Pascale Zaraté Gregory E. Kersten
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LNBIP 180

Group Decision and Negotiation

A Process-Oriented View

Joint INFORMS-GDN and EWG-DSS
International Conference, GDN 2014
Toulouse, France, June 10–13, 2014, Proceedings

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Lecture Notes in Business Information Processing 180

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Preface

The Group Decision and Negotiation meetings aim to bring together researchers and practitioners from the fields of humanities, social sciences, economics, law, management, engineering, decision science, and computer science. These diverse areas are characterized by different paradigms, methods of inquiry, and goals. But the challenges are common including the problems faced by decision makers who face tensions and the conflicts during all phases of the individual and negotiated decision processes. These challenges require researchers to gain insights into the dynamics among independent entities and the results of their interactions. Researchers, in an effort to provide practitioners with knowledge and tools, construct models, methods, and systems that are capable of aiding decision makers and even, in some cases, undertaking some decision-related activities on their behalf.

The GDN 2014 conference was the 14^{th} conference of the INFORMS Section on Group Decision and Negotiation. It was organized jointly with the EURO Working Group on Decision Support Systems (EWG-DSS). The EWG-DSS was founded during a memorable EURO Summer Institute on DSS that took place at Madeira, Portugal, in May 1989. Since then, the group has held meetings in various European countries, and has taken active part in the EURO conferences.

While in the past, GDN members participated in the DSS meetings and vice versa, this is the first joint conference that allows the relationships between these two organizations to be strengthened, thereby leading to the enhancement and enrichment of research projects in individual and group decision support, negotiation and auction support, as well as the design of systems and agents capable of actively participating in individual and group processes and in negotiations.

The GDN 2014 proceedings have two volumes, one Springer volume and one local volume. This volume contains 31 papers selected from among 88 submissions. The full-paper acceptance ratio is 35%, following the Springer LNBIP tradition in preserving a high-quality forum for the next GDN joint editions. Each selected paper was reviewed by at least two internationally known experts from the GDN Program Committee and external invited reviewers. The selected authors are academics, consultants, and software developers coming from Asia, Africa, Oceania, Europe, and the Americas. They represent the whole spectrum of GDN and DSS research, including: ethics and morality; advances in methodological foundations; field and laboratory experiments; system design, construction, and implementation; e-marketplaces and socioeconomic transactions; development of negotiation software agents; linguistics and text analysis; and group decision and facilitation. This GDN Springer LNBIP volume includes the contributions, which have been organized in 11 general topics and are described here.

1. Collaborative Decision Making : 3 papers
   – “Cooperative Decision Making: A methodology Based on Collective Preferences Aggregation” authored by Christophe Sibertin-Blanc and Pascale Zaraté
   – “Enhancing Collaborative Decision-Making Processes Using a Web-Based Application: A Case Study of a UK Precision Engineering SME” authored by Jorge E. Hernandez, David Savin, Andrew C. Lyons and Konstantinos Stamatopoulos
   – “Assessing Mergers and Budget Constraint in Multiple-Unit ICT Procurements – The Cooperation/Competition Dilemma” authored by Driss Zahi
2. Auctions : 3 papers
   – “Are Procurement Auctions Good for Society and for Buyers?” authored by Gregory Kersten
   – “The Effect of Bidding Mechanisms in Online Penny Auction” authored by Hsiangchu Lai, Jack Hsu and Hao-Min Tu
   – “Using Biddings and Motivations in Multi-Unit Assignments” authored by Mireille Ducasse and Peggy Cellier
3. Knowledge Decision Support Systems : 3 papers
   – “Knowledge-Based Decision Support Systems: A Survey on Technologies and Applications Domains” authored by Shaofeng Liu and Pascale Zaraté
   – “On the Use of Cognitive Maps to Identify Meaning Variance” authored by Pierre-Emmanuel Arduin
   – “A Framework for Optimizing Inventory Level of Global Critical Knowledge to Support Group Decision Making” authored by Jiang Pan, Shaofeng Liu, Sarah Tuck and Ali Alkhuraiji
4. Multi-Criteria Decision Making : 7 papers
   – “Dynamic MCDM for Multi-Group Decision Making” authored by Javad Jassbi, Rita Ribeiro and Fatima Dargam
   – “Kapuer : A Decision Support System for Protecting Privacy” authored by Arnaud Oglaza, Pascale Zaraté and Romain Laborde
   – “An MCDM Approach to Group Processes Using Choquet Integration” authored by Silvia Bortot and Ricardo Alberto Marques Pereira
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   – “Bipolar Approach Applied to Group Decision Making Problems” authored by Yasmina Bouzarour-Amokrane, Ayeley Tchangani and François Pérès

5. Multi-Agent Systems : 2 papers
   – "Adapting Agent's Interactions in Dynamic Contexts" authored by Pascal François Mbissane Faye, Samir Aknine, Onn Shehory and Mbaye Sene
   – "Interaction Protocols Adaptation for Negotiation in Opened Multi-Agent Systems" authored by Wassim Chtourou and Lotfi Bouzguenda
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   – "SAW-Based Rankings vs. Intrinsic Evaluations of the Negotiation Offers – An Experimental Study" authored by Ewa Roszkowska and Tomasz Wachowicz
7. Preference Analysis : 4 papers
   – "Making Sense of Intransitivity, Incompleteness and Discontinuity of Preferences" authored by Hannu Nurmi
   – "Preference Elicitation for Group Decisions" authored by Lihi Naamani-Dery, Inon Golan, Meir Kalech and Lior Rokach
   – "On Developing a Web-Based Time Preference Elicitation Engine: Implications for E – Negotiations" authored by Aseem Pahuja, Venkataraghavan Krishnaswamy and R.P. Sundarraj
   – "Using Value Ranges to Reduce User Effort in Preference Elicitation" authored by Emmanuelle Grislin-Le Strugeon
8. Data Analysis : 2 papers
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   – "Analysis of Data from a Corporate Prediction Market" authored by Daniel E. O'leary
9. DSS / GDSS Use : 2 papers
   – "An Integrated DSS Framework for Strategic Planning in Higher Education Institutions" authored by Osama Ibrahim, David Sundgren and Aron Larsson
   – "On Facilitating Group Decision Making Processes with VIP Analysis" authored by Alecsandra Ventura, Luis Dias and JoÃo ClÍmaco
10. Network Analysis : 2 papers
    – "The Network Perspective of Supply Chain Risks to Support Group Decision Making in Fast Moving Consumer Goods in Middle East Region" authored by Karim Soliman, Shaofeng Liu and Dongping Song
    – "A Distributed Decision Making and Propagation Approach for Trust-Based Service Discovery in Social Networks" authored by Amine Louati, Joyce El Haddad and Suzanne Pinson
11. Semantic Tools for Group Decision Making : 1 paper
    – "Semantic Web Tools and Decision Making" authored by Francisco Antunes, Manuela Freire and João Costa

We would like to take this opportunity to express our gratitude to all those who contributed to the 2014 GDN research events in Toulouse, including authors, reviewers, the Program and Organizing Committees, and institutional sponsors.

Collaboration leads to growth, which engenders accomplishment. The GDN 2014 Conference was made possible through the dedication and support of so many. We are very grateful to all participants of the GDN 2014 Conference and also to those who could not attend the meeting. Their contributions, their help in the organization of the sessions, and their efficient and very effective reviewing of the papers made both the meeting and these proceedings possible.

As in all previous GDN meetings, Melvin F. Shakun led us with his good spirit and helping hands. He, together with Colin Eden, Keith W. Hipel, Marc Kilgour, and Floyd Lewis, helped us to adhere to the traditions that took roots from the first meeting in Glasgow, in 2000. Following the memorable meetings in Vienna organized by Rudolf Vetschera, in Karlsruhe hosted by Christof Weinhardt, in Montreal hosted by Gregory Kersten, in Coimbra hosted by João Climaco and João Paulo Costa, in Delft hosted by Gwendolyn Kolfschoten, in Recife hosted by Adiel Teixeira de Almeida, and in Stockholm hosted by Bilyana Martinovski, the GDN 2014 meeting took place in Toulouse and it was hosted by Pascale Zaraté.

We thank the reviewers for their work. It is because of them that we are able to maintain the high academic standard of GDN meetings. Their work is greatly appreciated, especially since they were given little time. Our thanks go to the Program Committee members and the following reviewers : Ehsan Shahamatnia and Leonilde Varela, both from Portugal. Your excellent reviews provided the authors with much-needed feedback.

There have been many people who participated in all the aspects of the meeting and its preparation. Frédéric Amblard, Guy Camilleri, Michèle Cuesta, Véronique Débats, Marlène Giamporcaro, Daouda Kamissoko, Marie-Anne Laplaine, Evelyne Terral.

Financial and in-kind support donated by Toulouse 1 Capitole, Paul Sabatier University, IRIT, Région Midi-Pyrénées, EURO, and INPT-SAIC is gratefully acknowledged.

Finally, we hope you find the contents of this book useful and interesting. We hope the contributions can help you cope with many of the challenges involved in group decisions and negotiations and decision support systems, and that they will be referenced in the future when addressing any of the research areas mentioned.

April 2014

Pascale Zaraté
Gregory E. Kersten
Jorge E. Hernández

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Cooperative Decision Making: A Methodology Based on Collective Preferences Aggregation

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Abstract. The benefice of a collective decisions process mainly rests upon the possibility for the participants to confront their respective points of views. To this end, they must have cognitive and technical tools that ease the sharing of the reasons that motivate their own preferences, while accounting for information and feelings they should keep for their own. The paper presents the basis of such a cooperative decision making methodology that allows sharing information by accurately distinguishing the components of a decision and the steps of its elaboration.

Keywords: Cooperative Decision Making, Collective choices, Preferences Aggregation.

1 Introduction

In most organizations, the vast majority of decisions are taken after intensive consultation with numerous people, rather than by individual decision makers working in larger organizations [1]. In addition, these authors showed that the more complex the organizations become, the less the decisions are taken by lone individuals. According to [2], decision making processes in organizations generally involve several actors in interaction with one another. This interaction implies communication of information and an understanding shared by the decision makers involved in these processes.

The participants in a decision making process must pool their efforts and work towards a common goal, and they have to integrate multiple points of view which may not necessarily be compatible. They have to work together, although not necessarily in the same place or at the same time. They are committed to a coordination effort in order to solve the problem, where they have to divide the task of making the decision into different sub-tasks which will be assigned to individual contributors.

A number of authors have analyzed the process of group decision making from various perspectives. [3] has shown that the use of Information and Communication Technologies in organizations implies a modification of decisional processes. Indeed the

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decisional processes are more complex involving more actors. These modifications are present at two levels; in one hand, at the organizational level, the processes involve more actors at several degrees of responsibilities and in another hand the cognitive processes of decision makers are also modified. They face with an amount of information and must operate an ultra-rapid sorting out of information. New kinds of decision making processes are then defined, called: Cooperative Decision Making.

Several authors have defined cooperation on several points of view. [5] propose to use the definition of cooperative work as a starting point. They characterize cooperative work as people working together, who are mutually dependent for their work and who: support one another in the performance of their respective tasks. This definition is given from the viewpoint of an outside observer of the whole system. Also, *a contrario*, cooperation can be defined from the point of view of each agent involved in the general process. For [6], cooperation is the way of overcoming individual limitations. Cooperation can also be defined as the set of collective actions finalized and developed to deal with individual limitations. Based on this cooperative paradigm several associated concepts must be defined as coordination and collaboration. Cooperation is richer than collaboration in the sense that a mutual support is generated among the stakeholders. Coordination is the management of dependences involved in all collaboration or cooperation processes (for more details on these concepts see [3]).

Based on this paradigm of decision making, the difficulty for decision makers is to make a balance between their own preferences and the arising common preferences of the group. The objective of this this paper is to propose a methodology for the aggregation of the group's collective preferences and the decision makers' individual preferences. This methodology has for objective to support a facilitator involved in a group decision making process, and is not connected to studies developed in the social choice domain for which the collective decision making process is not supported by a system or a facilitator.

This paper is organized in four parties. The first part is devoted to the introduction of our problematic. In a second part, we introduce two kinds of works on which our research is based: a. the Group decision Making tools and the process to use them and b. works coming from tools for social simulation for which the data, hypothesis and methodologies of preferences aggregations are defined.

2 Methodology Context

The proposed methodology is based on several works about group decision making tools.

2.1 Tools for Group Decision Making

Group Decision Support Systems (GDSS) are a widely used collaborative technology that has proven to increase user participation and the quality of decision-making.

They are intended to provide computational support to collaborative decision-making processes [7].

In virtual organizations, GDSSs seem extremely adequate to improve strategic decisions made at the upper levels of the organizational structures, through better information acquisition, perception of different perspectives and options, and consensus formation. This thread leads to an increasing presence of GDSSs in organizations. Thus the facilitation activities must accompany such movement and the facilitator's interest is also kept (see [4]).

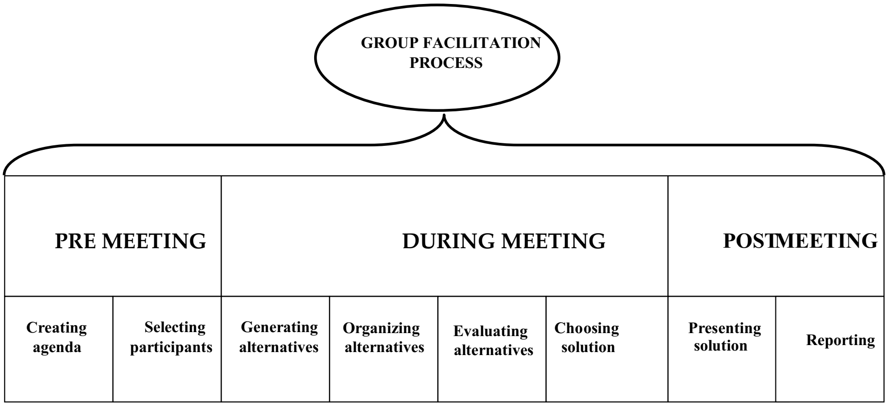


Fig. 1. Group facilitation process

[8] proposed a methodology to use PROMETHEE MCDA systems in a group decision making context. They propose that every decision makers fulfil their own individual preferences in a performances matrix. Then a global evaluation of each alternative is performed thanks to weighted sum aggregation technic. The decision makers could have the same weight or different weights. This is certainly very interesting in order to conduct a sensitive analysis among the stakeholders. Nevertheless, the decision makers have no possibility to share with the other participants their preferences or to co-built a decision. Our purpose is to propose a methodology for decision makers' preferences aggregation in a collaborative way. It means that the decision is co-built by the participants; they exchange their viewpoints trying to design a common representation of the problem at hand and then to reach an agreement or a consensus. It does not imply that all decision makers must share all criteria, preferences and weights, in another words all parameters of the decision. In our approach, the decision makers will agree on several criteria that are called collective criteria but they also can defend individual criteria that are personal to each stakeholder. We develop a methodology able to aggregate individual preferences as well as collective preferences.

To achieve this objective our proposal is based on a procedure able to support the participants in the sharing of information.

2.2 Group Decision Making Hypothesis

One dimension of any group decisions process is sharing information that supports the participants' preferences. The participants may announce their preferred alternative without providing each other arguments about the appropriateness of this alternative to solve the problem at hand. In this case, the decision process does not contribute to a deeper understanding of the problem, a better knowledge of the alternatives and the possible matches between the two. The decision does not benefit from being taken by a group (on the concept of cooperation see [5]. Thus the drivers of the final decision (if any) are not to be searched among the qualities of the alternatives but in exogenous factors like the organizational or social relationships between the participants. On the opposite case, participants may reveal to others all the reasons that justify their preferences while fully explaining the means-ends chain that leads to their choice. In this case, the decision process is the opportunity to investigate the matches between the problem and the alternatives as much as enabled by the participants' abilities, and the final decision will be fully rationalized by the coherent exposure of all the arguments in its favor. However, this way of doing is seldom practicable first because participants have personal information or considerations that they will not (strategic reasons) or may not (for privacy reasons) to be public and second because some reasons of their own preference are not so much crystal clear to themselves.

So a decision-making process methodology must account for the level of information sharing that is the most relevant with respect to the nature of the decision, the position of the participants and more globally the context of the decision process. Several level of information sharing can be considered: (1) information that results from discussion among the participants and are commonly agreed by them; they are considered as objective facts, so that no argument contradicting them should be considered; (2) information that is the own opinion of one of the participants and told to other as such and so are not assumed to be agreed upon by others; these information shed light on the preference stated by the actor but are not part of the participants common agreement; (3) information that are proper to one participant and that he does not make known by others. When using a GDSS, the facilitator should have the possibility to parameterize the tool that supports the decision process to adapt the sharing of information to the context.

It is very common that the group entrusted to take a decision includes on the one hand experts who have a good technical knowledge of the domain and of issues regarding the alternatives to be examined and, one the other one, people who are more versed in the problem side of the decision and will more or less bear the duty and be concerned by the consequences of the decision (e.g. the work to be done to implement the decision, the justification of the decision to stakeholders absent of the decision process, or the entailed changes in his own practice or in the practice of people he is related to). This is not a strict separation since each participant can position himself more or less as an expert or as concerned (or affected) by the decision, but these two roles, these two ways to contribute to the decision-making process, must be considered.

To this end, we propose to distinguish two stages in elaborating the ranking of the alternatives with regard to their relevance as a solution: first the scoring of alternatives with regard to the criteria used for their evaluation and second the suitability of a given scoring to fulfil the need of the problem. The scoring of alternatives is mainly a matter for experts because they are likely to be more experienced in the examination of such alternatives and to have a better (wider and deeper) knowledge of the domain thanks, among others, to interactions within their professional community. As for deciding whether the score of an alternative makes it more or less suitable for the problem, it is rather a matter for the concerned participants who have a better knowledge of the concrete problem, could consider many constraints (most often much more numerous than the criteria) related to details that can reveal to be of importance or can have a temporal perspective about the history and the becoming of the problem.

3 The Proposed Methodology

3.1 The Group Decision-Making Setting

As an illustrative example, consider the selection of a new collaborative platform intended to support the communications and coordination among the employees of a company spread between different sites [9]. The choice is to be made by a *group* of five participants G = $\{p_1, \dots p_5\}$ including two managers representative of the company, one software engineer from a partner company and two academicians, who have to rank a set of eight pre-selected software, the *alternatives* A = $\{a_1, \dots, a_8\}$, according to the quality of the solution they bring to the considered needs.

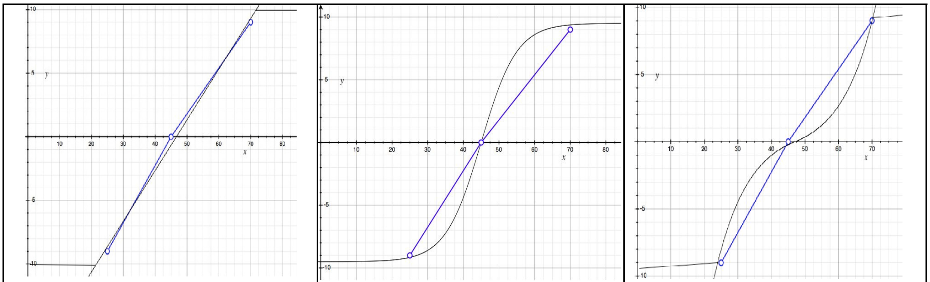
Four *criteria* are considered to evaluate the platforms:

- *Functionality*: it considers the functions related to collaboration (e-mail, calendar, forum, …), each one with its importance weight. The score of an alternative is the total weight of the offered functions over a scale of 100.
- *Cost* of the exploitation license per person and per year.
- *IHM*, the Human-Machine Interface (administration simplicity, usability).
- *Perenniality* of the software editor company and the product itself with regard to its position on the market.

Each alternative is amenable to be evaluated on a *scoring scale* which is either a numerical interval (e.g. functionality and cost) or a qualitative ordinal scale (e.g. IHM and perenniality). In this latter case, each value of the scale must be associated with a description, as much unambiguous as possible, of the characteristics and qualities of an alternative that gets this mark. Low values are assumed to correspond to characteristics that poorly satisfy the criterion and higher values to characteristics that satisfy it increasingly better. But this does not prevent a participant to have an inversed scale of preference and to consider that low values fit better the needs than high values.

For each criteria that is considered, we assume that each participant is able to define a *suitability function* that determines how much each value of the scoring scale of this criterion makes an alternative suitable as a solution, the scale of suitability being the same for all criteria and participant, for instance the interval [-10, 10]. A null suitability for a criterion means that the criterion is fulfilled at an acceptable level which does not particularly recommend or disqualify the alternative; more the suitability over a criterion is high, more the alternative is a good choice, and the converse for negative suitability values[1]. To define the suitability function over a criterion of a participant, he could be asked to indicate, within the scoring scale of the criterion:

- the *neutral score* that provides a null suitability;
- the *indifference score* beyond which a higher value does not increase the suitability;
- the *reject score* below which an alternative is definitely not an appropriate choice;
- *the shape of the interpolation* between the reject and indifference scores; it can be linear if the increase in suitability is proportional to the increase of the score (cf. figure 2.a), sigmoid if the transition between unsuitability and suitability is prompt (cf. figure 2.b), or if there is a plateau in the improvement of the suitability (cf. figure 2.c).



(a) linear improvement of the suitability | (b) sigmoide improvement of the suitability | (c) plateau improvement of the suitability

Fig. 2. various shape of the suitability function for the Functionality criterion, where reject score = 25, neutral score = 45 and indifference score = 70

Moreover, each participant, according to the relative importance he recognizes to each criterion, ranks the criteria by allocating to each of them a weight, every actor having the same total of weights to distribute, for instance 10. A criterion that is weighted by a not null value by a single participant is an *individual criterion* while others are qualified as *common criteria.*

1 [10], confirmed by [11], show that people makes more firm evaluations when they have neutral reference point.

Then, the following notations are used:

$score_p(a, c)$ the score of alternative a on the criterion c for the participant p,
$w_p(c)$ the weight of criterion c for the participant p,
$suit_p^c(x)$ the suitability function of participant p for the criteria c.

The assessment of an alternative a by a participant p will then be defined as:

$$assess_p(a) = \sum_{c \in C} w_p(c) * suit_p^c(score(a, c))$$

where C is the set of all the individual criteria, and the assessment of an alternative a by the whole group of decision-makers as:

$$assess(a) = \sum_{p \in G} assess_p(a).$$

Based on these notations, we propose the following methodology in order to take into account the collective preferences and the individual preferences.

3.2 Proposed Methodology

This methodology aims to allow participants to agree on a set of criteria but also to have their own preferences on some criteria and to share at a more small or large extent the reasons of their choice. This methodology is composed by 7 steps.

Step 1:
After discussion, each stakeholder agrees on the collective criteria. It implies that they find an agreement on the relevant criteria, the scoring scale of each criterion and the score of each alternative for each of these criteria. This assumes that the participants are able to measure the characteristics of each alternative in a quite objective way.

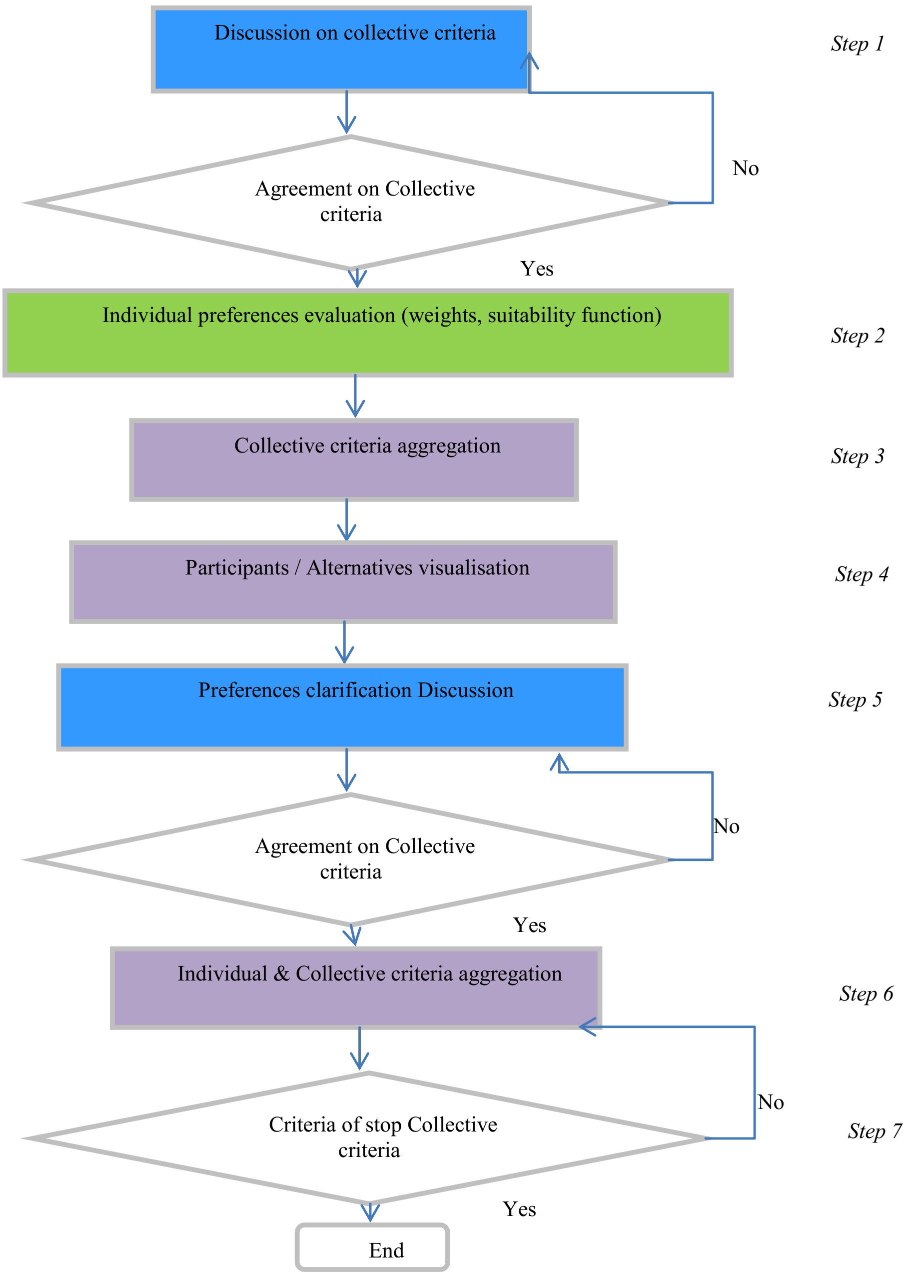
Step 2:
Each participant defines and enters into the GDSS:

- His own weights for the collective criteria and possibly also for additional individual criteria.
- His own suitability functions for all criteria to which it attributes a not null weight.

In the following, we suppose that the individual criteria or preferences are fully private and not shown to the group. However, it could be that a participant introduces a new criterion and wishes it to be known by others and such treated as the collective criteria.

Step 3:
The system computes:

- The global weight and the standard deviation of each collective criterion. This weight will be the sum of all weights assigned by all participants.
- The global suitability function of each collective criterion. This global suitability function is the mean of the suitability function of the participants.
- The global suitability of each alternative on each collective criterion: $suitability^c(a) = 1/5 * \sum_{p \in G} w_p(c) * suit_p^c(score(a, c))$. This global suitability is the mean of the assessments (i.e. the weighted suitability) of the participants.



Step 4:
In this step, the criteria are considered independently one another. The system shows the global weight and the global suitability function of each collective criterion. If all the participants agree, it can also show for each criterion the distribution of the

weights in the form of boxplots and also the dispersion (min and max value at each point of the scoring scale) of the global suitability function.

The system then provides information about the application of weights and suitability to the score of alternatives. It shows the gap between the global suitability of each alternative on collective criterion and the individual suitability of each alternative on individual criteria of each participant. The idea of this visualization is to see if the group forms a barycenter and the position of each participant. During this step the visualization is possible by participants or by alternatives.

Step 5:
The participants can then enter in a discussion step in order to clarify their preferences with regard to criteria. The group can then come back to the steps 1 or 2 in order to remove ambiguities; if the group is satisfied with the results then next step can be proceed.

Step 6:
All preferences are then aggregated: the individual preferences as well as the collective preferences thank to the weighted sum aggregation procedure.

Step 7:
This procedure is finished when the criteria of stop are achieved. These criteria of stop must be parameterized in the system and are based on two criteria: satisfactory level of participants and/or the deadline to make the decision is passed.

The steps of this methodology are shown in the figure 3. The blue steps represent the steps for which a discussion among the stakeholders is engaged. The green step represents a step for which the decision makers give their own preferences in a private way. The purple steps are those for which the system calculate all the necessarily results.

4 Conclusion and Perspectives

In this paper we proposed a methodology for supporting a group decision making process, as the first step toward the development of a group decision support system. This methodology is based on two levels of criteria evaluations: collective criteria and individual criteria. This methodology distinguishes the evaluation of alternatives on these criteria (their score), the weights of criteria and the suitability of a score for a solution to the problem addressed by the decision making process. This structuration of individual preferences favors the sharing of information while respecting the privacy of some individual preferences, and so it allows participants to engage in a co-decision making process to build a shared decision. This methodology will be implemented in a Group Decision Support System, in the JAVA programming language.

The proposed aggregation techniques are very simple and so it is very easy for each participant to understand how the GDSS processes the information he gives. The GDSS does not appear as a black-box and this foster the participants' adhesion to the final decision. However, these aggregation techniques could be refined depending of the kind of groups and of decisions. Another point to investigate is to consider in which cases *reject score* could intervene as veto thresholds. These two elements will be investigated as perspective of this work. This work can be investigated as perspectives.

References

1. Gorry, G., Scott Morton, M.: A framework for management information systems. Sloan Management Review 13(1), 50–70 (1971)
2. Smoliar, S., Sprague, R.: Communication and Understanding for Decision Support. In: Proceedings of the International Conference IFIP TC8/WG8.3, Cork, Ireland, pp. 107–119 (2002)
3. Zaraté, P.: Tools for Collaborative Decision-Making. John Wiley (2013)
4. Adla, A., Zaraté, P., Soubie, J.L.: A Proposal of Toolkit for GDSS Facilitators. Group Decision and Negotiation 20(1), 57–77 (2011)
5. Schmidt, K., Bannon, L.: Taking CSCW Seriously: Supporting Articulation Work. Computer Supported Cooperative Work (CSCW) 1(1) (1992)
6. de Terssac, G., Maggi, B.: Autonomie et Conception. In: de Terssac, G., Friedberg, E. (eds.) Coopération et Conception. Octaves Edition (1996) ISBN : 2-906769-33-9
7. Nunamaker, J., Briggs, R.O., Mittleman, D., Vogel, D., Balthazard, P.: Lessons from a dozen years of group support systems research: a discussion of lab and field findings. Journal of Management Information Systems 13(3), 163–207 (1997)
8. Macharis, C., Brans, J.P., Maréchal, B.: The GDSS PROMETHEE Procedure. Journal of Decision Systems 7(SI), 283–307 (1998)
9. Soner Kara, S., Cheikhrouhou, N.: A multi criteria group decisions making approach for collaborative selection problem. Journal of Intelligent and Fuzzy Systems 26(1) (2014)
10. Slovic, P., Finucane, M., Peters, E., MacGregor, D.G.: The affect heuristic. In: Gilovitch, T., Griffin, D., Kahneman, D. (eds.) Heuristics and Biases: The Psychology of Intuitive Judgment, pp. 397–420. Cambridge University Press, Cambridge (2002)
11. Labreuche, C., Grabisch, M.: Generalized Choquet-like aggregation functions for handling bipolar scales. European Journal of Operational Research 172, 931–955 (2006)

Enhancing Collaborative Decision-Making Processes Using a Web-Based Application: A Case Study of a UK Precision Engineering SME

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Abstract. The precision engineering sector lies at the heart of the UK's manufacturing capability. Successful precision engineering businesses are required to master process innovation and supply chain solutions. Companies operating in this sector support, amongst others, economy-driving industries such as aerospace, defence, motorsport, nuclear, off-highway equipment, oil and gas and renewable energy. The main companies that constitute this sector are SMEs (or small and medium-sized enterprises). In these types of business environment, the implementation of innovative, collaborative solutions has become a necessary strategy for enhancing SME decision-making processes as well as for improving overall business competitiveness. The aim of the research described in this paper is to present how, by implementing a web and online-based collaborative tool, precision engineering SME's can benefit, and are able to enhance their performance, by improving their production planning processes collaboratively. The research is presented with the help of a description of case study undertaken in a precision engineering SME.

Keywords: Collaborative decision-making, Operations Management, Web-based solutions, Precision Engineering.

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1 Introduction

Nowadays, business is undertaken on a global scale and enterprises have to be prepared for intense global competition and for reacting to unexpected changes in the market environment, for instance, in situations where high demand variability occurs. The basis of competition is multi-faceted and competitive performance can be predicated on the quality of the flow of information across enterprises. Hence, and as established by [2], supply chains can be regarded as global networks revolving around a core enterprise and its products while facilitating the cash flow, information flow and goods flow from purchasing materials to delivering the finished products to the final client [2]. Moreover, the size of these enterprises will influence the way in which information is treated and how the decision-making processes are supported. Large companies have a tendency towards long and medium-term relationships. For this, they utilise robust information technologies to mitigate potential information disruptions and also for adding value to their process. On the other hand, SME's operate mainly on a short-term basis and will depend on the requirements from large or medium enterprises.

Nevertheless, as addressed by [5], it has been realised that SMEs contribute the most to any national economy. According to [1], SMEs are the mainstays of the European industrial structure and they are the impeller of contemporary economics. Moreover, SMEs play significant roles in the innovation and knowledge transfer of a country [1]. However, SME survival is difficult in these competitive global environments. This is partly attributable to the relatively lower labour productivity and profitability of SMEs when compared to large companies. Therefore, continuous re-engineering the business processes and improving the performances of operations are critical to SMEs, which do not enjoy the luxury of an under-utilised resource. For this, efficient, agile, flexible and reliable solutions are expected to be employed to tackle the requirements of SME's, particularly for job shop and low- volume batch precision engineers. It has been argued by [11] that precision-engineered products constitute a significant proportion of UK exports. The aim of this paper is to present a real application of a web-based solution in a real SME from the UK's precision engineering sector. Within this it will be shown how these kinds of SME's can benefit from the use of these information technologies by supporting their individual decision-making process accessing shared information in a cloud environment. A conceptual model for the main decision-making process is presented with the purpose of theorising the elements of the case study. The main purpose of the web-based solution is to support the production planning process by enhancing the customer demand visibility.

The contribution from this paper can be seen from the provision of a clear view about the demonstrable applicability of a well-known web-based solution in a complex SME. It is expected that an SME can potentially take advantage of this contribution for dealing with the implementation of its own requirements and collaborative solutions. At first, a conceptual model is introduced providing the main description of the process and information flows from the SME, and primarily focusing on the collaborative production planning process. This is for the purpose of making clear the main elements selected for addressing the web-based solution.

Following this, the next section presents the case study of the SME from the UK northwest region. Guidelines are provided to articulate the implications of the web-based solution and the online support for the decision-making process. Finally, conclusions and further research are presented.

2 A Conceptual Model for the Collaborative Operations Management Decision-Making Process in Precision Engineering SMEs

The modelling domain encompasses the production planning process under a collaborative regime (see Fig. 1). The inputs and outputs of the process have been identified based on the literature and the SME interviews.

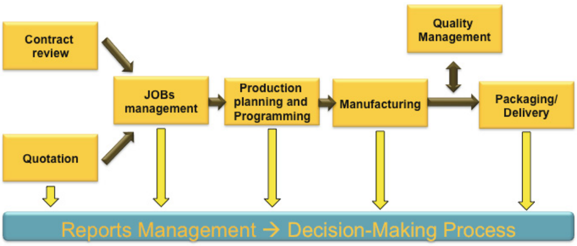

Fig. 1. Decision-making process flow across the precision engineering SME.

For a detailed description of the process, among many modelling languages [6], the IDEF0 approach was selected, since the main governances for these models are the information flow and the decision flow (see Fig. 2). In here, the production planning process is to be related to the information transformation of the materials requirements from the end customers to the lower tier suppliers and the decision-making reflection from the suppliers to the customers.

Therefore, the collaborative production planning process, in the precision engineering SME (PE-SMEs), is built on the real-time demands of the products from the customers of the manufacturer and the real-time materials demands sent from the manufacturer to its suppliers.

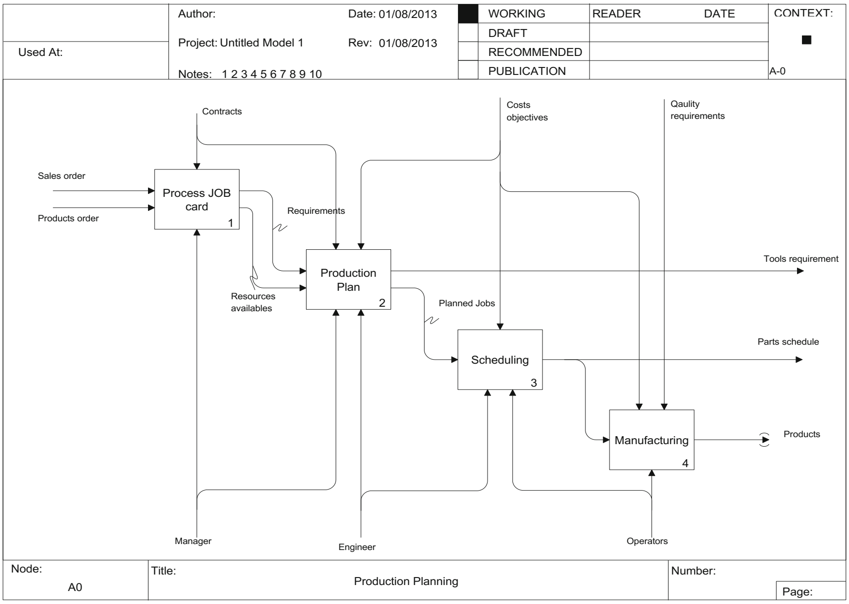

Fig. 2. Production planning information flow for the precision engineering SME.

As depicted in Fig.2, one important activity in the model is the MRP (Materials Requirement Planning). It is calculated by a traditional ERP system. The output of the MRP is part of the input information of the production planning for suppliers. The MRP outputs generally include the components, real-time finished goods inventory and the real-time requirements planning. The outputs of the MRP will be automatically updated to the collaborative platform online.

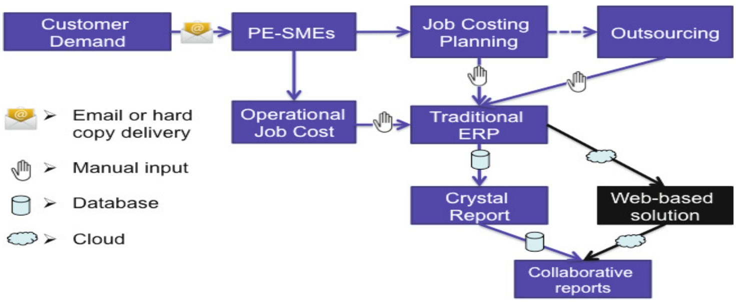

Fig. 3. The conceptual solution for enhancing the decision-making process in precision engineering SMEs.

In this case, the suppliers and the PE-SME will make their production plan based on the MRP outputs of the customers. Meanwhile, the decision flows in the suppliers, manufacturer and customer are also defined in the model. The conceptual web-based solution for the PE-SME is presented in Fig. 4.

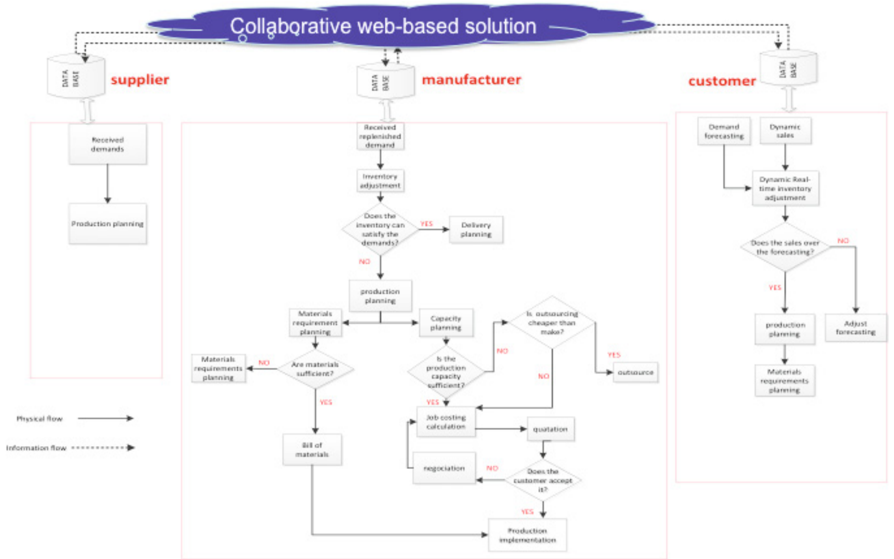

Fig. 4. The conceptual solution for enhancing the decision-making process in precision engineering SMEs.

Hence, and assuming that there are three main roles in the process, Fig. 4 shows that suppliers and customers can be seen as a group of individuals. The customers could be the large companies, which produce the finished precision products, the manufacturer and the suppliers could be the small and medium companies which produce the components for the customers. Then, the operators will compare the quantity of forecasting and the real sales in order to make the decision to replenish the products. Therefore, operators can log on to the collaborative platform and receive the MRP information from the shared ERP database system. From this, collaborative reports will be generated and shared amongst the supply chain parties through the net. The manufacturer can log on to the OPENBOOK and view the customers' MRP and the materials demand. Then, the manufacturer will be able to check its finished goods inventory and support its decision-making process collaboratively. Consequently suppliers and manufacturers are able to report their quotation, capacity, schedule, inventory and productive time to the customers. In this way, the individual decision-making process is now enhanced by up-to-date, shared, accessible and ready-to-use information available in the collaborative web-based system.

3 The Web-Based Implementation in a Real Precision Engineering SME

The case study is based in one precision engineering SME from the northwest region of the UK. This SME is a leading subcontract manufacturer of precision engineering components. It has experienced in supplying the highly-engineered components and assemblies to the customers across the world. The main capabilities of this SME concern CNC machining, wire & spark erosion, precision welding, sheet metal & fabrication, electromechanical clean assembly, testing and finishing solutions. It also operates in many industry sectors such as semiconductor, medical& life sciences, subsea, energy, oil and gas.

The company uses a commercially-available reporting system as a traditional way for reporting its operations' details and performance, and for extracting data from its ERP system. However, operating the reporting system is complex and time consuming. The reports are not customised to the users; once any error occurs or new data needs to be added to the reports, the operator has to start from afresh. Moreover, the ERP and the reporting system are the local systems, and the data from the ERP and the reports made by the reporting system are not visualised and made open to the SME partners. Hence, the management of the operation, in particular the production planning activity, is undertaken without due consideration of the customers and suppliers on-time information and consequently seriously limits the opportunities for introducing more lean and agile approaches for the manufacturing processes. Moreover, the delay of information and the ineffective information transfer processing leads to inaccurate production planning and product shortages. This means the level of customer service is undermined. Therefore, the SME has to improve its business operation processes in order to achieve its vision.

The solution proposed for this PE-SME is oriented to support the re-engineering of its business processes for the production planning with a collaborative planning approach by using a collaborative web-based tool OPENBOOK that is provided by the DNA Agile Group [8]. More solutions to be considered in further improvements can be obtained, for instance, from [7], [8], [9] and [11]. The OPENBOOK is a cloud-based system applied in the wide area network. It can be customised to connect all the parties in the supply chain in a collaborative manner. The database can be seen as a cloudy drive and it fulfils the data connectivity and logic in the cloud. Therefore, SME's can take advantage of this by re-engineering their processes over these types of web-based and online environments.

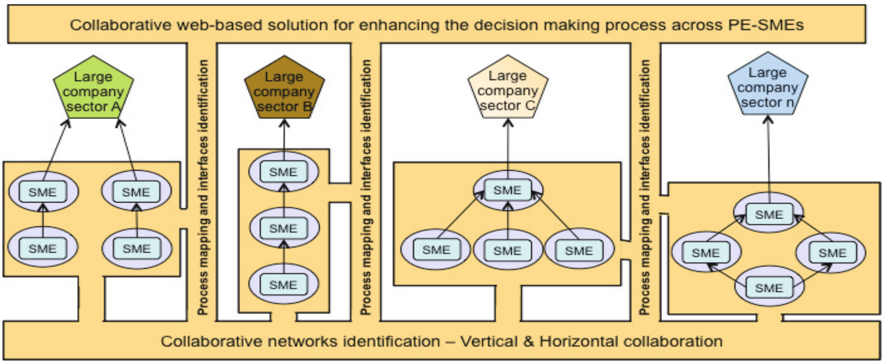

Fig. 5. PE-SME proposed collaborative web-based structure to handle the Openbook web-based solution.

It can be seen in Fig. 5 the collaborative structure over which the supply chain nodes supports their decision-making process. In special the PE-SME uses OPENBOOK for enhancing their visibility respect their customers. In this way, the web-based tool connects the data of both customers and suppliers to the PE-SME. The operators, in every company belonging to the supply chain, can log on to the OPENBOOK and extract the data from the ERP database and share it on the OPENBOOK cloud as reports. At the same time, the other designated people in the company or in the partner companies can see the reports. In this way, the operators in the companies can securely present the real-time business data to other employees, suppliers and customers and enable them to analyse the real time internal and external business status and risks. It is a customised tool for conveniently producing the reports and charts to help the users view and analyse the trends and performance of the business processes. The reports can be customised and the data can be shown in different formats such as tables, bar charts and line charts.

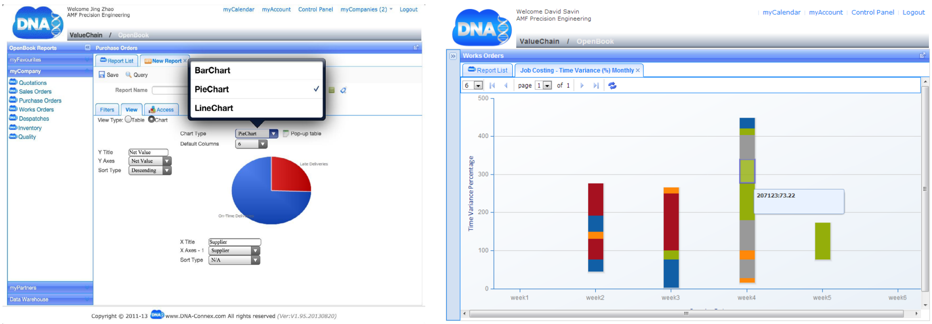

Fig. 6. Customised chart report for the PE-SME.

Hence, and after the application of this web-based tool, there were many benefits received by the manufacturing companies and its suppliers and customers. Firstly, the web-based solution helped the SME employees and its partners in the supply chain to exchange real time information. The real-time information can help the operators promote the informed decision making to avoid the risks associated with inaccuracies in the production planning process. Moreover, the web-based solution for the precision engineering SME has also improved the internal performance of the company by integrating the resources into the collaborative planning process. Therefore, all suppliers and customers in the supply chain can improve the competitiveness and performance by having a convenient mechanism for implementing collaborative supply chain management.

4 Conclusions

In overall terms, this study has provided a detailed analysis of an SME and the concepts of business process re-engineering and enterprise resource planning. This paper will be of particular value to companies who are looking to enhance their decision-making process collaboratively and also want to improve their management systems or operational practices which, in most cases, require a dramatic improvement in the organisation's core competences. It has been shown through this real decision support systems development experience that business re-engineering can help companies to develop more effective management systems and more reliable relationships with partners. Another consideration is that those companies, which have problems with their MRP systems, should strongly consider web-based technologies when seeking transparent and collaborative solutions with their customers. Many of the issues in ERP are just now beginning to be explored, and there is significant opportunity and need for future research and development in this area. Different information users of different enterprises have different demands on information integration. An individualised case study of ERP solutions for different business sectors with different market targets would, to some extent, fill the gaps left by previous studies. It will be interesting to see the evolving influence of ERP systems on small and medium companies' supply chain management. A further piece of research concerns the test of this proposed solution in different SMEs from different sectors across the UK and EU as well consider different coordination mechanisms to ensure the companies are accessing on-time and real-time information.

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References

1. Axelson, R.: Enhancing the competitiveness of EMSs in Europe-a strategic framework for support service. United Nations Economic Commission, pp. 1–32 (2007)
2. Cooper, M.C., et al.: Supply chain management, partnerships, and the shipper-thirdparty relationship, pp. 87–169. Auer Bach Publication, Taylor & Francis Group LLC, US (2004)
3. Dargam, F., Delibasic, B., Hernández, J.E., Liu, S., Papathanasiou, J., Ribeiro, R., Zaraté, P.: Proceesindgs, EWG-DSS Thessaloniki-2013, EURO Working Group on Decision Support Systems Workshop on "Exploring New Directions for Decisions in the Internet Age". IRIT Research Report: IRIT/RR–2013-28—FR (2013)
4. Federici, T.: Factors Influencing ERP Outcomes in SMEs: A Post-Introduction Assessment. Journal of Enterprise Information Management 22(1/2), 81–98 (2009)
5. Ghose, A.K.: SMEs and environment protection. Productivity 42(2), 210–216 (2001)
6. Hernandez, J.E., Lyons, A.C., Mula, J., Poler, R., Ismail, H.S.: Supporting thedecision-making process in a multi-level automotive supply chain with a collaborativemulti-agent system. Production Planning & Control (2013)
7. Kim, Dae, H., Lee, I., Lee, C.K.: Building Web 2.0 enterprises: A study ofsmall and medium enterprises in the United States. International Small Business Journal 31(2), 156–174 (2013) OpenBook (2013), `http://www.dna-agile.com/docs/DNAredthorn%20Brochure.pdf` (accessed December 16, 2013)
8. Peris, M., et al.: Acceptance of Professional Web 2.0 Platforms in Regional SME Networks: An Evaluation Based on the Unified Theory of Acceptance and Use of Technology. In: 2013 46th Hawaii International Conference on System Sciences (HICSS). IEEE (2013)
9. Ponis, S.T., Christou, I.T.: Competitive intelligence for SMEs: a web–based decision support system. International Journal of Business Information Systems 12(3), 243–258 (2013)

10. Precision Engineering Sector Report (2012), from ClearWater, `http://www.clearwatercf.com/documents/sectors/Precision_Engineering_Report_FINAL.pdf` (accessed December 16, 2013)
11. Verhagen, W.J.C., et al.: A critical review of Knowledge-Based Engineering: Anidentification of research challenges. Advanced Engineering Informatics 26(1), 5–15 (2012)

Assessing Mergers and Budget Constraint in Multiple-Unit ICT Procurements - *The Cooperation/Competition Dilemma*

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Abstract. Very often Telecom operators and service providers need to procure multiple products and technologies to deliver services to their end users. Regulatory bodies might issue specific requirements for service delivery in specific areas where operators have no incentive to invest. This is typically the case in mobile communication's industry where operators are forced by the license terms to provide services in low-revenue rural areas. They usually cooperate to build a shared network to reduce the cost of infrastructure while competing in major cities. Similar situation can be encountered in the Fiber to the Home (FTTH) service where the total cost of ownership is extremely high due to the high cost of civil works (e.g. trenching and pulling of fiber).Usually, Telecom authorities encourage operators to share the investment and develop partnerships to overcome the issue of business viability pertaining to high deployment cost. One way of achieving such goal is to deliver products and services under merger to benefit from economy of scale and scope and reduce marginal costs for the required products and services. In the same time, the merging firms are also competing on other standard products and services required by the buyer.

In this document we propose a model for multiple-unit procurement combining Merger and Budget Constraint under Cournot competition. Firms are requested to deliver two products A and B. We assume that the two firms have different marginal costs for product-A, subject to competition while product-B is delivered under merger between the two firms. The empirical part of the article shows that the buyer can comply with the budget constraint by setting a requirement on the minimum quantity of product-B to be delivered by the merger and in the same time optimize the total quantity of products A and B.

Keywords: ICT, Procurement, Oligopoly, Duopoly, Cournot, Merger, Budget Constraint.

1 Research Question

This section highlights our question of research pertaining to multiple-unit procurement under budget constraint. The central goal of this research is to provide an in-depth assessment of the interaction between the suppliers with regard to competition

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and cooperation scenarios on one hand and on the other hand investigate how the buyer can optimize the total acquired quantity under budget constraint. Given the actual state of literature, our research question is to propose a mechanism for multiple-unit procurement under merger and budget constraint.

2 Literature Review

Different variants of mergers among leaders and followers have been investigated in the literature. The results show that these mergers always lead to the emergence of new leaders and followers besides the fact that some of the competitors are eliminated thus maintaining what was identified as merger paradox. The merger paradox has attracted many researchers such as Perry and Porter (1985) who showed that the profitability of a 2-firm merger depends on how convex are the merging firms' costs. Heywood and McGinty (2003) showed that the merger can be more profitable to non-merging rivals thus creating an incentive to free-riding.

