

Fig. 1 Historical image from the Beeldbank database depicting a street corner in the centre of Amsterdam [24]

national importance, like cadastral information. After that we can easily look up all relevant information about buildings, for example the intended function, its floor-plan, age, address, neighbourhoods, etc. Every image in the beeldbank database has meta-data containing information about the type of figure (e.g. drawing, map, photo, author, date, title, description).

Figure 1 contains a historical image from the beeldbank dataset depicting a street corner in the centre of Amsterdam.

A part of the available metadata is being transformed into Linked Data format by the City Archive of Amsterdam, for example meta-data for Fig. 1 is available via their endpoint [25]. The location depicted in the image can be derived by humans reading the description "*De zijgevel van Brouwersgracht 137 en links Brouwersgracht 208-212*". For a Dutch speaker it is easy to conclude that the building on the right side in the image is on the "Brouwersgracht" street, number 137. And a simple lookup with the whole title in Google Maps [26] matches this building, however that is not always the case with other titles. Luckily, for most titles from beeldbank our heuristic worked and we got a geo-coordinate 'close' to the buildings depicted in the image:

https://www.google.com/maps/place/Brouwersgracht+137,+Amsterdam

Geo-coordinate: 52.3810575,4.8846276

This is good enough for this first stage, since we at least narrowed down the search space.

Since we now have the geo-coordinates we can prepare for the second step by gathering the StreetView images around the found coordinates. The Mapillary API

[27] provides various ways to gather street-view images, for example all images within a given radius from a geo-coordinate, a bounding box, the *n* nearest images for a geo-coordinate etc.

This example fetches the 100 images in a radius closest to the given coordinate 52.3810575,4.8846276:

https://a.mapillary.com/v3/images/?closeto=4.8846276,52.3810575&radius=100&per_page=100&client_id=<CLIENT-ID>

(*note that in order to try this link, one has to register for a Mapillary account*)

Which results in:


```
type:               "FeatureCollection"
▼ features:
  ▼ 0:
      type:           "Feature"
    ▼ properties:
        ca:           0
        camera_make:  "Trimble"
        camera_model: "Trimble TMX"
        captured_at:  "2016-08-15T08:44:53.268Z"
        key:          "yyHfvTjH7HEd_kRbBRxr2A"
        pano:         true
        user_key:     "jAve28suG8-ezvTWVkNHag"
        username:     "amsterdam"
    ▼ geometry:
        type:         "Point"
      ▼ coordinates:
          0:          4.886246514513118
          1:          52.38147442251949
  ▼ 1:
      type:           "Feature"
    ▼ properties:
        ca:           0
        camera_make:  "Trimble"
        camera_model: "Trimble TMX"
        captured_at:  "2016-08-15T08:44:54.648Z"
        key:          "qHC3Ycz7oi2jjbwj8-s9jA"
        pano:         true
        user_key:     "jAve28suG8-ezvTWVkNHag"
        username:     "amsterdam"
```


The images can be fetched by taking the *key* property and compose a URL via the Image Source URL pattern. For example, the yyHfvTjH7HEd_kRbBRxr2A key results in (Fig. 2).

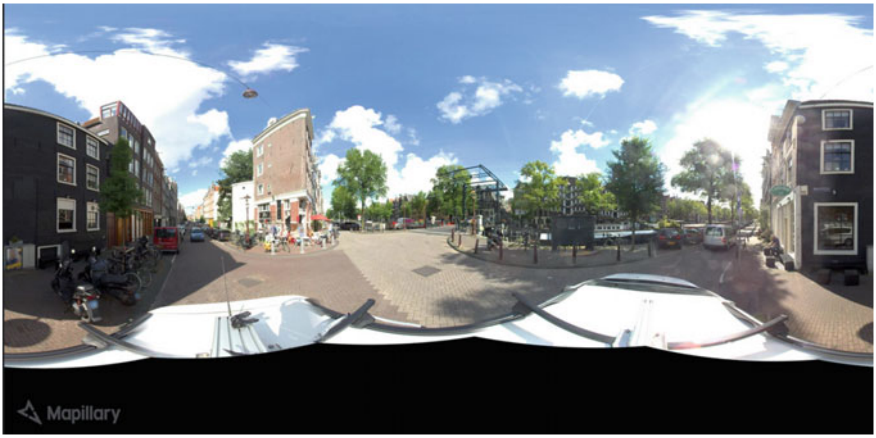

Fig. 2 Street view image retrieved via the Mapillary API for a given radius and geo-coordinate [28]

4.5 Beeldbank Data Visualization

The beeldbank data repository contains 300k+ images of Amsterdam including indoor and outdoor scenes, objects and people. The representation manifest through photography, sketches, paintings, maps etc. The first step to understand and evaluate a database is to visualise the content. For this purpose, we used a network pre-trained on Pittsburgh google street view dataset [R. Arandjelovic 2012] for representing the images in the beeldbank dataset. A small subset of the data repository is clustered and plotted in Fig. 3 to visualize the objects in the dataset. This will give a tangible representation of the beeldbank images for further investigation.

4.6 Image Matching of Historical and Street View Images

The aim of the historical image matching is to find a common built form across images in the beeldbank and the SVIs collected for that registered image, i.e. cross domain image matching task. The source domain is the SVIs which contains label (geo-tagged) information and the target domain is the beeldbank data repository containing coarse annotation (mostly up to the street level). The challenging computer vision task is to train a neural network for the image matching task on the domain with given labels (SVIs) and then transfer the knowledge to the domain without much annotated data, which is the beeldbank repository in our setup. To elevate the domain disparity, transfer learning algorithms [29] are required, which is the subject of research for this task. A further step is to align images from the two domains to create a 4D map of Amsterdam streets with historical images on top of the available SVIs. The procedure for collecting the SVIs are explained in the following:

Fig. 3 Visualization of a subset of the beeldbank repository

4.7 Revealing Discriminative Features in the Amsterdam Neighborhoods

The distinguishing research element here in relation to the conventional geo- localization task (image matching) is to not only look at the accuracy or precision of the algorithm but to understand what features are learnt by a computer to perform the localization task. What are the visual clues that a computer learns to discriminate the location of a scene? [30] Can we find visual attributes that represents regional features in a city like Amsterdam?

We proposed the classification task as a starting point to approach this problem, i.e., given a query image, the algorithm assigns one regional district to the object as a prediction of the location. The districts (classes) are comprehensive and disjoint for the whole city of Amsterdam. The research question to be answered here is if this problem statement for localization serves better for the humanities researchers to understand the underlying features of changes across the city? Does classification as a form of supervised data clustering discover higher level of discriminative semantic features? We aim to experimentally justify this hypothesis with visualising the learned features at the higher level of a deep network trained on the Amsterdam SVIs. The training data are collected to be street view images labeled by the name of neighborhoods in Amsterdam. The classification task is to assign the name of the neighborhood to the query image. The research area is to visualise the learnt attributes for this task and observe the visual discriminative elements in different regions in Amsterdam. This would serve as an attempt to make interpretable classifiers for humanities researchers that can interact with the machine.

4.8 Prospect

The automatic detection of buildings and architectural details in visual representations is helpful to make a large amount of non annotated images available for search and research. The case study on Amsterdam explains basic issues and promising approaches to achieve the recognition of architectural image content. Once established, the challenge will be to apply the knowledge and the technique to sets of images from lesser investigated contexts, e.g. vernacular architecture, informal settlements or pre-colonial buildings. Here, the approach outlined in this paper can provide a valuable method to (1) get better access to images of these lesser investigated fields of architecture and to (2) provide information on images of these architectures that does not contain meta-tags or annotations. On the long term this will allow for a more global and balanced writing of architectural history. Moreover, the analysis of discriminative features of neighborhoods will contribute to a better understanding of the correlation between built form and non-architectural factors. This can be achieved by combining e.g. data on local income, housing prices, types of businesses etc. with changing features of local facades e.g. state of maintenance or the amount of satellite antennas. We expect, that the results brought to architectural history by quantitative methods will reveal several unknown aspects within the field and thereby facilitate novel qualitative investigations of built form.

References

1. Löffler, Beate; Carola Hein; Tino Mager. „Searching for Meiji-Tokyo: Heterogeneous Visual Media and the Turn to Global Urban History, Digitalization, and Deep Learning“, in: *Global Urban History*, 20 March 2018. URL: https://globalurbanhistory.com/2018/03/20/searching-for-meiji-tokyo-heterogeneous-visual-media-and-the-turn-to-global-urban-history-digitalization-and-deep-learning/ [access: 12 April 2018].
2. Berners-Lee, Tim, James Hendler, and Ora Lassila. "The semantic web." Scientific American 284.5 (2001): 34–43.
3. Bauer, Florian, and Martin Kaltenböck. "Linked open data: The essentials." Edition mono/monochrom, Vienna (2011).
4. Wick M, Vatant B, Christophe B. Geonames ontology. URL http://www.geonames.org/ontology. 2015. Here: http://www.geonames.org/2759899/about.rdf [access: 20 March 2018].

5. The Getty Research Institute: *Art & Architecture Thesaurus® Online.* URL: http://www.getty.edu/research/tools/vocabularies/aat/index.html Here: http://vocab.getty.edu/page/aat/300140808 [access: 20 March 2018].
6. https://www.w3.org/RDF/.
7. Isaac, Antoine, and Bernhard Haslhofer. "Europeana linked open data–data. europeana. eu." Semantic Web 4.3 (2013): 291–297.
8. Ronzino, Paola, Achille Felicetti, and Sara Di Giorgio. "Integrating Archaeological Datasets: the ARIADNE Portal." AI* CH@ AI* IA. 2016.
9. Meroño-Peñuela, Albert, Ashkan Ashkpour, Marieke Van Erp, Kees Mandemakers, Leen Breure, Andrea Scharnhorst, Stefan Schlobach, and Frank Van Harmelen. "Semantic technologies for historical research: A survey." Semantic Web 6, no. 6 (2015): 539–564.
10. Van Aggelen, Astrid; Hollink, Laura; Kemman, Max; Kleppe, Martijn; Beunders, Henri, The debates of the European Parliament as Linked Open Data, Semantic Web, vol. Preprint, no. Preprint, pp. 1–10, 2016. https://doi.org/10.3233/sw-160227.
11. Shadbolt, Nigel, Kieron O'Hara, Tim Berners-Lee, Nicholas Gibbins, Hugh Glaser, and Wendy Hall. "Linked open government data: Lessons from data. gov. uk." IEEE Intelligent Systems 27, no. 3 (2012): 16–24.
12. Schreiber, Guus, et al. "Semantic annotation and search of cultural-heritage collections: The MultimediaN ECulture demonstrator." Web Semantics: Science, Services and Agents on the World Wide Web 6.4 (2008): 243–249.
13. Victor de Boer, Jur Leinenga, Matthias van Rossum and Rik Hoekstra. Dutch Ships and Sailors Linked Data Cloud. In Proceedings of the International Semantic Web Conference (ISWC 2014), 19–23 October, Riva del Garda, Italy, 2014 (p. 229–244).
14. Niels Ockeloen, Antske Fokkens, Serge ter Braake, Piek Vossen, Victor de Boer, Guus Schreiber, and Susan Legene. BiographyNet: Managing Provenance at multiple levels and from different perspectives. 3rd International Workshop on Linked Science 2013—Supporting Reproducibility, Scientific Investigations and Experiments.
15. http://www.clariah.nl [access: 15 March 2018].
16. Relja Arandjelovic, Petr Gronat, Akihiko Torii, Tomas Pajdla, and Josef Sivic. NetVLAD: CNN architecture for weakly supervised place recog- nition. CoRR, abs/1511.07247, 2015.
17. Albert Gordo, Jon Almazan, Jerome Revaud, and Diane Larlus. Deep image retrieval: Learning global representations for image search. CoRR, abs/1604.01325, 2016.
18. Matthew D. Zeiler and Rob Fergus. Visualizing and understanding convolutional networks. CoRR, abs/1311.2901, 2013.
19. Jason Yosinski, Jeff Clune, Anh Mai Nguyen, Thomas J. Fuchs, and Hod Lipson. Understanding neural networks through deep visualization. CoRR, abs/1506.06579, 2015.
20. The Common Lab Research Infrastructure for the Arts and Humanities (CLARIAH), URL: https://www.clariah.nl/en/.
21. Wolfgang Coy and Gertraud Koch in a public discussion at *Embedded Digitalities* in Basel, 5 April 2018.
22. Harari, Yuval Noah. *Homo Deus – A Brief History of Tomorrow*. London: Vintage, 2017. pp. 136, 137–40, 361–2, 462.
23. The beeldbank archive of historical images from Amsterdam, The Netherlands. https://beeldbank.amsterdam.nl/.
24. https://beeldbank.amsterdam.nl/beeldbank/weergave/record/?id=B00000013972.
25. https://data.adamlink.nl/saa/Beeldbank/table?subject=http%3A%2F%2Fbeeldbank.amsterdam.nl%2Fafbeelding%2FB00000013972.
26. https://www.google.com/maps/search/De+zijgevel+van+Brouwersgracht+137+en+links+Brouwersgracht+208-212/@52.3815462,4.88439,17z/data=!3m1!4b1.
27. https://www.mapillary.com/developer/api-documentation/.

28. https://d1cuyjsrcm0gby.cloudfront.net/yyHfvTjH7HEd_kRbBRxr2A/thumb-2048.jpg.
29. Mei Wang, Weihong Deng."Deep Visual Domain Adaptation: A Survey", School of Information and Communication Engineering, Beijing University of Posts and Telecommunications, Beijing, China., arXiv:1802.03601v3 [cs.CV] 24 Apr 2018.
30. Carl Doersch, Saurabh Singh, Abhinav Gupta, Josef Sivic, and Alexei A. Efros. "What makes Paris look like Paris?" ACM Trans. Graph., 31(4):101:1–101:9, July 2012.

Libraries, Archives, and Museums Interwoven in the Digital South: From a Paucity of Resources to Data Richness for Understanding the South Asian Subcontinent

James Nye

Keywords Libraries · Archives · Museums · Metadata · Intellectual property rights · Digital cultural heritage coalitions

The cultural heritage of South Asia[1] is one of the wonders of the world. It deserves to be more fully understood, better preserved, and easily accessible.

This paper explores the current scarcity of digital resources for understanding the rich heritage of South Asia and some of the reasons why the situation exists. Second, the history of preservation and access programs focused on library, archive and museum resources of the South Asian subcontinent is considered along with recently inaugurated initiatives to improve access for scholars and for citizens. A concluding section identifies factors which would result in a richness of data resources for South Asia comparable to those currently available for other world areas.

1 A Dirth of Resources

The South Asian subcontinent might be succinctly described as located in the digital South. The phrase "digital South" was coined by the author to describe the paucity of resources and digital formats for understanding the cultural heritage of what some

[1] South Asia is comprised of the sovereign nations Afghanistan, Bangladesh, Bhutan, India, the Maldive Islands, Nepal, Pakistan, and Sri Lanka. The region is home to more than one fifth of the world's population.

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call the Third World and others refer to as the global South. Comparisons with the enormous abundance of resources for understanding the cultural heritages of Europe, North America and East Asia reveal painfully stark disparities. There are numerous ironies, oddities, and obstructions that have given rise to this comparative dearth of resources from South Asia. Some of these are maladies dating to or are the consequence of British colonial domination of the region. But many, arguably most, should not be registered as colonial legacies. For example, in India we have the enormous irony of a country justly priding itself in educating some of the most adept practitioners in information technology and yet very few of those people address the needs of the region's cultural heritage. When we look at new initiatives such as the one announced last year by the Government of India for Massive Open Online Courses (MOOCs) it is shocking to find that only four or five out of more than 150 courses listed by the government address anything to do with the humanities and social sciences. Turning to Pakistan for another example, a country with Urdu as the national language, one finds the nation in the odd position of holding a modest percentage of Urdu language resources in the subcontinent. Attempts to improve access to the Urdu literary heritage require complicated interactions with the Government of India and with Indian institutions because the overwhelming majority of non-digital print assets in the Urdu language reside across the national border in India. Sri Lanka provides another example. Far too frequently one encounters the misplaced fear in the island nation that if resources from the country are digitized and made available for public access, no one will visit the archive collections and use the archival resources in that nation state. This is a pervading myth—a myth encountered virtually everywhere in the subcontinent—that runs absolutely counter to the needs of academics, both in country and worldwide, who are trying to understand the cultural richness of South Asia. A major museum in Nepal, severely damaged by the 2015 earthquakes, presents a deeply unfortunate example of a preservation irony. High-resolution images of all damaged objects in the museum along with detailed architectural drawings of the museum, part of a palace complex, would require terabytes of space for proper archiving. The funding agencies supporting restoration have not provided for repository space. Consequently, the images and drawings will almost certainly be lost for use by subsequent generations of scholars. The Maldive Islands provides a final example of an anomaly. Beyond the digital South, one might reasonably define the Maldives as the *deep* digital South, a designation shared with Bangladesh. The Maldive Islands was subordinated as a protectorate by the British under Ceylon (now named Sri Lanka) from the late nineteenth century. As a consequence of that complicated relationship with Ceylon, many of the most important assets, tangible and intangible assets for understanding the culture of that small but important island nation, were archived and held in Ceylon rather than in the country itself.

Further complicating the situation in the digital South and specifically in South Asia, the administrators and staff responsible for cultural institutions are often viewed with far less respect than they deserve. It is often said that librarians and archivists in the subcontinent are viewed as little more than peons. A consequence of this is that very few of the brightest people are attracted into the field of library science and archives management. This may partly explain why so little of the information technology energy is going towards libraries. If one takes the case of archives, it is common joke, but a substantial truth, that to be appointed as the head of an archive in South Asia is considered a punishment posting. If one has misbehaved, if one has done something to attract the ire of the political elite, one will end up appointed to what is seen as the lowest ranking opportunity in civil service, that is, to head an archive. Finally, South Asian museum have, until very recently, lacked adequate support for educational programs and found themselves well out of sync with best practices museology.

Further compounding the noted complications, highly variable climate combined with often inadequate housing facilities have resulted in gigantic loss over the centuries. Manuscripts fall prey to insect and rodent damage or the vicissitudes of monsoon climate. Books and periodicals, in addition to the maladies faced by manuscripts, were frequently printed on paper with high acid content and consequently, many cultural resources have disappeared without a trace. Museums have been underfunded, especially following mid-twentieth century independence from colonial rule. In sum, the material and human infrastructure in South Asian libraries, archives and museums is severely wanting.

2 Previous and Current Programs

On a more positive note, libraries, archives, and museums have benefited over nearly a century and a half from legislation and programs designed to register and distribute publications from the South Asian subcontinent. The 1867 Press and Registration of Books Act was enacted to regulate printing presses and newspapers printed in India. It provided for the registration of those publications and deposit of copies with archives in India. Additionally, copies of the publications could be selected by five collections in England. A consequence of that act is that a significant percentage of pre-Independence publications were documented in quarterly lists of publications produced and some of the publications were added to collections in the United Kingdom.[2] Provision for transmission of printed publications to the five collections in the United Kingdom terminated, for the most part, with independence in 1947 and 1948 for the former colonies in the subcontinent.

Beginning in the late 1950s, the Library of Congress began an important program for collecting and disseminating to selected U.S. academic libraries important publications through cooperative programs run from offices currently based in New

[2]While compliance with the 1867 act were uneven across time and administrative units, the best estimates are that no more than 85% of imprints were registered and deposited. Further, practices at the British Museum and the India Office Library, two of the libraries in England entitled to request copies strongly favored publications in English. In the early twentieth century, less than 15% of books in the regional languages of colonial India were requested in many years and, most of the newspapers and other periodicals in regional languages were acquired as specimen issues rather than as continuous runs.

Delhi and Islamabad.[3] The South Asia Cooperative Acquisitions Program (SACAP), as it is known, has provided to academic institutions in the United States copies of resources that are the envy of many of our colleagues in South Asia itself. The collection of publications delivered to the University of Chicago through the program, for example, consists of more than 700,000 volumes published since 1960 in the regional languages of the region with an estimated value of USD 34 million. A distinctive and important feature of SACAP is that where national boundaries have divided sub-regions with a shared language—Urdu for example, between India and Pakistan—SACAP has allowed U.S. institutions to build collections in a way that has supported scholarly needs and will eventually support collaborative digitization, to the benefit of our colleagues in the subcontinent.

The South Asia Materials Project (SAMP, known until 2014 as the South Asia Microform Project)[4] based in the United States, is another example of an important collaborative program for preservation and access to the cultural heritage of South Asia. Over more than a half century, SAMP has prepared high quality microfilm surrogates of resources necessary for understanding South Asia as a region and has made those resources available to researchers at member institutions. The program, recently renamed the South Asia Materials Project, has used member contributions in excess of USD 1.1 million over the past 50 years for the preparation of resources that address the needs of researchers in the humanities, social sciences, and the sciences. Since SAMP microfilms contain high-resolution images, they are a vital asset for future digitization that will benefit our colleagues in the subcontinent. One specific SAMP initiative is noteworthy both because of the methods deployed in the execution and the resulting resources preserved. The Microfilming of Indian Publications Project[5] was undertaken with colleagues in South Asia between 1990 and 2001. Using the *National Bibliography of Indian Literature, 1901–1953* as a source of well-selected historical publications, SAMP managed to create high-quality preservation microfilm copies of approximately 38,000 volumes. Those volumes are assets that are currently being digitized for open access.

Over the past twenty years several experiments have been undertaken to acquire, preserve, and disseminate private collections in India, Pakistan, and Nepal through collaborative engagements between North American libraries and bodies in the subcontinent. Specifically, institutional and external funds from North America have been raised to purchase and process private collections; new bodies or existing institutions in South Asia have provided homes for the collections; and as the collections have been preserved, cataloged, and made accessible, ownership of those collections is being ceded by the North American institutions or consortia to the South Asian

[3]The Library of Congress websites for the New Delhi and Islamabad Field Offices are respectively at https://www.loc.gov/acq/ovop/delhi/ and https://www.loc.gov/acq/ovop/islamabad/.

[4]SAMP, celebrating its 50th anniversary in 2017, maintains a website at https://www.crl.edu/programs/samp. It is noteworthy that the change of SAMP's name, from microform to materials, signaled a change in emphasis from preservation microforms to digital copies as a preferred form of conservation.

[5]Please see the Microfilming of Indian Publications Project website at http://dsal.uchicago.edu/bibliographic/nbil/nbil.php.

institutions. Those South Asian libraries and archives have provided an excellent base for ongoing collaborations. They have been led and staffed by some of the finest librarians and archivists in the region and brought imaginative new approaches to the preservation and dissemination of resources, most of which are extremely rare and endangered. For example, the Roja Muthiah Research Library in Chennai, the Madan Puraskar Pustakalaya in Kathmandu, the Mushfiq Khwaja Library and Research Centre in Karachi, and the Centre for Studies in Social Sciences, Calcutta have all received multiple grants from the Endangered Archives Programme[6] for preservation of collections at risk.

The British Library's project titled Two Centuries of Indian Print[7] is, in its first phase, digitizing more than 1,000 early printed Bengali books published between 1713 and 1914. Work is being undertaken with the School of Cultural Texts and Records at Jadavpur University and several other Indian institutions. If additional funding is obtained, the project may be extended to include materials in other South Asian languages and expand the participating institutions to include those specializing in other regional languages.

A newly formed organization called the South Asia Open Archives (SAOA)[8] is building upon antecedent programs to remedy some of the circumstances that have resulted in the digital South and to facilitate better understanding of South Asia's cultural riches. A founding group of nearly thirty institutions in South Asia, North America, and Europe joined in 2016 to establish and maintain, for non-commercial open access, a collection of materials for the study of South Asia and to federate with other collections of resources. All academic disciplines are encompassed, from the humanities through the sciences. Activities addressing major objectives during the first five years are funded by the USD 750,000 so far contributed by SAOA members and through external funds from foundations and other sources. Those objectives include:

- mass digitization of textual, visual, and sonic resources for open access,
- creation of large sets of numerical data through conversion of printed sources such as the decennial censuses of the subcontinent,
- resolving questions of intellectual property rights in South Asia through work with the responsible government bodies,
- training library and archive staff for engagement following international standards,
- collaboration for improvement of existing metadata and implementation of linked open data for resource description, and

[6]The Endangered Archives Programme, based at the British Library, is described on the website at https://eap.bl.uk/. Specific projects for the South Asian institutions mentioned are also described on that site.

[7]A project website is located at https://www.bl.uk/projects/two-centuries-of-indian-print.

[8]Information on the South Asia Open Archive is available at https://www.crl.edu/samp-open-archives-initiative. The charter for SAOA is found at https://www.crl.edu/sites/default/files/attachments/pages/SAMP%20Open%20Archives%20Plan%202016-01.pdf. Please note Appendix 1 of that document enumerating digitization priorities during the first five years.

- provision of interfaces for exploring SAOA resources and interlinking them with those of other trusted institutions—for example, interfaces for geo-navigation and analysis of large data sets, in support of collaborative, cross-disciplinary work.

SAOA has drawn inspiration and guidance from other projects, especially those associated with the digital South. The guiding principles of the International Dunhuang Project have resonated particularly well with SAOA. Those principles include: (a) free access to resources provided to all users, (b) comprehensive coverage of the resources distributed across repositories around the word, (c) requirement that images and data created be of very high quality, (d) assurance that data gathered is as rich as possible, (e) collaborative engagement by participating repositories, (f) maintenance of autonomy of partner institutions, and (g) provision for the long-term sustainability of the program and access to the scholarly resources. The Endangered Archives Programme's (EAP) commitment to avoid duplication of effort with other non-profit programs is another bedrock principle for SAOA. Rather than duplicating effort, SAOA seeks to complement and complete resources for presentation to scholars and citizens. Additionally, EAP's focus upon resources at risk has captured SAOA's attention as fundamentally important. Those risks may be from environmental, socio-political, or other factors that would imperil culturally significant resources.

3 Future Prospects and Recommendations

Moving forward, building upon earlier and current programs and projects, there are promising ways in which the digital South can be further addressed and the current dearth of digital resources can be replaced by abundance, by a richness of resources comparable to that currently available for many other world areas.

The DCH2017 conference on Digital Cultural Heritage held in Berlin offered a remarkable opportunity for learning, sharing approaches to the technical challenges faced by participants, and thinking strategically about what the participants might accomplish through collaboration. The papers included in this collection of essays address many of issues and approaches presented at the conference. One of the most important themes presented in papers and explored in discussions during the conference is development of partnerships across disciplines and across geographical sectors. This theme was also prominent in the Google summit on culture held in Florence in mid-February 2017.[9]

[9]The author participated in the two-day Google summit titled Digital Meets Culture. Participants from twenty-three countries included leaders of cultural institutions, academics, representatives of UNESCO, the European Commission, and national governments. Sessions at the summit centered on the preservation and accessibility of cultural heritage in the digital age. The summit produced "Recommendation for the future of digital and culture" focused "on the importance of digital technologies in fostering accessibility and audience engagement, in preserving and promoting cultural diversity and in enhancing the digital footprint of cultural institutions through digital skills." Please see the recommendations at https://www.lib.uchicago.edu/e/su/southasia/Recommendation-Digital_meets_Culture_2017.pdf.

Those involved in digitization of cultural resources related to South Asia will want to give special attention to a few considerations as they develop new programs for improved access. These suggestions are based on lessons learned through prior engagements by the author and his colleagues while working on preservation and access projects.

1. Documentation of library, archive, and museum holdings is fundamentally important. Because very few resources are currently described with appropriate metadata, the hard work of cataloging physical objects is necessary to support decisions about priorities for digitization activities. In other words, surveys of public and private collections in South Asia followed by cataloging of unique resources is an essential prerequisite for informed digitization programs.
2. Collaborations between actors in the subcontinent and those elsewhere in the world improve the likelihood of success in preservation, digitization, and presentation projects. The development of collaborative linkages takes time, it requires diplomatic skills, and the understandings informing collaborations must be renewed and refreshed on a regular basis if partnerships are to produce the expected results.
3. Funding is necessary and yet often difficult to secure for projects. Funds for sustaining digital resources are even more difficult to obtain and yet without corpus funding the future of the digitized cultural resources will not be secure.
4. Human infrastructure is essential. Problems noted earlier in this paper regarding perceptions of librarians, archivists, and museum staff often make it difficult to locate well-trained and committed staff in South Asia. Programs for training in best practices are often necessary before projects can be undertaken.
5. Private repositories rather than public institutions in South Asia are often the best targets for preservation and digitization. Private collections are often superior to those in institutions. Further, bureaucracy associated with public collections can be a major impediment in accomplishing preservation and access objectives.
6. Copyright and intellectual property regimens must be honored scrupulously. This is important for both legal and ethical reasons. Having declared that principle, it is important to work with government officials responsible for intellectual property in sovereign nations of South Asia to secure the broadest interpretation of what copyright law does and does not permit.

Recognizing the impediments present when working with cultural resources related to South Asia, building upon previous and current programs for digitization and access, and with attention to the cautionary notes included in this paper, one can reasonably expect that new projects will enhance the understanding, improve the preservation, and ease access to the rich cultural heritage of South Asia.

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Cultural Heritage Digital Data: Future and Ethics

Filippo Diara

Abstract Actual technologies are changing Cultural Heritage research, analysis, conservation and development ways, allowing new innovative surveys. Terrestrial and aerial laser scanner, terrestrial and aerial photogrammetric techniques, GIS (Geographic Information System) and remote sensing techniques are nearly much needed methods in the Cultural Heritage field. These survey techniques produce different kinds of data that needs to be managed in the best way possible. Ethical questions come up about the future of these data. It is nearly necessary dealing with problems like data storage, hardware and software relationship and data redundancy.

Keywords Accessibility · Cultural heritage · Digital data · Ethics · Future

1 Introduction to Data Ethics

Data (and big data) ethics can be considered as a distinct branch of applied philosophy. The focus on big data is concerned with what is being processed, the nature of what is being processed, the findings of analysing the data and who the processing is being done for 0 by [6].

Technology and computer science are part of the Cultural Heritage research from a long time. All digital data produced is strictly linked to hardware, software and network issues, and all these issues need to be managed for the data sharing, future accessibility and usability. Another important point is linked to the economic aspect, because most of these technologies applied to Cultural Heritage, such as geomatics technologies, are high cost solutions, and this reason bring us to reflect always on ethics.

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2 Cultural Heritage Actual Technologies: Metric Survey and Data Management

Metric survey, and then all geomatics techniques, is a necessary step of knowledge in the Cultural Heritage field, because it allows to register metric and geometric information in order to represent, communicate and preserve the surveyed object. This kind of survey, a 3D survey, can be carry out using different technologies, such as LiDAR and photogrammetric approach.

2.1 LiDAR Technique

Laser scanner (terrestrial and aerial) is a fundamental method included in LiDAR technique (Light Detection and Ranging or Laser Imaging Detection and Ranging). It is a *range based* technique because it produces electromagnetic signals that later are recorded into the machine in order to derivate metric information [9]. Laser scanner survey represents a versatile solution about big data acquisition, for example a large amount of information of complex architectures. Then the machine has the laser that, with a light beam (radiation beam) formed by photons, provide the necessary metric information to reconstruct objects and environments [2]. Touching materials, radiation beam has different behaviours: it is partly absorbed by the same material and partly reflected and relayed. Absorption is the relation between absorbed energy and incidental energy while reflectivity is the relation between reflected energy and incidental energy. The principal quality of laser scanner is the acquisition speed.[1] Moreover, the single point, touching the intercepted surface, is defined in a reference system where its origin is at the machine heart, with specific x, y, z, coordinates [1]. The ability to manage a large amount of information derived from laser scanner survey is an outstanding problem and the ability to reproduce high quality 3D models depends directly on software and processor power development.

2.2 Photogrammetric Technique

In addition to LiDAR techniques, the photogrammetric method applied to Cultural Heritage has experienced in the last years an enormous growth. Photogrammetry (UAV and terrestrial) is a technique that allows to obtain metric information, and then the geometric reconstruction of objects, starting from images (*image based technique*) and for this reason is based on photographic sensors [8]. Photogrammetry is therefore a method that allows the stereoscopic reconstruction of objects using a couple of pictures or more (taken from different points of view).

[1]It allows to obtain scanning sections up to 400.000 points per second. The final product of the scanning process is called point cloud or range map.

Photogrammetry, as well as LiDAR, can be helpful in case of damaged buildings or degraded archaeological objects, because photogrammetric survey (including low-cost surveys) allows to obtain volumetric data useful for future reconstruction or restoration, and it can be also helpful to freeze a particular situation.

The quality of photogrammetric survey depends on the images (pictures quality in terms of resolution), but many subjective and objective factors affect it, like the technical capabilities of the operator, shadows, reflexions, reverb and others issues, unlike the laser scanner that has optimum performance both day and night (ambient light), then without illumination. Innovation in the computer science and photographic field has encouraged the development of technologies applied to photogrammetry, allowing the software development for different aims (low cost and high cost) [3].

2.3 Storage and Data Management

The storage and data management useful to document a Cultural Heritage asset can be carry out through the utilization of relational and spatial DBMS (Data Base Management System) and others platforms. Moreover, for data management, GIS systems (Geographic Information System) have a fundamental importance the Cultural Heritage field.

GIS systems, initially used only for the military research, are based on storage and managing of geographic information. Briefly are techniques based on the satellites usage to obtain geographic information (geographic coordinate) and graphic information (digital images).

GIS solutions works with layers, in which vector and raster file can be located. Therefore, working like a CAD, GIS software allow to create shapes and lines in order to represent particular conformations located for example in a satellite image or a historic map. This possibility has a great importance in Archaeology, for example to locate archaeological sites and other points of interest in order to compare them in a unique platform.

As far as documentation and management are concerned, Building Information Modelling (BIM) is still in a growth phase and it represents a real challenge for Cultural Heritage assets. BIM, briefly, extends the possibilities of a traditional CAD capability allowing to establish geometric and semantic relations between 3D objects (surveyed as they are) and external data. Indeed, one of the most important capabilities of BIM technology is to combine the geometric information with data of different nature.[2]

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[2]Nowadays there are many commercial BIM solutions. However, these tools are thought and developed mostly for architecture design or technical installations. These commercial platforms are in most cases not suitable for all Cultural Heritage projects. The complexity of the Cultural Heritage assets bring specialists to reflect on the need to create a custom-made instrument. A suitable solution can be guaranteed by using open source software, because they allow to operate directly on source code, allowing modifying, improving, and adapting any tool to specific needs.

3 Hardware and Software Relations in the Cultural Heritage Field

Main technologies applied to the Cultural Heritage filed, described briefly before, are affected by computer science relations and issues. From the technical point of view some lines of reasoning are linked to the used instrumentation, in particular hardware related to the data management.

3.1 Storage Systems

In these years the technological development was so fast to make, in proportion, a large amount of data storage (often redundant data). Anyway, this growth must be coupled by the same evolution of the storage systems. Over about ten years we moved from the classic storage over magnetic disks supports (hard disk—HDD) to the best performing (greater reading and writing speed) but delicate (their performance can be change owing to temperature and power supply method) flash supports (solid state—SSD).

The reading and writing speed of the storage devices represents only a small aspect of the ethical problem of this kind of hardware. The data storage capability become fundamental in these terms. Now we are living in the gigabyte (GB) e terabyte (TB) era. By having a handful of GB o TB is like to have a lot of available space, but when we talk about specific professional areas of work the storage space is never enough.

In many academic laboratories the presence of hundreds of hard disks (internal and external) and also NAS systems with a lot of TB (like 40–80 TB) it means anyway to have a few available space, because this aspect is always relative according to the researches and the data quantity and in a few years we can lost a large amount of data due to forced clean actions and bad maintenance.

For ten years the big circulation and evolution of the storage systems based on cloud computing has favoured the data conservation methods and data backup but, on the other hand, it has made us reliant on internet. Many people think that cloud systems are something innovative, although we should talk about a return to the past because cloud computing can be compared to the host centring computing, where in both cases the storage and processing steps are not executed by the user [5].

3.2 Hardware and Software Relationship

A three-dimensional metric survey or any 3D reconstruction produces files and data that depend directly on the machine's hardware, in particular with two components: the main processor (CPU) and the graphic card (GPU), but the random-access memory (RAM) is very important too. Three-dimensional models, more and more complex and having a lot of information, will demand constantly an up-to-date hardware [4]. Graphic card is very important for 3D data visualization: point clouds, wire-frames, polygonal meshes and in particular photographic textures making the most of the GPU's graphic power, especially graphic clock and memory bus. As far as GPU's dedicated memory is concerned, if we got 2 GB sometimes this amount might not be enough to run smoothly 3D models: 3D model fluidity means the 360° analysis of it, but at a specific speed.[3]

CPU is another fundamental component for the processing and computing power and it makes possible the correct operation of the other components, where, as we've seen, the GPU is maybe the principal hardware element for 3D modelling [4]. Finally, CPU and GPU are very important for the creation and analysis of 3D complex models. Anyway, these components have a short duration before they becoming dated, depending on the workload they are subjected.

3.3 Software and File Compatibility

Software compatibility, operative systems (OS) compatibility and more in general different kinds of machines (computer) need to be mentioned. Many professional software (for research and data management) are developed following some guide-lines, in particular the higher circulation of operative systems. In fact, is evident that the majority of software is fully compatible principally with Windows operative system, barring the others OS and therefore many people (including free and open source OS). It's only recently that are developing professional software (in Cultural Heritage field) also for all, or almost, operative systems [3].

Another kind of compatibility issue is related to software in comparison with others software: Doing a project using different kinds of software we could have a lot of file with any format and extension. The management of a 3D model file format (IFC, XYZ, OBJ, PLY etc.) involves also to work inside many software and OS platforms and it could be dangerous for file compatibility and then for the project stability in general. Thus, should be necessary planning in details the entire project, including software and OS we could use.

3.4 Photography

In the Cultural Heritage field, such as archaeology or historical architecture, photography (that includes also hardware and software systems) has revolutionized the way to produce documentation, analysis and then also the way to teach. Nowadays photography is used also for other aims: photographic survey has become maybe the

[3]To run smoothly a 3D model means to *turn* it at minimum 30 frames per second and it also means to have monitors with a good refresh rate.

main way to do research, with which it is possible to investigate archaeological sites or historical buildings, we just think to the photogrammetric method, orthophotos, 3D photographic models and many others.

Moreover, in the photographic field the technological development was ruthless: photographic sensors, more complex lenses, more powerful micro-processor are making dated any photographic survey done a few years earlier; like a survey of an ancient masonry that needs a consolidation or restoration intervention, where the level of detail of pictures is very important for future studies (inside laboratories).

4 Ethical Issues in Cultural Heritage Digital Data

When we talk about Cultural Heritage some ethical questions are inevitably involved, especially in some aspects of research and communication.

The ethical question about data storage is fundamental. Analysing the innovative aspect of cloud storage we can anyway deduce that who have data (also personal and sensitive) into cloud systems is not the real owner but the donor. Without internet connection and then without these cloud services we do not own our data anymore because our data are like hostages in the cloud systems owner's hands. Following this reasoning we need also to involve the sphere of education of children and adolescents about the digital data sharing consequences [10].

As far as the hard disk data storage is concerned, what would happen if in a laboratory or in another workplace all storage devices (external and internal) stop working? How many data and years of research could be lost? Is it safe rely only on a specific storage device? How we can choose the best storage devices to ensure long life to our data?

Table 1 Example of a research in 2012–2013. Comparison between two metric survey techniques. Object of study: Camaldoli Monastery (Tuscany)

Technique	Detected part	Main steps	Time	Data size
Laser scanner survey	Entire monastery	– Direct geometry acquisition and 3D points generation	– About 2 h and 50 min	51 GB
Photogrammetric survey	Only the entrance courtyard	– Photos acquisition – 3D points generation	– 7 h for photos acquisition; 2 months for 3D points Generation (with dated hardware)	173.61 GB

Laser scanner survey and photogrammetric survey: 224.61 GB

Doing a project using LiDAR or photogrammetric techniques mean to manage also big data. Here is an example of a research: between 2012 and 2013 we worked into a project about metric survey of a courtyard in the Camaldoli monastery (Tuscany, Italy); this work included also the comparison between two kinds of techniques, laser scanner[4] and photogrammetric approach (just for the entrance courtyard). Final data obtained was useful to understand the differences between both techniques.

Anyway, this project was also of difficult managing, because we obtained up to 200 GB of data (as you can see in Table 1). The point is: how many projects like this in laboratories? How many backups? How many storage systems? How many economic resources to continue same analysis in years?

This reasoning brings us to reflect that we are living times in which every electronic and computer science purchase (especially hardware) outlives its purpose, becoming out of date in few years. The same thought concern also instrumentation and technologies applied to Cultural Heritage: about twenty years ago the specific instrumentation and machines purchase, in order to supply private or academic laboratories, was considered a real investment, because these instruments offered a huge potential both for final results both for the reliability through time.[5] Nowadays things have really changed: economic crisis has allowed, fortunately, more attention and caution as the economic resources usage and finding requires.

An ethical (and nostalgic) question is about dated scientific analyses carried out with pictures. For example, if we want to perform an analysis about buildings archaeology old studies made out with Rollei Metric 6006 (fully operative between the '80s and '90s) or other cameras we should revisit the original negatives and read them with professional photographic scanner (nowadays quite outdated). Now let's say (but not too much) that research has been carried out in Syria or in Jordan, or anyway in a country with a delicate political situation for different aspects, and the historical building is missing or destroyed. What we can do with the original negatives? What does it matter? Other similar questions could be: How much are the actual photographic surveys valid? How long we could use these kinds of data? How much data of these studies is stored in floppy disks only? In these terms everything is relative and to answer similar questions we have to consider any research and studies precarious, insecure and not permanent, also whether it seems good.

Therefore, we need to confine any instrument and technology, also hardware and software, during the time are used and then we need to consider them temporary. It is the same for the final data of a research: how long we could use final data of an architectural project? How long file like DWG, DXF, XYZ, OBJ, PLY, could be used? Could we use these kinds of file in ten years? (Fig. 1).

Moreover, when we produce any Cultural Heritage research involving computer science technologies we create a more or less significant data redundancy. For example, if we are doing an architectural investigation using total stations and laser scan-

[4]Used by Architecture Department of Florence for another research inside the monastery and it was surveyed entirely.

[5]This is another reason why in many universities the financial security of the period guaranteed too easy purchasing opportunities.

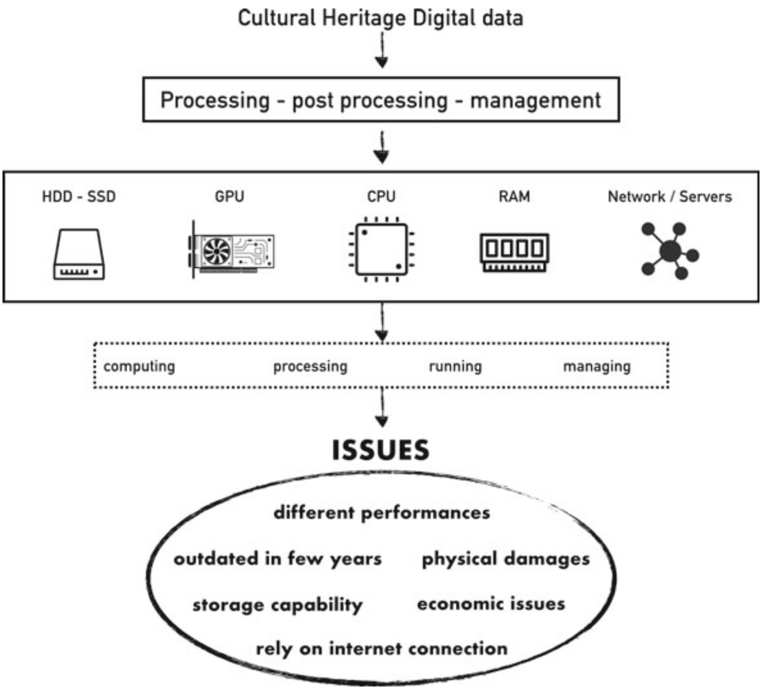

Fig. 1 Schema of hardware complexity managing of Cultural Heritage digital data

ners we need, necessarily, to plan it in detail. Laser scanner, working as an artificial eye, produces a large quantity of data (in this case point clouds) that it requires a discretization and cleaning process, to be done only in laboratory and not at the time of survey. If we want to scan an historical building located into a wooded area or in a dense vegetation area we should, necessarily, discretize point cloud concerning vegetation or woods, because for the purely architectonic survey purposes we do not need it. However, point clouds concerning vegetation is stored by the laser, taking up storage free space, and, if we consider the performance aspect, the laser uses more power and it creates likelihood of machine misfire.[6]

A fundamental ethical problem is focused on communication and access to final data. If we produce computerised data, result of digital instruments and technologies, this kind of data are not always available in the same way to everyone. As far as Cultural Heritage field is concerned, a not specialized community will hardly receive scientific technical data. Lately, this problem is an important issue to settle and thanks

[6]The same reasoning could be applied to a photographic survey. This kind of survey produces a lot of high resolution pictures, that in some cases containing the desired object within photographic framework (*canvas* o *layout*). It is therefore necessary discretize pictures, although outnumbered compared to laser scanner data.

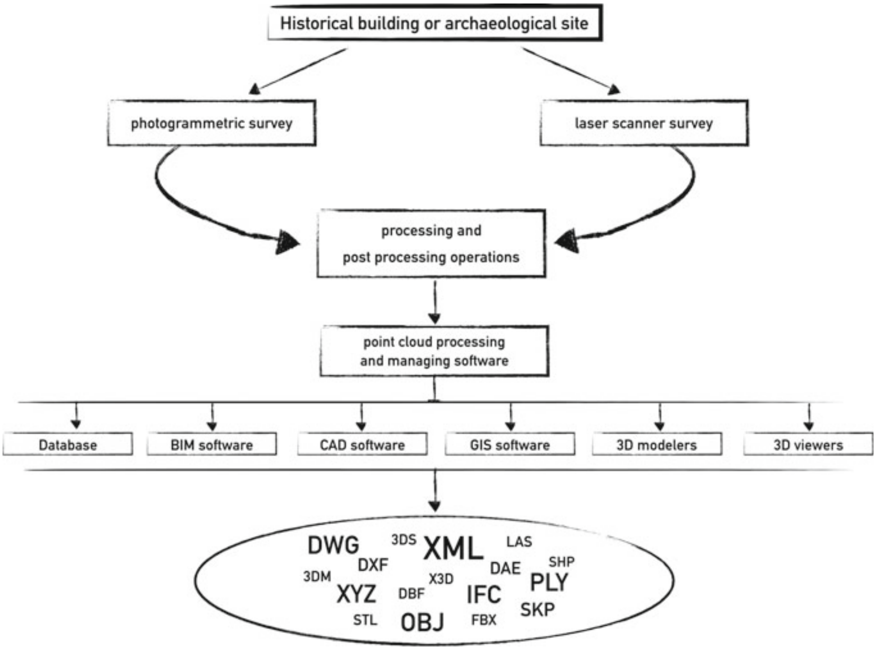

Fig. 2 Schema of software and file format complexity coming up during a digital research in architecture or archaeology

to new digital technologies (mid-cost, low cost, open source) it is possible to produce and communicate final data in a synthetic and clear way (but not trivial).

Moreover, we need to introduce another fundamental ethical problem: *backup choice*. Spree accumulation of data can bring us towards an information bulimia. We archive everything but we have potentially nothing. Can we back up all our computer files every hours, every days and forever? Can we back up all internet Cultural Heritage data? Obviously not because all our files and internet data (especially these) are dynamic and change every day and every seconds. Every day we have to do important choices about our data (professional, sensitive and other kinds of information).

Let's think about medieval copyists. All of them have made great contribution to our knowledge about the ancient roman poets and writers. We have a lot of poems and papers about Cicerone, Orazio, Tacito but we know nothing about others writers, also prolific and important. Why? The answer is the choice of medieval copyists, the backup choice. We can do the same reasoning for digital data and Cultural Heritage data. Nowadays we have automatic backup with NAS systems or clouds, although it is impossible to save every file we have. What would happen if our computers or hard disks accidentally break down before the backup of data? And what would happen if these storage systems are in a professional laboratory? If we really have to choose between copying a files group or another, what would we will choose? There isn't and can't exist a definitive solution. It is therefore important to find out how we can resolve this ethical problem coming to an agreement to ensure the right future and accessibility of data, choosing the best solution to preserve our important information (Fig. 2).

5 The Economic Issue

After this general panorama, we could say that in order to produce a large amount of digital data we need anyway to use a considerable sum of economic resources. Could Cultural Heritage researchers be considered *privileged*? From cultural point of view certainly of course, but the merely economic aspect is another issue. Could academic laboratories, inside public universities, always afford specific technologies and instruments? The answer is not obvious and it assumes an important ethical problem. On the other hand, who is owner of these instruments sets more accurately in research? Could Cultural Heritage researchers do scientific studies with *low cost* instruments? If it can be done, with equality of results, how these studies can be compared with others carried on with *high cost* technologies? Does it have the same importance? In order to reach final data, at the end of a research, if we use specific computerised instruments (and it has an economic relevance) that bring us to obtain equal results of a study carried on with low cost technologies, behind our methodological choice there is a problem.[7]

In the Cultural Heritage field, like archaeology, analyses carried out with *low cost* and FOSS (free and open source software) technologies have often proved to be most reliable, allowing to obtain more complete results than others researches. In these terms, the use of open source and free services could be considered a real challenge, because nowadays the FOSS adoption could be good solution to guarantee the best and complete data usability and accessibility, both for software and file formats. Moreover, FOSS solutions often allow to adapt software to Cultural Heritage needs and not the opposite, thus avoiding methodological stretches.

When we talk about technology and then computer science applied to Cultural Heritage we come up against ethical problems that we could hardly solve them. Nowadays doing research means to use specific technologies and instruments, and it means to do an important economic effort, from public or private entities.

Inevitably, research goes hand-in-hand with economic situations of countries and when we talk about economic situations of countries (funds, investments, etc.) we always run into ethical dilemmas. Therefore, talking in general about Cultural Heritage means (even if into academic areas we don't often realize it) run into sensitive ethical problems linked to economic aspects (Fig. 3).

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[7]The problem probably is that in the actual society for any objects and purchase there is the wrong conviction that any material object (but also hardware and software) if is more expensive it is more reliable.

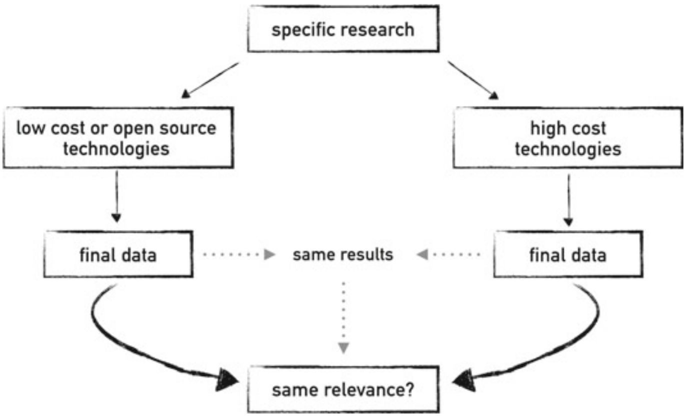

Fig. 3 Economic issue schema of using different budgets technologies

6 Conclusions

This reasoning makes us to suggest that digital data, and in particular Cultural Heritage data are living in an uncertain era, therefore it creates conditions for an ongoing research development. In the Cultural Heritage area, like any area of employment, every day we are given (directly and not) ethical dilemmas for any social aspect and the decision for an equal balance is up to us, in order to secure a good future for digital data and to prevent the abuse of data (especially big data) as a new origin of information and power [10].

All techniques we've seen produce a lot of information and data that need to be archived especially thinking about its accessibility (and when we talk about accessibility should also be included transparency of data) for the future and trying to ensure the future software and format compatibility for next researcher generation. For this reason, is necessary to carry out digital works without all possible new technologies just for fashion but thinking responsible to the aim of a specific research.

At the end we can say as we want responsible innovation (technological innovation) we have to do responsible research, cooperating each other to ensuring a responsive data to ethical issues [7].

References

1. Bartolucci, D.: Principi di laser scanning 3D, hardware, metodologie applicative, esempi. Dario Flaccovio Editore, Palermo (2009)
2. Bornaz, L.: I sistemi a scansione laser. La tecnica del laser scanner terrestre. Udine 24–26 novembre (2004)
3. Diara, F.: Sperimentazioni di nuove tecniche fotogrammetriche di medio e basso costo applicate all'Archeologia dell'Architettura", in *Conservazione e valorizzazione dei siti archeologici.*

Approcci scientifici e problemi di metodo, pp. 585–594, 9–12 July 2013. (2013)
4. Diara, F.: New software and technologies applied to documentation and communication of Cultural Heritage. Proceedings of "*Conference on Cultural Heritage and New Technologies (CHNT)*" meeting on Vienna (Austria) from 11 to 13 November 2013. (2014)
5. Hu, Tung-Hui: A prehistory of the cloud. MIT Press (2015)
6. Metcalf, J., Keller, E.F., Boyd, D.: Perspectives on Big Data, Ethics, and Society. The Council for Big Data, Ethics, and Society, May 23 (2016)
7. O'Leary, D. E.: Ethics for Big Data Analytics. IEEE Intelligent Systems, vol. 31, pp. 81–84 (2016)
8. Remondino, F., El Hakim, S.: Image—based 3D modelling: a review. The photogrammetric record (2006)
9. Remondino, F.: Heritage recording and 3D modeling with photogrammetry and 3D scanning. Remote sensing (2011)
10. Zwitter, A.: Big Data ethics. Big Data & Society, pp. 1–6, July-December (2014)

The Cartography Project: Towards a Relational Form of Documentation, the Case of Participatory Art Practices in Museums and Art Galleries

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Abstract This chapter describes a prototype platform developed by researchers at the Universities of Exeter and Nottingham in collaboration with Tate as part of the Research Councils UK funded Horizon project (2016–7). The prototype, hereafter called Cartography, consists of a web application enabling participants to input data and generate visualizations about participatory art practice in museums and art galleries. The chapter starts by analyzing the significance and changing role of performance documentation for museums and art galleries, focusing in particular on the role of the public in the context of participatory art practices. The chapter then makes a case for the capture of 'relational' forms of documentation which not only reflect how individual points of view sit in juxtaposition, or in opposition to each other, but also disclose important information about the rhizomatic nature of participatory practice. In conclusion, the chapter shows why relational documentation may offer significant insight into art and heritage more broadly.

Keywords Museum · Performance · Heritage · Relational documentation · Participation · Cartography

Since the 1960s, renewed efforts have been made to promote what can be described as a culture of participation. These efforts affected most areas of social activity, from research to art, architecture to business, journalism to politics. Neoliberal as well as left wing politicians in the UK, Europe and the US have embraced the concept largely to increase productivity within the experience economy, though artists, activists, and cultural organizations have tended to adopt participatory practices primarily to effect social change. Despite the growing recognition of the role of participatory practices

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in society, rarely have they been documented by utilizing participatory strategies. This means that participatory practices, which increasingly play a fundamental role in museums and other cultural organizations, do not tend to be documented by taking into account the viewpoints of the participants, by which we mean people who were variously engaged in these practices, whether as contributors, collaborators, beneficiaries or as spectators. This chapter describes the genesis and early development of a prototype platform for the documentation of participatory art practices in museums and art galleries, which intends to facilitate and indeed even privilege the documentation of subjective viewpoints mapping artworks as sets of relations. The chapter shows not only how crucial subjective viewpoints are in the context of participatory art practices but also why and how the documentation of participatory art should occur through relational forms of documentation so that these works could be understood as a series of associations connecting individuals, organizations, cultural heritage and related practices. Drawing from research in anthropology, human computer interaction, art history, performance studies and digital learning in the museum context, we also propose here that the use of relational documentation could bring to light important and under-researched knowledge about art and heritage.

Performance documentation, which originated as a way to capture performance, is now an important field of study for a wide range of disciplines including new media, human computer interaction, preservation, information studies, to name a few. The practice originated with the emergence of performance which established itself, as art historian RoseLee Goldberg suggested in her influential monograph *Performance Art: from Futurism to the Present* (1979) [1], at the time of the publication of the Futurist manifesto in 1909. Performance, which had also been popular among Constructivist, Dada, Surrealist and Bauhaus artists, subsequently re-emerged in the 1960s becoming one of the most prominent art forms of 20th and 21st centuries. The association of performance with a live event led scholars to question performance's relationship to documentation. Some researchers and practitioners noted that performance is ontologically inextricable from a live act which cannot be reproduced in documentation. This position was promoted by performance studies theorist Peggy Phelan who suggested that performance 'cannot be saved, recorded, documented, or otherwise participate in the circulation of representations *of* representation' [2]. Others implied that performance does not always originate in a live act and could find its point of origin in a documentation. This position was put forward by performance studies theorist Philip Auslander who suggested that documentation 'does not simply generate image/statements that describe an autonomous performance' but rather tends to produce 'an event as performance' [3]. The latter, as Auslander noted, was the case for Yves Klein's *Leap into the Void* (1960) in which the artist is seen jumping off a building though the action seen in the image documenting the work never took place in that the image is a photomontage. Others, especially art historians, tended to read performance and documentation in relation rather than in opposition to each other. Amelia Jones, for example, noted how we tend to encounter past performance works purely through their documentation (1997) [4] and Barbara Clausen pointed out that performance should not be considered purely as the 'authentic experience' of a live or present moment but rather as an 'ongoing process of an independent relationship between event, medialization, and reception' [5]. In most of these cases the question of whose role it was to produce a documentation, or even what should be in the documentation, did not seem to be as significant as the debate about the reproducibility of performance *as* documentation.

For this study, the questions as to who produces a documentation and what point of view they should capture is paramount. While performance documentation entered museums from the late 1930, at the same time that performance itself entered museums, it is only since the 1960s and 1970s that the approach to documentation has become more systematic, largely because of the work of photographers Peter Moore and Babette Mangolte, as well as, later, the photographer and video-artist Charles Atlas, resulting in a set of practices that are still influential nowadays. For Peter Moore, it was important to 'do justice, as much as you are able to, to the intention of the artist, rather than impose your own point of view on it to such a degree that it becomes distorted and unrecognizable' [6]. To achieve this, Moore stated, documentation should be shot 'from the point of view of someone in the audience in a "normal" viewing position' [7]. Babette Mangolte, on the other hand, adopted the two organizational concepts of automatism and chance. However, she too, like Moore, aimed to 'identify with the position of the spectator in the middle of the audience', rather than, as she claims had been the case for Moore, from the side, trying to 'capture the mental images that would become what an audience would likely remember of the piece', the so-called '"iconic" images for the piece' [8]. Moore and Mangolte's documentation strategies—capturing the artist intent and the point of view of the audience—were profoundly influential in the way that the practice of performance documentation subsequently evolved especially in terms of how museums would collect and show documentation in years to come.

Over the years, the purchase of performance as part of museum collections altered the way in which museums conceived of documentation. Originally documentation entered museums through acquisitions, produced or bought along works and documents pertaining to previous versions of the work, records about value, place in the collection, as well as records about its preservation. As Christiane Berndes, Curator and Head of Collection at the Van Abbemuseum, points out in her interview in *Histories of Performance Documentation* (2017), a lot of performance documentation that entered the museum in such ways, whether as photograph or videotape, over time then became the work. This has interesting consequences in terms of the changing value of documentation in the museum [9]. Thus Clausen explains in her essay in the same collection that documentation has been playing three functions in the history of museum practice: 'initially as a press image, then as a historical document, and finally as a work of art.' In this sense, Clausen suggests, documentation is not 'just a visual proof of an event', but, 'projected into the future', it produces 'the ability to comprehend the image as an index of its various future forms of existence as image, trace, and object' [10]. Documentation is therefore not only framing an action as art, leaving a trace so that this action may remain [11], and so reconstituting performance as an object, it is also the vehicle through which the aesthetic of the work can be re-interpreted over time.

While the intention of the artist and the point of view of the audience have formed the core of what performance documentation has tended to capture, in recent years attention has focused more and more on the documentation of the audience, not just in terms of what the audience sees, but what it does. This is a consequence of the increasingly active role played by the audience in the co-production of the artwork. Hence, more and more often, curators, like Annie Fletcher, Chief Curator Van Abbemuseum, consider documentation as something that should be about relations between artists and their work but also between the artists, the works *and* the public [12]. This suggests that a shift occurred in the way that museums think of documentation. No longer only a strategy for preservation, exhibition or re-activation, documentation has become a way of looking at the history of the reception and co-production of a work, showing the evolution of the inhabitation, interpretation and re-interpretation of a work by its audience over time. This way of thinking about art is in line with current research in art history conceiving of a new method, a 'biographical approach', which recognizes, as Renée van de Vall and others have suggested, that 'the meaning of an object and the effects it has on people and events may change during its existence' so that we should construct the 'lives' of these objects 'as individual trajectories' [13]. If the life of an object, an artwork or heritage more broadly, is formed by the individual trajectories that traverse it, then the mapping of these trajectories becomes crucial to document the life of the work itself.

We know that performance practice is to some extent about relations, but what makes relations especially important for participatory art practices? Art historian Claire Bishop, writing specifically in the context of participatory art practices famously noted that in participatory art 'the artist is conceived less as an individual producer of discrete objects than as a collaborator and producer of *situations'*. Thus the work of art, she indicated, 'as a finite, portable, commodifiable product is reconceived as an ongoing or long-term *project* with an unclear beginning or end; while the audience, previously conceived as a "viewer" or "beholder", is now repositioned as a co-producer or *participant'* [14]. Pointing out how participatory practice has been historically popular during times of political upheaval, such as 'in the years leading to Italian Fascism, in the aftermath of the 1917 Revolution, in the widespread social dissent that led to 1968, and in the aftermath of the 1970s', Bishop suggests that 'at each historical moment participatory art takes a different form, because it seeks to negate different artistic and socio-political objects'. Bishop's findings are crucial in the context of the documentation of participatory art practices in the museum for a number of reasons: first, Bishop notes how participatory artworks should be described as situations or projects, often spanning a period of time, and almost always produced by a group of people; second, she suggests that the audience is no longer merely a 'viewer' or 'beholder' but is a participant or even more importantly a co-producer of a given work; third, she suggests, the movement resurfaces at different points in time so as to 'negate different artistic and socio-political objects' [15]. This means that participatory art practices emerge from the collaboration of groups of individuals who tend to position themselves in relation to or even in opposition to particular socio-political objects. The current popularity of participatory art may thus be explained as a consequence of and/or in relation to the current period of political upheaval. This means that this art form is not only crucial in and of itself but also that it could be read as a socio-political barometer of its times. To map participatory art therefore tells us more about society at large.

Art historian Grant Kester, who entered a discussion with Bishop about the aesthetic value of participatory art practices, noted that participatory artworks could often be described as 'dialogical practices' or 'projects organized around conversational exchange and interaction' [16]. He suggested that these were a way of initiating 'local forms of 'solidarity which may, or may not, bear a *relationship* to larger political struggles or collective action' [17]. While, as Theatre Studies Historian Shannon Jackson noted, participatory art encompasses a wide range of practices like 'activist art, social work, protest performance, collaborative art, performance ethnography, community theatre, relational aesthetics, conversation pieces, action research', among others [18], these practices, as theorist and practitioner Michael Kelly pointed out, ultimately fall into three categories: '*relational*, activist and antagonistic' [19]. Moreover, as artist and theorist Susanne Lacy noted in her influential *Mapping the Terrain* (1995), participatory art must be defined for its capacity to 'communicate and interact with a broad and diversified audience about issues directly relevant to their lives' [20] in that it is the 'relationship between artist and audience' that may 'become the artwork' [21]. Here not only is the process more relevant that the object [22], the process is actually the artwork. These studies, carried out by some of the best regarded researchers and practitioners in the field, show that even at an ontological level participatory art practices are not only about relationships, they actually *are* relationships, whether in relation or in opposition to the past, society, the public, or all of the above. So, if participatory practices not only emerge from relationships and produce relationships but also generate artworks which are in themselves relationships, then a relational documentation model may be the most suitable strategy for the capture, building and analysis of the complexity of this form.

In *Experience or Interpretation* (2000) former Tate director Sir Nicholas Serota suggests that the 'best museums of the future' will make it possible for each of us to 'chart our own path, redrawing the map of modern art, rather than following a single path laid down by a curator' [23]. Building on Nicholas Bourriaud's *Relational Aesthetics* (1998) in which the curator suggested artworks should be judged 'on the basis of the inter-human relations which they present, produce or prompt' [24], Serota opens the path for relational forms of curation that intend to affect the way we experience museums more broadly. A relational model of documentation might then visualise not only relationships among artists, co-producers of works, participants, sites and organizations, but also the changing role of the museum in this context.

To begin to map these changes we decided to build a cartographic view of the field. To understand why we chose a cartographic model, we now need to dwell on what we mean by cartography, and so, invariably, by mapping in this context. While the word cartography originated in the early 19th century [25], the word map is more recent. As Peter Van der Krogt pointed out the term *chorographia* was in fact defined by Ptolemy as a representation of localities such a harbours, farms, villages river courses and such' so as to 'paint a true likeness and not merely to give exact positions and size', forming a 'portrait of place'. While the English language uses both words, 'map' and 'chart', to indicate 'different cartographic representations', most other modern languages only use one term, 'chart' (*kaart, Karte, carte, carta*, respectively, in Dutch, German, French, Italian) [26]. The term cartography conversely is a combination from the Greek word *chartès* and *graphein,* which means 'to describe' [27] and, in its subsequent use, often indicates 'the science of the graphical representation of geographical phenomena on maps' [28] though after 1840 the term usually had two meanings, 'the art of drawing maps and the drawing-up of a list of maps' [29]. The platform we aimed to build was meant to produce an evolving or even *live* map the field. Inspired by Michel de Certeau's vision of a 'practiced place' [30], we aimed to create a digital place that was to be formed through the intersection of subjective practices, in that users, whether artists, participants, curators, or researchers, would map their own experience of an artwork or, to put it differently, literally place the artwork in the context of the relationships that quite literally formed it.

So why would a cartography, and hence the *topos* of a 'practiced place', constitute an interesting documentation platform in relation to the specific field of participatory art? We know that our society is more 'map-immersed than any that has previously existed' [31]. Artists, among others, have a long history of making maps, from the Dutch and Italian Renaissance to the Surrealists, the Situationists, Fluxus and Pop. Fluxus maps were particularly interesting in the context of our project as they frequently required readers or viewers to complete them. Thus the multimedia artist Yoko Ono, for example, created a number of versions of *Map Piece* (1962), which instructed users to draw a map to get lost or draw an imaginary map and then try to navigate the actual streets of an existing town. In more recent times artists have been working with digital maps in the context of psychogeography, locative media, experimental geography, site specific and site sympathetic art, new genre public art, critical spatial practices, critical cartography and even biomapping. Some locative media apps were inspired by Situationist and Fluxus practice, such as the Serendiptor [32] and Dérive apps [33]. The former, developed by Mark Shepard at V2, combines a rooting service offered through Google Maps with instructions for action and movement inspired by Fluxus, Vito Acconci and Yoko Ono. According to the team that built it, the app was to help users to 'find something by looking for something else' (Serendipitor). Likewise, Dérive app, developed by a team led by Eduardo Cachucho, used Situationist strategies to allow users to explore urban spaces. These experiments with mapping suggest that maps are a practice as well as an object. They also suggest that maps tend to produce exploration of new terrains, terms and relations.

While maps are usually used by artists to convey a sense of place, design imaginary territories, or even portray human emotion [34], maps can also be 'performative, participatory and political'. Static maps tend to be more object-oriented while dynamic maps are more akin to practices [35]. We know from studies in anthropology that mapping is the production of knowledge as one goes [36]. We often assume that a cartography, however, implies a bird's eye view though we know from studies in art history that not all cartographic representations *merely* disclose a bird's eye view. In Johannes Vermeer's well-known *The Act of Painting* (1665–8) a cartographic map, signed by Vermeer, is seen hanging on the wall in front of the painter painting a portrait. The map features very prominently in the painting but is not what the artist is seen in the act of painting. Moreover, the fact that the painter is represented in the painting renders this a self portrait. Thus, as Svetlana Alpers shows, the painter is immersed within the world that is represented, acting both as an artist (as a subject and an object) and a cartographer [37]. We wanted to create a cartographic view that would reflect an immersive process while also producing a cartographic view which needed to be dynamic, capable of changing and adapting to new viewers.

We were very much aware that both map-making and cartography emerge from a history of colonial mapping, and we were therefore conscious of power structures inherent in defining and/or visualising relationships and structures in this way, which is why we wanted the map to be able to change. We were also aware of the risk that users would see our desire to recur to crowd-sourcing, which is essentially what participation to our Cartography may be read as in this context, as a form of labour exploitation. Much literature has been produced in relation to crowdsourcing, from Markus Meissen's study *The Nightmare of Participation* (2010), which shows just how easy it is for participation to become 'a method of placation rather than a real process of transformation' [38], to Bill Cooke Uma Kothari's 2001 edited collection *Participation: The New Tyranny,* showing how participation can lead to unjust and illegitimate exercises of power. Contributors to the latter study, social scientists and development specialists from various disciplines, challenge participatory practitioners and theorists, including crowdsourcing practices adopted by museums, suggesting that organizations can be naïve about questions of power, reinforcing, rather than overthrowing, existing inequalities [39], a criticism not too dissimilar from that posed by Bishop within the context of participatory art [40]. So to document participation from the participant perspective in participatory art is in itself a political gesture, an act of delegation and empowerment which could only work if it was truly inclusive, developed bottom-up, aiming to be beneficial especially for those who may be attempting to embrace this practice in years to come. We thought that the Cartography needed to be future-facing, not so much about the status quo, but rather about what could yet be changed. The Cratography should be an enabling tool as well as a documentation strategy.

At the heart of these comments denouncing the relationship of power and participatory practices is the fact that the two are inextricably and somewhat uncomfortably intertwined. Sherry Arnstein, who at the time of writing the seminal essay was based in the Department of Housing, Education and Welfare at Washington DC, wrote one of the first studies of participation, in which she described the now well-known 'ladder of citizen participation', later also often called 'Arnstein's ladder'. Published in 1969, the ladder was designed using examples from three federal social programs: urban renewal, anti-poverty and Model Cities. Interestingly, the ladder fore-grounded what Arnstein described as the citizen's 'power' in 'determining the plan and/or program', to address what was then perceived to be a controversy over participation, which she described as: 'eating spinach: no one is against it in principle because it is good for you'. For Arnstein, 'participation without redistribution of power is an empty and frustrating process for the powerless' [41]. To visualize this, Arnstein famously devised the ladder that shows, moving upwards, 'manipulation' and 'therapy', which are considered to be non-participatory [42]; 'informing' and' consultation', followed by 'placation', 'partnership' 'delegation' and 'citizen control'. Thus for Arnstein, the more successful the participatory plan or program, the bigger the transformation. So the question for us was, if participation, following Arnstein, is about empowerment in society, how could a situation emerge, within the context of the documentation of participatory art practices, through which this transformative gain in power could occur?

The relational frame that defines participatory art practices lent itself to the rhizomatic structures of digital architecture, so in our earliest discussions we agreed that we should try to develop a digital platform that could facilitate a shared, evolving form of documentation. Drawing on a database of artists, artworks and actions from across time and in many locations, we imagined a network of links and nodes, with a user-friendly front end that visualised a complex set of relationships. We thought this might then allow multi-authored contributions and hyperlinks to other, external, web-based collections or online documentation, offering participatory functionality, multiple perspectives and distributed editorial control. Eventually, the prototype platform we built entailed a web application responsible for enabling participants to input data and generate visualizations, and an associated server that was meant to store all the relevant data and allow for collaboration among users. The latter could, by utilizing an online interface, facilitate the entering of data, including text, image, video and audio commentary pertaining to artworks, artists, participants, spectators, institutions, festivals, installations in the field of participatory art practice in museums and art galleries.

The primary purpose of the platform was to visualize the rich and burgeoning history of the field, and a number of case studies were built in relation to works in the Tate collection so as to create a dialogue with works simultaneously being developed as part of Tate Exchange. The latter, which constitutes a new civic space in the Tate Modern Switch House, intends to act as a site for collaborative and innovative projects, comprising participatory events developed by artists, practitioners, and associates, within and beyond the arts sector, realizing Richard Sandell's vision of a museum as an agent for social inclusion and change (2010) [43]. Tate Exchange presents itself as an invitation to the audience, to Initiatives like Tate Exchange suggest that a responsibility of the museum may not only be the facilitation (as Nina Simon shows in her 2010 *The Participatory Museum*) [44] but also the documentation of such participatory practices. The platform prototype was built so as to encourage users to confirm or disagree with what others stated, leading to visualizations of divergence as well as, more canonically, convergence. The visualization of divergence, built bottom-up, was perceived to be crucial in our society which is increasingly dominated by algorithms that facilitate convergence and produce 'filter bubbles' [45] rather than dialogue and relationality.

To ensure that the platform was developed so as to generate a Cartography that would empower artists but also other participants to document each other's work, a set of workshops was conducted at Tate Britain and Tate Liverpool in 2016 and 2017 in which leading practitioners from the field of participatory arts were asked

Fig. 1 Tate Britain workshop

to contribute their ideas to the design of the platform as well as their response to and critique of the original proposition (see Figs. 1 and 2). This iterative way of researching and developing the platform made it possible for us to consider a number of cartographic models and finally select, following the first workshop in 2016, what we have subsequently referred to as a relational model of documentation. This was based on Graph Commons, an existing open source platform created by the artist Burak Arikan, so as to make visible the range of processes and practices that operate in participatory arts. Other cartographies in this field tend to be place-driven, as is the case of the work of Jake Barton, a New-York-based designer who creates public maps that are meant to generate social interaction and stimulate collaborative storytelling. Barton's work was especially interesting to us as it 'centered on performance' [46] and was also highly collaborative so that, for example, his *City of Memory* is a narrative map of New York 'that allows visitors to create a collective, online memory by submitting their stories' which create 'neighborhoods' by linking places together. Other projects, such as History Pin, advertised as 'a place for people to share photos and stories, telling the histories of their local communities' [47], and our own ArtMaps [48], which we developed in 2014 with the intention to make it possible for users to locate the Tate collection on a map, and which also used crowdsourcing to generate a sense of place. On this occasion, however, we did not so much want to map a terrain but rather record relations between people, places, organizations, among others that could inspire others to develop their own practice.

We decided that it was not only important that situations could emerge through the platform by supporting multiple perspectives and contested viewpoints, but also that the visualization of lineage should show long-term projects by association across countries and organizations so as to visualize which organizations had acted as cata-

Fig. 2 Tate Britain workshop

lysts for this work. We also felt contributors should not only be able to annotate what we had already uploaded but also that they should be enabled to generate entries even when they were not associated with any existing element in the Cartography. The latter, in particular, was considered, by the participants to the first workshop held at Tate Britain in 2016, as especially significant for those artists whose work may not as yet be in any museum or gallery collection. The participants to our first workshop had also identified potential barriers to participation, summed up by the comment: 'This project needs ambassadors and community leaders to broker the information gathering', suggesting that the production of digital heritage in a participatory context should not happen purely online and Tate's work on the five year HLF-funded Archives and Access project confirms that some level of facilitation may be needed [49]. Facilitated participation is essential for many audiences new to the material or the online format to feel that they can participate. So to document participation too the conditions for participating in the first place needed to be carefully orchestrated.

Our second engagement workshop took place at Tate Liverpool in 2017. Liverpool has a rich history of this practice, so we asked participants, who were members of three major participatory art projects in Liverpool, OK The Musical, Homebaked and The Welsh Streets, to feed back to us by focusing in particular on the importance of place in their work. In presenting their work to us, a number of factors became apparent. All three groups used social media (Instagram, Facebook, Vimeo, YouTube) to illustrate their practice to us (see Figs. 3 and 4). Worryingly, this suggests that the documentation of these artists' works is currently in the hands of commercial providers who do not have archiving standards at heart, so this justified our impression that the Cartography was in itself timely for a number of reasons. However, all groups indicated that at that point in time the Cartography looked like an art history

Fig. 3 Tate Liverpool workshop

and yet the field was not artist-centric. Moreover, some groups pointed out that the Cartography, at that stage in its development, did not visualize different versions of a work, was too static, and unable to show a whole range of materials that might be submitted, including, for example in the case of the work of the Welsh Streets, letters from residents, images and photos, a play, a film, amateur responses, interviews, learning materials and even a gardening project. Finally, Homebaked, indicated that the visualization did not communicate any sense of urgency, thus raising the concern as to why people should want to participate in such a project. Additionally, they specifically mentioned that the motivations or issues that drove their initiative—e.g. gentrification, housing justice—should be an option for organizing or searching the platform instead of the artists' names.

The feedback from the Liverpool workshop significantly impacted on the subsequent iteration of the platform but also revealed a number of factors that in the documentation of our encounters with art are often forgotten about. First, documentation does have an urgency as people's memories, our intangible heritage, will not last forever. Second, documentation is always ethically charged so one must not only think about participation but also ethics, ownership and authority. Third, in most forms of art, we still elevate individual artists over their collaborators and this is especially clear in documentation though this does not reflect the fact that artworks are often the result of a collaborative project. Finally, art, especially when hybrid, ephemeral, non-object based, subjective, needs to be documented through its reception. Moreover, documentation had became a prompt for conversation, challenging participants to reflect about power, ownership, place and transformation. These conversations about what the work was, what should be documented, what its relational quality was, were highly interesting and definitively worth capturing. This suggests

Fig. 4 Tate Liverpool workshop

that it is not only documentation that is interesting but also the *relational process* through which artists, practitioners, researchers and participants had arrived to it. This process was very much what we hoped the Cartography would visualize.

In looking at the final iteration of the prototype of the Cartography [50], it is clear that each of the artworks we focused on at the Liverpool workshops is now visualized as a set of relationships among people but also between organizations, artists and participants and between different art forms. Nina Edge's map (see Fig. 5), for example, expresses a complex rhizomatic structure which visualizes nodes of activity which radiate out, as well as interdisciplinary or relational patterns connecting distant points on the map. While Edge herself features prominently in the Cartography as an 'enabler' rather than an artist, so do her collaborators, Joe Farrag, Tom Calderbank, David Jacques, Felix Blow, Gopal Birdy, Bill McGarry, Sandi Hughes, Francesco Cuasco, John Lyons and Steve Hellens. This literally illustrates the workshop finding that had revealed how a strong sense of connectivity is crucial to make things happen in this field as is an agency and investment in the issues at play. In the workshop documents literally operated, to use Simon's term, as 'social objects' [51], prompting conversations among participants, which helped to define the web of relations that constitute their work. These conversations showed not only how works but also documentations originated as a consequence of an evolving set of relations. Faced with frequent lack of funding, a different value system was at work here, which privileged exchange and skill sharing, practices that are often neglected in canonic documentations but which are crucial not only in this specific practice but in art and heritage more widely. In fact, an alternative social model of practice begun to surface through the Cartography which captured the processes at the heart of the production of art and heritage and their documentation.

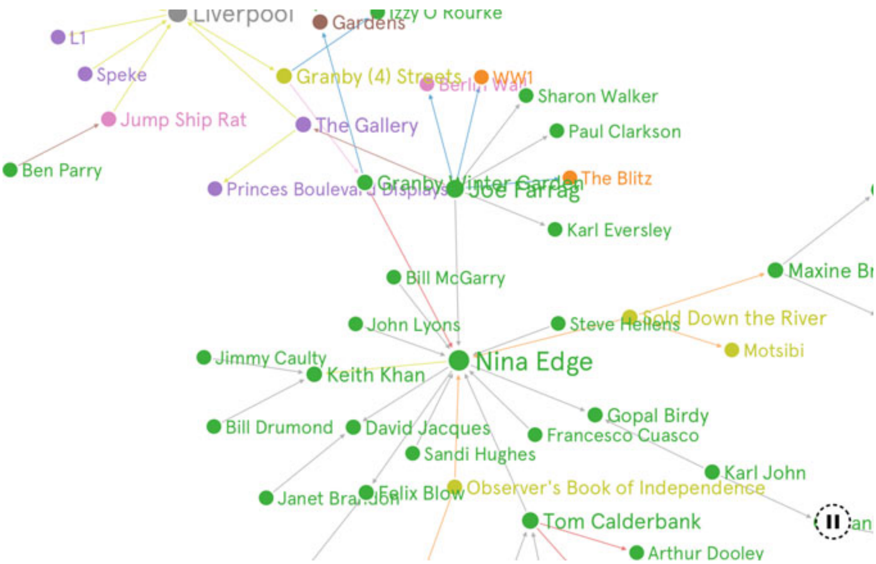

Fig. 5 Screenshot of the Cartography

In conclusion, the value of this project has been to show that while all forms of documentation are at some level hierarchical, the co-habitation of different hierarchies may be what a digital platform like that created by the Cartography can visualize in a range of ways. It is this emergent practiced space, this relational form of documentation, that may show us how the 'History' of this particular art can be rewritten as an intersection of a whole range of 'histories' of collaboration that may inspire generations in years to come. Our vision for the Cartography of participatory art practices was that it could constitute at once a mapping tool, through which new knowledge could be produced by users who would sign in and document their experience of a participatory artwork, and as an immersive field of practice that would develop iteratively over time through which a portrait of a genre would emerge. The Cartography would not only tell us about each participatory art form documented, it would also tell us about how these forms related to each other over a period of time. It would be at once a Cartography and a live archive, a space and a practiced place. It would privilege art and heritage as a practice and a process, as well as an object. And it would visualize our interpretation of this process. In other words, it would not only bring to light important and under-researched dimensions of art and heritage, it would also be a tool for remembering and re-remembering our role in meaning-making in this context.

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References

1. Goldberg, R. *Performance Art: From Futurism to the Present.* Thames and Hudson, London (1979).
2. Phelan, P. *Unmarked: The Politics of Performance.* Routledge, London (1993), p. 146.
3. Auslander, P. 'The Performativity of Performance Documentation'. *PAJ: A Journal of Performance and Art,* 84, 28:3 (September 2006), 1–10, p. 5.
4. Jones, A. '"Presence" in Absentia: Experiencing Performance as Documentation'. *Art Journal*, 4 (Winter 1997), 11–8.
5. Clausen, B. 'The (Re)presentation of Performance Art.' In: *After the Act*. Museum Moderner Kunst Stiftung Ludwig, Wien (2007), pp. 7–20, p. 7.
6. Argelander, R. 'Photo-Documentation (and an interview with Peter Moore)'. *The Drama Review,* 18:3, (1974), 51–58, 52.
7. Ibid., p. 53.
8. Mangolte, B. 'Balancing Act Between Instinct and Reason', media archive performance map (2009), http://www.perfomap.de/map1/i.-bewegung-plus-archiv/balancing-act-between-instinct-and-reason, verified 31/1/2017.
9. Giannachi, G. and Westerman, J. (eds) *Histories of Performance Documentation.* Routledge, London and New York: Routledge (2017), p. 42–8.
10. Ibid., p. 93–114.
11. Schneider, R. *Performance Remains Art and War in Times of Historical Reenactment.* Routledge, London and New York (2011).
12. Ibid., pp. 42–8.
13. Van de Vall, R., Hölling, H., Scholte, T., Stigter, S. 'Reflections on a biographical approach to contemporary art conservation' (2011), available online http://www.hannahoelling.com/wp-content/uploads/2016/09/Reflections_on_a_Biographical_Approach_t.pdf, verified 13/5/2017.
14. Bishop, C. *Artificial Hells: Participatory Art and the Politics of Spectatorship*. Verso, London and New York (2012), p. 2, original emphasis.
15. Ibid., p. 276.
16. Kester, G. *The One and The Many*. Duke University Press, Durham: North Carolina (2011), p. 8.
17. Ibid., p. 125, added emphasis.
18. Jackson, S. (2011) *Social Works: Performing Art, Supporting Publics*. Routledge, London and New York (2011), p. 11.
19. Kelly, M. 'Participatory Art', *Encyclopedia of Aesthetics.* Oxford University Press, Oxford (2014), no p., added emphasis.
20. Lacy, S. *Mapping the Terrain: New Genre Public Art.* Bay Press, Seattle (1995), p. 18.
21. Ibid, p. 20, original emphasis.
22. Ibid., p. 174.
23. Serota N. *Experience or Interpretation: The Dilemma of Museums of Modern Art.* Thames and Hudson, London (2000), p. 55.
24. Bourriaud, N. *Relational Aesthetics*, tr. S. Pleasance and F. Woods. Les presses du reel, Paris (1998), p. 112.
25. Van der Krogt, P. 'The Origin of the Word "Cartography"'. *e-Perimetron,* 10: 3 (2015) 124–142, p. 124.
26. Ibid., p. 125.
27. Ibid., p. 126.
28. Ibid., p. 132.
29. Ibid., p. 140.
30. De Certeau, M. *The Practice of Everyday Life.* Tr. S. Rendall. University of California Press, Berkeley, California (1984), p. 117.
31. Cosgrove, D. 'Art and Mapping'. *Cartographic Perspectives, Journal of the North American Cartographic Information Society*, 53 (2006), pp. 1–58, p. 7.