Heywood and McGinty (2007a) tried to solve the merger paradox by assessing the impact of the merger on the insider firms with regard to cost saving and economy of scale and scope. They also considered changes in the original assumptions like cost functions of the merged firms.

Research studies on mergers started with Stigler (1950), followed by the work of Salant, Switzer, and Reynolds (1983) and Deneckere and Davidson (1985). The results of their studies show that a horizontal merger that involves less than 80% of the firms in a symmetric linear Cournot oligopoly is likely to be unprofitable; moreover, non-merging firms will most likely react to the merger by increasing their quantities unlike the merged firms. This is known as Insiders' Dilemma or Merger Paradox. This is also shown in Hamada and Takarada (2007).

Deneckere and Davidson (1985) addressed mergers using differentiated products and price competition rather than quantity competition. Farell and Shapiro (1990) studied Cournot merger under cost asymmetry with the perspective of production rationalization of the merger. Levin (1990) analyzed mergers with homogeneous goods under symmetric Cournot competition. He showed such mergers can be profitable if the merged firms have at least 50% pre-merger market share.

Merger under Stackelberg competition with linear market demand and symmetric cost functions was addressed by Daugherty (1990), Feltovich (2001), Huck et al (2001), Escrihuela- Villar and Faulí-Oller (2008). Daughety (1990) investigated the case where two followers merge into a leader (behavioral changing merger) and showed that such merger is potentially profitable. Feltovich (2001) shows that mergers with linear cost lead to a reduction in total welfare.

Huck, Konrad and Müller (2001) investigated Stackelberg merger between firms with linear costs and showed that the merger between a leader and a follower leads to higher profit for the merged firms comparing to their profits before the merger. Huck et al. (2001) and Kabiraj and Mukherjee (2003) state that two leaders (followers) have an incentive to merge in case there is no other leaders (followers).

Gelves (2008) and Takarada and Hamada (2006) focused on mergers involving only two firms. Heywood and McGinty (2008) showed that under that with convex costs assumption, mergers between leaders and between followers are profitable. Escrihuela-Villar and Faulí-Oller (2008) show that a merger between a leader and several followers is always profitable independently from cost structure. They also show that the leadership assumption solves the merger paradox.M cGinty (2007b) and (2008) analyzed the case of Stackelberg mergers under cost convexity. In Heywood and McGinty (2008), the case of single leader merging with one or several followers was addressed while Heywood and McGinty (2007b) focused on mergers involving 2 firms only, both leaders giving rise to a leader or both followers giving rise to a follower.

Contribution

Quantity competition has attracted significant number of researchers. However, few papers are combining mergers and budget constraint in quantity competition. Our work complements the literature by introducing a procurement mechanism combining both competition and cooperation for multiple-unit procurements under budget constraint. We show in our contribution that under budget constraint, the buyer can optimize the total procured quantity by setting requirements on the merger.

3 Model Description

The Cournot Competition

In Cournot competition, both firms make simultaneous move and try to maximize their outcomes. We assume that product-A which is subject to competition, firms have different marginal costs while for product-B which is subject to cooperation they have the same marginal cost.

Product-A

The market demand is given as follows: $P_A = a_A - b_A(q_{1A} + q_{2A})$ where P_A is the price; q_{1A} and q_{2A} are respectively the quantities delivered by firm-1 and firm-2. We define $\prod_{q_{1A}}^{1}$ and $\prod_{q_{2A}}^{2}$ as the profit for firm-1 and firm-2 for product-A.

The profit maximization is calculated using FOC as follows:

$$\frac{\partial \prod_{q1A}^{1}}{\partial q_{1A}} = a_A - 2b_A\, q_{1A} - b_A q_{2A} - c_{1A} = 0 \quad \text{And} \quad \frac{\partial \prod_{q_{2A}}^{2}}{\partial q_{2A}} = a_A - 2b_A q_{2A} - b_A q_{1A} - c_{2A} = 0$$

This leads to the following reaction functions for firm-1 and firm-2:

$$q_{1A} = \frac{a_A - c_{1A} - b_A q_{2A}}{2b_A} = \frac{a_A - c_{1A}}{2b_A} - \frac{q_{2A}}{2} \quad \text{And} \quad q_{2A} = \frac{a_A - c_{2A} - b_A q_{1A}}{2b_A} = \frac{a_A - c_{2A}}{2b_A} - \frac{q_{1A}}{2}$$

By solving the above equations we obtain Cournot quantities q_{1Ac} , q_{2Ac} as follows:

$$q_{1Ac} = \frac{a_A - 2c_{1A} + c_{2A}}{3b_A} \quad \text{and} \quad q_{2Ac} = \frac{a_A - 2c_{2A} + c_{1A}}{3b_A}$$

The price is: $P_A = a_A - b_A(\frac{a_A - 2c_{1A} + c_{2A} + a_A - 2c_{1A} + c_{2A}}{3b_A}) = \frac{a_A + c_{1A} + c_{2A}}{3}$

The profits are:

$$\prod_{q_{1A}}{}^{1} = (P_A - c_{1A})q_{1Ac} = \frac{(a_A - 2c_{1A} + c_{2A})^2}{9b_A}$$

And

$$\prod_{q_{2A}}{}^{2} = (P_A - c_{2A})q_{2Ac} = \frac{(a_A - 2c_{2A} + c_{1A})^2}{9b_A}$$

Product-B

The market demand is given as follows: $P_B = a_B - b_B(q_{1B} + q_{2B})$ where P_B is the price; q_{1B} and q_{2B} are respectively the quantities delivered by firm-1 and firm-2. We assume that the two firms have the same marginal cost c_B and we define $\prod_{q_{1B}}{}^{1}$ and $\prod_{q_{2B}}{}^{2}$ as the profit for firm-1 and firm-2 for product-B.

The profit maximization is calculated using FOC as follows:

$$\frac{\partial \prod_{q1B}{}^{1}}{\partial q_{1B}} = a_B - 2b_B\, q_{1B} - b_B q_{2B} - c_B = 0 \quad \text{And} \quad \frac{\partial \prod_{q_{2B}}{}^{2}}{\partial q_{2B}} = a_B - 2b_B q_{2B} - b_B q_{1B} - c_B = 0$$

This leads to the following reaction functions for the leader and the follower:

$$q_{1B} = \frac{a_B - c_B - b_B q_{2B}}{2b_B} = \frac{a_B - c_B}{2b_B} - \frac{q_{2B}}{2} \quad \text{And} \quad q_{2B} = \frac{a_B - c_B - b_B q_{1B}}{2b_B} = \frac{a_B - c_B}{2b_B} - \frac{q_{1B}}{2}$$

By solving the above equations we obtain Cournot quantities $\boldsymbol{q_{1Bc}}$, $\boldsymbol{q_{2Bc}}$ for product B as follows:

$$q_{1Bc} = q_{2Bc} = \frac{a_B - c_B}{3b_B}$$

The price is: $P_B = a_B - b_B \frac{2(a_B - c_B)}{3b_B} = \frac{a_B + 2c_B}{3}$

The profits are: $\prod_{q_{1B}}^{1} = \prod_{q_{2B}}^{2} = (P_B - c_B)q_{1Bc} = (P_B - c_B)q_{2Bc} = \frac{(a_B - c_B)^2}{9b_B}$

The reaction functions are drawn as follows:

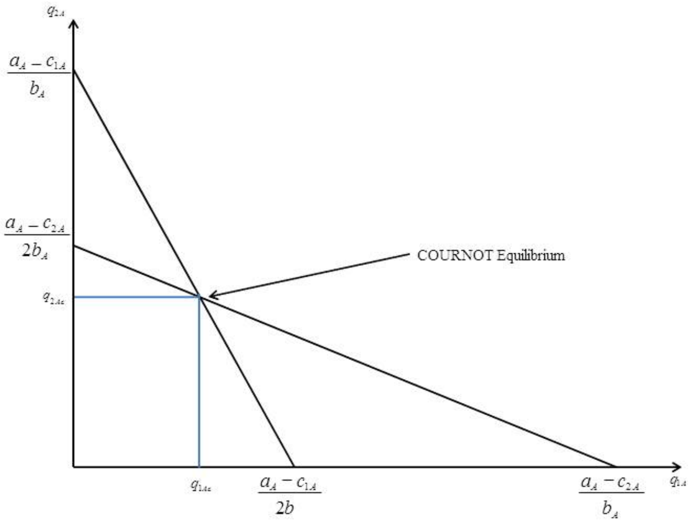

Fig. 1. Reaction curves and Cournot Equilibrium for product-A

The Merger Situation

Before firm-1 and firm-2 merge for the delivery of product-B, their total profit is given as follows:

$$\prod_{q_{1B}}^{1} + \prod_{q_{2B}}^{2} = \frac{2(a_B - c_B)^2}{9b_B}$$

After the merger, the situation becomes a monopoly producing a quantity q_M at a price P_M. The monopoly profit $\prod_M$ is expressed as follows:

$$\prod_M = (P_M - c_B)q_M = (a_B - b_B q_M - c_B)q_M = (a_B - c_B)q_M - b_B(q_M)^2$$

The monopoly profit is maximized for $q_M = \frac{a_B - c_B}{2b_B}$

The price becomes $P_M = \frac{a_B + c_B}{2}$ and the monopoly profit becomes $\prod_M = \frac{(a_B - c_B)^2}{4b_B}$

We can see that firms-1 and firm-2 have incentive to merge as $\prod_M > \prod_{q_{1B}}^1 + \prod_{q_{2B}}^2$

Moreover, the merger's marginal cost c_M will be even lower than c_{1B}, c_{2B} and c_B due to economy of scale and scope.

Budget Constraint

The total budget required for both product-A and product-B is:

$$B = [a_A - b_A(q_{1A} + q_{2A})](q_{1A} + q_{2A}) + [a_B - b_B(q_M)](q_M) \quad (1)$$

We assume that the buyer requests a quantity q_M for product-B higher that the total quantity for product-A. This can be expressed as follows $(q_{1A} + q_{2A}) = \alpha q_M$ where $\alpha \le 1$

(1) becomes $B = (\alpha a_A + a_B)q_M - (\alpha^2 b_A + b_B)q_M{}^2$

The minimum budget $B = 0$ corresponds to $q_M = 0$ or $q_M = \frac{\alpha a_A + a_B}{\alpha^2 b_A + b_B}$

The maximum budget $B_{\max} = \frac{(\alpha a_A + a_B)^2}{4(\alpha^2 b_A + b_B)}$ corresponds to $q_M = \frac{\alpha a_A + a_B}{2(\alpha^2 b_A + b_B)}$

Applying FOC to the budget B we obtain:

$$\frac{\partial B}{\partial q_M} = (\alpha a_A + a_B) \ -2(\alpha^2 b_A + b_B)q_M = 0 \text{ when } q_M = \frac{\alpha a_A + a_B}{2(\alpha^2 b_A + b_B)}$$

To ensure a high quantity for a given budget, the buyer shall target the decreasing part of the budget curve where $\frac{\partial B}{\partial q_M} < 0$. This leads to a quantity $q_M > \frac{\alpha a_A + a_B}{2(\alpha^2 b_A + b_B)}$

Now we assume that the buyer has a limited budget B_0 and we need to determine the corresponding quantity q_{M0} by solving the following: $B = B_0$

$$(\alpha^2 b_A + b_B)q_M{}^2 - (\alpha a_A + a_B)q_M + B_0 = 0$$

We retain the higher solution $q_{M0} = \frac{(\alpha a_A + a_B) + \sqrt{(\alpha a_A + a_B)^2 - 4B_0(\alpha^2 b_A + b_B)}}{2(\alpha^2 b_A + b_B)}$

The buyer shall require a quantity $q_M \geq q_{M0}$ which corresponds to a budget $B \leq B_0$ after deciding the value of α which represents the ratio between product-A and product-B. Figure-2 shows the budget as function of the merger quantity.

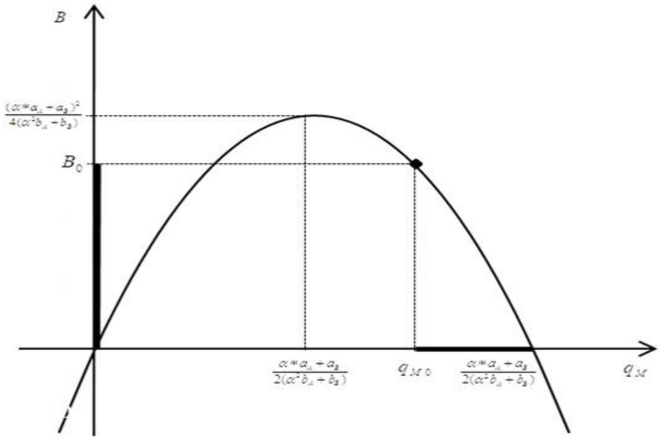

Fig. 2. Budget versus Merger's Quantity

4 Empirical Setup

The experiment consists of computerized simulations involving experienced and non-experienced bidders. The experiments were conducted in two (2) rounds following Cournot competition scheme as described in the model; round-1 is basic Cournot with free ride for product-A, merger for product-B and open budget while in round-2 we add budget constraint. We run 5 simulations in each round which gives a total of 10 simulations. The simulation tool is based on excel and consists of 2 modules; one for the bidder and on for the buyer.

It is important to mention that bidders' were given incentives to participate in the experiment. The winner is the one who succeeds to maximize the sum of the profits over the 2 rounds of the bidding. The market demand function and the profile of the bidders are shown as follows:

Product-A

$$P_A = 10 - Q_A \qquad c_{1A} = 2 \qquad c_{2A} = 3$$

The equilibrium quantities, price and budget are shown as follows:

$$q_{1Ac} = 3 \qquad q_{2Ac} = 2 \qquad P_c = 5 \qquad B_{Ac} = 25$$

Product-B

$$P_B = 14 - Q_B \qquad c_B = 6$$

The monopoly quantity, price and budget are shown as follows:

$$P_M = 10 \qquad Q_M = 4 \qquad B_M = 40$$

We use $\alpha = 0.7$

The requested merger quantity shall be: $Q_M = 4$

5 Results and Analysis

Simulations' results under open budget are shown as follows:

Table 1. Open Budget simulations' results

Simulation #	q1	q2	qM	q1+q2+qM	Profit-1	Profit-2	Budget	Consumer Surplus	Welfare
1	2,50	2,00	5,50	10,00	15,63	11,88	71,50	25,25	52,75
2	3,00	2,00	5,00	10,00	16,50	11,50	70,00	25,00	53,00
3	3,00	3,00	6,00	12,00	12,00	9,00	72,00	36,00	57,00
4	3,00	2,00	5,50	10,50	15,88	10,88	71,75	27,63	54,38
5	4,00	2,00	6,00	12,00	14,00	8,00	72,00	36,00	58,00
Mean:	3,10	2,20	5,60	10,90	14,80	10,25	71,45	29,98	55,03
SD:	0,55	0,45	0,42	1,02	1,82	1,67	0,84	5,59	2,37

Under open budget, the firms try to minimize the merger quantity because of the high marginal cost of product-B and play around the Cournot equilibrium for product-A.

Simulations' results under Budget Constraint (B=73) are depicted as follows:

Table 2. Budget Constraint simulations' results

Simulation #	q1	q2	qM	q1+q2+qM	Profit-1	Profit-2	Budget	Consumer Surplus	Welfare
1	3,50	2,00	7,80	13,30	9,53	3,78	73,11	45,55	58,86
2	3,00	3,00	7,90	13,90	6,40	3,40	72,19	49,21	59,00
3	3,00	3,50	8,00	14,50	4,50	1,75	70,75	53,13	59,38
4	4,00	2,00	8,00	14,00	8,00	2,00	72,00	50,00	60,00
5	3,50	2,00	7,85	13,35	9,34	3,59	73,03	45,94	58,86
Mean:	3,40	2,50	7,91	13,81	7,55	2,90	72,22	48,76	59,22
SD:	0,42	0,71	0,09	0,50	2,12	0,95	0,96	3,13	0,49

When the buyer considers Budget Constraint, the minimal quantity for the merger (product-B) as predicted by the model is communicated to both firms who see their profits decreasing. In the same time we notice an increase of 30% in total quantity and an increase of 7% in the welfare.

We show that under Budget Constraint, our model gives the possibility for the buyer to increase the total quantity as well as the welfare by controlling the merger quantity.

References

Amir, R., Grilo, I.: Stackelberg versus Cournot equilibrium. Games and Economic Behavior 36, 1–21 (1999)

Anderson, S.P., Engers, M.: Stackelberg versus Cournot oligopoly equilibrium. International Journal of Industrial Organisation, 127–135 (1992)

Bain, J.: A Note on Pricing in Monopoly and Oligopoly. American Economic Review, 448–464 (1949); Stackelberg Perfect Equilibria. International Economic Review, 61–71

Bertrand, J.: Theorie Mathematique de la Richesse Sociale. Journal des Savants 67, 499–508 (1883)

Che, Y.-K.: Design competition through multi-dimensional auctions. Rand Journal of Economics 24(4), 668–680 (1993)

Cho, I.-C., Kreps, D.M.: Signaling Games and Stable Equilibria. Quarterly Journal of Economics, 179–221 (1987)

Cournot, A.: Recherches sur les Principes Mathematics de la Theorie de la Richesse. Hachette. In: Bacon, N. (ed.) Researches into the Mathematical Principles of the Theory of Wealth, English edition. Macmillan, New York (1838, 1987)

Dockner, E., Jørgensen, S.: Optimal Pricing Strategies for New Products in Dynamic Oligopolies. Marketing Science 7(4), 315–334 (1988)

Edgeworth, F.Y.: Mathematical Psychics: an Essay on the Application of Mathematics to the Moral Sciences. Kegan Paul, London (1881)

Fjell, K., Pal, D.: A mixed oligopoly in the presence of foreign private firms. Canadian Journal of Economics 29, 737–743 (1996)

Friedman, J.W.: On the Strategic Importance of Prices versus Quantities. Rand Journal of Economics 19, 607–622 (1988)

Friedman, J.W.: Oligopoly and the Theory of Games. North-Holland, Amsterdam (1977)

Hahn, F.H.: The Stability of the Cournot Oligopoly Solution. Review of Economic Studies, pp. 329–331 (1962)

Hamilton, J., Slutsky, S.: Endogenous timing in duopoly games: Stackelberg or Cournot equilibria. Games and Economic Behaviour 2, 29–49 (1990)

Hazledine, T.: Price Discrimination in Cournot-Nash Oligopoly. Economics Letters 93, 413–420 (2006)

Holmes, T.J.: The Effects of Third-Degree Price Discrimination in Oligopoly. The American Economic Review 79, 244–250 (1989)

Kreps, D.M., Wilson, R.: Sequential Equilibria. Econometrica, 863–894 (1982)

Kreps, D.M., Scheinkman, J.A.: Quantity Pre commitment and Bertrand Competition Yield Cournot Outcomes. Bell Journal of Economics 14, 326–337 (1983)

Kutlu, L.: Price Discrimination in Stackelberg Competition. The Journal of Industrial Economics 57, 364–364 (2009), Notes and comments website: `http://www.essex.ac.uk/jindec/`

Levin, D.: Stackelberg, Cournot and collusive monopoly: Performance and Welfare Comparisons. Economic Inquiry, 317–330 (1988)

Manelli, A., Vincent, D.: Optimal Procurement Mechanisms. Econometrica 63, 591–620 (1995)

McAfee, R.P., McMillan, J.: Auctions and Bidding. Journal of Economic Literature 25(2), 699–738 (1987)

Milgrom, P., Roberts, J.: Predation, Reputation and Entry Deterrence. Journal of Economic Theory 27(2), 280–312 (1982)

Munier, B., Rullière, J.-L.: Are Game theoretic Concepts Suitable Negotiation Support Tools? From Nash equilibrium Refinements Toward a cognitive Concept of Rationality. Theory and Decision 34(3), 235–253 (1993)

Murphy, F.H., Sherali, H.D., Soyster, A.L.: A Mathematical Programming Approach for Determining Oligopolistic Market Equilibrium. Mathematical Programming 24, 92–106 (1982)

Riley, J.G., Samuelson, W.F.: Optimal auctions. Amer. Econ. Rev. 71(3), 381–392 (1981)

Thomas, L.G.: Price and Production Decision with Random Demand. Operations Research 22, 513–518 (1974)

Tirole, J.: Theory of industrial organization. MIT Press (1988)

Rothkopf, M.H., Whinston, A.B.: On E-Auctions for Procurement Operations. Production and Operations Management 16(4), 404–408 (2007)

Schmalensee, R.: Output and Welfare Implications of Monopolistic Third-Degree Price Discrimination. The American Economic Review 71, 242–247 (1981)

Shachat, J., Swarthout, J.T.: Procurement Auctions for Differentiated Goods. Decision Analysis 7(1), 6–22 (2010)

Shapiro, C.: Theories of Oligopoly Behavior. In: Schmalensee, R., Willig, R.D. (eds.) Handbook of Industrial Organization. North-Holland, Amsterdam (1989)

Stackelberg, H.F.: Market Structure and Equilibrium (Marketform und Gleichgewicht). Springer, Berlin (1934)

Tunca, T.I., Zenios, S.A.: Supply auctions and relational contracts for procurement. Manufacturing & Service Operations Management 8(1), 43–67 (2006)

Zabel, E.: Multi-period Monopoly and Uncertainty. Journal of Economic Theory 5, 524–536 (1972)

Are Procurement Auctions Good for Society and for Buyers?

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Abstract. Winning bids in reverse auctions are efficient solutions (providing that fairly weak assumptions about the bidders are met). The auctions are efficient, under the assumption that the utilities of all participants are quasi-linear. Typically, this assumption is unrealistic. If that is the case, auctions are inefficient mechanisms. This paper outlines the limitations and impracticability of the quasi-linearity assumption and proposes augmenting reverse auctions with negotiations. It shows that when the efficient frontier is concave, then it is possible to improve the winning bid through negotiations that follow auctions.

Keywords: reverse auctions, negotiations, Pareto optimality, mechanism efficiency, social welfare, quasi-linear utility, utility, efficient frontier.

1 Introduction

Exchange mechanisms, such as auctions and negotiations, are employed when sellers want to sell and buyers want to purchase a good. In business catalogues, negotiations and reverse auctions are typical exchange mechanisms. Buyers purchase goods when price does not exceed its subjective value for them, while sellers sell goods when the value of the good (typically costs) does not exceed its subjective price. This separation of value (costs) and price is violated when the price is a function of such variables as pre-payment, and prices of different components or services. The distinction is also problematic when the suppliers cannot separate price from those attributes of the good which they design to the buyer's specifications. Such a separation may also be difficult for the buyer who has to make separate trade-offs between the price and the good configuration, rather than global trade-offs between the value and the price.

The purpose of this paper is to show that in many circumstances reverse auctions are inefficient mechanisms. They became a pervasive exchange mechanism in the procurement of commodities, products and services because they reduce transaction costs as well as the price the buyer has to pay for the goods. They may be seen beneficial for the buyers who receive very good deals, but as it is shown here, these deals may be improved. Moreover, often they are not be beneficial for the society. Because reverse auctions are widely used in procurement by public organizations, their inefficiency may

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lead to undesired consequences at the macro-economic scale. Business organizations that use auctions should also be concerned because they may accept inferior deals.

Some goods are homogenous others are heterogeneous. When goods are homogenous and the buyers need not distinguish between suppliers (based on their reliability, trust etc.), then reverse auctions are likely to be price-only. If goods are heterogeneous and the good specification is important for the buyer, then the buyer may employ negotiations or multi-attribute auctions. In both types of auctions the buyer's and the sellers' utilities are defined on a set of attributes. In price-only auction the participants may use different attributes which are not revealed. In multi-attribute auctions participants use the same set of attributes, therefore, the discussion here focuses on multi-attribute auctions. However, it should be stressed that the results can be extended to price-only as well as combinatorial auctions.

Let $u()$ be utility defined on the good's N attributes; the attribute values may be real, ordinal, categorical, and nominal numbers:

$$u(\boldsymbol{x}) = u(x_1, x_2, \ldots, x_N),\ \ \boldsymbol{x} = [x_{1, \ldots,} x_N] \in X\,. \tag{1}$$

By convention the first attribute x_1 is price. The remaining N-1 attributes describe the good denoted here as $\boldsymbol{x}_{-1} = [x_{2, \ldots,} x_N]$; $\boldsymbol{x}_{-1}$ is a configuration of the good.

One of the issues discussed here is the relationship between price and other attributes. The standard assumption in auction theory is that *utilities are quasi-linear*, with price being numeraire and its remaining component (good's value or costs) expressed in the same monetary terms as price [1-3].

It is useful to differentiate between buyers and sellers when specifying their quasi-linear utilities because this shows the different role that price and value play on the utility value. Using index b to indicate the buyer and s to indicate the seller, we have the following two quasi-linear utilities:

$$\begin{aligned} u_b(\boldsymbol{x}) &= v_b(\boldsymbol{x}_{-1}) - x_1 \\ u_s(\boldsymbol{x}) &= -\, v_s(\boldsymbol{x}_{-1}) + x_1\,. \end{aligned} \tag{2}$$

Functions $v_b(\boldsymbol{x}_{-1})$ and $v_s(\boldsymbol{x}_{-1})$ are the valuation functions of the good. Valuation function $v()$ is assumed to be strictly concave (twice differentiable with $v_b' > 0;\ v_b'' <$ 0, and bounded from above).

Reverse auctions rely on the quasi-linearity assumption. It is a strong assumption because "it is not in general possible to model a well-behaved exchange economy as a transferable game" [4]. Luce and Raiffa [5] observe that situations in which quasi-linear utilities "can realistically happen remains obscure".

Section 2 discusses quasi-linear utilities and their implications which are relevant to reverse auctions. While these implications are useful because they assure that the reverse auctions are efficient mechanisms which result in efficient solutions, they seldom characterize real-life situations. Section 3 discusses the limitations of the quasi-liner utilities. It also gives examples to support the claim that realistically this type of utilities rarely occur.

The market participants' utilities are typically concave or linear [6-8]. In these situations the winning bid in a reverse auction may be efficient but the auction mechanism is not efficient. Section 4 shows that for such utilities it may be possible to increase the mechanism efficiency without decreasing the buyer's surplus. This increase requires that the buyer and the winning supplier engage in a post-auction negotiation.

2 Quasi-Linear Utility and Its Implications

Reverse auction mechanisms are efficient providing that the buyers' and suppliers' utilities are quasi-linear. This section reviews the key characteristics of such utilities and their use in reverse auctions.

2.1 Efficient Configuration

A solution obtained from the application of an exchange mechanism is efficient if it lies on the contract curve. When the utilities are quasi-linear, then there is only one efficient configuration for every supplier (see also [9]).

Proposition 1: If quasi-linear functions $u_b(\boldsymbol{x})$ and $u_s(\boldsymbol{x})$ represent the buyer's b and the supplier's s utilities respectively, and set $\tilde{X}_i$ is the set of efficient solutions representing possible trades between b and s, then there is only one efficient configuration of non-price attribute values $\tilde{\boldsymbol{x}}_{-1}$.

Proof (outline):: Assume that there are different efficient configurations ($\tilde{\boldsymbol{x}}_{-1}$ and $\dot{\boldsymbol{x}}_{-1}$) and let define pairs of indifference curves (U_{bj}, U_{sj}, j=1,2 …). Each pair is tangential at the same point; $\tilde{\boldsymbol{x}}_{-1}$ is tangential for (U_{b1}, U_{s1}) and $\dot{\boldsymbol{x}}_{-1}$ is tangential for (U_{b2}, U_{s2}). Let $d = \tilde{x}_1 - \dot{x}_1$ and define a pair of indifference curves tangential at a point $\dot{x}_1 = \tilde{x}_1 - d$. If tangential point $(\dot{\boldsymbol{x}}_{-1}, \dot{x}_1)$ of pair (U_{b2}, U_{s2}) is different from tangential point $(\tilde{\boldsymbol{x}}_{-1}, \tilde{x}_1)$ of pair (U_{b3}, U_{s3}), the difference has to be in their respective components $v_b(\boldsymbol{x}_{-1})$ and $v_s(\boldsymbol{x}_{-1})$. This requires that $v_b(\boldsymbol{x}_{-1})$ and $-v_s(\boldsymbol{x}_{-1})$ be tangential at two different points $\dot{\boldsymbol{x}}_{-1}$ and $\tilde{\boldsymbol{x}}_{-1}$ which is not possible because by definition they are concave. ♦

Proposition 1 holds that the buyer's and every supplier's utilities are quasi-linear. According to this proposition every supplier may have only one efficient configuration of the good. All but one configuration are inefficient irrespectively of their price.

2.2 Mechanism's Efficiency

An exchange mechanism is efficient if its solutions maximize joint utility of the buyer and the supplier. Auction theory uses the sum of the utilities as a joint utility function and such a function is also used here. One reason for using the sum appears to be the fact that auction mechanisms, which are used by buyers and suppliers with quasi-linear utilities are efficient.

The joint utility function w_{sb} is social welfare and it is the sum of the buyer's and supplier's utilities [9], [10]:

$$w_{sb} = u_b(\boldsymbol{x}) + u_s(\boldsymbol{x}) = v_b(\boldsymbol{x}_{-1}) - x_1 + x_1 - v_s(\boldsymbol{x}_{-1}) \\ = v_b(\boldsymbol{x}_{-1}) - v_s(\boldsymbol{x}_{-1}) \,. \tag{3}$$

From (8) it follows that the *efficiency of the mechanism does not depend on price* x_1, which buyer b pays the winning supplier s for good $\boldsymbol{x}_{-1}$.

According to Proposition 1, for every supplier there is a unique configuration $\boldsymbol{x}^*_{-1}$ which is efficient irrespectively of the price. Although every price is feasible, not every price can be accepted by the buyers and the suppliers. It is natural to assume that the buyer will not pay more than the value of the good and the suppliers will not accept a price that is lower than the costs of producing the good, i.e., their utility values are non-negative. The mechanism's efficiency maximization problem is as follows:

$$\max_{\boldsymbol{x}\in X, s\in S}\left(u_b(\boldsymbol{x}) + u_s(\boldsymbol{x})\right) = \max_{\boldsymbol{x}\in X, s\in S}\left(v_b(\boldsymbol{x}) - v_s(\boldsymbol{x})\right). \quad (4)$$

subject to:

$$v_b(\boldsymbol{x}_{-1}) - x_1 \geq 0. \quad (5)$$

$$v_s(\boldsymbol{x}_{-1}) + x_1 \geq 0 \ (s \in S). \quad (6)$$

Assume that supplier s^* is the winner and maximum social welfare is obtained when good $\boldsymbol{x}^*_{-1}$ is selected. If price does not affect welfare, then problem (4)-(6) maximizes social welfare for buyer b and m suppliers ($S = \{1, \ldots, m\}$). This can be generalized to every reverse auction in which utilities are quasi linear. Let:

$B = (1, 2,. \ldots)$ – the set (possibly infinite) of all possible buyers;

$S^b = (1, \ldots m_b)$ – the set of all suppliers who participate in the reverse auction in which b is the buyer; and

$RA_{q\text{-}l}(b)$ – the reverse auction mechanism in which utilities of all participants, i.e., buyer b, $b \in B$, and suppliers s, $s \in S_b$) are quasi-linear.

Proposition 2: Reverse auction mechanism $RA_{q\text{-}l}(b)$, $b \in B$, is efficient.

Proof (outline): The proof of this proposition directly follows from Proposition 1 and the fact that the solution of the maximization problem (4)-(6) does not depend on any other assumption regarding the buyers' and the suppliers' characteristics than the quasi-linearity of their utilities. In other words, if an auction $RA_{q\text{-}l}(b)$ set up by buyer b has a winner, then the winning bid maximizes social welfare. ♦

3 Limitations

Reverse auctions of the $RA_{q\text{-}l}$ type are efficient mechanisms and their outcomes are efficient solutions. Their underlying assumption is, however, strong and often unrealistic.

3.1 An Illustrative Example

Decision and negotiation analyses deal with problems which individuals and firms encounter when they need to choose one alternative from among many. They focus on constructing and solving models in which decision space is continuous or discrete and in which utility functions are linear, convex, quasi-convex or piece-wise convex.

Raiffa, Richardson and Metcalfe [9] present an example of a negotiation problem in which Amstore, a large retail firm, needs to build a new store and seeks a contractor.

The firm engages in a negotiation with a single contractor, Nelson. They need to agree on the values of three attributes: *price*, *design*, and *delivery time*. Each decision-maker has a preference structure which can be represented by a scoring function. Armstore, rather than transacting with a single contractor, sets up a multi-attribute reverse auction and uses it to select the contractor who would offer the best terms.

In the case discussed by Raiffa at al. [9] Armstore and Nelson valuate price differently, i.e., they assign different scores to price values. Therefore, their scoring functions are not quasi-linear. However, even when the scoring function used is similar to quasi-linear in that price is numeraire and other attributes' values are converted to money, the results may also differ. The attributes, attribute values, and the scores for the buyer (Armstore) and supplier S1 (Nelson) are shown in Table 1.

Table 1. Buyer's and supplier's attributes, their values and scores

Attribute	Value	Score (in $000s)	
		Buyer	**Supplier 1 (S1)**
Price ($000s)	90	90	90
	100	100	100
	110	110	110
Design	Complete	100	40
	Enhanced	95	25
	Basic+	70	17
	Basic	60	15
Delivery date	Long	45	10
	Medium	45	30
	Short	55	30

The set of feasible alternatives for all possible configurations of the three attributes in the scoring space is shown in Figure 1. Scores are calculated in the way that is typical for multi-attribute auctions [13], that is, the buyer's score is: $u_b = v_{b,\text{ Design}} + v_{b,\text{ Delivery}} - Price$. For S1, the score is: $u_1 = Price - v_{1,\text{ Design}} - v_{1,\text{ Delivery}}$.

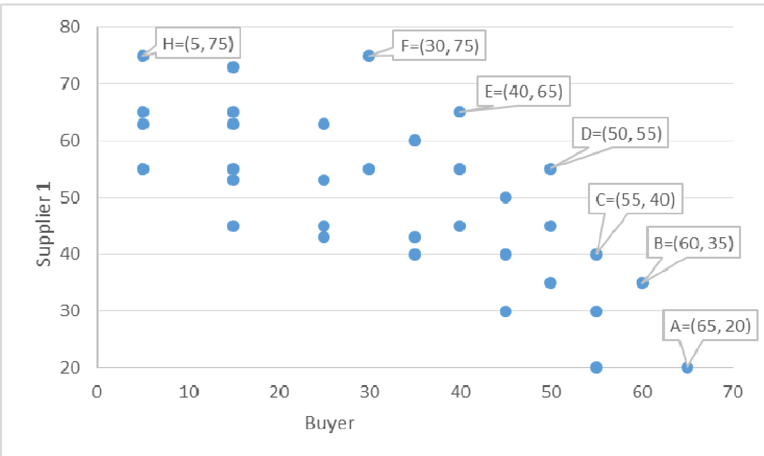

Fig. 1. Alternatives in scoring space; A to H are efficient

The buyer's and the supplier's scores for the selected alternatives are also shown in Fig. 1. The efficient frontier comprises six alternatives (A to F), however, only alternatives D, E and F maximize social welfare which is $105,000. Social welfare of other efficient alternatives (i.e., A, B and C), ranges from $85,000 to 95,000. This shows that some efficient alternatives maximize the social welfare and some do not.

It may not be possible to achieve social welfare equal to $105,000 when a reverse auction is used. If a supplier, other than S1, submits bid *B*, which yields the buyer's surplus equal to $60,000, then S1 either submits bid A (buyer's surplus is $65,000) or quits. Because S1's surplus at A is $20,000, she bids A and wins the auction. If this is an English auction (second-highest-bid), then the social welfare is $95,000; if it is the highest-bid auction, then social welfare is $85,000. Although the winning bid is an efficient solution the mechanism is inefficient.

The possible increase of social welfare is 10.5% for English auction and 23.5% for the highest-bid auction.

3.2 Multi-attribute Reverse Auctions

Single attribute auctions discussed in literature, including cases presented by providers of auction systems, do not offer information about the buyers' and the sellers' preferences. Therefore, in this section multi-attribute auctions are discussed.

Mars, Inc. set up a software platform for combinatorial and a multi-attribute auctions [10]. The attributes used in a number of auctions included payment and its terms (e.g., pre-payment, payment date, and discount) as well as turnaround time, delivery schedule, product quality, type of material, and color. It is likely that the payment and the different terms of payment were interdependent. In such a situation they should be incorporated into a single attribute "price". They could not, however, be combined with the payment attribute because they were subject to bidding. In effect the scoring function was not be quasi-linear.

The E.U. directives (Article 55 in 2004/17/EC or Article 53 in 2004/18/EC) require that public contracts be allocated by competitive bidding. The procurement authority has to either use a scoring function in which price and other attributes and their weights are given or a lexicographically ordered list of attributes. The scoring bidding is similar to the A+B bidding used by the US highway authorities in procurement of highway construction.

Lundberg and Marklund [11] argue that a multi-attribute scoring function should be used because it can represent society's preferences. This may be the case, but the society's preferences related to a single transaction are likely to be in conflict with the society's preferences related to the functioning of the national or regional economy. They also note that the representation of the buyer's utility with a quasi-linear function is reasonable because "Commonly, the price of the procured product constitutes only a small fraction of the procuring authority's total budget." (op. cit., p. 66). Neither the directive nor the authors address the issue of the utility of the suppliers and situations in which the expense is a significant item in the municipal and other public organizations' budget.

A series of multi-attribute auctions in which over 50 health plan providers (i.e., suppliers) competed for business from three large employers began in 1999 [12].

The result of these auction was reduction of annual rates between 2 and 8% while other employers' increased rates between 4 and 6%. Furthermore the time required to determine rates was reduced from five weeks to one week. Despite the success in 2000 and also in 2001 the number of employers dropped and in 2002 the auctions were discontinued [12].

There were four price attributes, which were aggregated into a composite score. There was also a number of non-price attributes, some of which were interdependent with the price attributes, i.e., the components of the composite. For example, the price composite score did not take into account attributes associated with service costs (e.g., safety, quality of service, and response time), which differently affected each of the price components. Although an effort was made to construct a quasi-linear function for the buyer, in effect the scoring function was not quasi-linear.

In this and in other cases no information was given about the suppliers' utility functions. Therefore, one cannot reject a claim that these utilities were quasi-linear. It may be possible that for every supplier the four different prices are linearly dependent and they may be aggregated into a single composite price. It may also be possible that the relationship between this composite price and all other attributes is linear. However, one cannot make such a claim without conducting a detailed study.

4 Improving Winning Bids in Non- RA_{q-l} Mechanisms

4.1 Efficient Frontier

One of the standard assumptions in decision analysis is that the set of feasible alternatives is convex. While this may not be the case when this set is discrete it has often been assumed that such a set is bounded by a convex hull.

Utility functions map the feasible set from the decision space onto the utility space. Quasi-linear utilities map the feasible non-concave set onto a set bounded by a linear efficient frontier with slope –1. Concave utilities (which reflect preferences of risk-averse decision makers) and a linear-concave utility result in a (quasi) concave efficient frontier. Also linear utilities result in concave frontier providing that the buyer's and the seller's preferences over the attributes differ [8].

Fig. 2 illustrates the linear efficient frontier LEF for quasi-linear utilities (shown with dotted line) and a concave efficient frontier CEF. Point A represents a winning bid which is close to the absolute maximum utility for the buyer. Point *B* represents the Nash solution which is the closest to the utopia point at which both parties reach their absolute maximum utility. In this example the maximum value of the sum of the utilities is reached at *B*. Points on LEF are equidistant from the utopia point; they yield the same social welfare making the auction mechanism efficient (see Proposition 2).

When the efficient frontier is a concave function, then the direction for social welfare maximization (joint improvement) is North-East. This is the direction that the negotiation participants should take if they wish to achieve the, so called, win-win agreement, which also maximizes social welfare. By contrast, in auctions the competition pushes the bidders to take the eastern direction (for the buyer's utility positioned on the horizontal axis). The result is that the winning bid may be efficient but it does not maximize social welfare efficiency.

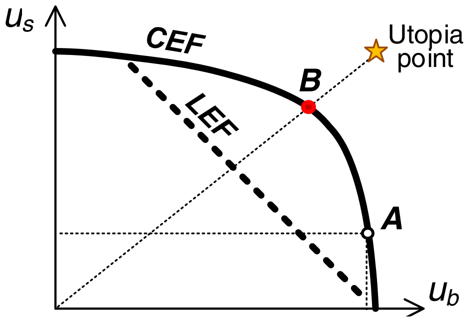

Fig. 2. Buyer *b* and seller *s* utility space. CEF –concave efficient frontier (continuous thick line) and LEF –linear efficient frontier (dotted thick line); *A* – winning bid and *B* – Nash solution.

Let assume that there are at least two suppliers s_1 and s_2 (s_1, $s_2 \in S$), such that $u_{s1}(B) > 0$ and $u_{s2}(B) > 0$.

Proposition 3: If the efficient frontier is continuous and concave and Assumption 1 is met, then the efficient winning bid can either maximize the buyer's surplus or be allocative efficient but not both.

Outline of the proof: For continuous and concave efficient frontier, the solution of the buyer's surplus maximization problem is different from the solution of the winning supplier's surplus maximization problem. Therefore, the solution of the social welfare maximization problem, which maximizes the sum of the buyer's and the supplier's utilities yields different and lower utility for the buyer then the utility obtained from the buyer's surplus maximization problem.

4.2 Improving Winning Bids through Negotiations

Suppliers, who participate in an auction, make bids which increase the buyer's utility. They may try to keep their own utility value at a certain level but, at some point during the auction, they have to decide whether to withdraw from it or to continue and bid at lower utility levels. The auction ends when no supplier is willing to make a bid that increases the buyer's utility. The winning bid lies on the right hand side of the Nash solution (point C in Fig. 2). The farther this bid is from the Nash solution, the greater is the buyer's utility but the smaller is the social welfare. The opposite is also true, if we move along the efficient frontier towards the Nash solution, then social welfare increases but the buyer's utility decreases. When the efficient frontier is concave then the degree of the loss of social welfare depends on the degree of the frontier's concavity and the winning bid. The social welfare loss relative to the buyer's gain may be significant.

Given the set of feasible alternatives, it is not possible to improve both social welfare and the buyer's utility when the winning bid is efficient. This is the case inasmuch as the buyer and the seller remain constricted by the constraints of the problem and are not willing to consider augmenting it through, for example, side payments. If a side exchange is acceptable, then they may seek solutions which increase both social welfare and the buyer's utility. This is due to the synergy that occurs when the efficient frontier is concave: it allows for offsetting a decrease of the buyer's utility by an increase in the supplier's utility.

The process of replacing the efficient winning bid with another alternative, which may be preferable to both the buyer and the winning supplier is described below and illustrated in Fig. 3.

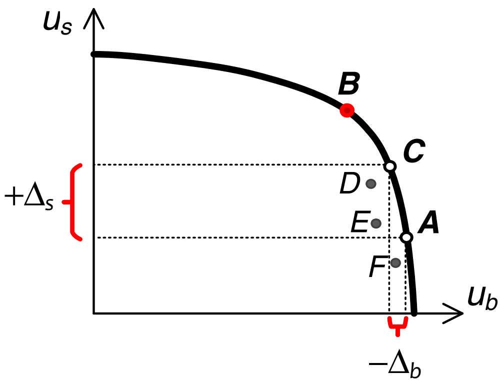

Fig. 3. Joint improvement of the winning bid *A* when *C* is accepted by both sides and the supplier offsets the buyer's loss

Consider a scenario in which seller *s* won the auction with efficient bid *A* = (47; 11.5). Buyer *b* knows that her utility can be approximated by a concave and she is confident that $u_s(A) < u_s(C)$. Although she does not know the winning seller's utility, based on the observation of the bidding process she thinks that the bidders do not significantly differ in terms of their costs. Therefore, she considers a possibility of seeking another alternative, which would eventually allow her to achieve greater utility value than $u_b(A) = 47$.

Buyer *b* decides to employ an activity similar to Raiffa's post-settlement settlement activity [13]. She knows that post-settlement settlements can result in a joint improvement of the final agreement when the interim agreement is inefficient. While this is not the case here, she can utilize the auction's myopic concern with the search for the best deal for the buyer to her advantage. She selects several alternatives (*C*, *D*, *E* and *F*), which yield lower than 47 for her utility. She presents these alternatives to supplier *s* noting that some of them may not be better for him than *A* ($u_s(A) = 11.5$), but other may be better. She adds that if there is an alternative that supplier *s* would strongly prefer, then she may consider to accept it, providing that he offers her a side payment that would offset her loss.

Supplier *s* selects alternative *C* = (45; 21.5). This alternative reduces the buyer's utility by $\Delta_b = 2$ and it increases the seller's utility by 10. The buyer converts this loss of her utility into money (or any other mean of exchange); the two units of utility are worth \$2,000. She suspects that the seller's windfall from the move from alternative *A* to *C* may be greater than \$2,000; therefore, she tells him that she would accept *C* if he pays her \$4,500.

If the winning supplier accepts offer *C*, then his utility increases by $\Delta_s = 10$ (from 11.5 to 21.5). After converting this utility increase to money (or any other mean of exchange) he observes that this increase is equivalent to \$10,000. Thus, after paying the buyer \$4,500 his net gain would be \$5,500. The supplier accepts the offer and alternative *C* becomes the jointly agreed "win-win solution".

Because the buyer's loss was more than offset by the seller's side payment and the seller's utility increased more than the side payment, social welfare also increased from 58.5 (47+11.5) to 66.5 (45+21.5). While it is lower than the Nash solution $B = (38, 31)$, which yields 69, the difference is much smaller.

This example shows that the choice of *C* rather than *A* with the side payment of \$4,000 has the following results: (1) it increases the buyer's utility by 5% (from 47 to 49.5, after the conversion of 4,500 to 4.5 units of utility); (2) it increases the winning seller's utility by 48% (from 11.5 to 17, after the conversion of 5,500 to 5.5 units of utility); and (3) it increases social welfare by 14%.

Market participants who want to maximize social welfare need to move in the North-East direction. However, suppliers who are pushed by competition and have to maximize the buyer's surplus in order to win a contract need to move in the North-West direction. Quasi-linear preferences together with the use of the sum of utilities as the measure of social welfare, remove the conflict because the East moves do not change the distance from the Utopia point (max u_b; max u_s). However, market participants should be aware of the conflict as it arises when other types of preferences and/or other welfare measures are deemed more suitable.

The above example illustrates the possibility of reaching solutions which are better than the winning bid. By employing a post-auction negotiation it may be possible to improve the results for both sides as well as increase social welfare. The negotiation may take different forms; if an intermediary (e.g., a modified auction system) has information about the buyer's and the winning supplier's preferences, then this intermediary may suggest alternatives which are efficient and lie in-between the winning bid and the Nash solution. The parties then may need to negotiate side payment values for the selected alternatives. As long as the transferred amount (∇_{sb}) is positive, i.e., $\nabla_{sb} = \nabla_s - \nabla_b > 0$, and the supplier increases his utility, i.e., $\nabla_s - \nabla_{sb} > 0$, both sides are better off.

5 Conclusions

The discussion on quasi-linear utility and its implications shows that while such utility is assumed in auctions it may not describe preferences of the market participant satisfactorily. Decision and negotiation analyses often rely on concave and linear utilities. Economics also views concave utilities as important because these utilities characterize decision makers who are risk averse. Recent experiments show that the majority of decision-makers are risk averse even when the stakes are small and risk averse attitude strongly increases with the increase of the stakes' importance [14]. This paper proposes a revised mechanism "auctions followed by negotiations" which allows risk neutral and averse buyers and suppliers to seek improvements over winning bids in reverse auctions. It also shows that social welfare can be increased benefiting the buyers and the sellers as well as the economy as a whole.

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References

1. Krishna, V.: Auction Theory. Academic Press (2009)
2. Milgrom, P.: An Economist's Vision of the B-to-B Marketplace, White Paper (2000)
3. Strecker, S., et al.: Electronic Negotiation Systems: The Invite Prototype. In: Proceedings of the Collaborative Business MKWI 2006. Potsdam, Germany (2006)
4. Bergstrom, T.C., Varian, H.R.: When do Market Games have Transferable Utility? Journal of Economic Theory 35(2), 222–233 (1985)
5. Luce, R.D., Raiffa, H.: Games and Decisions: Introduction and Critical Survey. Dover Publications (1957)
6. Keeney, R.L., Raiffa, H.: Decisions with Multiple Objectives: Preferences and Value Trade-Offs. Wiley, New York (1976)
7. Varian, H.R.: Intermediate Economics. A Modern Approach, 8th edn. Norton, New York (2010)
8. Mumpower, J.L.: The Judgement Policies of Negotiators and the Structure of Negotiation Problems. Management Science 37(10), 1304–1324 (1991)
9. Raiffa, H., Richardson, J., Metcalfe, D.: Negotiation Analysis. The Science and Art of Collaborative Decision Making. Harvard University Press, Cambridge (2003)
10. Hohner, G., et al.: Combinatorial and Quantity-discount Procurement Auctions Benefit Mars, Incorporated and its suppliers. Interfaces 33(1), 23–35 (2003)
11. Lundberg, S., Marklund, P.-O.: The Pivotal Nature of Award Methods in Green Public Procurement. Environmental Economics 2(3), 61–70 (2011)
12. Gupta, A., Parente, S.T., Sanyal, P.: Competitive Bidding for Health Insurance Contracts: Lessons from the Online HMO Auctions. Int. J. of Health Care Finance and Economics 12(4), 303–322 (2012)
13. Raiffa, H.: The Art and Science of Negotiation. Harvard Univ. Press, Cambridge (1982)
14. Holt, C.A., Laury, S.K.: Risk Aversion and Incentive Effects. American Economic Review 92(5), 1644–1655 (2002)

Exploring the Effect of Bidding Mechanisms in Online Penny Auction

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Abstract. Penny auction, an emerging popular auction mode, requires bidders to pay for each bid. Since its mechanism is different from traditional ones, the results of past studies may not be applied to this auction model. The goal of this study is to explore the drivers of engaging in penny auction. Perceived fairness and perceived value are the major cognitions we investigated. We inferred that certain mechanisms adopted by penny auctions may enhance perceived value and fairness of penny auction. An online experiment was implemented to examine the proposed hypotheses. The results confirmed most of our hypotheses – (1) intention to bid is a function of perceived hedonic value, transaction utility, and perceived price fairness and (2) bidding mechanisms have effects on bidders' perceptions. Implications for researchers and practitioners are also provided.

Keywords: penny auction, online auction, bidding mechanism, bidding behavior, hedonic value, perceived fairness.

1 Introduction

Online auction has become one of successful business models of e-commerce. According to IBISWorld [1], the annual growth rate of online auction industry from 2007 to 2012 was 10.4%. Its revenue has reached 219 billion dollars. While most popular online auction websites adopt English auction, a new business model of online auction appeared in Germany in 2005, named penny auction (or bidding fee auction). The main difference between penny auction and online English auction is that bidders have to pay fee when they submit a bid in penny auction. Even though bidders have to pay before they win the auction, this kind of auction websites is still getting popular. So far, QuiBids (http://www.quibids.com/en), DealDash (http://www.dealdash.com), and bidcactus (http://www.bidcactus.com/) are top three most popular sites in the U.S. The average number of closed auctions is about 18000 per week in these three websites. Moreover, their overall average trading volume is about $55000 per week [2]. Why people are willing to join the bidding even they have to pay for each of their bid has become an interesting issue.

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This new bidding mechanism stimulates people's arousal and makes them feel more excited or competitive. It even triggers bidders' negative emotions, which drive them to bid more in the bidding process [3]. As an outcome, penny auction sites have been getting popular in many countries in recent years [4]. However, given the significant differences between English auction and penny auction, most of the critical factors in English auction context (e.g. experience of seller, picture of products, reserve price, and initial price) are considered inapplicable in penny auction. This hints a need to explore the drivers of joining penny auction.

Furthermore, similar to all auction sites, high customer retention and bidder-to-auction ratio (Numbers of bidders in each active auction) are two essential elements that supporting a penny auction site [5]. Furthermore, different from English auction in which bidders pay nothing for bidding, bidders in penny auction have to pay for each bid. Since the number of bidding means revenue to the auction site, maintaining high bidding number is critical [6]. However, bidders quit bidding when they perceive high sunk costs [7]. In fact, several popular penny auction sites, such as Swoopo, went bankruptcies and shut their websites down because of insufficient participants. This hints another need to explore the drivers of penny auction. Specifically, understanding why some penny auction sites are more popular than others helps practitioners to adjust their strategies and bidding mechanisms to attract more new customers or retain current customers.

Drawn on the above two issues, the purpose of this study is to explore the drivers of penny auction. Specifically, we adopt value and fairness perspective to understand the antecedents of bidding intention. Furthermore, we also attempt to explore better mechanisms that can enhance perceived value and fairness. In the rest of this paper, we first introduce penny auction in the second section, followed by our research model and hypotheses in the third section. The fourth section provides research method and measurements while the fifth section includes the hypotheses testing and discussions. Finally, we end with conclusions in the sixth section.

2 Penny Auction vs Online English Auction

In penny auction, initial price for each item is set to $0. Bidders can submit a bid within a very limited time which is set in advance. Each new bid will reset the countdown timer of the auction to the predefined number of seconds, usually ranging from 10 to 30 seconds. Meanwhile, the auction price is raised by a tiny amount such as $0.01. If no new bidders bid before the countdown timer runs out, the last bidder wins the auction. The total price that the winner needs to pay is the final price plus the fees of all bids he/she has submitted. In general, the total price is much lower than the retail price. For the rest bidders, the bidding fees that they paid are not returned to them.

For example, there is a cell phone with a retail price - $3,000; per bid costs $1 and every bid will raise the price of the item by $0.01. If the final price in penny auction is $40, it means there are 4000 bids submitted by all bidders. Assuming that the winner submits 100 bids, $140 will be his/her total cost ($100 bidding fees plus $40 final price). This mechanism benefits both the winner and the auctioneer. For the winner, he/she buys the cell phone saving $ 2860 compared with the retail price in this case. For the auctioneer, collecting 4,000 bids means receiving $4,000 from the submitted bids in addition to $40 paid by the winner. In other words, the penny auction site gets $4,040 in total, which is $1040 more than the retail price.

A comparison between online English auction and penny auction is shown in Table 1. First, different from English auction, bidders in penny auction pay for each bid. Second, in penny auction, the final price is much lower than the retail price while in English auction the final price is close to the retail price. In addition, for penny auction, the ending time is uncertain and bidders have less time to make decisions. The instantaneity feature of penny auction brings bidders higher recreation value. Further, in most cases, items in penny auction are brand-new products.

Table 1. Differences between online English auction and penny auction

	Online English auction	Online penny auction
Bidding fee	Free	Pay per bid
Final price	Close to retail price	Much lower than retail price
Ending time	Fixed/Uncertain	Uncertain
Decision time	Flexible	Short
Instantaneity	Low	High
Recreation value	Low	High
Merchandise	Brand-new or second-hand	Brand-new

As described above, the loser in penny auction cannot get their bidding fees back. All the collected bidding fees become the revenue of penny auction websites, which results in the fairness concern of bidders and was deemed gamble and scam. To solve this problem, many auction sites have launched a new function called *Buy now* recently. It allows the involved bidders to purchase the product with retail price at any time in the bidding process and even some time after the bid closes. The bidding fees paid by the bidders can be deducted from the retail price. In other words, losers in the bidding would not lose the paid bidding fees. People believe that *Buy now* mechanism can boost bidding.

Furthermore, to ease the criticism of gamble, several penny auction sites also launch another new mechanism named *No new bidders.* Under this circumstance, a new bidder is not allowed after the price reaches the predefined threshold. It is believed that *No new bidders* can enhance fairness because it can reduce the number of people engaged in the bidding process. Further, in order to stimulate bidders to bid more and reduce the time to reach the final deal, some penny auction sites reduce the time setting of countdown timer from 30 to 10 seconds. It looks like bidders tend to submit more bids under high time pressure, and hence the revenue of the auction sites increase. The time to reach the final deal becomes shorter, too.

3 Research Model and Hypotheses

The purpose of this research is to investigate the driving factors of bidders' intention to bid in penny auction and how different bidding mechanisms will impact these driving factors. Also, we believe that the results would help auctioneers to adjust strategies and to dispense criticism of gambling. Since countdown timer settings, loser compensation mechanisms and competition mechanisms are the major mechanisms adopted by penny auction sites to attract more bidders, we wonder and investigate how different mechanisms impact people's cognition and then, how the cognition impacts their intentions to bid. The research framework is as Figure 1.

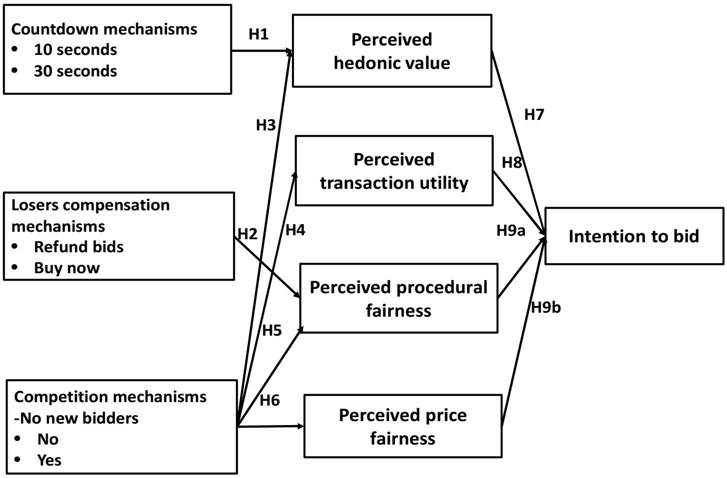

Fig. 1. Research model

Countdown Mechanism

In penny auction, the countdown timer determines how much time given to bidders to make decision. Kocher and Sutter [8] stated that sellers may manipulate time pressure to stimulate consumers' shopping desire. This phenomenon can be discovered in TV home shopping or online group buying context such as Groupon in which the time period for people to join is quite short. The time limit not only stimulates purchasing behavior but also may arouse hedonic perceptions [9]. People get excited under strong time pressure because it creates a similar sense of taking adventure. Therefore, H1 is proposed as follows:

H1: Consumers will perceive higher hedonic value when countdown timer sets a longer time.

Based on our observation, the range of the countdown timer setting is usually between 10 seconds and 30 seconds. So, in our research, we plan to compare the differences between 10 and 30 seconds.

Loser Compensation Mechanism

As indicated above, one major difference between penny auction and English auction is that bidders have to pay for each bid. In addition, since only the winner can get the product and losers cannot get their money back, the penny auction sites can collect lots of bidding fees which could be much more than the regular retail price of the sold item. It is considered not fair and even gets criticism of gamble and scam, which results in people's unwillingness to engage in penny auctions. This highlights the importance of perceived fairness in penny auction. There are several types of fairness. Thibaut and Walker [10] defined procedural justice as the extent to the effect that people can make on decision-making process and outcome. Gilliland [11] proposed a similar perspective, "formal characteristics of procedures", to explain procedural fairness in his study.

Recently, many penny auction sites have provided new game rules such as *Buy now* and *Refund bids* in order to compensate bidders who do not win the bid. *Buy now* allows the involved bidders to purchase the products with retail price. In addition, the bidding fees that the bidders spend on the auction can be deducted from the retail price. On the other hand, *Refund bids* allows the involved bidders to get back all the fees they have paid in the auction, but these bidding fees can only be used in the future biddings rather than be regarded as cash to buy products or be deducted when purchasing products. Either *Buy now* or *Refund bids* give bidders more alternatives in the bidding process. In other words, it lets the bidders have more control in the bidding process, which indicates procedural fairness. However, in some sense, the bidding fees become losers' sunk costs in penny auction with *Refund bids* mechanism [12]. It indicates that to join bidding in order to spend the refund bids is the only way that bidders can do. Compared with *Buy now* mechanism, it seems that *Refund bids* gives bidders less control in making decision. The following is therefore hypothesized.

H2: Consumers will perceive higher procedural fairness with "Buy now" than "Refund bids" mechanism.

Competition Mechanism

The essence of bidding is to beat other competitors in order to win the auction [13]. The more bidders join the auction, the more competitive it is. Competition may result in intrinsic excitement [14]. Competitive situation such as bidding would stimulate physiological arousal [15] and competitive arousal increases the hedonic value of shopping [16], [17]. For many people, penny auction is similar to a game. Players need to pay significant attention to other bidders and hence devise bidding tactics. If the auction is too competitive, it may reduce people's willingness to bid. However, it is very important to balance the hedonic value and the willingness to bid in order to attract enough bidders. It turns out that penny auction sites manipulate the competition by *No new bidders* mechanism. It means that new bidders are not allowed to join the auction after the price reaches a certain amount. Without *No new bidders* mechanism, bidders may face unlimited potential competitors. Since researchers have pointed out that there is positive relationship between competition and hedonic value [16], [17], we propose that *No new bidder mechanism* may reduce hedonic value.

H3: Consumers will perceive less hedonic value when the penny auction provides "No new bidders" mechanism than without it.

The higher price the consumers pay, the less transaction utility they get. Consumers pursuit transaction utility because taking advantage of a price-deal in a transaction makes people feel good [18]. In penny auction, there is a popular bidding strategy called sniping. Snipers would choose a perfect timing to bid and let other bidders have no enough time to react. Typically, snipers enter the auction at an extremely late timing. They begin to bid when other bidders spend most of their bids or purchase bids packs for a period of time. It is likely that common bidders spend more to win the auction if there are more snipers behind the auction. Since *No new bidders* mechanism will reduce the possibility of sniping behavior, higher transaction utility can be expected when this rule is presented.

H4: Consumers will perceive higher transaction utility when the penny auction provides "No new bidders" mechanism than without it.

No new bidders mechanism prohibits new bidders to engage in the bidding after the price has reached a certain amount. It is reasonable to believe that bidders tend to consider the procedural is fair if the *No new bidders* mechanism is present since sniping can be avoided. However, when this mechanism is not present, sniper may spend very few money and win the auction. In addition, with *No new bidders* mechanism, bidders wouldn't face unlimited potential competitors, and therefore can execute their bidding strategies more effectively. Bidders can have a better control on how they spend money on bidding. Therefore, we hypothesize H5 as follows:

H5: Consumers will perceive higher procedural fairness when the penny auction provides "No new bidders" mechanism than without it.

Price fairness refers to consumers' judgment about whether the price of commodities is reasonable and acceptable [19]. In penny auction, winner pays the final price in addition to his bidding fees to get the product, while losers has to pay the bidding fees but receive nothing. It is intuitive that the more bids the participants have placed, the more money they have to pay. However, when *No new bidders* mechanism is present, the final price would not be raised by sniping. Therefore, participants are expected to pay less in this condition, than the condition that *No new bidder* policy is absent. Hence, we propose H6 as follows:

H6: Consumers will perceive higher price fairness when the penny auction provides "No new bidders" mechanism than without it.

For many bidders, bidding process is similar to playing an exciting game with a lot of fun [6]. In the auction environment, bidding behavior is affected by bidders' emotional state, such as arousal and excitement [20]. Further, people may buy things for thrills, fun, enjoyment, and adventure in addition to fulfilling their living requirement [21]. We therefore propose the following hypothesis:

H7: Perceived hedonic value has a positive influence on bidding intention.

Transaction utility is modeled as the difference between a selling price and a reference price [22]. It has been considered as an influential factor in purchase decision [18]. Customers are more willing to purchase product with higher value [23]. In penny auction context, the final price is very often much lower than the retail price which is usually regarded as a reference price. Researchers also pointed out that final price of commodities is a leading enticement for consumers to patronize penny auction sites [12]. Therefore, we hypothesize that

H8: Perceived transaction utility has a positive influence on bidding intention.

The relationship between fairness and willingness to buy has been examined by past studies. For example, it is argued that unfairness leads to negative emotion such as anger [24]. People with negative emotion may take some actions such as withdrawing from a purchase toward sellers. Further, perceived price unfairness often induces perceived sacrifice and hence hinders consumers' willingness to buy [25]. Campbell [26] also showed that perceived unfairness would lead to consumers' resistance to prices and lower shopping intention. In addition, Kauffman et al. [27] demonstrated that if consumers perceive higher procedural fairness, they would have higher intention to purchase. Based on above findings, it is reasonable to argue that bidders are more likely to bid when they perceive fairness. Therefore, we hypothesize the followings.

H9a: Perceived procedural fairness has a positive influence on bidding intention.

H9b: Perceived price fairness has a positive influence on bidding intention.

4 Research Method and Measurement of Construct

An experiment with three factors (and two treatments in each) was conducted to investigate the effect of different bidding mechanisms and to test proposed hypotheses. Because there were two treatments in each factor, this yields a 2x2x2 factorial design. We constructed a penny auction website to simulate different bidding mechanisms. After introducing the purpose of the experiment and the rules of penny auction, each subject was asked to purchase a gift for his/her father, and then was randomly assigned to one of the eight groups and was asked to participate in a simulated penny auction. In different scenarios, subjects could choose to bid until win or choose *Buy now* to get the items. They also could choose to quit the auction at any time. After finishing simulated bidding, based on each given condition, subjects were then asked to fill a survey which focused on measuring their perception toward the value and fairness of penny auction and their intention to join the auction.

Totally, there were five variables to be measured. Each variable was measured on seven-point Likert-type scale, anchored from "1" (strongly disagree) to "7" (strongly agree). Most items of each variable were cited or revised from literature. When necessary, we developed items according to operational definitions in this study.

The five items of hedonic value were revised from Babin et al. [28], Lee et al. [29], and Byun and Mann [16]. Three items of procedural fairness were revised from Kauffman et al. [27] who investigated procedural fairness of online group-buying. There are three items of price fairness, which were cited and revised from Martín-Consuegra et al. [30] who studied price fairness, customer satisfaction and loyalty. The three items of transaction utility were revised from Lichtenstein et al. [31] and Grewal et al. [23]. For intention to bid, three items were revised from Kauffman et al. [27].

5 Hypotheses Testing and Discussions

There were 620 participants in our experiment, but only 386 samples were valid. Both sexes were almost equally represented of our total subjects. More than half of subjects' ages are between 21-25 years old. Subjects who have used penny auction sites count for 31.3 percent of the total subjects. Among these experienced subjects, numbers of winner count for 34.7 percent of total experienced subjects.

We used SPSS 20.0 to analyze demographic data. Covariance based method is popularly used to analyze a structure equation model (SEM). Thus, we used EQS 6.2 to measure the influence of different mechanisms on consumers' perception and the influence of hedonic value, transaction utility, procedural fairness and price fairness on bidding intention.

The adequacy of measurement was assessed by evaluating the reliability, convergent validity and discriminant validity. All indexes are higher than recommended cut-off point. Both Composite Reliability and Cronbach's Alpha values are all greater than 0.7 [32]. Factor loadings of all indicators are higher than 0.7. Averaged Variance Extracted for all factors exceeds 0.5. Furthermore, all indicators are loaded higher in intended construct than other constructs.

The most important step in SEM is whether the specified model fits the data [33]. All the indices of goodness of model fit, including normed χ^2 ($2.378 < 3$), NFI ($0.949 > 0.9$), CFI ($0.969 > 0.9$), GFI ($0.911 > 0.9$), AGFI ($0.883 > 0.8$), RMR ($0.045 < 0.08$) and RMSEA ($0.060 < 0.08$), fulfill the criteria. These statistics together indicate a strong evidence to satisfy the convergent validity and goodness of model fit. The final results of hypotheses testing are shown as Fig. 2.

It shows that only H9a is not significantly supported. Since the three mechanisms contain 2 treatments individually and the results of SEM reveal significant influence of them, we further examined the means of two experimental groups of each mechanism. We found that all hypotheses are supported except H3. Even the result is significant but it is opposite to our hypothesis. In other words, it shows that penny auction with *No new bidders* mechanism will bring more hedonic value to bidders than the penny auction which allows new bidders to join will. The reason could be that bidders may change their mood from excitement to anxiety if penny auction allows new bidders to keep coming because each bid represents cost for bidders. In contrast, with *No new bidders* mechanism, subjects may feel more sense of competition, and hence excitement.

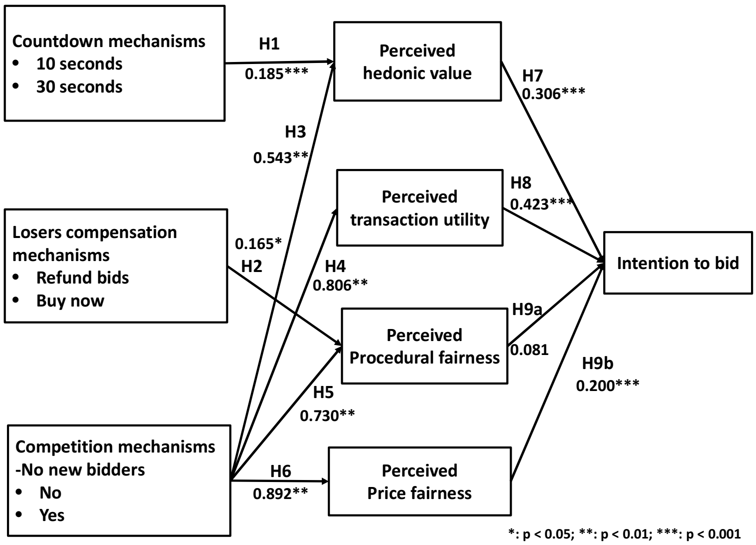

Fig. 2. Path analysis

Comparing the relative influence of the three significant variables on intention to bid, we found that transaction utility is higher than hedonic value, which is higher than price fairness. This implies that most bidders are attracted to join the bidding because the final price is much lower than the retail price in general. In addition, auction sites have to assure that bidding process can actually provide sufficient hedonic value to customers. While price fairness is also critical, it has less impact. Lastly, different from our expectation, procedural fairness is found to have no effect on bidding intention. It might be that most of our subjects have no penny auction experiences before. Even though we tried to make the experiments as real as possible, one limitation is that there is no actual cost for our subjects. That is, they did not lose money from doing the experiment. We believe that a feeling of injustice may only be elicited when subjects actually lose some money in the auction.

6 Conclusion

The purpose of this study is to understand (1) the antecedents of bidding intention, and (2) the impact of different mechanisms on perceived value and fairness. For the antecedents of bidding intention, the results demonstrate that perceived transaction utility is the most critical factor, followed by perceived hedonic value and perceived price fairness. However, perceived procedural fairness has limited effect. We are not sure if the insignificance of perceived procedural fairness is due to the experimental design. The results also demonstrate that different mechanisms will drive people's different cognitions. The bidding mechanisms are evolving rapidly. In this study, we explore the effects of certain mechanisms. The results generate some implications toward practitioners. For example, we encourage site owners to pay more attention on the selection of mechanisms since each mechanism has its own special effect. Even though the results allow us to understand this new auction more, this study includes only few mechanisms because of parsimony issue. Future studies are therefore encouraged to extend our study by incorporating other bidding mechanisms. Researchers may also incorporate other interesting factors such as personality in their studies. We also believe that there is a need to construct a real auction site to increase the validity of these findings. For example, participants in our study do not actually lose any money and, therefore, their perceptions in the artificial context cannot truly reflect their feelings in a real context. Furthermore, objective data such as actual bidding behaviors can then be collected to verify the results generated from subjective data (used in this study).

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References

[1] IBISWorld. E-Commerce & Online Auctions in the US: Market Research Report (2012), http://www.ibisworld.com/industry/default.aspx?indid=1930 (last retrieved on November 14, 2012)

[2] Allpennyauctions.com. Penny Auction Statistics - "Bang for Your Buck" Comparison (2012), http://www.allpennyauctions.com/site_ratings/ (last retrieved on November 14, 2012)

[3] Luscombe, B.: Losing Your Cents. Time Magazine (June 17, 2010), http://www.time.com/time/magazine/article/0,9171,1997462,00.html (last retrieved on December 15, 2013)

[4] Pennyauctionwizards.com. The History of Penny Auctions (2012), http://www.pennyauctionwizards.com/the-history-of-penny-auctions/ (last retrieved on November 14, 2012)

[5] Stix, E.: An Empirical Study of Online Penny Auctions. Working paper. An Empirical Study of Online Penny Auctions. Working paper (2012), http://cs.brown.edu/research/pubs/theses/ugrad/2012/estix.pdf (last retrieved on December 15, 2013)

[6] Augenblick, N.: Consumer and producer behavior in the market for penny auctions: A theoretical and empirical analysis (2009) (unpublished manuscript), http://www.stanford.edu/~ned789

[7] Wang, Z., Xu, M.: Learning and Strategic Sophistication in Games: The Case of Penny Auctions on the Internet. Working paper (2012), http://www.economics.neu.edu/zwang/Penny%20auction.02.2012.pdf (last retrieved on December 15, 2013)

[8] Kocher, M.G., Sutter, M.: Time is money—Time pressure, incentives, and the quality of decision-making. Journal of Economic Behavior & Organization 61(3), 375–392 (2006)

[9] Cabanac, M., Bonniot-Cabanac, M.-C.: Decision making: rational or hedonic? Behavioral and Brain Functions 3(1), 45 (2007)

[10] Thibaut, J.W., Walker, L.: Procedural justice: A psychological analysis. L. Erlbaum Associates (1975)

[11] Gilliland, S.W.: The perceived fairness of selection systems: An organizational justice perspective. Academy of Management Review, 694–734 (1993)

[12] Caldara, M.: Bidding Behavior in Pay-to-Bid Auctions: An Experimental Study. Working Paper (2012), `http://inside.econ.ubc.ca/webfm_send/458` (last retrieved on December 15, 2013)

[13] Ariely, D., Simonson, I.: Buying, bidding, playing, or competing? Value assessment and decision dynamics in online auctions. Journal of Consumer Psychology 13(1), 113–123 (2003)

[14] Deci, E.L., Betley, G., Kahle, J., Abrams, L., Porac, J.: When Trying to Win Competition and Intrinsic Motivation. Personality and Social Psychology Bulletin 7(1), 79–83 (1981)

[15] Malhotra, D.: The desire to win: The effects of competitive arousal on motivation and behavior. Organizational Behavior and Human Decision Processes 111(2), 139–146 (2010)

[16] Byun, S.E., Mann, M.: The Influence of Others: The Impact of Perceived Human Crowding on Perceived Competition, Emotions, and Hedonic Shopping Value. Clothing and Textiles Research Journal 29(4), 284–297 (2011)

[17] Nichols, B.S.: The development, validation, and implications of a measure of consumer competitive arousal (CCAr). Journal of Economic Psychology 33(1), 192–205 (2012)

[18] Thaler, R.: Mental accounting and consumer choice. Marketing Science 4(3), 199–214 (1985)

[19] Xia, L., Monroe, K.B., Cox, J.L.: The price is unfair! A conceptual framework of price fairness perceptions. Journal of Marketing 68, 1–15 (2004)

[20] Adam, M.T., Krämer, J., Jähnig, C., Seifert, S., Weinhardt, C.: Understanding auction fever: a framework for emotional bidding. Electronic Markets 21(3), 197–207 (2011)

[21] Arnold, M.J., Reynolds, K.E.: Hedonic shopping motivations. Journal of Retailing 79(2), 77–95 (2003)

[22] Thaler, R.: Transaction Utility Theory. In: Bagozzi, R.P., Tybout, A.M., Abor, A. (eds.) NA - Advances in Consumer Research, vol. 10, pp. 229–232. Association for Consumer Research, MI (1983)

[23] Grewal, D., Monroe, K.B., Krishnan, R.: The effects of price-comparison advertising on buyers' perceptions of acquisition value, transaction value, and behavioral intentions. The Journal of Marketing, 46–59 (1998)

[24] Xia, L., Kukar-Kinney, M., Monroe, K.B.: Effects of consumers' efforts on price and promotion fairness perceptions. Journal of Retailing 86(1), 1–10 (2010)

[25] Monroe, K.B., Martins, M.: Perceived price fairness: a new look at an old construct. Advances in Consumer Research 21(1), 75–78 (1994)

[26] Campbell, M.C.: Perceptions of price unfairness: antecedents and consequences. Journal of Marketing Research, 187–199 (1999)

[27] Kauffman, R.J., Lai, H., Ho, C.T.: Incentive mechanisms, fairness and participation in online group-buying auctions. Electronic Commerce Research and Applications 9(3), 249–262 (2010)

[28] Babin, B.J., Darden, W.R., Griffin, M.: Work and/or fun: measuring hedonic and utilitarian shopping value. Journal of Consumer Research, 644–656 (1994)

[29] Lee, M.Y., Kim, Y.K., Fairhurst, A.: Shopping value in online auctions: Their antecedents and outcomes. Journal of Retailing and Consumer Services 16(1), 75–82 (2009)

[30] Martín-Consuegra, D., Molina, A., Esteban, Á.: An integrated model of price, satisfaction and loyalty: an empirical analysis in the service sector. Journal of Product & Brand Management 16(7), 459–468 (2007)
[31] Lichtenstein, D.R., Netemeyer, R.G., Burton, S.: Distinguishing coupon proneness from value consciousness: an acquisition-transaction utility theory perspective. The Journal of Marketing, 54–67 (1990)
[32] Fornell, C., Larcker, D.F.: Evaluating structural equation models with unobservable variables and measurement error. Journal of Marketing Research, 39–50 (1981)
[33] Yuan, K.-H.: Fit indices versus test statistics. Multivariate Behavioral Research 40(1), 115–148 (2005)

Using Biddings and Motivations in Multi-unit Assignments

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Abstract. In this paper, we propose a process for small to medium scale multi-assignment problems. In addition to biddings, agents can give motivations to explain their choices in order to help decision makers break ties in a founded way. A group decision support system, based on Logical Information Systems, allows decision makers to easily face both biddings and motivations. Furthermore, it guaranties that all the agents are treated equally. A successful case study about a small course assignment problem at a technical university is reported.

Keywords: group decision support, thinkLet, formal concept analysis, logical information systems, course allocation, multi-unit assignment.

1 Introduction

In a multi-assignment problem, a set of indivisible resources is to be allocated amongst a set of agents, the agents have multi-unit demands [1]. One instance of such a problem is course allocation at universities, the agents are students and the resources are seats in courses. It has been shown by Ehlers and Klaus [2] that the only coalitional strategy-proof solutions to multi-assignment problems are sequential dictatorships. Namely, in order that no agent or group of agents ever gains by jointly misrepresenting their preferences, the agents must be totally ordered, then each agent in turn chooses her best choices. While dictatorships are commonly used and accepted in real life single-assignment problems, Budish and Cantillon argue that dictatorships can be highly unfair for multi-assignments, top agents get *all* their choices while bottom agents get *none* of them [1].

Several solutions are proposed. Budish and Cantillon [1] propose a course allocation system in several rounds, the students are randomly ordered but they choose one course at a time. At each round the order of the list is reversed, the first served student at a given round is the last served at the next round. While the several-round approach is widespread (see, for example, the New York City high school match [3]), it is not always possible to organize several rounds. Another widely used approach is based on course bidding, students have a number of points that they can distribute to the courses they want. Sönmez and Ünver [4], however, show that bids have in general two different roles, to infer student preferences and to determine who has the bigger claims on course seats.

P. Zaraté, G.E. Kersten, and J.E. Hernández (Eds.): GDN 2014, LNBIP 180, pp. 53–61, 2014.

Due to strategies used by students, preferences induced by bids may significantly differ from the true preferences. Students may bid higher for popular courses than for courses that they truly prefer. Sönmez and Ünver, therefore, propose a system in one round, where in addition to course bidding, students are requested to specify a totally ranked list of preferred courses. It reduces the number of students who get courses that are not their preferred ones.

Most of the approaches aim at large scale problems and they are fully automatic. However, there are cases where agents are not inclined to accept the blindness of automation, for example if they are not very numerous and they know each others well. In such a context, unfair decisions can lead to critical conflict situations.

We propose an interactive process for small to medium scale multi-assignment problems in one round, which allows agents to be treated equally with respect to biddings and motivations. Agents have a given number of bidding points that they can put on resources and they can give qualitative motivations to explain their choices. Biddings are used to make pre-assignments, and qualitative motivations help decision makers break ties in a founded way. The process is supported by a Group Decision Support System based on Logical Information Systems (LIS) [5], a paradigm of information retrieval that combines querying and navigation, formally based on a logical generalization of Formal Concept Analysis [13]. Logical faceted navigation in data allows decision makers to handle both biddings and motivations in a unified interface. Agents are dealt with by sets, for example the set of those who have bidden a given number of points for a course and who have given qualitative motivations. The system guaranties that, among a given set, all the agents are treated equally. The process can be seen as a thinkLet. A thinkLet provides a transferable, reusable and predictable building block for the design of a collaboration process [6,7]. In any of the repositories or GDN tools we are aware of (for example, the thinkLet catalog [6], MeetingWorks^{TM} [8], the environment of Adla et al. [9]), there is no thinkLet that enables decision makers to handle in a systematic way both quantitative choices and qualitative arguments. According to the taxonomy of groupware technologies proposed by Mittleman et al. [11], and as discussed in [10] for another thinkLet, the proposed process is another illustration that LIS tools significantly contribute to information access tools that provide group members with ways to store, share, find, and classify data objects. The process has been tested on a case study. 33 students had to choose between two courses for 4 different teaching modules. After an initial unsatisfactory process, the students requested that motivations were taken into account. They tried the proposed process. Both students and the teacher in charge of the course assignment voted for the proposed process to be deployed.

In the following, Section 2 specifies the multi-assignment process. Section 3 introduces the supporting LIS tool and describes the successful case study. Section 4 discusses the approach.

2 The Proposed Multi-unit Assignment Process

Input. 1) *A set of agents*; 2) *A set of modules*, for each module there are several resources, for each resource i there is a capacity constraint, c_i, all resources are independent; 3) *two parameters*: n, the number of bidding points per agent; and u_i, the number of units of resource i to save for the global arbitration step.

Output. *Each agent has one resource for each module.*

Objectives. 1) Treat all agents as equally as possible; 2) use as much as possible agents' biddings and motivations; and 3) fill up over-demanded resources.

Steps

1. **Agents' bidding.** Agents must choose a resource per module. They have n bidding points to distribute to the chosen resources. Agents can also specify motivations to explain their choices. They only know their own biddings.
2. **Validating balanced modules.** For each module, if the number of agents for every resource i fits capacity c_i, the choices are validated.
3. **Validating under-demanded resources.** For each unbalanced module, the choices for the under-demanded resources are validated.
4. **Validating over-demanded resources taking biddings into account.** For each unbalanced module, for each over-demanded resource i, agents are considered by sets according to their biddings. If the number of agents who have bidden the highest score is less or equal than $c_i - u_i$, their choice is validated. The process iterates on the scores, decrementing one by one, until the number of agents at that score added to the number of already valid choices is above $c_i - u_i$.
5. **Validating over-demanded resources taking motivations into account.** For each unbalanced module, for each over-demanded resource i where choices at bid score b can no longer be taken into account, the decision makers consider the arguments put forward by the agents who bidded b. They select the arguments that they find convincing and if the number of the corresponding agents is below $c_i - u_i$ those agents have that choice validated.
6. **Global arbitration.** When the previous steps are done for all the modules, the decision makers consider the agents who have some choices not validated yet. In particular, some agents may have more modules still pending than the others. The decision makers try to validate in priority enough choices for them so that they are not more disadvantaged than the other agents.
7. **Filling up over-demanded resources.** For each over-demanded resource i still below its capacity c_i, a dictatorship approach is used to fill it up.
8. **Swapping the choices not yet validated.** The agents' choice not yet validated cannot be taken into account. They are swapped to other still under-filled resources.

Note that the decision makers have to make actual decisions at step 5 to choose convincing arguments, at step 6 to try to assign at least one of their choices to so far unlucky agents, at step 7 to choose the criteria to rank the agents for the dictatorship method, and at step 8 if there are more than one under-filled resource in unbalanced modules. Another remark is that dictatorship is only used to finish filling up over-demanded resources at step 7, the last but one step. Note also an important property: *the order in which the modules are considered does not impact the result.* Indeed, modules are considered independently until global arbitration at step 6, at that moment, the focus is on the agent criteria and no longer on the modules.

3 Case Study: Course Assignment at a University

The process has been tested on a course allocation simulation for master students at the INSA of Rennes. At the beginning of the school year, students have to choose between two courses for 4 different teaching modules. Each course has a capacity of 20 seats. One characteristic of this choice is that it has to be done over less than a day, bidding included. In the initial process, for each module, students ticked one course out of two. Two modules were very unbalanced. Students suggested that, instead of plain chance, the assignment took into account their motivations. The teacher in charge kindly accepted to proof read emails Even after taking into account the messages, there had been complaints from students and the teacher in charge was not very satisfied. Reading the email messages was tedious. Not wanting to prejudice any student, he actually negotiated with teachers to enlarge the capacity for some courses. It cost him a lot of time and he was not convinced that it will be reproducible in the future. Furthermore, he could not be entirely fair to the students.

Research Methodology. The authors designed the process described in the previous section. A questionnaire was set up under Google Drive. Students used it to submit their choices, to distribute 8 biddings points and to give at most 3 arguments to motivate each choice. All the 33 students involved in the initial process answered. We could check the answers against the initial votes as well as the email messages sent by the students. The choices were consistent with the initial ones. We imported the csv file resulting from the answers under the tool introduced in the next paragraph. The authors together with the teacher in charge of the initial assignment run the process as described below.

Logical Information Systems (LIS) [5]. belong to a paradigm of information retrieval that combines querying and navigation. LIS are formally based on Logical Concept Analysis (LCA) [12], a logical generalization of a mathematical theory, Formal Concept Analysis [13]. In LCA, logical formulas are used to describe objects. Numerical and symbolic properties can thus be combined. From the descriptions of objects, a data structure, called *concept lattice*, is computed which partially orders both objects and properties and serves as navigation structure. Logical formulas are also used to represent queries and navigation links in the lattice and an interesting property of LIS tool is to maintain the consistency between them and the set of selected objects. Several LIS tools are available. In the following we use Camelis[1].

The assignment session. Let us illustrate the process, starting after the first 3 steps, namely when the students have voted, the modules for which there is a balanced distribution of votes are validated, and the under-filled resources are also validated. The unbalanced modules are Module 2 and Option B.

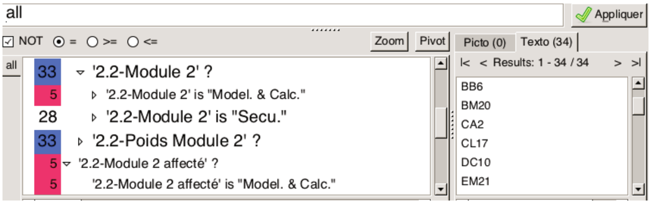

Fig. 1. Distribution of biddings for Module 2

Figure 1 shows a partial screen shot of Camelis. LIS user interface gives a *local view* of the concept lattice. The local view is made of three parts: (1) the *query* (top left), (2) the *extent* (bottom right), and (3) the *index* (bottom left). The *query* is a logical formula that typically combines properties, patterns and Boolean connectors. On the figure, the query area shows that there is no filtering yet (represented by `all`). The *extent* is the set of objects (called agents in the description of the process) that are matched by the query, according to logical subsumption. The objects (agents) are actually students in this case study. On the figure, one can see part of the identifiers corresponding to all students under consideration. Finally, the *index* is a set of properties, taken from a finite subset of the logic, it is restricted to properties associated to at least one object (student) in the extent. The index plays the role of a summary or inventory of the extent, showing which kinds of objects there are, and how many of each kind there are. In Figure 1, one can see that all 33 students have voted for Module 2 and that they all have given a bidding (`‘‘Poids’’`). 28 students chose `"Secu."`, as its capacity is 20, the decision makers have to go into step 4.

Figure 2 shows an actual query, namely `’2.2-Module2’ is "Secu." and (’2.2-Poids Module 2’= 3 or ’2.2-Poids Module 2’= 4 or ’2.2-Poids Module 2’= 6`. It means that we are interested in the students who had chosen Security with a bid of at least 3. There are 9 such students. No students had bidded 5. Note that the query has been obtained solely by clicking on properties of the index. The nine students corresponding to these high votes are assigned to their choice. The chauffeur had not selected the weight “2” because it corresponds to 15 students (not shown here but visible before the selection.) 9 + 15 students would amount to 24, above the limit of 20. Therefore step 4, for module 2, is completed.

[1] See `http://www.irisa.fr/LIS/ferre/camelis/`

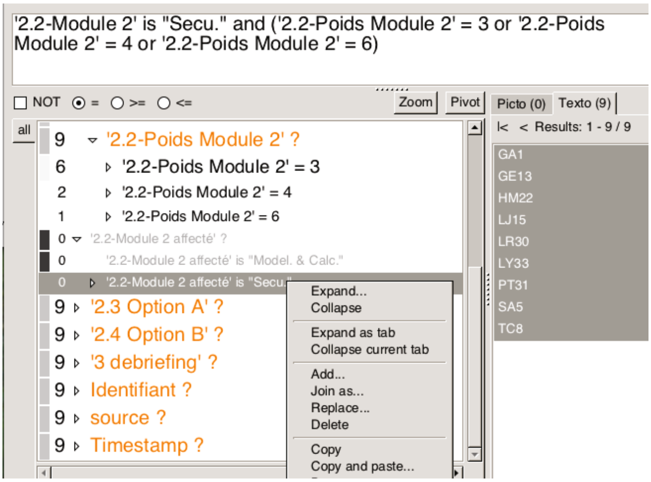

Fig. 2. Selection of students who had chosen course Security with a bid ≥ 3

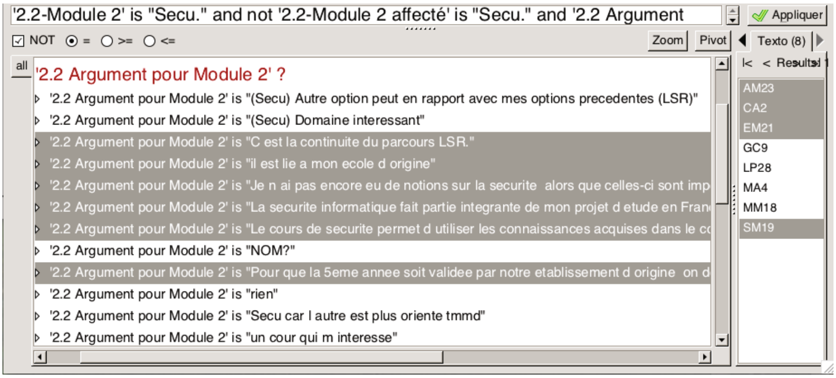

Fig. 3. Selection of convincing motivating arguments

Figure 3 illustrates step 5. The query selects students who have chosen Security, who are not yet assigned a course in Module 2 and who provided arguments for their choice. There are 8 such students. However, from the index areas, it can be seen that one of them added a blank information, another one said `Rien` ("nothing"). The decision makers click on the 6 arguments that were found convincing. The corresponding students are highlighted in the extent area. There are only 4 such students because some of them submitted several convincing arguments. Those 4 students have their choice validated for Module 2. Steps 3, 4 and 5 are then processed for Option B. At that point, Module 1 and Option A are totally assigned; there are still 11 unassigned students for Module 2 and 2 for Option B.

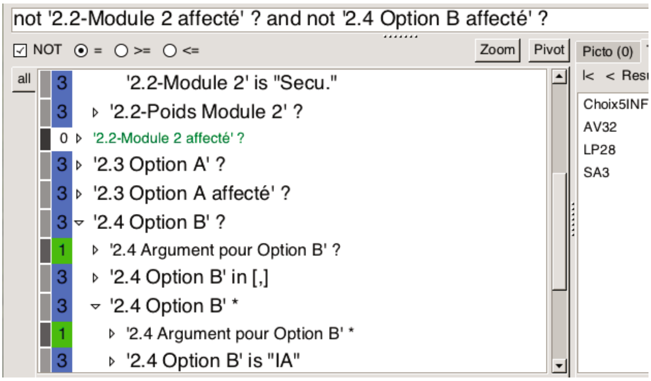

Fig. 4. Students with none of the 2 over-demanded courses assigned

Figure 4 illustrates step 6. The query selects students who still have both the over-demanded modules unassigned. There are only 3 such students. The decision makers make sure that they have at least one of their choices. The decision makers then finish the assignment, thanks to a dictatorship approach, using the ranking of the students according to the results of the previous year.

4 Discussion and Perspectives

Both quantitative biddings and qualitative motivations are taken into account. The initial steps fill the balanced resources. For each over-demanded resource, for a given bidding, either there is enough space for the whole set and all agents at that bidding level are assigned the resource, or the motivations related to that given set of agents, and only them, are analyzed (step 5). Therefore, a limited number of qualitative motivations have to be considered. Furthermore, the navigation mechanism of the supporting tool significantly helps select the motivations to be considered. Last, but not least, motivations for a given course and given agents are assessed all together as opposed to what happened in the initial process were the decision maker read all the emails (each email containing the motivations for all modules) before starting the assignment.

Fairness. An important advantage of the process is to insure that the agents are treated equally. Most assignment systems, see for example [2,1,4,3], start from an ordered list of agents, even if they do not implement a kind of dictatorship. It can be very unfair or arbitrary. A lottery is often used, at least to break ties. Our process, on the contrary, starts from the resources. The agents are considered by sets: all the agents fulfilling the criteria under consideration are treated equally, either a set is small enough to be assigned in the desired resources and all the agents are added, or it is too large and either the criteria are refined or nobody is added. Considering the agents by sets, thus, allows to treat them fairly with respect to the considered criteria. That is again made possible by the LIS capabilities of the tool. As discussed in introduction, Sönmez and Ünver argue that bidding, due to strategies of the agents, can induce biases [4]. They show that the bidding do not reflect the true preferences of agents. Students may bid higher for popular courses than for courses that they truly prefer. The authors show that asking students to also specify their preferences reduces the number of students who get courses that are not their preferred ones. With our approach, firstly, global arbitration at step 6 guaranties that even students who have been unlucky with their biddings are not too prejudiced. Secondly, the motivations play somehow the role of the preferences: at a given level of bidding, if there is competition, the decision makers can select the students with convincing motivations. The students of the case study strongly demanded that motivations were taken into account. Using a totally ranked list of preferred courses may nevertheless be helpful. A perspective is to thoroughly compare motivations and preferences. Another perspective is to enable some backtracking in the process. Indeed, at present, there is no rule to design the number of units that should be saved until the global arbitration. It is therefore possible that, at the global arbitration step, there are more prejudiced agents to be assigned than free available over-demanded resources.

Tuning the Process. In the case study some students reported that they would have preferred to have more bidding points than simply 8. Indeed, American universities can offer over 100 points to bid [4]. However, their objective is to have a totally automatic process while the objective of our approach is to give assets to agents who are able to justify their choices. The number of biddings is a major parameter of the process. In the one hand, if agents have very few bidding points, they do not have a lot of possibilities to distribute them and the sets of agents to be considered at each step can be large. In the extreme case, for a module all students could bid the same value and thus be in the same set. In that case, the decision makers tasks of steps 5 and 7 are time-consuming. They have to look at many motivations and may need to find many objective criteria to distinguish the agents. On the other hand, if agents have many points, the sets are smaller and the automatic part of the process gets closer to filling up the resources. In that case, the work of the decision makers is easier, if not null. However, the bidding process for the agents is much harder, and the bidding differences can be meaningless. A perspective is, thus, to investigate guidelines to set up the number of bidding points. Currently, it is experimentally set.

5 Conclusion

As opposed to existing approaches, quantitative biddings and qualitative motivations of the agents drive the major part of our process without having to order the agents except at the end of the process. Furthermore, our process is the only one we are aware of that can take into account qualitative motivations in a tractable way, at least for small to medium problems. The process is supported by a LIS tool that, thanks to logical faceted navigation, allows decision makers to handle both biddings and motivations in an integrated interface. Furthermore, it guaranties that all the agents are treated equally.

The students concerned by the case study were favorable to the new process. At the end of the simulation, the teacher in charge decided to use the process and the tool for the next assignment. He was confident to be more serene if some students would not have some of their choices, knowing that the decision will be fair to students fulfilling the same criteria.

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References

1. Budish, E., Cantillon, E.: The multi-unit assignment problem: Theory and evidence from course allocation at harvard. American Economic Review 102(5) (2012)
2. Ehlers, L., Klaus, B.: Coalitional strategy-proof and resource-monotonic solutions for multiple assignment problems. Social Choice and Welfare 21(2), 265–280 (2003)
3. Abdulkadiroglu, A., Pathak, P.A., Roth, A.E.: The new york city high school match. American Economic Review 95(2), 364–367 (2005)
4. Sönmez, T., Ünver, M.U.: Course bidding at business schools. International Economic Review 51(1), 99–123 (2010)
5. Ferré, S., Ridoux, O.: An introduction to logical information systems. Information Processing & Management 40(3), 383–419 (2004)
6. Briggs, R., de Vreede, G.J.: ThinkLets: Building Blocks for Concerted Collaboration. Center for Collaboration Science, Univ. of Nebraska at Omaha (2009)
7. Kolfschoten, G.L., de Vreede, G.J., Briggs, R.O.: Collaboration engineering. In: [14], ch. 20, pp. 339–357
8. Lewis, L.F.: Group support systems: Overview and guided tour. In: [14], ch. 14, pp. 249–268
9. Adla, A., Zaraté, P., Soubie, J.L.: A proposal of toolkit for gdss facilitators. Group Decision and Negotiation 20, 57–77 (2011), 10.1007/s10726-010-9204-8
10. Ducassé, M., Cellier, P.: Fair and fast convergence on islands of agreement in multicriteria group decision making by logical navigation. Group Decision and Negotiation (2013)
11. Mittleman, D.D., Briggs, R.O., Murphy, J., Davis, A.: Toward a taxonomy of groupware technologies. In: Briggs, R.O., Antunes, P., de Vreede, G.-J., Read, A.S. (eds.) CRIWG 2008. LNCS, vol. 5411, pp. 305–317. Springer, Heidelberg (2008)
12. Ferré, S., Ridoux, O.: A logical generalization of formal concept analysis. In: Ganter, B., Mineau, G.W. (eds.) ICCS 2000. LNCS, vol. 1867, pp. 371–384. Springer, Heidelberg (2000)
13. Ganter, B., Wille, R.: Formal Concept Analysis: Mathematical Foundations. Springer, Heidelberg (1999)
14. Kilgour, D.M., Eden, C.: Handbook of Group Decision and Negotiation. Advances in Group Decision and Negotiation, vol. 4. Springer, Netherlands (2010)

Knowledge Based Decision Support Systems: A Survey on Technologies and Application Domains

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Abstract. Knowledge-Based Decision Support Systems (KBDSS) have evolved greatly over the last few decades. The key technologies underpinning the development of KBDSS can be classified into two categories: technologies for knowledge modelling and representation, and the technologies for reasoning and inference. This paper provides a review on the recent advances in the two types of technologies, as well as the main application domains of KBDSS. Based on the examination of literature, future research directions are recommended for the development of KBDSS in general and in particular to support group decision making.

Keywords: DSS, KBDSS, Intelligent DSS, knowledge modelling and representation, reasoning and inference, application domains.

1 Introduction

Decision support Systems (DSS) are developed to support decision makers in their semi-structured tasks and appeared in the 70's. The first architecture proposed by [1] was composed by: (1) A model base management system; (2) A data base management system; (3) A human-computer interface.

In order to develop systems the most usable possible, in the 1990s, DSSs were enriched by techniques rooted in Artificial Intelligence, particularly the introduction of a knowledge base into the architecture previously described, so as to give the system the capacity for reasoning. This approach is an Expert Systems type approach, for which the modes of reasoning and the problem to be solved are modeled first and then used on a machine by way of inference engines. This approach leads to develop Intelligent DSS or also called Knowledge Based DSS.

According to [2] the components of a DSS can usually be classified into five distinct parts:

- A database management system and the associated database: which stores, organizes, sorts and returns the data relevant for a particular context of decision making;
- A model base management system and the associated model base: which has a similar role to the database management system, except that it organizes, sorts and stores the organization's quantitative models;

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- The inference engine and the knowledge base: which performs the tasks relating to recognition of problems and generation of final or intermediary solutions, along with functions relating to the management of the process of problem solving;
- A user interface: which is a key element in the functions of the overall system;
- A user: who forms an integral part of the process of problem solving.

Thus, in the architecture of these systems, we see the emergence of a technological part drawn from Artificial Intelligence, integrating knowledge modeling into the problem to be solved. The advantage to this architecture lies in the emphasis placed on reasoning in the taking of the decision, and supported by tools such as knowledge-based systems.

The idea of this work is to study the evolution of Knowledge Based DSS (KBDSS) in recent years on several criteria. We studied 29 papers in order to define what are the most used: technologies for knowledge modelling; technologies for reasoning as well as what are the principal application domains. The methodology used to select the papers include four key steps: (1) An initial search was conducted with “ISI Web of Science”. Keywords used for the initial search were “knowledge base”, “reasoning” and “decision support system” and we refined the search by selecting the Science Technology and Social Science in order to eliminate results from arts and humanities. The search is further refined by restricting to the period of 1990-2013. We believe that 1990 is an appropriate starting point for research in KBDSS. We used the “knowledge base”, “reasoning” and “decision support system”, because they have been used as keywords in most cited articles on the subject and to obtain the most complete results possible. (2) Then, on the basis of a thematic analysis of the abstracts of the selected papers, we eliminated those which did not address “knowledge base” or “reasoning” in relation to decision support systems. We also did a cursory reading of the articles we eliminated to be sure that they were out of scope of our literature review. (3) We added five papers that were not included in ISI searching results from two well known journals in DSS area: International Journal of Decision Support Systems Technology, and Journal of Decision Systems. (4) We complemented our selection adding three books widely cited in DSS field. The final selection includes 29 references as analyzed in this literature review.

This paper is organized as follows. After this introduction, in a second part we draw a survey of technologies used for first knowledge modeling and second reasoning. In the third part, we present the main application domains for which KBDSS are successfully designed. The fourth part is devoted to finding the relationships among the used technologies, the application domains. These relationships are then used in order to present some recommendations for KBDSS design. In the last section we propose a conclusion.

2 Survey on Technologies

In order to analyze these papers, we define several criteria. We firstly distinguish two criteria based on the used technologies, which are the used technology for knowledge modelling and then used technologies for reasoning implementation.

2.1 Technologies for Knowledge Modelling

We firstly must distinguish the technologies used for knowledge modelling. We distinguish two kinds of knowledge representations**: clustering** and **ontology.**

The clustering techniques consists in dividing the knowledge in different classes or knowledge classification. Similar rules are represented in the same cluster and distinct clusters of rules are formed using representatives. Several papers use this kind of techniques [3], [4], [5]. These authors assume that time is gaining when dealing with large knowledge base. We noticed from these authors that the future direction can be asked in the following question: When a cluster is formed of several rules, a couple of them will be fully relevant to the question, most of them are only partially relevant, how to increase the relevance?

The ontology modelling technique consists in capturing consensual knowledge, i.e. not personal view of the target phenomenon but one accepted by a group; ontology is not just about presenting information to humans but also processing the information and reason about it. Some works have been conducted on ontology engineering process for which the following steps are proposed: feasibility study, kick-off, refinement, evaluation, maintenance. From the following authors [6], [7], [8], [9] several perspectives have been drawn along the following two axes: a. Clear understanding of how to build ontologies in a systematic way and b. Building fuzzy rules into ontology.

The two main knowledge representations consist in clustering and ontologies. Nevertheless, the considered knowledge can divide three kinds or levels: a. **contextual knowledge**; b. **content knowledge** and c. **unstructured knowledge**.

About contextual knowledge, [10] proposed a review paper in which the context of knowledge is seen through the DSS environment, such as clinical setting, knowledge states of the patients and physicians, and emotions; case-based reasoning suited for capturing contextual knowledge.

From the content knowledge we saw two sub-levels of knowledge: a. medical knowledge; b. organizational knowledge. For the medical knowledge, this kind of implementations have been studied in several works and medicine is the main application domain of KBDSS (for this point see section III.a.). On the other hand ([9] proposed a model of organizational knowledge in the K4Care project.

[11] proposed to develop a model for unstructured knowledge based on narratives documents for which Knowledge resided in client's records and stories.

Some other authors propose to exploit this knowledge through data mining techniques in order to elicit knowledge from explicit data sources [6] or to discovery new knowledge [3]. In order to achieve this objective this paper presents several techniques of learning methods for example lazy learning based on explanation-based learning and that does not cover all the space of known examples and eager learning.

All these modelling technologies are then used by inference engine in order to produce new pieces of knowledge or solutions to a problem. We propose in the next section a classification of reasoning or inference technology based on the same 29 papers.

2.2 Technologies for Reasoning

We distinguish five reasoning or inference technologies: Rule-based reasoning (**RBR**), Case-based reasoning (**CBR**), Narrative-based reasoning (**NBR**), Ontology-based reasoning (**OBR**) and Genetic Algorithms (**GA**).

About the Rule-based reasoning technology, several kinds of rules modelling are used: Traditional RBR; Logical Elements Rule Method for assessing and formalizing clinical rules; Rule verification to ensure high quality of guidelines encoded in KB-DSS in the form of rules: redundancy, inconsistency, circularity, incompleteness. This technology is predominant and is used in the following systems implementation [3], [4], [5], [12], [13], [14], [15], [16]. From these papers the following future directions of implementation are drawn to Belief RBR (vagueness, incompleteness, non-linear relationships) and fuzzy rule-based.