32. http://serendipitor.net/site/, verified 5/2/2018.
33. http://deriveapp.com/s/v2/, verified 5/3/2018.
34. D'Ignazio, C. 'Art and Cartography', in Kitchin, R. and Thrift, N. (eds) *International Encyclopaedia of Human Geography,* vol. 1, Elsevier Ltd., Oxford (2009), pp. 190–206, pp. 191-2.
35. Crampton, J. 'Cartography: performative, participatory, political', *Progress in Human Geography,* 21/5/2009, 1–9, p. 1.
36. Ingold, T. *The Perception of the Environment.* Routledge, London and New York (2000), p. 231.
37. Woodward, D. (ed.) *Arts and Cartography: Six Historical Essays.* The University of Chicago Press, Chicago and London (1987), pp. 51–97.
38. Meissen, M. *The Nightmare of Participation* (2010), http://turbulence.org/blog/2010/10/31/thenightmare-of-participation-by-markus-miessen/, p. 34, verified 2/3/2017.
39. Cooke, B. and Kothari, U. (eds.) *Participation: The New Tyranny*. Zed Books, London, New York (2001).
40. Bishop, C. *Artificial Hells: Participatory Art and the Politics of Spectatorship*. Verso, London and New York (2012),
41. Arnstein, S.R. 'A Ladder of Citizen Participation'. Jo*urnal of the American Institute of Planners.* 35:4. (1969), 216–224, p. 216.
42. Ibid. p. 217.
43. Sandell, R. 'Museums as Agents of Social Change', *Museum Management and Curatorship,* 17: 4. (2000), 401–418.
44. Simon, N. (2010) *The Participatory Museum*, http://www.participatorymuseum.org, verified 1/7/2017.
45. Pariser, E. *The Filter Bubble: What the Internet is Hiding From You.* Harmonsworth, Penguin (2012).
46. Cosgrove, D. 'Art and Mapping'. *Cartographic Perspectives, Journal of the North American Cartographic Information Society*, 53 (2006), p. 41.
47. History Pin, https://www.historypin.org/en/, verified 18/3/2018.
48. Sinker, R., Giannachi, G. and Carletti, L. 'Art Maps—Mapping the Multiple Meanings of Place'. *International Journal of Art & Design Education*, (2013) 32: 362–373. https://doi.org/10.1111/j.1476-8070.2013.12025.x).
49. Archives and access, http://www.tate.org.uk/about-us/projects/transforming-tate-britain-archives-access, verified 18/3/2018.
50. The Cartography Project http://www.tate.org.uk/research/research-centres/tate-research-centre-learning/cartography-research-project, verified 12/3/2018.
51. Simon, op. cit.

Digitization of Old Maps and Possible On-line Tools for Their Use

Milan Talich

Abstract Old maps are one of the most important historical sources. Today's modern methods of digitization for on-line access allow much more than just making copies of old maps for viewing. Is it possible to fully exploit the potential of old maps as cartographic works with all of their specific properties. The various tools and services for digitized old maps are shown in this chapter. Thanks to georeferencing of this digitized images of old maps followed by layering associated with opacity can be effectively compared the contents of the different maps between themselves. For these purposes are important on-line tools for georeferencing of raster images of old maps. Important are also on-line tools for display of georeferenced maps in 3D view on digital terrain model. On-line tools of new generation can do also automatized processing of georeferenced raster images of digitized old maps. These are e.g. searching for occurrences of map symbols, classification of digitized old maps, automatized extracting of texts etc. In addition to the above, this chapter also deals with the requirements for proper digitization of old maps. Reported are mainly requirements for the preservation cartographic properties of old maps. Special attention is paid to the preservation of positional accuracy of drawing on old maps during their digitization.

Keywords Old maps · Digitizing · Georeferencing · Map services · Chartae-Antiquae.cz

1 Introduction

Old maps, plans, atlases and globes are certainly part of our cultural heritage. They are part of our history, they illustrate the situation at the time of their creation and complement other historical sources. They are also an important proof of the skill, knowledge and artistic excellence of our ancestors (Fig. 1).

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The process of creating the maps is, in contrast to other historical documents, specific works. From the cartographic point of view, the oldest view maps are considered to be pictures or sketches rather than real maps. However, since the early 18th century, maps began to be created based on accurate geodetic measurements and mathematically defined cartographic displays. From such maps, it was possible to precisely measure lengths, determine directions and calculate the areas. It should be noted that each map has its accuracy based on the mapping method used, the instrumentation and the scale used. Maps, plans and globes are therefore works that have their cartographic properties. Only by knowing these features is it possible to extract all of their information potential from them.

The need to digitize and access these archive materials does not need to be emphasized. In view of their importance as historical sources, the old maps are increasingly of interest to researchers. This naturally increases the effort to use them with modern methods, especially digital ones. However, mere digitization and subsequent free online access to view old maps is not enough for users. There are requirements to preserve and exploit the full potential of old maps as cartographic works with all their specific properties. And that's not all. Users are increasingly asking for value added, which will allow them to work better with digitized old maps and gain more information than is possible in their classical use of paper maps.

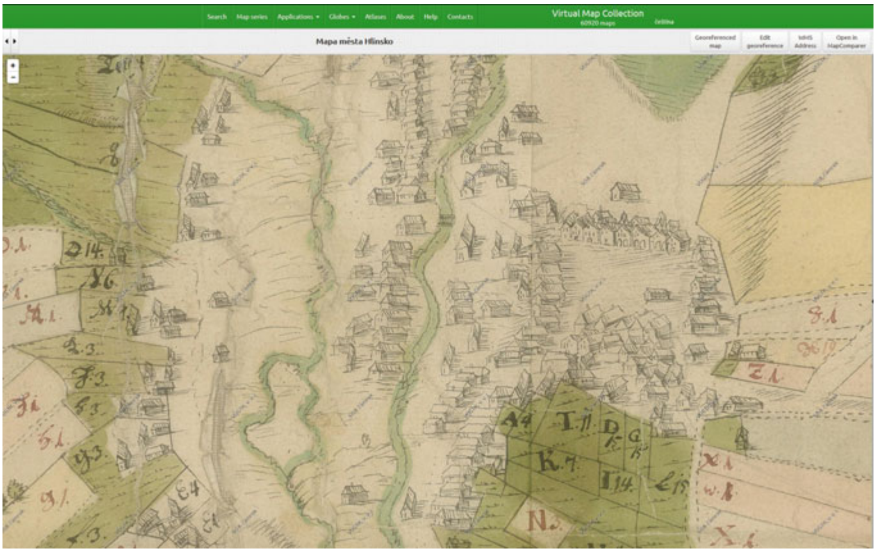

Fig. 1 Part of the manuscript map of Hlinsko town from 1731, State Regional Archives in Zámrsk, http://www.chartae-antiquae.cz/maps/19248

2 Basic User Requirements for Digitized Old Maps

The first basic user requirement is clearly the free online availability of digitized old maps. For simple maps viewing, it is enough to provide raster images of the maps in a suitable zoomable way that will be fast enough on common internet lines and allow basic image manipulation such as zooming or scrolling. This kind of use will surely satisfy, for example, the provision of old maps through Zoomify.

However, among the basic requirements of users, the requirement for preserving all cartographic properties of old maps can also be included. Of course, when it comes to real maps with such features and not mere sketches without any scale and cartographic projection. In order to preserve their cartographic properties, the digitized raster images of the old maps must be georeferenced, i.e. placed in the coordinate system taking into account their cartographic projection used. Georeferencing problems will not be dealt with in detail in this text, because it is a relatively demanding operation in which it is necessary to adhere to a number of rules based on the theory of mathematical cartography and elastic transformations. The correct methodological procedure for precise georeferencing of a larger map set is given e.g. at [1]. But important is that when a georeferenced map is made available, the user can directly measure the lengths, directions, areas, coordinates, etc. in the web application on the monitor screen. The digitized map thus remains its cartographic properties.

3 Values Added of Digitized Maps

If digitization of old maps is achieved and resulting georeferenced raster images are provided in an appropriate standardized online way, it is natural that users want to work the most efficiently with them. They expect some value added compared to the original paper map, which allows them to make better use of these digitized data than before. Here are examples of such value added.

3.1 Finding and Displaying Suitable Maps Available Online

The most basic requirement is to have a tool for finding and displaying the required maps provided on-line from as many sources as possible, such as map collections of archives, libraries or museums. A user (researcher, explorer, etc.) interested in, for example, a specific area in a specific time period and looking for maps displaying this area within a certain scale, inserts this data into the search tool. For example, the area can be defined by a range of coordinates, or defined on an underlying map. The result will be a list of the corresponding maps provided by individual libraries, etc., including meta-information about them and links for their display. Application for

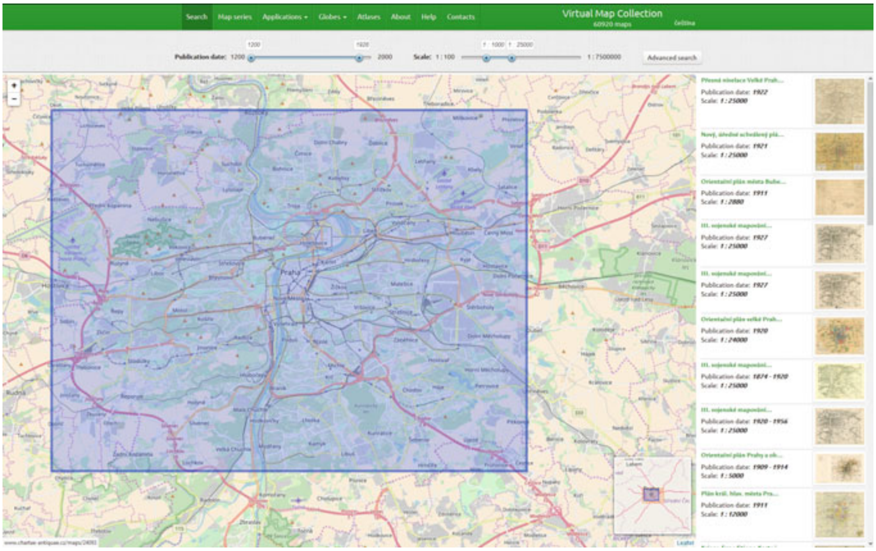

Fig. 2 Geographic Search on Virtual Map Collection Chartae-Antiquae.cz [5]

viewing maps in the form of non-georeferenced raster image then allows to browse maps swiftly pan and zoom to the smallest detail. Users will certainly appreciate it, especially for large maps.

This task is called geographic search of maps and has been in the forefront of interest of a number of institutions in recent years. There have been made several webapplications to solve it. For example, it can be list CartoMundi [2], Cartesius-Portal [3], geographic search in the Moll's map collection [4], or geographic search of maps in Virtual Map Collection Chartae-Antiquae.cz [5] (Fig. 2).

3.2 *The Ability to Compare the Situation on a Map*

The ability to compare the situation on old maps on-line can be a very high value added of the digitized maps compared to the original paper maps. It allows to lay two different maps on the monitor side by side, no matter where their original paper maps are. In addition, even when viewing maps in Zoomify, it is easy to compare maps of different scales. Of course, only in proportion to the scale differences and the generalization of compared maps.

But much more useful is the ability to compare maps by layering them together with transparency or overlay. It will also help to reveal even minor changes in the drawing of situation, such as the course of communications or the extent of water or forest areas, etc. The user can compare maps of different time periods, different scales, and different cartographic projections, which come from different map collections. This, however, assumes that the maps will be georeferenced and provided in a standardized way so that they can be used uniformly in map applications, regardless of who is their provider. There are more standards for map services there. However, the Open Geospatial Consortium (OGC) Web Map Service (WMS) [6] and the Open Source Geospatial Foundation (OSGeo) Tile Map Service (TMS) [7, 8] appear to be the most widespread and most suitable for providing raster map data.

These services, in addition to common single maps, are mainly used to publish important map sets (multi-sheet maps), which are more useful to georeferencing. In the case of larger map sets with a larger number of sheets, it is also necessary to perform so-called mosaicing, i.e. the binding of individual digitized map sheets in one seamless raster. Technically, of course, it is not necessary to create one huge file of raster format with all map sheets, but it is necessary to ensure that the respective tiles (separate parts of the raster on which the file is divided) are georeferenced and composingable. During the mosaic process, other problems arise and need to be addressed. Especially because individual paper map sheets are affected by paper collision. After scanning map sheets is necessary to remove the paper collision and then merge the sheets with the respect to the cartographic projection used.

As an example of a good practice for such on-line comparison of maps, can be mentioned the MapComparer web application on the chartae-antiquae.cz portal. Maps can be compared in this application in two ways. The first is to compare maps in one large map window. In this window, the maps are inserted and displayed each in the individual layers, and the transparency tool can be used for comparing of their contents. In MapComparer is possible easily to compare any maps found in the portal database (about 64,000 maps). Likewise, any other map provided by WMS, Zoomify, or as a custom raster image from your PC can be added. Using the slider bar, the layers can be made more transparent and mutually compared (Fig. 3).

When comparing more than two maps, this method is less practical and unclear for the user. MapComparer is therefore provided with a maps view feature in two or up to four map windows. Different maps can be inserted into each window and compared they visually at a glance. Zooming and scrolling the map in one window synchronously scrolls all the maps in the other windows. The user still compares the same area at the same scale in all the windows. To each window, multiple maps can be placed using multiple layers that can be turned on or off, or to regulate their transparency. It is therefore possible to compare e.g. 10 maps at the same time, both visually and ensuring transparency.

Several map sets are preset in the application that are most used to track changes on old maps. However, the user can attach other maps to the application that are provided to anyone via WMS, such as e.g. cadastral maps, geological maps, maps of archaeological sites, etc. To the map window, the user can also upload maps that are not provided by WMS, but are displayed on the site via the Zoomify application and/or the maps that has stored on its computer. Such maps are not georeferenced and must be managed separately in the application. It is important to emphasize that for the use of all these functionalities the user needs only an Internet browser and does not need any own GIS or specialized software.

3.3 *Online Georeferencing of Zoomify Old Map Images*

To use more advanced tools e.g. such as mentioned in the previous paragraph maps are required to be georeferenced. The proper georeference in the form of the elastic transformation of the raster image is usually done using the control (identical) points given both in the old map and in the underlying map.

For easy and fast georeferencing of raster map images provided in Zoomify format, is possible to use, for example, an online application on the chartae-antiquae.cz portal. After entering an internet address of the map at zoomify format, its accessibility check is performed and a custom application window for georeferencing open—see Fig. 4. Here is an old map, which is supposed to be georeferenced and an underlying map. On both maps, a number of control points will be marked successively, and then a custom transformation is made to show the georeferenced old map. Control points can be interactively added or deleted in the areas where they are needed. The application instantly converts the transformation to the resulting georeferenced map. This makes it easy to achieve the desired positional accuracy of georeferencing in the whole area of the map. The final result of georeferencing is a WMS link where is possible to view the original zoomify map in georeferenced form. This link can also be used to display the resulting georeferenced map in the user's GIS systems.

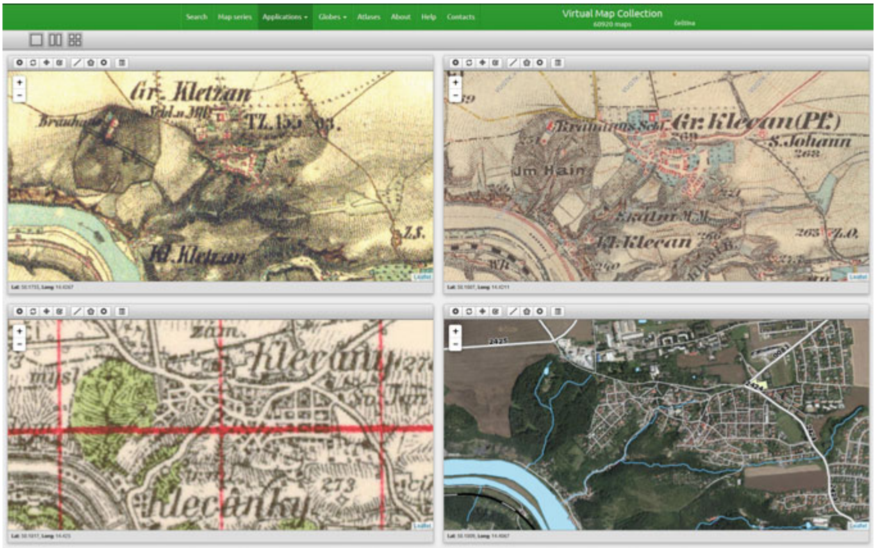

Fig. 3 MapComparer, web application on the chartae-antiquae.cz

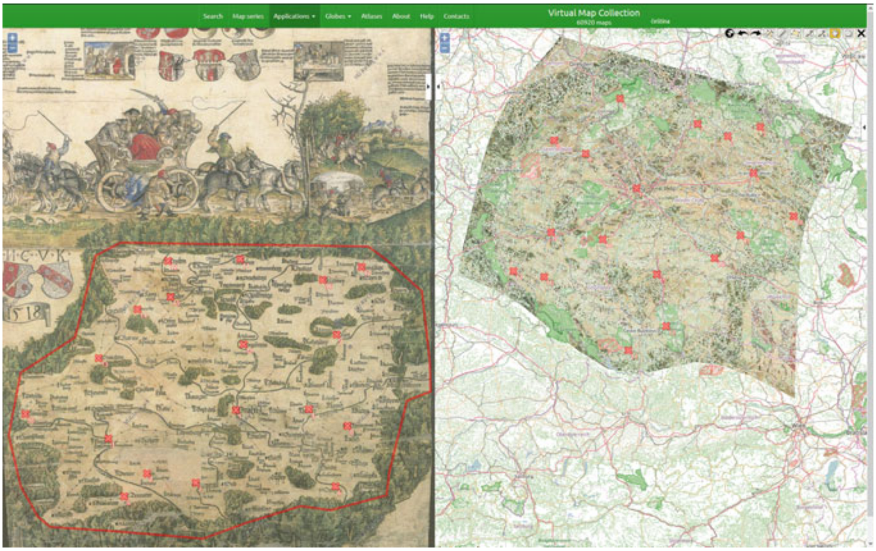

Fig. 4 Online application for georeferencing of zoomify old maps on the chartae-antiquae.cz

3.4 Viewing of Georeferenced Map on a 3D Map

If old maps are already georeferenced and provided in a standardized way, we can start using more sophisticated services with value added. One of these is to display a georeferenced map on a 3D map. Again, chartae-antiquae.cz serves as an example of good practice. The "3D Visualization of Digitized Maps" application allows to view any maps provided in the WMS or TMS format on a 3D map (3D model). The Cesium library, which uses WebGl, is used to view the 3D map, so viewing is not possible on older web browsers. The resulting 3D map model, can be moved, rotated, tilted, zoomed in or out, and can be changed the direction of the light by setting the time. An example of a map view in a 3D model is shown in Fig. 5.

For both applications (georeferencing and 3D view), detailed helps for their use are available. Again, it is important to emphasize that for the use of all these functionalities the user needs only a web browser and does not need any own GIS or specialized software.

3.5 Automatic Detection of Map Symbols

Another significant value added can be, in general, automatic search and recognition of objects in raster images of digitized old maps. A particular useful application can be, for example, the search for map symbols/markers on the map. With some degree

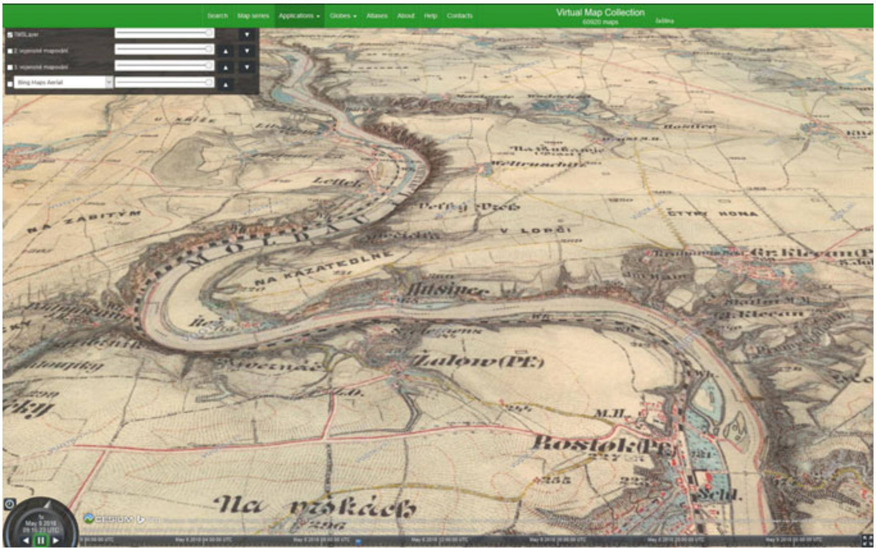

Fig. 5 Online application for viewing of georeferenced old map on a 3D map on the chartae-antiquae.cz

of probability, you can search for objects such as map symbols. The significance of this option increases with large maps with many map sheets. Such map sets are in the same cartographic projection, with the same expression of the Earth's surface, the same map symbols, and the same colours used. Therefore, the existence of an online tool available to solve this task can be very useful to all researchers.

For example, the chartae-antiquae.cz portal implements a map symbols search application in special maps of III. Military survey (1: 75,000). These maps have many map symbols. However, these are not user-friendly maps thanks to a very dense drawing including hachures. For a quick search, a special application has been created, where the map symbols are already automatically searched by machine recognition of objects in a raster image. It is sufficient for the user to tick the relevant map symbol in the branding key, and on the selected map sheet these symbols are immediately highlighted—see Fig. 6.

3.6 Possibility to Use Digitized Maps in User Map Applications

This value added seems to be the most fundamental of all of the above—especially for its generality and versatility. If digitized old maps, respectively their raster images, will be provided in a georeferenced form in a standardized way (WMS and/or TMS

Fig. 6 Online application for automatic detection of map symbols on the chartae-antiquae.cz

format), than it will allow individual users to create their own applications using this provided data for own special purposes.

The spectrum of users of old maps is huge and it is possible to use old maps in almost all fields of human activity. Therefore, it is not possible to cover all user needs in advance and create appropriate tools for them. It will be much more efficient and promising if the old maps will be available to users in a standardized way. At the same time, standardized way of availability will allow the use of their cartographic properties. It is then just on users to ensure optimal use of provided data in their own applications for their own needs and at their own expense.

4 Basic Requirements for Digitizing Old Maps

Here are just a few principles that should be respected, given their importance and the facts above.

4.1 The Accuracy of the Scan of Old Maps in Terms of Their Position

Scanning of old maps created based on cartographic projections must be done in a way that allows them to preserve their cartographic properties. The most important is to achieve the highest positioning accuracy of individual pixels in the raster image. This can only be done by using accurate cartometric scanners, whose positional accuracy will be regularly checked (attested). In this control measurement, the testing scanner usually takes a raster image of the control grid on non-shrink material (e.g. plastic astralon film). The raster image is then evaluated in terms of positional accuracy. From experience, the mean coordinate error at the point of the grid points should be less than 0.10 mm. The maximum offset at position should be less than 0.30 mm. For more information about testing the accuracy of scanners see e.g. [9].

4.2 Scanning Parameters

The optical resolution of the scanner should be at least 400 dpi in both directions. However, the optical resolution 600 dpi is recommended, optimal is 800 dpi. A 400 dpi resolution is enough only to view old maps on the monitor. For the use of more sophisticated services, such as automated search and object recognition in raster images of digitized maps, a minimum resolution of 600 dpi is required. As well as for georeferencing process of maps should be at least 600 dpi resolution, because the elastic transform raster distortion occurs each pixel raster image.

To maintain colour fidelity, scanning should be performed in a colour gamut of at least 24 bits, including an ICC (International Color Consortium) profile [10], which has been approved as an ISO 15076-1:2005 international standard (Image technology colour management—Architecture, profile format and data structure) [11]. This colour profile characterizes the colour gamut (reachable area of colour in a certain colour space) and the properties of the reproduction device or media. The information can then be used to accurately reproduce or display colours on a printer, monitor, plotter, or other device. ICC profiles are mainly used in DTP applications where they are used to convert between RGB and CMYK colour spaces and to ensure colour matching when reproducing colours.

5 Conclusion

It can be said that today to clients of archives, libraries and other map collections, where old maps are kept, the availability of these old maps online is not enough. They require more than just viewing old maps on the monitor. To users is necessary to provide some value added that will allow them to use of digitized old maps better than is the using of original paper maps. However, this can be achieved only with the proper digitization and the appropriate way of providing old maps on the Internet.

Examples of several such value added show where possibilities of using old maps by digital methods are going. At the same time, there are listed some basic principles that need to be complied when digitizing old maps. At the same time, managers and owners of map collections can be strongly encouraged to digitize their old maps according to these guidelines so as not to lose their cartographic properties. Furthermore, to provide digitized old maps in a standardized way (preferably WMS/TMS) to enable this data to use in user's map applications.

In conclusion: the future life of old maps is to shift their understanding from nice pictures (artefacts) to an online service available.

References

1. TALICH, Milan, SOUKUP, Lubomír, HAVRLANT, Jan, AMBROŽOVÁ, Klára, BÖHM, Ondřej and ANTOŠ, Filip: Georeferencing of the Third Military Survey of Austrian Monarchy. In: Proceedings of the 26th International Cartographic Conference, Dresden, Germany, 25–30 August 2013, str. 898–899, International Cartographic Association, ISBN 78-1-907075-06-3. http://icaci.org/files/documents/ICC_proceedings/ICC2013/_extendedAbstract/266_proceeding.pdf.
2. Arnaud J.L.: Cartomundi, a new interface to find maps by geo-localisation. http://icaci.org/documents/ICC_proceedings/ICC2011/Oral Presentations PDF/C3-Digital technologies and cartographic heritage/CO-266.pdf, cit. [8. 5. 2018].
3. CartesiusPortal, maps and aerial photographs of Belgium and Central Africa online: http://www.cartesius.be/CartesiusPortal/, cit. [8. 5. 2018].
4. Moll's map collection, Geographical Search: http://mapy.mzk.cz/en/, cit. [8. 5. 2018].
5. Virtual Map Collection Chartae-Antiquae.cz: http://www.chartae-antiquae.cz/en/, cit. [8. 5. 2018].
6. The OpenGIS® Web Map Service Interface Standard (WMS), http://www.opengeospatial.org/standards/wms, cit. [9. 5. 2018].
7. The Open Source Geospatial Foundation (OSGeo), https://www.osgeo.org/, cit. [9. 5. 2018].
8. Tile Map Service Specification (TMS), https://wiki.osgeo.org/wiki/Tile_Map_Service_Specification, cit. [9. 5. 2018].
9. ANTOŠ, Filip, BÖHM, Ondřej and TALICH, Milan: Accuracy testing of cartometric scanners for old maps digitizing. In: 9th International Workshop on Digital Approaches to Cartographic Heritage, Budapest, 4–5 September 2014, 8 pp. http://naki.vugtk.cz/media/doc/publikace/antos_et_all-acuracy_testing.pdf.
10. International Color Consortium (ICC), http://www.color.org/, [cit. 9. 5. 2018].
11. ISO 15076-1:2005—Image technology colour management. Architecture, profile format and data structure. Part 1: Based on ICC.1:2004-10, http://www.iso.org/iso/catalogue_detail.htm?csnumber=40317, cit. [cit. 9. 5. 2018].

Efoto Hamburg: From Image Data to a Digitally Mediated Cultural Heritage Process

Mareike Schumacher

Abstract In this article we elaborate the theoretic foundation of the efoto project and how it was used for technical implementation of a mobile application. Further we show how images can be interpreted as data and how they may be transferred into objects of cultural relevance and as such integrated into a cultural heritage process We prove that Cultural Heritage may be defined by combining statements from the UNESCO with insights from discussions on sustainability, especially cultural sustainability, cultural sciences and identity creation and that such a definition leeds to an understanding of Cultural Heritage as an ongoing social process.

Keywords Photography · Digital humanities · Culture · Cultural heritage · Digital applications

1 Introduction

Photography is a medium, which combines several functions. It can be seen as a means of documentary, an artform, a trigger for memory, an illustration for a text, the quote of a moment and even as a kind of language. Yet the large amounts of photographic images which not only are already stored in archives but also increase every day and even minute thanks to digital hard- and software make it harder to include images in traditional cultural heritage preservation and presentation. New ways to deal with this "image data" ought to be found in order to bring historic pictures back into cultural processes, transfer them into cultural heritage and thus preserve them in a sustainable way. This is what we search to achieve in the efoto project. In this article we present our understanding of photography, data and cultural heritage. We show how these theoretic insights were used for practical implementation of a digital infrastructure containing one backend and multiple frontends. Our leading question is reflected in the title and can be reformulated as:

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How can large amounts of image data, including historical and recent photographs of the city of Hamburg, be (re-)integrated into a social cultural process in order to convert them into cultural heritage? We chose to differentiate between data and cultural heritage as two counterparts as regards the status of images in efoto. As a case study for our concept of cultural heritage we use the efoto application itself, showing how the implemented features may meet the goal of transferring (photographic) data into a cultural heritage process.

2 The Efoto Project

When efoto started in 2015, altogether there were over 1 million historic images stored in the 11 joining partner institutions. Photographs were stored in digital databases or—more often—on archival shelves. However, access to these potentially culturally valuable images was complicated for the public. Searching for a specific picture or a subject one had to reach out to several institutions to find it. Once an image was found, the institution holding it had to check whether the image could be handed out and be used for the purpose in demand. In short, most of the images, especially those not digitized, were just lying in their archive not ever being looked at or used in one way or the other. The aim of the efoto project is to revive these images by bringing museums, public and private archives together to build a joint database for historic images and make them accessible for the public via a mobile application. A network of University, cultural ministry and partner institutions from the cultural heritage sector is working together in order to bring historic image data to the cityscape and include it into a digitally mediated process of cultural heritage, thus giving rise to the cultural relevance which, in our eyes, is inherent to it.

The chance and the challenge deriving from the network of project partners is to combine multiple interests. The archival mission is to choose those images which should be preserved and preserve them for a very long time (and to throw away the others). Museums are keen on presenting curated units of pictures in exhibitions. Therefore the images should be stored in the highest possible quality and enriched with high quality metadata. The public and political administration want all images to be freely accessible arguing that the public has already paid once for these images to be taken (at least the ones which were made by officials) and another time for digitization. In addition to that there are political strategies and guidelines like the eCulture Agenda 2020 [1] of the city of Hamburg and the European Inspire Guideline [2] which should be met. Finally from the University perspective it is most important to collect all collectable data, including not only images but also how people react to and interact with them, in order to analyse it and to find out more about the importance of photographic pictures to cultural heritage.

3 Theoretic Foundation of Efoto

Turning back to the kind of objects we deal with, we would like to elaborate a bit on what photography means and how it is used in cultural processes. By the time being we imported about 60,000 images into the efoto backend. Roughly 11,000 were georeferenced and published inside the efoto mobile application. These images cover a time span from the late 19th century to 2017. There clearly is a focus on older photography and there are gaps especially before, during and after World War II and in the 1990s. Nevertheless all kinds of photography—analogue, digital and even the newest mobile technology—are covered. So roughly from the beginning of photography up to today all traditions and social uses are of relevance building up a theoretic backdrop for efoto.

3.1 Photography

It has been stated quite often that a huge and ever growing number of images are taken today [3–5]. Although, in the 1990s, the "death of photography" has been proclaimed more than once [6, p. 47], from today's perspective it seems that the use and the social meaning of images were increasing ever since the medium was invented. But in fact the data in efoto, which, at the moment, still is a rather small sample, displays a gap in documentary photography in this period. The deep disappointment manifesting in the above cited statement and possibly also in the gap in the efoto data can be associated with the growing possibilities of photographic manipulation [6, p. 47f]. And indeed the subject of falsehood especially in the context of image-sharing platforms like instagram is still thematized very regularly up to today.[1] The fundamental dialectics of photography, which are expressed in the discussions about life and death of the medium, seem to be that photographs represent the real and the false (or fake) in the same way, making them indistinguishable.

But even without taking into account the possibilities of manipulation in the first part, the duality of the aim to represent reality on the one side and the need of choosing a certain moment, a section, a time of day or a mood for making an image has always been part of photography [8, p. 66]. And images are central to perception of reality. As Susan Sontag puts it in her collection of essays "On Photography" already Plato "tried to loosen our dependence on images by evoking the standard of an image-free way of apprehending the real" [9, p. 80]. Nevertheless photographs, in opposition to other forms of imaging as e.g. paintings, had and still have the notion that they may be used as proof, if not for the whole image it shows, then at least for its single parts to have existed [9, p. 3, 10, p. 86]. As Berger puts it very nicely, photographs "do not translate from appearances. They quote from them." [10, p. 96]. Sontag goes even further stating that a photograph is more than a representation, that

[1]To name just one example the travel photographer and instagram influencer Carolyn "The Slow Traveler" hacked her own instagram account with strongly manipulated images of herself [7].

it is indeed an extension of something [9, p. 81]. As such a quote or even reality-extension appears to be completely unmediated, it implies a claim for reality. But on the other side the limitedness of the information the seemingly so real photograph gives, triggers the urgent need to interpret it in terms of context, connection to a past and a future (e.g. of the moment shown) and especially the relation to the onlooker [10]. In addition to that the immediacy of a photographic image, be it fake or real, works like a shortcut to the experience of the observer thus touching her not only on a level of information but also of perception and emotion [10, p. 126]. It might be this direct link from photographic image to its onlooker which evokes that photographs have, what Sontag calls the "extraordinary power to determine our demands upon reality and are themselves coveted substitutes for firsthand experiences" [9, p. 80].

Indeed the connection of experience and photographic picture seems to be of importance for the way they are used, today. Especially young people tend to share pictures as experiences [8, p. 61]. This means there not only was a shift in what photographs are regarded as—experiences or moments rather than mementoes—there was also a shift in usage. Instead of collecting pictures and organizing them in family albums as a kind of chronicle, people communicate by sharing pictures [8 p. 61f, 5, p. 3]. The social functions of communicating with and through pictures are in the first place identity creation of individuals and groups and bonding between individuals and groups [8, p. 61 and 63]. Although the communicative function of photographs seems to make them somewhat ephemeral, the collection and storage still happens [8, p. 68]. This can be in a rather unconscious way, because sharing also means distributing pictures and the possibilities that photographs last longer than their makers thought they would (and sometimes should) are quite high [8, p. 69ff]. But memory creation through or with photographic images also happens very deliberately. In almost all image-featuring social media, today, shared photographs do not vanish after they have been posted,[2] instead they are included into a personal dynamic feed which differs from the public feed. This personal feed forms the profile of the user and is central to identity creation in social media [12]. People often choose very carefully what kind of information be it in textual or visual form shall be visible on their profile page [13, p. 1826].

Leaving out all technical determinations and focussing especially on uses of photographic images we define photography as follows:

> *Photography is a means to represent some aspects of reality, which is especially likely to trigger interpretation in terms of temporal and personal context and relation. It can be used for various purposes such as documentation, communication, experience, identity creation, memory or art.*

In any case photographies incorporate information in one way or the other and thus can be seen as data.

[2]Snapchat in this regard seems to be the exception proving the rule. When the app started in 2011 all chats including snapshots an videos were deleted 10 s after the recipient opened them. In 2016 a feature called "memories" was released which allows users to save pictures, texts and videos from the snapchat application to their mobile phone [11].

3.2 Image Data

While it may seem obvious to regard user generated images, which are surely mostly originally digital, as data, it might seem a bit unusual to refer to historic photographs from archives and museums as data. Data is often described as symbols [14, p. 1; 15, p. 170] or source containing information [16, p. 104]. It is described as raw, insignificant and meaningless [14, p. 1]. But data can be processed and thus turned into information [15 p. 170], which than can be transformed into knowledge, understanding and wisdom [14, p. 2]. Against this seemingly quite common description of data as basis of a hierarchy of increasing value, we follow Tuomis reversed model. Tuomi states that there is no such thing as raw data, because it always is collected, structured or articulated in some way. Thus there has to be a knowing mind or in other words knowledge coming before data [16, p. 107]. This fact is even stressed further by elaborating on how this collected data was similar to information and how most often not one person accumulates data but that there usually must be an interpersonal knowledge standing before data [16, p. 111]. Coming back to photography we would like to modify Tuomi's model a bit once again using insights of Susan Sontag. For us the structure is not hierarchical but rather systemic. Information and knowledge lead to data, which leads to more information and knowledge. It is rather unlikely that this process follows a linear structure, because data can be analysed and interpreted not only by one but by several persons and not only in one but in several ways. In Sontags words the systemic structure is created as follows:

"Through being photographed, something becomes part of a system of information, fitted into schemes of classification and storage which range from the crudely chronological order of snapshot sequences pasted in family albums to the dogged accumulations and meticulous filing needed for photography's uses in weather forecasting, astronomy, microbiology, geology, police work, medical training and diagnosis, military reconnaissance and art history." [9, p. 121].

Whereas Sontag mostly refers to non-humanistic research traditions, here, her mention of art history in the last place implicates that photographic information can also be relevant for humanistic inquiry. Although the designation of research objects as data still seems to be a bit unusual in the Humanities [17], once the term is acknowledged Tuomis reversed hierarchy is very familiar to researchers dealing with cultural objects, be they textual, visual, audio-visual or other [17]. We follow Schöch in his rather metaphoric description of data as "window into the object of study" [17, paragraph 4], which seems to fit perfectly on photography. But we would like to widen his definition of data in order to include non-digital datasets and a non scientific purpose:

In the efoto project data is seen as selectively constructed abstraction and/or representation of some aspects of a given object of socio-cultural significance.

We see archived photographs as data rather than objects or even cultural artefacts, because, from our perspective, the latter need a subject dealing with them and/or including them into cultural actions. Of course there are images in the databases which are already used and thus achieved the status of being an object or artefact of cultural value but a higher number of pictures at the moment is not included in everyday cultural actions. The need of socio-cultural anchorage comes with an understanding of cultural heritage as ongoing social process.

3.3 Cultural Heritage

The UNESCO defines cultural heritage as “legacy of physical artefacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations.” [18]. This definition has already been widened by the UNESCO itself in order to include digital materials which are shared through time and space via the internet and thus valued in a way that could make them important not only for today but also for future generations [19]. Especially regarding the amount of possible materials which could be meant by the definition of digital heritage, the question arises how to make out those which really are culturally significant. As Willer points out, legacy is not a simple handing on of objects which are undoubtedly of cultural value. Usually heritage is a complex act between someone who wants to pass on something to someone else (usually of a younger generation) and this someone who may accept or decline the heritage object [20, p. 141]. What can already be a hassle when only few people are involved, of course, becomes even more complex when it comes to groups or whole societies. At this point Willer brings the concept of sustainability into the discussion of cultural heritage, because the dynamics between former and future generations are reflected in a similar way in sustainability studies. In a very early definition of sustainability it was stated that, “Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.” [21, p. 16]. Although the focus lies on ecologic aspects, here, the fact that one has to mediate between the needs of generations is equally important in cultural heritage. Although there has been some debate on cultural sustainability already, we would like to stress this a little further. Up to now culture has been made out as one mainstring of sustainability, because things (and values) which are anchored in a culture will be considered in decision-making [22] (we call this cultural sustainability). In addition to that sustainability plays an important role in cultural heritage preservation [23] (we call this sustainability of culture). Here we want to combine the idea of cultural sustainability with sustainability of culture by stating that only those objects (and by objects we mean tangible as well as intangible and digital objects), which play an active role in the culture of a group or society are of cultural value and thus become cultural artefacts. Of course anchorage in culture is not an everlasting state, which is why we emphasize that cultural heritage can not be viewed as a well defined set of objects or artefacts but should be regarded as constant process in which several (former, recent and future) generations take part. In the end we came up with the following definition of cultural heritage:

> *Cultural Heritage is a process in which cultural artefacts are preserved and handed on to future generations in a way that makes them able to use these cultural artefacts as part of their everyday and/or cultural life.*

In the following we would like to turn to the efoto infrastructure in order to show how we process photographic data so that it can be anchored in the culture of the city of Hamburg, and thus turned into cultural artefacts, which may be considered relevant for cultural heritage.

4 The Efoto Infrastructure

Efoto brings together historic images and technical implementations. Although in reality there is an interplay between contents and digital mediation, in the following we want to focus efoto from the content-perspective first and come to the technical side later on. Doing so we illustrate the line of development of the project, which started off with images and the aim to bring them to the citizens in the first place. Nevertheless we reference between content and technical implementation where needed.

4.1 Images in Efoto

The images in efoto can be classified into three groups. The largest number was made for documentary purposes, some were made and published as postcards and a few fall under portrait and family photography in a broad sense. One example for the first category is the collection of the brothers Dransfeld containing about 1300 architecture photographs. The two photographers were hired to do a documentary of several projects of the "Oberbaudirektion" (former ministry for urban development) of Hamburg led by architect Fritz Schumacher around 1926. This collection can be seen as the kind of quote from reality, which Berger mentions. The images mostly show buildings, which are still there, today, but which went through more or less changes. Looking at these photographs one can clearly see that the moment in which they were taken was chosen very consciously. Houses stand in very bright light and people are rarely shown. Especially when interiors are presented everything seems to be light and clean implying a starting point or innovation. As many of the buildings photographed are still part of the cityscape today, they do immediately trigger interpretation in terms of giving them a past and a future and relating them to the moment being just as Berger describes it. Many people in Hamburg still live in such "Schumacher-Bauten" ("Schumacher-buildings") or have been to school in one of the very constructions shown on the images. Relations to the own identity and to the identity of the city are automatically created. Besides the opportunity to view single pictures the collection provides the possibility to look at whole series. Hereby context

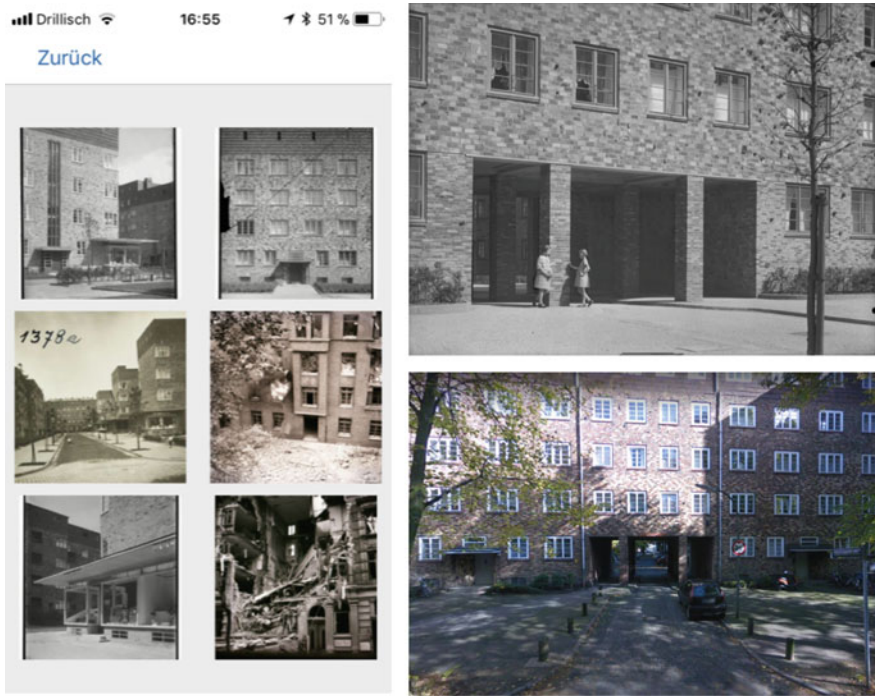

Fig. 1 The picture on the left shows a screenshot of the efoto application presenting a cluster of pictures in the area of the Helmholtzstraße. The two pictures in the first row and the first pictures of the second and third row are from the series of Dransfeld photographies provided by the Staats- and Universitätsbibliothek Hamburg. The second pictures in the second and third row are from a different time span (around 1943), made by different photographers and provided by history workshops. Pictures on the right side show one of the original digitizations from the Dransfeld collection and a screenshot from the same spot taken from Google maps (showing the status quo from 2008)

shows automatically. Additionally through the network of partner institutions series, as for example the one of the block of buildings in the Helmholtzstraße/Bunsenstraße shown in the figure below, are supplemented by other pictures of the same area (Fig. 1).