The Case-based reasoning technology relies on past and similar cases to find solutions to new problems; it is a kind of implementation of a sort of automatic ranking of past lessons and making available best practice cases. Five steps are distinguished in the process of Case-based reasoning: interpretation, retrieval, reuse, revise, retain. The following authors have implemented KBDSS based on CBR [6], [17]. The following trends are drawn for CBR: extensive application of ontologies to improve the use of the domain from past experiences and diminish impasse situations.

[11] proposes a Narrative-based reasoning KBDSS. This system deals with unstructured narrative information. The objective is to share experience and lessons learned for decision making through stories and narratives. For this system an NBR algorithm comprises three key modules: key concept extraction, similarity analysis, and association analysis. For this implementation the author proposes as future work to measure the similarity among the key concepts in order to have a more precise determination on the similarity analysis and association analysis.

([8]) and ([9]) propose to implement the reasoning technology for KBDSS through Ontology (Ontology-based technology). Knowledge is implemented through ontology navigation. The K4Care project provides a Case Profile Ontology from a formal representation of all the healthcare concepts and relationships and constraints between concepts, related to the care of chronically ill patients. This project then implements a medical DSS reasoning loop. These authors precise that future ontology will include restrictions on the interactions among intervention plans with the purpose of extending the DSS with mechanisms to compare treatments.

[13] proposes a KBDSS based on Genetic algorithm. He implemented a co-evolutionary genetic algorithm for detecting gamma ray signals: 5 layer hierarchy – input layer, condition layer, rule layer, consequence layer, output layer are distinguished.

Independent of the used implementation technologies, KBDSS are developed for several kinds of application domains. These application domains are described in the following section.

3 Survey on Application Domains of KBDSS

Based on the 29 papers reviewed, the application domains of the KBDSS can be classified into four main areas: medicine, manufacturing, environmental management and others. The applications in medicine are predominant.

3.1 Medicine

The application of knowledge-based systems in Medicine started in early 1970s. Since then, KBDSS has been extensively explored to support decision making in all aspects of medicine because of the fact that medical conditions are highly diverse, fast changing and sometimes unpredictable. This section presents the recent advancements of KBDSS in medicine decision making to support medical tasks, including clinical, management (treatment) and follow-up, in particular,

- clinical diagnosis to improve the accuracy of analysis of conditions and adaption of evidence-based standard intervention plans to the conditions [3], [7], [8], [15], [12], [18];
- clinical pathways to standardize medical activities and thereby improve healthcare quality ([5];
- clinical risk assessment to help reduce medical errors and patient safety incidents and thus reduce the healthcare service costs caused by patient safety incidents [14];
- medication review to improve medication usage, leading to reductions in drug-related problems and potentially savings on healthcare system costs [19];
- home care assistance to support the management of complex distributed healthcare systems ([9];
- mental healthcare for offering timely and quality services so as to maintain the health of the community [11]; and
- finally, it is worth noting that a guest editorial provides a good overview of KBDSS application to health sciences ([10], [17].

3.2 Manufacturing Production Scheduling and Process Optimization

A second main domain that KBDSS has been widely explored is manufacturing including process design and optimization, production planning and scheduling, supply chain and logistics. Manufacturing industry requires support from KBDSS because of a number of reasons: (1) The central role and importance of the manufacturing activities in the value chain. Manufacturing holds the key to delivering high quality products and services to customers on time and with cost competitiveness. Customers will not be willing to pay if there are no products and services to satisfy their requirements. (2) The need for knowledge support from experts and professionals. Manufacturing practices have been existed for hundreds of years which have built up rich experience and best practices in the form of declarative knowledge or procedural knowledge. Sharing, reusing and learning from the vast amount of knowledge developed over time are crucial for continuous improvement of business performance. (3) The high complexity of manufacturing decision situations, including not only the products and the supply chains but also the materials and the market. To make a good manufacturing decision will require knowledge support from the whole value chain, i.e. to bring knowledge from the upstream chain originating about the raw materials and the downstream chain reaching out to final customers and market. Plenty of research has investigated capturing and structuring manufacturing knowledge for business process and reasoning mechanisms for knowledge based systems in the area. An earlier review on intelligent manufacturing systems can be found in [20]. Recent development on a knowledge-based multi-role decision support system for process optimization in steel making classified manufacturing knowledge in three distinguished categories: public knowledge, rule sets and boundary values [16].

3.3 Environmental Management

The use of knowledge based systems has been proven to be a suitable approach to supporting decision making in environmental systems, especially in the management of water and waste water. Water pollution is an important issue in urban and industry-dominated basins. This section looks at a specific type of environmental issue through waste water systems. The complexity of an urban waste water system lies in the fact that it consists of a number of inter-connected parties such as industries, households, the sewer system, the waste treatment plant and the river. Capturing the huge amount of data and information from the various sources and providing knowledge that can be shared between the various parties has been a challenge for adopting KBDSS in water management practices. Recent research highlighted the importance of using knowledge-based approaches in waste water management decision support systems, in terms of knowledge about the processes, possibilities of improvement and innovation to be effectively revealed, pooled and distributed among all parties involved in the process of industrial wastewater discharges [6], [21].

3.4 Others

Some other applications of KBDSS are scattered around various interesting domains, for example in detecting gamma ray signals in the universe [13] and road safety with the application to car driving [22].

4 Relationships among Application Domains and Used Technologies

The previous sections looked at the used technologies in KBDSS and their application domains separately. This section presents the relationships between different technologies and that between the technologies and application domains. Recommendations on developing future KBDSS are subsequently provided.

4.1 Relationships

As discussed in section 2, there are two main types of technologies in relation to KBDSS: technologies for knowledge modelling and representation, and technologies for reasoning and inference. Main application domains of KBDSS are discussed in section 3. The relationships among the technologies and applications are illustrated in Figure 1. This Figure is generated based on the elicitation of internal relationships existing between different elements (such as clustering and ontology) within each

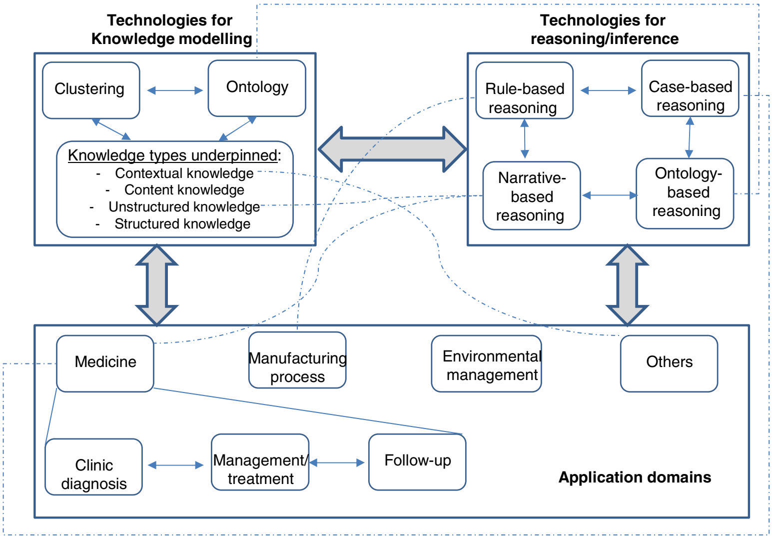

Fig. 1. Relationships among technologies and applications

component (such as modelling technologies) and the external relationships between the three components (i.e. modelling technologies, reasoning technologies and applications).

As shown in the Figure 1, the three blocks in the relationship chart are technologies for knowledge modelling, technologies for reasoning and inference, and the application domains. Three types of relationships can be elicited. Type I relationships are the internal links between elements within the same block and represented by thin solid arrows. For example, links between clustering and ontology, as well as the links between different clinic diagnosis, treatment plan and follow up decisions [5]. Type II relationship are external links between different blocks, such as links between modelling and reasoning technologies. These types of relationships are represented by solid block arrows. For a KBDSS to properly function in any domain areas, it has to be created using appropriate both knowledge modelling and reasoning technologies [8], [9]. Type III relationships are cross links among elements in different blocks which are represented by dashed thin lines. For example, the links from ontology technology through ontology-based reasoning to medical application domain demonstrate that specific knowledge representation technology such as ontology needs particular reasoning mechanism and fits particularly well in medical application, because of the nature of medical decision situation with high variety, high dynamics and unpredictability [8]. Understanding the different types of relationships within, between and across different blocks will help us to justify and choose the right technologies for the development of knowledge base and reasoning mechanisms for the right application domain. Please note that not all links are illustrated in the Figure to keep the Figure clean enough to be legible.

4.2 Recommendations

Based on the examination of the KBDSS technologies and application domains, certain challenges and trends have been observed for future research directions from two perspectives: KBDSS development in general and in particular to support group decision making.

Challenges and recommendations for future KBDSS development in general:

- Even though ontology has been well researched as a means of capturing knowledge and modelling knowledge structure, building a moderately sized ontology in a KBDSS is still a time consuming task. One challenge lies in the acquisition of domain-specific terminology and relationships from a conceptual model. To meet the challenge, ontology learning is emerging to discover ontological knowledge from various forms of data automatically or semi-automatically [23]. Key elements of ontology learning include information extraction, ontology discovery and ontology organization. It is hoped that the advancement of relevant technologies such as cluster analysis may shed lights on identifying the relationships between terms applicable to the domain knowledge. Ontology learning is certainly in its infancy and requires more research in the future in order to support the creation of better KBDSS.
- Even individual reasoning technologies such as rule-based reasoning, case-based reasoning, narrative-based reasoning and ontology-based reasoning have matured and been tested in real-world applications, there is a trend that a combination of different technologies need to be investigated in order to remedy the limitations of a single technology. For example, a commonly accepted limitation of rule-based reasoning is its scalability, i.e. when the total number of rules in the knowledge base increases, the time needed to infer also considerably increases [4]. However, this drawback can be rectified by a combination use of rule-based reasoning together with clustering technology, i.e. by clustering similar rules to form distinct clusters of rules, the time needed for inference can be greatly reduced. Apart from the speed, accuracy has been an important issue to most reasoning technologies. Future research should spend more effort in verifying knowledge [24], for example the rules in the knowledge base should be validated by experts. The need for the knowledge verification becomes even more critical in clinical KBDSS since a single piece of incorrect or inaccurate knowledge could result in a dangerous or wrong recommendation in turn could cause harm or safety issue to patients [12]. A third challenge for reasoning technologies is how to incorporate the uncertainty of knowledge in KBDSS. Recent research has shown that by integrating existing rule-based reasoning or case-based reasoning with fuzzy logic and artificial networks can enhance the reasoning performance in terms of uncertainty [5], which should remain as a hot topic for future research. Finally, because of the intrinsic nature of incompleteness of knowledge, neither domain knowledge nor contextual knowledge is static or complete, as knowledge itself evolves all the time and we would never have complete knowledge of a decision problem or solution at a time. In parallel, reasoning technologies to infer new knowledge based on exiting knowledge captured in the knowledge base should address this issue of evolution [13].

- In terms of application domain, there is plenty of opportunity to explore KBDSS in new industries and sectors other than the domains reviewed in this paper. Inside the medicine domain, future research needs to better address the integration of knowledge from various healthcare stakeholders such as doctors, nurses, patients, carers and the community, so that more coherent healthcare services can be provided across various activities including clinic diagnosis, treatment, home care, community support, and follow up actions [10]. In the manufacturing domain, knowledge about customer and markets, product design and production, as well as maintenance and end-of-life treatment should be integrated in the knowledge base, and the KBDSS should enable the smooth flow of knowledge across the supply chain to foster the emerging knowledge chain management technologies [25].

<u>Recommendations for the development of KBDSS in group decision making:</u>
Decision makers have to work together in group decision making context, therefore a group decision support system (GDSS) emphasizes on both the use of communications and collaborations as well as decision models [24]. KBDSS supporting group decision making has to address knowledge sharing between the group decision makers. It has been well acknowledged that the difficulty of knowledge sharing lies with the sharing of tacit knowledge, especially when decision makers come from very different background and confusing terms (such as business intelligence, enterprise information portal, communities, groupware, knowledge management and knowledge network) are being used simultaneously. When plenty of knowledge-based intangibles (including people's abilities, professional knack, trade secrets, routines – unwritten rules of individual and collective behavior patterns) are floating around the group, but the contextual knowledge is not well defined, it would cause great cognitive burden to decision makers [26]. To address the above issues, existing research has investigated and proposed solutions to the development of interactive learning environment to encourage knowledge transfer across disciplines, use of overlapping teams and joint learning. Further research is needed to develop typologies that can facilitate more effective sharing of tacit knowledge by integrating core elements including trust and care, leadership charisma, knowledge culture, concept ba and social network analysis [27]. By developing the typology and adopting it into KBDSS, the right communication and collaboration infrastructure will be provided to support knowledge flow in group decision making. So far, there is very little research published to address the knowledge modelling and reasoning mechanisms that are particularly suited to foster communication and collaboration to support group decision making, even though some knowledge artefacts as tools have been developed for collaborative user-driven design [28]. Plenty of opportunities exist for future research in integrating mature knowledge modelling and reasoning technologies into functioning KBDSS that can support group decision making scenario, especially in real world decision practices such as in medicine, manufacturing, environmental management and other real decision cases. As a first step, we suggest that new knowledge modelling and reasoning technologies that aim to support group decision making should seriously consider more coherent methodologies such as knowledge chain management and multi-stakeholder approaches.

5 Conclusions

This review paper focuses on the recent development on relevant technologies and application domains of knowledge-based decision support systems (KBDSS). It complements a number of recent survey papers in the literature which were focused on specific, related areas, such as the integration of knowledge based-systems and DSS [29] ontology engineering [23], and contextual knowledge in medical CBR systems [10]. However, this paper brings together knowledge modelling technologies, reasoning and inference technologies together with applications domains, by eliciting the links across different technologies and application domains. Therefore, this paper extends the review to a much broader picture and provides a synergistic view of KBDSS with more complex composition. Recommendations for future research are provided for the development of future KBDSS in general and in particular to support group decision making.

References

1. Sprague, R.H., Carlson, E.D.: Building effective decision support systems. Prentice-Hall, Englewood Cliffs (1982)
2. Marakas, G.M.: Decision Support Systems, 2nd edn. Prentice-Hall (2003)
3. Armengol, E.: Classification of melanomas in situ using knowledge discovery with explained case-based reasoning. Artificial Intelligence in Medicine 51, 93–105 (2011)
4. Wakulicz-Deja, A., Nowak-Brzezińska, A., Jach, T.: Inference processes in decision support systems with incomplete knowledge. In: Yao, J., Ramanna, S., Wang, G., Suraj, Z. (eds.) RSKT 2011. LNCS, vol. 6954, pp. 616–625. Springer, Heidelberg (2011)
5. Yang, H., Li, W., Liu, K., Zhang, J.: Knowledge-based clinical pathway for medical quality improvement. Information Systems Front (2011), doi:10.1007/s10796-011-9307-z
6. Cortes, U., Sanchez-Marre, M., Sanguesa, R., Comas, J., Roda, I.R., Poch, M., Riano, D.: Knowledge management in environmental decision support systems. AI Communication 14, 3–12 (2001)
7. Minutolo, A., Esposito, M., De Pietro, G.: A pattern-based knowledge diting system for building clinical decision support systems. Knowledge-Based Systems 35, 120–131 (2012)
8. Riano, D., Real, F., Lopez-Vallverdu, J.A., Campana, F., Ercolani, S., Mecocci, P., Annicchiarico, R., Caltagirone, C.: An omntology-based personalisation of healthcare knowledge to support clinical decisions for chronically ill patients. Journal of Biomedical Informatics 45, 429–446 (2012)
9. Valls, A., Gibert, K., Sanchez, D., Batet, M.: Using ontologies for structuring organisational knowledge in home care assistance. International Journal of Medical Informatics 79, 370–387 (2010)
10. Montani, S.: How to use contextual knowledge in medical case-based reasoning systems: a survey on very recent trends. Artificial Intelligence in Medicine 51, 125–131 (2011)
11. Wang, W.M., Cheung, C.F.: A narrative-based reasoning with applications in decision support for social service organizations. Expert Systems with Applications 38, 3336–3345 (2011)
12. Cesario, E., Esposito, M.: A knowledge-based method for verifying the reliability of clinical DSSs. In: Proceedings of the 8th International Conference on Signal Image Technology and Internet Based Systems (2012)

13. Huang, H., Pasquier, M., Quek, C.: Decision support system based on hierarchical co-evolutionary fuzzy approach: a case study in detecting gamma ray signals. Expert Systems with Applications 38, 10719–10729 (2011)
14. Kong, G., Xu, D.L., Body, R., Yang, J.B., Mackway-Jones, K., Carley, S.: A belief rule-based decision support systems for clinical risk assessment. European Journal of Operational Research 219, 564–573 (2012)
15. Medlock, S., Opondo, D., Eslami, S., Askari, M., Wierenga, P., de Rooij, S.E., Abu-Hanna, A.: LERM (Logical Elements Rule Method): A method for assessing and formalizing clinical rules for decision support. International Journal of Medical Informatics 80, 286–295 (2011)
16. Zhang, R., Lu, J., Zhang, G.: A knowledge-based multi-role decision support system for ore blending cost optimisation of blast furnaces. European Journal of Operational Research 215, 195–203 (2011)
17. Bichindaritz, I., Montani, S.: Advances in case-based reasoning in health sciences. Artificial Intelligence in Medicine 51, 75–79 (2011)
18. Schipper, J.D., Dankel II, D.D., Arroyo, A.A., Schauben, J.L.: A knowledge-based clinical toxicology consultant for diagnosing single exposures. Artificial Intelligence in Medicine 55, 87–95 (2012)
19. Bindoff, I., Stanfford, A., Peterson, G., Kang, B.H., Tenni, P.: The potential for intelligent decision support systems to improve the quality and consistency for medication review. Journal of Pharmacy and Therapeutics 37, 452–458 (2012)
20. Harding, J.A., et al.: Data mining in manufacturing: a review. Journal of Manufacturing Science and Engineering –Transactions of the ASME 128(4), 969–976 (2006)
21. Aulinas, M., Nieves, J.C., Cortes, U., Poch, M.: Supporting decision making in urban wastewater systems using a knowledge-based approach. Environmental Modelling and Software 26, 562–572 (2011)
22. Brezillon, P., Brezillon, J., Pomerol, J.C.: Context-based methodology for decision making: application to car driving. International Journal of Decision Support Systems Technology 1(3), 1–20 (2009)
23. Easton, J.M., Davis, J.R., Roberts, C.: Ontology engineering: the “what’s”, “why’s” and “how’s” of data exchange. International Journal of Decision Support Systems Technology 3(1), 40–53 (2011)
24. Zarate, P.: Tools for Collaborative Decision Making. Wiley-ISTE (2013) ISBN: 978-1-84821-516-0
25. Liu, S., Moizer, J., Megicks, P., Kasturiratne, D., Jayawickrama, U.: A knowledge chain management framework for global supply chain integration decisions. Production Planning and Control (2013), doi:10.1080/09537287.2013.798084
26. Grundstein, M., Rosenthal-Sabroux, C., Pachuski, A.: Reinforcing decision aid by capitalizing on company’s knowledge: future prospects. European Journal of Operational Research 145(2), 256–272 (2003)
27. Shaqrah, A.A.: A typology of tacit knowledge sharing themes to fostering group decision support system. International Journal of Decision Support Systems Technology 2(3), 41–50 (2010)
28. Lindgren, H.: Knowledge artefacts as tools to communicate and develop knowledge in collaborative user-driven design. Proceedings CBMS (2012)
29. Liu, S., Duffy, A.H.B., Whitfield, R.I., Boyle, M.B.: Integration of decision support systems to improve decision support performance. Knowledge and Information Systems 22(1), 261–286 (2010)

On the Use of Cognitive Maps to Identify Meaning Variance

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Abstract. Cognitive science, as well as psychology, considers that individuals use internal representations of the external reality in order to interact with the world. These representations are called mental models and are considered as a cognitive structure at the basis of reasoning, decision making, and behavior.

This paper relies on a fieldwork realized as closely as possible from the respondents. We propose an approach based on graph theory in order to study the meanings given by several people to the same concept, and to identify those who give it the same meaning.

The use of tools from graph theory combined with the study of cognitive maps leaded us to highlight the importance of interaction notably within group decision making. This idea, as well as the limits of our approach, are discussed at the end of this paper.

Keywords: cognitive map, mental model, graph theory, interaction, group decision making.

1 Introduction

Mental models are "personal, internal representations of external reality that people use to interact with the world around them" for Jones et al. in [10]. These representations are abstractions of the reality relying notably for an individual on his/her personal experiences, perceptions and understanding of the world that surrounds him/her.

These representations may vary from one person to another, as well as the meanings they give to the same concept. For Daft and Weick, "Interpretation gives meaning to data, but it occurs before organizational learning and action." ([5], p. 286), that it the reason why we consider that identifying meaning variance could be useful for group decision making or negotiation. If authors as Hall et al. in [9] and Morgan in [18] focus on cognitive mapping as a way to improve management and to study communication breakdown risks, others as Quinn in [20] and Langan-Fox et al. in [15] consider cognitive mapping as a way to elaborate a "shared or team mental model" ([15], p. 242). For Eden and Ackermann in [7], cognitive maps can be used for issue structuring in the context of a group decision support system.

P. Zaraté, G.E. Kersten, and J.E. Hernández (Eds.): GDN 2014, LNBIP 180, pp. 73–80, 2014.

In this article, we propose an approach in order to identify people who give the same meaning to the same concept through the use of cognitive maps and their analysis with tools of graph theory. The efficiency of the proposed approach relies notably on the fieldwork with the respondents: the meanings they give to the same concept have to be understood. After introducing background theories in the area of cognitive mapping, we present tools of graph theory in order to study cognitive maps. Our own approach is then explained and discussed, from the interviewing of the respondents to the identification of meaning variance through the use of their cognitive maps.

2 Background Theory and Assumptions

This study relies on the assumption that two individuals give the same meaning (respectively different meanings) to the same concept if and only if their cognitive maps related to this concept are practically similar (respectively different). Section 2.2 refines this idea of "quasi-similarity".

Mental models and their elicitation with cognitive maps are introduced in the first part of this section. Tools of graph theory which can be used to study cognitive maps are then presented in the second part of this section.

2.1 Mental Models and their Elicitation through Cognitive Maps

In 1943, Craik drew a parallel between machines functioning and human brain in [4]. This parallel leaded to mental models, which are functional representations of the reality: we use them to interact with the world. They are functional in the sense that they are simplified and incomplete.

Klayman and Ha, with the theory of "confirmation bias", suggest in [14] that individuals seek information adapted to their actual understanding of the world. Indeed for Collins and Gentner in [3], when you explain a domain with which you are unfamiliar, you try to instantiate it on a familiar domain, that you think as being similar. You can for example use water flow to explain electrical current.

Cognitive maps are knowledge structures representing for an individual his/her assumptions and beliefs on the world for Kearney and Kaplan in [13]. These assumptions and beliefs provide himself/herself a framework to interpret new information and to elaborate decisions regarding on new situations ([11] and [12]). Eden sees cognitive maps as "model of thinking" ([6], p. 261). Jones et al. highlight in [10] how cognitive mapping allows studying understanding similarities and differences between several people. Most of the procedures used to elicit mental models consider that they can be represented as a network of concepts and relations and rely on direct or indirect elicitation:

Direct Elicitation. The respondent is here asked to realize a representation of his/her mental model by using drawings, words, and symbols. In [13], the authors introduce a method where the participants must identify the concepts that they consider as important for a given domain, and organize them visually / spatially in a way that represents their understanding of the given domain.

Indirect Elicitation. For Carley and Palmquist in [2], the representation of a mental model can be extracted from written documents or oral propositions.

Mental models elicitation has to focus not only on the concepts that are considered as important, but also on the way they are organized from a cognitive point of view and on their interactions. Cognitive mapping is the process for someone of realizing a cognitive map of his/her mental model related to a domain. It leads to understand how people understand a system. Group decision making and negotiation could be improved if individuals with different points of view are stimulated to work together. A shared understanding has to be identified and supported between the different stakeholders for Jones et al. in [10]. For Weick, a kind of "convergence" can be obtained across managers ([21], p. 80). Decision making processes concern simultaneously individuals, groups, and societies. That is the reason why identifying meaning variance, i.e. differences of understanding, has to be considered as a source of improvements for negotiation and group decision making.

2.2 Analyzing Cognitive Maps with Tools of Graph Theory

Ozesmi and Ozesmi use in [19] the elicitation of mental models by asking respondents to define important variables for a given system. These variables are then written on cards and the respondents have to organize them in a way that reflects their understanding of the system. Ozesmi and Ozesmi propose to use graph theory tools in order to explore the complexity of the constructed networks. The density is for example a way to study cognitive maps, by counting the nodes (N) and the connections (C), the density (D) can be determined as follows:

$$D = \frac{C}{N^2}$$

more the density is high, more the number of relations between the concepts in the cognitive map is high. The hierarchical index from Mac Donald, noted h and introduced in [17], can also be envisaged:

$$h = \frac{12}{(N-1)N(N+1)} \sum_v \left[\frac{d^-(v) - \sum d^-(v)}{N} \right]^2$$

where N is the total number of nodes and $d^-(v)$ the outdegree of the node v. The value of this index is 0 when the system is democratic and 1 when it is hierarchical. The interested reader can have a look at [19] or [16] where the authors present these measures and others. They are notably interested in the most mentioned nodes and in the most central nodes. The firsts are those which are mentioned by the most important number of respondents, whereas the seconds are those which have, for a given respondent, the higher degree in his/her cognitive map. Our approach focuses on these two last measures, which allow rapid experimentations. In the future, they will be compared with others measures in order to justify the relevance of this choice.

3 Our Approach to Identify Meaning Variance

The study presented in this section has been realized with the participation and the agreement of five Computer Science students and five Management Science students at Paris-Dauphine University in 2013.

The first part of this section presents the way of conducting the interviews. The construction of the results is then explained in the second part of this section. Finally these results are discussed in the last part of this section. Every concept given by the students has been translated into English.

3.1 Conducting the Interviews

First of all when you intend to conduct cognitive mapping interviews, you have to realize your own cognitive map of the studied concept. This precaution may prevent reactions you may have during the interviews and that would influence the ongoing cognitive mapping. "Information System" is the studied concept in this work.

The number of interviews has also to be considered. We limited our study to ten interviews not only for practical reasons, but also according to Ozesmi and Ozesmi that noticed in [19] how the number of new concepts can stagnate depending on the number of interviews (see figure 1). For Carley and Palmquist in [2], this stagnation may result from a limited vocabulary for a given subject. Glaser and Strauss in [8] consider notably that a researcher "trying to reach saturation [...] maximizes differences in his groups in order to maximize the varieties of data bearing on the category" (p. 62).

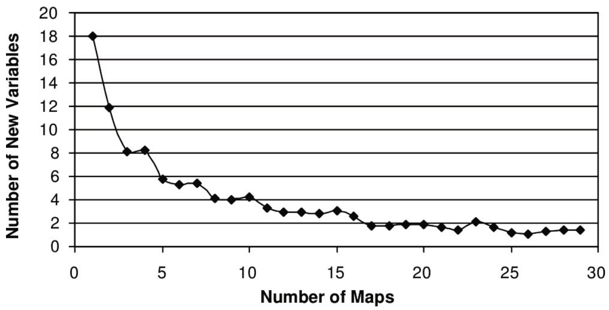

Fig. 1. The number of new concepts depending on the number of interviews (source: Ozesmi and Ozesmi in [19])

The interviews have all been realized individually and the relation between the researcher and the respondent has clearly been explained: this is not an exam, there is no evaluation. The average duration of an interview was 7'14". Post-it notes and a pen were given to the respondent and we began asking: "Imagine that you have to explain what an "Information System" is to someone who absolutely does not know what it is. What concepts or ideas do you need?".

The respondent was invited to write these concepts on as many post-it notes as necessary. The average time between the end of the question and the beginning of an answer was 10,29 seconds. Even when he/she thought he/she had finished, we asked our question again in order to ensure that no concept was forgotten. Then a large piece of paper was given to the respondent, who was invited to organize his/her post-it notes. New concepts could be added at every moment, and at the end we asked to the respondent if the production he/she realized corresponds to the representation for him/her of an “Information System”, i.e. if this production corresponds to the *meaning* he/she gives to this concept.

3.2 Constructing the Results from the Interviews

The figure 2 represents the graph associated to the cognitive map generated by the first respondent for the concept of “Information System”. The links between nodes are not necessarily causal as it may be the case in cognitive maps. The most mentioned nodes and those which are the most central are now going to be studied.

The firsts are determined by counting the number of occurrences of every node, so that within our sample of respondents “Data”, “Human Resources” and “Information” are the most mentioned nodes (these results are presented more precisely in [1]). The seconds are determined by regarding every cognitive map as an undirected graph. Post-it notes become nodes and their position as well as their relationships become edges. So that in the case of the first cognitive map, whose associated graph is presented figure 2, the most central nodes are “Information” and “Human Resources”: these nodes are the most connected to the rest of the graph. Table 1 represents for our sample of respondents the most central nodes per respondent, regarding to the most mentioned nodes. From this table the figure 3 can be generated and highlights the respondents which have common central nodes regarding to the most mentioned nodes: the meaning they gave to the concept of “Information System” seems to be closer for them (in green) than for the others (in white). The reader may have noticed several respondents who have no central nodes regarding to the most mentioned nodes (respondents 2, 3, and 9). Indeed their most central nodes are not related to the most mentioned nodes. We say that the meaning they gave to the concept of “Information System” is *unusual* for the considered group.

3.3 Discussing the Results

The major restriction of our approach is that it is reductive because it focuses only on the most mentioned and on the most central nodes. This restriction, induced by Ozesmi and Ozesmi in [19] constitutes nevertheless a strength of our approach: it is necessary in order to treat cognitive maps, which can rapidly lead to complex graphs. According to our experimentations, this restriction, even if it reduces cognitive maps semantic only to the most mentioned and the most central nodes, strongly accelerates the way of conducing that kind

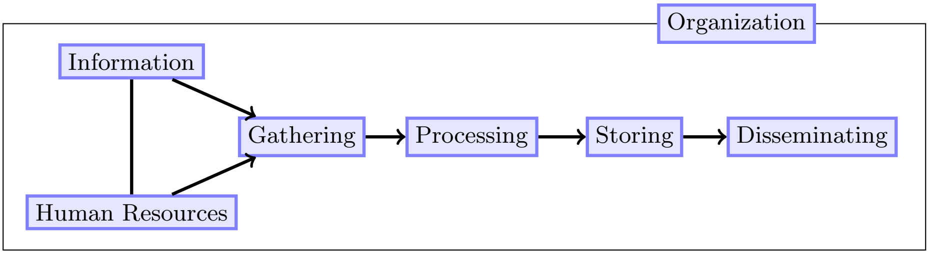

Fig. 2. The graph associated to the cognitive map generated by the first respondent for the concept of "Information System"

Table 1. The most central nodes per respondent (lines), regarding to the most mentioned nodes (rows)

	Data	Human resources	Information
Respondent 1		Human resources	Information
Respondent 2			
Respondent 3			
Respondent 4		Human	
Respondent 5	Database		
Respondent 6	Data		Information
Respondent 7		User	
Respondent 8	Data Structure		
Respondent 9			
Respondent 10			Dissemination of Information

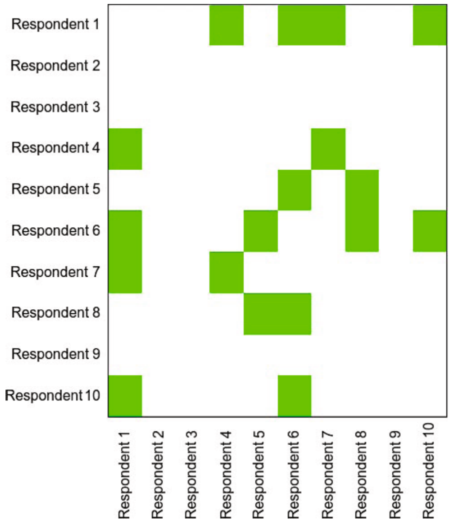

Fig. 3. Respondents whose central nodes are common regarding to the most mentioned nodes, the meaning they gave to the concept of "Information System" seems to be close

of investigation. The results can easily be processed by concept-mapping and mind-mapping software for example.

The reader may have noticed in the figure 3 that the respondents 1 and 6 are those who central nodes are common to the greater number of persons regarding to the most mentioned nodes. Table 1 shows how these respondents are those who have several central nodes. This observation leaded us to conclude that the meaning they gave to the concept of "Information System" covers several meanings given by the others respondents. We are now trying to establish a connection between the cognitive maps, i.e. the most central nodes for a respondent, and his/her academical background, i.e. if he/she is a Computer Science student or a Management Science student.

4 Conclusions and Future Works

In this paper we presented an approach in order to identify meaning variance between the members of a group by analyzing their cognitive maps through the use of graph theory tools. We began introducing background theories in the area of mental models and cognitive mapping. We presented then tools of graph theory which can be used to study cognitive maps. We finally explained and discussed our approach from the interviewing of the respondents to the identification of meaning variance through the use of their cognitive maps.

Individually and during face-to-face interviews, our approach has been thought as closely as possible from the respondents. A concept is given and the respondents are then asked to represent their understandings of this concept. These representations are analyzed with tools of graph theory in order to highlight the respondents who gave a similar meaning to the given concept. It is crucial to give to the respondents the time to realize their representations. The atmosphere must be relaxed and the respondents have to feel confident.

Nevertheless our approach is reductive in the data considered. Relying on Ozesmi and Ozesmi [19] notably, we proposed to focus only on the most mentioned nodes and on the most central nodes in order to analyze respondents' cognitive maps. This weakness is otherwise a strength of our approach: it makes feasible an analysis expensive to realize when the cognitive map as a whole is considered.

The conducted interviews lead us to consider not only the concepts identified by the respondents, but also their meanings. Only with ten students and during an academical case study, we observed so much that people can give different meanings to the same concept. We are now focusing on interactions during group decision making in order to observe, to identify, and to manage meaning variance through the use of cognitive maps.

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References

1. Arduin, P.-E.: Vers une métrique de la commensurabilité des schémas d'interprétation (English title: Towards a metric of the commensurability of interpretative frameworks). PhD thesis, Paris-Dauphine University (2013)
2. Carley, K., Palmquist, M.: Extracting, representing, and analyzing mental models. Social Forces 70(3), 601–636 (1992)
3. Collins, A., Gentner, D.: How people construct mental models. In: Holland, D., Quinn, N. (eds.) Cultural Models in Language and Thought, ch. 10, pp. 243–265. Cambridge University Press (1987)
4. Craik, K.J.W.: The Nature of Explanation. Cambridge University Press (1943)
5. Daft, R.L., Weick, K.E.: Toward a model of organizations as interpretation systems. The Academy of Management Review 9(2), 284–295 (1984)
6. Eden, C.: On the nature of cognitive maps. Journal of Management Studies 29(3), 261–265 (1992)
7. Eden, C., Ackermann, F.: Group decision and negotiation in strategy making. Group Decision and Negotiation 10(2), 119–140 (2001)
8. Glaser, B.G., Strauss, A.L.: The Discovery of Grounded Theory: Strategies for Qualitative Research. Aldine Publishing Company, Chicago (1967)
9. Hall, R.I., Aitchison, P.W., Kocay, W.L.: Causal policy maps of managers: Formal methods for elicitation and analysis. System Dynamics Review 10(4), 337–360 (1994)
10. Jones, N.A., Ross, H., Lynam, T., Perez, P., Leitch, A.: Mental models: An interdisciplinary synthesis of theory and methods. Ecology and Society 16(1) (2011)
11. Kaplan, S., Kaplan, R.: Environments for people, chapter Attention and fascination: The search for cognitive clarity. Ulrich's, MI (1982)
12. Kaplan, S., Kaplan, R.: Cognition and environment: Functioning in an uncertain world. Ulrich's, MI (1989)
13. Kearney, A.R., Kaplan, S.: Toward a methodology for the measurement of the knowledge structures of ordinary people: The conceptual content cognitive map (3CM). Environment and Behavior 29(5), 579–617 (1997)
14. Klayman, J., Ha, Y.-W.: Hypothesis testing in rule discovery: Strategy, structure, and content. Journal of Experimental Psychology 5, 596–604 (1989)
15. Langan-Fox, J., Code, S., Langfield-Smith, K.: Team mental models: Techniques, methods, and analytic approaches. Human Factors 42(2), 242–271 (2000)
16. Langfield-Smith, K., Wirth, A.: Measuring differences between cognitive maps. Journal of the Operational Research Society 43, 1135–1150 (1992)
17. MacDonald, N.: Trees and Networks in Biological Models. John Wiley and Sons (1983)
18. Morgan, M.G.: Risk Communication: A Mental Models Approach. Cambridge University Press (2002)
19. Ozesmi, U., Ozesmi, S.L.: Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. Ecological Modelling 176, 43–64 (2004)
20. Quinn, N.: Finding culture in talk: a collection of methods, chapter How to reconstruct schemas people share, pp. 33–81. Palgrave Miller (2005)
21. Weick, K.E.: Sensemaking in Organizations. Foundations for Organizational Science. SAGE Publications (1995)

A Framework for Optimising Inventory Level of Global Critical Knowledge to Support Group Decision Making

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Abstract. Knowledge is the strength of an organisation. However, how much knowledge should be stored in the knowledge-base of a decision support system (DSS) has remained as a key question under investigation. Hence, a Lean-Knowledge Inventory Model (Lean-KIM) will be presented in this paper to optimise organisational knowledge inventory levels and knowledge flow for providing group decision makers with sufficient and high quality knowledge for decision making. This paper presents new contributions by integrating Lean Philosophy with nine knowledge activities to improve the knowledge management performance for group decision-making with respect to knowledge capture, creation, reposition, diffusion and application.

Keywords: group decision-making, knowledge flow, knowledge inventory, critical knowledge, Lean knowledge inventory, Lean knowledge chain management.

1 Introduction

It is widely known that knowledge can help organisations to maintain and increase their competitiveness. But how much knowledge should be stored in the knowledge-base of a decision support system (DSS) has remained as a key question under investigation. Actually, keeping unnecessary knowledge is a type of waste because of the holding and set-up costs for the knowledge [1], and also could increase the workload for decision makers. It is an intractable problem to group decision-making.

In the context of group decision making, a group of decision makers need to communicate and collaborate as well as share the critical knowledge. To enable efficient knowledge sharing, the right level of knowledge has to flow smoothly across decision makers which are responsible for different activities for example in a supply chain. Therefore this paper is concerned with knowledge chain management that intends to support group decision making. The focus of the paper is a framework to optimise organisational knowledge inventory level and knowledge flow of a DSS, by developing a lean knowledge inventory model (lean-KIM), in order to provide decision makers with sufficient and quality knowledge applied and shared at the right time,

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in the right place, and at the right cost. This concept echoes the ultimate goal of Lean philosophy (e.g. "*right product, right place, right time, right quantity, right quality, and right cost*" [2]).

2 Literature Review

In order to support group decision making, people have to capture, create, share and store knowledge for reuse, which highlights the importance of knowledge inventory, knowledge flow, knowledge chain and knowledge chain management.

2.1 Knowledge Flow

When the knowledge management (KM) models and strategies are applied to businesses situations involving a group of decision makers, knowledge flow is one of the most important elements in all KM activities. It is the interaction between group members of an organisation [3], and consists of a series of processes, events, and activities through which data, information, and knowledge are transferred from one company to another.

Knowledge inflow and knowledge outflow are the two types of knowledge flow. Knowledge inflow processes (such as mentoring and training) serves to increase knowledge inventory at different rates with different characteristics. Knowledge outflow represent knowledge inventory reduction caused by employee turnover, knowledge decay and knowledge obsolescence [4].

2.2 Knowledge Chain

A knowledge chain (KC) is created by knowledge flowing amongst people, departments and organisations. Knowledge flowing through KCs can be personal, group and corporation knowledge [5]. In a supply chain context, KCs consist of various organisations such as core enterprises which are the leaders in knowledge chain, and the participating parts such as universities, research institutes, suppliers, selling agencies, and customers, as well as competitors. Each member organisation has a different role to play in the KC [3].

2.3 Knowledge Chain Management

Knowledge chain management (KCM) is a tool for enterprises to gain competitive advantages through managing knowledge flow, creating knowledge and integrating knowledge advantages of each individual member of KC effectively [5-7]. The evolution of KCM theory has been represented by a series of knowledge chain models [5, 7]. The earliest and also the most famous knowledge chain model was developed by Holsapple and Singh [6] via a Delphi study.

In their model presented in Figure 1, there are five primary knowledge manipulation activities and four managerial influences on the conduct of knowledge management. These nine KM activities can effectively promote organisational learning and projection, and consequently the organisation's competitiveness will be strengthened [6].

Fig. 1. The knowledge chain model [6]

2.4 Knowledge Inventory

Organisational knowledge inventory is the sum total of the information and knowledge resources owned by an organisation among employees. It may include company databases, electronic documents, reports, product requirements, design rationale, project experiences, etc. [8]. It is critical to knowledge-based workforce to meet future demand. By analysing knowledge inventory, organisations can find out the knowledge gap, and then identify strategies to acquire it [9, 10].

3 A Framework for Optimising Knowledge Inventory

This paper proposes a Lean-Knowledge Inventory Model (Lean-KIM) shown in Figure 2, which contains three steps to optimising knowledge inventory. The first step is to integrate lean philosophy into knowledge chain management by which organisational knowledge can be captured, created, stored, diffused and applied more effectively and efficiently. Step 2 is to identify critical knowledge. Then the third step is to store the knowledge by using a suitable inventory strategy according to the characteristics of the knowledge, consequently to achieve the final goal. In turn, the optimised knowledge inventory will further support the performance of lean knowledge chain management by providing the organisation with sufficient and quality knowledge. The detailed explanation of the Lean-KIM will be provided in the following sections.

Fig. 2. Lean-KIM

3.1 Step1: Lean-Knowledge Chain Management

Lean philosophy seeks the ideal way—"*right product, right place, right time, right quantity, right quality, and right cost*" [2], which coincidentally echoes the principles of KCM (e.g. to provide the right knowledge or information to the right person at the right time and at the right level [6]). Being inspired by this idea, the authors developed The Lean Knowledge Chain Management Model, as shown in Figure 3, to optimise knowledge flow and knowledge inventory by using eight types of waste *(8Ws)* as a tool to supervise the five knowledge manipulation activities and involving six lean principles *(6Ps)* as the guiding ideology for the four managerial activities.

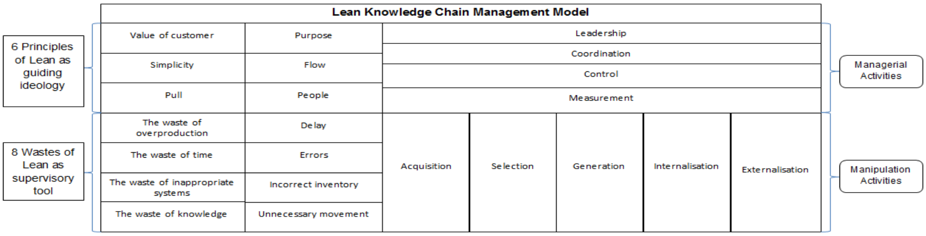

Fig. 3. Lean knowledge chain management model

3.1.1 Eight Types of Waste (8Ws) in Knowledge Manipulation Activities

The Waste of Overproduction

Overproduction means too much unnecessary data and information has been made and/or delivered too early. Besides, wasting time finding necessary information and knowledge is also included in this point [11]. It may exist in all of the five manipulation activities. To avoid this waste, in knowledge internalisation for instance, the knowledge required needs requisite cleansing, refining, and filtering before being stored in a targeted knowledgebase and shared across the network [6].

The Waste of Time

Everyone needs to prioritise the time and to seek never to delay a value adding step by a non-value adding step. In knowledge chains, the aim of every manipulation activity is to add value to the knowledge required by the next activity. Therefore all these eight wastes can be regarded as non-value adding steps [11].

The Waste of Inappropriate Systems

It means inappropriate computer and automation systems. Such as an order processing system or a poorly developed decision support system. This type of waste could happen in all of the five knowledge manipulation activities as they are performed by either human or computers.

The Waste of Knowledge

It refers to reinventing wheels, or re-discovering knowledge all over again, knowledge and experience that the company has already used but simply allowed to disappear.

Besides, a company should encourage employees to think, create, and use the thought of all employees, not just managers [11]. This type of waste could happen in all of the five knowledge manipulation activities.

Delay

It refers to knowledge users waiting for information and knowledge to make critical decisions. Great business opportunities never last long. It could easily fleet away while decision makers waiting for information and knowledge. This type of waste could be caused by poorly managed knowledge acquisition, selection, generation and internalisation.

Unnecessary Movement

"*Allowing every knowledge worker to share and have access to all available information can be counterproductive*" [12]. Non-value adding movement of information is a type of waste. A number of knowledge transfer and handling operations among 'the wrong people', 'in the wrong place', with inappropriate knowledge sharing structures may cause commercial secret leakage, information loss or distortion [13].

Incorrect Inventory

If critical Knowledge is out-of-stock, decision makers are unable to get exactly what is required. This type of waste may exist in knowledge selection, generation, internationalisation and externalisation. Thus, raw data or information must be cleaned, filtered and transformed for providing decision makers with purpose and requirements-oriented support rather than unfocussed information support [14].

Errors

Incorrect data, lost or damaged information and knowledge is also a type of waste. Errors could exist in all the five knowledge manipulation activities.

3.1.2 Six Lean Principles (6Ps) for Knowledge Managerial Actives

Value for Customer

It means making value for the final customers, the next process, the next company along the chain, or the customer's customers [2]. In knowledge chain management, the main tasks for knowledge measurement is to assess the execution of knowledge management activities, to identify and recognise value-adding processors and knowledge resources in order to make sure that every member in the knowledge chain provides specific knowledge resources which meets the next processes' requirements in the right form, at the right time and in the right cost.

Purpose

The purpose for Lean knowledge management is to reduce waste, complexity, and bureaucracy in order to optimise the supply-demand ratio of required knowledge, and to improve the efficiency and effectiveness of the five knowledge manipulation activities. Therefore, in the process of knowledge measurement, organisations should evaluate whether their KM performance works for or against the purpose. In addition, the purpose not only should be fully understood by top managers, it also needs to be passed down to the workforces who engage in the processes of knowledge manipulation activities.

Simplicity

Simplicity could be applied in operation, systems, technology, control, and the goal [11]. From the perspective of lean Knowledge chain management, simplicity could be applied in knowledge measurement and control to check and remove the complexity (i.e. complex computer systems, unreasonable knowledge sharing structure in an organisation, complex and massive improperly organised knowledge resources, etc.) in the knowledge manipulation processes [11,15].

Flow

It means making knowledge move and keeping value flow. Actually, the ultimate aim of the managerial activities is to support and guide knowledge to flow in the knowledge chain effectively and efficiently. For example, organisations measure the knowledge resources and processors, and then control their knowledge to ensure accuracy, consistency, relevance, importance, and currency so that they would have enough knowledge with good quality to flow among group decision makers in their organisation. Knowledge coordination and leadership is to establish facile communications channels, culture and environment to make knowledge flow more smoothly [6].

Pull

"Having set up the framework for flow, only operate as needed" [11]. Pull means that no one upstream should produce goods or service until the customer or downstream process asks for it [2]. There are two main areas of pull, inspired by Peter Hines, that are necessary to consider within a lean KCM. One is pull-based knowledge delivery. Another one is pull-based lean improvement.

People

Knowledge is created by people and is the strength of today's corporation, especially tacit knowledge [16]. Thus, an important task of KM is to maintain as much of the knowledge worker's relevant knowledge for the corporation as possible [12]. And people should be placed in the central point in the process rather than physical or financial capital [17, 18].

3.2 Step2: Identifying Critical Knowledge

Critical knowledge has been defined by many scholars in various ways, for example, as *"the necessary knowledge to solve problems dealing with a given objective and that should be capitalised*" [19], "*essential that contributes to added value and business performance*" [20], "*vital expertise, ideas and insights*" [13], and "*with regard to its scarcity, cost and delay of acquisition*" [21].

Only a few works exist about the identification of the knowledge on which it is necessary to capitalise, thus the authors intend to use the GAMETH method which refers to The Global Analysis Methodology [20] to locate the company's critical knowledge for improving the quality of decision making. It contains three stages. The first stage is to identify the sensitive processes which contribute the organisation's objective. Stage 2 is to identify the determining problems which would weaken the sensitive processes. The final stage is to identify the organisation's critical knowledge which is needed solve the determining problems.

3.3 Step3: Knowledge Inventory Strategies

The knowledge inflow and outflow going through Knowledge inventory, is similar to an actual goods inventory. Just-in-time (JIT) and Just-in-case (JIC) could be used for optimising knowledge inventory [4].

In the context of knowledge inventory, each strategy has both advantages and disadvantages. JIT gains knowledge inflows just as they are needed, thereby saving time and money invested in holding unnecessary knowledge. But if the lead time for a certain type of knowledge is long or unpredictable, this may cause a stock-out situation which could be difficult and very expensive to remedy. JIC however provides a safety stock of knowledge to prevent unexpected demand. It provides flexibility for an organisation to respond quickly to unexpected circumstances. However, as more knowledge is held, more knowledge can be used and also needs to be maintained. [22].

4 Methodology for Evaluating the Lean Knowledge Framework

A data triangulation approach will be used to evaluate the lean knowledge framework proposed in Section 3. The data collection methods will consist of three different kinds of interviews which are F2F focus-group interview, F2F one-to-one interview and online interview, as shown in Figure 4.

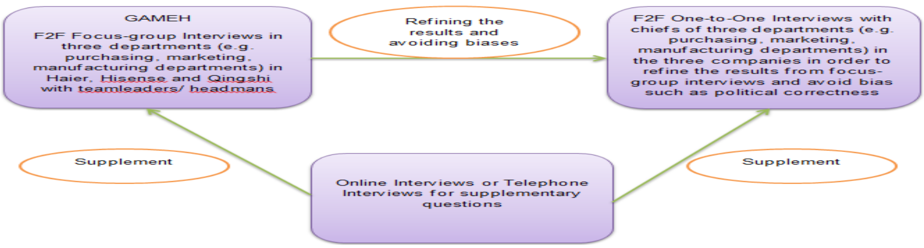

Fig. 4. Data collection Methods

By following the instruction of GAMETH method from theoretical framework, the nine sets of focus-group interviews will be conducted with middle managers of three departments (e.g. purchasing department, customer service and marketing department), in three global manufacturing companies respectively. A series of open questions will be used. This method can help participants to share understanding based on the common representation of objective and sub-objectives to reach.

The one-to-one interviews will be conducted with nine senior managers of these departments in order to confirm and/or refine the results gathered from the focus-group interviews. The questions will also be open questions. The reason why not to invite senior managers to join in the focus-group interviews is to avoid respondent bias.

The online interview will be conducted after the focus-group interviews and one-to-one interviews. A series of open and close questions will be sent via email to interviewees who have joined in the previous interviews in order to replenish and insure the coherence of the result gathered from interviews.

Three supply chain cases chosen for the framework evaluation are: Haier, Hisense and Qingshi. Haier and Hisense are household appliances manufacturers. Their products include refrigerators, TVs, air conditions, laundry machines and PCs. Their suppliers are mainly from Germany, Japan, the U.S. and China. Haier has 12.5% share of the world's refrigerator market and 9.8% of its laundry machine purchases. Hisense's products are exported to over 100 countries and regions include Europe, the U.S., Africa and Southeast Asia. Qingshi is a food production enterprise. Its suppliers are from Belgium, New Zealand, Australia, and China. Its markets include Japan, South Korea, Singapore and China.

5 Conclusions

Knowledge is the strength of an organisation. However, holding and updating unnecessary knowledge not only is a waste of resources, but also causes distraction and confusion when users retrieve the required knowledge from the Knowledge base, especially when a group of decision makers need to share the knowledge. Hence, this paper has presented a Lean-KIM to optimise organisational knowledge inventory levels and knowledge flow for providing group decision makers with sufficient and high quality knowledge for decision making.

This paper presents new contributions by integrating 8Ws and 6Ps with five knowledge manipulation activities and four knowledge managerial activities respectively to further improve the knowledge chain management performance for group decision-making with respect to knowledge capture, creation, reposition, diffusion and application.

The limitation of this paper is that the evaluation of the Lean-KIM and Lean KCM frameworks with case studies has not been completed, and therefore there are no empirical results represented so far. In the follow six months the authors will conduct detailed case studies with the three companies mentioned above in order to have a more comprehensive insight of these two frameworks.