The postcard collection in efoto is more various in terms of photographers and providing partner institutions. Most of the postcards came to efoto via the history workshops, which especially follow the aim to archive and represent everyday history. The postcards in efoto range from being published in the 1890s to the 1960s. By now only the front images are published in the efoto application but for most of the postcards the backside is also stored in the backend, so as soon as there is a technical implementation for showing batches, front and back can be presented together. Nevertheless the picture-side of the postcards often is a combination of image and text. Many postcards have a title, which indicates the location a picture was taken at.

Fig. 2 Especially charming example of a postcard in efoto from 1914. It shows a wine store with three people in front. Textual information added by the publishing house gives the name of the shop and its owner and the exact adress it was located at. Underneath there are two lines of hardly readable handwriting in the old German lettering system. On the right side google maps screenshot showing the same adress around 2008

Some have handwriting on them. The handwriting in this case is an additional trigger for interpretation and relation to the onlooker. Not only is there a personal dimension in what is written, there also is the quality of the handwriting as picture. As there are mostly older postcards in efoto this means that people have used an old German writing system. Letters used are not always readable for younger generations but they can be linked with family memories especially of grandparents, who used this writing or hybrid systems of older and newer letters. Altogether with the postcards we have a different kind of data than with the documentary photography named above. Postcards not only are a combination of image and text, they also have been through a different formation process in the system of data creation. Firstly there has been a photographer creating an image and therefore interpreting reality. This image was sold to a publishing house, which could also influence the photograph by choosing a certain section and leaving out others and by adding text. In both steps there were one or more knowing minds involved in the creation of the image as data. Finally somebody bought the postcard, wrote something on it and send it to someone else. Although the enrichment of the picture with personal information made in this step initially probably was not meant for publication, from todays perspective it is a very rich kind of infornation, because one can relate to it on several levels. In addition to that, one postcard motive could have been chosen by many people, who all added different information to it. So the systemic aspect of data creation becomes especially relevant, here (Fig. 2).

The third category of photographs in efoto is portrait and family photography. The collection of images falling into this category is rather small and contains mostly portrait photography from professional studios. By chance one family album of an employee of one history workshop was also digitized and made available online so it could also be importet by efoto. Both portrait and family photography share the one big advantage over documentary images that they mostly show people. So for onlook-

Fig. 3 Three examples of portrait and family photography. The first and the second are inside and outside studio photographs. They are very well arranged and moments and sections are chosen very consciously. The third picture is of different quality. It seems to be more of a snapshot taken in a very private atmosphere and moment

ers many personal reference points are included. Besides time and space which are also important in documentary photography and for postcards, parameters as age and status of the depicted person show and especially in the case of family photography more individual traits as fashion/style or daily routines may be interpreted from a picture (Fig. 3).

In the end the variety of purposes, quality and reference points is the pecularity and the special value of content in efoto. Illustration of special interests can be found as well as general representations of the cityscape of Hamburg. By this multiplicity a whole range of cultural facets is shown which makes it likely that the images will be used as cultural objects once people get access to them. In developing an application providing this access we tried to meet the multiplicity of content with a range of different features. Some of those shall be described more detailed, here.

4.2 The Efoto Application

At the center of the efoto application stands a powerful backend which is designed as graph database. Data and metadata are stored in a relational system including e.g. image data, keywords, collections, geo positions and audio files. This backend can be connected to several frontend applications of which the efoto mobile application is one, the content management system is another. The possibility to add even more frontend applications to the backend and therefore to the primary and metadata opens up the opportunity for present and future generations to use it in different ways. The relational character of the graph database ensures that the original structure is kept, while new features are only increasing complexity.

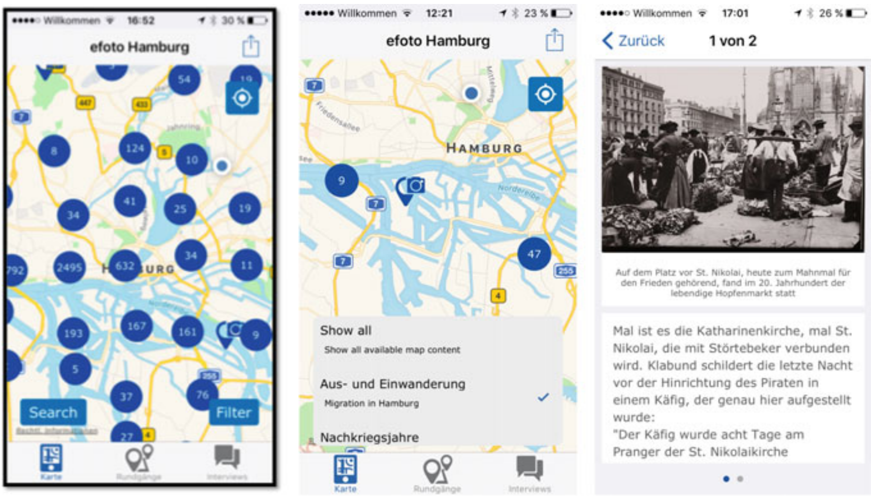

Fig. 4 Start screen of the efoto mobile application, pre-defined searches and chapter of a city walk

The creation of direct relations between data and metadata which happens during the import is the first step for linking images to possibly relevant textual and therefore easily machine readable information.[3] In a second step an algorithm is used to find information about the geolocation of a given photograph. Possible geo coordinates are added automatically. Once the geo positions have been manually verified and the image and its basic information has been published, it shows on an interactive map which is the start screen of the efoto application (see Fig. 4). As the illustration shows image data clusters into units of spatial proximity. By zooming in and out users can manipulate the accuracy of matching spatial information. Users can also automatically zoom into the very geo position they are located at momentarily. This means that not only images are related to each other via geo position but also images and users are linked. Thus space is the first access point to image data.

Apart from the discovery of single images or image clusters via their spatial anchorage, users can also explore images through predefined search queries (see Fig. 4, second screenshot). These searches are presented as thematic filters containing a number of pictures linked with a certain tag. Searches are designed dynamically so as soon as an efoto partner uploads an image and tags it according to a search this image will show in the collection. This dynamic guarantees that filters remain open enough to ensure that users may be surprised or even irritated by a selection and start to reflect on the images. Especially the reflection on this second level—for example

[3]When we started with efoto in 2015 one of our visions was to directly use pictorial information for relating data among itself. However, pattern recognition algorithms back then still have been far more slowly and not as powerful as they develop to be today. So we decided to concentrate on textual and geo information first and come back to pattern recognition later.

about why certain aspects are found in a selection of pictures—is central to culture[4] and thus ensures that images stay alive.

Our conception of space is threefold. As the main focus of efoto lies on the city of Hamburg, urban space is especially central to us. Secondly we deal with virtual space as representation of space in the efoto-infrastructure. Thirdly we take into account narrative space. We assume that space is a very important factor in identity creation. Further we see identity creation as a narrative process which consists of structuring and presenting certain life events in order to form a consistent and meaningful self. The technical implementation incorporates all three spatial facettes—urban, virtual and narrative space. Far before being imported into the efoto backend pictures are interpreted by our partner institutions in order to connect them to urban space. Not machine readable aspects as for example street signs and facades in combination with temporal information (besides concrete dates also for example style of clothing or vehicles) are turned into a standardised textual metadata-format. We stress the interpretative aspect here, because we see the act of "reading" a picture and thus integrating it into the history of the city in a meaningful way, as part of a cultural process. In addition to that we meet our model of a systemic relation between information, data and knowledge, here. Images, which once were made for a certain purpose incorporating the information of the time and place they show are interpreted using the information and knowledge of a later time period. Knowledge and information reframe the images thus creating a new kind of data which will be handed on for more reinterpretation and more reframing. Image and metadata are presented in form of virtual representations. Finally users can start interpreting and using the images in efoto for their own purposes. Images e.g. may be enriched with small narratives about personal or group identities and thus be integrated not only in the systemic process of data-, information-, and knowledge-creation but also in cultural acts. As soon as a user relates to an image in addition to its status as data it achieves being a cultural object or artefact, because of the subject—object relation created.

A simple on the spot comparison between an older representation of a certain place and the actual configuration of it can trigger quite a lot of non spatial information. For example the historic image below compared to the actual surrounding of a user represented by the second image shows a sense of atmosphere, fashion, architecture and urban environment (Fig. 5).

Of course, these are only supra individual aspects. In addition to that a place might already contain non-spatial values for an individual user which then can be connected to the historic image data. For example the spot shown in the picture above might be the place where a user got a proposal. Such individual information might be shared with other users via comments or audio notes in the efoto application. But also if they are not shared, the relation between user, place and historic image will be created and the image itself will be integrated into an (individual) process of remembrance and identity creation. In any case the image becomes a cultural artefact as it is integrated into an individual or supra individual process of remembrance and identity creation as these are cultural acts [25]. As already stated above it is not

[4] In this understanding of culture we follow Niklas Luhmann [24].

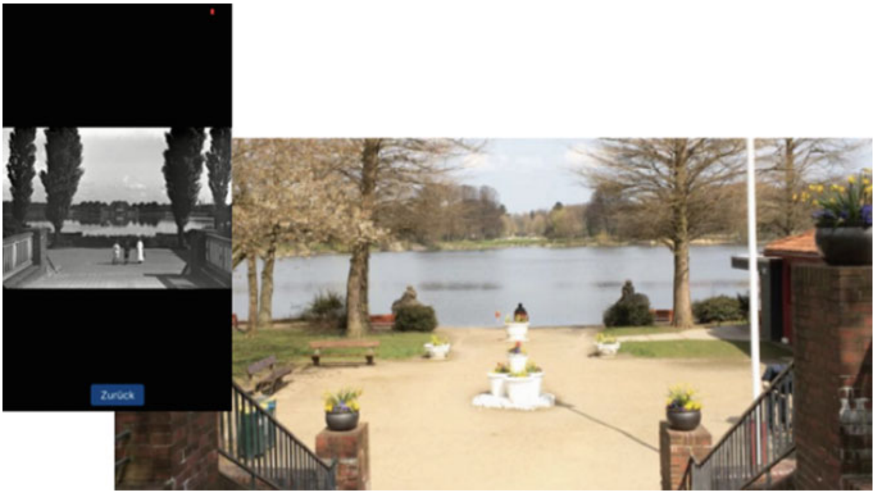

Fig. 5 Comparison of a historic image (taken around 1920) in the efoto application and the same place photographed in 2017

important for turning image data into cultural objects that they are connected to more than one individual. But, as we elaborated before, the act of heritage includes handing an object on to somebody else, who is most likely but must not be from a different (younger) generation.

Although the process more and more turns into a digitally mediated one (we plan to integrate citizen science and social annotation features), images in efoto are mostly curated very traditionally. Regardless of whether they are archived or displayed by our partner institutions the process resembles the act of creating family albums. Pictures are selected, ordered and enriched manually, access and distribution are complicated (see above). With efoto archives and museums of Hamburg search to approach the way younger generations use images in their everyday life and culture to communicate and to bond with others in a very direct and instantaneous way. In order to achieve the goal of approximating younger users we developed a, at this moment still prosperous, feature called historical selfie. When a user takes a picture of herself in front of a cityscape of Hamburg, the background will be exchanged automatically with a matching historic image. This collage can be shared to efoto or in social networks. Through this feature one can not only integrate some aspects of the cultural identity of the city into ones own identity, but also experience some aspects of city history through the making, sharing and looking at pictures (Fig. 6).

Another prosperous feature is the sharing of historic images on social media platforms as Facebook or Twitter and the integration of contemporary images of Hamburg via Instagram. Beside these on the go sharing features a profile page shall be implemented which links a selection of images to an individual user thus presenting a facet of a meaningful identity as citizen of Hamburg.

Fig. 6 Illustration of the historic selfie which can be published in efoto or shared in social media

5 Conclusion

In this article we demonstrated how images are turned into data using information and knowledge, how they are turned into cultural objects and how these objects may be handed on to future generations in order to form a sustainable cultural heritage. We would now like to conclude according to our research question that image data can be integrated into a social cultural process in three steps. First image data must be linked to information and to other image data. In efoto we do so via geo references, metadata and a dynamic filtering system. The more links there are the more likely is it that an individual user may connect to an image in order to use it for her own cultural purposes (such as identity creation or remembrance). Georeferences are the most basic link we provide in the application. As increasing unusualness rises the probability that people start to reflect on an intra individual level about cultural significance of one or more images or certain aspects of them, dynamic searches were implemented to show thematized image collections provided by different partner institutions. Once this second level reflection [24] is started a cultural process is taking place. Finally in a third step we try to approach younger users in their way of using images culturally in order to hand on the image heritage of our city to future generations. Instantaneousness, the ability to share and the possibility to communicate and bond via pictures are central parameters for sustainable integration into cultural processes, which is—in our understanding—cultural heritage.

As efoto Hamburg is an ongoing project, the question wether the theoretic foundation outlined above, is indeed key element to digitally mediated cultural heritage efforts cannot be fully answered by now. The future will show which images are really turned into cultural objects and handed on to future generations and how large this amount of image data might be. Nevertheless we hope that we have been able to add an at least partly practical perspective to the ongoing discussions about digitization and digital mediation of cultural heritage. At least we could prove the possibility to implement abstract ideas and models into concrete technical features, thus providing a complex digital infrastructure with one backend and multiple frontends, as prove of concepts for cultural heritage theory.

References

1. Ministry of Culture of the free an hanseatic city of Hamburg: eCulture Agenda 2020. http://www.hamburg.de/contentblob/4359742/51291cc39d56f6ed227d05bdbf6e5a4e/data/eculture-agenda-2020.pdf, view date 4.4.2018
2. European Commission: Inspire Guideline. https://inspire.ec.europa.eu/Technical-guidelines3, view date 4.4.2018
3. Mota, S. P.: Memory, Selfhood and Sociality in the age of networked photography. In: Tomanic Trivundza, I., Carpentier, N., Nieminen, H., Pruulmann-Vengerfeldt, P. (Eds.): Past, Future and Change: Contemporary Analysis of Evolving Media Scapes. Ljubljana Press, Ljubljana (2013) 175–186
4. Winston, J.:Photography in the age of Facebook. Intersect: The Stanford Journal of Science, Technology and Society 6, no. 2 (2013) 1–11
5. Sankey, M.: Walter Benjamin on Instagram in the age of digital reproduction. (2000). https://www.researchgate.net/profile/Michael_Sankey/publication/306111201_Walter_Benjamin_on_Instagram_in_the_age_of_digital_reproduction/links/57b2895208ae0101f17a5ef7/Walter-Benjamin-on-Instagram-in-the-age-of-digital-reproduction.pdf, view date 4.4.2018
6. Batchen, G.: Metamorphoses. Photography in the Electronic Age (1994) 47–50
7. "The slow traveller": Why I hacked my own Instagram account. https://www.theslowtraveler.net/i-hacked-my-own-instagram-account/, view date 6.4.2018
8. Dijck, van J.: Digital photography: communication, identity, memory. Visual Communication 7, no. 1 (2008) 57–67
9. Sontag, Susan: On Photography. Rosetta, New York (2005)
10. Berger, J.: Appearances. In: Berger, J., Mohr, J.: Another Way of Telling. Pantheon Books, New York (1982) 83–129
11. Verstraete, G.: It's about Time. Disappearing Images and Stories in Snapchat. Online Magazine of the Visual Narrative 17, no. 4 (2016)
12. Gündüz, U: The Effect of Social Media on Identity Construction. Mediterranean Journal of Social Sciences 8, no. 5 (2017) 85–92
13. Zhao, S., Grasmuck, S., Martin, J.: Identity construction on Facebook. Digital empowerment in anchored relationships. Computers in Human Behaviour no. 24 (2008) 1816–1836
14. Bellinger, G., Castro, D., Mills, A.: Data, Information, Knowledge and Wisdom (2004) http://www.systems-thinking.org/dikw/dikw.htm, view date 4.4.2018
15. Ackoff, R.: From Data to Wisdom. In: Ackoff's Best. John Wiley & Sons, New York (1999) 170–172
16. Tuomi, I.: Data Is More Than Knowledge. Implication of the Reversed Knowledge Management and Organizational Memory. Journal of Management and Information Systems 16, no. 3 (2015) 103–117
17. Schöch, C.: Big? Smart? Clean? Messy? Data in the Humanities. Journal of Digital Humanities 2, no. 3 (2013) http://journalofdigitalhumanities.org/2-3/big-smart-clean-messy-data-in-the-humanities/, view date 4.4.2018
18. UNESCO: Tangible Cultural Heritage, http://www.unesco.org/new/en/cairo/culture/tangible-cultural-heritage/, view date 4.4.2018

19. UNESCO: Digital Heritage, http://www.unesco.org/new/en/communication-and-information/access-to-knowledge/preservation-of-documentary-heritage/digital-heritage/concept-of-digital-heritage/, view date 4.4.2018
20. Willer, S.: Kulturelles Erbe und Nachhaltigkeit. In: Klimpel, P., Keiper, J. (eds.): Was bleibt? Nachhaltigkeit in der digitalen Welt. iRights Media, Berlin (2013) 139–152
21. Hauff, V. (Ed.): Our Common Future. (1987) http://www.un-documents.net/our-common-future.pdf, view date 4.4.2018
22. Brocchi, D.: Die kulturelle Dimension der Nachhaltigkeit. In: Magazin Cultura21, Köln (2007). http://davidebrocchi.eu/wp-content/uploads/2013/08/2007_dimension_nachhaltigkeit.pdf, view date 17.8.2016
23. Klimpel, P., Keiper, J. (Eds.): Was bleibt? Nachhaltigkeit in der digitalen Welt. iRights Media, Berlin (2013)
24. Luhmann, N.: Kultur als historischer Begriff. In: Gesellschaftsstruktur und Semantik: Studien zur Wissenssoziologie der modernen Gesellschaft Band 4. Frankfurt (1995) 31–54
25. Assmann, J.: Kollektives Gedächtnis und kulturelle Identität. In: Assmann, J., Hölscher, T.: Kultur und Gedächtnis. Suhrkamp, Berlin (1988) 9–10

3D Sketching of the Fortified Entrance of the Citadel of Aleppo from a Few Sightseeing Photos

Jean-Baptiste Barreau, Emmanuel Lanoë and Ronan Gaugne

Abstract Originally built during the Ayyubid era by the son of Saladin, al-Malik al-Zahir Ghazi (1186–1216), and rebuilt throughout the Mamluk era (1260–1516), the entrance to the citadel of Aleppo was particularly affected by an earthquake in 1822, bombings during the Battle of Aleppo in August 2012, and a collapse of ramparts due to an explosion in July 2015. Even if compared to other Syrian sites, there are still enough vestiges to grasp the initial architecture, the civil war situation makes extremely difficult any "classic" process of digitization by photogrammetry or laser scanning. On this basis, we propose a process to produce a 3D model "as relevant as possible" only from a few sightseeing photographs. This process combines fast 3D sketching by photogrammetry, 3D modeling, texture mapping and relies on a corpus based on pictures available on the net. Furthermore, it has the advantage to be applicable to destroyed monuments if sufficient pictures are available. Five photos taken in 2005 by a tourist archaeologist around the entrance were first used to generate a partial and poor quality point cloud with photogrammetry. The main elements of the inner gate and a part of the arched bridge are distinguishable on the point. Because the architecture is fairly rectilinear and symmetrical, it has been possible to redraw in 3D most of the outlines by constantly comparing with what is visible on these first photos. The next step is the enrichment of the 3D model from the initial geometric basis and thanks to a corpus of photos available on the internet. This corpus was constituted from selection of pictures obtained with a search on Google Web Search and the keywords "Citadel" and "Aleppo". The selection took into account both the resolution of the images and the coverage of the items of interest and gathered 66 pictures. The enrichment of the 3D model is performed through an iterative process made up of four main steps: (i) orthophoto extraction from some photos of the corpus

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(ii) 3D modeling from these orthophotos (iii) seamless texture extraction (iv) texture mapping. There are still some uncovered lateral areas, unreadable engraved wall writings, and some details are reconstructed naively, but the essential items, allowing to visually characterize the fortified entrance as a whole, have been reconstituted. The 3D model was first used to produce some renderings intended to obtain first reviews from archaeologists and architecture specialists, photos and complementary documents allowing correcting and filling the gaps. We wish to set a collaborative process to improve the model, based on an exchange with experts of the domain. The resulting model aims at feeding an interactive website dedicated to 3D display of heritage under threats. Other rendering of the model such as virtual reality or 3D printing could also be considered to share this testimony of our heritage. The application of this methodology to other sites deserves further studies that would depend on the possibilities of photogrammetry, the architectural complexities and human means for 3D modeling.

Keywords Crowd-sourced photogrammetry · 3D sketching · Endangered heritage · Syrian cultural heritage

1 Introduction

Aleppo is the second city in Syria. It has a really important architectural heritage and is in the UNESCO World Heritage List. Islamic ruling made it a great city by rebuilt walls, gates, towers and the citadel. Recently, this heritage have been destroyed due to the internal war in Syria [1]. Previously, Aleppo was also destroyed several times when Hulagu Khan placed it under siege in 1260 [2] and in 1822 with an earthquake [3] which demolished 30% of its building (cf. Fig. 1). The conservation, transformation, destruction, and re-invention of the heritage has been thus well-studied [4]. Originally built during the Ayyubid era by the son of Saladin, al-Malik al-Zahir Ghazi (1186–1216), and rebuilt throughout the Mamluk era (1260–1516) until Al-Achraf Qânsûh Al-Ghûrî, the entrance to the citadel of Aleppo was particularly affected by the earthquake, bombings during the Battle of Aleppo in August 2012, and a collapse of ramparts due to an explosion in July 2015 (cf. Fig. 2).

Considering the recent events, the experiments of 3D digitizations and reconstructions of the Syrian architectural heritage are numerous. Several sites were digitally documented and reconstructed thanks to a photographic coverage of some UNESCO sites before the war through different projects, with various techniques such as spherical photogrammetry [5, 6], photogrammetry and laser scan [7]. After the beginning of war, several projects explored crowd-sourced methods to document and reconstruct the damaged or destroyed heritage. The temple of Bel in ancient city of Palmyra was first digitized by photogrammetry thanks to a combination of professional pictures and some from the public domain [8], and the Project Mosul [9] with 3D reconstructions based on various sources of pictures.

Fig. 1 Painting of Hulagu Khan (by Rashid-al-Din Hamadani), drawing of Al-Achraf Qânsûh Al-Ghûrî and antique newspaper broad sheet for 1822 being a narrative of the disastrous earthquake in Aleppo (sold by "Bibelots London" shop)

Fig. 2 In front of the citadel on 13 December 2016 (© RFI) and urban structure around in January 2016 (© Directorate-General for Antiquities and Museums)

Fig. 3 Top: 3d models from a visitor site plan [30], CIPA database [5], Sketchfab [10]/Bottom: the video games Minecraft [31] (left) and Uncharted 3 (center and right) [11]

In the case of the Citadel of Aleppo, it exists different works of 3D representation. With his photo modelling, W. Wabeh allows a global visualization of the building from a point of view located on the adjoining street [5]. We can also cite a 3D model of the Citadel in sketchfab [10], and 3D elements of gameplay in video game environments, such as Minecraft and Uncharted [11] (cf. Fig. 3).

Currently and even if compared to other Syrian sites, there are still enough vestiges to grasp the initial architecture, the geopolitical situation makes extremely difficult any "classic" process of digitization by photogrammetry or laser scanning. In parallel with this, at the same time, the close-range photogrammetry has been used for at least a decade to reconstruct buildings as they were before their destruction [12]. In the reference book dedicated to it [13], it is defined that the close-range photogrammetry "encompasses methods of image measurement and interpretation in order to derive the shape and location of an object from one or more photographs of that object". With the advent of crowd sourcing, participatory photogrammetry strategies emerge [14], especially from heterogeneous sources [15, 16]. The iconographic databases concerning heritage, for research and teaching purposes, are also widely used today [17, 18].

This paper proposes a process to produce a 3D representation of the entrance to the citadel of Aleppo, as it was before damage and enough detailed for a close point of view, from a very poor photographic coverage of the monument. This production took place as part of the West Digital Conservatory of Archaeological Heritage project [19].

2 Method

Our approach focuses on the fact that we have fixed constraints concerning the corpus of photos at our disposal, in order to test the possibility of doing the best with a minimum of resources. Examples of 3D productions made from very few photos, and usable in the context of scientific reasoning, are scarcely available. Among them, we can point a relatively old work of control survey of a drilling platform (16 photos) [20] and, more recently, 2 studies of collision crush [21] and forensic 3D analysis [22] (sometimes only 2–3 photos).

Our global process, based on the work of Kitamoto et al. [23], can be described in 5 steps (cf. Fig. 4):

1. Selection of sightseeing photos taken with the same camera, zoom and lighting settings
2. Photogrammetry and mesh generation
3. Manual modeling of volumes from the photogrammetry mesh and symmetric deductions
4. Selection of a corpus of photos available on the internet showing the details of the characteristic elements of the building
5. Texture mapping and renderings.

2.1 Modeling of Volumes

Thus, five argentic photos taken in 2005 by a tourist archaeologist around the entrance were first selected and used to generate a partial and poor quality cloud with pho-

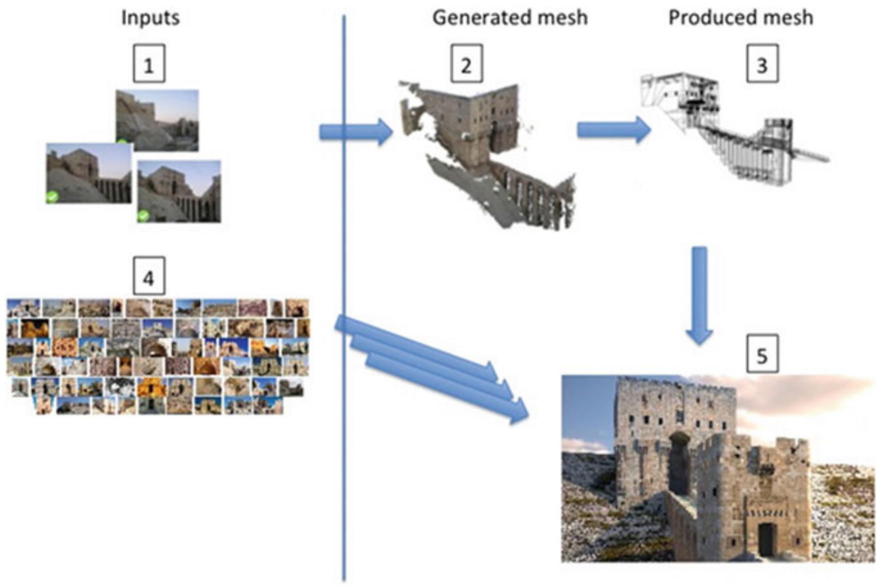

Fig. 4 Presentation of the global process

Table 1 Photogrammetry numerical results

Photo alignment		Dense cloud		Mesh building	
Accuracy	Highest	Quality	Ultra high	Surface type	Arbitrary
Pair selection	Generic			Source data	Dense cloud
Key point limit	40,000	Depth filtering	Aggressive		
Tie point limit	4000			Interpolation	Extrapolated
Camera aligned	3/5	Points number	1,131,556	Face count	226,309
Tie points	2034				

togrammetry. It was done with Agisoft Photoscan Professional Edition 1.2.2 and the numerical results are summarized in the Table 1. The main elements of the inner gate and a part of the arched bridge are distinguished on the point (cf. Fig. 5).

The mesh generated by Photoscan was then integrated into the 3ds Max 2015 modeling software. There was indeed support for drawing the outlines of the main parts of the building: inner an outer gates, machicolations, entrance with reliefs depicting dragons, arched bridge and portions of ramparts around.

Because some fine details are not very noticeable on the mesh from photogrammetry, we generated orthoimages by illuminating it, in the CloudCompare software, to improve the readability of the elements. These orthoimages and meshes were then integrated into 3ds Max to model the elements a little more finely. Because the architecture is fairly rectilinear and symmetrical, it has been possible to complete the parts not covered by the photogrammetry (cf. Fig. 6).

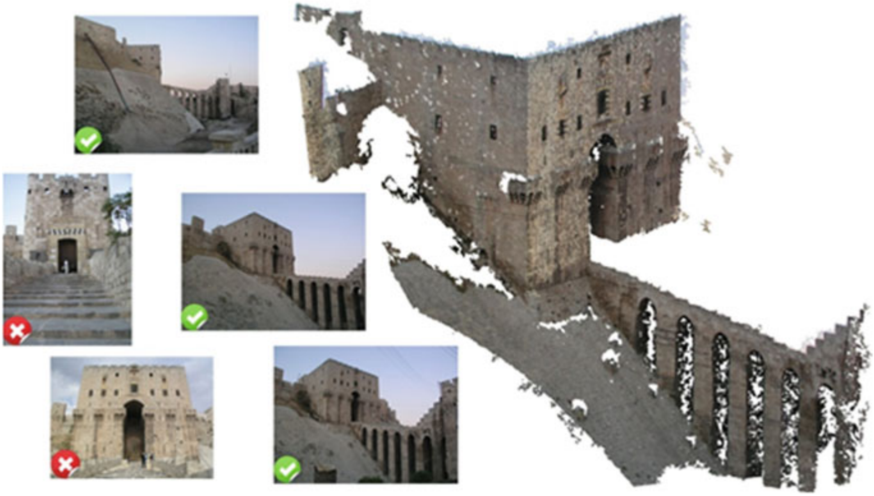

Fig. 5 Photos used to do the photogrammetry (green ticks: aligned photos/red crosses: not aligned photos) and low quality point cloud

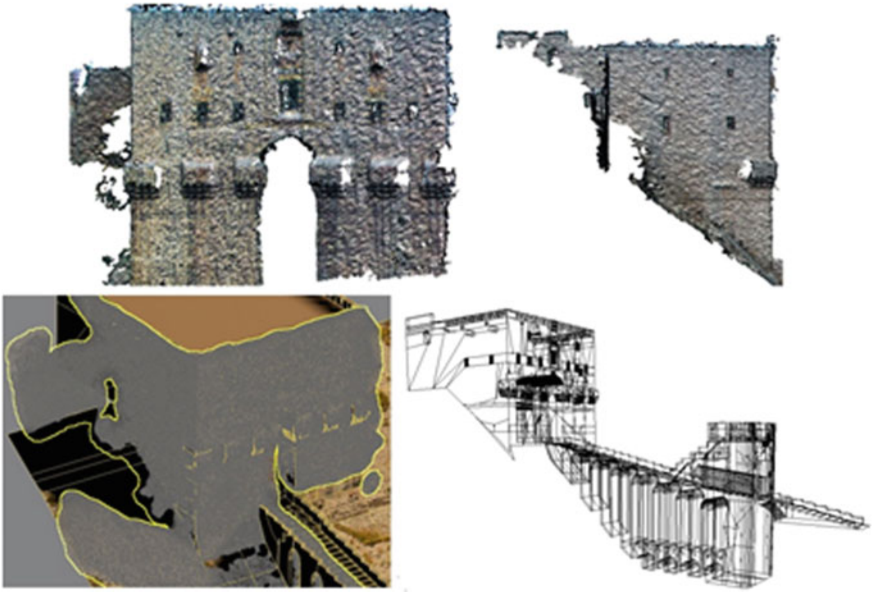

Fig. 6 Top: Illuminated front and side views which supported the 3d modeling/bottom: mesh from photogrammetry on manual modeling and wireframe model redrawn (Polys: 704 850/Verts: 828 585)

2.2 Texturing

The next step is the enrichment of the 3D model from the initial geometric basis and thanks to a corpus of photos available on the internet, sometimes taken by professional photographers [24], and a 3D web virtual tour [25]. This corpus was constituted from selection of pictures obtained with a search on Google Web Search and the keywords "Citadel" and "Aleppo". The selection took into account both the resolution of the images and the coverage of the items of interest and gathered about 60 pictures (cf. Fig. 7).

The enrichment of the 3D model is performed through an iterative process made up of four main steps (cf. Fig. 8):

1. Orthophoto extraction from some photos of the corpus thanks to a "Perspective Crop Tool" (software photoshop CS6): it corrects trapezium or perspective distortions that occur, systematically in our corpus, when an object is photographed on an oblique plane and not on a normal plane. On some orthoimages with unwanted features, such as tourists in front of the lens, the use of Photoshop's "Clone Stamp Tool" is sometimes necessary to "remove" them. Color homogeneity, thanks to the Photoshop's "Match color" tool used with a reference texture, may also be relevant.
2. Manual 3d modeling of details from these orthophotos: when reading certain photos, the morphology of certain details becomes understandable. A finer sculpture of them, textured afterwards with uniform portions of these photos, allows to increase the realism. The diamond barred window, modeled after reading a photo with a high resolution on the area, illustrates this step.
3. Seamless texture extraction: it may happen that some parts to texture, such as the bottom of the outer gate, are not present in any photo of the corpus. We need thus to create a seamless and tileable texture. This technique, well known in computer graphics, consists of the use of the "Offset filter" photoshop.

Fig. 7 Corpus of photos available from the internet intended to enrich the model

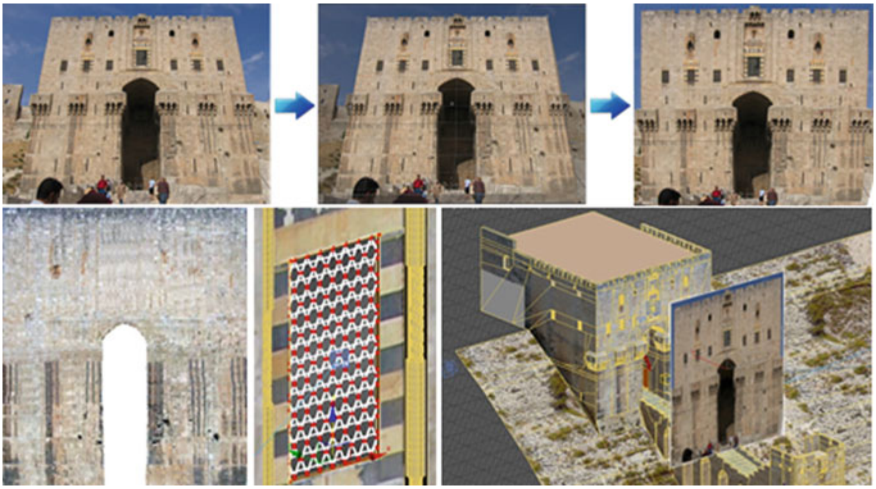

Fig. 8 Top: use of "Perspective Crop Tool"/Bottom: cleaned orthophoto with homogenized colors, diamond barred window modeled from a photo, front face of the gate mapped with the corresponding orthophoto (shown in 3d to illustrate the example)

4. Texture mapping in 3ds Max, especially with the UVW Map Modifier because the volumes are relatively simple.

3 Results

The resulting 3D textured model is presented in Fig. 9 and renderings are done with the CPU/GPU renderer V-Ray. There are still some uncovered lateral areas, unreadable engraved wall writings, and some details are reconstructed naively, but the essential items, allowing to visually characterize the fortified entrance as a whole, have been reconstituted. The 3D model was first used to produce some renderings intended to obtain first reviews from archaeologists and architecture specialists, photos and complementary documents allowing correcting and filling the gaps.

In order to test its geometric relevance, a comparison between our model and the one that is down- loadable from sketchfab [10] was first performed. However, the validity of it is not assured and this overlay shows many differences (cf. Fig. 10). It should be interesting to compare the model we produced with more reliable models such as the one in [6]. Beyond the comparison of the resulting models, it should also be interesting to mix our approach with the previous works fully based on automatic reconstruction from photogrammetry. We believe that our approach can be complementary of automated methods in order to improve the resulting meshes, under the condition of a careful control of the coherency of the images added during the texturing phase in order to avoid inconsistent representations.

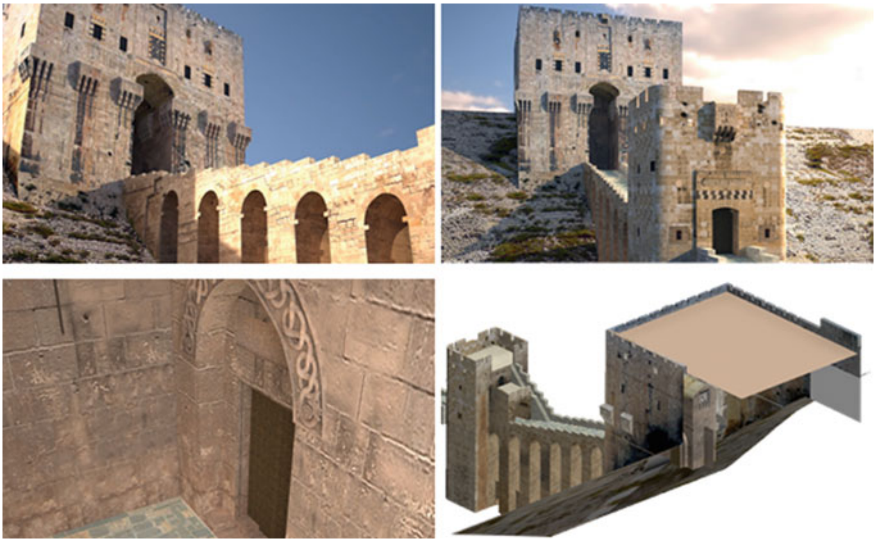

Fig. 9 Rendering of the resulting 3D textured model: the inner gate overlooking the arched bridge (top), the outer gate in the foreground (center), the entrance with reliefs depicting dragons (bottom left) and a side view illustrating the need for a better resolution photo of the right wall and the lack of details on the roof (bottom right)

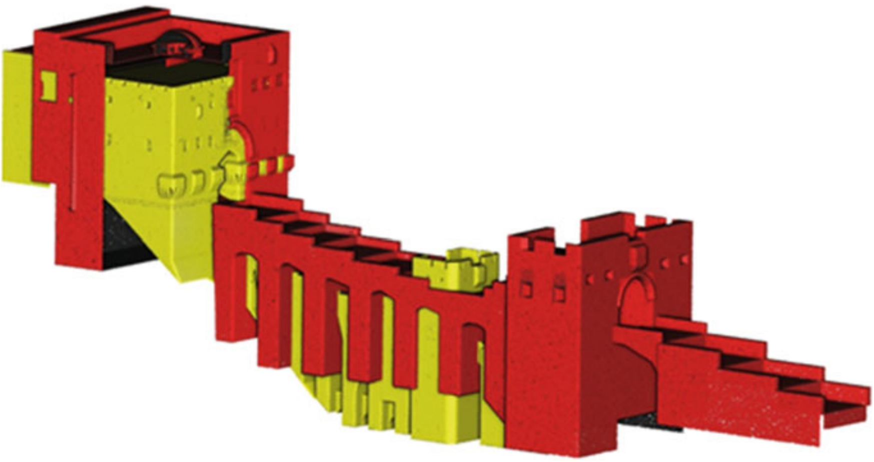

Fig. 10 A cutaway model of the one that is downloadable from sketchfab [10] (in red) over our model (in yellow) with CloudCompare software

The second approach consisted of inlays of our model on various existing photos. To do this, we used the tool "Perspective Match" of 3ds Max which uses a background image to orient a camera so that its position and field-of-view match the perspective of the image (cf. Fig. 11). This method makes it possible to reveal several differences, such as the height of the bridge, which will involve corrections. The goal here is to highlight the value of an iterative process that is self-monitoring.

This 3D representation of the Citadel of Aleppo was made possible thanks to:

1. Taking at least 3 sightseeing photos by making a quarter turn around the building (it is likely that the photographer was not aware that it offered the possibility of photogrammetry)
2. Many architectural symmetries and relatively simple volumes to deduce a large number of elements not covered by the photogrammetry
3. An absence of deadline constraints, concerning the 3D production, making possible the iterative process of a relatively completed modeling, carried out by a single person by intermittence.

It is unlikely that conditions 1 and 2 will be fulfilled for possible process applications on other archaeological sites. However, we believe that, if the evolutions of the photogrammetry techniques will make it possible to obtain similar results, even smaller or too heterogeneous corpuses of sightseeing photos, it will be quite possible to apply the process.

4 Perspectives

In the immediate future, we want to develop a collaborative process to improve the model, based on an exchange with experts of the domain.

To do this first of all, we want to study the possibilities of textured 3d printing that are currently emerging [26, 27]. The objective would be to observe, with a 3D printed citadel at a given scale, the differences between finely sculpted or textured details.

At the same time, we are considering to deploy the 3D model at scale 1 within the Immersia platform [28] or in a virtual reality headset, to propose experiments around the validation of the reconstitution by experts. We believe that this kind of model can be integrated into a collaborative work application, where users can add annotations, or even 3D sketches to complete certain parts.

As for the possibilities of mediation, these are obviously numerous, but they are not the heart of our objectives. We will however try to feed interactive websites dedicated to 3D display of heritage under threats. With regard to other Syrian sites, there is still a lot of things to develop. For example, it would be interesting to test the latest reconstruction techniques from a single image [29] on sculted elements present in a single photo. We are also currently interested in the destroyed funeral towers of Palmyra.