References

[1] Liu, S., Smith, M.H., Tuck, S., Pan, J., Alkuraiji, A., Jayawicjrama, U.: Where can knowledge-based decision support systems go in contemporary business management-a new architecture for the future. In: The 2014 International Conference on Economics, Business and Marketing Management (2014)

[2] Hines, P.: The principles of the lean business system. S A Partners (2010)

[3] Gu, X., et al.: Knowledge chain, knowledge chain management and Knowledge advantage (2005), http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=1500120 (accessed Date: November 1, 2012)
[4] MacKinnon, D.J.: Knowledge as inventory: near-optimising knowledge and power flows in the edge organisation. In: The 10th International Conference on Command and Control Research and Technology (ICCRT), June 13-15, MCLean, VA, USA (2005)
[5] Liu, S., et al.: A knowledge chain management framework for global supply chain integration decisions. School of Management, Plymouth University (2012)
[6] Holsapple, C.W., Singh, M.: The knowledge chain model: activities for competitiveness (2001), http://www.sciencedirect.com/science/article/pii/S0957417400000506 (accessed Date: November 1, 2012)
[7] Tseng, S.: A study on customer, supplier, and competitor knowledge using the knowledge chain model. International Journal of Information Management 29, 488–496 (2009)
[8] Prasad, M.V.N., Plaza, E.: Corporate memories as distributed case libraries. In: Proceedings of the 10th Banff Knowledge Acquisition for Knowledge-based Systems Workshop, vol. 2, pp. 40: 1–19 (1996)
[9] Dieng, R., Corby, O., Giboin, A., Ribiere, M.: Methods and tools for corporate knowledge management. International Journal of Human-Computer Studies 51(3), 567–598 (1999)
[10] Chen, A.N.K., Hwang, K., Raghu, T.S.: Knowledge life cycle, knowledge inventory, and knowledge acquisition strategies. Decision Sciences 41(1), 21–47 (2010)
[11] Bicheno, J., Holweg, M.: The lean toolbox: the essential guide to lean transformation, 4th edn. PICSIE Books, Buckingham (2009)
[12] Huang, S., Cummings, J.N.: When critical knowledge is most critical: centralisation in knowledge-intensive teams. SAGE Journals (2011)
[13] Bergeron, B.: Essentials of knowledge management, 2nd edn. John Wiley & Sons (2003)
[14] Liu, S., Duff, A.H.B., Whitfield, R.I., Boyle, I.M.: Integration of decision support systems to improve decision support performance. Knowledge and Information Systems 22(3), 261–286 (2010)
[15] Staats, B.R., Brunner, D.J., Upton, D.M.: Lean principles, learning, and knowledge work: evidence from a software services provider. Journal of Operations Management 29(5), 376–390 (2011)
[16] Nonaka, I., Takeuchi, H.: The knowledge creating company: how Japanese companies create the dynamics of innovation. Oxford University Press, New York (1995)
[17] Bahra, N.: Competitive knowledge management. Palgrave, New York (2001)
[18] Hislop, D.: Knowledge Management in organisations. Oxford University Press, New York (2009)
[19] Tseng, T., Huang, C.: Capitalising on knowledge: a novel approach to crucial knowledge determination. IEEE Transactions on Systems, Man, and Cybernetics—Part A: Systems and Humans 25(6) (2005)
[20] Grundstein, M.: From capitalising on company knowledge to knowledge management (2000), http://basepub.dauphine.fr/bitstream/handle/123456789/4141/MG-Morey.pdf?sequence=1 (accessed Date: March 11, 2013)
[21] Ermine, J., Boughzaka, I., Tounkara, T.: Critical knowledge map as a decision tool for knowledge transfer actions. The Electronic Journal of Knowledge Management 4(2), 129–140 (2006)
[22] MacKinnon, D.J.: Modeling skill growth and decay in edge organisations: near-optimising knowledge & power flows (phase two). In: Command and Control Research and Technology Symposium: The State of the Art and the State of the Practice, San Dirgo, CA, US (2006)

Dynamic MCDM for Multi Group Decision Making

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Abstract. Multiple Criteria Decision Making (MCDM) models make preference decisions over multiple attributes' alternatives available, which in most of the cases conflict among themselves. On the other hand, the classic MCDM model assumes that the decision maker has a pre-defined fixed set of criteria, when taking a decision, and is presented with a clear picture of all available alternatives. This classic view reduces the solution to computing the score of each alternative, producing a ranking, and choosing the one that maximizes this value. As most of the real-world decision making scenarios take place in dynamic environments, involving multiple alternatives which usually have conflicting attributes, classic MCDM models do not really satisfy their requirements, especially when we deal with multiple groups in the decision process. Dynamic MCDM models are more appropriate to solve real decision problems, since they cater for the impact of time within the decision making process. In this paper, we investigate an MCDM model for group decision making, by taking into consideration its dynamic perspective. A case-study about hotel ranking, involving multi-groups in the decision making process is sketched to illustrate the approach.

Keywords: MCDM, Dynamic MCDA, Group Decision Making, Multi-Groups.

1 Introduction

The term dynamic is generally used for time dependent behavior in problems where complex system dynamism could happen due to any changes in supportive variables including population and space [11]. The concept of localization, which is of interest in most social sciences, is based on dynamism of population or location. Modeling such systems implies dealing with problems with different players in different regions and considering their various specific characteristics. Such scenarios are common in Geographic Information Systems (GIS) with their capabilities of spatial databases and Multi-criteria Decision Analysis (MCDA) techniques [6] to support a user or a group of users in making spatial decisions [13] [14]. Classic Multiple Criteria Decision Making (MCDM) models assume that the decision maker has a pre-defined fixed set of criteria, when taking a decision, and is presented with a clear picture of all available alternatives. This classic view reduces the solution to computing the score of

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each alternative, producing a ranking, and choosing the one that maximizes its value. Although traditionally many approaches focused on the classic MCDM and MCDA techniques [6] [19] for individual decision making, substantial efforts have been made to integrate MCDA for group and collaborative decision making, especially in GIS applications [1] [5] [7] [8] [10] [17]. As most of the real-world decision making scenarios take place in dynamic environments, involving multiple alternatives which usually have conflicting attributes, classic MCDM models do not really satisfy these requirements, especially when we deal with multiple groups in the decision process [15]. Dynamic MCDM is an emerging concept, developed to answer the question of impact of time in changeable and/or evolving decision processes [3] [15] [16]. Applications to safe landing of spacecraft and supplier selection demonstrated its applicability [4] [9] [18] [14].

Recently the Dynamic MCDM [3] was customized to solve the problem of MCDM in the presence of past and future information [9]. Dynamic MCDM models are more appropriate to solve real decision problems. In this paper, we investigate a MCDM model for group decision making, by taking into consideration its dynamic perspective. An example about hotel ranking, involving multi-groups in the decision making process is sketched to illustrate the approach.

2 Dynamic Multi Criteria Decision Making

MCDM models make preference decisions over multiple attributes' alternatives available, which in most of the cases conflict among themselves [19]. The aim of this paper is to customize models in case of multi-population multi-criteria decisions. For example, in the ranking of hotels, an example sketched here for illustrative purposes, multi-groups are involved in the decision making process. The main problem is to aggregate different decision matrices from different regions/societies to rank alternatives. The chosen example refers to hotel rankings and leads us to a wider perspective of understanding the concept of Dynamic MCDM, while the supportive variable is not limited to time. This scenario can also face new challenges of multi-dimensional problems, when both time and population are changed as supportive variables in complex systems.

To clarify the problem let's consider an example of University ranking. There are several criteria to evaluate for understanding the current situation of universities and finally by aggregating the results of these criteria the ranking could be done. There are several criteria in all ranking lists but they could be divided in two classes. Some come from hard data, i.e. they could be easily measured, while others are qualitative criteria and need to receive votes or feedback. For instance, student satisfaction is a criterion that requires survey questionnaires to be measured and then those need to be aggregated. So far, the important issue here is to apply a statistical method, that assumes all participants are similar and there is no dynamism involved in the problem. In reality, due to the dynamism in populations, different approaches are evaluated and it is observed that the viewpoints of people might be affected by their previous experiences. Also, emphasis on some particular attributes can vary according to geographical references. In some countries, for instance, socialization is more important, while for others technology or teaching methodologies play more important roles. Also the level of satisfaction of a community is usually based on the gap between the considered desire and the current situation, which can be totally different for different groups of people, in different geographical locations, under different social and economic status.

Modeling such scenarios just by using classical MCDM methods [19] or specialized aggregation techniques [2], without considering the above-mentioned challenges of changeable locations and time evolution, is a way to over-simplify the problem. Furthermore, much information is missing by using this simplification process. For instance, in the University ranking example, we would need different decision matrices - to represent groups of people from different locations or populations - and we have to aggregate all decision matrices to find the final ranking. The final Universities ranking will be the outcome of the aggregation of decision matrices from different populations.

There are many cases, however, in which aggregating decision makers' preferences from different types of decision makers are important, such as brand ranking or best player or supplier selection; for international multi-branches companies, with different offices across the world, such issue could be a great challenge. In an international competition, as for example the Eurovision song contest, the same concern has to be considered as people are voting from different countries and it is important to consider the dynamism of population in a process of data fusion for final ranking.

In this paper we take into account all the considerations mentioned above about real-scenario models, and we propose an approach to deal with problems of multi-criteria / multi-attribute decision making in presence of group decision makers by considering the impact of its application dynamism. Below we describe the model proposed in this work.

3 Modelling Process

A Decision Matrix in MCDM problems is usually built based on three variables (see Figure 1 for example):

- a_i (i=1 to m), alternatives;
- C_j (j=1to n), jth Criteria;
- x_{ij}, which represents the level of achievement or satisfaction of alternative "a_i " for criteria "C_j".

In real dynamic problems, however, we will receive different matrices from different populations. Each population has its own characteristic and points of views. Population here, means group of people (or objects) with similar characteristics, where the objectives and the expectations follow the same pattern of behavior. For each problem, different types of population should be categorized related with the type of problem, so it is a clustering and not a classification task. The final decision matrix is determined by aggregation of all decision matrices from different populations. Figure 1 illustrates this concept.

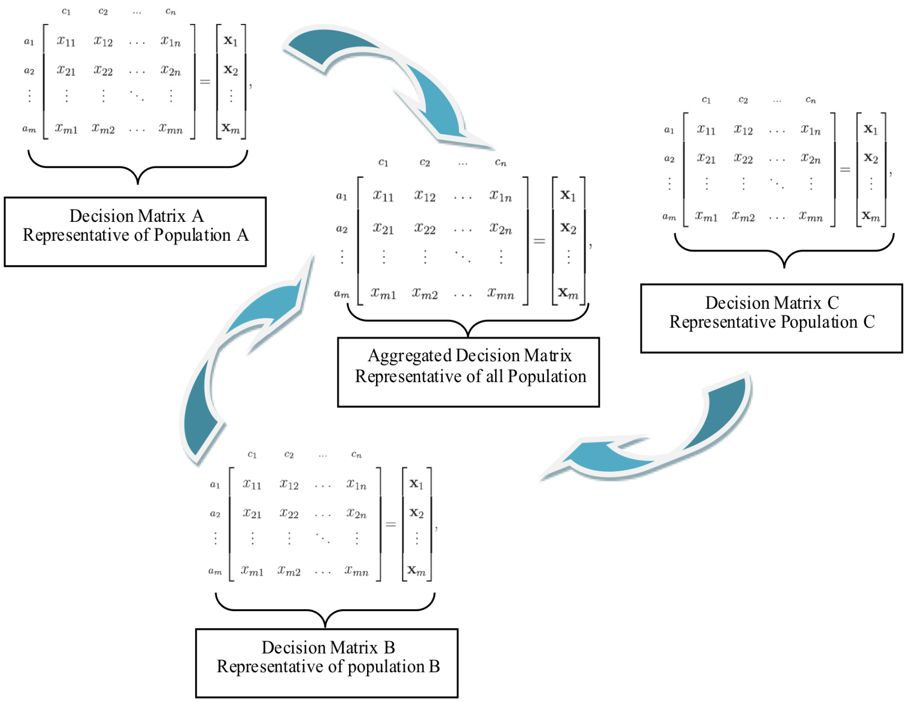

Fig. 1. DMCDM model for multi Group /Population Decision making (3 group/populations)

In real problem decision processes, you may miss some matrices or receive more from new populations. In each iteration, the final decision matrix could be provided by aggregating the available matrices using the dynamic MCDM model [3] [16]. Needless to say, the problem could be spatial-temporal with future data, since after aggregating the result of each population, past and future information could be used to consider the dynamism of time, using the extended model by [9].

The flowchart, shown in Figure 2 below, shows the proposed steps for using dynamic MCDM for multi-group multi-criteria decision making in the presence of multi-groups. After, the four steps of the process are described.

Step 1: Clustering decision makers in a different population

The first step is to find how different populations or groups could be classified. In many cases there are pre-defined criteria such as location, which could be used to separate different populations by dividing people based on their countries or by organizational department; both are a good examples. Also experts could do this classification based on their knowledge on patterns of behaviour of different groups. In this method experts or managers could divide people based on their characteristic. Finally different quantitative approaches for clustering could be implemented including Data Mining approach such as fuzzy clustering or statistical models.

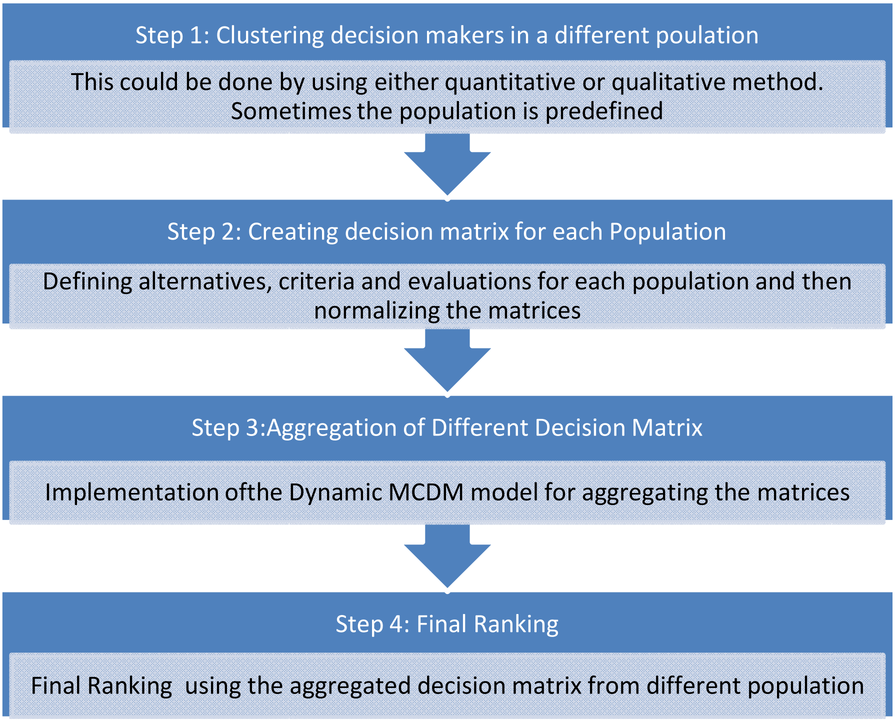

Fig. 2. Process of DMCDM for Multi Population Decision Making

Step 2: Creating decision matrix for each Population
This step is a regular process in MCDM. For each population decision matrix based on the level of satisfaction for each alternative corresponding to each criterion should be determined.

Step 3: Aggregation of Different Decision Matrix
This is the most important part of the proposed model in this work. It supports the main idea of considering differences between different populations in a process of decision making, which could cause dynamism in problem. In other words, instead of aggregating all data together we have now different matrices, each one representing a population, so considering assumptions such as weight and importance of each population the final values could be determined. The final decision matrix is a result of merging all matrices in a process called data fusion [16]. To implement this approach both respective criteria values and various resulting vectors should be merged. Many classes of operators are effectively employed for this purpose including weighted average methods, conjunctive methods, scoring methods, max-min, parametric, reinforcement. There is no best operator because they context-dependent on the type of problem and decision objectives, therefore choosing an appropriate operator is an important task [2]. This step ends by creating the final decision matrix.

Step 4: Final Ranking
Finally the priorities of alternatives are found out via the implementation of ranking algorithms. Usually, the highest rating is the one selected.

4 Illustrative Example: Hotel Ranking

In this work we sketch a Hotel Ranking problem to illustrate the capability of the model (the example will be fully developed into a DSS in the future). The example context is to rank the best Hotel/City using travelers' feedback votes on a scale of 0-5. It was elaborated using data from the Tour Homepage TripAdvisor (December 2013). This example uses a reduced version of the case-study under development, considering only three Chain-Hotels: Marriott, Hilton and Radisson blue, together with nine European cities, namely: Lisbon, Madrid, London, Paris, Rome, Stockholm, Vienna; Prague; and Warsaw.

This location problem can answer two main objectives: (1) Which is the best European capital in terms of 4/5-stars hotels; and (2) Which of the 4/5-stars hotel-chains is the best based on performance in European capitals. It could also be useful to merge data to find best Cities/Hotels. Results of this procedure could be applied, for instance, as a meta-product to enrich the touristic information in the Travel Agencies' web-platforms with an intelligent DSS.

To clarify the application of the proposed model we will use the first location population issue (1), i.e. "Which is the best European city regarding 4/5-stars hotels". Since we are using a reduced sub-set, step 1 (clustering) is simplified and the defined "cluster" is composed of 3 chain-hotels, Marriot, Hilton and Radisson blue. In step 2, e created the input matrices for three hotel-chains, using the evaluations from TripAdvisor, as shown in Table 1, (a), (b) and (c). In step 3, we aggregate the decision matrices using a simplified version of the dynamic MCDM model [3] [16].

In this example we used the geometric mean for aggregating the three populations into a combined decision matrix. The reason for using the geometric mean instead of the common weighted average is due to its superior performance for many MCDM [19]. For example, the geometric mean calculation for the combination of the sleeping quality values of the 3 hotels for Warsaw [for (a) = 4.5; for (b) = 5; and for (c) = 4.5] would be:

$$CityAttribute_{1,9} = \text{geometric mean } (4.5,5,4.5) \Rightarrow 4.661$$

In step 4 we combine the attributes from the joined decision matrix to obtain a final rating and the ranking (best solution wins). Again here, for simplicity purposes, we used again the geometric mean with equal weights, for aggregating the attributes on the combined decision matrix. The final aggregation and its respective normalized rating are shown in Table 2.

Table 1. Input evaluations for 3 hotel-chains (a), (b) and (c)
(Source: Tour Homepage TripAdvisor, Dec, 2013)

(a)

Marriott	Sleep Quality	Locatio n	Rooms	Service s	Value	Cleanliness
Lisbon	4.5	3	4	4	4	4.5
Madrid	4	4	4	4	4	4.5
London	4.5	4	4	4	4	4
Paris	4.5	3.5	4	4	3.5	4.5
Rome	4.5	4.5	4	4.5	3.5	4.5
Stockholm	4.5	3.5	4.5	4.5	4	4.5
Vienna	4.5	4.5	4	4.5	4	4.5
Prague	4.5	4.5	4.5	4.5	4	4.5
Warsaw	4.5	4.5	4.5	4.5	4	4.5

(b)

Radisson Blu	Sleep Quality	Location	Rooms	Services	Value	Cleanliness
Lisbon	4	3.4	4	4	4	4
Madrid	5	4.5	4	4	4	4.5
London	5	4.5	4	4.5	4	4.5
Paris	4.5	4.5	4	4.5	4	4.5
Rome	3.5	3.5	3	3.5	3	3.5
Stockholm	4.5	4.5	4.5	4.5	4	4.5
Vienna	5	4.5	4.5	4	4	4.5
Prague	4.5	4.5	4.5	4.5	4.5	4.5
Warsaw	5	4.5	4.5	4.5	4	4.5

(c)

Hilton	Sleep Quality	Location	Rooms	Services	Value	Cleanliness
Lisbon	NA	NA	NA	Na	NA	NA
Madrid	4.5	3.5	4.5	4.5	3	4.5
London	4	4	3.5	3.5	3.5	4
Paris	4	4	4	4	3.5	4.5
Rome	4.5	4	4.5	4.5	4	5
Stockholm	4.5	4.5	4	4.5	4	4.5
Vienna	4.5	4.5	4	4	4	4.5
Prague	4.5	3.5	4.5	4.5	4	4.5
Warsaw	4.5	3.5	4.5	4.5	4.5	4.5

The results obtained (Table2) clearly show that for the three populations of hotel-chains considered, the best capital-city of Europe is Warsaw (score=1), closely followed by Prague (score= 0.994). The worst capital-city is Lisbon (0.892), which result may derive from the fact that really only 2 populations were considered, since there were no input data available in Table 1 (c). The latter result also illustrates the robustness of the proposed model, because it supports handling uncertainty (in this case lack of information for one city). Further detailed discussions about the results do not apply here for this simplified illustrative example.

Table 2. Final aggregated value and normalized score

Cities	Aggregated Rating	Normalized score
Lisbon	3.929	0.892
Madrid	4.142	0.940
London	4.066	0.923
Paris	4.095	0.930
Rome	3.957	0.898
Stockholm	4.323	0.981
Vienna	4.324	0.981
Prague	4.380	0.994
Warsaw	4.406	1.000
MAX	4.406	

Finally, it should be highlighted that the full dynamic process to determine the final ranking should be carefully thought after, because the choice of aggregation operators and of populations can be much more complicated in real case studies. Moreover, in this example we did not show the temporal dynamicity of the model. However, it is easy to imagine that, along the time, there could be more hotel evaluations, changes of attributes etc. This way, the future rankings could also change over time. We are currently working on the development of a complete case-study based on this example and in the near future we intend to publish its results and respective detailed discussions.

5 Final Discussion and Further Work

The model presented in this work is based on the paradigm of dynamic environment/problem, introduced as a meta-system by Klir [11] and on a dynamic multi-criteria decision making framework [3] [16]. In this work, not only time could bring dynamism in to problem but population and location could have same impact. The main issue in this paper was to consider population or location in multi group multi criteria decision making problems.

The advantages of this model comparing with classic models are:

- Population/Location considered as important variables for ranking when decision makers are more than one.
- In case of the lack of data the model could work so it is proved to be robust in terms of missing data.
- Presence or absence of decision maker (which is called population in the paper) in each iteration will not cause problem and the model still could works properly.

Further, the proposed approach deals with Multi Dimensional Dynamic MCDM, where not only Population/Location is varying but also time is important and could affect the level of satisfaction of values in the decision matrix.

The Hotel Ranking is an example of Web 2.0 development, in the sense that it is supposed to be embedded in existing tourism systems, like TripAdvisor, allowing for a participatory and fully interactive web-platform, including double direction in web-communication by means of users' contributions as well as consumption of information. The integration of our Dynamic MCDM methodology into the Web 2.0 platform offers an effective analytical tool for further dissemination and participation in some applications. Nonetheless, as spotted in [12], there are some critical challenges with the Web 2.0-based DSS, namely: Systems have been built based on models containing collaborative knowledge targeted at human (and only human) consumption and interpretation of information; Sharing of any collaborative knowledge elements relies on the decision maker's common sense; No shared and consensual model is accepted by a group of decision makers; among others. The enhancement of such a model is urged to apply technologies of Web 3.0, which is supposed to suit much more appropriately the needs of collaborative and group decision making in web-platforms. As defined in the literature, Web 3.0 is the integration of Semantic Web technologies with the community-based methods and principles of Web 2.0. It is then also a challenge for us to integrate the proposed Dynamic MADM approach, presented here, in web-applications, which can profit from the already available level of participatory information given by the Web 2.0 platform, taking also advantage of the automatized concepts of semantic web, via means of ontologies and the like.

In addition, as future work, the hotel ranking case study will be developed as a complete proof-of concept of the approach and also as a full-fledged web-based decision support system targeting travel agencies' services for the benefit of their clients.

References

1. Bailey, D., Goonetilleke, A., Campbell, D.A.: A new fuzzy multi-criteria evaluation method for group site selection in GIS. Journal of Multi-Criteria Decision Analysis 12(6), 337–347 (2003)
2. Calvo, T., Mayor, G., Mesiar, R. (eds.): Aggregation Operators: New Trends and Applications. STUDFUZZ, vol. 97. Physica-Verlag, Heidelberg (2002)
3. Campanella, G., Ribeiro, R.A.: A Framework for dynamic multiple criteria decision making. Decision Support Systems 52(1), 52–60 (2011), `http://dx.doi.org/10.1016/j.dss.2011.05.003`
4. Campanella, G., Pereira, A., Ribeiro, R.A., Varela, M.L.R.: Collaborative Dynamic Decision Making: a Case Study from B2B Supplier Selection. In: Hernández, J.E., Zarate, P., Dargam, F., Delibašić, B., Liu, S., Ribeiro, R. (eds.) EWG-DSS 2011. LNBIP, vol. 121, pp. 88–102. Springer, Heidelberg (2012)
5. Feick, R.D., Hall, B.G.: Balancing consensus and conflict with a GIS-based multiindividual, multi-criteria decision support tool. GeoJournal 53(4), 391–406 (2002)
6. Figueira, J., Greco, S., Ehrgott, M. (eds.): Multiple Criteria Decision Analysis: State of the Art Surveys. Kluwer Academic Publishers, Dordrecht (2005)
7. Jankowski, P., Nyerges, T.L.: Geographic information systems for group decision making. Taylor & Francis, London (2001)

8. Jankowski, P., Nyerges, T.L.: GIS-supported collaborative decision making: results of an experiment. Annals of the Association of American Geographers 91, 48–70 (2001)
9. Jassbi, J., Ribeiro, R.A., Varela, R.L.: Dynamic MCDM with future knowledge for supplier selection. Journal of Decision Systems (2014), `http://dx.doi.org/10.1080/12460125.2014.886850`
10. Kyem, P.A.K.: On intractable conflicts and participatory GIS applications: the search for consensus amidst competing claims and institutional demands. Annals of the Association of American Geographers 94(1), 37–57 (2004)
11. Klir, G.: Facets of Systems Science, 2nd edn. Kluwer/Plenum, New York (2001)
12. Jelokhani-Niaraki, M., Malczewski, J.: A Web 3.0-driven Collaborative Multicriteria Spatial Decision Support System. Cybergeo: European Journal of Geography, document 620 (2013), `http://cybergeo.revues.org/25514`, doi:10.4000/cybergeo.25514
13. Malczewski, J.: GIS and multicriteria decision analysis. Wiley & Sons, New York (1999)
14. Malczewski, J.: GIS-based land-use suitability analysis: A critical overview. Progress in Planning 62(1), 3–65 (2004)
15. Ribeiro, R.A.: Dynamic Multi-criteria Decision Making (MCDM): A framework (Invited Talk Abstract). In: Dargam, F.C.C., Leopold-Wildburger, U., Pickl, S., DeTombe, D., Plá, L., Liu, S., Hernández, J., Delibasic, B., Ribeiro, R., Zaraté, P. (eds.) Proceedings of the EURO Mini-Conference Graz-2013 on "Collaborative Decision Systems in Economics and in Complex Societal and Environmental Applications", Graz, Austria, vol. I (October 2013) ISBN: 978-3-943207-06-4
16. Ribeiro, R.A., Falcão, A., Mora, A., Fonseca, J.M.: FIF: A Fuzzy information fusion algorithm based on multi-criteria decision making. Knowledge-Based Systems Journal (2013), `http://dx.doi.org/10.1016/j.knosys.2013.08.032`
17. Simao, A., Densham, P.G., Haklay, M.: Web-based GIS for collaborative planning and public participation: An application to the strategic planning of wind farm sites. Journal of Environmental Management 90(6), 2027–2040 (2009)
18. Simoes, L., Bourdarias, C., Ribeiro, R.A.: Real-Time Planetary Landing Site Selection – A Non-Exhaustive Approach. Acta Futura 5, 39–52 (2012), doi: `http://dx.doi.org/10.2420/AF05.2012.39`
19. Triantaphyllou, E.: Multiple Criteria Decision Making Methods: A Comparative Study. Kluwer Academic Publishers (2000)

Kapuer: A Decision Support System for Protecting Privacy

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Abstract. Pervasive computing allows a world full of electronic devices connected to each other, autonomous, context aware and with a certain level of intelligence. They are deployed in our environment to ease our life. However today users don't control the traffic around their data. The use of mobile devices might increase this problem because the system is more complex and requests of personal data is transparent to users in order to reduce their cognitive load. The goal of Kapuer is to inform the user on requests about his privacy and help him protect his privacy by assisting him in the writing of authorization policies. But a risk remains, informing too much the user can drown him into a huge amount of information and could quit using the system. The idea around Kapuer is to make the user conscious of the situation without bothering him too much.

Keywords: privacy, decision support system, access control.

1 Introduction

With the rising of mobile computing and the increasing amount of devices connected to the Internet, exchanges of data between those devices have exploded. Disclosure of these data can put in danger privacy. The user of a device has to know about those exchanges of personal data and there must be a way for him to control them. Access-control systems allow to write authorization policies and then to control personal data. However, one needs some skills to write such policies. So it's not accessible to all users. In addition, because users have a different way to see their privacy and then a different idea on how to protect their personal data, it's not possible to have an administrator behind all users to write policies instead of users. In order to make accessible control of personal data by the user, we have developed a system, Kapuer, combining an access control system to write authorization policies and a decision support system (DSS) to understand the behavior of a user regarding privacy. In order to do that, the system needs to learn user's preferences in terms of privacy. The goal of our work is to develop a DSS, which proposes authorization policies to the user after having learned his preferences. The system uses interactions with the user to learn his preferences through a continuous learning during all the system execution . This preferences learning is based on multi-criteria decision making

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(MCDM) [1]. We present in this article how we have designed Kapuer and also notions like meta-criteria, which help the system having better results. The rest of the article will be organized as follow. We first present access-control system. Then we present our way to model preferences. After, we introduce Kapuer and its architecture. Finally we conclude and discuss about future work.

2 Access Control System

Since their beginning, access control systems have evolved a lot, but their goal is still the same: using authorization policies to control access to resources. Some of these systems have interesting features. Role Based Access Control (RBAC) [7] systems are, as indicated in their names, using the notion of roles to build their authorization policies. These systems have emerged in the nineties at the same time than multi-users applications. Roles are useful as they allow administrators to group users according to their functions. Then permissions can be granted directly to roles instead of users. The number of authorization policies is lower than if administrators had to write one for each permission for each user. But RBAC is not accessible to ordinary people since grouping access authorization is a complex task. Moreover user's preferences about privacy being different for each one, an administrator behind each user to write their own authorization policies is mandatory.

Roles are efficient with lot of users but each one of them has to have well-defined roles. Every time a new user enters the system, the administrator has to give him one or many roles or this new user won't have any access. If we are working in an open and dynamic environment where users can come and go, RBAC is no more helpful. To deal with all these new situations, another approach has been proposed: Attribute Based Access Control (ABAC). Attributes are used to characterize all elements present in a policy. That way, contextual situations [2] can be described by using attributes for the user requiring access, the action he wants to perform, the resource he wants to access but also for all kind of environmental or contextual attributes like when is the resource requested or why is it requested. This allows more flexibility for administrators who no longer write policies based on users but on situations. This way, users can be added to the system and granted permissions without any additional tasks, they will be automatically recognised by their attributes. Once again, even if ABAC is designed for open environment and attributes allows a lot of flexibility, it doesn't fit our needs for the same problem as RBAC, an administrator has to be present to write the policies due to the complexity of the task.

3 Preferences Modelling

Our approach is based on a Multi-Criteria Decision Making model. In general situations, a criterion is the association of an identifier and a value. The value in the MDCA approach is associated to the weight of the criterion. The higher this value is, the more important this criterion is for the user. Here Kapuer is used to learn user's preferences in terms of privacy. Then if a criterion has a low value and a request is received with this involved criterion, does it mean that the user considers that the data doesn't have to be disclosed or is it just that the system hasn't had the time to learn enough about that criterion? It is not possible to answer this question with criterion build in this way. To resolve this problem, for each criterion c_i, we don't use one value but two values. The first, g_{c_i} represent the user's preference for disclosure and the second f_{c_i} represent the user's preference for non-disclosure. These two values are correlated. During their update, g_{c_i} and f_{c_i} can only increase. The learning of preferences is continuous and infinite, a high value of g_{c_i} doesn't always mean the user agrees to disclose his data in the presence of this criterion. It can also mean that this criterion has shown pretty often among all requests and that is has been updated many times. To identify the signification of the two values of a criterion, we have to calculate the score s_{c_i} of the criterion c_i. This score is used by the DSS after an interaction with the user. During this interaction, the user has decided if he agrees or not to disclose the requested data. The calculation is $s_{c_i} = |f_{c_i} - g_{c_i}|$. This way, the score s_{c_i} determines the signification of c_i among the user's preferences. A low score reflects that there are no clear reasons for the user to choose between the two actions based on this criterion. On the contrary, a high score tells that this criterion is important for the user's decision. The technical part of the system (equations) will be considered as confidential for commercial purpose.

Each criterion is part of a class of criteria. We have defined six different classes, corresponding in the six types of attributes used for the access-control :

– **What** data to protect (phone number, contact list, etc.)
– **Who** wants to have access to data (John, Lisa, an unknown person, etc.)
– **When** is the access requested (the different days of the week, the different hours of the day, etc.)
– **Where** is the user at the time of the request (at home, at work, etc.)
– **How** data will be stocked (how long, who will have access, etc.)
– **Why** data will be used, what is the purpose. (charitable, to be sold, etc.)

A criterion can be seen as an instance of a class of criteria. For example the criterion ("John", 2.0, 3.0) is an instance of the class "Who", the name of the criterion is "John" and his values are "2.0" for f_{c_i} and "3.0" for g_{c_i}.

We introduce the notion of meta-criterion. A meta-criterion is a criterion defined by other criteria of the same class. Each criterion refers to a meta-criterion. A meta-criterion allows to group many criteria sharing a same property like roles group users. For example, we have two criteria ("Father", 1.0, 1.0) and ("Mother", 1.0, 1.0). The meta-criterion ("Parents", 3.0, 3.0) gathers the two criteria "Father" and "Mother". So a criterion is defined by a 4-uplet (identifier, associated meta-criterion, disclosure value, non-disclosure value). Then, we can redefined criteria "Father" and "Mother" as follow: ("Father", "Parents", 1.0, 1.0), ("Mother", "Parents", 1.0, 1.0).

A meta-criterion being also a criterion, he is defined similarly. Thereby it is possible for each class of criteria to create a hierarchy between its criteria

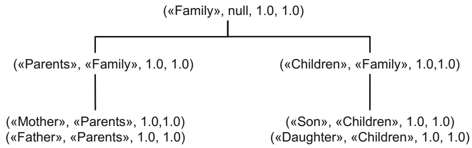

Fig. 1. Criteria's hierarchy

(Figure 1). There are two cases when a criterion doesn't have a meta-criterion to define his place in the hierarchy. When the criterion is on top of the hierarchy (for example, the criterion "Family" in Figure 1) or when the criterion doesn't belong to any group and can't be associated to a meta-criterion. This hierarchy of criteria is defined for the six class of criteria.

4 System Architecture

Kapuer is a combination of an access control system and a decision support system. Its goal is to provide assistance to a user who wants to protect his privacy. Writing authorization policies is a hard task, even for administrators so for a user without any skills in security, it is impossible. To design Kapuer, we have used a classic XACML [5] architecture build around our main component, the DSS (Figure 2).

Kapuer starts to work when a request is received. A request is a demand from a person or an application to access some personal data. Whenever a request is received,the Policy Enforcement Point (PEP) intercepts it. The PEP is a component used to translate the request into attributes. When the request is successfully translated, it's send to the Policy Decision Point (PDP), which pursue the process. The goal of the PDP is to verify if there is a match between existing authorization policies in the policy base and the request and if there is to give the associated decision. If there is a match, the decision of the rule is sent back to the PEP. The decision can have two different value, "Permit"

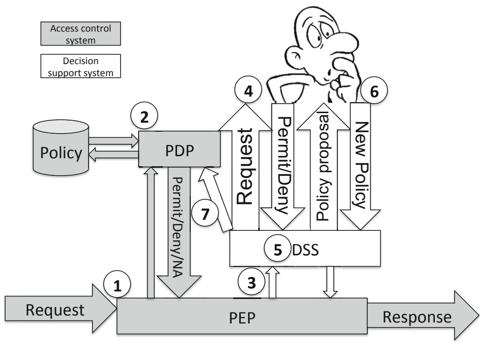

Fig. 2. Architecture of our approach

or "Deny". If there is no match between policies and the request, the decision "Not Applicable" is sent back to the PEP. This last case is when there is no rule to handle the request. Normally in that case, the designer of the access-control system implements a logic to still give an answer to the requester. In most of the case, the decision "Not Applicable" is seen as a "Deny" to prevent disclosure of data not managed by an authorization policy. In Kapuer, the decision "Not Applicable" only means that the actual knowledge of user's preferences is not enough to propose a new authorization policy and handle the request. Then Kapuer has to improve its learning and for this, it informs the user of the current request and ask him what is the decision to take. The user can choose between the two available actions, "accept" or "decline" the disclosure. When the user has taken his decision, the DSS analyses it in order to understand it and improve the user's preferences.

It is required, for a better understanding of the user's behaviour, to analyse why this decision was taken. In order to do that and to follow the MCDA approach, the request is decomposed into criteria. Meta-criteria intervenes here. Kapuer doesn't use the criteria of the request only but also all the combination of the criteria and their meta-criteria. Then we don't have a unique list of criteria but a set of lists. Once Kapuer has all those lists, it uses them and the actual user's preferences to calculate the score S_R of each list. To calculate these score, we aggregate the criteria using a aggregation operator. The result of S_R allows Kapuer to know if the user has a strict preference for the choice he just made or not. If there isn't a strict preference, Kapuer just updates all criteria and meta-criteria involved in the request. Otherwise it interacts again with the user to propose him to write a new authorization policy. Kapuer explains what the rule is and let the user decides if it really suits him. If that's the case, a new policy is written and placed in the policy base. On the contrary, if the policy doesn't suit the user, it is because there is an error of understanding in the preferences so criteria are updated with the new user's decision. At this time, Kapuer always have a decision to transmit to the PEP, which translates it into the language of the requester and then sends the final decision.

5 Evaluation

Evaluating our work is necessary in order to show its feasibility in real life. Without interaction, our system isn't able to learn preferences, thus assistance isn't possible. In order to obtain enough data to compare, we must have lots of users involved for tests and as many devices. To avoid those constraints, we have developed a simulator. We have implemented in this simulator a set of criteria and a hierarchy for each class. That way, we are able to generate easily a lot of requests by taking randomly one criterion of each class. Then the system takes these requests one by one and analyses them as explained in the previous section. The remaining problem is the lack of users to take decision during all interactions. To go beyond this issue, we have implemented a set of aurhotization rules to imitate an user's behaviour. Each time the system needs an interaction, it will simply look at that list and check if one rule matches. All rules need to be exclusive to avoid doubts if two or more rules match the same request and give different decision.

The number of interactions between our system and the user should be limited in order to annoy him as less as possible. Using meta-criteria to aggregate policies is a way to decrease interactions, but it isn't enough. This number of interactions also depends on the preferences learned and how fast the DSS learns them. One of the parts that affect the most this learning is how the criteria's aggregation is done to calculate requests' scores and the criteria's update. Using the simulator is a good tool to test several aggregation operators. During our simulations, we have played each set of requests on three different operators:

– The weighted mean, an operator used in the majority of DSS because of its simplicity.
– The Choquet integral [3], a more complex operator that uses importance of each class of criteria and interactions between them for more accuracy. We choose the Choquet integral because we thought that for this problem, criteria are not independant. Its implementation isn't easy. We have used Kappalab [4], a plug-in of R to made our Choquet operator.
– Our own operator is between the weighted mean and the Choquet integral, working not only on the request's criteria but also with all the combinations possible of those criteria. We have used this mixed operator to look if combinations of criteria will help the system find possible interactions between two or more criteria.

We ran ten simulations of 200 random requests to compare the three different operators and see if one of them shows better results. We evaluate four different metrics. First the number of interactions. It shows the level of abstraction of each operator. The more policies are created, the lower-level they are. Then, it indicates if an operator can adapt itself to a system with more criteria. The second metric is the number of requests processed by policies. It shows the learning speed. The more requests are handled by policies, the faster preferences are learned. The third metric is the level of completeness, ie the ratio between the number of requests covered by the policies created and the number of requests possible with the behaviour's rules that simulate the user. It shows, after 200 requests, the percentage of requests that will be handled by Kapuer. The last metric is the number of interactions made during the 200 requests. It's the sum of the number of policies and the number of requests non-processed by policies. For our first tests, we have implemented three classes of criteria:

– **What** data to protect with six criteria. "Contact list" and "Calendar" with the same meta-criterion "Data". "Name" and "E-mail address" with the meta-criterion "Info". "GPS" and "Camera" with the meta-criterion "Service".
– **Who** wants to have access to data with nine criteria. "Jimmy", "Lee" and "Billy" with the meta-criterion "Family". "Bob", "Jay" and "Fred" with the criterion "Friend". "Pierrick" and "Mick" with the meta-criterion "Colleague" and "John" with the meta-criterion "Unknown".

- **When** is the access requested with fourteen criteria for each half-day and two meta-criteria (”Morning” and ”Afternoon”)

Finally, users are simulated by two different behaviours. The first one, B_{cx}, is complex. It agrees to share data with members of the family all the time, with colleagues on morning, with friends on afternoon and doesn't share anything with unknowns. The second behaviour, B_{op}, is open to all requests. The results are shown in Figure 3 (note that coordinates don't use the same scales).

The results show that there isn't an operator way above the others. No one have the best results in all four metrics. Kapuer is interesting for users if it handles the more possible requests. After 200 requests, whatever the behaviour, the three operators are above 80% of completeness. So more than four out of five further requests will be handled by the system. The mixed operator even reaches 98.9% with B_{op}. This level has to be confronted with the number of policies created. As we already said, the more policies are created, the lower-level they are. Then if we strongly increase the number of criteria in the system, the system needs more time to learn user's preferences. If the created policies are low-level, it will lead to a lower level of completeness. Then, if Choquet and the weighted mean have good results in those cases, our operator will have better results in a system with more criteria and more important, Choquet and the weighted mean are not stable, results can vary a lot between two simulations whereas our operator is very stable.

Fig. 3. Results of the simulations

The other important point for users is to limit interactions. We can see that a complex behaviour brings more interactions than an open one. The learning speed has an impact on interactions. Choquet and the weighted mean have more requests processed by policies. It shows that they create policies faster than our mixed operator, but with B_{cx} they create so many policies that they require more interactions than our operator. Three times during the simulations, Choquet and the weighted mean have had peaks in the results. Way more policies are created because they are low-level. With a low level of abstraction, the level of completeness is also lower and it increases the number of interactions. On the contrary, whatever the behaviour, our operator is more stable than the two other for the four types of metrics.

6 Conclusion and Future Work

Kapuer shows that a DSS can help the users protect their privacy, even if he has no skills in security. We have tested three operators. None is the best but our mixed operator has good results and is the most stable. A prototype of Kapuer [6] has been implemented on an Android device but it wasn't practical and fast enough to do lots of tests. This is why we have developped a simulator, allowing us to compare different operators on a same set of requests. The learning speed still needs to be increased. We are working on an initialization phase, few questions asked to the user before the first use of the system, to have a first idea of his preferences. It should allow Kapuer to be faster. Finally, we need to test Kapuer in real situations. To do that, we are currently improving the Android prototype and tests it with real users.

References

1. Bouyssou, D., Dubois, D., Pirlot, M., Prade, H.: Concepts et méthodes pour l'aide la d cision 3. Lavoisier (2006)
2. Dey, A.: Understanding and using context. Personal and ubiquitous computing (2001)
3. Grabisch, M.: Modelling data by the Choquet integral. In: Information Fusion in Data Mining, pp. 135–148 (2003)
4. Kappalab, `http://cran.r-project.org/web/packages/kappalab/` (last access December 2013)
5. OASIS XACML committee, eXtensible Access Control Markup Language (XACML) Version 2.0. (last access December 2013) `http://www.oasis-open.org/committees/xacml/`
6. Oglaza, A., Laborde, R., Zarate, P.: Authorization policies: Using Decision Support System for context-aware protection of user's private data. In: Proceedings of the 12th IEEE International Conference on Trust, Security and Privacy in Computing and Communications (IEEE TrustCom 2013) (July 2013)
7. Sandhu, R., Coyne, E., Feinstein, H., Youman, C.: Role-based access control models. Computer, 38–47 (1996)

An MCDM Approach to Group Processes Using Choquet Integration

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Abstract. We consider a model of non-additive Choquet aggregation in group processes, with reference to the context of effort estimation in Project Management. The groups considered are formed by "experts" (people with specific technical competence) and "non-experts" (people with less specific technical competence, usually experts in related fields), so that the typically complementary biases of the two classes contribute to a more balanced estimate. We present two simple examples which illustrate how the Choquet aggregation results improve those of the classical weighted mean (additive case). Finally, we discuss the relation between the average Choquet weights of consensual coalitions of experts and non-experts and their individual Shapley values.

Keywords: aggregation, MCDM, group processes, project management.

1 Introduction

The classical aggregation scheme of group processes for effort estimation in Project management is the weighted mean, a fundamental type of aggregation function, see for instance Calvo, Mayor, and Mesiar [6], Beliakov, Pradera, and Calvo [1], Grabisch, Marichal, Mesiar, and Pap [20].

In this paper, however, we consider a more general aggregation framework, with interesting extra degrees of freedom: the Choquet integral, which is defined with respect to a non-additive capacity and corresponds to a large class of aggregation functions, including the classical weighted mean - the additive capacity case - and the ordered weighted mean (OWA) - the symmetric capacity case. Comprehensive reviews of Choquet integration con be found in Grabisch and Labreuche [17,18,19], Grabisch, Kojadinovich, and Meyer [15], plus also Wang and Klir [35], Grabisch, Nguyen and Walker [22], Grabisch, Murofushi and Sugeno [21].

In the framework of Choquet integration, in order to control the exponential complexity in the construction of the capacity ($2^n - 2$ real coefficients), Grabisch [13] introduced the so called k-additive capacities, see also Grabisch [14], and Miranda and Grabisch [30]. The 2-additive case in particular (see Miranda, Grabisch, and Gil, [31]; Mayag, Grabisch, and Labreuche, [28,29]) is a good trade-off

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between the range of the model and its complexity (only $n(n+1)/2$ real coefficients are required to define a 2-additive capacity). The Choquet integral with respect to a 2-additive capacity is an interesting and effective modelling tool, see for instance Marques Pereira and Bortot [26,27,5], Berrah and Clivillé [2], Clivillé, Berrah, and Maurice [9], Berrah, Maurice, and Montmain [3].

In this paper we propose an aggregation model based on Choquet integration with respect to a 2-additive capacity. The groups considered are formed by "experts" (people with specific technical competence) and "non-experts" (people with less specific technical competence, usually experts in related fields), for the typically complementary bias of the two classes contribute to a more balanced estimate. In other words, we exploit the synergies between experts and non-experts in an MCDM framework, aggregating the individual estimates by means of non-additive Choquet integration, and representing the complementary bias by the interaction structure underlying the capacity.

The approach presented in this paper stems from the idea that, in order to mitigate the innate optimism of experts, we should add to the panel of estimators people that have opposite characteristics, i.e., non-optimistic approach in estimate formulation. Such people are typically non-experts, prudent in delivering their opinion on a topic that they are not fully comfortable about.

The paper is organized as follows. Section 2 reviews the basic definitions and results on capacities and Choquet integration, particularly in the 2-additive case. In Section 3 we present our aggregation model using Choquet integration, with two numerical examples. We also discuss the relation between the average Choquet weights of consensual coalitions of experts and non-experts and their individual Shapley values.

2 Capacities and Choquet Integrals

In this section we present a brief review of the basic facts on Choquet integration, focusing on the Möbius representation framework. For recent reviews of Choquet integration see [17,15,18,19] for the general case, and [31,28,29] for the 2-additive case in particular.

Consider a finite set of interacting individuals $N = \{1, 2, \ldots, n\}$. Any subsets S, $T \subseteq N$ with cardinalities $0 \leq s$, $t \leq n$ are usually called coalitions. The concepts of capacity and Choquet integral in the definitions below are due to [8,34,10,11,12].

In order to keep the notation as simple as possible, we denote $\mu(\{i\})$, $\mu(\{i,j\})$, etc by $\mu(i)$, $\mu(ij)$, etc. For the same reason, given a coalition $S \subseteq N \setminus \{i\}$ not involving the element $i \in N$, we write $N \setminus i$ and $\mu(S \cup i)$ instead of $N \setminus \{i\}$ and $\mu(S \cup \{i\})$. Analogously, given a coalition $S \subseteq N \setminus \{i,j\}$ not involving the elements $i, j \in N$, we write $N \setminus ij$ and $\mu(S \cup ij)$ instead of $N \setminus \{i,j\}$ and $\mu(S \cup \{i,j\})$, respectively.

Definition 1. *A* capacity *on the set N is a set function $\mu : 2^N \longrightarrow [0,1]$ satisfying*

(i) $\mu(\emptyset) = 0$, $\mu(N) = 1$ (boundary conditions)
(ii) $S \subseteq T \subseteq N \quad \Rightarrow \quad \mu(S) \leq \mu(T)$ (monotonicity conditions).

Capacities are also known as *fuzzy measures* [34] or *non-additive measures* [10]. A capacity μ is said to be additive over N if $\mu(S \cup T) = \mu(S) + \mu(T)$ for all coalitions S, $T \subseteq N$, with $S \cap T = \emptyset$.

Definition 2. *Let μ be a capacity on N. The* Choquet integral $\mathcal{C}_\mu : [0,1]^n \longrightarrow [0,1]$ *with respect to μ is defined as*

$$\mathcal{C}_\mu(\mathbf{x}) = \sum_{i=1}^{n} [\mu(A_{(i)}) - \mu(A_{(i+1)})]\, x_{(i)} \qquad \mathbf{x} = (x_1, \ldots, x_n) \in [0,1]^n \tag{1}$$

where $(\cdot)$ indicates a permutation on N such that $x_{(1)} \leq x_{(2)} \leq \ldots \leq x_{(n)}$. Moreover, $A_{(i)} = \{(i), \ldots, (n)\}$ and $A_{(n+1)} = \emptyset$.

The Choquet integral is a continuous and idempotent aggregation function. Within each comonotonicity cone of the domain $[0,1]^n$, the Choquet integral reduces to a weighted mean, whose weights depend on the comonotonicity cone. In fact, given $\mathbf{x} \in [0,1]^n$, we can write $\mathcal{C}_\mu(\mathbf{x}) = \sum_{i=1}^{n} w_{(i)}\, x_{(i)}$ where $w_{(i)} = \mu((i), (i+1), \ldots, (n)) - \mu((i+1), \ldots, (n))$, with $w_{(i)} \geq 0$, $i = 1, \ldots, n$ and $\sum_{i=1}^{n} w_{(i)} = 1$ due to the boundary and monotonicity conditions of the capacity. In the additive case, $w_{(i)} = \mu((i))$, and the Choquet integral reduces to a weighted averaging function (WA), that is, $\mathcal{C}_\mu(\mathbf{x}) = \sum_{i=1}^{n} w_{(i)}\, x_{(i)} = \sum_{i=1}^{n} \mu((i)) x_{(i)} = \sum_{i=1}^{n} \mu(i) x_i = \sum_{i=1}^{n} w_i\, x_i$.

In the context of non-additive capacities the notion of effective importance or influence of the individual elements of N as expressed by the Shapley values [33,23,25] plays an important role in Choquet integration.

Definition 3. *Let μ be a capacity on N. The* importance index *or* Shapley value *of criterion $i \in N$ with respect to μ is defined as*

$$\phi_\mu(i) = \sum_{T \subseteq N \setminus i} \frac{(n-1-t)!\, t!}{n!} [\mu(T \cup i) - \mu(T)] \qquad i \in N \tag{2}$$

where t denotes the cardinality of coalition $T \subseteq N$.

The Shapley value $\phi_\mu(i)$ amounts to a weighted average of the marginal contribution of element i w.r.t. all coalitions $T \subseteq N \setminus i$ and can be interpreted as an effective importance weight, since

$$\phi_\mu(i) \in [0,1]\,, \qquad \sum_i \phi_\mu(i) = 1 \qquad i \in N\,. \tag{3}$$

Moreover, the Shapley value $\phi_\mu(i)$ corresponds to the Choquet weight of element $i \in N$ averaged over all comonotonicity cones [16].

A capacity μ can be equivalently represented by its Möbius transform m_μ [32,7,14,24,30] in the following way.

Definition 4. *Let μ be a capacity on the set N. The* Möbius transform $m_\mu : 2^N \longrightarrow \mathbb{R}$ *associated with the capacity μ is defined as*

$$m_\mu(T) = \sum_{S \subseteq T} (-1)^{t-s} \mu(S) \qquad T \subseteq N \tag{4}$$

where s and t denote the cardinality of the coalitions S and T, respectively.