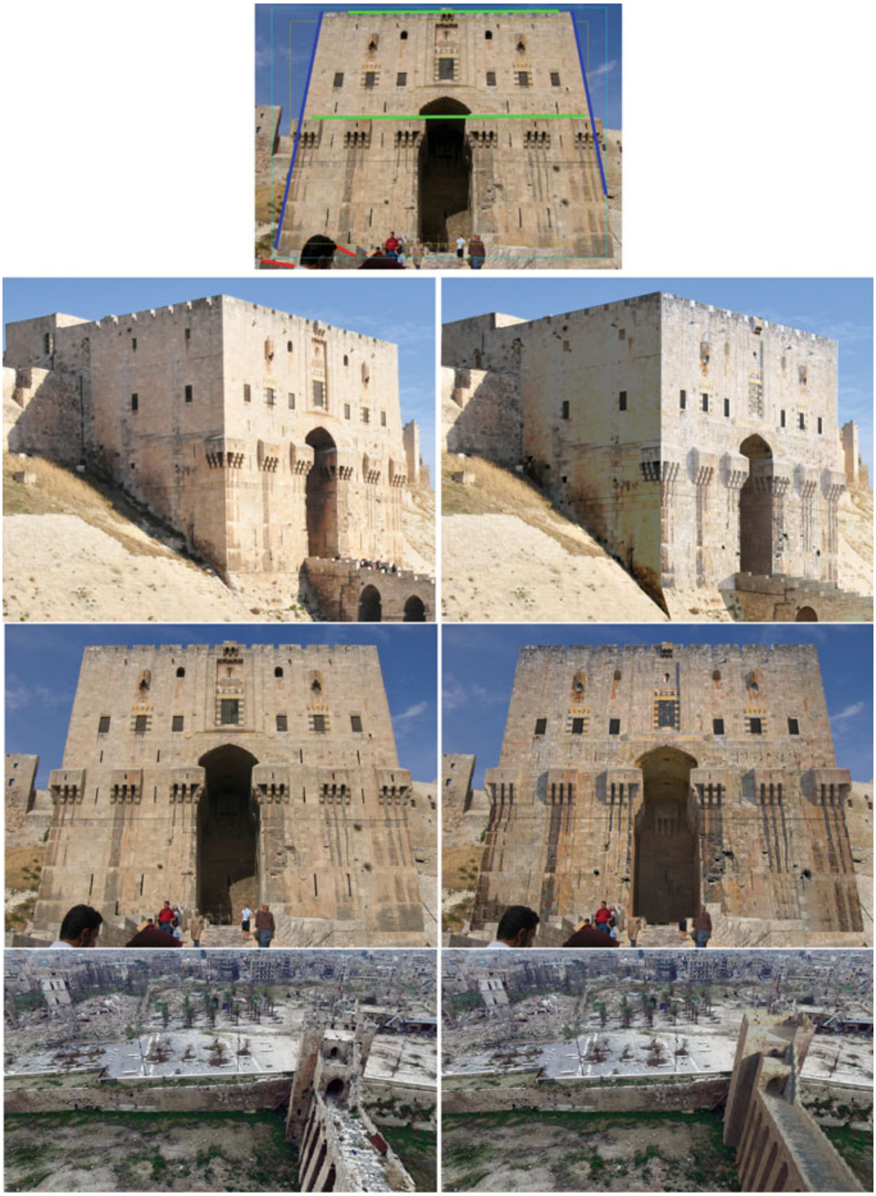

Fig. 11 Top: view of the "Perspective Match" tool in 3DS Max/Left: original images/Right: Inlaid views of our 3D model

References

1. Alafandi, R., and Rahim, A. A. Architectural heritage of Aleppo: past, present and future. In 3th International Conference on Universal Design in the Built Environment 2013 (ICUDBE2013), Kulliyyah of Architecture and Environmental Design, Putrajaya International Convention Centre (PICC) Malaysia, 11th–12th November 2013 (2013), International Islamic University Malaysia, pp. 1–17.
2. Grousset, R. The empire of the steppes: a history of Central Asia. Rutgers University Press, 1970.
3. Knost, S. Living with disaster: Aleppo and the earthquake of 1822. In Historical Disaster Experiences. Springer, 2017, pp. 295–305.
4. Lafi, N. Building and Destroying Authenticity in Aleppo: Heritage between Conservation, Transformation, Destruction, and Re-Invention. In Gebaute Geschichte. Historische Authentizität im Stadtraum, A. S. Christoph Bernhardt, Martin Sabrow, Ed. Wallstein, July 2017, pp. 206–228.
5. Fangi, G. Documentation of some cultural heritage emergencies in Syria in August 2010 by spherical photrammetry. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences 2, 5 (2015), 401.
6. Fangi, G., Piermattei, L., and Wahbeh, W. Spherical photogrammetry as rescue documentation for the reconstruction of some unesco sites in syria. International Journal of Heritage in the Digital Era 2, 3 (2013), 335–341.
7. Andrés, A. N., Pozuelo, F. B., Marimón, J. R., and de Mesa Gisbert, A. Generation of virtual models of cultural heritage. Journal of Cultural Heritage 13, 1 (2012), 103–106.
8. Wahbeh, W., Nebiker, S., and Fangi, G. Combining public domain and professional panoramic imagery for the accurate and dense 3d reconstruction of the destroyed bel temple in palmyra. ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences 3, 5 (2016).
9. Vincent, M. L., Gutierrez, M. F., Coughenour, C., Manuel, V., Bendicho, L.-M., Remondino, F., and Fritsch, D. Crowd-sourcing the 3d digital reconstructions of lost cultural heritage. In Digital Heritage, 2015 (2015), vol. 1, IEEE, pp. 171–172.
10. Issa, H. Sketchfab Aleppo castle, 2015. https://sketchfab.com/models/6f129c1d9eee4c4b98dc4c167c202e90.
11. Dog, N. The art of the Uncharted Trilogy. Dark Horse Comics, 2015.
12. Yilmaz, H. M., Yakar, M., Gulec, S. A., and Dulgerler, O. N. Importance of digital close-range photogrammetry in documentation of cultural heritage. Journal of Cultural Heritage 8, 4 (2007), 428–433.
13. Luhmann, T., Robson, S., Kyle, S., and Harley, I. Close range photogrammetry. Wiley, 2007.
14. Hashemi, N., Nourollahichatabi, S., et al. Image-based models using crowd sourcing strategies. DIGITCULT 1, 3 (2016), 65–79.
15. Hartmann, W., Havlena, M., and Schindler, K. Towards complete, geo-referenced 3d models from crowd-sourced amateur images. ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences 3, 3 (2016).
16. Somogyi, A., Barsi, A., Molnar, B., and Lovas, T. Crowd sourcing based 3d modeling. International Archives of Photogrammetry, Remote Sensing & Spatial Information Sciences 41 (2016), B5.
17. Lopez-Romero, E., and Daire, M.-Y. The icare project: Insights into the formation and consolidation of archaeology in western France (ca. 1850–1990). Bulletin of the History of Archaeology 23, 1 (2013).
18. Spring, D. Des images contre le néant, 2016. http://wp.unil.ch/allezsavoir/des-images-contre-le-neant/.
19. Barreau, J.-B., Gaugne, R., Bernard, Y., Le Cloirec, G., and Gouranton, V. The West Digital Conservatory of Archaelogical Heritage Project. In DH (France, 2013), pp. 1–8.
20. Brande-Lavridsen, O., and Juhl, J. A photogrammetric survey of a drilling platform. International Archives of Photogrammetry and Remote Sensing 27 (1984), 111–115.

21. Han, I., and Kang, H. Three-dimensional crush scanning methods for reconstruction of vehicle collision accidents. International journal of automotive technology 17, 1 (2016), 91–98.
22. Mayda, M. Forensic photogrammetry: A case study, 2017. https://info.photomodeler.com/blog/forensic-photogrammetry-case-study/.
23. Kitamoto, A., Andaroodi, E., Matini, M., and Ono, K. Post-disaster reconstruction of cultural heritage: citadel of bam, iran. In Proceeding of IPSJ SIG computers and the humanities symposium, Kyoto (2011), pp. 11–18.
24. Demeter, D. Aleppo—Aleppo citadel, 2015. http://www.syriaphotoguide.com/home/aleppo-aleppo-citadel.
25. Turlar, S. The citadel of Aleppo—3d virtual tour, 2009. http://www.3dmekanlar.com/en/the-citadel-of-aleppo.html.
26. Song, H., and Lefebvre, S. Colored fused filament fabrication. arXiv preprint arXiv:1709.09689 (2017).
27. Willis, S. The maker revolution. Computer 51, 3 (2018), 62–65.
28. Gaugne, R., Gouranton, V., Dumont, G., Chauffaut, A., and Arnaldi, B. Immersia, an open immersive infrastructure: doing archaeology in virtual reality. Archeologia e Calcolatori, supplemento 5 (2014), 1–10.
29. Jackson, A. S., Bulat, A., Argyriou, V., and Tzimiropoulos, G. Large pose 3d face reconstruction from a single image via direct volumetric cnn regression. In Computer Vision (ICCV), 2017 IEEE International Conference on (2017), IEEE, pp. 1031–1039.
30. Aleppo on the road to damascus, 2011. http://www.bigjourney.ru/little-journeys/turkey-and-syria-april-2011/aleppo-po-puti-v-damask.
31. AhmedKiing. Citadel of Aleppo (adventure), 2012. https://www.planetminecraft.com/project/citadel-of-aleppo-adventure/.

The Integrated Survey of the Pergamum by Nicola Pisano in the Cathedral of Pisa

Giovanni Pancani and Matteo Bigongiari

Abstract (M.B.) The paper deals with the methodologies and development of digital survey protocols and uses the Pulpit of the Cathedral of Pisa as the case study. The documentation project of the pergamum has forced to face the morphological complexity of this sculptured architecture: the wealth of decorations, sculptures, panels, columns and caryatids, which make the monument unique, likewise increase the complexity of reproducing a 3D model that describes its morphological and material characteristics. A first database of point clouds had already been made in the past years Pancani (Piazza dei Miracoli a Pisa: il Battistero. Metodologie di rappresentazione e documentazione digitale 3D, 2016 [1]); these measurements were made using a terrestrial laser scanner Z + F 5010C with integrated camera: these measurements were made with a Z + F 5010C terrestrial laser scanner with an integrated camera, performing 15 high-resolution scans around the pergamum. The result obtained however was not excellent: the limit of this model is the lack of shooting points at different altitudes, which led to have the pulpit described in its main dimensions; however the static nature of the instrument has created a cloud of points with numerous areas of shade, especially in the portions at the top of the monument, which do not allow to appreciate its sculptural qualities. Recently, the problem of the documentation of the Pergamum has been tackled a second time, trying to analyze the errors of the past experience in order to obtain a reliable and complete 3D model. For the purposes of the research the problem was divided into two different points of view: the morphological and metrically more reliable survey with laser scanner instruments; the realization of a three-dimensional textured model obtained with SfM technologies; since both methodologies work with point clouds it is understandable that it is possible to dialogue between the two databases; in fact the laser data can be used to check the error of the photographic one. A new laser scanner measurement campaign was carried out to follow the methodological protocols developed in recent years of scientific activities by the research group

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coordinated by the writer Pancani (La Città dei Guidi: Poppi. Il costruito del centro storico, rilievi e indagini diagostiche, 2017 [2]). In addition to controlling the quality of the data collected during the acquisition phase, particular attention was focused on the recording phase of the obtained points clouds. In the attempt to define procedures to guarantee the reliability of the general point cloud, the certification phase of the survey was carried out. The database constitutes the metric and morphological basis on which to base all the following phase of realization of the photographic model: the use of SfM technologies today allows to create 3D point cloud from the alignment of the various photographs, not creating a model in metric scale, but based on the size of the acquired pixels; this procedure allows in the acquisition phase to take frames from different points of view, easily and quickly succeeding in integrating the shaded parts otherwise present in the laser scanner survey; the development of the calculation algorithms of the programs has led today to have clouds of increasingly reliable points and comparable to laser instruments Gaiani (I portici di Bologna Architettura, Modelli 3D e ricerche tecnologiche, 2015 [3]). For the survey of the pulpit it was necessary to define reliability protocols during the phase of acquisition of the frames, so as to guarantee the correct definition of the final texture to be applied to the model, and to check the error of alignment of the photographs. Because of the complexity and size of the clouds of points obtained it was considered useful to manage the creation of the 3D model in programs for the management of mesh models, to be able to manage the large amount of morphological information, control the size and number of triangles to obtain and optimize the mesh eliminating any errors due to digital noise. Finally, the 3d model was texturized, obtaining a high definition mapping model of the whole object.

Keywords Laser scanner survey · SfM survey · Integrated digital survey · Pisa's pergamum · Giovanni pisano

1 Introduction (G.P.)

The research project on the documentation of the monuments of Piazza dei Miracoli in Pisa has involved the Department of Architecture (DiDA) of the University of Florence for years and has been and continues today to be an opportunity to experiment with the latest and current useful technologies to the morphological description of an architectural object [1]. It is precisely in this area of research that Giovanni Pisano's project for the survey of the pulpit is included; the ambo that had been commissioned to Giovanni replaced a previous one, made by Guglielmo (1157–1162), who was sent to the Cathedral of Cagliari, which at that time was dependent on the archbishop of Pisa. Giovanni Pisano's pulpit was finished by 1310 and survived the great fire of the Cathedral on 25 October 1596. During the restoration works, between 1599 and 1601, the pulpit was dismantled and its pieces were placed in different places, including the Campo Santo and the Opera della Primaziale warehouses. It was not repositioned until 1926, when it was rebuilt in a different position from the

Fig. 1 Digital reconstruction, obtained from SfM survey of the Pergamun made by Nicola Pisano

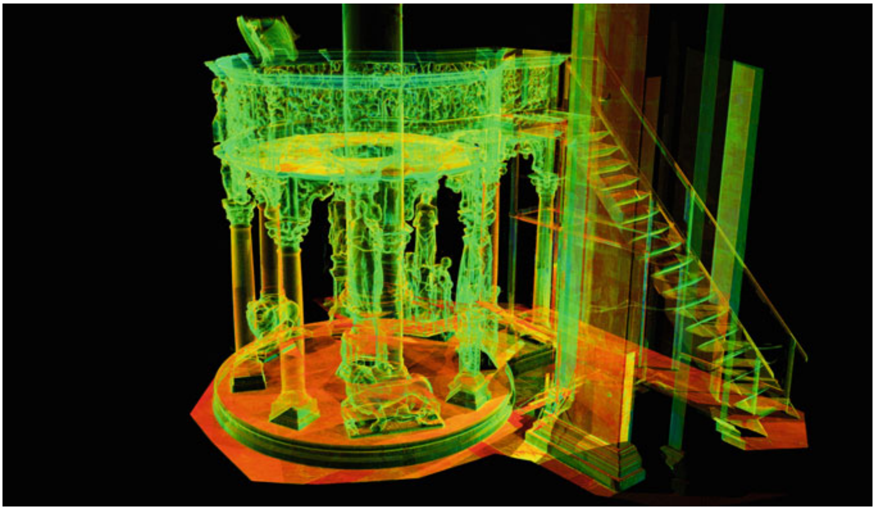

Fig. 2 3D point cloud of the Pergamun realized with laser scanner technology

original one and, certainly, with the parts not in the same order and orientation as it was intended by the author, since there was no documentation of how it was the arrangement of the various elements, including the panels, before dismantling. It is not even known whether he possessed a marble staircase or not. The four "simple" columns were donated by Mussolini because after the reconstruction some pieces (like the staircase) were missing. To honor the Duce these columns were put in plain sight, placing the caryatids in the rear part, less visible, when, it is supposed, it should have been exactly the opposite (Figs. 1 and 2).

2 Laser Scanner Survey

2.1 The Acquisition Phase (G.P.)

The laser scanner survey of the Nicola Pisano's pulpit required careful planning before fieldwork. First of all it was necessary to define the acquisition scale suitable to represent the object of the survey; due to the great presence of a sculptor, the definition scale of 1:20 was chosen.

It is appropriate at this time to introduce the concept of resolution of the survey [2]: since the remote sensing instruments make a massive measurement, not discretizing the points useful for the graphic rendering, the resolution consists in the density of the points measured by the instrument; to be more precise, it consists in the distance between the points of the acquisition mesh, which must be designed in relation to the distance between the instrument and the object of the survey, to guarantee the necessary definition.

Ensuring the adequacy to the chosen scale of values means obtaining a datum that satisfies and ensures tolerances in the measurement [4]: in the case of the 1:20 scale the permissible error must be within a range of 4–6 mm (Fig. 3).

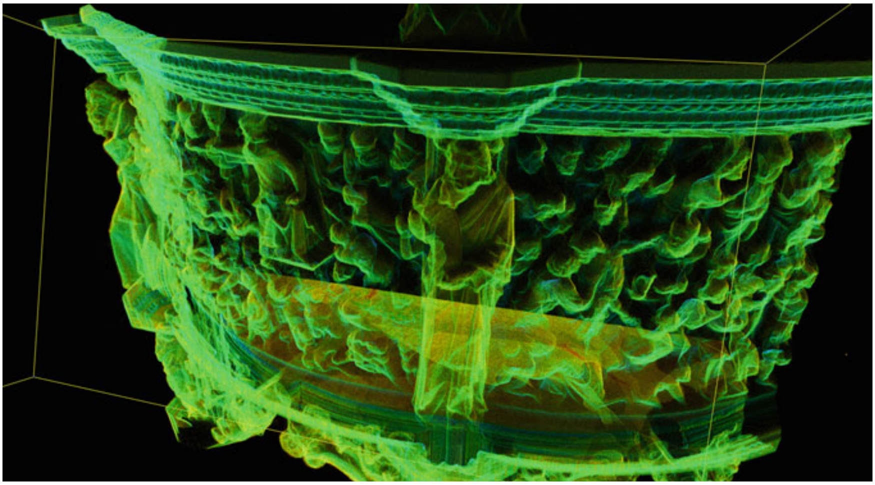

Fig. 3 Detail of the point cloud made with the laser scanner; the high resolution of the survey is shown

The laser scanner survey was therefore designed to ensure compliance with these definition parameters; for these reasons the scans were set at a higher density than what is now normally used for architectural surveys, usually drawn in a scale of 1:50 [5]. The instrument used, a Z + F Imager 5010c, has the technical characteristics to be able to provide point clouds with the density and quality required (the nominal error on the single measurement at 25 m is less than one millimeter); given the geometric conformation of the object to be detected, 25 scans were designed positioned around the pulpit at a distance never exceeding 5 m. Each scan was made at 360° with a resolution of 6 mm to 10 meters away from the point of acquisition, a distance that guarantees the proper definition of the lower part but not so much in the highest points. To avoid accuracy problems, it was decided to densify the acquisition mesh of the single scans bringing the 3 mm resolution mesh.

The individual scans acquired the morphological datum (X, Y, Z) with the intensity value of the single points, and furthermore, through the integrated camera of the scanner, the photographic images were acquired providing the RGB value at each point of the cloud [6].

2.2 *The Registration Phase (G.P.)*

The scans made around the monument create a single point cloud with polar coordinates whose origin is fixed in the laser beam receptor; to obtain a total point cloud, which describes the object of the survey, it is necessary to carry out a rigid roto-translation of the single positions on one of them; this sets its own as a reference coordinate system of the general model (Fig. 4).

This process, called registration of point clouds, is performed by recognizing homologous points between two consecutive scans (Rinaudo in Pancani 2017). The evolution of point cloud management software has led to a progressive change of cloud registration techniques: at first the registration was done with the use of targets, then with the evolution of the software and instruments, which acquire more and more quickly a large amount of information, the scans are registered by overlapping points. This method has been made quick and functional thanks to the user friendly interface of the programs that allow today to rotate in real time one scan on the other [7]. This system brings numerous advantages both in terms of reliability (when there are so many overlapping points with a very dense mesh the registration is not based on just three points/targets but on millions) and of speed (they do not have to be given anymore alphanumeric codes to the targets, a very time-consuming process [5]). Furthermore, by not using targets during acquisition, field work is considerably reduced, because it is no longer necessary to study the positioning of the remarkable points.

Through the visual alignment procedures, the 25 scans were combined into a single registration group, the optimization of the cloud constraints obtained from the pre-alignment process made it possible to obtain a much more reliable data. Since the object has a circular morphology and the scans have created a closed polygonal

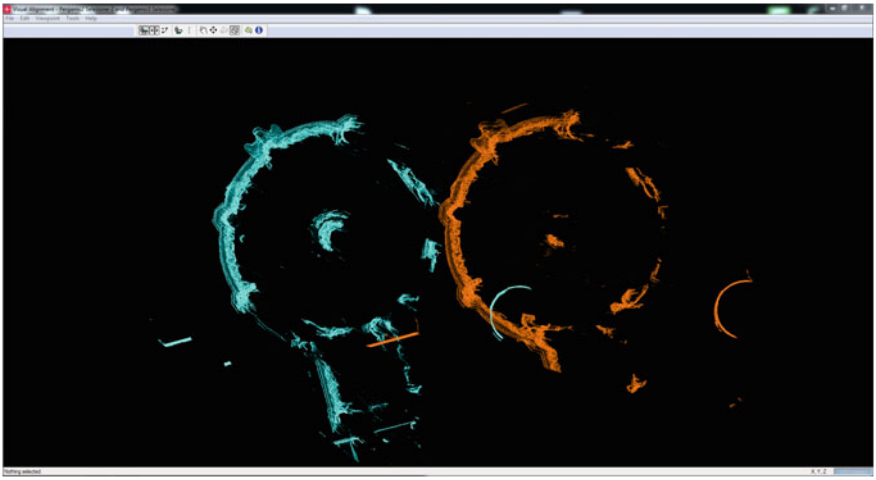

Fig. 4 Visual registration of two point clouds: the cyan one has to be moved over the orange one to complete the registration

scan position, it has been possible to obtain a recording where the single errors, that are inevitably obtained in uniting a scan to the next one, although minimal, have been compensated from the closure of the perimeter of the polygonal.

2.3 Testing (G.P.)

When it comes to the reliability of the digital survey, it is necessary to distinguish between instrumental accuracy and that of the definitive model that gathers all the scanning stations; while the instrumental accuracy is defined by statistical parameters coming from accurate laboratory tests, and is therefore to be considered reliable on every single scan, it is certainly improper to base on the same numerical data, which characterize the single scan, the general registered model (Fig. 5).

The verification of the recordings can not even be based only on the data coming from the software registration panel: they define for each cloud constraint used an alignment error (usually between 4 and 20 mm when the registration was successful), but this is not a usable datum because it is derived from the average of the movements of all in points that compose the single scan, calculating in this way also the possible digital noise spots or the thin surfaces that can mistakenly be assimilated (the case of grass and vegetation is exemplary).

There are no regulatory protocols to evaluate the quality of registrations of point clouds, which is why for several years the Survey Laboratory's research focuses on the definition of appropriate methodologies for testing and verifying the correctness and reliability of the registered model [2, 5].

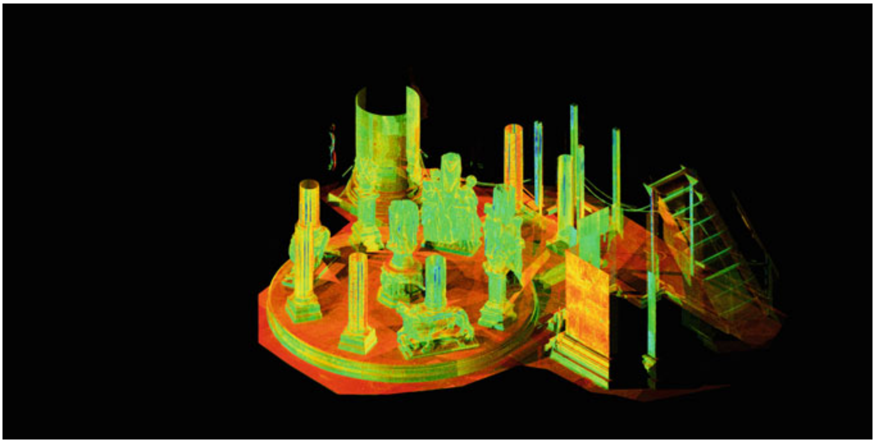

Fig. 5 The laser scanner point cloud is cut to investigate the slices of the sections

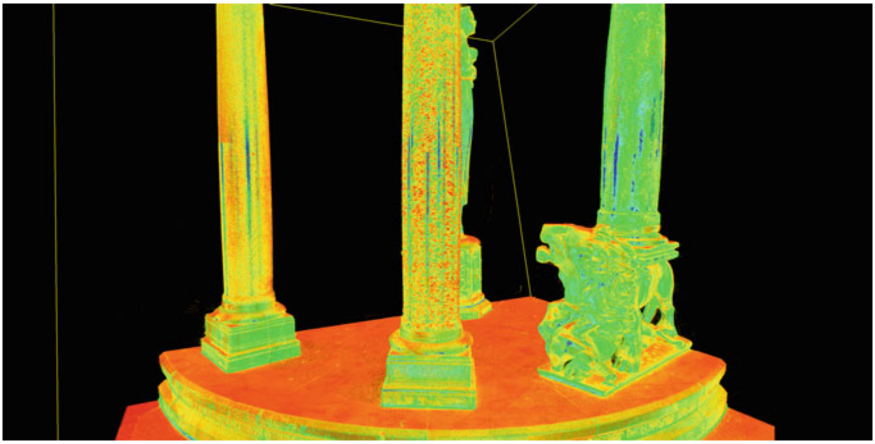

Fig. 6 The laser scanner point cloud is cut to investigate the slices of the sections

The solution adopted to quantify the error value in the registration of the scans is based on the verification of the distance between the section slice, each belonging to a different laser scanner station. The three-dimensional point model is cut from vertical and horizontal planes in different points, to investigate the remarkable points in which it is considered more probable to see a misalignment: more attention is given to the edges, the moldings and so on. The distance between the section slice of the models is now measured and when it occurs that this value is greater than the tolerance allowed by the survey definition scale, it means that the registration is not sufficiently reliable and needs to be improved (Fig. 6).

To ensure a reliable registration, it is necessary to check each individual rototranslation operation, therefore every single cloud constraint realized: only by proceeding carefully to the verification of the sections it is possible to guarantee a final model within the tolerances of the return scale.

2.4 Results and Problems of the Laser Scanner Survey (G.P.)

The laser scanner survey obtained from the 15 stations corresponded to the tolerance parameters required for the 1:20 scale of representation, nevertheless the result obtained was not completely satisfactory (Fig. 7).

First, by analyzing the RGB data coming from the instrument's integrated camera, it was noted that for the individual scans the color of the points could be considered satisfactory, but it was not equally appreciable for the registered model: switching from the intensity display mode to the RGB data, the point cloud suddenly became very confusing and its morphology was not easily understandable; this fact was caused by the strong differences in lighting in the cathedral that led the integrated camera to make frames at very different exposures depending on the surrounding conditions; in this way joining points with different exposure the data became very confused.

Secondly, the digital model appeared to be excessively noisy with evident echoes in the limit points (in edges or in curved surfaces where the laser beam strikes in a tangent direction): probably the choice of a single beam interferometers instrument (single beam) is not optimal during the acquisition phase to record the data of surfaces as complex as the sculptures.

The laser scanner scans presented some problems in the ability to describe the complex morphology of the monument. There was not a scaffold to scan from the top so the instrumental height was almost fixed; since the scans from altitudes around

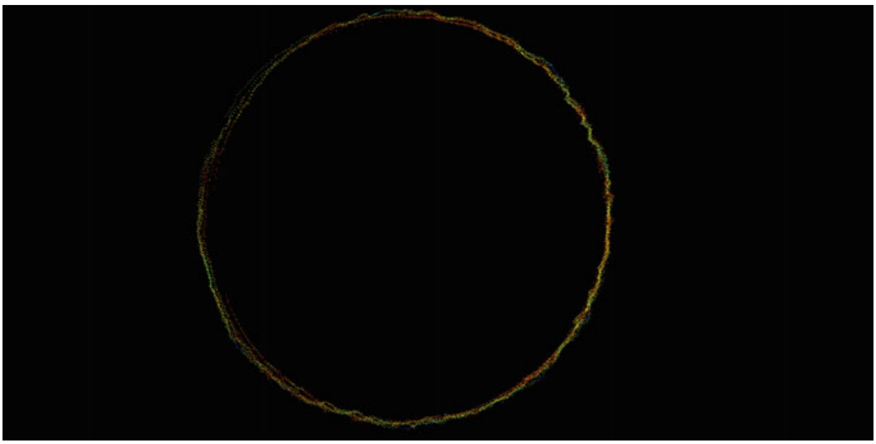

Fig. 7 Horizontal section of a column: it is clear the misalignment and the data error

50–60 cm in height were precluded by the numerous visitors to the Cathedral, the product had many areas in the shade, and was therefore insufficient to describe the complex morphology of the pulpit.

Finally, unfortunately, due to the characteristics of the marble material of the pulpit, the laser scanner survey did not really appear to be highly reliable: if you make a section with a horizontal plane, the columns of the object do not have a regular geometry, but the circumference is definitely deformed, especially at the points of orthogonal incidence of the radius with respect to the instrument (where the intensity value is higher).

Because of all these problems, it has been considered necessary to integrate the data of the laser scanner survey with other detection methods, in this case we opted for the SfM acquisition systems.

3 Structure from Motion Survey

3.1 The Acquisition Phase (M.B.)

The photographic survey of San Giovanni's pulpit has foreseen several precautions: the morphological complexity of the object has required numerous photographic shots to reconstruct the sculptures that compose it in three-dimensional space; the high detail necessary to describe on a suitable scale the sculptures also required to provide a very high definition of the frames, not considering the scale of representation 1:50 to be sufficient for the description of a complex architectural object, in the same way as previously for laser scanner survey. It is clear that these two requirements highlighted in the phase of the "acquisition project" of the survey led to the awareness of carrying out a decisively massive photographic intervention, despite the modest dimensions of the object (Figs. 8 and 9).

Before proceeding to the survey of the pulpit, its morphology has been carefully studied, in order to design the most correct method to resume the architecture in its complexity so as to obtain a three-dimensional model as complete as possible of information. The pulpit was conceived as a circular platform supported by a trilithic structure that supports the parapets finely decorated with high relief sculptures; the vertical structural elements of the perimeter, which alternate between columns and caryatids, support the marble floor together with the central caryatid; along the north side of the church the circular perimeter is modified with the addition of two columns supporting the rectangular plan to which the wooden ladder rests, which allows the celebrating presbyter to ascend to give rise to his orations. This structure, regular in its morphology, however, presents great complexity due to the sculpture that characterizes the "low" part of the object: if the parapet for the presence of sculptural palimpsests requires to be photographed from many angles in order to be able to create the lateral surfaces of the sculptures in space, it is evident how the sculptural and architectural elements in the lower register require to be photographed at 360°.

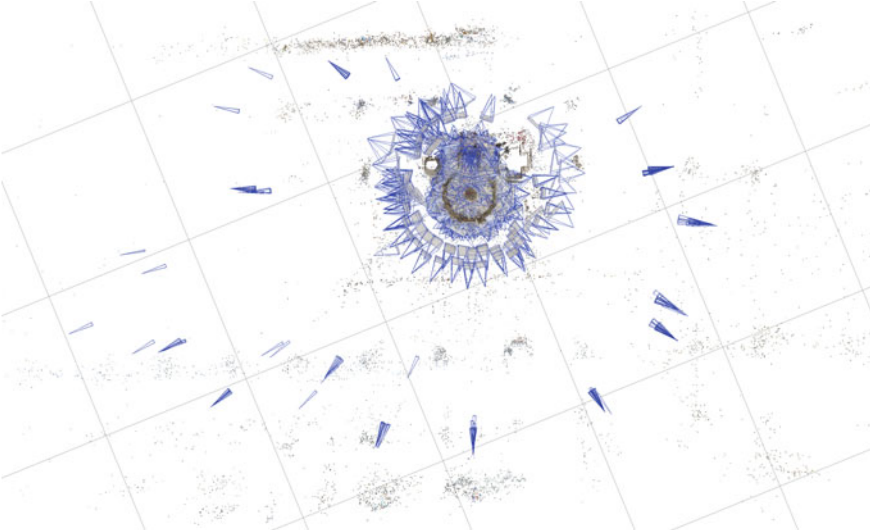

Fig. 8 3D sparse cloud obtained by the Structure from Motion reconstruction, where man can see the in planimetry the disposition of the cameras

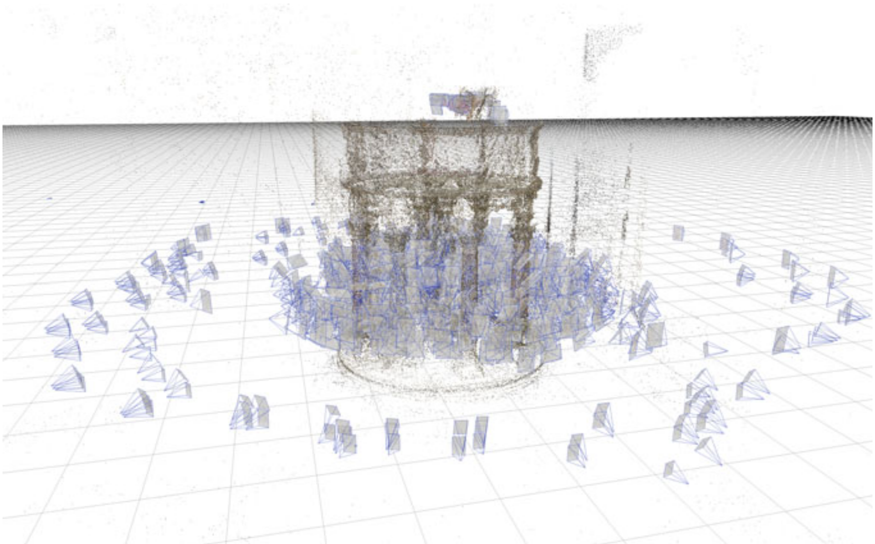

Fig. 9 3D sparse cloud obtained by the Structure from Motion reconstruction

To be able to acquire these objects from all angles theoretically it would be enough to arrange the filming positions so as to create a circumference around the pulpit in order to be able to take all the surfaces from multiple angles; unfortunately, however, in this case it is not a verifiable condition: the strong differences in lighting between the outside and inside of the first level do not allow only the external elements to be resumed with good quality; moreover, also due to the poor lighting conditions, in order to acquire the frames with a shutter speed which avoids the micro-blur effect, it is necessary to open the diaphragm of the camera; this thing does not allow to obtain a large depth of field to focus the distant points from the focusing point.

In the choice of the correct instrumentation to be used, the lighting conditions in which the Pulpit is located have been considered: the cathedral of Pisa, which is one of the most splendid examples of the Tuscan Romanesque style, has a window surface percentage that is much lower than the walled one: this characteristic not only causes a low level of indoor lighting, but also high spots where the sun's rays enter. For this reason it was necessary to provide for the use of tools that could achieve high quality frames despite the light present was noticeably unfavorable to photographic shooting. In order to guarantee a high level of definition, which is able to describe the sculptures in its details, and a frame of good quality at the exposure level, two different cameras were used, both full frame, i.e. 24 × 36 mm sensor format: a mirrorless Sony A 7R, capable of producing high quality frames even with a rather high sensitivity, so as to encourage shooting without a tripod; and a Sony A900, which by mounting a telescopic lens has been used for long distances to eliminate points hidden by the architectural elements and the morphology of the sculptures (Fig. 10).

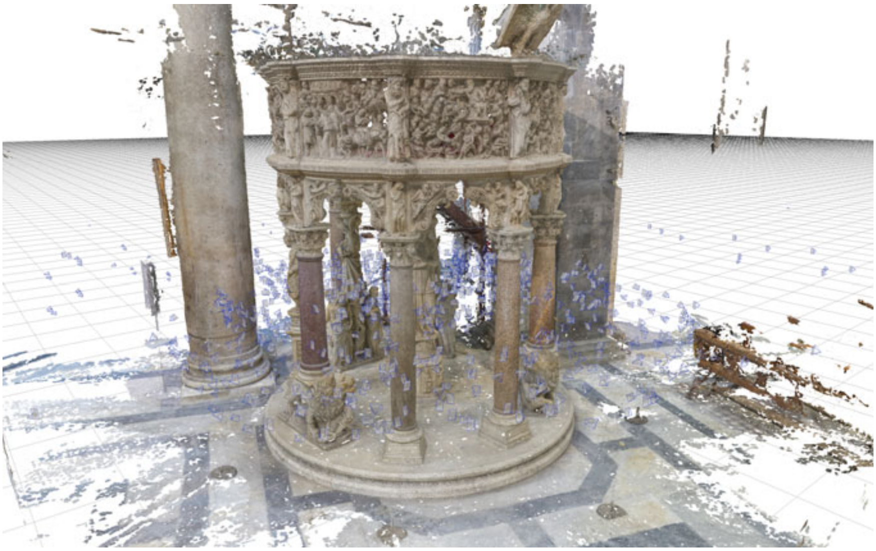

Fig. 10 3D dense cloud obtained by the Structure from Motion reconstruction

To better reconstruct the surfaces of the pulpit, it was decided to make frames following three levels of investigation: a first general moving around the object at close distance, a second rotating around the elements of the first level, a third taking the second level from a great distance.

Obviously, each of these photographic sequences, filming objects from different distances, required to use lenses with different focal lengths. For the first one a Sony Zeiss Sonnar T * FE 55 mm f1.8 ZA was used, rotating around the pulpit at a more or less fixed distance never exceeding 5 meters, with the exception of the portion hidden by the pillar of the church, at the same laser scanner survey mode. To be able to have more shooting points the frames were acquired both from man height and from a height of less than one meter from the ground. For the second sequence was used a Sony FE 28 mm f/2, ideal for moving around objects even at close distances, less than 2 meters, and with this lens were acquired all the columns, the caryatids the floor and the ceiling of the lower level. The third and last sequence was made with a telezoom Sony 70–400 mm f/4–5.6 G SSM, as already mentioned to try to eliminate the hidden points of close-ups, especially as regards the morphology of the high-reliefs of the upper level.

The choice of the focal length was primarily based on the study of the resolution to be guaranteed to the frames to fit in the scales of definition of the three-dimensional model; while in the case of the laser scanner survey, directly acquired in metric scale, it is possible to evaluate the definition on the basis of the set point mesh, as regards the photographic survey the evaluation of the definition values must be designed on the basis of the pixels that define the surfaces (Fig. 11).

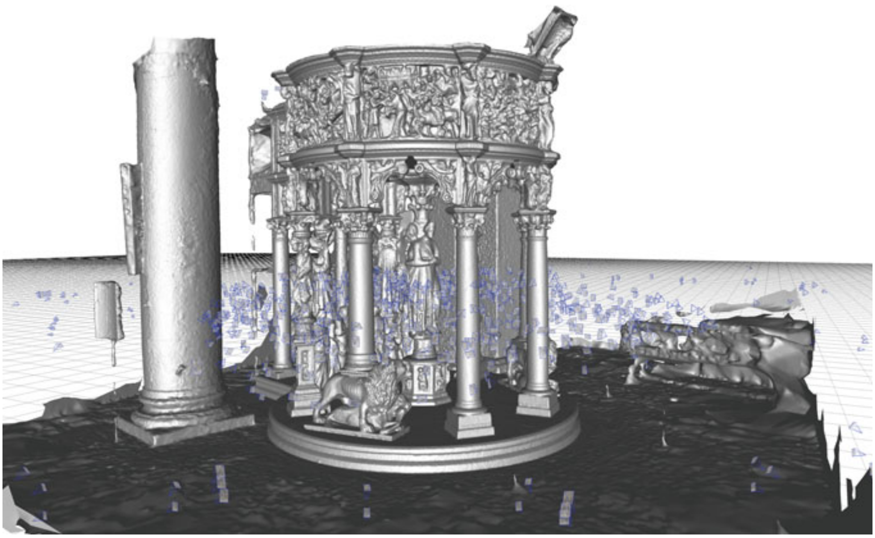

Fig. 11 3D mesh obtained by the triangulation of the dense cloud

3.2 Data Processing (M.B.)

Approximately 1200 frames were acquired at the end of the photographic shooting operations; 300 with the Sony Alpha 900 at 24MP, and 900 with the Sony A 7R at 36 MP: a very high-level dataset that is highly descriptive of the pulpit. Before proceeding with data processing in the software dedicated to the reconstruction of the three-dimensional scene, a careful quality control on the frames was made: we tried to have safety shutter speeds to avoid the micro-blur effect in the photographs [8]; especially for acquisitions from close distances when moving around the object there are repeated changes of exposure, the risk of having frames out of focus or with an incorrect exposure should be avoided. For this reason the frames in.raw format have been imported into a software with the purpose to verify the correct focus and to adjust the parameters. In this way the white balance was equalized for all the shots so as to have the most uniform color possible. Due to the different surface exposures, it was also decided to limit the presence of over-shaded and shaded areas, minimizing the Highlights and Shadow parameters. Finally we tried to make the exposure of the surfaces as homogeneous as possible by varying the parameter according to the frame (the photographs were taken in aperture priority, leaving free to vary the shutter speed). Once verified, all the files were saved in.tiff format with a compression that did not lose the original quality (.lzw) (Figs. 12 and 13).

The dataset obtained was very large, over 60 GB of data, which is why we decided to experiment with the use of different data reconstruction software in order to determine which was the most appropriate for such a mass of information; the research

Fig. 12 3D textured mesh

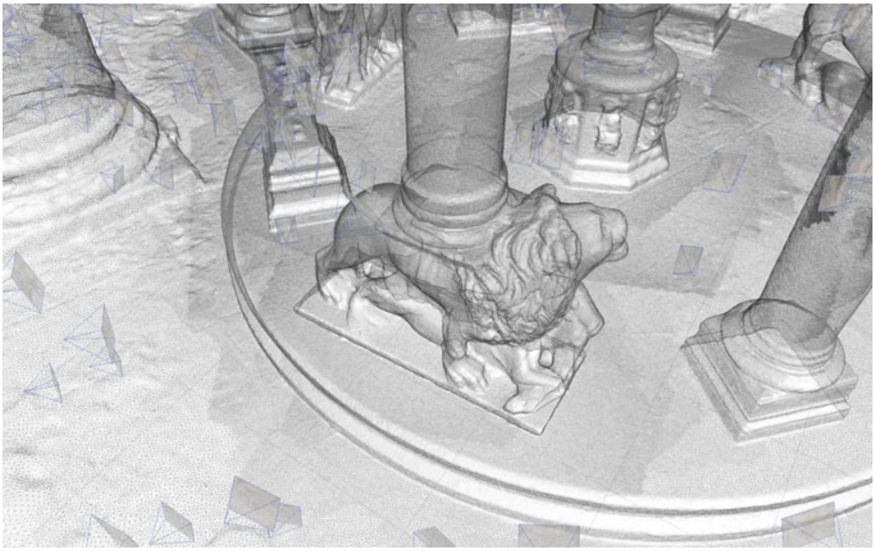

Fig. 13 Detail of the 3D mesh model where it is possible to see the resolution and the isometric triangles

group has been using SfM software for the reconstruction of three-dimensional scenes [5], useful for documentation and extractions of rectified textures (most of the times Agisoft Photoscan pro). The constantly evolving programs are able to provide today, under favorable shooting conditions, highly reliable models: reliability varies according to the resolution of the frame but can reach, for the scale 1:50, 2 cm [9]; unfortunately, the management of data of this size would have required the use of overly performing calculation machines, which are not present in the laboratory (The guide to Agisoft Photoscan provides that for every megapixel you should expect the use of a certain amount of RAM by the computer, reaching in this case too high level of memory).

The recent developments of other software for the management of photogrammetric data have led rather to the experimentation of new applications able to manage the photographic data more quickly: in this context the 3D Zephir program was used. The program is the subject of an agreement between DiDA and the manufacturer, 3D Flow, with the aim of experimenting with its applications in the architectural field in order to perfect its operation and update its functionality (Fig. 14).

The program's workflow basically follows the state of the art of the other SfM acquisition management software: it is divided into 4 processes, during the first the acquisition points of the frames are arranged in space (SfM process); in the second the data of the point clouds is densified; in the third one proceeds to the realization of a mesh surface based on the triangulation of points; finally the model obtained is texturized.

Fig. 14 Detail of the textured 3D mesh where it is shown the high resolution of the texture

The algorithms that realize these processes make the calculation of operations easier and less time consuming: something that we could pleasantly appreciate by inserting a photo dataset larger than 60gb. For other objects where the exposure is better and the data should not be post-produced, it is sufficient to use jpegs to reconstruct the scene.

The photographs have been subjected to the quality control of the software in order to identify the potentially dangerous frames for the quality of the alignment; after this phase, the positioning errors of the cameras were verified, eliminating the few badly arranged ones. After having densified the datum, on the basis of 6 control points the three-dimensional point cloud has been scaled obtaining an error lower than the tolerances, caused in part in the human action of the choice of the homologous points.

To check the quality of the mesh, it was extracted and imported into a software dedicated to the management of reverse engineering processes (Geomagic Wrap 2017), to test the quality of the triangulation of the points. the model obtained apparently had a regular arrangement of the triangles of the surface, a good quality index, which was verified by the software which, by activating a surface optimization algorithm, found imperfections, tips etc. [9]. Only in the portion of the model in which it was difficult to acquire the three-dimensional data of the statues of the second register; the rest of the surface was substantially error-free. On the contrary, usually the meshes coming from the Photoscan software have percentages of much higher imperfections. Verified the quality of the mesh has been re-imported into Zephir and texturized.

4 Conclusion

4.1 The Integrated Survey, Developments and Problems (G.P.)

Despite the fact that the new photogrammetric survey management platforms allow to combine data coming from laser scanner and photographic acquisitions [10], it was considered preferable in this case to avoid this procedure for several reasons: in the first place, the data of the laser scanner survey, as previously analyzed, is not highly reliable, or rather it may be inaccurate in some places, as can be seen from the horizontal sections of the columns. Combining the unreliable starting data with a more precise one, as in this case the photogrammetric one, would not lead in any way to an integrated survey more efficient than the original; for this reason, on the contrary, it was preferred to combine the two surveys to scale the photogrammetric one on the basis of some control points similar to the laser scanner survey. Obviously, these points have been selected on the less reflective surfaces so as not to take the spatial coordinates of unreliable points and thus give the photographic model highly reliable measurements (at least within the required representation scale).

References

1. Pancani, G. (2016) Piazza dei Miracoli a Pisa: il Battistero. Metodologie di rappresentazione e documentazione digitale 3D. Edifir. Firenze.
2. Pancani, G., (2017) La Città dei Guidi: Poppi. Il costruito del centro storico, rilievi e indagini diagostiche. Edifir. Firenze.
3. Gaiani, M. (a cura di) (2015) I portici di Bologna Architettura, Modelli 3D e ricerche tecnologiche. Bologna.
4. Docci M., Maestri D. (1994) Manuale di rilevamento architettonico e urbano, editore Laterza, Roma-Bari.
5. Bertocci, S., Minutoli, G., Mora, S., Pancani, G. (2015) Complessi religiosi e sistemi difensivi sul cammino di Santiago de Compostela: rilievi ed analisi perla valorizzazione e il restauro della cattedrale di Santa Maria la Real a Sasamòn. Firenze.
6. Balzani, M., Maietti, F., Mugayar Kühl, B. (2017) Point cloud analysis for conservation and enhancement of modernist architecture. In *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2/W3, 2017 3D Virtual Reconstruction and Visualization of Complex Architectures, 1–3 March 2017*, Nafplio, Greece.
7. Parrinello, S., Gomez Blanco, A., Picchio, F., (2017) El palacio de Generalife. Del levantamiento digital al proyecto de gestión. Pavia University press. Pavia.
8. Forti, G., (2006) Photography, theory and practice of reflex, Editrice reflex, Roma.
9. Fantini F. Bertocci, S., Parrinello S., Vital R. (2013) Masada Notebooks. Report of the research project 2013. Vol 1. Edifir. Firenze.
10. Bigongiari, M., (2017) Il rilievo del centro storico di Brolo. in Arrighetti, A., Minutoli, G., Gentile, S. *Bianca Terra. Studi per il recupero e la valorizzazione del centro storico di Brolo.* Armenio Editore. Brolo (ME).

Virtual Representation of Archaeological Stratigraphy. 3D Modeling and Interactive Presentation of the Late Roman Towers (Archaeological Museum, Milan Italy)

Simona Morandi and Marco Tremari

Abstract The e work is an analysis of the recording, processing and presentation of the 3D data of late roman towers inside the area of the Archaeological Museum of Milan. The aim of this research is to examine the possibilities offered by digital technologies to record and enhancing the archaeological heritage and to increase the divulgence and presentation with interactive products.

Keywords Archaeological heritage · Photogrammetry · 3D modeling · Augmented and virtual reality · 3D mapping of stratigraphy · Late roman site · Comunication of CH

1 Introduction

The aim of this paper is to show the use and the potential offered by modern digital 3D modeling technologies, mostly the digital photogrammetry and the virtual archaeology, to record and enhancing the archaeological heritage and to increase its presentation and divulgence with interactive products.

The research presented here is an analysis of the recording, processing and presentation of the 3D data of a late roman towers inside the area of the Archaeological Museum of Milan, part of the city previously occupied by the Monastery of St Maurizio and rich of historical and ancient monuments (Fig. 1).

The survey and three-dimensional documentation of the towers was realized during the project sponsored by the City of Milan for the restoration work and valorization of the monumental complex "Polygonal tower, Roman walls and *circus* tower" built in the late Roman period as part of the magnificent plan of Maximian (286–305 AD) when Milan was capital of the Western Roman Empire.

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Fig. 1 The site of the Archaeological Museum of Milan previously occupied by the Monastery of St Maurizio: a panoramic view of the area (left) and aerial views of the site and towers (right)

The union of the 3D model managed by Augmented Reality (AR) e Virtual Reality (VR) technologies with mobile devices gives several opportunities in the field of study and communication, improving on-site exploration of the landscape and the monuments, enhancing the archaeological sites.

2 The Site

The Archaeological Museum in Milan, inaugurated in 1965, is placed in an area rich in historical significance and ancient monuments: the area of the Monastery of St. Maurizio. In its cloister in fact there are two exceptional structures attributable to the period in which Mediolanum became the imperial seat (late 3rd–4th century) these structures, now it become a symbol of the museum: a square tower that closed the short side of the Roman circus and a polygonal tower attached to a huge tract of the city walls, structures that survived the subsequent destruction because embedded in the medieval monastery, first as a bell tower of the monastery church, the other as a place of prayer. In the garden between the two towers there are also located the remains of a domus built in the late first century BC and already it demolished during the urban renewal of the late 3rd century A.D.

This area of the Roman city, in the corner formed by the city walls, was occupied by the Roman Circus and its square tower, and the connecting wall to one of the surviving towers on the city wall circuit. The area enclosed by these structures was probably the home to a small garrison. The area later fell into decay and was taken

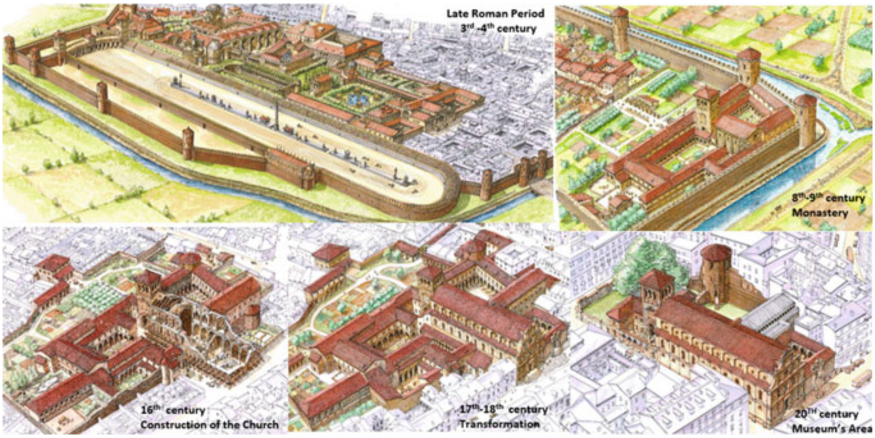

Fig. 2 The Area of the Circus between the Late Roman Period and the 20th century (reconstruction by F. Corni)

over, in the early medieval period, for the construction of the monastery, the remains of which are still visible today in the grounds of the Museum (Fig. 2).

Between the end of the Longobard period and beginning of the era of Charlemagne (8th–9th century A.D.), the Great Benedictine Women's Monastery was constructed on the ruins of the Circus and Imperial Palace, using the city walls as a base. The only surviving part of the Middle Ages monastery is the arched lodge which crowns the square tower of the Roman circus, transformed into a bell tower, between the 8th–9th century and a cycle of frescoes painted in the polygonal tower (dated back to the end of the 13th century—beginning of the 14th century).

During the 16th century, the Monastery expanded and was transformed; new buildings were erected which required the demolition of preceding structures and large areas of land. The new church, completely re-built on the previous and smaller Middle Age building between 1503–1511, consisted of two halls one for the enclosed order and one for the faithful, separated by a wall which exactly corresponded to the ancient Roman city wall. With the growth of the Monastery, the towers were progressively surrounded by structures from the medieval period until the dissolution of the monastery, in the 17th century. broken up after the Napoleonic suppression in 1798, the monastery gradually lost its original structure and became, successively, a barracks, school, prison, police and military station [1] (Fig. 2).

During the Second World War, the area suffered severe fire during an incendiary raid and immediately after the war the damaged structures were demolished, freeing the circular tower, and allowing for a campaign of restoration carried out in the 1950s and 1960s, till the foundation of the Museum (Fig. 3).

Fig. 3 The transformations of cloister of the Monastery of St. Maurizio in the years following the Second World War

3 The Survey and the Methodology

The work revolved around the necessity for a group, composed entirely of archaeologists, to find immediate and economical solutions to apply during the survey, the study and the communication of the archaeological sequence of the prospects of the two late Roman towers.

The primary objective of this application was to preserve digitally the historical site and roman tower in 3D with high fidelity and precision, and to provide a 3MD multimedia experience for research and educational purposes. During fieldwork the methodology and software employed were very sustainable, intended at surveying the site and considering the issues related to the disclosure of the acquired and processed archaeological data, for the audience of visitors, not only for scholars and for professionals.

In the course of the restoration work, the plaster was removed from the interior of the square towers and it was possible to complete the documentation of these complex structures. Given the height of the towers preserved up to 23 m, and the problems involved in conducting a traditional photogrammetric survey in barely accessible areas, it was decided to carry out the acquisition of data by the technique of uncalibrated photogrammetry, 3D image-based modelling. This permitted the construction of a 3D model of all the structures, in the area under study.

The first step of the work was the realization of a photographic coverage of the site, aimed at creating a detailed mapping and georeferenced contextualization of the roman structures and the generation of a 3D model thought the use of the modern digital photogrammetry.

The towers, still well preserved in the area of the Museum (the polygonal tower up to 17 m high, and the square tower up to 23 m) were subject to survey using 3D modeling and non-calibrated photogrammetry, applying the techniques of close range and aerial photogrammetry, now well consolidated during the last few years in the realm of architectural and engineering survey.

This methodology was applied because the traditional methodology of topographic survey and photogrammetry did not give satisfactory results, especially in the less accessible areas due to the presence of structures (such as the stairwell constructed in the square tower in the 20th century) and the height of the elevations [2].

The image-based 3D modelling is important tool for producing realistic and accurate 3D models in a practical and cost-effective manner. This method of three-dimensional recording, through uncalibrated photogrammetry, makes use exclusively of digital photographs to produce a 3D reconstruction of real objects, based on the integration of data acquisition, modelling and representation and is a suitable technique for areas such as archaeological recording reducing drastically with this methodology time and effort required during the survey [3, 4].

The application of 3D image-based modelling method on this archaeological site, using a simple acquisition hardware (digital camera) and low cost software for data processing, has led to a notable increase in the quality and amount of documentation; moreover, it has also reduced drastically the time and effort during on-site acquisition, processing and visualisation.

Photogrammetry allows the conversion of the photographed environment into a measurable three-dimensional model, with much more details and informations than it is possible to obtain with traditional topographic survey and data accuracy is comparable to that of the 3D representations obtained from laser scanner [5].

The acquisitions on site were made both with aerial and terrestrial photogrammetry (Fig. 4). The first step was the acquisition of orthogonal and oblique images for the contextualization of the archaeological structures within the museum complex, using close range aerial.

To this end, we made use of a small tethered helium-filled zeppelin, suitable for rapidity, accuracy and cost-effectiveness and easier to use for causes of accessibility in urban zones than drones.

The zeppelin carried a 24 megapixel full frame Nikon D600, mounted on a radio-controlled pantograph with remote shutter release. This method permitted the access to the square tower, overcoming the problems represented by the presence of buildings huddled to its base.

The second stage was the photographic recording of the internal prospects of the polygonal tower (24 sides) and square tower, taking advantage of a custom-built structure consisting of a telescopic mast mounted on a tripod base, which could reach the height of 8 m.

The mast carried a Panasonic DMC-GH4 16 megapixel camera with remote control settings, permitting shooting and verification on a screen, using a simple smartphone (Fig. 4).

Fig. 4 Aerial and terrestrial photogrammetry to document the site and realise the 3D model

The low-cost software, Agisoft PhotoScan, was used to process the data obtained digital close range photogrammetry and aerial photography.

This software automatically orientates even very large set of images and generates high-density point cloud from which graphics processing is then applied to extract a 3D photorealistic model, a scaled and detailed texturized representations of the archaeological data, and 2D plans and prospects (Fig. 5).

The aim of this work was to survey and process the digital data to obtain an accurate three-dimensional model, which has the benefit of instantly displaying the object in its entirety: an authentic photorealistic reproduction from which the data could be then extracted for the two-dimensional analysis of the structural details and transformations (Fig. 6).

The 3D model of the archaeological evidence is extremely important not only for study, allowing the archaeologist to develop and display the data thanks to continuous contact with the object of research within the three-dimensional space, but also for aspects of the conservation and monitoring of the monument. The 3D model has in fact various and efficacious values as scientific, didactic, historical and additional depending on the information that it provides, and it can also be suitable to estimate the evolution of the environment quantifying the changes in the area through time. This virtual copy has also the advantage of instantly representing the object in its original architecture and entirety, making available the data to a general public, of not only scholars and professional and helping people to visualize the ancient site and comprehend it better [6].

The photographic documentation with digital photogrammetry, made the generation of detailed ortophotos relatively simple for even the difficult not accessible areas. The ortophotos extracted from the 3D model, representing the 2D prospects, were

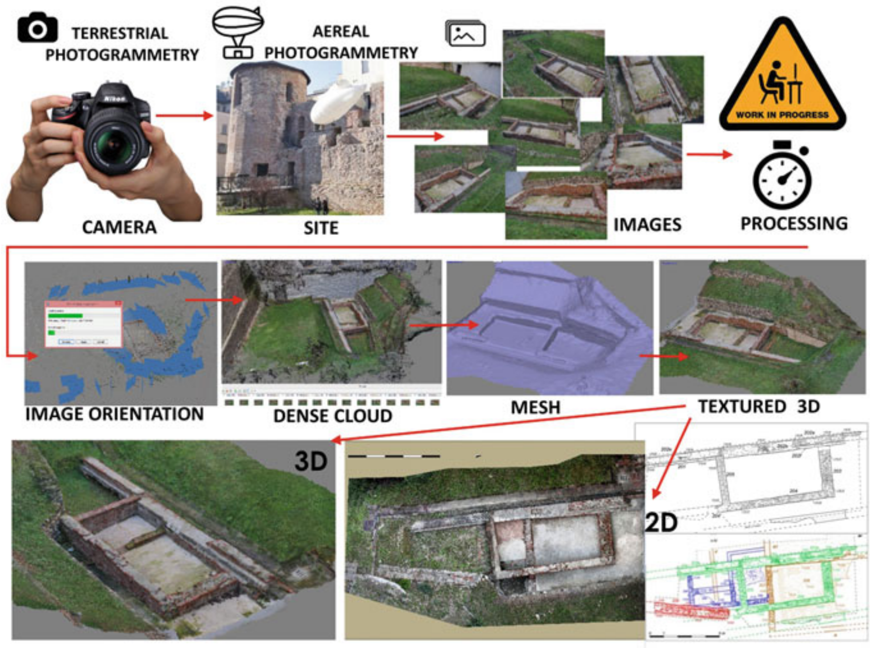

Fig. 5 Workflow: from the photos obtained with digital photogrametry to 3D models and 2D plans

imported into AutoCAD to form the underlying image for the analysis of the stratigraphic sequence of the towers and the vectorization of the structures; the phases studied were indicated with different hatches and colors for each phase and subphase on the ortophotos. The same stratigraphic phases, corresponding to the transformation of the structure over the centuries, have been also indicated directly on the 3D model obtained by photogrammetry, so that they could be perceived three-dimensionally. The historical evolution of the tower, mapped on the model, made possible to rebuild 3D representations of it in the different periods(Fig. 7).

4 Results and Future Application

The 3D models of towers proved to be an effective tool for the dissemination of archaeological data and were the starting point for different communication solutions that allows visitors to take a virtual tour of the same through applications for smartphone and tablet.

The availability of the 3D models, produced by photogrammetric survey (IBM), allows the application of AR and VR, technologies that contribute to a greater involvement in the knowledge of archeological remains thanks to personalized browsing of

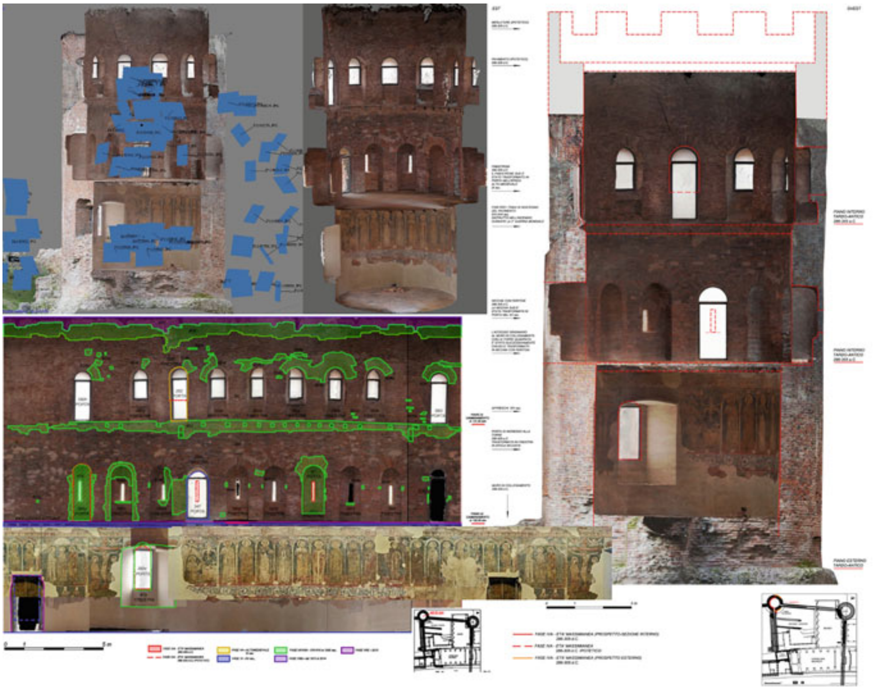

Fig. 6 3D from digital photogrammetry: the polygonal tower sectioned E-W and prospects with interpretation

real and digital scenes (Fig. 8). This will be of great value, for example to visitors who are unable to climb the stairs to explore the towers in person: they will be able to navigate and interrogate them from a video screen. AR and VR allowing to recognize the different phases of the tower on the 3D model, will be also useful for archeologist and students.

After the archaeological survey, the need for a non-traditional and alternative method of musealization of the site context was immediately clear. As the structures were no easy visible, without enter the museum, we decided to use the AR solution as a way to explore and enjoy the late roman towers, giving people the possibility of a virtual visit of them. AR has been used for the 3D rendering of the entire archaeological area; one custom marker was created, suited to be recognized by the software responsible for reproduction in AR environment of the photorealistic 3D model [7]. This marker for AR applications will be included in the brochure made by the Archaeological Museum to enrich it with the three-dimensional model and multimedia contents available for tourism and divulgation. The user could also interact with panels that will be located outside the museum. This will be of great value for visitors that will be able to navigate the interior area of the museum with the two towers from a video screen.

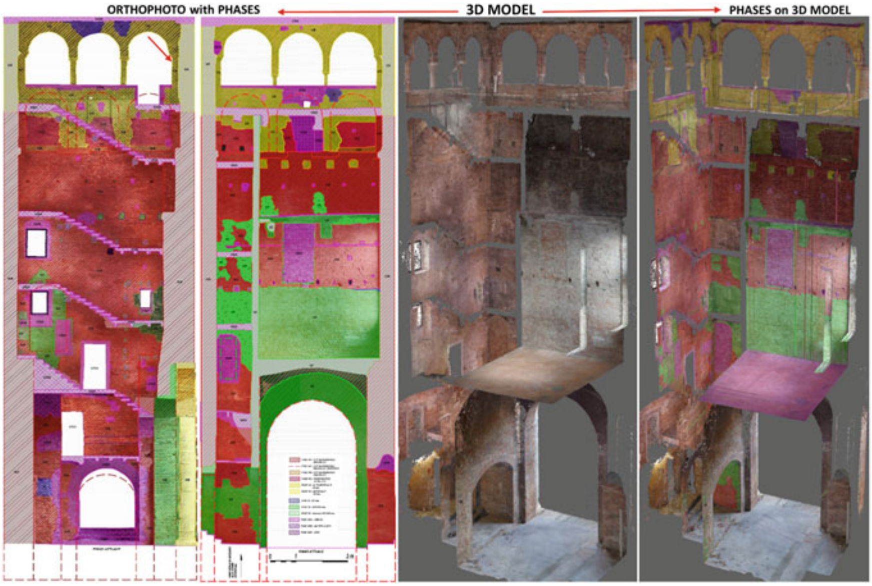

Fig. 7 Square tower: internal prospects with indication of the phases on the orthophotos and on the 3D model

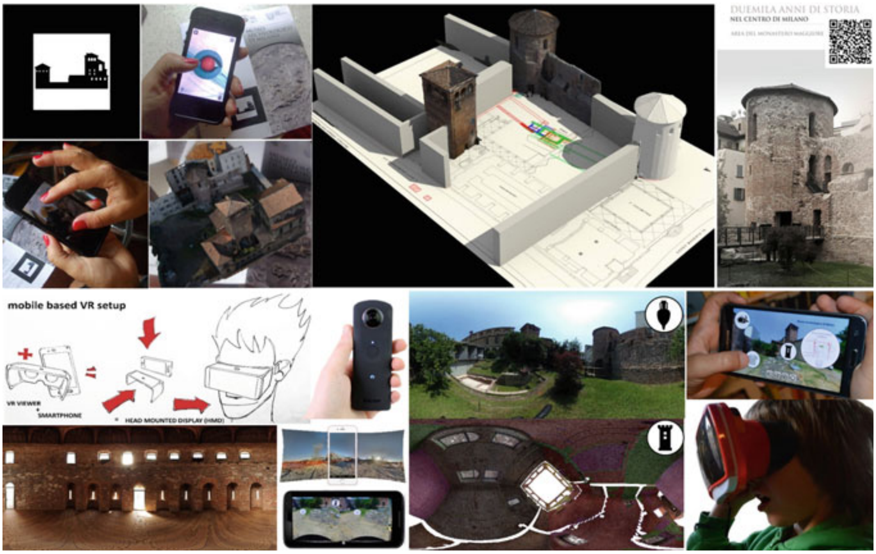

Fig. 8 The 3D model of the site and the towers managed by AR and VR. Top left brochure with the AR marker and the site 3D model displayed by AR; top right the mobile application.; bottom explanation of the mobile based VR and 360° panoramic views of the area and tower navigable in VR

Furthermore, the panoramic camera Ricoh Theta was used to capture 360° images of the Museum's area and the interior of the towers; the panoramic photos were stitched together with the proprietary software and a virtual tour of the site and the reconstruction of the church during the times was created with Kolor Pano Tour. The virtual tour is going to be published to use it with a simple virtual reality head mounted display (HDM) and an application for smartphone [8]. This system produces an immersive experience permitting the virtual visit of the archaeological site in order to understand how the landscape and the site have transformed also to people who are unable to visit the site in person. The direct fruition of the virtual model through a fully immersive VR tour could open the path for an innovative development in the field of archaeology maintenance, improving our understanding of the spaces and allowing to immediately georeference the information [9].

The purpose was to realize a virtual tour of the area to display the nowadays view of the archeological site, the stratigraphic phases of the structures mapped directly on the 3D model and the 3D reconstruction of the area in different periods. The future intention is to make a virtual reconstruction of the area in both the late roman and medieval period, so it will be possible to have some panoramic views of the area as it was in the past. The visitor using of AR e VR could perceive the evolution of the tower over the centuries and recognize in the masonry elevation the structures corresponding to each phases of its life.

A firm specialized in computer applications for museums (ETT), did in collaboration with the Museum an application to make an interactive presentation of the towers, accessible by smartphone. The application is making use of our 3D survey, AR and VR to add a new dimension to the presentation of the archaeological remains and make the towers "accessible" by smartphone via beacon from the base.

The 3D model has been also merged into an interactive digital publication system, represented by 3D PDF, with models that can be explored by the viewer, queried and easily downloaded by the scanning of a QR code from the Museum's website [10].

5 Conclusion

The technological improvements in spatial data collection and 3D imaging developments are changing our perception of the real world; surveying, data processing, modeling, Augmented and Virtual Reality, are main elements of these development processes to achieve the output products.

The application of digital photogrammetry and the virtual reconstruction at the area of the archaeological Museum of Milan was particularly interesting and effective producing a conspicuous increment in the amount and quality of the documentation. Considering that, at the time of the survey, no documentation of the interiors of the towers was available, after few days of survey and elaboration of data, 2D and 3D graphic documentation of the whole archaeological area was obtained, suitable both for scientific and informative purposes. The three-dimensional models both reality-based and hypothetic run by AR and VR technologies with mobile devices provides several advantages in the research, study and communication, improving on-site exploration of the landscape and the archaeological sites.

The case of study presented would be a model to valorize with low cost and non-invasively technologies the archaeological heritage with interactive products that increase the study, the presentation and the divulgence. Acquired data are the basis of many usable applications.

First, they are an authentic image of the present status of the archaeological structures, at a precise moment of the survey. This information can be useful later to control the natural decay of the remains or possible damage. Besides, the data may also be used to prepare a digital reconstruction of the original appearance of the whole the site and landscape, effective both for academic and popular publications.

The interactive products potentially increase the divulgation and visualization for the general public, in the belief that the preservation and protection of the archaeological heritage is possible only through its knowledge and the disclosure to a larger audience.

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References

1. Blockley, P., Cecchini, N., Pagani, C. L'area archeologica del Monastero Maggiore di Milano. Una nuova lettura alla luce delle recenti indagini in Quaderni del civico museo archeologico e del civico gabinetto numismatico di Milano, fasc.4 (2012), Ferrara
2. Morandi, S., Le torri romane:documentazione e studio attraverso l'image based 3Dmodelling, Il progetto, la ricerca e la comunicazione del dato, in D. Caporusso, Le Torri Romane del Monastero Maggiore,, Quaderni del civico museo archeologico e del civico gabinetto numismatico di Milano, n.6, (2017) pp. 97–107
3. Taylor, C.J., Devebec, P., Malik, Recostructing polyhedral models of architectural scenes from photografs." Proceedings of the European Conference on Computer Vision, (1996)
4. Manfredini., M., F. Remondino,, Modellazione 3D da immagini. Pipeline Fotogrammetrica, in "Modelli Digitali 3D In Archeologia: Il Caso Di Pompei, Benedetti, Gaiani., Remdino Pisa,2010, pp. 162–199
5. Fassi., Fregonese, L., Ackermann, S., De Troia, V., Comparison between laser scanning and automated 3D modelling techniques to reconstruct complex and extensive cultural heritage areas. ISPRS Workshop 3D-ARCH: 3D virtual reconstruction and visualization of complex architectures, Trento, (2013) pp. 73–80
6. M. Russo, F. Remondino, G. Guidi,1. Principali tecniche e strumenti per il rilievo tridimensionale in ambito archeologico. Archeologia e Calcolatori, 22, (2011) pp. 169–198
7. Milgram, P., Kishino F., A taxonomy of mixed reality visual displays in «IEICE» Transactions on Information Systems, Vol E77-D, No.1(1994)
8. Fabola A, Miller A., Exploring the past with google cardboard, in Digital Heritage, (2016) pp. 277–284

9. Fassi F., Mandelli A., Teruggi S., Rechichi F., Fiorillo F., Achille C., 2016, VR for Cultural Heritage. A VR-Web-BIM For The Future Maintenance Of Milan's Cathedral, Salento AVR16 (2016)
10. Fiorini A., 2012, Tablet Pc, fotogrammetria e pdf 3D: strumenti per documentare l'archeologia in «Archeologia e Calcolatori», n 23, pp. 213–22

Opening up Research Data in Film Studies by Using the Structured Knowledge Base Wikidata

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Abstract The paper shows how context-aware relational infrastructure enables non-technical disciplines to become more involved in data-oriented research practices and environments. A new Open Access journal from the field of film studies is presented that, with the help of the semantic annotation tool neonion, creates associations between its research articles and the community-database WikiData. The tool is designed to integrate seamlessly into the workflow of a film scholar while still supporting the formal structure of data annotation that is necessary in a Linked Open Data environment. By doing so the tool helps to get researchers used to the notion of structured data publication while not overwhelming them with technological concepts. In the end both publication environments - the journal and WikiData - benefit significantly. On the one hand the journal and its articles reach a broader audience, resulting in greater impact. On the other hand, WikiData receives highly profiled data that can be linked back to scientifically reliable sources.

Keywords Annotation · WikiData · Film Studies · Digital Pubishing · Linked Open Data · Recommendation System

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1 Introduction

In fields of research such as medicine, biology or chemistry scholarly communication has significantly changed over the past fifteen years. The scientific article—far from disappearing as many authors have suggested—turned into a complex multi-purpose object. Among other things many journals have developed article formats which are meant to be understandable by both humans and machines, an approach which became known under the term semantic publishing [1].

Semantic publishing comprises online publications in which structure, for example the line of arguments or important entities are formally marked-up in such a way that a program is capable of interpreting the marked-up units. Based on an approach like this, scientists in biomedicine, for instance, are able to extract information about medical entities and to ingest them into medical databases [2]. Likewise, formally marked-up articles enable additional services to enrich the online version of an article with contextual information or with further helpful resources that might create a better reading experience [3–5].

In the arts and humanities comparable examples are rare. Journals such as the "Zeitschrift für digitale Geisteswissenschaften"[1] (ZfdG) or the TEI Journal[2] offer TEI-XML versions of their articles only. One of the reasons can be found in the fact that the humanities traditionally take a different position both towards factual knowledge as well as towards the form of publication than the sciences [6–8]. Rather, it is part of the humanities' key agenda to critically reflect on different approaches of how knowledge is created, for example by empirical methods or by analyzing textual structures. For the presentation of their results the narrative aspect of text serves as a useful and established tool and bears a crucial aspect of meaning.

However, recent innovations in electronic scholarly communication related to the concept of Nano-Publications [9] have been welcomed and discussed by humanities researchers more openly [10, 11]. Nano-Publications are publications which contain factual information linked with data about its source and context. This structure allows both to manage contradicting information at the same time as well as related contexts, sources and information in a way that resembles scientific discourse in a formal structure.

In our paper we show how the concepts behind Nano-Publications can be realized practically in the context of film and media studies by opening up factual knowledge from scholarly research. We argue that Wikidata can serve as a centralized and curated version of the Nano-Publication concepts, which is better suited to humanities researchers. We demonstrate how factual knowledge from scholarly articles in the Open Access online journal Apparatus[3] can be semi-automatically extracted by using the semantic annotation software neonion,[4] and automatically ingested into

[1] http://www.zfdg.de/.

[2] http://jtei.revues.org/.

[3] http://www.apparatusjournal.net.

[4] http://www.neonion.org.

the open structured knowledge base Wikidata[5] where it will be available as referenced statements to the public. We also explain how the publication of extracted and networked factual knowledge may support certain approaches in film studies, specifically New Film and New Cinema History. Furthermore, we highlight how in reverse the data quality of existing collaborative projects, such as the Wikidata project, can profit from scholarly research, and how opening up research results can improve scholarly communication.

2 The Use Case: Open Access Journal Apparatus

The Open Access Journal *Apparatus. Film, Media and Digital Cultures in Eastern, Central and South-Eastern Europe* was conceived by Natascha Drubek during a Heisenberg Fellowship, received project funding by the Deutsche Forschungsgemeinschaft (DFG) and went online in 2015. It is currently hosted by the Freie University (Berlin) and since 2017 co-published by the Brandenburg Center for Media Studies (ZeM) in Potsdam. The journal is published twice a year and all articles undergo a double blind peer review process. Apparatus supports the integration and international visibility of research about and from Central and Eastern Europe which allows publications in the original language, while an abstract and keywords are provided in three languages (German, English and Russian). The editorial team consists of Adelheid Heftberger and Irina Schulzki with Natascha Drubek as the editor-in-chief.

The project, put forward by Heftberger, was to develop a vision for future electronic publications in the film and media studies, by using Apparatus as a use case. Even though people are surrounded by moving images online, academic electronic publishing still follows a very traditional path despite its multimodal and multimedia focus and objects of analysis.[6] Videos are rarely included within articles, and the infrastructure for creating and sharing research data is not developed yet. However, the aim of the project was not only to facilitate enriching articles with moving images to a larger amount, but to find ways of how to link the factual information published in the articles to existing knowledge bases.

From the publishers' perspective there are several advantages in linking the journal to Wikidata. Firstly, it will allow a wider dissemination of research carried out in a highly specialised field, and will at the same time increase the general visibility and impact of the journal itself. Secondly, the journal will be integrated in a larger network of knowledge production and exchange, and be enabled to contribute directly to open science. For the authors the advantages of being linked to Wikidata are quite obvious as well, not only will there be more access points to their research but they will

[5] https://www.wikidata.org.

[6] One example for the inclusion of video clips in online publications within the film and media studies is the Open Access Journal mediaesthetics, published by Cinepoetics (Freie University Berlin): https://www.mediaesthetics.org/index.php/mae/index.

also become part of the open science community themselves by providing curated data as a first step. Enhanced publications should, prospectively, also lead to not only providing data to Wikidata but conversely importing and enriching articles with already existing data.

Research data does not only include factual information in textual form (like authority files of people and film titles or biographical information) but authors in Apparatus often publish archival documents which are not easily accessible otherwise or difficult to find. These documents can be full scans or data extracted for the articles. In any case, readers will benefit from archival research carried out by scholars and eve more so, if it is linked to other resources.

In the following, we explain, how authors and editors can be enabled to make semantic enrichments suitable for supporting extended forms of publication on exemplary articles published in Apparatus.

3 Enriching Apparatus Publications with Explicit Semantics

Using the articles published in Apparatus as a use case, we have developed a workflow that enables semantic enrichment without detailed technical knowledge by the domain experts. Thus, authors and editors can focus on their their subject-specific domain knowledge while creating reliable structured data.

The formalized creation of semantic information in the form of annotations in text allows to connect subject-specific knowledge to existing external knowledge bases based on the principles of Linked Open Data (LOD) [12]. Re-use of external knowledge representations improves automated sense-making of semantically enhanced textual resources, with advantages in navigation, retrieval and indexing.

Figure 1 provides an overview of the workflow, which consists of manual semantic annotation of the selected article by incrementally extending the controlled vocabulary of neonion . Following the computational evaluation of new annotations (deduction), users can choose from a list of suggestions for the existing vocabulary (curation). Additionally, through close connection with Wikidata (mapping), these manually created semantic annotations can be translated into schema-compliant object instances according to the Wikidata data model and uploaded into their knowledge database (ingestion). We explain the general properties of this workflow in more detail in the following section.

3.1 Assisted Annotating with Neonion

The browser application *neonion* [13] has been developed to provide an interface for collaborative annotation of textual resources. Besides the ability to create com-

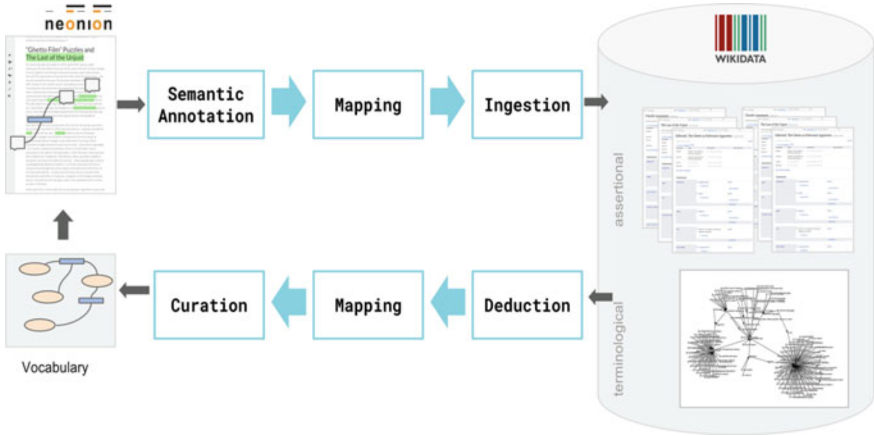

Fig. 1 Two way workflow of annotating concepts in articles and linking them to Wikidata and extending articles by information provided by Wikidata

ments and highlights, its most characteristic feature is the possibility to add structured semantic annotations, including the identification and classification of object relationships using a locally managed controlled vocabulary. The controlled vocabulary in *neonion* is modeled as a collection of concepts and their properties. Different object types (concepts) can be related to each other using appropriate relations (properties). Both concepts and properties can be enriched with mapping information for alignment with external resources, like public authority files.

Typically, a vocabulary such as this is created and tailored to domain-specific requirements. To ensure that the annotation software can be used by experts with little or no technical background, we allow users to work with the annotation tool without a rich predefined vocabulary. Therefore, they get to use only a limited and generic vocabulary at first, which is then semi-automatically extended in order to assist in identifying and classifying annotated entities. To this end, terminological knowledge is derived from available information on annotated entities and used for candidate generation for extending the vocabulary a recommender.

In summary, we hide, to a certain degree, the complexity of the underlying controlled vocabulary which is used for the semantic annotation. Although *neonion* offers easy-to-use interfaces for the editing of vocabularies, the effort involved in familiarizing non-technical experts with the conceptual peculiarities of the concrete software solution as well as the creation, design, and maintenance of a domain-suitable vocabulary is known to potentially represent a significant hurdle for interested parties without a technical background [14]. Our interactive process which includes feedback from the domain experts, generates candidates for a gradual expansion of the vocabulary defining permissible concepts and properties.

3.2 Using Wikidata as a Public Authority Resource

As an ontological foundation and authority control for our approach, we utilize the openly and collaboratively built structured knowledge base Wikidata [15]. Its paradigm of multilinguality enables consistency of aligned vocabularies across the various languages in which Apparatus's authors publish. Furthermore, its open and pluralistic approach contributes to a comparatively rapid increase in its scope and coverage, but also means that there is no consensus on the validity of all statements it holds in stock. Conflicting and divergent statements about object instances can therefore easily be placed side by side. Statements are extended with so called qualifiers that provide information about trustworthiness, author, scope or the context of a factual assertion. The data model of Wikidata hence explicitly provides for evaluative attributions of statements.

Whenever users select part of a text in neonion's semantic annotation mode, they are prompted to classify the selected named entity with a concept available from the controlled vocabulary. Based on the chosen category, an interactive search is performed by neonion against multiple Wikidata endpoints in order to look up appropriate candidates for entity identification. Once the user assigns the correct entity, the system can proceed to extract additional knowledge based on this choice from Wikidata. The result contains terminological axioms which the system can reason upon in order to determine concepts and properties that potentially make a suitable amendment to the vocabulary in terms of subject-matter coverage.

Figure 2 shows the Wikidata-driven tooling using neonion. Person names, like the Soviet director Dziga Vertov in our example, are annotated using a very limited vocabulary, and are then linked to corresponding Wikidata items (image top left). Recommendations for possible extensions of the vocabulary are extracted using knowledge about those entities (image bottom left). The list on the right shows structured assertions from annotations using vocabulary recommendations, which have been converted to Wikidata statements. Button icons indicate whether a statement is already present on Wikidata (green) or would be new information (image right).

For example, looking for already existing information on Soviet directors in Wikidata usually reveals various relationships to objects instantiating the types "film" or "award". From these results, terminological knowledge can be derived, i.e., general statements about possible relationships between object types. Suggesting a concept "film award" and a property "award received" applicable to a human subject (e.g. a director) might be useful for scholars who research the history of film festivals and therefore annotate a number of directors in a publication. Suggestions are discarded or added to the vocabulary according to the feedback given by the annotator.

Several scenarios are possible for the delivery of factual information from Apparatus articles to Wikidata: If a local statement already exists in Wikidata, the editorial contribution consists in adding a bibliographical statement to the existing statement. The qualification of statements via adding references is one of the explicit requirements that Wikidata places on contributors, but this requirement is only fulfilled as part of the current content. By referring to the bibliographic data record of an article

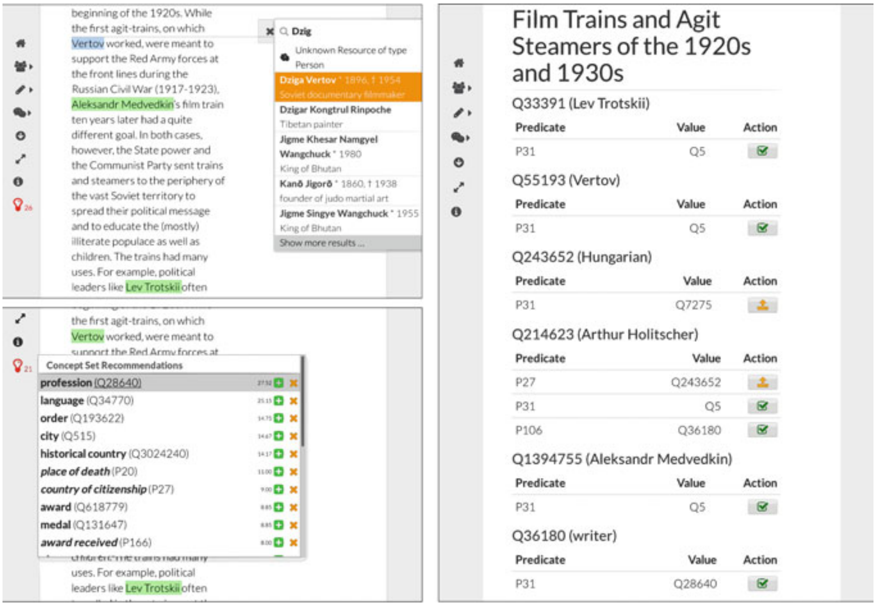

Fig. 2 Screenshots depicting Wikidata-driven tooling within neonion's annotating interface

which can be easily accessed and read as an Open Access publication, our most simple contribution is to provide a statement with a bibliographic source that can be checked and validated at any time.