Conversely, given the Möbius transform m_μ, the associated capacity μ is obtained as

$$\mu(T) = \sum_{S \subseteq T} m_\mu(S) \qquad T \subseteq N\,. \tag{5}$$

According to (5), the Shapley values in Definition 3 can also be expressed in terms of the Möbius transform [13,24],

$$\phi_\mu(i) = \sum_{T \subseteq N \setminus i} \frac{m_\mu(T \cup i)}{t+1} \qquad i \in N\,. \tag{6}$$

Defining a capacity μ on a set N of n elements requires $2^n - 2$ real coefficients, corresponding to the capacity values $\mu(T)$ for $T \subseteq N$. In order to control exponential complexity, Grabisch [13] introduced the concept of k-additive capacities, with $k = 1, \ldots, n$. We consider here the 2-additive case.

Definition 5. *A capacity μ on the set N is said to be* 2-additive *if its Möbius transform satisfies $m_\mu(T) = 0$ for all $T \subseteq N$ with $t > 2$, and there exists at least one coalition $T \subseteq N$ with $t = 2$ such that $m_\mu(T) \neq 0$.*

The 2-additive case is the simplest non-linear capacity model and it has been studied and applied in various contexts, see for instance [26,27,5,2,9,3,28,29]. In the 2-additive case, the capacity is written as

$$\mu(T) = \sum_{i \in T} m_\mu(i) \; + \sum_{\{i,j\} \subseteq T} m_\mu(ij) \qquad T \subseteq N\,. \tag{7}$$

Moreover, for 2-additive capacities, the Shapley values in (6) are given by

$$\phi_\mu(i) = m_\mu(i) + \frac{1}{2} \sum_{j \in N \setminus i} m_\mu(ij) \qquad i \in N\,. \tag{8}$$

3 A Non-additive Choquet Aggregation Model

Let N be a set of interacting agents. We consider two different classes of agents in N: the class of expert agents N_e and the class of non-expert agents N_a. Clearly $N = N_e \cup N_a$ and $N_a \cap N_e = \emptyset$. Accordingly, for every coalition of agents $T \subseteq N$

we have $T = T_e \cup T_a$ and $T_a \cap T_e = \emptyset$. The cardinality of N_e, N_a, T_e, and T_a is indicated as n_e, n_a, t_e, and t_a respectively, with

$$n_e + n_a = n\,, \qquad\qquad t_e + t_a = t\,. \tag{9}$$

In our model we wish to emphasize the inter-class consensus between agents in N_e and N_a with respect to the intra-class consensus between agents in the same class. This effect is obtained by assigning positive interaction between agents in different classes, and negative interaction between agents in the same class, in the framework of 2-additive capacities described in the previous section.

We associate to each agent $i \in N$ a weight $w_i > 0$. These weights are normalized to unit sum $\sum_{i=1}^{n} w_i = 1$. We suppose that all agents in the same class have the same associated weight

$$w_i = \begin{cases} w_e & \text{if } \ i \in N_e \\ w_a & \text{if } \ i \in N_a \end{cases} \qquad\qquad i \in N \tag{10}$$

with $w_e \geq w_a$. Therefore, we have

$$\sum_{i \in N} w_i = \sum_{i \in N_e} w_i + \sum_{i \in N_a} w_i = n_e w_e + n_a w_a = 1\,. \tag{11}$$

We define a 2-additive capacity $\mu : 2^N \longrightarrow [0,1]$ in the following way: with reference to Eq. (7), in which the 2-additive capacity μ is expressed in terms of its Möbius transform, we define

$$\mu(T) = \sum_{i \in T} m_\mu(i) \;+ \sum_{\{i,j\} \subseteq T} m_\mu(ij) \qquad\qquad T \subseteq N \tag{12}$$

where

$$m_\mu(i) = w_i \qquad i \in N \tag{13}$$

$$m_\mu(ij) = -\alpha \qquad \text{or} \qquad m_\mu(ij) = \beta \qquad i,j \in N \tag{14}$$

depending on whether i, j are in the same class or in different classes, respectively.

In view of the boundary constraint $\mu(N) = 1$, the assignment (13) for the individual capacity values, with $\sum_{i=1}^{n} w_i = 1$, implies the overall balance of the pairwise interactions (14), as expressed by (19) below. This balanced interactive scenario refers to the general framework introduced in [4] with the convenient choice $D = 1$ for the normalization coefficient. In this way, the individual Choquet weights associated with the capacity μ remain equal to the basic weights w_i, $i = 1, \ldots, n$ assigned to the agents in our model.

The graph interpretation of this definition, with singletons $\{i\}$ corresponding to nodes and pairs $\{i,j\}$ corresponding to edges between nodes, is the following: the value of the 2-additive capacity μ on a coalition T is given by the sum of the nodes and edges contained in the subgraph associated with the coalition T.

Therefore we have

$$\mu(T) = \sum_{i \in T} w_i + m_1(T)\beta - m_2(T)\alpha \qquad T \subseteq N \tag{15}$$

where the value $m_1(T)$ indicates the number of edges inside the coalition T between agents in different classes, i.e. the number of edges between an expert agent $i \in T_e$ and a non-expert agent in $j \in T_a$. Its value is given by

$$m_1(T) = t_e \cdot t_a \qquad T \subseteq N\,. \tag{16}$$

Similarly, the value $m_2(T)$ indicates the number of edges inside the coalition T between agents in the same class, i.e. the number of edges between two expert agents $i, j \in T_e$ or two non-expert agents $i, j \in T_a$. Its value can be computed as follows,

$$m_2(T) = \frac{1}{2}t_e(t_e - 1) + \frac{1}{2}t_a(t_a - 1) \qquad T \subseteq N\,. \tag{17}$$

From the boundary condition $\mu(N) = 1$ in Definition 1 and (15) with $T = N$,

$$\mu(N) = \sum_{i \in N} w_i + m_1(N)\beta - m_2(N)\alpha = 1 \tag{18}$$

plus definitions (16) and (17), we obtain the balancing constraint for the parameters α and β,

$$[n_e(n_e - 1) + n_a(n_a - 1)]\,\alpha = 2n_e n_a \beta\,. \tag{19}$$

Given the weight normalization assumption, $\sum_{i=1}^{n} w_i = 1$, this balancing constraint expresses the fact that the overall sum of the edges in the graph associated with the 2-additive capacity μ over N is null. In the following result we obtain the conditions on the (independent) parameter α that ensure the monotonicity of the capacity.

Proposition 1. *The capacity μ introduced in (12) - (14) and (19), satisfies the boundary conditions $\mu(\emptyset) = 0$ and $\mu(N) = 1$. Moreover it is monotonic, that is, $\mu(S) \leq \mu(T)$ for $S \subseteq T \subseteq N$, for $0 \leq \alpha \leq min(\alpha_e, \alpha_a)$ and $\beta \geq 0$ as in (19), where*

$$\alpha_e = w_e/(n_e - 1) \qquad \alpha_a = w_a/(n_a - 1)$$

for $n_e, n_a \geq 2$. If $n_e = 0, 1$ and $n_a \geq 2$ the constraint is simply $0 \leq \alpha \leq \alpha_a$. Analogously, if $n_e \geq 2$ and $n_a = 0, 1$ the constraint is simply $0 \leq \alpha \leq \alpha_e$.

Proof: The boundary conditions $\mu(\emptyset) = 0$ and $\mu(N) = 1$ are clearly satisfied, the latter corresponds to the choice of the parameters α and β as in the balancing constraint (19).

In order to prove monotonicity it suffices to show that $\mu(T \cup i) \geq \mu(T)$ for all $i \in N, T \subseteq N \backslash i$. In our 2-additive model, this means that the individual capacity contribution of element $i \in N$ to any coalition $T \subseteq N \setminus i$ should dominate the overall sum of the interactions between $i \in N$ and the elements in the coalition considered. Accordingly, the monotonicity of the capacity directly constraints the negative interactions associated with parameter $\alpha \geq 0$. The detailed proof is deferred to an extended version of this paper (in preparation). We obtain $\alpha \in [0, min(\alpha_e, \alpha_a)]$ and β is correspondingly given by (19). □

In our 2-additive model, the Shapley values as in (8) are written as

$$\phi_\mu(e) = w_e - \frac{1}{2}\,\alpha(n_e - 1) + \frac{1}{2}\,\beta n_a\,, \quad \phi_\mu(a) = w_a - \frac{1}{2}\,\alpha(n_a - 1) + \frac{1}{2}\,\beta n_e\,. \tag{20}$$

Example 1. We want to aggregate the estimates given by three agents X_1, X_2, and X_3. Suppose X_1 and X_2 are expert agents and X_3 is a non-expert agent. Table 1 shows the estimates and the weights associated to each agent.

Table 1. Single agent estimates in Example 1

Agent	Estimate	Weight	Class
X_1	100	0.4	Expert
X_2	110	0.4	Expert
X_3	60	0.2	Non-expert

In this example there is a significant consensus between agents in the same class (two experts). In such case the non-additive Choquet aggregation in our model is designed in order to attenuate the overall weight of the consensual group. Accordingly, in this example we expect the final estimate produced by the Choquet integral to have a lower value than the standard weighted mean.

In the standard aggregation scheme the final estimate is computed by the weighted mean with weighting vector $\mathbf{w} = (w_1, w_2, w_3) = (0.4, 0.4, 0.2)$. Therefore we obtain

$$\mathcal{W}_{\mathbf{w}}(100, 110, 60) = 0.4 \cdot 100 + 0.4 \cdot 110 + 0.2 \cdot 60 = 96\,. \tag{21}$$

Now consider the Choquet integral. Due to Proposition 1, the standard weight distribution $w_e = 0.4$, $n_e = 2$ and $w_a = 0.2$, $n_a = 1$ requires $\alpha \leq 0.4$ in order to ensure the monotonicity of the capacity. In this example we consider $\alpha = 0.2$ and $\beta = 0.1$ which satisfy the balancing constraint (19).

We can now compute the value of our capacity on every coalition of agents

$$\mu(1) = w_1 = 0.4\,, \quad \mu(2) = w_2 = 0.4\,, \quad \mu(3) = w_3 = 0.2$$

$$\mu(1,2) = -\alpha + w_1 + w_2 = 0.6\,, \quad \mu(1,3) = \beta + w_1 + w_3 = 0.7 \tag{22}$$

$$\mu(2,3) = \beta + w_2 + w_3 = 0.7\,, \quad \mu(1,2,3) = 2\beta - \alpha + w_1 + w_2 + w_3 = 1\,.$$

The associated Choquet integral leads to a new final estimate. Since

$$x_3 = 60 \,<\, x_1 = 100 \,<\, x_2 = 110 \tag{23}$$

we obtain

$$\begin{aligned} C_\mu(100, 110, 60) &= \sum_{i=1}^{3} (\mu(A_{(i)}) - \mu(A_{(i+1)})\, x_{(i)} \\ &= [\mu(3, 1, 2) - \mu(1, 2)]\, x_3 + [\mu(1, 2) - \mu(2)]\, x_1 + \mu(2) x_2 \\ &= [1 - 0.6]\, 60 + [0.6 - 0.4]\, 100 + [0.4]\, 110 \\ &= 0.4 \cdot 60 + 0.2 \cdot 100 + 0.4 \cdot 110 = 88\,. \end{aligned} \tag{24}$$

Note that using the Choquet integral we obtain a different final estimate. If we compare (21) with (24) we have

$$C_\mu(100, 110, 60) = 88 < \mathcal{W}_{\mathbf{w}}(100, 110, 60) = 96\,. \tag{25}$$

In this case, with respect to the classical weighted mean aggregation, the Choquet integral has reduced the joint weight of the consensual agents X_1 and X_2 (both experts) and, accordingly, has increased the single weight of agent X_3

$$0.2 + 0.4 = 0.6 < w_1 + w_2 = 0.8\,. \tag{26}$$

Example 2. Consider now the situation illustrated in Table 2.

Table 2. Single agent estimates in Example 2

Agent	Estimate	Weight	Class
X_1	100	0.4	Expert
X_2	60	0.4	Expert
X_3	110	0.2	Non-expert

In this example there is a significant consensus between agents in different classes (expert and non-expert). In such case the non-additive Choquet aggregation in our model is designed in order to emphasize the overall weight of the consensual group. Accordingly, in this example we expect the final estimate produced by the Choquet integral to have a higher value than the standard weighted mean.

In the standard aggregation scheme the final estimate is computed bythe weighted mean with weighting vector $\mathbf{w} = (w_1, w_2, w_3) = (0.4, 0.4, 0.2)$. Therefore we obtain

$$\mathcal{W}_{\mathbf{w}}(100, 60, 110) = 0.4 \cdot 100 + 0.4 \cdot 60 + 0.2 \cdot 110 = 86\,. \tag{27}$$

The capacity μ is the same as in the previous example. The associated Choquet integral leads to a new final estimate. Since

$$x_2 = 60 \;<\; x_1 = 100 \;<\; x_3 = 110 \tag{28}$$

we obtain

$$
\begin{aligned}
C_\mu(100,60,110) &= \sum_{i=1}^{3}(\mu(A_{(i)}) - \mu(A_{(i+1)})\, x_{(i)} \\
&= [\mu(2,1,3) - \mu(1,3)]\, x_2 + [\mu(1,3) - \mu(3)]\, x_1 + \mu(3)x_3 \\
&= [1 - 0.7]\, 60 + [0,7 - 0.2]\, 100 + [0.2]\, 110 \\
&= 0.3 \cdot 60 + 0.5 \cdot 100 + 0.2 \cdot 110 = 90\,. \qquad (29)
\end{aligned}
$$

Again using the Choquet integral we obtain a different final estimate. If we compare (27) with (29) we have

$$C_\mu(100,60,110) = 90 > \mathcal{W}_{\mathbf{w}}(100,60,110) = 86\,. \qquad (30)$$

In this case, with respect to the classical weighted mean aggregation, the Choquet integral has increased the joint weight of the consensual agents X_1 and X_3 (one expert and one non-expert) and, accordingly, has reduced the single weight of agent X_2

$$0.5 + 0.2 = 0.7 > w_1 + w_3 = 0.6\,. \qquad (31)$$

Summarizing, the two examples described illustrate how the non-additive Choquet aggregation has the effect of emphasizing the consensual weight between agents in different classes (experts and non-experts), and attenuating the consensual weight between agents in the same class.

In general, with $n_e = 2$ and $n_a = 1$ as in the two examples above, the Shapley values as in (20) reduce to

$$\phi_\mu(e) = w_e + \frac{1}{2}\,(-\alpha + \beta) \qquad \phi_\mu(a) = w_a + \beta\,. \qquad (32)$$

Moreover, we can compute the average Choquet weights of the two types of coalitions $\{e,e\}$ and $\{e,a\}$, meaning $\{e_1,e_2\}$ in the first case, and $\{e_1,a_1\}$ or $\{e_2,a_1\}$ in the second case. The average Choquet weight of a coalition corresponds to the overall Choquet weight associated with its members when these are consensually expressed by a common value, averaged over all possible comonotonicity cones.

Let x_1, x_2, x_3 be the estimates of the three agents e_1, e_2, a_1, respectively. In the case of the coalition type $\{e,e\}$ we consider the coalition $\{e_1,e_2\}$ and the two profiles $x_1 = x_2 < x_3$ and $x_3 < x_1 = x_2$. The average Choquet weight $\varphi_\mu(ee)$ of the coalition type $\{e,e\}$ is thus given by

$$
\begin{aligned}
\varphi_\mu(ee) = \varphi_\mu(e_1e_2) &= \frac{1}{2}\Big[(\mu(1,2,3) - \mu(3)) + (\mu(1,2) - \mu(\emptyset))\Big] \\
&= 2w_e - \alpha + \frac{1}{2}\,\beta = 2\,\phi_\mu(e)\,. \qquad (33)
\end{aligned}
$$

Analogously, in the case of the coalition type $\{e,a\}$ we consider, for instance, the coalition $\{e_1,a_1\}$ and the two profiles $x_1 = x_3 < x_2$ and $x_2 < x_1 = x_3$. The average Choquet weight $\varphi_\mu(ea)$ of the coalition type $\{e,a\}$ is thus given by

$$\varphi_\mu(ea) = \varphi_\mu(e_1 a_1) = \frac{1}{2}\Big[(\mu(1,3,2) - \mu(2)) + (\mu(13) - \mu(\emptyset))\Big]$$
$$= w_e + w_a - \frac{1}{2}\,\alpha + \frac{3}{2}\,\beta = \phi_\mu(e) + \phi_\mu(a)\,. \tag{34}$$

The average Choquet weight $\varphi_\mu(ea)$ could equivalently be computed considering the coalition $\{e_2, a_1\}$ and the two profiles $x_2 = x_3 < x_1$ and $x_1 < x_2 = x_3$.

The results expressed in (33) and (34) are in fact instances of a general fact: in the 2-additive case, the average Choquet weight of a coalition coincides with the sum of the individual Shapley values of its elements (to appear). This form of additivity of the average Choquet weights does not apply to capacities with higher complexity (k-additive with $k \geq 3$), although such cases are interesting for their richer interaction structure.

In summary, we consider a model of non-additive Choquet aggregation in group processes with reference to the context of effort estimation in Project Management. The groups considered are formed by “experts” and “non-experts”, whose complementary biases in the Choquet aggregation scheme are expressed by a 2-additive capacity with subadditive interaction ($-\alpha \leq 0$) between individuals of the same type and superadditive interaction ($\beta \geq 0$) between individuals of different types. In our model we assume a balanced interaction structure (the overall sum of positive and negative interactions is null) which determines a proportionality relation between the two interaction parameters $\alpha, \beta \geq 0$. The balanced interaction structure can be scaled from the additive case $\alpha, \beta = 0$ to a maximum non-additive case which is determined by the monotonicity constraint of the capacity (see Proposition 1): $\alpha = min(\alpha_e, \alpha_a)$ and corresponding β. In other words, the model has one parametric degree of freedom on a bounded interval in relation to the degree of non-additivity desired. Although an experimental validation is out of the scope of this paper, we provide two simple examples which illustrate how the Choquet aggregation results improve those of the classical weighted mean (additive case). Finally, we discuss the relation between the average Choquet weights of consensual coalitions of experts and non-experts and their individual Shapley values.

References

1. Beliakov, G., Pradera, A., Calvo, T.: Aggregation Functions: A Guide for Practitioners. STUDFUZZ, vol. 221. Springer, Heidelberg (2007)
2. Berrah, L., Clivillé, V.: Towards an aggregation performance measurement system model in a supply chain context. Comp. in Industry 58(7), 709–719 (2007)
3. Berrah, L., Mauris, G., Montmain, J.: Monitoring the improvement of an overall industrial performance based on a Choquet integral aggregation. Omega 36(3), 340–351 (2008)
4. Bonetti, A., Bortot, S., Fedrizzi, M., Marques Pereira, R.A., Molinari, A.: Modelling group processes and effort estimation in Project Management using the Choquet integral: an MCDM approach. Expert Systems with Applications 39(18), 13366–13375 (2012)

5. Bortot, S., Marques Pereira, R.A.: Inconsistency and non-additive capacities: the Analytic Hierarchy Process in the framework of Choquet integration. Fuzzy Sets and Systems 213, 6–26 (2013)
6. Calvo, T., Mayor, G., Mesiar, R.: Aggregation Operators: New Trends and Applications. STUDFUZZ, vol. 97. Springer, Heidelberg (2002)
7. Chateauneuf, A., Jaffray, J.Y.: Some characterizations of lower probabilities and other monotone capacities throught the use of Möbius inversion. Mathematical Social Sciences 17(3), 263–283 (1989)
8. Choquet, G.: Theory of capacities. Ann. de l'Institut Fourier 5, 131–295 (1953)
9. Clivillé, V., Berrah, L., Mauris, G.: Quantitative expression and aggregation of performance measurements based on the MACBETH multi-criteria method. International Journal of Production Economics 105(1), 171–189 (2007)
10. Denneberg, D.: Non-additive measure and integral. Kluwer Academic Publishers, Dordrecht (1994)
11. Grabisch, M.: Fuzzy integral in multicriteria decision making. Fuzzy Sets and Systems 69(3), 279–298 (1995)
12. Grabisch, M.: The application of fuzzy integrals in multicriteria decision making. European Journal of Operational Research 89(3), 445–456 (1996)
13. Grabisch, M.: k-order additive discrete fuzzy measures and their representation. Fuzzy Sets and Systems 92(2), 167–189 (1997)
14. Grabisch, M.: Alternative representations of discrete fuzzy measures for decision making. International Journal of Uncertainty, Fuzzyness and Knowledge-Based Systems 5(5), 587–607 (1997)
15. Grabisch, M., Kojadinovich, I., Meyer, P.: A review of methods for capacity identification in Choquet integral based multi-attribute utility theory: Applications of the Kappalab R package. European Journal of Operational Research 186(2), 766–785 (2008)
16. Grabisch, M., Labreuche, C.: How to improve acts: an alternative representation of the importance of criteria in MCDM. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems 9(2), 145–157 (2001)
17. Grabisch, M., Labreuche, C.: Fuzzy measures and integrals in MCDA. In: Figueira, J., Greco, S., Ehrgott, M. (eds.) Multiple Criteria Decision Analysis, pp. 563–604. Springer, Heidelberg (2005)
18. Grabisch, M., Labreuche, C.: A decade of application of the Choquet and Sugeno integrals in multi-criteria decision aid. 4OR 6(1), 1–44 (2008)
19. Grabisch, M., Labreuche, C.: A decade of application of the Choquet and Sugeno integrals in multi-criteria decision aid. Annals of Operations Research 175(1), 247–286 (2010)
20. Grabisch, M., Marichal, J.L., Mesiar, R., Pap, E.: Aggregation Functions, Encyclopedia of Mathematics and its Applications, vol. 127. Cambridge University Press, Cambridge (2009)
21. Grabisch, M., Murofushi, T., Sugeno, M.: Fuzzy Measure and Integrals: Theory and Applications. Physica-Verlag, Heidelberg (2000)
22. Grabisch, M., Nguyen, H.T., Walker, E.A.: Fundamentals of Uncertainty Calculi with Appl. to Fuzzy Inference. Kluwer Academic Publishers, Dordrecht (1995)
23. Grabisch, M., Roubens, M.: An axiomatic approach to the concept of interaction among players in coop. games. Intl. J. of Game Theory 28(4), 547–565 (1999)
24. Marichal, J.L.: Aggregation operators for multicriteria decision aid. Ph.D. Thesis, University of Liège (1998)

25. Marichal, J.L.: The influence of variables on pseudo-Boolean functions with applications to game theory and multicriteria decision making. Discrete Applied Mathematics 107, 139–164 (2000)
26. Marques Pereira, R.A., Bortot, S.: Consensual Dynamics, Stochastic Matrices, Choquet Measures, and Shapley Aggregation. In: Proc. 22nd Linz Seminar on Fuzzy Set Theory: Valued Relations and Capacities in Decision Theory, Linz, pp. 78–80 (2001)
27. Marques Pereira, R.A., Bortot, S.: Choquet measures, Shapley values, and inconsistent pairwise comparison matrices: an extension of Saaty's A.H.P. In: Proc. 25th Linz Seminar on Fuzzy Set Theory: Mathematics of Fuzzy Systems, Linz, pp. 130–135 (2004)
28. Mayag, B., Grabisch, M., Labreuche, C.: A representation of preferences by the Choquet integral with respect to a 2-additive capacity. Theory and Decision 71(3), 297–324 (2011)
29. Mayag, B., Grabisch, M., Labreuche, C.: A characterization of the 2-additive Choquet integral through cardinal information. Fuzzy Sets and Systems 184(1), 84–105 (2011)
30. Miranda, P., Grabisch, M.: Optimization issues for fuzzy measures. Intl. Journal of Uncertainty, Fuzzyness and Knowledge-Based Systems 7(6), 545–560 (1999)
31. Miranda, P., Grabisch, M., Gil, P.: Axiomatic structure of k-additive capacities. Mathematical Social Sciences 49(2), 153–178 (2005)
32. Rota, G.C.: On the foundations of combinatorial theory I. Theory of Möbius functions. Zeitschrift für Wahrscheinlichkeitstheorie und Verwandte Gebeite 2(4), 340–368 (1964)
33. Shapley, L.S.: A value for n-person games. In: Kuhn, H.W., Tucker, A.W. (eds.) Contributions to the Theory of Games. Annals of Mathematics Studies, vol. II, pp. 307–317. Princeton University Press, Princeton (1953)
34. Sugeno, M.: Theory of fuzzy integrals and its applications. Ph.D. Thesis, Tokyo Institut of Technology (1974)
35. Wang, Z., Klir, G.J.: Fuzzy Measure Theory. Springer, Heidelberg (1993)

Spatial Multi Criteria Decision Analysis Based Assessment of Land Value in Abu Dhabi, UAE

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Abstract. Urban and economic development is affected by the value of land. Therefore, land value appraisal methods are important to determine the significance of land segments. A significant number of these models do not apply geospatial analysis in their estimations. This paper presents a land valuation model based on spatial multi criteria decision analysis (SMCA) to assess land values in Abu Dhabi, UAE. Through this study, criteria maps were generated and combined to produce a final map ranking land segments based on their relative value.

Keywords: Spatial Multi Criteria Decision Analysis, GIS, Spatial Analysis, Land Value, UAE.

1 Introduction

Land influences trends of urban and economic development and therefore determining its value is critical for decision makers. Its significance depends on varying physical, economic, and geographic characteristic.

Land value is mainly determined by its production capability and its opportunity cost. Other factors such as associated services, land use, taxation, supply and demand, or policy also affect land worth [1]. Price is one way to value land, but it is usually associated with uncertainties such as interest rates and inflation, and is assessed relative to a certain period of time [2]. Internationally accepted approaches for market valuation include cost, income and sales comparison [3].

As land value changes on the long term can be influenced by several factors such as depreciation, inflation and supply [4], exact market prices are often hard to establish. This is especially true in the case of the UAE, where most of the land is owned by the government. Consequently, in some cases, land prices cannot be estimated as it can be provided for free for certain purposes. In addition, price estimates are not available, and data needed to produce exact prices are not attainable.

Land valuation can be performed using Geographic Information Systems (GIS) to introduce a new dimension to the environmental economic assessment by taking into account the geographical location to produce more accurate results [5].

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In this Analysis, a model is suggested to evaluate the relative value of the land across Abu Dhabi, UAE, based on spatial multi-criteria decision analysis (SMCA). To the best of our Knowledge, the application of SMCA in land valuation has not been done before. Using it in estimating land values would provide an interesting analysis platform especially for countries in which land prices are not attainable.

2 Background

Several economic models that address land valuation exist in the literature. These models are usually complex, and depend on obtaining accurate data (see examples [4, 6, 7]). WH Verheye, 2000 proposed agricultural numerical land valuation techniques based on natural physical parameters [8]. On the other hand, Zhu et al., 2011 estimated the cost of wetland services of Yeyahu wetland nature reserve, using economic valuation methods such as carbon tax, replacement cost, market price, avoid cost, travel cost, and contingent valuation methods [9]. Eade & Moran, 1996 built a spatial economic valuation model to produce maps depicting the environmental economic value of land cells based on natural capital data layers that contained estimated benefit values, which were estimated based on the strength of assets in each cell. The strength was assessed based on identified factors related to the environmental assets, such as biodiversity, quantity of productive vegetation and the presence or absence of each factor among others [5].

Integrating Multi Criteria Decision Analysis (MCDA) with GIS could improve the decision making process especially with problems involving geographical contexts such as land valuation. MCDA is a decision aiding tool that combines information from multiple criteria through a variety of approaches [10, 11]. MCDA encompasses numerous approaches in ranking criteria, weighing and combining them [12]. SMCA implements MCDA in a GIS environment for decision making purposes using spatial data and value judgments [13]. SMCA is usually used in the literature to assess the suitability of land for a particular purpose such as landfill sites, ecological corridors, prawn farming locations, and land use planning and management (see reviews in [14-18].

Geneletti, 2010 used a decision making model which was adapted to planning by Sharifi and Rodrigues, 2002 and Sharrifi and Zucca, 2008 [19, 20] to identify landfill sites using SMCA [17], this model has mainly three stages:

- Intelligence: Relevant objectives and values and associated criteria are identified [19]. This stage may require the involvement of stakeholders or experts in the field [17].
- Design: This stage involves evaluating possible options to achieve the identified objectives, collecting and processing data, and running models [19].
- Choice: Alternatives are compared and ranked [19], and usually a sensitivity analysis is performed [21].

Criteria are usually identified to represent the problem at hand. It can be determined in relatively large numbers to describe the problem explicitly. Alternatively, fewer criteria can be chosen by simplifying the problem. The latter option is frequently used when data availability is a constraint [22]. To be able to capture the essence of a decision problem, criteria and sets of criteria should be selected according to desirable characteristics [23]. A criterion should be comprehensive and measurable, and a set of criteria should be operational (meaningful and useful to the problem), complete, decomposable, minimal and non-redundant. Respectively, each attribute will be represented by a map layer [22].

3 Methodology

3.1 Model Overview

In order to accomplish the stated objectives, a model was adapted from Geneletti's SMCA approach [17]. The model followed these steps:

Phase 1. Intelligence:
- a. Identifying the objective of the model;
- b. Identifying criteria to be used in the evaluation.

Phase 2. Design:
- a. Data preparation;
- b. Creating and combining criteria maps:
  - i. Normalization of scores;
  - ii. Weight assignment to criteria;
  - iii. Aggregation of criteria maps.

Identifying the Objective of the Model

The purpose of the model is to assess the relative value of the land based on spatial multi-criteria decision analysis (SMCA). Consequently, the model aims to rank land segments in Abu Dhabi, UAE based on their relative value, taking into account characteristics affecting it.

Identifying Criteria to be Used in the Evaluation

For the purpose of demonstrating the concept of the proposed model, criteria were determined based on available datasets, which included Abu Dhabi land use/cover and Abu Dhabi road network. Table 1 contains the list of criteria used in the model.

Data Preparation

The land use/cover dataset was obtained from the Environmental Agency-Abu Dhabi (EAD)[1], and the road network dataset was extracted from the OpenStreetMap

[1] `https://www.ead.ae/en/`

initiative (OSM)[2]. The land use/cover dataset contains several classes including rangeland, forestry or wooded Parkland, built-up or industrial Areas, agricultural Area, quarry or mineral exploration, mangrove, racetrack or stable, communication Facility, waste disposal, water resource Area (Fresh/brackish), and cemetery.

Creating and Combining Criteria Maps

To generate the final map, criteria maps were created and then combined by implementing general SMCA steps: factor normalization, weight assignment, and lastly aggregation [22].

Normalization of Scores
Normalization aims to unify criteria for comparison, and it was performed either using linear functions or Boolean allocation. For each defined criterion, a criteria map was created using the raster format. In every map each land cell got a normalized dimensionless value within a 0-1 range, according to its defined end points.

End points were set to be able to evaluate every land cell relative to each criterion. End points can be measured qualitatively or quantitatively [22], and they were either based on distance (m) where land cells were evaluated based on their distance from the respective criteria, or Boolean scales.

Using the example of the “distance to roads” attribute, where the identified end points’ values are 300-1000m, locations within 300m away from the road will be taking a normalized score of one, and locations that are is further than 1000m from the road will take a normalized score of zero. All other locations will be normalized according to a linear interpolation between the endpoints. On the other hand, “Rangeland” is an attribute that is measured on a Boolean scale. Accordingly, if the location is a rangeland it will get a normalized score of one; otherwise will get a score of zero. Table 1 shows end points and normalization logic for each criterion.

Weight Assignment to Criteria
Weights reflecting the importance of datasets as a whole and each criterion within them in the final map were allocated, as referred in Table 1. For example, the “Distance to built-up or industrial areas” was assigned the largest weight of 0.3, as it reflected, in our opinion, how important this attribute is for the value of land.

Aggregation of Criteria Maps
Criteria maps were aggregated at two levels to produce the final map. At the first level, criteria maps that were produced for each criterion were combined within each dataset. At the second level, the resultant maps at level one were aggregated to generate the final map.

To combine criteria maps at each level, the value for each land cell was calculated by weight summation, which was preferred for the sake of simplicity. The value of a cell was calculated according to equation 1 and 2:

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[2] `http://www.openstreetmap.org/#map=5/51.500/-0.100`

$$V_j = \sum_j^n \sum_{i=1}^n w_i x_{ij} \quad (1)$$

$$\text{Where } \sum_i^n w_i = 1 \quad (2)$$

Where V_j is the relative value of the land cell j, w_i is the weight assigned to the factor i (criterion or dataset), x_{ij} is the normalized value of cell j according to factor i.

Table 1. Attributes used in producing the final land value map, alongside with their endpoints, normalization, and weights

<table>
<tr><th>Attribute</th><th>Dataset</th><th>Endpoints</th><th>Normalization</th><th>Weights (Level 1)</th><th>Weights (Level 2)</th></tr>
<tr><td>Rangeland [Boolean]</td><td>Land use/cover</td><td>Applicable/Not applicable</td><td>0,1</td><td>0.1</td><td rowspan="11">0.8</td></tr>
<tr><td>Distance to forestry or wooded park-land [m]</td><td>Land use/cover</td><td>0-1000</td><td><0 =1, linear 0-1000, >1000=0</td><td>0.1</td></tr>
<tr><td>Distance to built-up or industrial areas [m]</td><td>Land use/cover</td><td>0-1000</td><td><0 =1, linear 0-1000, >1000=0</td><td>0.3</td></tr>
<tr><td>Distance to agricultural area [m]</td><td>Land use/cover</td><td>0-2000</td><td><0 =1, linear 0-2000, >2000=0</td><td>0.1</td></tr>
<tr><td>Distance to quarry or mineral exploration [m]</td><td>Land use/cover</td><td>0-1000</td><td><0 =1, linear 0-1000, >1000=0</td><td>0.05</td></tr>
<tr><td>Mangrove [Boolean]</td><td>Land use/cover</td><td>Applicable/Not applicable</td><td>0,1</td><td>0.05</td></tr>
<tr><td>Racetrack or stable [Boolean]</td><td>Land use/cover</td><td>Applicable/Not applicable</td><td>0,1</td><td>0.05</td></tr>
<tr><td>Communication facility [Boolean]</td><td>Land use/cover</td><td>Applicable/Not applicable</td><td>0,1</td><td>0.05</td></tr>
<tr><td>Distance to waste disposal [m]</td><td>Land use/cover</td><td>0-5000</td><td><5000=0, >5000=1</td><td>0.05</td></tr>
<tr><td>Distance to water resource area (Fresh/brackish)</td><td>Land use/cover</td><td>200-1000</td><td>< 200=1, >1000 =0, linear 200-1000</td><td>0.1</td></tr>
<tr><td>Cemetery [Boolean]</td><td>Land use/cover</td><td>Applicable/Not applicable</td><td>0,1</td><td>0.05</td></tr>
<tr><td>Distance to roads [m]</td><td>Road network</td><td>300-1000</td><td><300=1, linear 300-1000, >1000 =0</td><td>1</td><td>0.2</td></tr>
</table>

3.2 Model Limitations

One of the limitations of the model is related to data availability constraints. Other relevant criteria would have contributed to a more accurate model if the geospatial data sets were available. In addition, inability to access relevant stakeholders for the identification of criteria, end points and weights, pose another constraint as engaging stakeholders would improve the results.

4 Preliminary Results

To process the spatial data, criteria maps were treated according to the model described in the previous sections. Map layers were then combined in a final map, where relative values for each cell were calculated. As a last step, protected areas were excluded from the resultant map, as they represent a special case of land valuation that would not be captured in this model.

Fig. 1 represents the resultant map after running the model. The map represents the relative value of land segments within Abu Dhabi, UAE. Values are assigned to each cell, they range from 0-0.68, and are differentiated by a grey color scale. It can be noticed that the highest scoring areas are within the industrial or built up areas or close to roads. This could be attributed to the high weights assigned to the respective criteria. Since rangeland accounts for approximately 92% of the total area of the emirate, it can be noticed from the resultant map that most of the locations take low values.

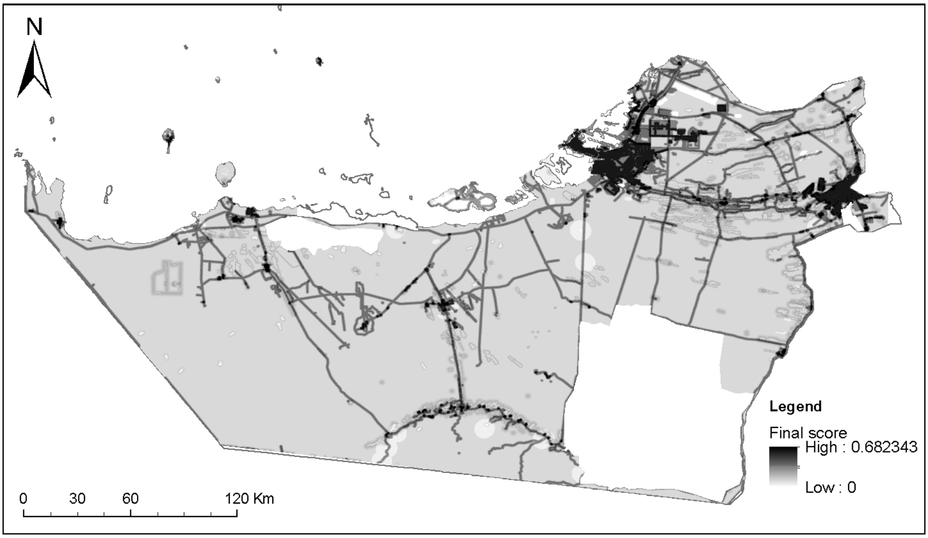

Fig. 1. Final map representing rankings of land value in Abu Dhabi, UAE

5 Conclusion

This study proposed a model, based on SMCA, for land valuation in the UAE. It allows assessing land value across a spatial boundary and displaying the relative value of predefined land cells. In this analysis, a map displaying relative values of land cells in Abu Dhabi, UAE was produced based on identified criteria.

The developed model provides a conceptual framework for land valuation that does not change rapidly over time. This Model could be used by potential policymakers and investors as a decision aiding tool to assess different land choices when evaluating projects and policies. Specifically, in the case of the UAE, this tool could be also used to account for the opportunity cost in projects in which the government is involved in, and the land is provided for free.

The model lays out foundation for further development, by involving potential stakeholders to increase the results accuracy, and conducting a sensitivity analysis to test the variation of the weights in the final outcome. Through collective brainstorming sessions and/or individual surveys, relevant stakeholders from the governmental and private sector such as Abu Dhabi Urban Planning Council and real estate agents, would be invited to provide their insights about the criteria that should be considered, and how to set their end points and respective weights.

Also, advanced weighing methods could be utilized such as pairwise comparison in which weights of criteria are derived by assessing the relative importance of each criterion in comparison with the rest of the criteria. Moreover, the model could be validated and calibrated against actual market prices.

References

1. FAO: Overview of land value conditions. Land and water development division, Rome (2003)
2. Verheye, W.: The Value and Price of Land. UNESCO-EOLSS Publishers, Oxford (2007)
3. Saskatchewan Assessment Management Agency: The Assessment System in Saskatchewan – An Overview (A Resource for Boards of Revision for 2013). Saskatchewan Ministry of Government Relations, Saskatchewan (2012)
4. Liu, Y., Zheng, B., Huang, L., Tang, X.: Urban residential land value analysis: Case Danyang, China. Geo-spatial Information Science, 228–234 (2007)
5. Eade, J., Moran, D.: Spatial economic valuation: benefits transfer using geographical information systems. Journal of Environmental Management, 97–110 (1996)
6. Chabala, L.M., Kuntashula, E., Hamukwala, P., Chishala, B.H., Phiri, E.: Assessing the Value of Land and Costs of Land Degradation in Zambia first draft report. The University of Zambia (2012)
7. Rossiter, D.G.: A theoretical framework for land evaluation. Geoderma. 165–190 (1996)
8. Verheye, W.: Use of land evaluation techniques to assess the market value of agricultural land. Agropedology. 88–100 (2000)
9. Zhu, L., Chen, Y., Gong, H., Jiang, W., Zhao, W., Xiao, Y.: Economic value evaluation of wetland service in Yeyahu Wetland Nature Reserve. Chinese Geographical Science, 744–752 (2011)

10. Belton, V., Stewart, T.: Multiple criteria decision analysis: an integrated approach. Springer (2002)
11. Chen, Y., Yu, J., Khan, S.: Spatial sensitivity analysis of multi-criteria weights in GIS-based land suitability evaluation. Environmental Modelling & Software, 1582–1591 (2010)
12. Figueira, J., Greco, S., Ehrgott, M.: Multiple criteria decision analysis: state of the art surveys. Springer (2005)
13. Malczewski, J.: GIS ‐ based multicriteria decision analysis: a survey of the literature. International Journal of Geographical Information Science, 703–726 (2006)
14. Ferretti, V., Pomarico, S.: An integrated approach for studying the land suitability for ecological corridors through spatial multicriteria evaluations. Environment, Development and Sustainability, 1–27 (2012)
15. Fitzsimons, J., Pearson, C.J., Lawson, C., Hill, M.J.: Evaluation of land-use planning in greenbelts based on intrinsic characteristics and stakeholder values. Landscape and Urban Planning. 23–34 (2012)
16. Hossain, M.S., Das, N.G.: GIS-based multi-criteria evaluation to land suitability modelling for giant prawn farming in Companigonj Upazila of Noakhali. Computers and Electronics in Agriculture, 172–186 (2010)
17. Geneletti, D.: Combining stakeholder analysis and spatial multicriteria evaluation to select and rank inert landfill sites. Waste Management, 328–337 (2010)
18. Liu, Y., Lv, X., Qin, X., Guo, H., Yu, Y., Wang, J., Mao, G.: An integrated GIS-based analysis system for land-use management of lake areas in urban fringe. Landscape and Urban Planning, 233–246 (2007)
19. Sharifi, A., Rodriguez, E.: Design and development of a planning support system for policy formulation in water resources rehabilitation: the case of Alcazar De San Juan District in Aquifer 23. Journal of Hydroinformatics, 157–175 (2002)
20. Sharifi, M., Zucca, A.: Integrated planning and decision support systems: concepts and application to a site selection problem. Spatial Decision Support for Urban and Environmental Planning, pp. 5–31. Arah Publications, Kuala Lumpur (2008)
21. Geneletti, D., Beinat, E., Chung, C., Fabbri, A., Scholten, H.: Accounting for uncertainty factors in biodiversity impact assessment: lessons from a case study. Environmental Impact Assessment Review, 471–487 (2003)
22. Malczewski, J.: GIS and multicriteria decision analysis. John Wiley & Sons (1999)
23. Keeney, R.L., Raiffa, H.: Decisions with multiple objectives: preferences and value trade-offs. Cambridge University Press (1993)

Rank Ordering Methods for Multi-criteria Decisions

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Abstract. Criteria weights are typically cognitively demanding to elicit and numeric precision is problematic since information in real-life multi-criteria decision making often is imprecise. One important class of methods rank the criteria and receive a criteria ordering which can be handled in various ways by, e.g., converting the resulting ranking into numerical weights, so called surrogate weights. In this article, we analyse the relevance of these methods and to what extent some validation processes are strongly dependent on the simulation assumptions. We also suggest more robust methods as candidates for modelling and analysing multi-criteria decision problems of this kind.

Keywords: Multi-criteria decision analysis, Criteria weights, Criteria ranking, Rank order.

1 Introduction

Methods attempting to elicit precise criteria weights range from direct rating (DR) and point allocation (PA) methods to more elaborated ones, but when it comes to providing reasonable weights, we have significant difficulties due to the fact that we do not seem to have the required granulation capacity and we also suffer from other deficiencies. To somewhat facilitate eliciting weights from decision-makers, some of the approaches utilise ordinal or imprecise importance information to determine criteria weights and sometimes values of alternatives.[1]

[1] introduced a process utilising systematic simulations. The basic idea is to generate surrogate weights as well as "true" reference weights from some underlying distribution and investigate how well the result of using surrogate numbers match the result of using the "true" results. The idea in itself is good, but the methodology is vulnerable since the validation result is heavily dependent on the distribution used for generating the weight vectors. This article discusses some important aspects and shortcomings of some popular weight methods as well as the validation techniques for these. We also discuss the relevance and correctness of some common measurements for method validation and conclude with a discussion of more robust methods that might be better candidates.

[1] Other approaches use intervals to express uncertainty inherent in elicitation procedures, e.g., [2,3].

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2 Rank Ordering Methods

Different elicitation formalisms have been proposed by which the decision-maker can express preferences. Such a formalism is sometimes based on scoring points, as in point allocation (PA) or direct rating (DR) methods. In PA, the decision-maker is given a point sum, e.g. 100, to distribute among the criteria. Sometimes, it is pictured as putty with the total mass of 100 that is divided and put on the criteria. The more mass, the larger weight on a criterion. In PA, there are consequently $N-1$ degrees of freedom (DoF) for N criteria. DR, on the other hand, puts no limit to the number of points to be allocated. The decision-maker allocates as many points as desired to each criterion. The points are subsequently normalized by dividing by the sum of points allocated. Thus, in DR, there are N degrees of freedom for N criteria.

In [4], there is a discussion on weight approximation techniques which brings the suggestions of rank sum (RS) weights and rank reciprocal (RR) weights. They are suggested in the context of maximum discrimination power, and are both alternatives to ratio based weight schemes. The rank sum is based on the idea that the rank order should be reflected directly in the weight. Assume a simplex S_w generated by $w_1 > w_2 > \ldots > w_N$, where $\Sigma w_i = 1$ and $0 \leq w_i$.[2] Assign an ordinal number to each item ranked, starting with the highest ranked item as number 1. Denote the ranking number i among N items to rank. Then the RS weight becomes for all $i = 1,\ldots,N$

$$w_i^{\mathrm{RS}} = \frac{N + 1 - i}{\sum_{j=1}^{N}(N + 1 - j)} = \frac{2(N + 1 - i)}{N(N + 1)}$$

Another idea discussed is rank reciprocal weights. They have a similar origin as the RS weights, but are based on the reciprocals (inverted numbers) of the rank order for each item ranked. These are obtained by assigning an ordinal number to each item ranked, starting with the highest ranked item as number 1. Then denote the ranking number i among N items to rank and the rank reciprocal (RR) weight becomes

$$w_i^{\mathrm{RR}} = \frac{1/i}{\sum_{j=1}^{N}\frac{1}{j}}$$

A decade later, [5] suggested a weight method based on vertices of the simplex of the feasible weight space. To use the rank order, the ROC (rank order centroid) weights are calculated. These are the centroid components of the simplex S_w. The weights then become the centroid (mass point) components of S_w. The ROC weights are then, for the ranking number i among N items to rank, given by

$$w_i^{\mathrm{ROC}} = 1/N \sum_{j=i}^{N}\frac{1}{j}$$

In this way, it resembles RR more than RS but is, particularly for lower dimensions, more extreme than both in the sense of weight distribution, especially the largest and smallest weights.

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[2] We will, unless otherwise stated, presume that decision problems are modelled as simplexes S_w.

2.1 A Combined Method

Since these weight models in a sense are opposites, it interesting to see how extreme behaviours can be reduced. A natural candidate for this could be a linear combination of RS and RR. Since we have no reasons to assume anything else, we suggest balancing them equally in an additive combination of the Sum and the Reciprocal weight function that we will call the SR weight method:

$$\mathrm{w}_{\mathrm{i}}^{\mathrm{SR}} = \frac{1/i + \frac{N+1-i}{N}}{\sum_{j=1}^{N}\left(1/j + \frac{N+1-j}{N}\right)}$$

Of course, other combinations of weights would be possible, but the important results of the paper are obtained using SR and comparing it with others weight functions. For another candidate, the actual mix of the proportions between the methods would affect the results in accordance with its proportions. As will be shown below, all results are sensitive to the underlying assumptions regarding the mind-sets of decision-makers. The SR method is a representative of a class of methods able to handle varying assumptions on decision- maker behaviour.

2.2 Geometric Weights

Geometric weights are based on the idea that the rank order should be reflected multiplicatively in the numeric weights. The multiplicative nature of the geometric weight can be motivated by the likewise multiplicative nature of the terms $w_i^X v_i(a)$ that the overall value $V^X(a) = \sum_{i=1}^{m} w_i^X v_i(a)$, that an alternative a is evaluated by, consist of. Assign an ordinal number to each item ranked, starting with the highest ranked item as number 1. Denote the ranking number *i* among *N* items to rank. Then the geometric sum (GS) weight becomes

$$w_i^{\mathrm{GS}}(\mathrm{s}) = \frac{s^{i-1}}{\sum_{j=1}^{N} s^{j-1}} \quad \text{for } 0 < s < 1$$

As usual, a larger weight is assigned to lower ranking numbers. Similar to some other suggested weight methods, GS contains a parameter *s*.

3 Assessing Models for Surrogate Weights

The underlying assumption of most de facto standard simulation studies is that there exist weights in the decision-maker's mind which are inaccessible by any elicitation method. We will continue this tradition when determining the efficacy, in this sense, of some ranking approaches below. The modelling assumptions regarding decision-makers above are then inherent in the generation of decision problem vectors by a random generator. Thus, following an *N*–1 DoF model, a vector is generated in which the components sum to 100%, i.e., a process with *N*–1 degrees of freedom. Following an *N* DoF model, a vector is generated keeping components within [0%, 100%] and subsequently normalising, i.e., a process with N degrees of freedom. Other distributions modelling actual decision-makers would of course be possible, and could be elicited in one way or another. The important observation is that the validation methods are highly dependent of the model of decision-makers and this produces significant effects on the reliability of the validations.

3.1 Simulation Studies

Thus, in the simulations described below it is important to realize which background model we utilise. As stated above, when following an N–1 DoF model, a vector is generated in which the components sum to 100%. This simulation is based on a homogenous N-variate Dirichlet distribution generator. On the other hand, following an N DoF model, a vector is generated without an initial joint restriction, only keeping components within [0%, 100%] yielding a process with N degrees of freedom. Subsequently, they are normalised so that their sum is 100%. We will call the N–1 DoF model type of generator an *N–1-generator* and the N DoF model type an *N-generator*.

3.2 Comparing the Methods

An N–1 DoF model presents a computer simulation consisting of four steps, assuming the problem is modelled as the simplex S_w.

Generation Procedure

1. For an N-dimensional problem, generate a random weight vector with N components. This is called the TRUE weight vector. Determine the order between the weights in the vector. For each method X' ∈ {ROC,RS,RR,EW}, use the order to generate a weight vector $w^{X'}$.
2. Given M alternatives, generate $M \times N$ random values with value v_{ij} belonging to alternative j under criterion i.
3. Let w_i^X be the weight from weighting method X for criterion i. For each method X ∈ {TRUE,ROC,RS,RR,EW}, calculate $V_j^X = \sum_i w_i^X v_{ij}$. Each method produces a preferred alternative, i.e. the one with the highest V_j^X.
4. For each method X' ∈ {ROC,RS,RR,EW}, assess whether X' yielded the same decision (i.e. the same preferred alternative) as TRUE. If so, record a hit.

It should be noted that most simulation studies to date arrive at the same conclusions regarding ROC, RS, and RR. As we have emphasised above, this is not surprising since different simulations using the same assumptions on degrees of freedom and definitions of weighting methods should (modulo programming errors) yield the same results. A study by [6], though, came up with a different result where RS performed better than ROC with RR in third place. Their paper also suggests a new surrogate weight, ROD, which generates almost identical weights to RS and, thus, performs almost identically. For our purposes, we will consider the latter two equal and will not discuss ROD separately. The random weight distribution in most other simulations (in step 1 of the generation procedure above) is generated by an *N*–1 procedure, thus generating a vector with *N*–1 DoF. Roberts and Goodwin, however, employ a different distribution generating function where a fixed number, say 100, is given to the most important criterion and the others are uniformly generated as U[0,100]. As explained above, this *N*-generator is not the same as *N*–1-generators based on a Dirichlet distribution and thus, their simulation study instead yields the result that RS outperforms ROC with RR in third place. Given an *N*-generator, RS outperforms ROC and RR with EW far behind. ROC is slightly better than RR. While yielding a different "best" weighting method, this result is consistent with the other study results considering it is merely a consequence of choice of DoF in the simulator generator.

Our simulations were carried out with a varying number of criteria and alternatives. There were four numbers of criteria $N = \{3, 6, 9, 12\}$ and five numbers of alternatives $M = \{3, 6, 9, 12, 15\}$ creating a total of 20 simulation scenarios. Each scenario was run 10 times, each time with 10,000 trials, yielding a total of 2,000,000 decision situations generated. For this simulation, an *N*-variate joint Dirichlet distribution was employed to generate the random weight vectors for the *N*–1 DoF simulations and a standard round-robin normalised random weight generator for the *N* DoF simulations. Unscaled value vectors were generated uniformly, and no significant differences were observed with other value distributions. The results of the simulations are shown in the tables below, where we show a subset of the results with chosen pairs (*N*,*M*). The tables show the winner frequency for the six methods ROC, RR, RS, GS, SR, and EW (equal weights) utilising the simulation methods *N*–1 DoF, *N* DoF and a 50% combination of *N*–1 DoF and *N* DoF. All hit ratios in all tables are given in per cent and are mean values of the 10 scenario runs.[3] In Table 1, using an *N*–1-generator, it can be seen that ROC outperforms the others, when looking at the winner, but with GS and SR close behind. RR is better than RS behind the others. In Table 2, the frequencies have changed according to expectation since we employ a model with *N* degrees of freedom. Now RS outperforms all others. SR and GS are close behind while ROC and RR are far behind. In Table 3, the *N* and *N*–1 DoF models are combined with equal emphasis on both. Now, we can see that in total RS, SR, and GS generally perform the best.

Table 1. Using an *N*–1-generator

N–1 DoF	Winner	ROC	RS	RR	GS	SR
3 criteria	3 alternatives	90.2	88.2	89.5	90.0	89.3
3 criteria	15 alternatives	79.1	76.6	76.5	78.2	76.9
6 criteria	6 alternatives	84.8	79.9	82.7	83.9	83.1
6 criteria	12 alternatives	81.3	75.6	78.2	80.0	78.9
9 criteria	9 alternatives	83.5	75.6	79.5	82.0	81.2
12 criteria	6 alternatives	86.4	77.8	80.8	84.8	84.1
12 criteria	12 alternatives	83.4	72.9	76.8	81.4	80.2

[3] The standard deviations between sets of 10 runs were around 0.1-0.3 percent.

Table 2. A model with *N* degrees of freedom

***N* DoF**	**Winner**	**ROC**	**RS**	**RR**	**GS**	**SR**
3 criteria	3 alternatives	87.3	89.3	88.3	88.6	89.1
3 criteria	15 alternatives	77.9	81.1	79.1	80.1	80.6
6 criteria	6 alternatives	80.1	87.3	78.1	84.3	85.1
6 criteria	12 alternatives	76.4	84.3	74.3	81.0	82.0
9 criteria	9 alternatives	76.3	87.2	69.8	82.2	83.0
12 criteria	6 alternatives	77.5	90.3	67.8	84.5	84.6
12 criteria	12 alternatives	73.4	87.6	63.1	80.8	81.7

Table 3. *N* and *N*–1 DoF models are combined

Combined	**Winner**	**ROC**	**RS**	**RR**	**GS**	**SR**
3 criteria	3 alternatives	88.8	88.8	88.9	89.3	89.2
3 criteria	15 alternatives	78.5	78.9	77.8	79.2	78.8
6 criteria	6 alternatives	82.5	83.6	80.4	84.1	84.1
6 criteria	12 alternatives	78.9	80.0	76.3	80.5	80.5
9 criteria	9 alternatives	79.9	81.4	74.7	82.1	82.1
12 criteria	6 alternatives	82.0	84.1	74.3	84.7	84.4
12 criteria	12 alternatives	78.4	80.3	70.0	81.1	81.0

3.3 Introducing Noise

In the above simulations, rankings are induced from the "true" weights. But this assumes that the decision-maker is perfect in converting its belief into orderings, i.e. that the elicitation is perfect. This assumption can at least partly be taken account of by slightly altering the generated "true" weights before the order is generated. For instance, a 10% noise in this sense means that after a generation of a "true" weight vector in step 1 in the generation procedure, the weights are multiplied by a uniformly distributed random factor between 0.9 and 1.1 for the generation of the ranking order (not for the "true" test). By this approach, the size of the change also depends on the true weights. Attributes which have a large true weight will be changed more than attributes which have a small true weight. This in turn will introduce more errors in the important attributes. The generated order in a way simulates that the decision-maker can be uncertain regarding the weight ordering. A measure of robustness can then be that the less affected the method is by this disturbance, the more robust it is.

Table 4. Introducing noise

Combined	**Noise**	**ROC**	**RS**	**RR**	**GS**	**SR**
9 criteria and	0%	79.9	81.4	74.7	82.1	82.1
9 alternatives	10%	79.0	80.7	73.9	81.6	81.5
	20%	78.2	79.8	73.0	80.4	80.3
	30%	76.9	79.0	72.5	79.0	78.8

From Table 4 it can be seen that the behaviour of the respective methods are similar and the hit percentage naturally decreases when the amount of noise increases. Nevertheless, all five methods are quite robust in this sense, even at 30% noise level.

3.4 Discarding Unnatural Decision Situations

It can be argued that the vectors generated by the simulations do not always constitute natural decision problems. For instance, the simulator could generate a weight vector with one component as high as 0.95 and the others correspondingly low. Likewise, the simulator could generate a problem with a weight as low as 0.0001 and such a criterion would probably not be considered at all in real life. Therefore, a filter was designed to discard weight vectors deemed unnatural. Below, we can see the effect of cut-off filters on the simulation results. We used two filters. The weak filter discarded all generated "true" vectors with a component larger than $0.7 + 0.3/N$ or smaller than $0.05/N$. The strong filter discarded all generated "true" vectors with a component larger than $0.6 + 0.25/N$ or smaller than $0.1/N$. If a vector was discarded, a new vector was generated assuring that the total number of vectors remained constant in each simulation. Table 5, Table 6 and Table 7 show the results from applying the weak and strong cut-off filters to three selected decision simulations.

Table 5. Filter with 3 criteria and 3 alternatives

Combined	Cut-off	ROC	RS	RR	GS	SR
3 criteria and	None	88.8	88.8	88.9	89.3	89.2
3 alternatives	Weak	88.5	89.6	89.3	89.5	89.8
	Strong	88.3	90.3	89.4	89.7	90.2

Table 6. Filter with 6 criteria and 12 alternatives

Combined	Cut-off	ROC	RS	RR	GS	SR
6 criteria and	None	78.9	80.0	76.3	80.5	80.5
12 alternatives	Weak	78.8	80.9	76.7	81.3	81.6
	Strong	78.6	82.3	76.8	81.7	82.4

Table 7. Filter with 9 criteria and 9 alternatives

Combined	Cut-off	ROC	RS	RR	GS	SR
9 criteria and	None	79.9	81.4	74.7	82.1	82.1
9 alternatives	Weak	79.9	82.8	75.1	83.0	82.7
	Strong	79.8	83.5	75.4	83.5	83.3

From the tables, it can be seen that most methods improve when faced only with "reasonable" decision situations, the improvement being between 1% and 2%. SR and RS improved the most, with GS and RR less so. The exception is ROC which does not improve at all, rather the hit rate diminishes slightly as extreme decision vectors are cut off.

4 Conclusion

The aim of this study has been to find robust multi-criteria weights that would be able to cover a broad set of decision situations, but at the same time have a reasonably simple semantic regarding how they are generated. To summarise the analysis, we look at the average hit rate in per cent over all the pairs (*N*,*M*) that we have reported in the tables above. From the table, it is clear that, considering performance averages, GS and SR are the best candidates when it comes to finding the winning alternative, closely followed by RS. The other surrogate weighs are not in contention. For example, the ROC method relies too heavily on the assumption of decision-makers having an internal decision process with *N*–1 degrees of freedom for a decision problem with *N* criteria. Further, the three methods RS, GS, and SR all handle both noise and "unnatural" decision situations equally well. In conclusion, to be robust a rank ordering method should fare well under the varying assumptions. We have above discussed various aspects of performance and it can be seen that the GS and SR methods are the most efficient and robust surrogate weighs that both perform very good on average and are stable under varying assumptions on the behaviour of the decision-maker. Of the two, GS performs a little bit better but is more complex since it requires a parameter to be selected. As simplicity could be regarded an additional sign of robustness, we conclude that GS and SR are equally robust and better choices for surrogate weight functions than the other candidates in the paper.

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References

1. Barron, F., Barrett, B.: Decision Quality Using Ranked Attribute Weights. Management Science 42(11), 1515–1523 (1996)
2. Danielson, M.: Generalized Evaluation in Decision Analysis. European Journal of Operational Research 162(2), 442–449 (2005)
3. Danielson, M., Ekenberg, L.: A Framework for Analysing Decisions under Risk. European Journal of Operational Research 104(3), 474–484 (1998)
4. Stillwell, W., Seaver, D., Edwards, W.: A Comparison of Weight Approximation Techniques in Multiattribute Utility Decision Making. Organizational Behavior and Human Performance 28(1), 62–77 (1981)
5. Barron, F.H.: Selecting a Best Multiattribute Alternative with Partial Information About Attribute Weights. Acta Psychologica 80(1-3), 91–103 (1992)
6. Roberts, R., Goodwin, P.: Weight Approximations in Multi–attribute Decision Models. J. of Multi–Criteria Decision Analysis 11, 291–303 (2002)

Defining Preferences and Reference Points – A Multiple Criteria Decision Making Experiment

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Abstract. In this paper we study how do the decision makers proceed in analyzing the multiple criteria decision making (MCDM) problem. Based on the results of the questionnaire-based experiment, we investigate how do they define the reference points in the decision problem and specify their preferences. We also study what kind of problems do they encounter while analyzing such a multiple criteria decision making problem. Finally, we consider what MCDM methods could be used to fit the decision makers way of analyzing the preferences and conducting the decision process.

Keywords: multiple criteria decision making, preference analysis, linguistic scales, reference points.

1 Introduction

In the multiple criteria decision problems the decision makers (DMs) need to take into consideration many and usually conflicting criteria, which makes the whole decision process complicated and time-consuming. Therefore a variety of multiple criteria decision making (MCDM) methods were proposed to support DMs in analyzing their preferences and building the ranking of alternatives or sorting them into the predefined categories. These methods differ in both the formal construction and the approaches to the elicitation of the DM's preferences. They may use the notion of a unique synthesizing criterion [9;16], the outranking relations [2;15], the direct assignments of rates or scores [9] or the pair-wise comparisons expressed by means of the linguistic scales [16]. They may also apply the concept of reference points [7;11], the fuzzy relations [8] or verbal judgments [3;12]. Some guidelines may be found that help the DMs selecting the most adequate MCDM method depending on decision situation or preferable preference articulation mode [5] and a number of research confirms the applicability of various MCDM methods for solving real-world problems [18]. In this paper, however, we try to experimentally investigate how do the DMs proceed in analyzing the MCDM problems. In particular we aim to find what

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are the levels of measurement and types of scales most frequently used by DM to describe their preferences; how precisely do they define a feasible decision space (e.g. frames, reference points) and what kind of the problems they experience during the decision process. It could help us to identify the issues that may require decision support and which of the MCDM methods may be of use in providing such a support to DMs. This experiment is a part of a bigger project on supporting the multi-issue negotiations, in which the negotiators face the problem similar to the classic MCDM one (they need to design and score a negotiation template [13]). Therefore while analyzing the results we will refer to the negotiation situation and possible consequences that may affect the process of negotiation analysis.

The paper consists of three more sections. In section 2 we describe the decision making experiment, as well as the case we used, the participants and the questionnaire the participants were asked to fill in. Then, in section 3 we present the descriptive statistics of the experiment and the major results we obtained. Finally, in section 4 we discuss and comment on the results.

2 Experimental Setup

We designed our experiment as a questionnaire-based survey that employed a predefined MCDM problem of choosing a flat to rent. The participants of the experiment were 109 undergraduate, graduate and PhD students of four Polish universities, from different fields of study: computer science, international business and econo-physics. They were faced with the decision problem with four alternatives described by means of four criteria of different type and complexity, such as a purely quantitative (*rental cost*), qualitative (*fittings*), and fuzzy one (*commuting time*) and also by a mixed meta-criterion (*size*). The problem was presented to the participants in a form of a decision matrix (Table 1).

Table 1. The list of alternatives to evaluate

Alternative	*Rental cost (PLN)*	*Size (rooms and floorage)*	*Fittings*	*Commuting time (minutes)*
A	1200	2 rooms (one with a kitchenette), 35 m2	fridge, microwave, washing machine	10-12 min.
B	950	3 rooms (living room with a kitchenette), 54 m2	fridge, dish washer, washing machine, internet access	approx. 30 min.
C	900	2 rooms + kitchen, 35m2	fridge, washing machine, internet access (cable)	approx. 20 min.
D	700	1 room + kitchen, 25 m2	fridge, washing machine, TV set, cable TV, internet access (cable)	approx. 30 min.

According to the problem description the participants had to evaluate the alternatives, build the ranking and give a convincing reasoning on their decision, since they were told they decide on behalf of themselves and their colleague, who is going to share the flat with them. To learn on the decision process and the DM’s way of expressing his preferences we formulated eleven questions to answer. For the purpose of this paper we analyzed the following three of them:

1. If you were asked to formulate short evaluation of the alternatives, how would you presented your preferences over them?
2. Having read and analyzed the problem, how would you specify the ideal (most preferable) and the anti-ideal (least preferable) flat-hiring alternative?
3. What kind of problems did you encounter while comparing the offers?

All the questions in the questionnaire were designed as the open questions to avoid imposing on the respondents the predefined set of answers and to enforce them to elaborate their own comprehensive descriptions.

3 Results

3.1 The Ways of Describing the Preferences

First we have verified how did the participants define their preferences over the alternatives, to identify the most commonly used scales and the ways of verbalizing their priorities. Having analyzed the responses for question number 1 we identified five main categories of defining the global evaluation of alternatives (Fig. 1) that correspond to the typical levels of measurement [4]:

1. **Descriptive** – a verbal description of an alternative exposing its selected features without references to any grade or ranking, e.g. “expensive, but close to the university”, “good fittings and relatively cheap”; or allowing for building a partial order of the alternatives, e.g. “A – too expensive”, “B – quite interesting”, “C – an exquisite offer”, “D – too few rooms”.
2. **Linguistic** – a verbal categories with a clearly defined and intuitively interpreted gradation, using such terms as ”very good”, “outstanding”, “best” etc.
3. **Ordinal** – a numeric scale based on simple school grading, using the grades from the ranges $\langle 1;6 \rangle$ or $\langle 2;5 \rangle$.
4. **Interval** – a numeric scale with a subjectively defined range suggesting the meaningfulness of the differences in grades, e.g. using the ranges $\langle 0;10 \rangle$ or $\langle 0;100 \rangle$.
5. **Pictorial** – using a pictograms (e.g. stars) to evaluate and define a ranking or quality of the alternatives, e.g. A - ☆☆☆, B - ☆☆☆☆☆, C - ☆☆☆☆, D - ☆.

Out of 106 participants who answer this question, 100 (94%) used a single system of evaluation, while the remaining 6 respondents combined two of them, e.g. they used both the descriptive and numerical scale: “A – too expensive (2/5), B – good for many flat mates (3/5), etc. What is interesting, that 53% of the evaluations was done in a non-numerical way (linguistic and descriptive), while only 37% of respondents used the quantitative evaluations. Only four respondents used a pictorial description, which may be surprising, for our participants are young people who browse through the web daily and come across with similar systems of evaluation in very many websites (e.g. Amazon, eBay etc.). It is also interesting that a particularly high percentage of students from econo-physics (67%) and computer science (63%)

expressed their preferences in qualitative way (scales no. 1, 2 and 5), while the profile of their studies are rather formal and contains many courses related to mathematics and decision making. The question that still needs to be answered is: are the DMs perceptually unable or simply do not feel the need to use more sophisticated numerical scales?

Scale	*Group of students*				
	PhD	*Econo -physics*	*Comp. science*	*Internat. Business*	*Total*
Descriptive	4	7	15	4	30
Linguistic	1	1	5	20	27
Ordinal	5	1	7	9	22
Interval		1	6	10	17
Pictorial			2	2	4
Combined scale		2		4	6
Total	10	12	35	50	106

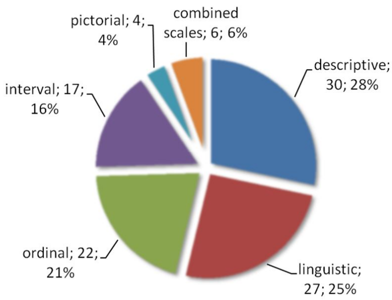


Fig. 1. The scales used in defining the evaluation of the alternatives

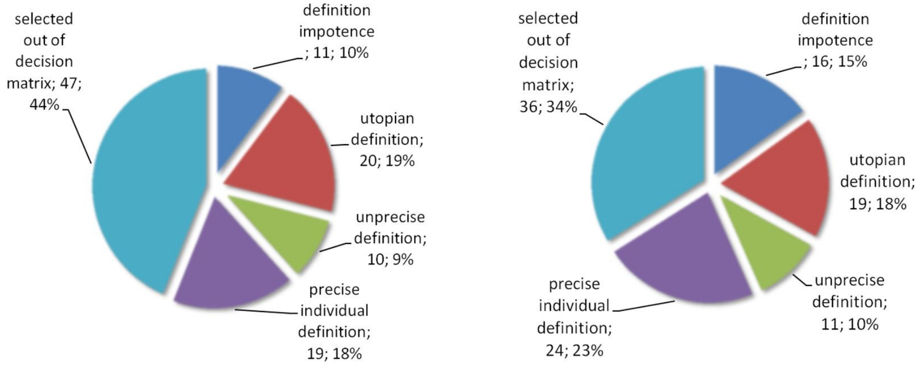
Finally, if we look at these results from the viewpoint of the negotiation analysis and the potential negotiators that have to be supported in designing and scoring the negotiation template, the conclusions are dramatic. Adding up all the participants that declared their preferences qualitatively (57%) and the ones that used a weak ordinal scale (21%) we obtain 78% of the respondents who operate with the preference systems that cannot be used in negotiation analysis such as measuring the scales of concessions, drawing the negotiation history and dance graphs or conducting a fair solution analysis.

3.2 Defining the Reference Points

Some MCDM methods apply the notions of reference points [7;11], which are helpful in defining a feasible decision space and constructing a scoring system for the evaluation of the alternatives. Such reference points are also defined in negotiations in a form of BATNA, aspiration and reservation levels [13]. Therefore in our experiment we have analyzed the way the respondents define the ideal and anti-ideal solutions as the frames for their decisions. Stemming from the descriptions provided in the questionnaires the five main categories of definition may be identified (Fig. 2).

1. **Definition impotence** – avoiding to define the reference alternatives due to some objective or subjective reasons. In most situations the respondents replied that they are “not able” to define such points, such points “do not exist” or they have “too few information to declare the reference points”.
2. **Utopian definition** – the description indicating the direction of preferences but using the categories that are not verifiable outside of the DM’s internal (but not defined explicitly) structure of preferences, e.g. “low costs”, “short commuting time”, “nice flat”, “good fittings”.

3. **Imprecise definition** – a partial or complete description of the alternative, specifying the resolution levels in interval or fuzzy way, e.g. “price about 1000 PLN”, “costs up to 900 PLN, “35-45 m^2”.
4. **Precise individual definition** – a full specification of an alternative using the resolution levels from the decision matrix as well as the ones outside of it (invented by the DM), e.g. “costs: 500 PLN; 2 rooms; washing machine, microwave, internet access, commuting: 15 minutes”.
5. **Selecting an alternative from decision matrix** – declaring one of the alternative: A, B, C or D to be the best or the worst one.



Definition of anti-ideal solution　　Definition of the ideal solution

Fig. 2. The ways of defining the reference points in the experiment

These five clusters fit the general dichotomic categorisation that identifies the specific (categories 4 and 5) and unspecific (categories 2 and 3) reference points only [6]. The specific definition of the reference point was more common for the anti-ideal alternative than for the ideal one (62% vs. 57%). However, in both the situations there is a relatively big group of DMs that are not able to define precisely or define at all the reference points (38% and 43% respectively). The most interesting here are, however, the definitions of the reference points. Out of 126 precisely defined alternatives (categories: 4 and 5), only 12 (10%) were based on the extreme resolution levels chosen from the decision matrix (i.e. minimum price, maximum floorage etc.). The remaining 114 used the intermediate options. It is an important result that should be taken into account when considering a particular MCDM method to be applied to support the decision/ negotiation problem. Some of them, such as SAW [10] or TOPSIS [17], build the scoring systems in which the extreme rates are assigned to the extreme reference points (that consists of extreme options). All other rates are assigned by comparing the performance of each resolution level with the extreme ones. It may affect the final ranking of the alternatives and lead to the situation, in which the under-bad and over-good alternatives appear [14].

3.3 Problems and Difficulties with Evaluating the Alternatives

We have also analyzed the participants' descriptions of the problems they faced during the process of building the rankings and evaluating the alternatives. They responses may be classified into following four different categories (Fig. 3):

1. **No difficulties** – the respondents declared not to have any problem with evaluating, comparing and ranking the alternatives.
2. **Lack of information** – the DMs claimed not to have all required information to make a thorough decision. For some of them the additional issues, yet not described in the case, were important such as the description of the residential district (parking places, security service) and surrounding (distance to shop centres, cinemas etc.). The others claimed they cannot make the final decision not knowing the preferences of the flat-mate-to-be.
3. **Similarity of the alternatives** – the DMs considered all the offers from the decision matrix to be very similar, and for the assumed granularity of their scoring systems (yet not explicitly defined) they seemed to be rather indifferent.
4. **Multi-attribute aggregation problems** – the respondents wrote about difficulties related to the problem structure and the necessity of analyzing the multitude of the criteria. In particular they found it difficult to weight the criteria, compare various resolution levels of the criteria, rating them, make the trade-off analysis.

Problems and difficulties encountered	*No. of participants*
No difficulties	30
Lack of information	18
- about flat mate's preferences	4
- about additional issues	14
Similarity of the alternatives	6
Multi-attribute aggregation problems	52
- uncertainty about their own preferences	17
- trade-off analysis	23
- setting the weights	3
- rating the options and aggregating the rates	9
Total	106

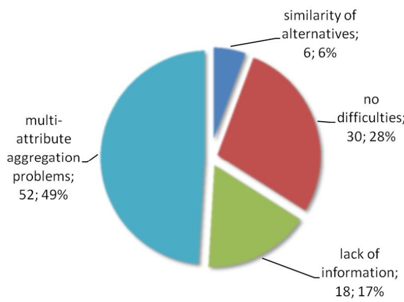


Fig. 3. The structure of problems and difficulties in evaluation of alternatives

There were 30 respondents (28%) who declared no difficulties within the decision process (Fig. 3). However, when analyzing the evaluations of the alternatives they provided, we found 15 of them (see Section 3.1) inconsistent with the corresponding rankings predefined by the DMs at the beginning of the assignment. It shows that the DMs are sometimes not aware of the complexity of the problem and may think they are able to conduct a reliable and coherent decision analysis, while in fact they are not.

The next 6 participants found the decision process difficult because of the similarity of all the alternatives under consideration. The reasons of such a problem may be twofold. First, it may be related to the second category of difficulties (lack of information), i.e. the DMs might have not found relevant information in the decision matrix that would allow to differentiate between the alternatives. On the other hand, it might be because of their inability to elicit their own preferences, and if offered the support, they would have been able to compare them efficiently.

The biggest group of respondents (52 DM / 49%) encountered the problems related directly to making the multiple criteria decisions. They had problems with verbalizing their preferences, not being sure what they truly are (17 respondents). They wrote that: (1) they were not able to decide, whether the commuting time should be taken into consideration or not in comparing the alternatives; or (2) they were not sure, what kind of housing conditions they expect from the flat they are going to rent, so it was difficult to evaluate the ones from the decision matrix. The other difficulties were related to accomplishing the basic tasks of the decision making process: setting the criteria weights (3 DMs), rating the options (9 DMs) and aggregating them in order to conduct the trade-off analysis (23 DMs). They are, however, the technical problems, that can be solved by applying any of MCDM supportive mechanisms that will take into consideration also the other recommendations defined in sections 3.1 and 3.2.

4 Conclusions

In this paper we described the experiment that we had conducted to identify how do the DMs proceed and what difficulties they encounter in analyzing MCDM problems. Since we wished to conclude also for a multi-issue negotiation we designed our experiment as the decision making problem, in which the DM should take into account the preferences of the potential flat mate, he is going to share the flat with. Surprisingly, only 4 out of 106 participants pointed out explicitly that the flat-mate-to-be's preferences should be taken into account before making the final decision. It may indicate, that in some group decision making processes the DM may not be interested in satisfying the goals of the other party, which violates the prenegotiation recommendations on a mutual design and evaluation of the negotiation template [13].

The results confirm also that the decision support in solving multi-issue negotiation/ decision problems is necessary. There were 52 DMs (49%) who wanted to conduct the analysis of their preferences but failed, for different reasons. So the MCDM methods should be applied in the process of negotiation template design and evaluation, however, they should be adequately modified and adopted to meet the DMs' individual needs, expectations and capabilities. As shown in Section 3.1 the vast majority of DMs prefer to express their preferences in a qualitative way. Most preferably, they use the verbal descriptions or some linguistic evaluations when building the rankings or rating the alternatives and options. From the viewpoint of the negotiation analysis, the strong scales describing the alternatives (offers) are required to measure the scale of concession, track the negotiation progress and conduct the post-negotiation efficiency (and fairness) analysis. Therefore the support mechanism should be able to map the linguistic evaluations into the numerical (at least interval) equivalents, that will allow for making the calculations required. Thus, it should be interesting to adopt such MCDM methods as AHP [16] or MACBETH [1]. What is also interesting, more than 80% of DM were able to define, more or less precisely, the reference points, so the linguistic TOPSIS or SAW may also be of use, providing they will be modified to allow the under-bad or over-good alternatives to be evaluated (see [14]).

The use and usefulness of the methods proposed above will depend on the individual DM's characteristics, such as the capabilities of using formal MCDM methods or the way of expressing the preferences. Hence, the further research based on the larger group of other types of DMs (such as sales or procurement managers) is required, which would help us to consider what MCDM method fits what kind of a decision-making profile (describing the way of reasoning and analyzing the MCDM problem) of the potential negotiator. Such a research designed as a web-based decision making experiment, employing the software tools that support decision analysis by means of the MCDM method proposed is our future work.

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References

1. Bana, C.A., De Corte, J.-M., Vansnick, J.-C.: On the mathematical foundation of MACBETH. In: Multiple Criteria Decision Analysis: State of the Art Surveys, pp. 409–437. Springer (2005)
2. Brans, J.-P., Vincke, P.: A preference ranking organisation method: The PROMETHEE method for MCDM. Manage. Sci. 31(6), 647–656 (1985)
3. Brzostowski, J., Wachowicz, T.: NegoManage: A System for Supporting Bilateral Negotiations. Group Decis Negot, 1–34 (2013)
4. Fife-Schaw, C., Breakwell, G., Hammond, S., Fife-Schaw, C., Smith, J.: Levels of measurement. Res. Method Psychol. 3, 50–63 (2006)
5. Guitouni, A., Martel, J.-M.: Tentative guidelines to help choosing an appropriate MCDA method. Eur. J. Oper. Res. 109(2), 501–521 (1998)
6. Heath, C., Larrick, R.P., Wu, G.: Goals as reference points. Cognitive Psychol. 38(1), 79–109 (1999)
7. Hwang, C.-L., Yoon, K.: Multiple Attribute Decision Making: Methods and Applications. Springer, New York (1981)
8. Jahanshahloo, G.R., Lotfi, F.H., Izadikhah, M.: Extension of the TOPSIS method for decision-making problems with fuzzy data. Appl. Math. Comput. 181(2), 1544–1551 (2006)
9. Keeney, R.L., Raiffa, H.: Decisions with multiple objectives: preferences and value trade-offs. Wiley, New York (1976)
10. Kersten, G.E., Noronha, S.J.: WWW-based negotiation support: design, implementation, and use. Decis. Support Sys. 25(2), 135–154 (1999)
11. Konarzewska-Gubala, E.: BIPOLAR: multiple criteria decision aid using bipolar reference system. Document du LAMSADE 56 (1989)
12. Larichev, O.I., Moshkovich, H.M.: Verbal decision analysis for unstructured problems. Kluwer Academic Publishers, Boston (1997)
13. Raiffa, H., Richardson, J., Metcalfe, D.: Negotiation analysis: The science and art of collaborative decision making. The Balknap Press of Harvard University Press, Cambridge (2002)
14. Roszkowska, E., Wachowicz, T.: Negotiation Support with Fuzzy TOPSIS. In: Teixeira de Almeida, A., Costa Morais, D. (eds.) Group Decision and Negotiations 2012 Proceedings, Editoria Universitaria, Federal University of Pernambuco, Recife, pp. 161–174 (2012)
15. Roy, B.: Classement et choix en présence de points de vue multiples. RAIRO-Operations Research-Recherche Opérationnelle 2(V1), 57-75 (1968)
16. Saaty, T.L.: The Analytic Hierarchy Process. McGraw Hill, New York (1980)
17. Wachowicz, T., Błaszczyk, P.: TOPSIS based approach to scoring negotiating offers in negotiation support systems. Group Decis. Negot. 22, 1021–1050 (2013)
18. Zopounidis, C., Doumpos, M.: Multicriteria classification and sorting methods: A literature review. Eur. J. Oper. Res. 138(2), 229–246 (2002)

Bipolar Approach Applied to Group Decision Making Problems

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Abstract. This paper considers group decision making problems (GDM) in bipolar context where actors provide their preferences over alternatives through positive and negative attributes. A soft consensus model based on distance between evaluations is proposed to narrow the differences between decision makers and to ensure convergence of individual preferences towards group preferences. A feedback mechanism defined by the identification and consensus phases is introduced to reach a consensus. For a group with interactive relationships, the potential reciprocal influence of decision makers is considered using concordance and discordance measures.

Keywords: group decision, consensus, bipolarity, proximity measures, discordance, concordance, vicinity.

1 Introduction

Due to the high complexity of socioeconomic environment, it is difficult and impracticablefor a single decision maker to consider all important aspects in practical decision making problems.Therefore, group decision making (GDM) has widely caught attention in the decision making field [1]. Usually, to solve GDM problems, two different processes have to be carried out: the consensus process and the selection process. The former consists in obtaining the highest consensus level among decision makers, that is, to obtain a state were the opinions of the different actors are as closed as possible to each one. The consensus process is usually guided by a 'moderator' whose main task is to guide experts towards a final solution with a high level of consensus. The latter process consists in obtaining the final solution to the problem from the opinions expressed by actors in the last round of the consensus process [2]. To achieve consensus, the literature proposed first a total aggregation of individual evaluations in a unique value representing the common opinion[3]. Several aggregation methods have been proposed; geometric mean [4], [5], Bayesian approach [6], analytical hierarchy process (AHP) [7], [8], fuzzy set theory [9], [10], etc.Other methods based on local preferences, were then introduced considering that

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unanimity is not required to reach a consensus[11], [12], [13]. In this case, the consensus process can use concordance and proximity measures to work towards a common solution.Considering GDM problem based on individual assessments where each actor gives his local preferences after evaluation, this paper proposes a bipolar approach to achieve consensus and selection processes. Using bipolar evaluation, each decision maker express his local preferences for each alternative using selectability and rejectability measures representing respectively positive and negative impacts of alternatives considering objectives achievement.Since thegroup decision members usually come from different backgrounds with various fields of expertise and levels of knowledge, each actor has distinct information and shares partially objectives with the other members [14]. Thismay generate conflict (disagreement) and/or agreement due to potential positive and/or negative interactions between the actors. To consider this potential influence, the concordance and discordance measuresare introduced to quantify potential vicinity influence of each decision maker.A soft consensus process based on distance measuresis then proposed to reach an agreement and select one or more legitimate common solution(s).The rest of the paper is organized as follows. Section 2 describes the modelling and bipolar evaluation phases. Section 3 presents the proposed consensus model which is illustrated in section 4 by an example. A conclusion is given in the last section.

2 Modeling Bipolar Evaluation Process

Let us consider a GDM problem characterized by a set of decision makers $D = \{d_1, d_2, \dots. d_p\}$ and an alternative set $A = \{a_1, a_2, \dots a_n\}$. To evaluate alternatives, each decision maker identifies a set of attributes. In bipolar analysis framework, attributes are divided into supportability and rejectability categories according to their support/rejection and evaluation results are represented for each actor d_k by a priori selectability and rejectability measures noted respectively $\mu_{s_0}^k(a_i)/\mu_{r_0}^k(a_i)$ ([15], [16], [17]). In case of interactive group,the potential influence related to each actor opinionis modeled throughrelative degreesof concordance and discordance noted $\omega_{kk'}^c, \omega_{kk'}^d$ representing respectively the degree of agreement or disagreement of each vicinity members $d_{k'} \in V(d_k)$ of actor d_k, with $\sum_{k' \epsilon V(d_k)} \omega_{kk'}^c = 1$ and $\sum_{k' \epsilon V(d_k)} \omega_{kk'}^d = 1$. To obtain concordance and discordance measures, several methods can be employed. For a relatively quick estimate, the AHP method can be used by making a pairwise comparison. Considering concordance and discordance degrees, the relative bipolar measures noted $\mu_s^{k/V(d_k)}(a_i)/\mu_r^{k/V(d_k)}(a_i)$ can be defined to include vicinity effects in final bipolar measures as follows, see equations (1) and (2).

$$\mu_s^{k/V(d_k)}(a_i) = \frac{\sum_{k' \in V(d_k)} \left(\omega_{kk'}^c \mu_{s_0}^{k'}(a_i) + \omega_{kk'}^d \mu_{r_0}^{k'}(a_i)\right)}{\sum_i \left(\sum_{k' \in V(d_k)} \left(\omega_{kk'}^c \mu_{s_0}^{k'}(a_i) + \omega_{kk'}^d \mu_{r_0}^{k'}(a_i)\right)\right)} \quad (1)$$

$$\mu_r^{k/V(d_k)}(a_i) = \frac{\sum_{k' \in V(j)}\left(\omega_{kk'}^{c}\mu_{r_0}^{k'}(a_i)+\omega_{kk'}^{d}\mu_{s_0}^{k'}(a_i)\right)}{\sum_i\left(\sum_{k' \in V(d_k)}\left(\omega_{kk'}^{c}\mu_{r_0}^{k'}(a_i)+\omega_{kk'}^{d}\mu_{s_0}^{k'}(a_i)\right)\right)} \tag{2}$$

This means that relative bipolar measures of decision maker d_k take only into account the evaluations of its vicinity$V(d_k)$ according to their importance degree. Final bipolar measures are then deduced by associating initial and relative measures according to its individualism (see equation (3) and (4)).

$$\mu_s^k(a_i) = \sigma^k \mu_{s_0}^k(a_i) + (1 - \sigma^k)\mu_s^{k/V(d_k)}(a_i) \tag{3}$$

$$\mu_r^k(a_i) = \sigma^k \mu_{r_0}^k(a_i) + (1 - \sigma^k)\mu_r^{k/V(d_k)}(a_i) \tag{4}$$

where $0 \le \sigma^k \le 1$: is selfishness degree of decision maker d_k. When σ^k tends to 0, holistic (altruistic) decision maker gives more importance to vicinity opinions. Inversely, if σ^k tends to 1, decision maker is considered as individualistic person and will ignore vicinity opinions.

3 Recommendation Process

This section deals with consensus achievement method based on individual evaluations. To express local preference of each decision maker, satisficing game theory sets [18], [19], are proposed as individual recommendation tool.

The satisficing game theory [18] is characterized by the triplet $\langle A, \mu_s^k, \mu_r^k \rangle$ where A^k is a discrete set of alternatives, and μ_s^k/μ_r^k are respectively selectability/rejectability measures. With this formalism, satisficing alternatives noted $S_q^k \subseteq A$ are those that present a better selectability measure than rejectability measure, as given by equation (5).

$$S_q^k = \{a_i^k \in A: \mu_s^k(a_i) \ge q^k \mu_r^k(a_i)\} \tag{5}$$

whereq^k is the boldness or caution index of decision maker d_k. It can be used to adjust the aspiration level: increaseq^kif too many alternatives are declared satisficing or decrease it if$S_q^k$is empty for instance.To avoid the Pareto dominance that may exist in satisficing alternatives set, equilibrium set noted $\mathcal{E}^k$ is defined by equation (6).

$$\mathcal{E}^k = \{a_i^k \in A^k: \mathcal{D}^k(a_i^k) = \phi\} \tag{6}$$

where $D^k(a_i^k)$:is the set of alternatives that are strictly better than a_i^k. Thus, the satisficing equilibrium set $\mathcal{E}_q^{S,k}$ is given by equation (7).

$$\mathcal{E}_q^{S,k} = \mathcal{E}^k \cap S_q^k \tag{7}$$

Assuming that each decision maker $d_k$identifies his satisficing equilibrium set $\mathcal{E}_q^{S,k}$, if $\bigcap_{\boldsymbol{k=1}}^{\boldsymbol{p}} \mathcal{E}_q^{S,k} \neq \emptyset$, an agreement can be reached among the common alternatives ($a_i \in \bigcap_{\boldsymbol{k=1}}^{\boldsymbol{p}} \mathcal{E}_q^{S,k}$) using some selection criteria. Otherwise, a flexible feedback mechanism is proposed to guide them toward a consensus.

3.1 Consensus Achievement Process

A 'soft' consensus process based on proximity and bipolar consensus measures is proposed in this section. The proximity measures (equation (8)) are used to assess the gap between evaluationsof decision maker on each alternative, while bipolar consensus measures are used to evaluate the gap between an actor $d_k$and the rest of the group on bipolar evaluations of a given alternative (see equation (9) and (10)).

These measures are then integrated into a proposed feedback mechanism to guide actors in adjusting their evaluations to reach a consensus on an interactive basis. In each iteration, the proximity measures are first used to rule out the alternatives presenting strong divergences. Bipolar consensus measures are then deployed to identify the decision makers who have the widest gap over the remaining alternatives. To achieve the convergence, boundary conditions (threshold) are set for each level (alternatives proximity and consensus among decision makers). This process is carried out in a discussion session with a feedback mechanism helping decision makers to change their opinions.

Proximity measure: isused to calculate the average distance between decision maker assessments considering a given alternativea_i. It is obtained by equation (8).

$$d_i = \sum_k \sum_{k',k' \neq k} \left[\left(d_{s_i}^{kk'}\right)^2 + \left(d_{r_i}^{kk'}\right)^2 \right]^{\frac{1}{2}} \Big/ \binom{p}{2} \tag{8}$$

where $d_{s_i}^{kk'} = \Theta_k \mu_s^k(a_i) - \Theta_{k'} \mu_s^{k'}(a_i)andd_{r_i}^{kk'} = \Theta_k \mu_r^k(a_i) - \Theta_{k'} \mu_r^{k'}(a_i)$ are respectively the gap between supportability/rejectability measures of decision makers d_k and $d_{k'}$on the assessment of the alternative a_i according to the importance degree Θ_k of each actor and $\binom{p}{2} = \frac{p!}{2!(p-2)!}$ is the binomial coefficient.

Bipolar consensus measures: aredefined for determining the distance between $d_k$and the rest of the group considering bipolar evaluation measures of a given alternativea_i.

$$d_{s_i}^k = \sum_{k',k' \neq k} \left(\left|d_{s_i}^{kk'}\right|\right)/p - 1 \tag{9}$$

$$d_{r_i}^k = \sum_{k',k' \neq k} \left(\left|d_{r_i}^{kk'}\right|\right)/p - 1 \tag{10}$$

where $d_{s_i}^k$, $d_{r_i}^k$ are respectively, consensus measures of supportability and rejectability.

Feedback Mechanism. The feedback mechanism is generally represented by identification and recommendation phases. According to the above structure, the following section presents a feedback process proposed in connection with the bipolar approach [19].

Identification Phase. The identification phase is used to evaluate for each alternative, the closeness of the individual evaluations and compare them to tolerances accepted by the decision group and/or the analyst (moderator). Alternative with a high variation (proximity measurements exceeding threshold) are discarded. To identify decision makers that have differences on the remaining alternatives, the distance between the individual bipolar assessments is then calculated using bipolar consensus measures. From these measures, evaluations of alternatives can be modified using the following steps:

- Identification of alternatives whose proximity measure d_i fulfills the condition (1) $d_i \leq \omega$, where ω represents the permissible threshold between alternatives (the average distances on the alternatives set may be considered as the threshold). This allows excluding alternatives that may create conflicts and focusing on alternatives already converging.
- Identifying decision makers whose opinion move away from other group members through the non-observance of the following conditions: (2) $d_{s_i}^k \leq \omega_s$,(3) $d_{r_i}^k \leq \omega_r$, i.e. decision makers whose bipolar measures do not meet the supportability and/or rejectability thresholds denoted respectively by ω_s , ω_r.

*Recommendation phase.*The recommendation phase starts with a discussion assignment in which decision makers not fulfilling conditions(2) and (3) are encouraged to make changes to the assessments of the alternatives that meet condition(1). The recommendations are based on the following rules:
- For $d_{s_i}^k > \omega_s$: decision maker$d_k$presents a significant difference related to his selectability measure compared to other decision makers. To know if the considered alternative presents an important (positive divergence)or a very low (negative divergence) selectability, the divergence direction of the selectability measures is defined by $div_{s_i}^k = \sum_{k',k' \neq k} \left(d_{s_i}^{kk'}\right)/p - 1$. If $div_{s_i}^k > 0$, alternative a_i provides a good selectability measure, no change is required. Otherwise ($div_{s_i}^k < 0$), selectability measure is smaller than average, an increase of this measure is therefore recommended. Similar recommendations are implemented for rejectability measures.

Once the changes made, the set of satisfactory balance of each decision maker is rebuilt. The iterative process can be stopped when $\bigcap_{k=1}^{p} \mathcal{E}_q^{Sk} \neq \emptyset$. If the solution satisfies the group, the process is ended. Otherwise, a new iteration can be proposed.

4 Application Example

The considered example here is an adaptation of a wind farm implantation problem considered in the literature by Lee et al [20]. Decision group is composed of three decision-makers: wind specialist, local administration and public authority denoted respectively asd_1, d_2, d_3. The goal is to select a location for a wind farm installation to achieve a set of objectives related to socio-economic, performance and operability notions. Five potential sites are under consideration. The bipolar evaluation of alternatives is carried out through BOCR analysis that consists in evaluating alternatives over benefit, opportunity, cost and risk factors through a distribution of attributes on these factors[15]. Considering the relative concordance and discordance measures represented by the followingmatrices and individualism degree $\sigma^k = 0.5, \forall\, d_k$, the final bipolar results are given in the following table.

$$\omega_{kk'}^c = \begin{bmatrix} - & 0.1 & 0.9 \\ 0.7 & - & 0.3 \\ 0.2 & 0.8 & - \end{bmatrix} \omega_{kk'}^d = \begin{bmatrix} - & 0.7 & 0.3 \\ 0.2 & - & 0.8 \\ 0.6 & 0.4 & - \end{bmatrix}$$

Table 1. Final bipolar measures

D	Bipolar measures	a$_1$	a$_2$	a$_3$	a$_4$	a$_5$
d_1	(μ_s^1)	0.196	0.197	0.188	0.209	0.209
	(μ_r^1)	0.202	0.189	0.207	0.209	0.193
d_2	(μ_s^2)	0.198	0.193	0.204	0.195	0.209
	(μ_r^2)	0.193	0.196	0.189	0.211	0.210
d_3	(μ_s^3)	0.202	0.181	0.120	0.212	0.205
	(μ_r^3)	0.196	0.198	0.197	0.199	0.209

Graphical representation of these results in the plan (μ_r, μ_s) for each actor isgiven on figure 1 below. The caution index q^k is assumed to be 1 ,$\forall d_k$. The satisficing equilibrium sets ($\mathcal{E}_q^{S,k}$) of actors are as follows: $\mathcal{E}_1^{S,1} = \{a_5, a_2, a_4\}$, $\mathcal{E}_1^{S,2} = \{a_3\}$ and $\mathcal{E}_1^{S,3} = \{a_1, a_4\}$. In this case there is no common solution $\left(\bigcap_{k=1}^{3} \mathcal{E}_1^{S,k} = \emptyset\right)$, we propose then to seek a consensus using the proposed process.

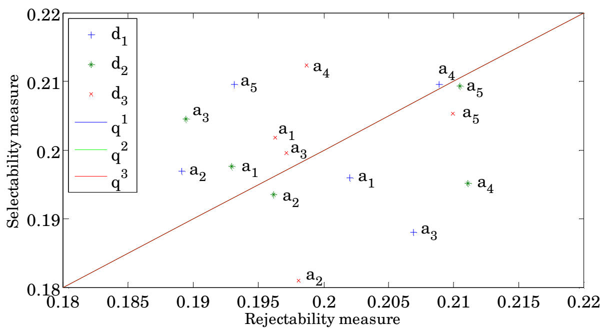

Fig. 1. Graphical representation of alternatives ($\boldsymbol{\sigma^k} = [\mathbf{0.5\ 0.5\ 0.5}]$)

Identification Phase. The identification of the alternatives with strong differences consists in calculating proximity measures defined by equation (8) from the final bipolar measures (table 2). The obtained results are given by the following vector $d_i = [0.0077\ \ 0.0079\ \ 0.0119\ \ 0.0113\ \ 0.0090]$. Assuming that the average distances on the set of alternatives is the tolerance threshold, the proximity distance must not exceed 0.0096 ($d_i \leq 0.0096$). It is thus inferred that alternatives a$_3$ and a$_4$ are widely divergent and should therefore be discarded. Assuming that the thresholds ω_s ,ω_r were obtained from averages of bipolar distances on the set of alternatives, the following table 3 shows the gaps observed at the actor level for each alternative.

Table 2. Bipolar consensus measures

		$d_{s_i}^k$			$d_{r_i}^k$	
D	d_1	d_2	d_3	d_1	d_2	d_3
a$_1$	0,0017	0,0019	0,0031	0,0025	0,0035	0,002
a$_2$	0,0033	0,0022	0,0034	0,0026	0,002	0,0032
a$_3$	0,0046	0,0024	0,0026	0,0045	0,0056	0,0034
a$_4$	0,0039	0,0067	0,0048	0,0014	0,0012	0,0023
a$_5$	0,0007	0,0009	0,0005	0,0057	0,0033	0,0042

Recommendation Phase. Table 3 shows that decision maker d_1 presents a deviation from the average concerning selectability measure of alternative a_2. The meaning of the divergence is positive ($div_{S_2}^{1} = 0.003$), the selectability measure is important and cannot be modified. Decision maker d_2 presents a divergence regarding the rejectability measures of alternatives a_1 and a_5. The divergence direction of the rejectability measures is given by $div_{r_1}^{2} = 0.0035$ and $div_{r_5}^{2} = -0.0015$. The recommendation consists to reduce the rejectability measure of a_5. Alternative a_1 which has a low rejectability is spared. For d_3 strong rejectability measure on alternative a_5 is observed compared to the rest of the group. The negative divergence direction ($div_{r_5}^{3} = -0.0042$) implies a recommendation of reducing this measure. The reduction of rejectability measures of alternatives a_5 by decision makers d_2 and d_3 to $\mu_r^2(a_5)$= 0.2005 and $\mu_r^3(a_5)$= 0.1980 respectively gives the following satisficing equilibrium sets$\left(\mathcal{E}_q^{S,k}\right)$; $\mathcal{E}_1^{S,1} = \{a_5, a_2, a_4\}$, $\mathcal{E}_1^{S,2} = \{a_3, a_5\}$ and $\mathcal{E}_1^{S,3} = \{a_1, a_4, a_5\}$. The solution obtained is the alternative a_5 $\left(\bigcap_{k=1}^{3} \mathcal{E}_1^{S,k} = a_5\right)$.

In the example discussed here, the integration of positive and negative influences of decision makers in the model and the relatively small number of decision makers allowed reaching a consensus quickly after a single recommendation step. The individualism average rate considered for all decision makers allows also to nuance the individual assessments and reduce differences that a high degree of individualism could make appear. A sensitivity analysis can be performed by varying the caution index and/or individualism degree to test different possible scenarios and stability of recommended solutions.

5 Conclusion and Perspectives

This paper proposed an approach to solve group decision making problem from a bipolar analysis, separating the positive and negative aspects of alternatives. The potential vicinity influence is considered through concordance and discordance measures, individualism degree of actors and their impact were also considered. To guide decision makers toward a common solution, a consensus process based on proximity and bipolar consensus measures has been proposed to identify alternatives with widely divergence and actors showing a significant assessment gap on bipolar measures relative to other members. Selection process is then deployed using satisficing game theory sets. The results obtained through the application of the proposed approach highlighted the applicability and interest of our approach. The development of a software tool for decision support based on the bipolar approach is envisaged as well as the development of the bipolar evaluation approach for the resolution of strategic game problems.

References

1. Jiang, Y., Xu, Z., Yu, X.: Compatibility Measures and Consensus Models for Group Decision Making with Intuitionistic Multiplicative Preference Relations. Appl. Soft Comput. (2013)

2. Alonso, S., Herrera-Viedma, E., Cabrerizo, F.J., Chiclana, F., Herrera, F.: Visualizing Consensus in Group Decision Making Situations. In: IEEE International Fuzzy Systems Conference, FUZZ-IEEE 2007, pp. 1–6 (2007)
3. Leyva Lopez, J.C.: A Consensus Model for Group Decision Support Based on Valued Outranking Relations, Lisbon, Portugal. Presented at the EURO XXIV (July 11, 2010)
4. Wheeler, T.A., Hora, S.C., Cramond, W.R., Unwin, S.D.: Analysis of core damage frequency from internal events: Expert judgment elicitation: Part 1, Expert panel results, Part 2, Project staff results (1989)
5. Cook, W.D., Kress, M.: Ordinal Ranking with Intensity of Preference. Manag. Sci. 31, 26–32 (1985)
6. Bonano, E.J., Apostolakis, G.E.: Theoretical foundations and practical issues for using expert judgements in uncertainty analysis of high-level radioactive waste disposal. Radioact. Waste Manag. Nucl. Fuel Cycle 16, 137–159 (1991)
7. Korpela, J., Tuominen, M.: Group decision support for analysing logistics development projects. In: Proceedings of the Thirtieth Hawaii International Conference on System Sciences 1997, vol. 2, pp. 493–502 (1997)
8. Lai, V.S., Wong, B.K., Cheung, W.: Group decision making in a multiple criteria environment: A case using the AHP in software selection. Eur. J. Oper. Res. 137, 134–144 (2002)
9. Hsu, H.-M., Chen, C.-T.: Aggregation of fuzzy opinions under group decision making. Fuzzy Sets Syst. 79, 279–285 (1996)
10. Moon, J.H., Kang, C.S.: Use of fuzzy set theory in the aggregation of expert judgments. Ann. Nucl. Energy 26, 461–469 (1999)
11. Herrera-Viedma, E., Alonso, S., Chiclana, F., Herrera, F.: A Consensus Model for Group Decision Making With Incomplete Fuzzy Preference Relations. IEEE Trans. Fuzzy Syst. 15, 863–877 (2007)
12. Herrera-Viedma, E., Herrera, F., Chiclana, F.: A consensus model for multiperson decision making with different preference structures. IEEE Trans. Syst. Man Cybern. Part Syst. Hum. 32, 394–402 (2002)
13. Herrera, F., Herrera-Viedma, E., Verdegay, J.L.: A model of consensus in group decision making under linguistic assessments. Fuzzy Sets Syst. 78, 73–87 (1996)
14. Xu, J., Wu, Z.: A discrete consensus support model for multiple attribute group decision making. Knowl.-Based Syst. 24, 1196–1202 (2011)
15. Bouzarour-Amokrane, Y., Tchangani, A., Pérès, F.: Defining And Measuring Risk And Opportunity In Bocr Framework For Decision Analysis. Presented at the Proceedings of 9th International Conference on Modeling, Optimization and SIMulation, MOSIM 2012, Bordeaux, France, June 6-8 (2012)
16. Bouzarour-Amokrane, Y., Tchangani, A., Pérès, F.: Evaluation process in end-of-life systems management using BOCR analysis. In: Presented at the IFAC Conference on Manufacturing modelling, Management and Control, Saint Petersbourg (2013)
17. Tchangani, A., Bouzarour-Amokrane, Y., Pérès, F.: Evaluation Model in Decision Analysis: Bipolar Approach. INFORMATICA 23, 461–485 (2012)
18. Stirling, W.C.: Satisficing Games and Decision Making: With Applications to Engineering and Computer Science. Cambridge University Press (2003)
19. Bouzarour-Amokrane, Y., Tchangani, A., Pérès, F.: Résolution des problèmes de décision de groupe par analyse bipolaire. Presented at the 5èmes Journées Doctorales (JDJN) GDRMACS, Strasbourg (2013)
20. Lee, A.H.I., Chen, H., Kang, H.: Multi-criteria decision making on strategic selection of wind farms. Renew. Energy 34, 120–126 (2009)

Adapting Agent's Interactions in Dynamic Contexts

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Abstract. This work addresses the efficient multi-agent coordination problem based on negotiation which take into account the unpredictable behaviours and availabilities of the agents and the dynamic evolving of the tasks. To ensure and to adapt dynamically negotiations, we provide a new negotiation protocol based on the *recommendation* and on *alliance* principle. We also provide an experimental performance evaluation.