3.3 *Recommending Additional Annotations*

The linked data structure, in which Wikidata content is modelled, allows for the computation of structure-based similarity measures in addition to data mining methods for the purpose of identifying semantically similar terms. In addition to simple concept and property recommenders based on graph transversal, which are necessary to tackle cold-start problems, we most notably employ the association rule mining engine Snoopy as a property recommender system [16].

Snoopy is a recommendation system supporting the collaborative creation of structured knowledge bases [17, 18]. To this end, it generates association rules from assertional axioms of which the knowledge base's instance knowledge consists. Those rules can be used to determine vocabulary terms likely to be used in co-occurrence with a given set of other descriptors. This is in tune with Snoopy's contribution to knowledge base collaboration, which aims at enabling assisted input of structured knowledge while at the same time enforcing compliance with schema definitions emerging from community input. The system generates recommendations based on

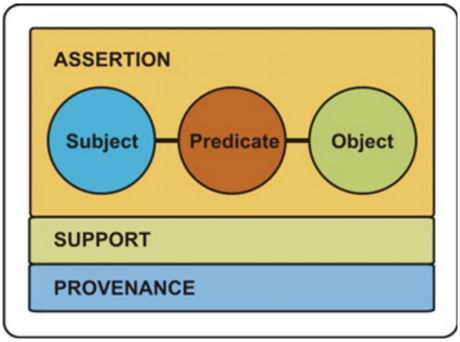

Fig. 3 A basic model of Nano-Publications (http://nanopub.org/)

previous input, thereby ‘snooping’ knowledge its users are likely to have about a given subject, and reinforces alignment with the terminologies toward which the entire community is leaning.

4 Supporting the Development of Data Publication Cultures in Non-Data-Centric Scholarly Environments

As has been noted in the introduction we relate our approach to the broader topic of digital publishing in the humanities, specifically Nano-Publications as a emerging standard of data publication in academia. It is true that Nano-Publications define a specific semantic schema [19] which is used neither by our infrastructure nor by Wikidata. Nevertheless, the conceptual foundation is astonishingly similar, as Fig. 3 demonstrates. It shows a diagram, used in the Nano-Publication research field in order to explain the essential components of a Nano-Publication. What is called the *assertion* equates to an annotation in neonion and to what is represented as a *statement* in Wikidata. The annotated source (the article) in the neonion environment is one possible type of what is referred to as *support* for an assertion in Nano-Publications, it is what is added as a bibliographic statement to Wikidata an what is generally called a reference in Wikidata terms. *Provenance* finally comprises metadata about the creation of specific Nano-Publications, i.e. who created the Nano-Publication and when did this happen. The same information is recorded both by neonion as well as by the *revision history* in Wikidata.

The comparison shows how similar the foundational ideas of data publication are between different environment like neonion, Wikidata and Nano-Publication despite the aforementioned differences. Consequently, our infrastructure is also intended to introduce data publication concepts and Nano-Publication concepts in particular in domains such as film and media studies in which a culture of data publication has not yet developed.

Another advantage of using Wikidata instead of directly publishing Nano-Publications in this context is Wikidata’s approach. What is published can be discussed, modified and curated in a transparent collaborative manner on the Wikidata platform, which everyone knows because it is used already for Wikipedia. This makes it extremely accessible. Where data publication is required that adheres more to academic principles and practices of data publication a transformation from Wikidata to Nano-Publications can be done easily: Wikidata also exposes its data in a way that complies with Linked Open Data principles. We are therefore convinced that the approach we described in the present paper is well suited to stimulate the development of a data culture in disciplines where such culture rarely exist.

Finally, there is another reason for this conviction. It exceeds the issue of technological accessibility and the question how much research communities are used to data publication concepts, and rather regards questions of research methodology and the topic of annotating. In humanities research annotating is a key component of the research process itself [20, 21], not just an issue of data integration. It is closely connected with the immediate confrontation with the research object such as a research article and part of an exploratory process. Moreover, if there is anything that comes closest to the notion of data in the history of humanities disciplines then it is using annotations as a resource. Hence, the decision was to start with an annotation tool for the annotation of articles during the process of reading (neonion), and afterwards to transform its outcome into data-like statements. These can be accessed in a document-oriented environment (Wikidata) and relating this to the emerging standard of Nano-Publications means to support a process where this and other data publication standards show up out of a familiar context for humanities researchers instead of trying to 'teach' them. We believe that at the long-term this will proof to be much more successful.

5 Conclusion

Our approach of schema alignment and semantic recommendations is beneficial in three ways. First, its advantage of enabling scholars with little or no technical background to intuitively configure a content-sensitive vocabulary for semantic annotation has been discussed above. Second, the alignment with schema information which is easily accessible and agreed upon within the scope of Linked Open Data, allows for the mapping of factual information about individual instances which users of our workflow make explicit in documents they work on. Finally, the approach familiarizes non-data-centric research disciplines with data publication concepts and models in a subtle and understandable way.

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References

1. Shotton, David. ‘Semantic Publishing: The Coming Revolution in Scientific Journal Publishing’. Learned Publishing 22, no. 2, 2009, 85–94.
2. Ciccarese, Paolo, Marco Ocana, and Tim Clark. ‘Open Semantic Annotation of Scientific Publications Using DOMEO’. Journal of Biomedical Semantics 3, no. S-1, 2012).
3. Shotton, David, Katie Portwin, Graham Klyne, and Alisair Miles. ‘Adventures in Semantic Publishing: Exemplar Semantic Enhancements of a Research Article’. PLoS Comput Biology 5, no. 4, 2009, 1–17. https://doi.org/10.1371/journal.pcbi.1000361.
4. Diender, Bas. ‘Enhanced Publications: An Enhanced Experience?’, 2010.
5. Gielkens, Charley, and Jeroen Hulman. ‘Identifying Requirements for Enhanced Publications’. Computer Science.nl, 2011, 1–15.
6. Drucker, Johanna. ‘Humanities Approaches to Graphical Display’. Digital Humanities Quarterly 5, no. 1, 2011. http://www.digitalhumanities.org/dhq/vol/5/1/000091/000091.html.
7. Owens, Trevor. ‘Defining Data for Humanists: Text, Artifact, Information or Evidence?’ Journal of Digital Humanities 1, no. 1, 2011. http://journalofdigitalhumanities.org/1-1/defining-data-for-humanists-by-trevor-owens/.
8. Schöch, Christoph. ‘Big? Smart? Clean? Messy? Data in the Humanities’. Journal of Digital Humanities 2, no. 3, 2013. http://journalofdigitalhumanities.org/2-3/big-smart-clean-messy-data-in-the-humanities/.
9. Mons, Barend, and Jan Velterop. ‘Nano-Publication in the E-Science Era’. In Workshop on Semantic Web Applications in Scientific Discourse (SWASD 2009), 2009. http://www.surffoundation.nl/SiteCollectionDocuments/Nano-Publication-Mons-Velterop.pdf.
10. Heßbrüggen-Walter, Stefan. ‘Tatsachen Im Semantischen Web: Nanopublikationen in Den Digitalen Geisteswissenschaften?’ Historyblogosphere–Bloggen in den Geschichtswissenschaften, Edited by Peter Haber and Eva Pfanzelter, 2013, 149–160.
11. Schmidt, Nora. ‘Semantisches Publizieren Im Interdisziplinären Wissenschaftsnetzwerk. Theoretische Grundlagen Und Anforderungen’, 2014.
12. Bizer, Christian, Tom Heath, and Tim Berners-Lee. ‘Linked data-the story so far’. International journal on semantic web and information systems 5.3, 2009, 1–22.
13. Müller-Birn, Claudia et al. ‘neonion: Combining Human and Machine Intelligence’. In Proceedings of the 18th ACM Conference Companion on Computer Supported Cooperative Work & Social Computing. ACM, New York (USA), 223–226, 2015.
14. Breitenfeld, Andre, Maximilian Mackeprang, and Ming-Tung Hong. ‘Enabling Structured Data Generation by Nontechnical Experts’. Mensch und Computer 2017-Tagungsband: Spielend einfach interagieren 17, 2018.
15. Vrandečić, Denny, and Markus Krötzsch. ‘Wikidata: a free collaborative knowledgebase’. Communications of the ACM57.10, 2014, 78-85.
16. Zangerle, Eva and Müller-Birn, Claudia ‘Recommendation-Assisted Data Curation for Wikidata’ Position Paper at the Wiki Workshop 2018 (held at The Web Conference 2018), Lyon, France, 2018. https://zenodo.org/record/1194790#.Wsu9pdNuYWo.
17. Zangerle, Eva et al. ‘An Empirical Evaluation of Property Recommender Systems for Wikidata and Collaborative Knowledge Bases’. Proceedings of the 12th International Symposium on Open Collaboration, OpenSym 2016, 18.1-18.8.
18. Gassler, Wolfgang, Eva Zangerle, Günther Specht. ‘Guided curation of semistructured data in collaboratively-built knowledge bases’. Future Generation Computer Systems 31, 2014, 111–119.
19. Kuhn, Tobias, et al. ‘Decentralized Provenance-Aware Publishing with Nanopublications’. PeerJ Computer Science, August 2016. ProQuest, https://doi.org/10.7717/peerj-cs.78.
20. Lordick, Harald, et al. ‘Digitale Annotationen in der geisteswissenschaftlichen Praxis’. Bibliothek Forschung und Praxis, Bd. 40, Nr. 2, 2016, S. 186–199. DeGruyter, https://doi.org/10.1515/bfp-2016-0042.
21. Walkowski, Niels-Oliver. ‘Digital Publications Beyond Digital Communication’. DARIAH-DE Working Paper Series, Nr. 17, 2016. urn:nbn:de:gbv:7-dariah-2016-3-4.

Gamification in Cultural Heritage: A Tangible User Interface Game for Learning About Local Heritage

Ferdinando Cesaria, Anna Marina Cucinelli, Giuseppe De Prezzo and Italo Spada

Abstract During recent years, information and communication technologies have widely affected the cultural heritage sector, offering incredible opportunities to enhance the experiential value of heritage assets. Digital tools are powerful instruments for improving the cultural activities, and at the same time, they represent new paradigms for enhancing the diffusion and acquisition of the cultural message. Techniques such as augmented reality, virtual reality and, more broadly, all multimedia technologies, are offering the visitors new opportunities of interaction with the cultural activities. Furthermore, another trend has gained significant attention: increasing user's engagement through gamification. Several studies have showed the efficacy of gamification and serious games in learning, revealing improvements in learning achievements. This research aims at investigating and proposing new tools to improve the interest of students in cultural heritage and enhance their learning experience. We describe the design, development and use of a game addressed mainly to primary school students, which utilizes computer vision techniques and computer graphics to raise their engagement during educational workshops at the Caracciolo Castle in the town of Sammichele di Bari (Bari, Italy). The game combines manual activities with visual information in computer graphics, showed in a digital screen. The interaction with the player relies on a tangible user interface based on computer vision techniques. Our system utilizes a simple web camera, which recognizes the user's interactions with the tangible game board during the game, and guarantees a kinesthetic learning process. In this paper, we provide detailed descriptions of the system and, afterwards, we discuss the possible implications.

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1 Introduction

Information and communication technologies (ICTs) offer powerful tools in the cultural heritage sector. Cultural organizations are increasingly embracing emerging digital technologies to add interactive elements to their exhibitions [10]. The value of digital tools for use and interpretation of heritage assets is now well established as is their value in the cultural heritage education [14, 15]. However, it is important to highlight that the use of technology in cultural heritage must be always at service of the cultural message; thus it is crucial to pay attention to the scientific data carried by the cultural assets [16]. When correctly implemented, ICTs may provide a wider access to the cultural heritage, not only from a spatial point of view, but also in terms of enlarging the potential audience. Therefore, ICTs may contribute to stimulating people to recognize the importance of the past and the history, encouraging appreciation of valuing the cultural heritage education and arts, key factors in development of knowledge society and creativity ability [20].

Technologies such as augmented realty, virtual reality and games, for their intrinsic visual and interactive nature, may be exceptionally suitable to enhance the enjoyment and understanding of cultural heritage and, consequently, they may be used as powerful learning tools. In particular, several studies have already showed the positive effects of gamification and serious games in learning [3, 5, 8, 9, 17, 19]. Gamification is the use of game design elements in non-gaming contexts to increase the user's engagement and experience [6]. Games may encourage learning activities by enhancing engagement and by building challenges to achieve an intended learning objective. Games that have as primary goal education rather than entertainment are referred to as education-oriented games or more generally serious games [12].

The popularity of video games, especially among young people, makes them a powerful medium for educational purposes. Furthermore, the main strengths of serious games such as visual expression of information, interactivity, entertainment, and engagement make them compelling for the cultural heritage valorization, communication and user's engagement [1]. Unlike other compelling multimedia technologies such as virtual reality, augmented reality, audio guide, which offer the opportunity to better understand and enjoy cultural assets, but can lack the active learning mechanism, computer games are able to provide entertainment and captivating experience. For this reason, the use of serious games in cultural sector stands out when the learning purpose is crucial [13].

In this work, we propose new tools to improve the interest of students in cultural heritage and enhance their learning process. We describe the design, development and use of a game, which aims to raise the engagement and learning process of primary students during educational workshops at the Caracciolo Castle in the town of Sammichele di Bari (Bari, Italy). Although it is mainly addressed to the workshop's students, the exhibition is open to all visitors of the castle that can play and enjoy the activity. The game, thanks to a tangible user interface, combines manual activities and visual information in computer graphics. The system utilizes computer vision techniques and computer graphics. We provide a detailed description of both the design of the system and the technologies involved. Following, we describe the possible implications.

2 Learning About Local Heritage

2.1 The Main Project: Discovering the Territory of Old Peucetia

The project described in this paper concerns the use of a tangible user interface game to learn about a cultural heritage, specifically about the castle Caracciolo in Sammichele di Bari in Apulia (Italy). It is a part of a bigger project aiming to promote the local heritage of old Peucetia in Apulia and to encourage children and primary school students to learn about these heritage assets.

The territory of the old Peucetia is in the region around Bari in Apulia among the municipalities of Gioia del Colle, Acquaviva delle Fonti, Casammassima, Sammichele di Bari. The name "Peucetia" is derived from its ancient inhabitants, the Peuceti, a lapygian tribes that occupied the area before the Roman conquest (Fig. 1).

The project involved a network of educational workshops and activities that have been organized in the historical buildings of towns of old Peucetia in order to let students of primary school discover the history and the environment of the region.

Fig. 1 The area of old Peucetia

Fig. 2 Multimedia installations

The workshops rely on multimedia installations and interactive tools, which were designed, developed and installed by our team (Fig. 2). Through simulations and activities, students and general visitors of the exhibitions can immerse themselves in the ancient times, and discover the history of their region. The serious game described in this paper is the instrument in support of the educational workshop held in the castle of Sammichele.

2.2 *Building the Castle of Sammichele Di Bari*

Construction of the castle "Caracciolo" in Sammichele di Bari (Fig. 3) started from the "Centurione Tower", built at the end of the 15th century. The tower became important for the population as a small fortification in the territory. Around it, a small rural village developed, origin of Sammichele di Bari. Between the 16th and 18th century, the castle was subjected to several events, which determined the development of the castle. In the 16th century, it was owned by the Genoese banker Heronimo Centurione, in 1606 by the Jewish-Portuguese Michele Vaaz, who gave the name "San Michele" to the town, while in 1675 it was owned by the baron Antonio De Ponte. The dukes Caracciolo took possession of it in 1797 and then the restoration works were assigned to the architect Amenduni in the second half of the 19th century, who rebuilt the east facade covering it with bossage, widening the openings on the ground floor and changing the three windows of the first floor into neo-Gothic mullioned windows.

The educational workshop held inside the castle of Sammichele di Bari aims at letting the children discover its structure and its history, starting from an examination and construction of a model of the medieval castle. The workshop is supported by a serious game with a tangible user interface. In order to complete the game, it is

Fig. 3 Caracciolo castle

necessary to physically solve a puzzle; each time the right element of the puzzle is inserted in the right spot, a part of the digital castle modelled in 3D takes shape on the screen. When a task is completed, the avatar of the castellan appears and interacts with the students to increase their engagement. The scene of a medieval village has been designed in order to raise the enchantment of the activity.

A camera located under the table on which the students introduce the items of the puzzle recognizes the elements inserted and confronts their position with the supposed one. If the spot is correct, the digital part of the game triggers the computer based feedback actions, which is the construction of the corresponding part of the castle and the virtual participation of the castellan.

In order to make the system works we have designed a tangible user interface based on a wooden box, which serves as the table of the game, into which 3d printed puzzle pieces can be inserted (Fig. 4).

3 Developing the Game

The design and development of the game followed several steps. One part of the work was related to the scene design, another part was related the tangible user interface.

Fig. 4 Tangible user interface

3.1 Scene Design

Like in any game, the goal of the game design is to give players an immersive experience. Immersion is the subjective suspension of disbelief that let players to be absorbed by the game theme. Higher level of immersion is related to higher level of enjoyment and engagement [4]. In our project the focus of the activity was the castle, thus, we needed to design a scene consistent with a medieval landscape, but also enchanting for the players of the game. At the same time, the digital reconstruction of the castle had to be factual with the real construction stages. Therefore, we focused on the authenticity of the castle's digital model and on the charm of the global scene.

The modelling of the castle followed a specific workflow. First, we analyzed the source material such as historical literature and archived technical drawings; then, we realized a photographic campaign and a technical relief of the outdoor prospect of the castle. After recovering technical and historical documents about the castle, we worked on the building of the 3D data, proposing the castle to its early history.

The first step to build the model was to import the planimetry of the castle on the software platform (technical drawing), obtaining the orthographic views of the architecture. By using the software tool "poly-line" the base or the floor of the structure were built in 2D. The work continued modelling the perimetral walls the façade and the castle towers.

To facilitate the game dynamics, the modeled elements were not grouped in just one geometry but they were kept as separated elements. Completed the architecture

3D model, the geometries have been characterized in terms of materials and textures. Thanks to the dedicated photographic campaign resulting from the first step of the activity, we assigned for each surface a specific texture, returning how the castle should have been in the 17th century (Fig. 5).

Once we modelled the real castle, we placed it in an environment that does not represent the real surroundings around Sammichele di Bari, but a fictional medieval ambiance to improve the enthralling aspect of the experience.

At the beginning of the game, the castle is not present in the scene; it takes shape piece by piece during the game progress until the castle is completed. Two different sceneries are loaded runtime according to the time of the day, one in the daytime (Fig. 6), and one at night (Fig. 7).

Fig. 5 3D model of the castle

Fig. 6 Daytime landscape with and without the castle

3.2 The Tangible User Interface

A Tangible User Interface relies on physical objects, instruments, and surfaces as physical interfaces to interact with digital information [18]. It couples physical representation with digital representations. In our work, we have built a box, which serves as the table for the game, where users need to insert the right element in the right spot in order to interact with the digital scene. The setup system is based on a wooden box with a camera and illumination source inside (Fig. 8).

In this setup, the camera is located under the board in which users introduce the items of puzzle. It sends the video stream to the game application, which analyses

Fig. 7 Night landscape with and without the castle

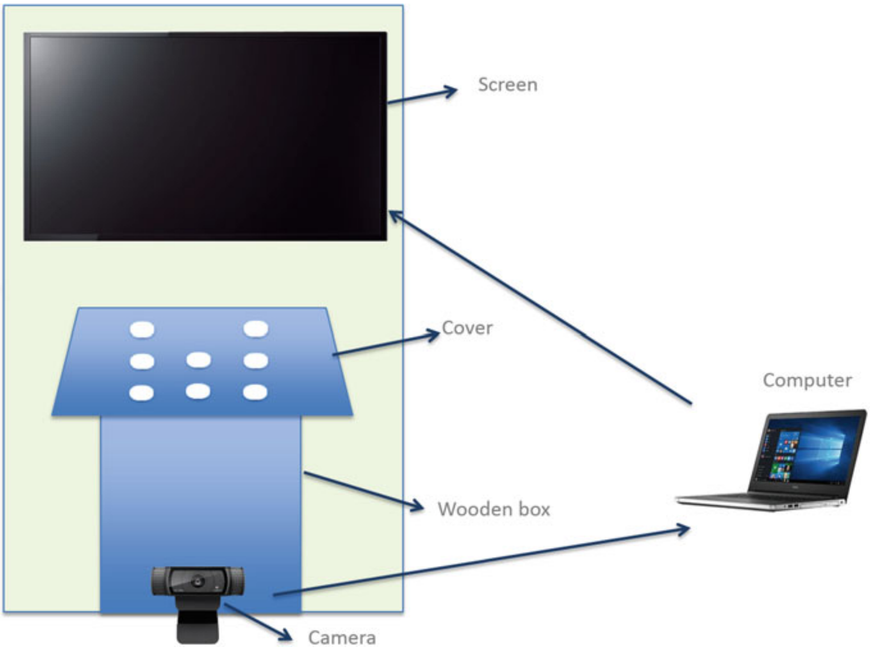

Fig. 8 Runtime system

the stream using computer vision techniques and recognizes the elements inserted. The interaction with the game occurs according to this analysis.

In order to make the recognition of the physical object possible, we placed fiducial markers under the puzzle pieces. Fiducial markers are images placed in the environment and detectable by a video camera by comparing their similarities with their pre-stored templates [7]. They are widely used in Augmented Reality applications to calculate their position and determine the camera pose, in order to mix virtual objects with real environment according the viewer perspective [2]. In the implementation of the computer vision algorithms, we used ARToolkit, an open source computer tracking library.[1]

In the design of the tangible user interface we needed to take into account both the constrains related to the marker recognition and the ergonomics of the system. In order to contain all the pieces of the puzzle, the area of the board could not be smaller than $70 \times 70\ \text{cm}^2$, and, since both children and adults can play the game, we needed to put the board at a useable and conformable height for both. Thus, we built the wooden box of $70 \times 70 \times 85\ \text{cm}^3$, and we placed the camera inside it. The ability to recognize the markers is affected by the position of the camera. A marker too far from the camera is unlikely to be detected. Hence, given the field of view of the camera, we inserted it at 75 cm from the top, the shortest distance able to frame all the board area (Fig. 9).

Another key factor affecting the detection of markers is their illumination. According to a study on the design and tracking of ARToolkit markers [11], the best illumination conditions are reached with a light intensity in the range of 55FC 2.8 KFC, and with a light-marker-camera angle of 90°, which we have achieved by inserting a led strip around the top part of the box (Fig. 10).

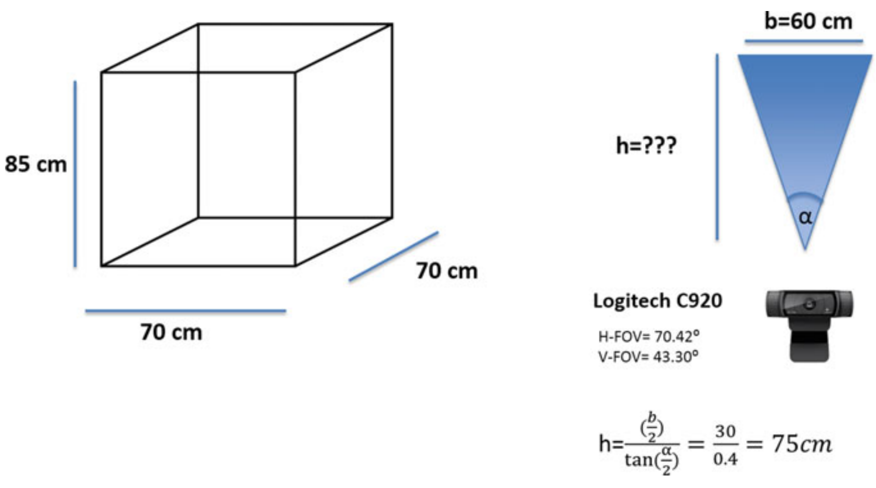

Fig. 9 Box structure

[1]https://artoolkit.org/.

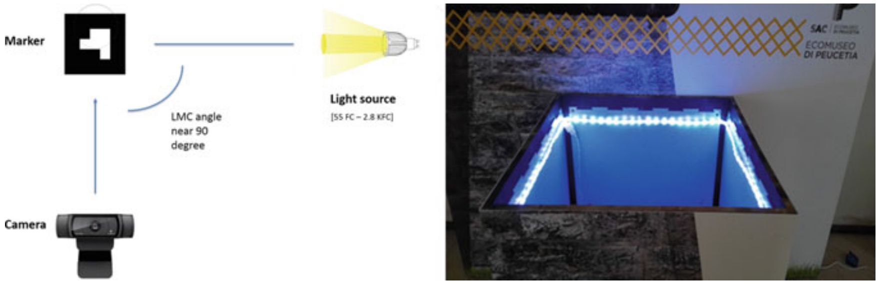

Fig. 10 Box lighting

Fig. 11 System at work

Following the described specifications, we were able to build a reliable and affordable tangible user interface system (Fig. 11).

4 Conclusion

Gamification and serious games offer significant new possibilities in cultural heritage education, encouraging learning activities by increasing engagement of students and by creating designed challenges. Using modern consumer hardware in combination with techniques derived from computer graphics, computer vision and human computer interaction broadens myriad of opportunities in interaction and appreciation of cultural assets.

In our project, we used computer vision and computer graphics techniques to build a tangible user interface game, which relies on gamification techniques as support for learning about cultural heritage. We focused on the technical and ergonomic aspects to achieve an affordable and reliable system.

Teachers remarked increased motivation and engagement of their students with the use of the game during the educational workshop. However further tests are needed to better understand what game mechanics should be implemented in order to achieve higher learning levels.

As other fields, ICTs are effective in cultural heritage education only when they are not used for their own sake, but keeping in mind the final aim of their use. Therefore, the design of serious games requires iterative collaboration of various experts with specific competences and skills.

Our aim was to design, build and test an affordable tangible user interface game to demonstrate the potential of serious game in cultural heritage education. Further research is needed to reach higher learning levels and find good practices to set as a standard for specific learning tasks.

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References

1. Anderson, E. F., McLoughlin, L., Liarokapis, F., Peters, C., Petridis, P., & Freitas, S. (2009). Serious games in cultural heritage.
2. Azuma, Ronald T. "A survey of augmented reality." *Presence: Teleoperators and virtual environments* 6.4 (1997): 355–385.
3. Barata, Gabriel, et al. "Engaging engineering students with gamification." *Games and virtual worlds for serious applications (VS-GAMES), 2013 5th international conference on*. IEEE, 2013.
4. Brown, Emily, and Paul Cairns. "A grounded investigation of game immersion." *CHI'04 extended abstracts on Human factors in computing systems*. ACM, 2004.
5. Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, *59*(2), 661–686.
6. Deterding, Sebastian, et al. "From game design elements to gamefulness: defining gamification." *Proceedings of the 15th* (Zhao, 2015) *academic MindTrek conference: Envisioning future media environments*. ACM, 2011.
7. Fiala, Mark. "Designing highly reliable fiducial markers." *IEEE Transactions on Pattern analysis and machine intelligence* 32.7 (2010): 1317–1324.
8. Guillén-Nieto, V., & Aleson-Carbonell, M. (2012). Serious games and learning effectiveness: The case of It'sa Deal!. *Computers & Education*, *58*(1), 435–448.
9. Hamari, Juho, Jonna Koivisto, and Harri Sarsa. "Does gamification work?–a literature review of empirical studies on gamification." *System Sciences (HICSS), 2014 47th Hawaii International Conference on*. IEEE, 2014.
10. Johnson, Larry, et al. *The NMC Horizon Report: 2015 Museum Edition*. New Media Consortium. 6101 West Courtyard Drive Building One Suite 100, Austin, TX 78730, 2015.
11. Khan, Dawar, Sehat Ullah, and Ihsan Rabbi. "Factors affecting the design and tracking of ARToolKit markers." *Computer Standards & Interfaces* 41 (2015): 56–66.
12. Michael, D. R., & Chen, S. L. (2005). *Serious games: Games that educate, train, and inform*. Muska & Lipman/Premier-Trade.
13. Mortara, Michela, et al. "Learning cultural heritage by serious games." *Journal of Cultural Heritage* 15.3 (2014): 318–325.

14. Ott, Michela, and Francesca Pozzi. "Towards a new era for Cultural Heritage Education: Discussing the role of ICT." *Computers in Human Behavior* 27.4 (2011): 1365–1371.
15. Richards, Cameron. "From old to new learning: global imperatives, exemplary Asian dilemmas and ICT as a key to cultural change in education." *Globalisation, Societies and Education* 2.3 (2004): 337–353.
16. Spada, I., Cesaria, F., Chionna, F., Cucinelli, A. M., & Scarano, T. (2017). The Virtual Reconstruction of Torre Guaceto Landscape (Brindisi, Italy). *Conservation Science in Cultural Heritage*, *16*(1), 277–313.
17. Su, C-H., and C-H. Cheng. "A mobile gamification learning system for improving the learning motivation and achievements." *Journal of Computer Assisted Learning* 31.3 (2015): 268–286.
18. Ullmer, Brygg, and Hiroshi Ishii. "Emerging frameworks for tangible user interfaces." *IBM systems journal* 39.3.4 (2000): 915–931.
19. Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van Der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games.
20. Zhao, Pei, Sara Sintonen, and Heikki Kynäslahti. "The pedagogical functions of arts and cultural-heritage education with ICTs in museums–a case study of FINNA and Google Art Project." *INSTRUCTIONAL TECHNOLOGY* (2015): 3.

Quasi–Mixed Reality in Digital Cultural Heritage. Combining 3D Reconstructions with Real Structures on Location—The Case of Ancient Phalasarna

Gunnar Liestøl and Elpida Hadjidaki

Abstract Traditional Mixed Reality as it is currently experienced on popular mobile devices has its obvious limitations in the context of Cultural Heritage. Neither the sensor fusion approach nor the pattern recognition solutions are precise or stable enough to provide a satisfactory visual match between the live video feed and the graphical layer of digital information. The fundamental incompatibility between 2D live video and dynamic 3D graphics also makes this a short–lived solution in a long–range perspective. While we are waiting for sustainable solutions for real time 3D capture and display on mobile and wearable devices it is pertinent to employ and evaluate transitional alternatives for effective use on location . In the research and development reported here we created a static 3D version of the current archaeological site based on photogrammetry. This is done in order to test how it may serve as an intermediate level of representation for increased precision when combining the real present with the reconstructed past. In this chapter we present and discuss the experiences we have gained exploring this type of Indirect Augmented Reality, which we have named 'Quasi–Mixed Reality', on location at the archaeological site of Ancient Phalasarna on western Crete.

Keywords Quasi–mixed reality · Indirect augmented reality · Mixed reality · Situated simulations · Sitsim · Ancient Phalasarna · Photogrammetry

1 Introduction

After a decade of mixed and augmented reality applications available for smartphones and tablets we still have no enduring and satisfactory solution for precise and close coupling of the real and the virtual when visiting cultural heritage sites. Neverthe-

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less, games like Monster Buster and Pokémon GO, as well as applications for finding restaurants, tube stations and much more, are in abundant supply, if not always in wide–spread popular use. Such applications normally combines a live video feed from the phone's physical camera with an added digital 3D graphics layer. These services may work well in pointing out approximate direction and distance to a place of interest in the vicinity of the user. However, in the context of cultural heritage and on site dissemination and explanation their value and usability are more limited.

Archaeological remains and artifacts may be difficult to understand for the untrained eye when exploring the residual structures of an ancient city or settlement on location. While cultural remnants may be relatively easy to distinguish from the natural environment, it will often be completely impossible for the visiting layman to understand their original shape, use and significance. Positioned physical means, like information boards and plaques, may be helpful in providing explanations and interpretations close to the object, but they can never furnish the object with rich and deep contextual information and knowledge without cluttering the environment and thus disturb the cultural experience one initially intends to improve.

The challenge and goal of close coupling in the mixing of digital depiction and physical reality will most probably find sustainable solutions in near future employments of real time 3D capturing and display [1]. Only then can live digital representation of the real environment be fully integrated with and augmented by additional digital representations of various kinds. Meanwhile, we must look elsewhere for interim solutions, and regarding these we should aim to achieve two things: both solve the immediate challenge for better precision, as well as prepare for the forthcoming interfaces, conventions and potential of Augmented and Mixed Reality based on real time 3D capture and display.

In the current situation we may distinguish between two main types of augmented and mixed reality applications on popular mobile devices (smartphones and tablets):

(1) computer vision–based registration/pattern recognition, and
(2) sensor–based registration (aka 'sensor fusion').

The first solution requires a visual mark the pattern recognition software can interpret in order to place the digital 3D object in the right position on the screen and in accordance with the video information (we should here also include emerging camera–based solutions like Apple's ARKit and Google's ARCore). In the second solution, the case of 'sensor fusion', the hardware sensors (GPS, magnetometer, accelerometer and gyroscope) work together to determine the position, orientation and movement of the mobile device, so that the graphics layer can be placed on top of the video feed as precisely as possible [2].

Both approaches have their limitations. With the sensor fusion method it is difficult to attain the graphical match one would require in a cultural heritage context; for example, if you have an ancient monument, such as the base of a building, and you want to add the shape and look of the original structure on top of the current remains (as presented by the video information at the foot of the screen) the graphical layer representing the reconstruction will not attach itself accurately to the (video representation) of the visible structures. Instead it will continue to move as the sensors struggle to calculate and update position, orientation and movement of the device.

The computer vision–based registration functions under other conditions. It is more stable in the alignment of the video images with the 3D graphics objects, but it is dependent upon a continuous visual connection between the fiducial markers (or other forms of visual pattern) and the video camera. If this connection is broken, for example by the interference of other visitors or lack of light, the positioning collapses. In addition, it is neither very practical nor attractive for a cultural heritage site or an exhibition room to place a number of fiducial markers on valuable antique objects or spread out over a large archaeological site.

These methods have room for improvement, and accuracy is continually rectified. Interesting experiments using live 360° video panoramas mixed with point cloud models have shown good accuracy in AEC settings, both indoor and outdoor [3]. Unfortunately, such solutions still require specialized hardware and do not have the kind of mobility and availability we are concerned with in this context, that is: what can be achieved by means of off–the–shelf hardware, primarily and for the time being, smartphones and tablets, and eventually smartglasses.

Regardsless, there is also a limitation of a more fundamental character involved. The mixing of video and graphics produces a profound problem of compatibility: video is 2D and digital graphics in this context is 3D. Allthough this problem can be partly compensated for, the two levels of representation can never be fully integrated [4]. As a consequence we have looked to, and practiced, another form of mobile AR, know in general as Indirect Augmented Reality (IAR) [5].

2 Indirect Augmented Reality

The notion of 'Indirect Augmented Reality' was launched as an ultimate vision of a live representation of the physical world providing increased complexity by "… a large array of video cameras and other sensors that would capture, in real time, the real environment and permit a perfect reconstruction of that environment, in real time, as seen from any arbitrary viewpoint." [5], similar to our anticipated live 3D capture mentioned above. However, IAR has often been associated with still image–based panorama solutions [6], as static image panoramas [5], or as dynamic environments but with constrained movement between predefined positions [7] (Fig. 1).

In our own experiments with situated simulations (sitsim), as a form of Indirect Augmented Reality [6], we have established the mix (in mixed reality) as a relationship between the full screen 3D graphics environment and the real world outside the device. The advantage with this variant of the sensor fusion method is that the lack of positioning precision is not a pressing problem. This is due to the fact that the graphical congruence is not a question of direct match between objects (and levels) on the screen, but a correspondence between the user's visual perception of the real environment and the user's visual perspective into the 3D graphics environment on the screen. This is a solution that has proved itself well in a series of applications for

Fig. 1 To the left an IAR situated simulation from the '*Roman Forum*' AR–application: The user is physically facing the Capitoline hill and the ruins of the rostra (speaker's platform). On the screen one can see Mark Anthony giving his eulogy for the assassinated Julius Caesar. According to Appian a wax copy of Caesar's beaten body was erected on a pole. The image to the right is from the '*Omaha Beach*' AR–application: The user is physically facing east along the beach. On the screen one can see surviving soldiers crossing the upper part of the tidal flat in the early morning on D–Day before finding temporary cover behind the shingle bank on top of the beach. In both these examples the information on the screen (perspective etc.) is updated continually as the user move. Simultaneously the digital environment include animations to represent actions and events

various cultural heritage sites: the Roman Forum, Acropolis in Athens, the Oseberg Viking ship grave mound in Norway, D–Day on Omaha Beach and more [8–11].

However, a problem arises when you have a reconstruction of an ancient site with considerable visual difference between the current archaeological structures and remains and the reconstructions based on the archaeological evidence. This is the case with parts of the Ancient Phalasarna site on the western tip of Crete.

3 Ancient Phalasarna—History, Excavations and Traditional Dissemination

In 333 BC Ancient Phalasarna was turned into a unique fortified harbour built with Persian funding to be used as the main naval base on Crete against Alexander the Great's forces. From here Spartans, Persians and Greeks hoped to retake the Greek islands and Asia Minor from the Macedonians, cut off Alexander's supply routes, and prevent his attack against the great King Darius of Persia. However, Alexander defeated this master plan. Nevertheless, the city was left with a magnificent military port that harboured the Phalasarnian warships for centuries to come. The ancient city was finally destroyed by the Romans in 69 BC. By that time the inhabitants had turned to piracy and were attacked by Roman forces under the command of general Metellus 'Creticus'.

The harbor region of Ancient Phalasarna has been excavated since 1986 [12, 13]. Notable finds include six fortification towers, fortification walls, quays that ringed the harbor, a channel that provided exit to the sea, a winery, a bath house, a road and a merchant's house. Prior to the development and publication of the app described in this chapter the site has been disseminated by means of various modes and media: The first excavations put Phalasarna as an archaeological site into tourist guides and maps for West Crete. It has been the subject of television documentaries (in Greek), articles in newspapers and popular periodicals (in Greek), and has a website. Brochures in Greek and English are available for distribution, and there is a limited amount of signage at the site. Many artifacts are displayed in local museums. Tourists can visit the site without charge during opening hours, and groups frequently request tours from the excavator.

4 Ancient Phalasarna and Quasi–Mixed Reality—The Circular Tower

In 2010 we developed a simple sitsim prototype reconstructing Ancient Phalasarna as of 333 BC. In 2013 this prototype was extended to also include 69 BC and the Roman attack and destruction of the city. These implementations of Indirect Augmented Reality simulations worked well in showing extensive reconstructions and the city as a whole, but they did little to explain the meaning and function of the majority of structures visible on the site today. The visual and figurative difference was just too substantial between the past and the present. The large fortification wall on the eastern slope of the acropolis is relatively easily identifiable as such. However, it is difficult for the visiting layman to understand most of the exposed structures on the site. Even the remaining base of the excavated circular tower on the south east side of the harbour fortifications, despite its characteristic shape, is demanding for visitors to imagine in its original shape (Fig. 2).

Fig. 2 Most people manage to distinguish between natural and cultural structures in the terrain, but it may be difficult to imagine what these remains represent. In the left photo we see a part of the quay and fortified harbour, which today is positioned 6.5 m above ancient sea level. In the photo to the right is the exposed base of the circular tower located on the south–east corner of the Ancient Phalasarna harbor fortifications. How may monuments like these best be reconstructed by means of Augmented Reality (AR)?

It was obviously need for a middle ground, a mode of representation where the current architectural remains could be provided with partial digital reconstructions without loosing the context of the current conditions. As mentioned above, we had already opted out the Mixed Reality solution, while the loose coupling of our preferred Indirect Augmented Reality approach favored large digital reconstructions. How could we better, and with greater detail and precision connect the physical structure of today with a digital version of the missing parts so that visitors could experience less comprehensible parts of the site as whole objects unifying the physical remains with digital augmentations?

The solution was to create a digital 3D version of the archaeological site as it looks today, including both its untouched and excavated areas as well as the surrounding terrain, all based on photogrammetry. This was conducted in two ways: The general area was photographed from a drone at different altitudes, and the excavated parts were captured manually by ground photography. Accordingly, the general site and surrounding area were modelled in relatively low resolution, while a higher density of triangles was earmarked for the excavated and exposed portions (Fig. 3).

The 3D terrain model then records and represents the shape and look of the Ancient Phalasarna harbor installations at the time of the photo sessions (2015–16). With a 3D–model of the current terrain in place it was possible to add reconstructions immediately onto the digital capture of the current state of the sites surface, for example with the circular defense tower on the south–eastern side and the harbour. The tower is 9 m in diameter and is today preserved to a height of 4.5 m. An impressive feature that is noteworthy on this tower is the carved molding above its base. With the *'quasi–mixed reality'* method it was now possible to show, with high accuracy, the past state of this building in matching combination with its present condition [14] (Figs. 4, 5, 6) .

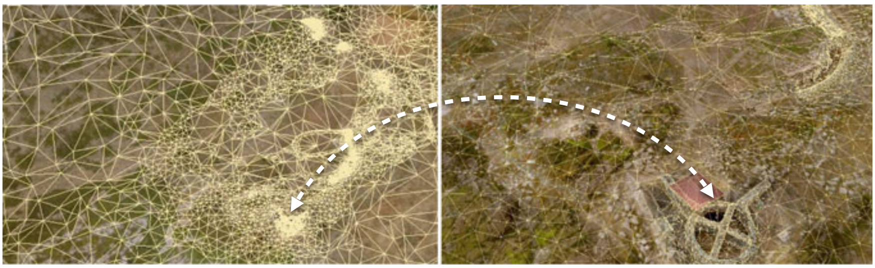

Fig. 3 Different resolution in different parts of the terrain model. In the image to the left one can see the higher density of triangles in certain parts of the site's central area. The image to the right shows a close up of partly the same terrain. The circular tower (at the arrow tips in both pictures) and the excavated quay have a much higher concentration of triangles than the nearby areas, which in this context are of less significance for the purpose of the AR situated simulation

Fig. 4 In the left photo the user is positioned just south–west of the circular tower. In the right photo we see the user's view of the real environment and the corresponding 3D-model on the screen. Note the more limited cut in the real photo than on the screen

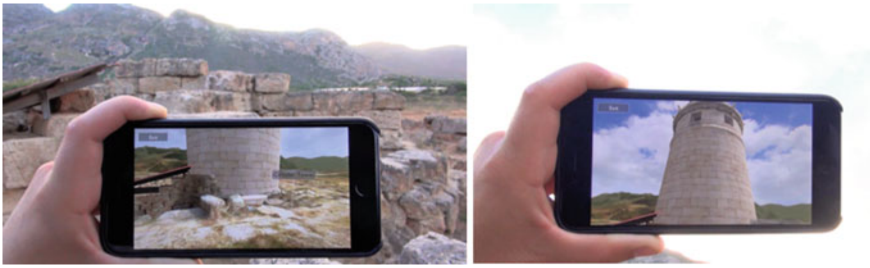

Fig. 5 In the left photo the reconstructed tower appears on top of the base. In the photo to the right the user is tilting the camera (phone) upwards and viewing the top of the tall tower, which in ancient times probably was about 17 m high

Fig. 6 The full sized tower is placed on the digital copy of the real terrain. The sign post in front of the edifice is the spatially positioned hypertext link that activates the graphical reconstruction and its corresponding voice–over. Note the seamless joint between the remaining base and the reconstruction

5 Limits of Quasi–Mixed Reality and Partial Reconstruction—A Ship in a Pond!

Encouraged by the experience with Quasi–Mixed Reality and the partial reconstruction of the circular tower we tried the same approach with another structure: the quay with its characteristic mooring rings. Since the sea level today is 6.5 lower than in ancient times due to an earthquake in western Crete in 365 AD it was important to bring the excavated quay in contact with the sea. We thus moored one of the modelled ships to the 3D–modelled quay and added water around the ship to indicate the ancient sea level and the relationship between quay, mooring, vessel and water. The effect was strikingly informative because at a micro level it brought explanatory context to the excavated structures.

However, it also had a side effect—an almost comic one—which we had not anticipated. The partial reconstruction which worked so well with the tower now, in a wider perspective, had the opposite effect. The limited reconstruction of the ancient sea level in which the moored trireme floated created a visual paradox: it made it look like the opposite of the open connecting ocean—it rather had the appearance of a self–contradiction: a seagoing vessel in a tiny pond! (Fig. 7)

Capturing the real environment of an archeological or cultural heritage site to create a one–frame 3D model of the current surface and terrain represents a promising way of combining existing artefacts and ruins with digital reconstructions. The precision achieved is far superior to the Mixed Reality solutions combining 2D video and 3D graphics. However, the current surrounding is not recorded and represented in real time, so it requires continual updating and revisioning, for example as the excavations unfold and expose new structures.

Our implementation of this Quasi–Mixed Reality mode of combining the real and the virtual—present and past—also shows that it needs to be done with caution. Partial reconstruction proved to be effective in the example with the circular tower,

Fig. 7 In the left photo a partial reconstruction with a ship moored to the quay floating in and surrounded by the water level from ancient times. Although it provides explanatory context by adding the ancient sea level in a limited area the partial reconstruction has a slightly unrealistic side effect: the ship is perceived as floating in a pond without connection to the sea. While the full reconstruction of the harbour as it may have looked in 333 BC, in the wider perspective, provides a much more informative context; the position of the quay in the harbour and its connection to the sea

where the added digital reconstruction completed the existing structure with seamless mending and gave an informative impression of the whole. While on the other hand the quay structure, which was not broken or destroyed, when adding a partial context provided mixed results. In Quasi–Mixed Reality designs it is thus important to understand the different meanings and functions involved in the use of partial and total reconstructions.

The Ancient Phalasarna situated simulation AR app was recently updated and is now connected to a tracking application that records user sessions every time the application is activated and used on location. Feedback from this tracking will be important for future updates of the system.

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References

1. Dai, A., Niesser, M., Zollhöfer, M., Izadi, S., Theobalt, C. (2017) 'BundleFusion: Real–Time Globally Consistent 3D Reconstruction Using ON–the–Fly Surface Reintegration' in *ACM Transactions on Graphics*, Vol. 36, No. 3, Article 24, pp. 24:1–18. Publication date: May 2017.
2. Nurminen, A., Järvi, J., and Lehtonen, M. (2014) 'A Mixed Reality Interface for Real Time Tracked Public Transportation', paper presented at the 10th ITS European Congress, Helsinki, Finland 16–19 June, (2014).
3. Côté, S., Trudel, P., Desbiens, M. A., Giguère, M. & Snyder, R. (2013). 'Live mobile panoramic high accuracy augmented reality for engineering and construction.' In: N. Dawood and M. Kassem (Eds.), *Proceedings of the 13th International Conference on Construction Applications of Virtual Reality*, 30–31 October 2013, London, UK.
4. MacIntyre, B., Lohse, M., Bolter, J. D. & Moreno, E. (2001) 'Ghosts in the Machine: Integrating 2D Video Actors into a 3D AR System' in *Proceedings of the International Symposium on Mixed Reality*, pp 189–202.
5. Wither, J., Tsai, J.-T. and Azuma, R. (2011) 'Indirect augmented reality', *Computer and Graphics*, 35(4): 810–822.
6. Bolter, J. D., Engberg, M. & MacIntyre, B. (2013.) Media studies, mobile augmented reality, and interaction design. *Interactions* 20, 1 (January 2013), 36–45. DOI=http://dx.doi.org/10.1145/2405716.2405726.
7. Madsen, J. B. & Madsen, C. (2013). 'An interactive visualization of the past using a situated simulation approach.' in *Proceeding of Digital Heritage Congress,* pp. 307–314.
8. Liestøl, G. & Morrison, A. (2013) 'Views, Alignment and Incongruity in Indirect Augmented Reality' in Proceedings of ISMAR 2013, *IEEE International Symposium on Mixed and Augmented Reality - Arts, Media and Humanities*. 1–4 Oct. 2013, pp 23–28.
9. Liestøl, G., Rasmussen, T. and Stenarson, T. (2011) 'Mobile Innovation: Designing & Evaluating Situated Simulations' in *Digital Creativity* 2011, Vol. 22, No. 3, pp. 172–184. Abingdon: Routledge, Taylor & Francis Group (2011).
10. Liestøl, G. (2014) 'Along the Appian Way. Storytelling and Memory across Time and Space in Mobile Augmented Reality', in M. Ioannides et al. (Eds.) *Progress in Cultural Heritage: Documentation, Preservation, and Protection*. Berlin Heidelberg: Springer Verlag, pp 248–257.
11. Liestøl, G. (2018) 'Storytelling with mobile augmented reality on Omaha Beach: Design considerations when reconstructing an historical event in situ.' MW18: MW 2018. Published February 16, 2018. Consulted April 28, 2018. https://mw18.mwconf.org/paper/

storytelling-with-mobile-augmented-reality-on-omaha-beach-design-considerations-when-reconstructing-an-historical-event-in-situ/.

12. Hadjidaki, E. (1988). 'Preliminary Report of Excavations at the Harbor of Phalasarna in West Crete'. *American Journal of Archaeology, 92*(4), 463–479. https://doi.org/10.2307/505244.
13. Hadjidaki, E. (2001) The Roman destruction of Phalasarna. In Higham, N.J. (ed.) *Archeology of The Roman Empire, A tribute to the life and works of Professor Barri Jones*. BAR International Series, vol. 940, pp. 155–166.
14. A video of the system in use is available at. https://youtu.be/lphW5YbQaEo.

Digitization of Acoustic Heritage in a Service of Protection, Research and Promotion of European Cultural Heritage

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Abstract Archaeoacoustic research is closely related to the development of information and communication technology (ICT), generating digital data that could be further re-used. In this paper we argue that digitization of cultural heritage should include acoustic heritage in a systematic manner. We show how the sound of historical places could be researched and how it contributes our knowledge on past building practices. In order to provide a closer insight into the contribution of ICT to archaeoacoustic research, we present two examples. The study of Roman theatre in Crete (Greece) points out the significance of virtual acoustics analysis for the architectural reconstruction of theatres, as well as the ability of the digitalization of ancient monuments (above all through 3D models) together with the digitalization of ancient sounds (by the auralisation) to provide a valuable alternative to valorize our past and cultural heritage. The example of presentation of archaeoacoustic research results of Orthodox temples in medieval Serbia proved that public is thirsty of the new experiences and (re)bonding to its (often remote) cultural heritage. The paper considers the need for recognizing acoustic heritage in the framework of international heritage regulations, as a prerequisite for its systematic digitization, and discusses the challenges of acoustic heritage digitization, referring to several projects as poten-

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tial role models—i-Treasures, OpenAIR library, 3D-ICONS. In order to contribute Europeana and make acoustic heritage accessible for further usage, it is necessary to develop guidelines for digitization of acoustic heritage and its presentation through the auralisation.

Keywords Acoustic heritage · Archaeoacoustics · Digital cultural heritage

1 Introduction

The Digital Revolution effects various fields of science and contributes the multi-disciplinary collaborations. Archaeology as well has been attracted by the vortex of the digital innovation. As Zubrow [1] summarized, the impact of digital revolution on archaeology is reflected in several manners: the representation of the real world in a compact and efficient way; counting, doing statistics, manipulating and evaluating measurements summarily and analytically; modelling and simulating real world processes; creation of virtual worlds; worldwide dissemination of the results and representations.

One of the most helpful digital tool for archaeology is the three-dimensional modelling. The 3D reconstruction of historic buildings, monuments and archaeological sites is useful to store data, visualize interpretations in order to verify their accuracy, and to restore the aspect of our cultural heritage that has been destroyed by the flow of time and by human's negligence. In addition, 3D models can be used to develop and carry out analyses which results enhance the study and the knowledge about that specific building or the site. Already in 1994, Lukesh took advantage of 3D models in order to determine the density of artefacts found for each unit of an archaeological excavation [2]. Recently, more advanced analyses have been applied to 3D archaeological reconstructions, such as 3D visibility analysis [3, 4] and virtual acoustics analysis [5, 6]. Nevertheless, they are still not largely implemented.

Information and communication technology (ICT) initiated the development of multidisciplinary fields of research (such as archaeoacoustics, digital archaeology, etc.) that are closely related to the digitization of cultural heritage. Thus, data gathered in the archaeoacoustic research could also be re-used for the wider audience. In this paper we argue that digitization of cultural heritage should include acoustic heritage in a systematic manner. We firstly show how the sound of historical places could be researched and how it contributes our knowledge on building practice of various historical periods. In order to illustrate this and provide a closer insight into the contribution of ICT to archaeoacoustic research, we shortly present two studies—ancient Roman theatre on Crete and medieval Orthodox churches in Serbia. In the next section we consider the need for recognition of acoustic heritage through the prism of international cultural heritage conventions and digital policies. Finally, we discuss the further steps and challenges in digitization of acoustic heritage. Setting the goal to systematically contribute digital acoustic heritage content to Europeana, as the largest platform for digital cultural heritage, we point out the prerequisites and suggest the official recognition of acoustic heritage and the creation of guidelines for its digitization.

2 Researching Sound of Historical Places

2.1 How Is Acoustics Researched in Historical Places?

Archaeoacoustics is a multidisciplinary, interdisciplinary and cross-disciplinary field of research focused on the sound of historical places. Although employing routine acoustic measurements, its multidisciplinary approach enables valuable insights for other scientific disciplines and thus contributes to the interpretation of cultural heritage. The development of ICT has a significant role in reinforcing archaeoacoustic research. The in situ acoustic measurement, 3D modeling and operating the specialized acoustic software became easier and cheaper in the turn of the 21st century. There are two complementary approaches in archaeoacoustic studies, based on the quantitative and qualitative criteria in the evaluation of acoustic heritage.

Impulse response. Acoustic measurement of impulse response in situ is based on recording of appropriate acoustic excitation in a certain space. The impulse response is an acoustic signature or imprint of any closed-space area, containing information about all acoustic parameters defined by modern acoustic science. The measuring procedure requires a test signal that enables the excitement of the space in the entire range of frequencies of interest, of sufficient level to enable the measurement and of such character that can easily be transformed to impulse response through the use of deconvolution function (sine-sweep or MLS signal). These measurements are performed by placing a microphone in the positions of listeners, while sound excitation is played on the speaker in the position of a performer (singer, actor, choir, etc.). This way, we obtain acoustic parameters that quantify the acoustic properties of the space. Various historical places have been researched this way—from prehistoric caves, megalithic temples, cromlechs, antique theatres and sacred medieval architecture.

Acoustic 3D model. In the case of a poor state of archaeological remains or a need to reconstruct the architecture as it was in one specific moment of the past, we can also use three-dimensional model for acoustic research. Computer models enable the comparison of acoustic parameters of various spaces, quick adjustments (such as properties of materials, presence of audience, etc.), auralization and detailed tracking of the direction of sound wave reflection. This method was used for analysis of acoustics of antique theatres, odea and sacred architecture.

Auralisation. Beside above described objective methods of obtaining acoustic parameters, for archaeoacoustics is also important to include the subjective evaluation of sound experience. However, the large distances among historical sites are often an obstacle. Due to the ICT development, this obstacle could be overcome by auralisation of space—a reconstruction of sound in a chosen space that could be heard using subsequent reproduction. Auralisation is an audio equivalent of 3D computer visualization—it forms the basis of an audio reconstruction and presentation of the studied space, thus contributing the multi-sensory recreation of the past [7]. It requires an impulse response, binaurally recorded in situ or obtained in modeling process, and anechoic[1] recording of the sound (speech, song or whatever that was performed in that specific place in the period that we are researching). Combining this "dry" recording with the previously obtained spatial component of the sound for a chosen space, results in a recording of how it would sound in a desired space. In this way, we can compare the experience of sound in different spaces when they are excited with the same acoustic content. Besides using the auralisation for the examination of acoustic heritage, it could also be used for the multi-sensory presentation of cultural heritage.

Subjective evaluation of room acoustics. In the beginning of 21st c., the holistic approach to cultural heritage was adopted. Modern conservation theories, shaped by international conventions, first expanded the limits of cultural heritage from dominantly physical aspect, and then offered everyone to take part in identification, research, evaluation and protection of the heritage. Faro Convention (2005) placed the people and the human values in the centre of the concept of cultural heritage [8]. Regarding acoustic heritage, that implies the necessity to appreciate the experience of modern-day users of historical spaces. In order to get the subjective evaluation of acoustics, we can use auralisation. That way, we can also compare various performances in various places.

2.2 Acoustics in Digital Archaeology: Roman Theatre at Kazinedes in Gortyna, Crete

By means of 3D modelling together with virtual acoustics analysis, it is possible to visualize, analyze and verify the hypothetical reconstructions of historical buildings, and therefore to obtain more information about the poorly preserved monuments. An illustrative example is a research of ancient Roman theatres in Crete. In order to formulate the accurate hypotheses about the theatres' architecture and the typology of performance that were carried on there, seven partly preserved Roman theatres were studied. Only few of them have been completely excavated and investigated (the one in Aptera [9] and the theatre of the Pythion in Gortyna [10]), some are still under examination (the theatre of Hersonissos [11], the one at the acropolis of Gortyna [12], and the small theatre of Ierapetra) and about the others there are only a few remains. Here we consider the case of the theatre at Kazinedes in Gortyna (II-III century AD).

Only few remains of the theatre at Kazinedes in Gortyna are visible on the surface (Fig. 1), but the archaeologist Montali investigated the area and proposed a hypo-

[1] *Anechoic* means that the audio recording has no acoustic environment information already inprinted.

Fig. 1 Orthophoto of the area occupied by the remains of the theatre at Kazinedes, in Gortyna (from Google Earth)

thetical reconstruction of the theatre on the base of the data acquired in situ and on the comparisons with other Roman theatres [13]. He estimated that the theatre could accommodate 5000 spectators. The hypothesis of Montali has been digitally reconstructed in 3D Studio Max and the model has been imported in the software Odeon Room Acoustics which enabled to virtually analyze the acoustic characteristics of the 3D model (Fig. 2).

Acoustics closely corresponds to the geometry of architecture. In the case of ancient theatres, Canac identified the acoustic role of architectural elements as niches, *parodoi* (lateral access to the orchestra), walls, seats, and orchestra's floor [14]. Therefore, besides Montali's, another hypothesis has been also virtually reconstructed and analyzed. This other hypothesis is characterized by the absence of the portico in *summa* cavea and by open corridors between the cavea and the scene, as it might be read from the aerial images and the remains in situ.

In order to evaluate the quality of the theatre acoustics, in both virtual reconstructions we observed and compared following acoustic parameters: reverberation time (T30), early decay time (EDT), clarity (C80), definition (D50) and speech transmission index (STI). There are recommended optimal values for these parameters [15]. The reverberation time T30 around 1 s may be a sign of good comprehension of a spoken performance and around 2 s may be optimal for the listening of a musical performance. Values of C80 over 3 dB generally indicate a good understanding of speech, while under 3 dB should mean a better enjoyment of music. Values of D50 over 0.50 may indicate the ease to understand a speech, under 0.50 are probably more suitable for a good listening of music. The STI above 0.60 indicates a good intelligibility of speech and above 0.75 the intelligibility is excellent [15]. Previous researches demonstrated that the difference between T30 and EDT in open-air

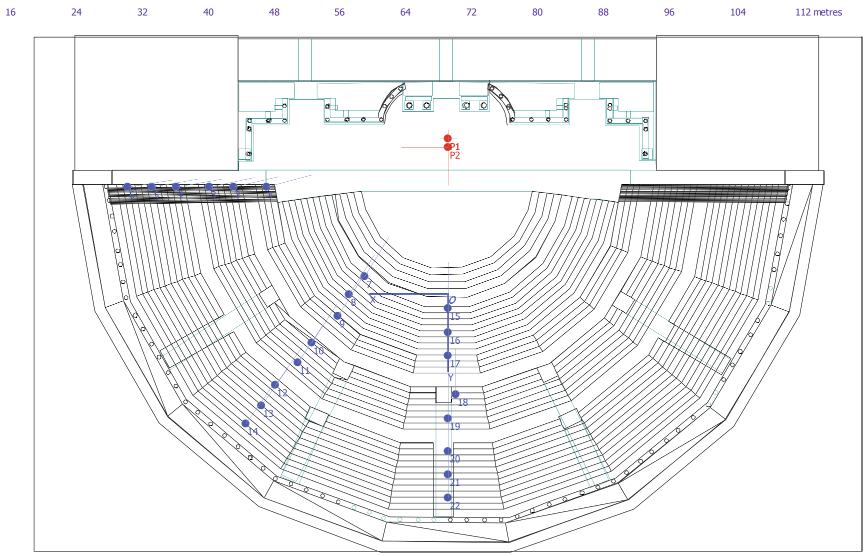

Fig. 2 Top view of the 3D model representing the theatre at Kazinedes according to Montali's hypothesis, with receivers in the seating area and the source on the stage

theatres is generally between 0.2 and 0.4 s, which indicates that the levels of the reverberant sound in the open air theatres are fairly low [16].

Odeon Room Acoustics works with enclosed spaces but here we are dealing with open-air theatres. The proposed solution [17, 18] that is adopted here is to insert the 3D model of the theatre into a bounding box that follows the dimension of the theatre and the open-air effect was simulated giving to surfaces of the box an absorption coefficient equal to 0 and setting the number of rays to 500,000 [19].

After having applied the correct materials to each surface of the 3D models and having placed 22 receivers in the seating area plus one omni-directional source (with an overall gain set at 60 dB) in the central area of the stage of each model, the analysis was initiated. The results are displayed in the Table 1—Montali's hypothesis in gray and in the other reconstruction in white. We observe that for Montali's reconstruction T30 is a bit too high (in particular at low frequencies) for a spoken performance, and too low (at the highest frequencies) for a musical performance. The difference between T30 and EDT exceeds 0.4 s at highest frequencies. The C80 exceeds 3 dB, but not at lowest frequency. The STI value is 0.66. On the contrary, results of the other reconstruction shows that the values of all the parameters are optimal for a good comprehension of the speech; furthermore the STI value is 0.77 indicating an excellent intelligibility of spoken performances. According to the virtual acoustics analysis, the second reconstructive hypothesis may be more reasonable and reliable [20].

The data obtained from the virtual acoustics analyses of all the examined Roman theatres in Crete are going to be inserted in an online database dedicated to the

Table 1 Average values of the acoustics parameters obtained from the virtual acoustics analysis of the 3D model representing Montali's hypothesis (*in gray*) and other reconstructive hypothesis (*in white*)

	T30 [s]	EDT [s]	C80 [dB]	D50
125 Hz	1.71	1.57	2.18	0.50
	1.34	1.12	3.83	0.61
250 Hz	1.51	1.16	4.28	0.61
	1.14	0.79	6.26	0.71
500 Hz	1.39	0.96	6.23	0.70
	0.93	0.66	8.00	0.77
1000 Hz	1.32	0.89	6.43	0.71
	0.86	0.65	8.07	0.77
2000 Hz	1.26	0.77	6.87	0.73
	0.82	0.73	8.37	0.77

architecture of the Roman theatres. It is very important to store and share with the scientific community the values of the acoustic parameters. A wide collection of information about the acoustic quality of ancient theatres, including the ones well preserved and that allow to take measurements in situ, will enable scholars to quickly compare their own results with the previous researches and therefore to achieve more complete and accurate conclusions.

Furthermore, still through the software Odeon Room Acoustics, auralised files have been produced for each receiver placed in the seating area of the theatre. A monolog from "The Trojan women" by Euripides has been recorded in the anechoic room of the Laboratory of Acoustics and Sensors Orso Mario Corbino of the CNR in Rome.[2] The listening of the auralised files confirmed that the second reconstruction is the most probable, if we assume that a good comprehension of the speech was necessary in the Roman theatres. The audio files obtained through the auralisation will be used in a VR application which will allow the user to virtually experience an ancient performance in an ancient theatre.

The implementation of digital models and virtual acoustics analysis open new prospects for the researchers involved in the reconstruction of the architectural structure of ancient theatres: new hypothesis can be formulated and then tested with scientific and quantitative analyses, and new solutions need to be provided in order to store these additional information in an efficient way. In addition, the digitalization of ancient monuments (above all through 3D models) together with the digitalization of ancient sounds (by the auralisation), provides a valuable alternative to valorise our past and Cultural Heritage.

[2]This recording has been produced thanks to the support of Dr. Paola Calicchia, Dr. Cristina Pace and Martina Giovanetti. The resulting values from the virtual acoustics analysis can be found at the website https://romantheatres.ims.forth.gr/, developped at GeoSat ReSeArch Lab.

2.3 Presentation of Archaeoacoustic Research Results: Orthodox Temples in Medieval Serbia

Archaeoacoustic researches of medieval temples tend to answer various research questions—the purpose and efficiency of inbuilt acoustic vessels, the changes of acoustics according to architectural transformations, the comparison of temples from the same or different historical periods, etc. In the case of Serbian architectural heritage, medieval temples and monasteries have a significant place due to their essential role in state-building history and cultural identity. Besides acoustic vessels findings [21], contemporary users—monks and faithful—prove the importance of acoustics and ascribe a significant value to the specific sound characteristics inside the Serbian medieval temples. However, the heritage protection experts overlook its cultural-historic value [22]. In order to draw attention of experts and to bring the acoustic and architectural heritage closer to the wider public, our multidisciplinary team presented the archaeoacoustic research results on the exhibition *Archaeoacoustics: Sacral Architecture of Medieval Serbia*, held in the Museum of Science and Technology in Belgrade, from November to December 2017 [23].

On the exhibition we have presented the application in which the visitor could explore the sound of medieval Serbian churches. Besides readings and preaching, the dominant sound during the divine liturgy is Byzantine chanting, which was continually transmitted from medieval period. Therefore, for the auralisation[3] we have used recordings of Byzantine chanting.[4] In the application the visitor could choose one of the four audio recordings - m/f choir and m/f one chanter - and then hear how it would have heard in four different churches—Žiča (13th c.), Poganovo (14th c.), Manasija (15th c.) and church in village of Brzan (19th c.). Three of the churches are from medieval period and one is a wooden church from 19th c., representing the period under Ottoman rule when monumental building was decreased .[5] Inviting the visitors to compare the acoustics of these temples, we advised them to focus on the overall experience of listening, not only to the audio content but to everything that happens in the sound-excited space (Fig. 3).

The exhibition was very well received. National medias reported on it and during 2018 it was presented in three more museums in Serbia. This proved the interest of public for this kind of cultural content and the results of collaboration of humanities and digital technologies.

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[3]The impulse responses were measured in situ by prof. dr Dragana Šumarac Pavlović and prof. dr Miomir Mijić (Laboratory of Acoustics, Faculty of Electrical Engineering, University of Belgrade).

[4]Byzantine chanting was recordered in the Audio studio of The School of Electrical and Computer Engineering of Applied Studies in Belgrade.

[5]Nevertheless, in these wooden churches the practice of acoustic vessels was transmitted—they were hang by the neck on the ridge beam.

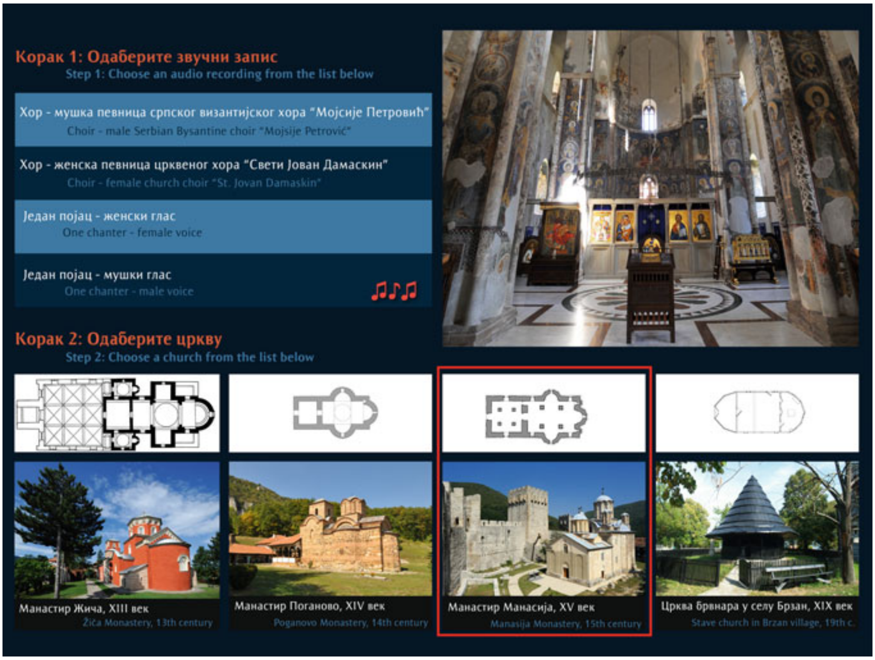

Fig. 3 The interface of the application presented on the exhibition *Archaeoacoustics: Sacral Architecture of Medieval Serbia,* held in the Museum of Science and Technology in Belgrade (2017) and authored by Zorana Đorđević (architecture), Dragan Novković (acoustics) and Marija Dragišić (ethnology-anthropology)

3 The Place of Acoustics in Cultural Heritage Digitization

3.1 Recognizing Acoustic Heritage

Although nowhere officially recognized as such, acoustics of historical places was often considered as acoustic heritage [24–27], referring to "the quantifiable acoustic properties of buildings, sites and landscapes from our architectural and archaeological past" that forms "an important aspect of our intangible cultural heritage" [7]. This approach to acoustic heritage is encouraged by UNESCO Convention for the Safeguarding of Intangible Cultural Heritage (Paris 2003), which recognizes deep-seated interdependence between the intangible and the tangible cultural heritage [28]. Using this recommendation as a guide, acoustic heritage could be defined as an intangible part of building heritage, which unquestionably contributes to its cultural and historical value. In favor of recognizing the acoustic heritage there are various contemporary definitions of conservation which share the orientation towards the preservation of heritage integrity in a manner that enables the continuity of values and significance, as well as the accessibility to current and future generations [29].

In other words, the recognition and valorization of the sound in historical places is in agreement with the contemporary ideas which offer holistic approach to heritage, significantly extending from the physical aspect of the remnants of the past.

The Framework Convention of the European Council on the Value of Cultural Heritage for Society (Faro 2005) recognizes the need to put people and human values at the center of an enlarged and cross-disciplinary concept of cultural heritage [8]. In the case of acoustics of historical places, this document is important because it encourages users of these places to participate in the process of its identification, study, interpretation, protection, conservation and presentation. As acoustics of certain historical places is intentionally designed to contribute the quality of our experience, undoubtedly we can talk about its social value.

3.2 Challenges in Digitization of Acoustic Heritage

In 2003 UNESCO adopted the *Charter on the Preservation of Digital Heritage,* pointing out that "the digital heritage of all regions, countries and communities should be preserved and made accessible, so as to assure over time representation of all peoples, nations, cultures and languages" [30] and thus help the interpretation, communication, and conservation of cultural heritage. The Charter recognizes cultural, educational, scientific, and other information sources, whether initially created as digital or transferred from analogue to digital. Furthermore, it suggests the development of multidisciplinary education and collaboration.

Many EU funded projects are created around these goals of long-term digital preservation of cultural heritage and provide an access for the general public and future generations. Probably the most ambitious one is the project Europeana with the overall target to digitize the entire cultural heritage of Europe by 2025 and make it accessible online through Europeana cultural heritage platform. In this point, the platform gathers more then 50 million artworks, artefacts, print, photographs, museum objects, archival documents, monuments, archaeological sites, books, videos and sounds from across Europe. Europeana engages the research and innovation, education, tourism, and creative sectors [31]. Banding together this wide range of cultural heritage opens the possibility to approach the area where tangible and intangible cultural heritage meet, such as acoustic heritage. Although the recordings of various soundscapes are included, there are no references to soundscapes of historical places, nor acoustic heritage of any kind. In 2011 only 2% of content in Europeana was sound or audiovisual material [32]. Therefore, *Recommendation on the digitization…* encouraged the increase of the underrepresented content accessible through Europeana in order to make the website more interesting for users. Although Europeana website was criticized for limited functions considering intangible cultural heritage [33], the increased interest in this kind of digital content would certainly lead to the improvements of the website functionality. The Council Conclusions on the role of Europeana pointed out the need for some changes. Europeana "encourages the availability of high-quality data ready for re-use which improves availability of cultural heritage on open platforms and social media and promotes its reuse in other sectors", but it needs "to better reach and engage end-users, content shared through Europeana needs to be presented in attractive and diverse ways" [31].

Directive 2013/37/EU of the European Parliament and of the Council emphasizes that digitization ensures the greater online accessibility and re-use of cultural material for education, work, tourism and leisure [34]. The collections of digitized cultural heritage, with corresponding metadata, are a potential basis for the products, services and innovative applications in cross sectoral cooperation. Using ICT in a service of cultural heritage includes collaboration among various research fields. The EU funded project i-Treasures was created in order to develop an open and extendable platform to provide access to ICH resources for both research and education—transmission of traditional intangible and rare arts from living human treasures to new generations. Its goal is to digitally treasure and improve the accessibility and presentation of ICH, and thus raise public awareness [33]. This project is an example of cross-sectoral cooperation with multiple mutual benefits.

Open Acoustic Impulse Response (OpenAIR) library project is specifically focused on digital acoustic heritage. It is an online repository for impulse responses and auralisation data gathered from numerous heritage sites, with the aim to survey, preserve, re-crate and creatively apply obtained acoustic data for music production, mixed media artwork and audio for gaming. Beside it provides the valuable source for archaeoacoustic and virtual acoustic research, it also challenges its presentation and further usage of acoustic data, i.e. combining it with Virtual Reality technology [7].

On the other hand, archaeoacoustic research often provides digital data on acoustic heritage, which could be then further contributed to Europeana or OpenAIR library for public access. In order to contribute with high-quality content, it is necessary to develop a theoretical framework and a guidelines that would be internationally recognized and implemented. Considering digital acoustic heritage as an audio equivalent of 3D computer visualization, it is appropriate to follow the existing guidelines, such as the London Charter principles for the computer-based visualization of cultural heritage that aims to enhance the rigour with which the 3D modelling methods and outcomes are used. It suggests that each community of practice should develop the Implementation guidelines under the theoretical framework of London Charter [35]. Thus, in order to increase its applicability in the field of archaeological heritage the eight Principles of Seville were formulated: interdisciplinarity, purpose, complementarity, authenticity, historical rigour, efficiency, scientific transparency, training and evaluation. Pointing out the need for multidisciplinary cooperation, it also states that "computer-based visualization should seek forms of collaboration with other methods and techniques of different nature to help improve current archaeological heritage research, conservation and dissemination process" [36]. It is a window for acoustic heritage as well. New technologies and the combination of various digitalized objects inbreathe a new value to old contents. For example, 3D model of a reconstructed temple and a divine service from the historical period that we have reconstructed. That way, the visual and audio reconstruction would complement one another.

However, in order to systematically digitize European acoustic heritage and contribute it to Europeana or other platforms, it is necessary to develop a guidelines. For example, there are numerous acoustic parameters (defined within ISO 3382 standard) and they provide different information about room acoustics [37]. Therefore, it is needed to establish which parameter is relevant for the analyzed case, weather it is cromlech, ancient theatre or temple. It is closely related to the type of building as well as to the activity (ceremony, performance, etc.) that took place there. Creating this kind of guidelines would facilitate the comparisons among different buildings and enable the research to follow the same direction, enhancing the archaeological interpretations. As a corresponding example in the Virtual Archeology, there was a 3D-ICONS project that aimed to establish a production pipeline of 3D models of architectural and archaeological monuments, and contribute that digital content to Europeana. The purpose of this project was to produce around 4000 accurate 3D models, process them into simplified forms in order to make them accessible on the web. The 3D-ICONS guidelines elaborated all the steps of the 3D model production and its optimal delivery and display of rich and complex 3D assets online, in an adequate forms, useful to both general public and the researchers [38].

The previous examples showed that digital acoustic heritage has the ability to reproduce values, thus proving its capability to transcend time. Acoustic heritage proves the multidimensional nature of cultural heritage. As an inseparable part of past building cultures, acoustic heritage deserves the systematic research. Only then, we can use it as a guideline in making a building conservation and restauration decisions. Digitization of acoustic heritage contributes the preservation and presentation of cultural heritage. It could increase the application of digital content and add up to the experience of cultural heritage.

4 Conclusion

Digitization of cultural heritage proved its ability to develop over time and engage professionals from various scientific disciplines. Archaeoacoustic research is strongly affected with the ICT development, which lead to the significant increase of the interest in sound of historical places in two last decades. In this paper, we showed how the sound of historical places can be researched and what we can expect from the research results. The study of Roman theatre in Crete pointed out the significance of virtual acoustics analysis for the architectural reconstruction of theatre, which are now destroyed and not well documented. It also emphasized the ability of the digitalization of ancient monuments (above all through 3D models) together with the digitalization of ancient sounds (by the auralisation) to provide a valuable alternative to valorize our past and cultural heritage. The example of how archaeoacoustic research results could be presented using the auralisation, considered the case of Orthodox temples in medieval Serbia. Exhibited in the Museum of Science and Technology in Belgrade, they draw more attention of the wider public and nowadays users of these medieval places than the heritage professionals. This speaks in favor of the fact that the public is thirsty of the new experiences and (re)bonding to its (often remote) cultural heritage. Therefore, in this paper we considered the need for recognizing acoustic heritage in the framework of international heritage regulations, as a prerequisite for its systematic digitization. Finally, discussing the challenges of acoustic heritage digitization, we referred to several projects as potential role models—i-Treasures, OpenAIR library, 3D-ICONS—on the way to contribute acoustic heritage content to Europeana and make it accessible for further usage. In order to achieve this, we pointed out the necessity to develop the guidelines for digitization of acoustic heritage and its presentation through the auralisation.

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References

1. Zubrow, E.: A historical context. In: Evans, P., Daly, P. (eds.): Digital Archaeology. Bridging method and theory. Routledge Taylor & Francis Group, London and New York (2006) 8–260
2. Lukesh, S.: Expanding the Archaeologist's Toolkit: Scientific Visualization of Archaeological Data. In: Imaging the Past: Electronic Imaging and Computer Graphics in Museums and Archaeology, a Conference at the British Museum, London 3rd-5th November, 1994. British Museum Occasional paper No. 114, London (1996) 245–257
3. Landeschi, G., Dell'Unto, N., Lundqvist, K., Ferdani, D., Campanaro, D. M., Leander Touati, A.-M.: 3D-GIS as a platform for visual analysis: Investigating a Pompeian house. Journal of Archaeological Science, vol. 65 (2016) 103–113
4. Manzetti, M. C.: 3D visibility analysis as a tool to validate ancient theatre reconstructions: the case of the large Roman theatre of Gortyn. Virtual Archaeology Review, vol. 7, no. 15 (2016) 36–43
5. Iannace, G., Maffei, L., Trematerra, P.: The Acoustics Evolution of the large Theatre of Pompeii. In: Proceedings of The Acoustics of Ancient Theatres Conference, Patras (2011)
6. Foteinou, A., Murphy, D. T.: Perceptual validation in the acoustics modelling and auralization of heritage sites: the acoustic measurement and modelling of St Margaret's Church, York, UK. In: Proceedings of The Acoustics of Ancient Theatres Conference, Patras (2011)
7. Murphy, D., Shelly, S., Fonteinou, A., Brereton, J., Daffern, H.: Acoustic Heritage and Audio Creativity: the Creative Application of Sound in the Representation, Understanding and Experience of Past Environments. Internet Archaeology, Vol. 44 (2017)
8. Council of Europe: Framework Convention of the European Council on the Value of Cultural Heritage for Society (Faro, 2005)
9. Niniou-Kindeli, V., Chatzidakis, N.: The Roman theatre at Aptera: a preliminary report. In: Francis, J. E., Kouremenos, A. (eds): Roman Crete. New perspectives, Oxbow Books, Oxford Philadelphia (2016) 127–153
10. Bonetto, J., Francisi, D.: Il teatro del Pythion di Gortina: storia di un teatro romano a Creta. In: Proceedings XVIII International Congress of Classical Archaeology, Merida, vol. 1 (2014) 941–944
11. Μανδαλάκη, Σ.: Αρχαιολογικές Ειδήσεις: Νομός Ηρακλείου, Επαρχία Πεδιάδος, Χερσόνησος. Θέατρο. Κρητική Εστία, vol. 7 (1999) 244–258
12. Καντα, Α., Λυριντζης, Α., Νικολοπουλου, Κ.: Το Μεγάλο Θέατρο της Γόρτυνας-Τα πρώτα αποτελέσματα. In: 1° ΔΙΕΘΝΕς ΔΙΕΠΙΣΤΗΜΟΝΙΚΟ ΣΥΝΕΔΡΙΟ ΓΟΡΤΥΝΑΣ, Ηρακλειο (2014) 91–99

13. Montali, G.: Il teatro romano di Gortina. Bottega D'Erasmo, Padova (2006)
14. Canac, F.: L'acoustique des théatres antiques. Ses enseignements. Centre National de la Recherche Scientifique, Paris (1967)
15. Spagnolo, R.: Manuale di acustica applicata. CittàStudi, Torino (2014)
16. Gade, A., Angelakis, K.: Acoustics of ancient Greek and Roman theatres in use today. The Journal of Acoustical Society of America, vol. 120, no. 5 (2006) 3148–3156
17. Lisa, M., Rindel, J. H., Christensen, C. L.: Predicting the acoustics of ancient open-air theatres: the importance of calculation methods and geometrical details. In: Baltic-Nordic Acoustical meeting, 8–10 June, Mariehamn (2004)
18. Iannace, G. Maffei, L., Aletta, F.: Computer simulation of the effect of the audience on the acoustics of the Roman theatre of Beneventum (Italy). In: Proceedings of The Acoustics of Ancient Theatres Conference, Patras (2011)
19. Lisa, M., Rindel, J. H., Gade, A. C., Christensen, C. L.: Acoustical Computer Simulations of the Ancient Roman Theatres. In: ERATO Project Symposium, Istanbul, Turkey (2006) 20–26
20. Manzetti, M. C.: Reconstructing ancient theatres according to virtual acoustics analysis. In: Proceedings of the 2nd Conference on Computer Applications and Quantitative Methods in Archaeology. Greek Chapter (CAA-GR) Athens, December 20th-21st 2016, Athens (2017) 81–87
21. Đorđević, Z., Penezić, K., Dimitrijević, S.: Acoustic vessels as an expression of medieval musical tradition in Serbian sacral architecture. Musicology, Vol. 22 (2017) 105–132
22. Драгишић, М., Ђорђевић, З.: Препознавање и вредновање звука у непокретном културном наслеђу. In: Културно добро - вредност и значење. Завод за заштиту споменика културе града Београда, Београд (2017) 73–83
23. Đorđević, Z., Novković, D., Dragišić, M.: Archaeoacoustics: Sacral Architecture of Medieval Serbia. Museum of Science and Technology—Belgrade, Belgrade (2017)
24. Đorđević, Z.: Intangible Tangibility: Acoustical Heritage in Architecture. Integritet i vek konstrukcija Vol. 16, No 1 (2016) 59–66
25. Elicio, L., Martellotta, F.: Acoustics as a cultural heritage: The case of Orthodox churches and of the "Russian church" in Bari. Journal of Cultural Heritage (2015) 1–6
26. Suárez, R., Alonso, A., Sendra, J.: Intangible cultural heritage: The sound of the Romanesque cathedral of Santiago de Compostela. Journal of Cultural Heritage, Vol 16/2 (2014) 239–43
27. Haddad, N. A.: Reviving the Architectural and Acoustical Theatre Heritage: the Role of ERATO Project. In: Proceedings of the Fifth International Conference of the Center for the Study of Architecture in the Arab Region: Responsibilities and Opportunities in Architectural Conservation: Theory, Education, and Practice, (2008) 421–434
28. UNESCO: Convention for the Safeguarding of Intangible Cultural Heritage (Paris, 2003)
29. Ćosić, N.: Pod lupom: Vrednosti i značaj u procesu konzervacije. In: Kulturno dobro danas—Vrednost i značenje. Zavod za zaštitu spomenika kulture grada Beograda, Beograd (2017) 81–96
30. UNESCO, Charter on the Preservation of Digital Heritage. In: Records of the General Conference, Resolutions, Vol. 1 (2003) 74–77
31. Council of the European Union: The role of Europeana for the digital access, visibility and use of European cultural heritage - Council conclusions (2016)
32. European Commission: Recommendation on the digitization and online accessibility of cultural material and digital preservation (2011/711/EU). Official Journal of the European Union (2011) 39–45
33. Cozzani, G., Pozzi, F., Dagnino, F. M., Katos, A. V., Katsouli, E. F.: Innovative technologies for intangible coultural heritage education and preservation: the case of i-Treasures. Pers Ubiquit Comput, Vol. 21 (2017) 253–265
34. Directive 2013/37/EU of the European Parliament and of the Council. Official Journal of the European Union L 175/1 (2013)
35. London Charter for the computer-based visualization of cultural heritage (2009), http://www.londoncharter.org (accessed on April 1st, 2018)

36. Principles of Seville: International Principles of Virtual Archaeology (2011), http://smartheritage.com/seville-principles/seville-principles (accessed on April 1st, 2018)
37. Lacatis, R., Gim, A., Sevillano, A., Cerd, S., Vera, C.: Historical and chronological evolution of the concert hall acoustics parameters. In: Acoustics 08 Paris, Paris (2008)
38. Corns, A., Deevy, A. Devlin, G., Kennedy, L., Shaw, R.: 3D-ICONS:Digitizing Cultural Heritage Structures. New Review of Information Networking, Vol. 20 (2015) 59–65