1 Introduction

In this work, we aim to devise an efficient multilateral negotiation protocol which allows stable coalitions [7][10] when it is impossible to predict ahead of task achievement the required coalitions and when the agents must negotiate in an open context (agents may randomly join or leave the environment), in a distributed context (without a pre-existing structure or a central control), in a heterogeneous context (different behaviours and strategies) and in a competitive context (selfish agent). While many works are done in the field of stable coalition formation [6][9], the case of stability discussed in this work is not in the art.

Our case study concerns a scenario where the agents assist a set of persons and robots in disaster recovery through the establishment of an ad-hoc network. The nodes of this ad-hoc network which harbour the agents are formed by this set of autonomous robots located in areas considered as dangerous for humans (explosions, rock slides, ...) and personal devices of human rescuers which assist in localizing and in finding the best coalition for the evacuation of the injured. A rescuer has not all knowledges about the distribution of the resources and availability of the other rescuers.

The remainder of this paper is as follows. Section 2 gives an overview of negotiations in dynamic context. Section 3 details our negotiation mechanism. Section 4 gives an experiment evaluation and section 5 concludes this work.

2 Related Work

Coalition formation mechanisms for ad-hoc networks are presented in [2], focusing on the MANET environment. That study models an ad-hoc network as a

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graph where nodes are the agents and arcs are the communication links between them. In this way, the members of a coalition will be all the agents of which links can be activated. However, this approach requires knowing all possible links, the positions of the potential participants and re-computing the graph if an agent moves or becomes unavailable. The inaccessibility in MANET is handled by [11], which introduces *Mobile Middle Agents (MMAs)* which are distributed (optimally) across the system. These *MMAs* are in charge of connecting inaccessible agents. Yet, this solution is feasible only if these *MMAs* are available. In [4], a dynamic coalition formation mechanism (DCF-A) is proposed, to enable rational agents to react to events which occur dynamically. In DCF-A, each coalition built is represented by a distinguished agent acting as the coalition leader. The leader examines coalition adjustments by building hypothetical re-configurations and evaluating the risk of adding and removing coalition members. If the leader identifies a significant improvement in coalition value (by simulation), it informs the members about the alternatives. In turn, the agents send their own estimations. Then, the agents and the leader begin a negotiation phase to re-configure the coalition. However, the leaders are sensitive central points and there is no mechanism to manage their unavailability. In addition, the agents in DCF-A are considered not selfish and always available, which is not the case in the problem we solve. To form stable coalitions [7] searches for a social welfare maximizing coalition structure in a corresponding coalition structure graph (the core of a game). Only coalition structures that maximize the social welfare are core-stable. A study on coalition structure's (core) stability [1] in co-operative games in structured environments focuses on characteristic function games defined on graphs that determine feasible coalitions. In contrast to our work, to determine a feasible coalition that study requires that goals, agent positions, etc. are known ahead of coalition formation (and do not change during task execution). In our dynamic and ad-hoc context, the nodes may join or leave the environment at random. Further, searching for an optimal coalition structure is computationally hard [8] and the nodes in our environment have limited resources. Our work's focus is not on computing the a-priory stable coalition structures but on devising protocols that lead selfish agents to coalitions which can be stabilized in face of dynamic changes, and can be computed in acceptable time. Dynamic tasks in dynamic environments are dealt with in [3] by proposing a coalition formation method based on MDP to determine the evolution of the task assuming a deterministic task evolution. However that study does not consider the unavailability of agents or the stability of the coalitions *during* task execution. It assumes that the agents are homogeneous and co-operative.

3 The Agent's Negotiation

We define a task as a set of actions to be performed (e.g. fire to extinguish) whereas the goal is an objective that an agent wants to reach (e.g. a reward). To achieve its own goals, an agent $a_i \in A : A=\{a_1, a_2, ..., a_n\}$ attempts to dynamically determine the team-mates of its *view* $\vartheta(a_i)$ which depends on its neighborhood size. If a_i *view* $\vartheta(a_i)$=($\{a_j, Al_{a_i,a_j}\}, \{a_k, Al_{a_i,a_k}\}$), then a_j and a_k are its neighbors. Al_{a_i,a_j} and Al_{a_i,a_k} are respectively the *alliances* between a_i and a_j and between a_i and a_k. An *alliance* Al_{a_i,a_j} is an agreement between two agents a_i and a_j on mutual resource and information facilitation. Within an *alliance*, an agent commits to helping its ally in return to similar help from the ally. The aim of *alliances* is to facilitate the resource acquisition, to reduce the negotiation's delay and the communication cost. An *alliance* can be cancelled by an agent for instance if the *reliability* of its ally is below some threshold. The *reliability* of a_j is computed by a_i by using the *Poisson law* [12] which expresses the prior probability of random events over a time interval t (agents' withdrawal events). Thus, the *reliability* of a_j is: $\rho_{a_j}=e^{(-\lambda_{a_j})} * (\frac{(\lambda_{a_j})^k}{k!})$.

However, the agents are autonomous and selfish, thus a_i cannot know the intentions of a_j and must suppose by computing ρ_{a_j} that, a_j will not have the intend to break their *alliance* (0 break). Thus the *reliability* is computed for k=0, then $\rho_{a_j}=e^{(-\lambda_{a_j})} * (\frac{\lambda_{a_j}^0}{0!}) \Rightarrow \rho_{a_j} = e^{(-\lambda_{a_j})}$ where λ_{a_j} is the withdrawal rate of a_j from *alliances* with a_i. We assume that, if a_i note 10 withdrawal of a_j, then a_i deletes all *alliances* with a_j. Thus, to update ρ_{a_j}, the agent a_i computes the withdrawal rate as follow: $\lambda_{a_j}= \frac{NW}{10}$ where NW is the number of withdrawal.

An *alliance* Al_{a_i,a_j} can be: *equitable*, *preferable* or *non-dominated.* If Al_{a_i,a_j} is *equitable* it means that, Al_{a_i,a_j} is feasible, is not a constraint for a_i and a_j and enhances the performances of both agents. If a_i prefers Al_{a_i,a_j} over Al_{a_i,a_k} (e.g. because a_i has more confidence in a_j than in a_k due to their reliability), then Al_{a_i,a_j} is preferable and this preference relation is noted: $a_j \succ_{Al} a_k$. If Al_{a_i,a_j} is *non-dominated*, it means that, Al_{a_i,a_j} is equitable and preferable.

To start up a negotiation phase (see algorithm 1), an agent a_i determines the priority of the task it manages by computing the invariant vector $\varPi$. For more details on how to build an MDP and to compute the invariant vector $\varPi=\{\varPi_0,\varPi_1,\varPi_2\}$: $\sum_{j=0}^{2} \varPi_j=1$, see [5]. For example, if the MDP of the task T has the states $S=\{s^0, s^1, s^2\}$ where s^0 is the *"in progress"* state, s^1 is the *"decreasing"* state and s^2 is the *"uncontrollable"* state, and if $\varPi=(\frac{1}{4}, \frac{3}{10}, \frac{9}{10})$, this means that, the probability of having T in the state: *in progress* equals $\varPi_0=\frac{1}{4}$, in *"decreasing"* equals $\varPi_1=\frac{3}{10}$ and in *uncontrollable* equals $\varPi_2=\frac{9}{10}$.

After that, a_i computes the wait-for-response time εt which is an estimation of the probable response delay of the neighboring agents after a request. dt_1 is the signal modulation delay and dt_2 the round-trip delay time. To manage bandwidth and to avoid synchronization message loops, the agents use a *non-return broadcast* and *TTL (Time To Live)* principle. The *non-return broadcast* principle entails that if an request (coalition demand, recommendation, ...) arrives from a_i, its neighboring agents cannot return to it the same request. The TTL is the message hop count such as:$1 \leq TTL \leq |\frac{Sz}{2*\varUpsilon}|$ where Sz is the size of the disaster area, $\varUpsilon$ the signal range (e.g. Bluetooth 100 mWatt, $\varUpsilon \leq$100 meters). A message is transmitted by the agents until TTL=0.

After that, a_i sends a message $Declare(T, R_{min}, Al_{a_i}^P)$ which contains the task T, the information about the minimum resources R_{min} that T requires and the future *alliance* $Al_{a_i}^P$. The $Al_{a_i}^P$ proposal of a_i contains the resource R_{a_i} and the time T_{help} it commits to contribute in the future in a coalition of an ally which agrees to remain in its coalition. $T=\{\Theta_T, S_T, \varphi_T, \Delta\}$, where $\Theta_T=\{t_1, t_2, ..., t_n\}$ comprises sub-task(s) t_i and where $S_T=\{S_{t1}, S_{t2}, ...S_{tn}\}$ is the set of sub-task(s)' states. $\varphi_T=(\alpha, \beta)$ is the location of T in the deployment environment (e.g. latitude α and longitude β). The constraints associated with task execution is Δ : $\Delta=(D, Cons, val, \{\Pi_0, \Pi_1, \Pi_2\})$ where D is the stochastic execution time, $Cons$ the constraints on agents' resources limitation (e.g. energy supply) and val the reward associated with T. However the *reward* of an a_i is: $reward_{a_i}=val * \frac{\delta t_{a_i}}{D}$ where δt_{a_i} the time period that a_i remains in the coalition. a_i gets the maximum reward if it sticks with the coalition until task completion ($\delta t_{a_i}=D$). This reward policy aims to motivate agents to remain in their coalition and minimize coalition hopping. D is the time between the start and the expected end of task execution. To compute D, an a_i estimating the average number $\bar{N}$ of agents needed in the coalition due to R_{min} (assuming that each agent contributes one resource). D is expressed by: $D = \frac{\bar{N}}{\sum_{j=1}^{N} \bar{X}_j}$ where $\bar{X}_j$ is the expected task execution throughput contributed by a_j. If a_i does not know the contribution level of other agents, then, by default it uses its own contribution $\bar{X}_i$.

If an agent a_j aims to participate to coalition's negotiation and is agreed with $Al_{a_i}^P$, sends to a_i a message $Help(P_s, t_i, R_{a_j})$ to specify the sub-task $t_i \in T$ it wants to manage, its *probable stability* P_s and its resources R_{a_j}. After that, both agents a_i, a_j establish the *alliance* Al_{a_i,a_j} and each one updates its *history set*. The *history set* of a_i stores its allies where each ally a_j is identified, paired with a *reliability* ρ_{a_j}, linked to the information on its resource(s) R_{a_j} it is ready to provide and to its probable stability P_s. The *probable stability* P_s of an agent is equal to: $P_s = 1 - Q_s$ where Q_s is the probable disconnection of the device which harbor the agent. To determine Q_s an agent uses the *modified geometric distribution* [12] which is the prior probability distribution of the first occurrence of a failure. $Q_s=(q_s)^k * (1 - q_s)$, where $q_s=e^{-\lambda_i} * \frac{\lambda_i^k}{k!}$. λ_i is the arrival rate of disconnections of the device i and k the number of its disconnections since its first starting. A larger P_s entails that the device is more highly preferred.

When a_i can validate the requirement if $R_{a_j} \in R_{min}$ then it removes R_{a_j} to R_{min}. After that, a_i sends a $Def\_Ack(a_j)$ to a_j and both agents synchronize their knowledge if it exists other agents which take part in the coalition. In the algorithm 1, the steps 1 to 13 are done if R_{min} is not reached or if the third declaration (line 13) is done without to get enough resource for ending the negotiation. All notified agents in these steps become *primary agents*, responsible for their sub-task and must find more resources if the coalition requires more resources. This, for distributing the control of the coalition and its robustness despite the dynamic of the context. However, if a *primary agent* becomes unavailable its task is managed by the other *primary agents* in its coalition by using their *history set*. The set of *primary agents* of a coalition is called the *backbone*. However, an agent must be at most in one *backbone*. This, for avoiding the renegotiation of many coalitions because of the unavailability of one *primary agent*.

If the minimum resource(s) R_{min} is not met, the *primary agents* opt for using their *history set*. A *primary agent* a_i begins by finding the set of ally a_j which has the required resource(s) such that ρ_{a_j} is maximized. If several allies can provide the resource(s), a_i sorts the allies by their P_s and sends a *recommendation* request $Recom(T, R_{min}, Al^P_{a_i})$ one by one in a descending P_s value. Two cases may occur when a_j receives a *recommendation* request from a_i:

Algorithm 1. Negotiation

Require: T
Compute Π of T and L which is the max length with a neighboor
Compute εt=$((2 * dt_1) + dt_2)$: dt_1=$(2 * \frac{Frame\_Size}{Network\_Speed})$, dt_2=$(2 * \frac{L*Frame\_Size}{Network\_Speed})$
Compute TTL, D, $Al^P_{a_i}$=(R_{a_i}, T_{help}) where T_{help}=D and $Declare(T, R_{min}, Al^P_{a_i})$
repeat
  if $(Help(P_s, t_i, R_{a_j}))$ and $t_i \subseteq T$ and $R_{a_j} \subseteq R_{min}$ **then**
    remove R_{a_j} *to* R_{min}, $Def\_Ack(a_j)$ and store a_j in *history set*
  else
    Evaluate again D, T_{help}=$(T_{help} - \varepsilon t)$ and $Al^P_{a_i}$=(R_{a_i}, T_{help})
    $Declare(T, R_{min}, Al^P_{a_i})$
  end if
  $k++$ and wait during (εt)
until $(k$==$3)||(R_{min}$==$NULL)$
if $(R_{min}$==$NULL)$ **then**
  Break the finding resource process
else
  $Recom(T, R_{min}, Al^P_{a_i})$
  if $(SendRecom(a_j, Al_{a_i,a_j}))$ **then**
    $AckSendRecom(a_j, Al_{a_i,a_j})$
    if $AckRecom(a_j)$ and $R_{a_j} \in R_{min}$ **then**
      remove R_{a_j} *to* R_{min}, $Def\_Ack(a_j)$ and store a_j in *history set*
    end if
  end if
  if $SendNewAl(Al_{a_j,a_i})$ and Al_{a_j,a_i} *is equitable* **then**
    $AckSendNewAl(Al_{a_j,a_i})$, $Def\_Ack(a_j)$ and store a_j in *history set*
  end if
end if

(1) a_j has an *alliance* with a_i. Then, a_j examines the *alliance* which they share. If a_j can honor the *alliance*, it proposes its resources $(SendRecom(a_j, Al_{a_i,a_j}))$ and waits a_i's response $(AckSendRecom(a_j, Al_{a_i,a_j}))$ before joining the a_i's coalition. If a_j cannot honor the *alliance*, it tries to find a set of allies in its *history set* which can honor the *alliance*. If a_j finds a set of allies, it responds to the *recommendation* request of a_i by sending this set. If a_j cannot address the request it ignores it, knowing that its *reliability* will be demoted by a_i.
(2) a_j has no *alliance* with a_i. In this case, a_j sends an *alliance* request $SendNewAl(Al_{a_j,a_i})$ and waits for response $AckSendNewAl(Al_{a_j,a_i})$. If a_i accepts the *alliance* (Al_{a_j,a_i} is equitable) it sends also a $Def\_Ack(a_j)$ and then a_j stores a_i in its *history set* and proceeds with the steps detailed in **(1)** above. if a_i does not accept the *alliance* then a_j ignores the request.

Proposition 1. The *recommendation* enable the transitivity of *alliances.*

Proof. Let Al_{a_i,a_j} be an *alliance* between a_i and a_j. Let Al_{a_j,a_k} be an *alliance* between a_j and a_k. If $a_i \succ_{Al} a_j$ and $a_j \succ_{Al} a_k$ exist and a_i needs the skill of a_k then a_j will recommend a_k with $\rho_{a_k} \geq 0.5$ due to Al_{a_i,a_j} and a_j does not want a_i lose confidence in its *reliability* because selfish agents always search to improve their abilities to achieve their goals. Thus, $a_i \succ_{Al} a_k$ exist. □

Proposition 2. The *backbone* is in a Nash equilibrium, if each *primary agent* has a *non-dominated alliance* with at least one agent of the *backbone.*

Proof. If each agent a_i in the *backbone* has a *non-dominated alliance* Al_{a_i,a_j} with at least one agent a_j of the same *backbone* then $a_i \succ_{Al} a_j$ and Al_{a_i,a_j} is equitable for a_i. In addition, if a_i leaves the *backbone* when a_j in the *backbone* has an *alliance* with it, a_j will reduce the *reliability* of a_i which in return will reduce the ability of a_i to reach its goals. We deduce that, if each *primary agent* has at least one *alliance non-dominated* with one agent of the *backbone*, the agent will not have the incentive to leave the *backbone* which will be in a Nash equilibrium. □

Proposition 3. If the MDP of a task is ergodic, then all agents of the game have the same knowledge about the risk of the task.

Proof. A MDP possesses at least one invariant vector. If the MDP is ergodic [5] the invariant vector is unique and independent of the initial distribution of the MDP. Thus, for all matrix P of the T, Π exists, is unique and independent on the initial state of T known by the agents. The proof is implied. □

4 Experiments

To experiment our work, we have developed a simulator (in Java) due to the fact that none of protocol such as FIPA-CONTRACT-NET can take into account the dynamic of task and the unpredictability availability of autonomous selfish agents during multilateral negotiation. Randomly, an agent can initiate a coalition formation, free of any commitment, or unavailable. Each agent understand the negotiation mechanism in the same way. The dynamics, the location and the skills required for a task are randomly generated. The population size in each run is chosen between 10 to 100 and each run has 3 simultaneous tasks where each task state is set randomly. The simulations were performed on a PC with an Intel i7 (3 GHZ) and 4GB of RAM. At the beginning of a simulation trial (run), each task is assigned to one agent which should negotiate and form its task's coalition. Dealing with their resource constraints and the time constraints of the tasks, the aim of each agent is to get the maximum reward. We randomly disable a set of agents to simulate network topology changes. The messages are freely exchanged by respecting the $non-return\ broadcast$ and the TTL principle. In the figure 1, we study the probability to have one stable coalition (C1) or two stable coalitions (C2) etc. according to the *Ratio* which is equal to the number of available resources on the total number of required resources to form the three coalitions when the agents' withdrawal pursues a Normal distribution $failure \sim N(0.5, (0.1)^2)$. For example

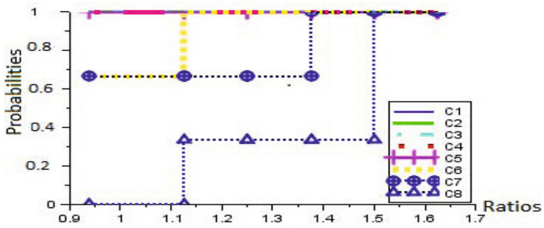

Fig. 1. Guarantees level of having stable coalitions according to the Ratios

consider 3 required coalition in an environment which has 25 agents which can join each coalition. If the first coalition requires 10 agents, the second requires 8 agents and the third requires 12 agents, then the *Ratio* in this environment is $\frac{25}{10+8+12}=\frac{25}{30}=0.833$. In the following simulations 2, we study the influences of the tasks' invariant vector on the stability provided by our method. In the legends, $P1$ means only one of three tasks has a probability to become uncontrollable (Π_2) superior or equal to 0.5, $P2$ means two of three tasks have a probability to become uncontrollable (Π_2) superior or equal to 0.5, $P3$ means all tasks have the same probability to become uncontrollable (Π_2).

In the third phase of the simulation, we compare the runtime after 6 sequential runs of our method with the time needed for forming core-stable coalitions (CS) such as in [1]. The number of agents begins by 10 and we add 10 agents before each run. The figure 3 shows that over time, our mechanism performs better due to the existence of *alliances* between the agents.

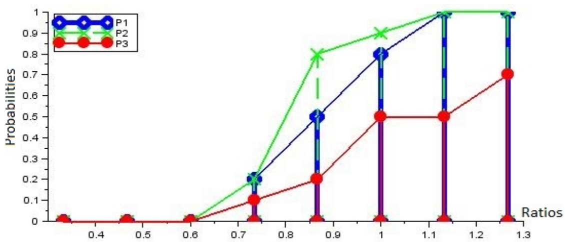

Fig. 2. Probability to form three stable coalition according to $P1$, $P2$ and $P3$

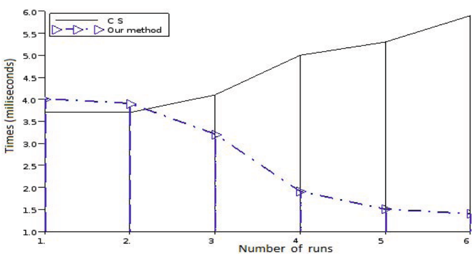

Fig. 3. Comparing the runtime of coalition formation mechanisms

5 Conclusion

Using multi-agent coordination through coalition formation in ad-hoc and mobile device context where dynamic tasks evolve such as in disaster areas requires dynamic stabilization of agents' interactions. To tackle this problem, we have proposed a new multilateral negotiation protocol based on *recommendation* and on *alliances* principle. Our experimental results show the importance of our method in the context of dynamic and unpredictable environment with limited resources, where tasks and resources may change during task execution.

References

1. Chalkiadakis, G., Markakis, E., Jennings, N.R.: Coalitional stability in structured environments. In: International Joint Conference on Autonomous Agents and Multi-Agent Systems, pp. 779–786 (2012)
2. Jiang, T., Theodorakopoulos, G., Baras, J.S.: Coalition formation in manets. In: Army Science Conference, Orlando, FL, USA (November 2006)
3. Khan, M.A., Turgut, D., Bölöni, L.: Optimizing coalition formation for tasks with dynamically evolving rewards and nondeterministic action effects. In: AAMAS (2011)
4. Klusch, M., Gerber, A.: Issues of dynamic coalition formation among rational agents. IEEE Intelligent Systems (June 2002)
5. Ortner, R.: Linear dependence of stationary distributions in ergodic markov decision processes. Operations Research Letters-Journal-Elsevier, 619–626 (January 2007)
6. Barberà, A.G.S.: On coalition formation: durable coalition structures. Mathematical Social Sciences-Elsevier 45, 185–203 (2003)
7. Sandholm, T.: Distributed rational decision making. In: Weiss, G. (ed.) The Textbook Multiagent Systems: A Modern Introduction to Distributed Artificial Intelligence, pp. 201–258. MIT Press (1999)
8. Sandholm, T., Larson, K., Andersson, M., Shehory, O., Tohmé, F.: Anytime coalition structure generation with worst case guarantees. arXiv preprint cs/9810005, 10 (1998)
9. Sandholm, T.W., Larson, K., Andersson, M., Shehory, O., Tohmé, F.: Coalitions structure generation with worst case guarantees. AI Journal (1999)
10. Shehory, O., Kraus, S.: Methods for task allocation via agent coalitions formation. AI Journal (1998)
11. Šišlák, D., Pěchouček, M., Rehák, M., Tožička, J., Benda, P.: Solving inaccessibility in multiagent systems by mobile middle agent. Multiagent and Grid Systems, 73–87 (2005)
12. Yates, R.D., Goodman, D.J.: Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers. John Wiley and Sons, INC, Rutgers (2005)

Interaction Protocols Adaptation for Negotiation in Opened Multi-agent Systems

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Abstract. This work addresses the Interaction Protocols (IP) adaptation issue for negotiation in Opened Multi-Agents Systems (OMAS). By OMAS, we mean the agents evolve in a changeable and dynamic environment, and can be led to form dynamically partnerships which they can enter or leave any time, and in that play variable roles. The IP based negotiation is considered as an interesting aspect for coordination in OMAS since they structure and organize the negotiation between agents to reach a common decision on the considered negotiation object. Obviously, to ensure an efficient negotiation between agents, we need to adapt their interaction protocols if these are not perfectly suitable for them. More precisely, the paper defends that versioning technique is a good solution to deal with interaction protocols adaptation at build time (or a priori) in OMAS. First, it presents a Versioned Interaction protocol Meta-Model (VIP2M for short) for IP versions modeling. Then, it shows how we extend the VIP2M meta-model with the contextual dimension to facilitate the selection of an IP version among several. Finally, it gives a running example to better illustrate the use of IP versions.

Keywords: Interaction Protocols, Negotiation, Opened Multi-Agent Systems, Adaptation, Versions.

1 Introduction

Opened Multi-Agent Systems (OMAS for short) is a hot research topic, which investigates the coordination of several agents in an open, dynamic and unstable context. These agents can dynamically built partnerships in which they hold different roles and they can join or leave this partnership at any time. A fundamental problem for OMAS is the coordination between agents which is an important challenge to guarantee the coherent and efficient behavior of agents of the modeled system and help them to converge to the common goal. Coordination in OMAS raises two main specific sub-problems which are: (i) the finding of partner's agents able to realize a requested service and (ii) the negotiation between agents. In this paper, we focus on the second sub problem. One possible way to deal with this negotiation is to use interaction protocols (IP). According to [1], an interaction protocol can be defined as a group of coordination rules that govern the behavior of the agents during their

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participation in conversations. These rules define, which, when and how the agents can interact in conversation. Indeed, the interaction protocols based negotiation is widely recognized as an efficient mechanism to evaluate and select the best provided service. Several works have been proposed in the literature for instance in [1, 2 and 3]. These research works consider protocols as entities of first class and address the engineering issue such as specification, validation and implementation of protocols for specifying and developing a multi-agent system in stable context. In this paper, we also consider IP as first class entities but to deal with negotiation in OMAS within an engineering perspective. Thus, the interaction protocols adaptation is needed in order to support the coherent interaction between agents involved in opened multi-agent system. In addition, the adaptation issue can be addressed according to the two complementary points of view. The first one concerns the management of problems (called exceptions) which can occur under the execution of protocols. The second point of view concerns the re-use and the modification out (i.e., at build time) and in progress of execution of the IP modeled. This point of view is based on meta-model aspect. One possible way to deal with IPs adaptation at build time is the use of versioned technique which captures all the predicable changes of the considered interaction protocol. More precisely, the paper tries to answer to the following questions:

- *What Interaction protocol Meta-model that we must adopt?*
- *How the version notion can help the IP schemas adaptation?*
- *How the context notion can help to describe the conditions use of interaction protocols versions?*

This paper defends the following idea: versioning is an interesting solution to deal with interaction protocols adaptation at build time. Indeed, this versioning technique has taken a considerable importance because it permits to keep trace of the previous versions of an entity, which supports the re-use of these versions if the same situation arises. Also, it allows the definition for the same entity several versions which can be used in an alternative way. This technique can be used with benefit to deal with IP adaptation issue. Each version of IP corresponds to the given situation. Versioning is used in several field of computer science in which is highlighted the need to describe evolution/changes of entities over time. Thus versions are used in databases [4], in data warehouse [5], in software engineering to handle software configuration [6] and in conceptual models such as the Entity Relationship or the OMT (Object Modeling technique) models [7, 8]. Moreover, the use of the context notion is not new. It was adopted in various research areas such as the web services [9, 10], the retrieval information [11] and the business process management [12], from where a state of the art at the same time rich and recent. It aims at solving the adaptation issue at build time using context notion. In this paper, we show how we use in combined way the version and context notions to deal with interaction protocols schemas adaptation at build time.

The contribution of this paper is threefold. First, it introduces a Versioned Interaction Protocol Meta-Model (VIP2M for short) to model the IP versions. Second, it extends the VIP2M by the contextual dimension in order to model the condition use (or strategy) of an IP version. Third, the paper proposes a running example to illustrate how we exploit the proposed solution.

The remainder of this paper is organized as follows. Section 2 introduces the VIP2M meta-model that we propose for interaction protocols versions modeling. Section 3 extends the VIP2M meta-model by adding the contextual dimension. Section 4 exposes a running example to illustrate the use of IP versions. Finally, we conclude the paper and underline the main perspectives.

2 The Versioned Interaction Protocol Meta-Model

The starting point of our contribution is the IP meta-model proposed in [13]. Indeed, we have studied in depth some existing IP meta-models [1, 13, 14, 15] based on three criteria that we have defined and namely, the usability, the simplicity and the completeness. The interested reader can find more information in [16].

2.1 Motivations for Using Versioning Technique

This section gives an answer to the following question: *in which case of interaction protocol adaptation versions are useful?*

The interaction protocol adaptation cases discussed here are inspired of works defended in [17, 18]. These works have proposed taxonomy of business process flexibility and we have adopted it to the context of interaction protocol because we believe that an interaction protocol can be viewed as process organized around coordinated actions to realize a given goal. More precisely, we resume the adaptation cases according two distinctive classes: adaptation a priori (i.e. at build time) and adaptation a posteriori (i.e. at run time). Regarding the first class, we can also distinguish two sub cases:

- Adaptation by design for handling predicable changes in IP where strategies can be defined at design-time to face these changes;
- Adaptation by under specification, for handling foreseen changes in IP where strategies cannot be defined at design-time but rather defined at run-time. As suggested in [19], a rule-based system could be used to select one of the modeled alternative versions at run-time. However, a rule-based system is a technical solution for the dynamic selection of an alternative version, and we believe that a conceptual solution, introducing a contextual model in modeled IP (as in [20] for business processes), could be richer to deal with this problem. We will explain later that the dynamic selection of an appropriate version of IP, in our context, is based on the context notion describing a set of rules. More precisely, this selection is made by a moderator agent (see section 4) based on the information submitted by the negotiation initiator.
- Adaptation by change, for handling unforeseen changes in IP, which require occasional or permanent modifications in IP schemas.

To our opinion, versions are a help to both adaptation by design, under specification and change. As for adaptation a posteriori, it is quite possible to define, using alternative versions, each possible execution path of the considered interaction protocol.

2.2 The Proposed Versioning Kit

The underlying idea of our proposition is to model, for each versionable class of the IP meta-model, both entities and their corresponding versions. According to [20], a versionable class is a class for which we would like to handle versions. The versioning kit (see figure 1) we use to make classes of the IP meta-model versionable is very simple: it is composed of two classes, four properties and two relationships.

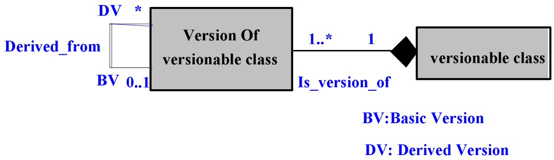

Fig. 1. The Versioning Kit [20]

Each versionable class is described as a class, called “Versionable class”. Moreover, we associate to each of versionable class, a new class, called “Version of”, whose instances are versions of the versionable class, and two new relationships: (i) the “is version of” relationship which links a versionable class to its corresponding “Version of” class; and (ii) the “derived from” relationship which describes versions derivation hierarchy. This latter relationship is reflexive and the semantic of both sides of this relationship are: (i) a version (BV) succeed to another one in the derivation hierarchy and, (ii) a version (DV) precedes another one in the derivation hierarchy. Thus, using this kit, it is both possible to describe entities and their corresponding versions. The creation of versions is managed as follows: (i) a couple (version, entity) is obviously created when the first version of an entity is created; and, (ii) new versions can be created by derivation of an existing version, giving rise to derived or alternative versions. Finally, regarding properties, we introduce the classical properties for versions ([19]) such as version number, creator name, creation date and status in the “Version of” class. No other additional properties are needed in each versionable class.

2.3 Merging the Versioning Kit with the Interaction Protocol Meta-Model

We use this versioning kit to make some classes of the IP meta-model versionable. The result is the Versioned Interaction Protocol (VIP2M) meta-model visualized in figure 2. We think that it is necessary to keep versions for four classes: the Protocol class, the ProtocolProfile class, the ProtocolBehavior class and the Role class. It is indeed interesting to keep changes history for these classes since these changes correspond to changes in the way that interaction protocol is carried out. At the protocol level, versions describe evolutions in profile and behavior. On the other side, at the profile level, versions of ProtocolProfile describe evolution in terms of properties and parameters (inputs and outputs).

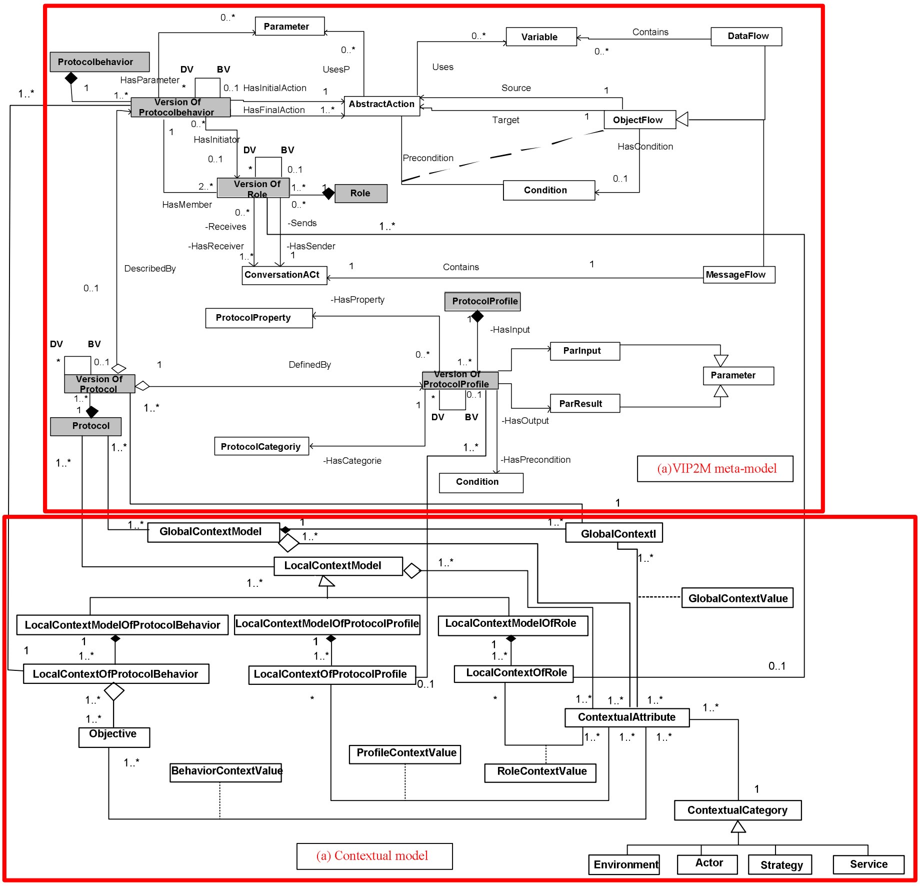

Fig. 2. The VIP2M meta-model

Regarding the versions of ProtocolBehavior, they describe the evolution of actions and roles. Finally, for the versions of Role they describe the different version of initiator and members involved in conversation due to the modification of Conversation Act. Figure 2 (a) below presents the new obtained meta-model in terms of classes and relationships.

3 The Contextualized Versioned Interaction Protocol Meta-Model

The proposed VIP2M meta-model permits to model different versions of the same interaction protocol. The question that must be resolved is: *What is the appropriate version of IP and that the agent is going to lunch the execution of IP instance among all the versions of an interaction protocol?*

To answer to this question, we present the contextual model and we show how we integrate it in the VIP meta-model in order to model the IP versions contexts.

3.1 The Proposed Contextual Model

The contextual model, Visualized in figure 2(b), defines the use conditions of IP versions. In our contribution, the contexts are viewed as first class entities and specified through two concepts: context model and context which corresponds to the instance of context model. A context model defines a set of contextual attributes describing the needed knowledge to the definition of context. A contextual attribute belongs to a specific category and takes a well determined value. More precisely, we distinguish four contextual categories: Environment, Service, Strategy and Actor.

Moreover, in this model, we distinguish two types of context models: global and local. The first one is devoted to the interaction protocol while the second is devoted to the protocol profile, protocol behavior or role. The global context model/local context model defines a set of contextual attributes describing knowledge necessary for the definition of global context/local context. Regarding the local context of protocol behavior, it is described around a set of objectives. Each one is defined on several contextual attributes. The value of contextual attribute in both global and local contexts is thus determined. Finally, we integrate the contextual model in the VIP2M meta-model in order to describe the IP versions contexts. More precisely, we associate the global context to the interaction protocol version. Regarding the local context, it is related to the version of protocol entity: protocolprofile, protocolbehavior and role.

4 Running Example

To better illustrate the use of contextualized IP versions, we give an example of opened multi-agent system titled online sales of the cars (see figure 3). The reason why it's an OMAS, firstly, the involved agents are distributed geographically (i.e., the seller and the buyers in our example). Secondly, they can join or leave the market at any time and consequently, the number of participants is not known a priori. More precisely, our OMAS is organized around three types of agents: seller, buyer and moderator. The Moderator is an agent which implements the negotiation protocol: it ensures that each conversation act of a conversation is consistent with the corresponding negotiation protocol. The moderator agent selects the appropriate version of an IP based on the information's submitted (i.e., the number of buyers is fixed and the time of negotiation is limited) by the seller describing a given context (i.e., the first version of the auction protocol of our example, step1). During the negotiation, the OMAS can evolve either by the arrival of new buyers or the departure of buyer. This new context requires the adaptation of the considered IP version by selecting another IP version (i.e., the second version of auction protocol, step2) that fulfills the new requirements (undefined buyers and unlimited negotiation time).

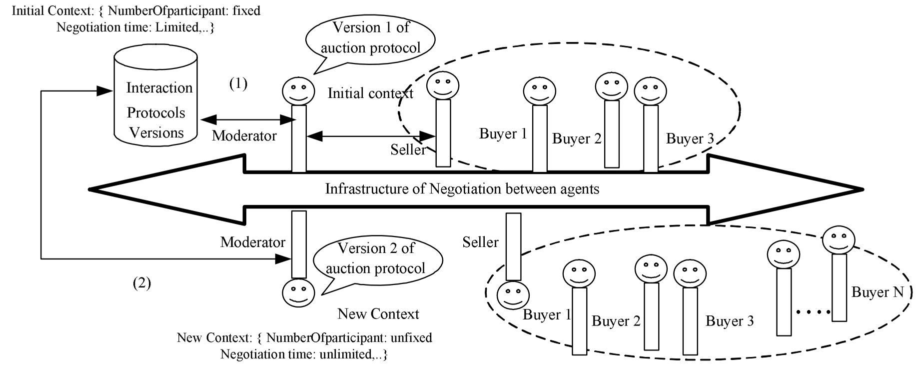

Fig. 3. The running example

5 Conclusion

In this paper, we have addressed the interaction protocol adaptation issue for negotiation in opened multi-agent systems. More precisely, we have proposed a VIP2M meta-model to describe the IP versions. In order to describe the use conditions of IP versions, we have extended the VIP2M meta-model with the contextual dimension. We have also given a running example to show how we exploit the modeled IP versions. We believe our solution is currently unique in trying to address the adaptation of interaction protocols at build time by using conjointly the version and context notions. Well articulated, these two notions permit to manage the IP adaptability. The version notion permits to keep track of the IP evolution. Regarding the context notion, it allows the definition of using conditions of IP versions. As future wok, we plan to propose a method allowing the dynamic selection of IP versions based on their context. To do this, we also plan to define an ontology of context to allow the implementation of filtering mechanism (comparison) which implement other thing that a simple equality.

References

1. Hanachi, C., Sibertin-Blanc, C.: Protocol Moderators as Active Middle-Agents in Multi-Agent Systems. In: JAAMAS, vol. 8(2), pp. 131–164. Springer (2004)
2. Mazouzi, H., Seghrouchni, A.E.F., Haddad, S.: Open protocol design for complex interactions in multi-agent systems. In: Proceedings of the AAMAS: Part 2, pp. 517–526. ACM, Bologna (2002)

3. Stephen, C., Martin, P.: Ontologies for Interaction Protocols. In: Proceedings of the Workshop on Ontologies in Agent Systems, AAMAS, Bologna, Italy (2002)
4. Bouaziz, R., Brahimi, Z.: Gestion des données temporelles dans un environnement multiversion de schemas. TSI 28(1), 39–74 (2009)
5. Zouari Turki, I., Ghozzi Jedidi, F., Bouaziz, R.: Constraints to manage consistency in multiversion data warehouse. In: Proceedings MIPRO 2012, pp. 1607–1612 (2012)
6. Kimball, J., Larson, A.: Epochs: Configuration Schema, and Version Cursors in the KBSA Framework CCM Model. In: Int. Workshop on Software Configuration Management, Trondheim, Norway, pp. 33–42 (1991)
7. Roddick, J., Craske, N., Richards, T.: A Taxonomy for Schema Versioning based on the Relational and Entity Relationship Models. In: Int. Conference on the Entity Relationship Approach, Arlington, Texas, USA, pp. 137–148 (1994)
8. Andonoff, E., Le Parc, A., Hubert, G., Zurfluh, G.: Context Aware Business Process Evaluation and Redesign. In: Int. Conference on the Entity Relationship Approach, Cottbus, Germany, pp. 472–487 (1996)
9. Mrissa, M., Ghedira, C., Benslimane, D., Maamar, Z., Rosenberg, F.: Sc. Dustdar.: A Context-based Mediation Approach to Compose Semantic Web Services. ACM TOIT 8(1) (2007)
10. Qiu, L., Chang, L., Li, F., Shi, Z.: Context optimization of AI planning for semantic Web services composition. Service Oriented Computing and Applications 1(2), 117–128 (2007)
11. Chaker, H., Chevalier, M., Soulé-Dupuy, C., Tricot, A.: Business Context Information Manager: An Approach to Improve Information Systems. In: Beigl, M., Christiansen, H., Roth-Berghofer, T.R., Kofod-Petersen, A., Coventry, K.R., Schmidtke, H.R. (eds.) CONTEXT 2011. LNCS, vol. 6967, pp. 67–70. Springer, Heidelberg (2011)
12. Matthias, W., Daniela, N., Frank, L.: Benefits of Business Process Context for Human Task Management. In: IACSIT vol. 2(4) (2011)
13. Bouaziz, W.: la coordination à base de Protocoles dans les Systèmes multi-Agents: Application au Workflow Inter-Organisationnel. Defended thesis at UT-1 (September 2010)
14. Tamma, V., Phelps, S., Dickinson, I., Michael, W.: Ontologies for supporting negotiation in e-commerce. Engineering Applications of Artificial Intelligence 18(2), 223–236 (2005)
15. Parsons, S., Rodriguez Aguilar, J., Klein, M.: Auctions and bidding: A guide for computer scientists. ACM Computing Surveys Journal (2011)
16. Chtourou, W., Bouzguenda, L., Gargouri, F., Laouar, R.: Using Versioning Technique for Interaction Protocol Adaptation in Opened Multi-Agent Systems. In: Opened Multi-Agent System. Proceeding of the 2nd ICSENT, Hammamet-Tunisia (December 2013)
17. Schoneneberg, H., Mans, R., Russell, N., Mulyar, N., van der Aalst, W.: Process Flexibility: A Survey of Contemporary Appraoches. In: Int. Workshop on CIAO/EOMAS, France, pp. 16–30 (2008)
18. Nurcan, S.: A Survey on the Flexibility Requirements related to Business Process and Modeling Artifacts. In: HICSS, Waikoloa, Big Island, Hawa, USA, p. 378 (2008)
19. Adams, M., ter Hofstede, A., Edmond, D., van der Aalst, W.: Worklets: A Service-Oriented Implementation of Dynamic flexibilty in Workflows. In: Proceeding of the OTM, Montpellier, France, pp. 291–306 (2006)
20. Bessai, K., Claudepierre, B., Saidani, O., Nurcan, S.: Context Aware Business Process Evaluation and Redesign. In: Int. Workshop on BPMDS, Montpellier, France (2008)

Modeling Negotiation as Social Interaction for ENS Design: The PROSPER Approach

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Abstract. The design of electronic negotiation systems should be sufficiently flexible to accommodate various types of mechanisms, as well as different roles of the participants. The current work relies on social interaction theory in order to propose design principles and a model for an ENS. The model is presented using a representational framework for IS meta-artifacts in the spirit of design science research. The features and functioning of the resulting system called PROSPER (a Platform Relying On Social Participation for E-market Realization) are presented.

Keywords: electronic negotiation systems, social interactions, design science research.

1 Introduction

The modeling of negotiation is very important in both classical negotiation studies and electronic negotiation systems (ENSs). Recently ENS designers have been putting significant efforts into this. For instance, the Invite system (invite.concordia.ca) focuses on modeling negotiations as state-based processes, which can be represented by various forms of protocols. Other research streams of ENSs focus on different aspects of negotiation, such as negotiation support, decision support, or agent-based negotiation. It would be beneficial for all these streams to have a general form that can be used to represent various types of negotiations. Consequently, modeling of negotiations becomes a core issue.

Although a general form of modeling negotiations is desirable, the associated challenges are also obvious. Negotiation as a robust and flexible mechanism has its theoretical roots in multiple disciplines. Whether we are able to obtain a general form for negotiation that can cover so many possibilities is questionable. However, it should be easier to obtain a form of negotiation models that can both help to abstract negotiation and organize most negotiation issues in a coherent manner. The current work attempts to propose a way to model negotiation as social interaction. Focusing on designing an ENS, the feasibility of this approach is demonstrated by presenting a system named 'PROSPER' (a Platform Relying On Social Participation for E-market Realization). In order to introduce the developed prototype system, a framework of representing meta-artifacts proposed by Vahidov [1] is adopted.

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2 Background

ENSs refer to a family of systems that facilitate and support negotiations involving two or more parties over internet [2, p363]. ENSs evolved mainly from two lines of research. The first line includes Decision Support Systems (DSSs) and Negotiation Support Systems (NSSs) [3]. The second line includes research for the design and development of groupware. ENSs are concerned with not only the support of individual negotiators, but also the collective interaction and decision making. The negotiation processes need to be facilitated, managed, and supported.

ENSs have roots in multiple disciplines. Negotiation research is an active research field, but this field itself is not paradigmatic. There is no overarching framework that is able to connect multiple lines of research in a coherent manner although negotiation is the focal phenomenon of interests. Historically, negotiation research disperse widely in multiple disciplines, including anthropology, social psychology, political sciences, economics, management, law and others [4].

ENSs are complex systems. There are at least two reasons that would account for the complexity of ENSs. ENSs consider a large volume of features and functions to be desirable, since its conceptualization refers to various types of systems. Kersten and Lai [2] identify four groups and 17 types of functions that have been found in the past research in ENSs.

New means to negotiate are still emerging. If we look at the evolvement of the research of negotiation and ENSs, the process reflects a trend that innovative means are continuously developed for negotiations (e.g., software agents).

3 Towards Unified View of Negotiations

In order to provide an effective design of ENSs, it is desirable to have a general view, which is fundamental enough to convey most aspects of negotiations. Past attempts included protocol design, mechanism design, and system architecture to just name a few [2, 5].

Roughly, the challenges of modeling negotiations come from four perspectives. First, negotiation has different types of compositions, particularly in terms of the relations and roles of participants. Second, negotiations may follow different processes. Third, participants confront different negotiation problems. Fourth, participants may join in a negotiation in different ways, e.g., with or without decision support, face-to-face or remote, and using software agents or human users. The requirements from the first two perspectives often prescribe desirable features of negotiation instances. In contrast, the last two mainly focus on the individual level. Such a division suggests that an effective modeling method of negotiation needs for successfully bridging the individual level issues with those on instance level or even higher levels.

It may be difficult to obtain a unified model that is able to integrate the extremely diversified negotiation aspects. It would be easier if we can abstract negotiation at the right level that allows the negotiation model to be further extended and diversified. Theory of social interaction is concerned with how individuals are connected with larger social structures and how they interact with each other in general. It was mainly developed from sociology, socio-psychology, and psychology [6]. Among its concepts, two notions, those of actor and role, are particularly useful in understanding how interactions take place.

Social interactions take place in instances. *Actor* is a notion that refers to the participants. Individual behaviors in social contexts are regulated by social structures, which are often shaped by laws, institutions, cultures, norms, relations, and many others. *Role* is a key component that connects individuals with social structure. By using the concepts of actor and role, we can depict a social interaction instance. These two notions also make it easier to model negotiation instance. For instance, an ENS can provide the overall facilities to manage the lifecycles of negotiation instances. Each instance can be configured with a group of actors. Actors can be deemed as proxy accounts associated with actual users who participate in an instance. Roles in the system can be conceptualized as containers holding a group of permissible behaviors of actors. To summarize, we can compose miniature social structures managed by ENS.

4 Design of the PROSPER System

By adopting the two key concepts of actor and role, we believe it would be easier to bridge the configurations of both negotiation instance and each individual participant. Vahidov [1] provided a structural framework that is useful to represent a meta-artifact. The current work adopted this framework to describe the meta-artifact and the prototype system named 'PROSPER'. This framework has three main dimensions, i.e., Simonian, Aristotelian, and Feyerabenian dimensions. The Simonian dimension includes four perspectives from which a meta-artifact can be described, i.e., analytical, synthetic, technological, and implementation. The Aristotelian dimension includes four categories, i.e., motivation, structure, behavior, and instantiation. The Feyerabenian dimension considers the alternative conceptualizations of a meta-artifact and is not considered here.

4.1 Analytical Layer

The focus of the analytical perspective is to represent the target meta-artifact in a set of relevant system characteristics and processes supported.

Motivation. Negotiation processes are often regulated by social rules, laws, and institutions. These elements of our social structure often prescribe a procedural discourse that requires the participants to comply. Good examples can be found in the research of mechanisms design and comparison of negotiations and auctions [7]. Each participating party of a negotiation instance is a placeholder that may accommodate multiple social actors in various means. Each participating party may be supported by various technologies and decision aides. From a system perspective, these are optional features. Overall, it would be desirable that an ENS has the following salient features:

- It robustly supports various compositions of negotiations.
- It supports multiple types of mechanisms, e.g., auctions or negotiations.
- It supports multiple means to participate in negotiations.
- It permits each party to use heterogeneous decision aids.

Structure. As mentioned earlier, communication support, and optional use of decision tools and agents are important for an ENS. However, they are often optional to negotiation and/or do not specifically characterize a type of system. The current work structurally delineates the relation between an ENS and negotiation instances. It argues that the following features are more salient in an ENS:

- The system can manage the life cycle of a group of negotiation instances;
- The system can robustly create negotiation instances for different configurations;
- Negotiation instances will be the units which could be used to bootstrap a large diversity of configurations for various negotiation types.

Behavior. Negotiation is often modeled as a process which can be decomposed into several stages. For instance, model of negotiation process involving three stages, i.e., pre-negotiation, negotiation, and the post-negotiation had been proposed [8, 9]. Conventionally a negotiation process is adopted as the key component managed by an ENS. In contrast, the current work argues that negotiation processes can be diversified and should not be the back-bone component managed by an ENS. Within the same negotiation instance, participants may follow heterogeneous processes. In our approach negotiation instance should is viewed as the back-bone component that bootstraps all configurations of other sub-components. In order to simplify the system structure, it will be helpful to restrict the main system function to managing the lifecycles of created negotiation instances. The aspects such as negotiation protocol, participation, and negotiation problem are configurable with each negotiation instance.

Instantiation. The PROSPER system adopts a popular design pattern, i.e., *configuration-deployment-execution*, to set the structural relation between the system and negotiation instances. The main managed components in PROSPER system is negotiation instance. Each negotiation instance bootstraps a group of components or features that are configured with it. The system also needs to manage several groups of meta-components that can be used to configure negotiation instances.

4.2 Synthetic Layer

Motivation. An effective method of modeling negotiation need to nicely resolve four types of issues that has been reviewed in the prior sections:

- The compositions of a negotiation instance are configurable;
- The adopted protocols or mechanisms of negotiation are configurable;

- The modes of participation of each party are configurable;
- The types of negotiation problems are configurable.

Structure. The two notions of actor and role have been noted to be useful to model negotiation. They will help to bridge the configuration between instance and individual participants. Details about how to instantiate these two notions in the design will be discussed.

First of all, a design pattern, actor, can be adopted to represent the participating actors in negotiation. Each negotiation instance will include an instance actor and multiple regular actors. The regular actors represent a proxy account of the actual participants. The instance actor is used to control the process and status of negotiation instances. Each regular actor maintains a private roster of its permissible contacts, i.e., other actors. The actors can send message only to these actors included in its roster. The design pattern of actor helps the system to model a negotiation instance as a miniature social structure, within which social actors can be connected in the desirable ways. Figure 1 shows an example of configuring a negotiation instance.

Behavior. The generic process to create negotiation instances is introduced in the prior sub-section of analytical perspective. Technically, the system must manage a group of components that could be used in different negotiation instances in order to support the bootstrap process of negotiation instance. The number of managed meta-components should not be limited. Creating an object from meta-data is a frequently used method to initialize a live component. The creation of live components often involves a factory design pattern. When a component is required, the system will first find the right factory for the component by its type. Afterwards, the system can feed the factory with meta-data and then obtain the desired live component from it. The factory takes care of the process of creating parts and assembling all the pieces into a live object that can be used.

Instantiation. According to the adopted representational framework different layers may relate to different projects, e.g. synthetic vs. technological. In our case, however, a single artifact has been developed, and its “instantiation” will be presented in the next section.

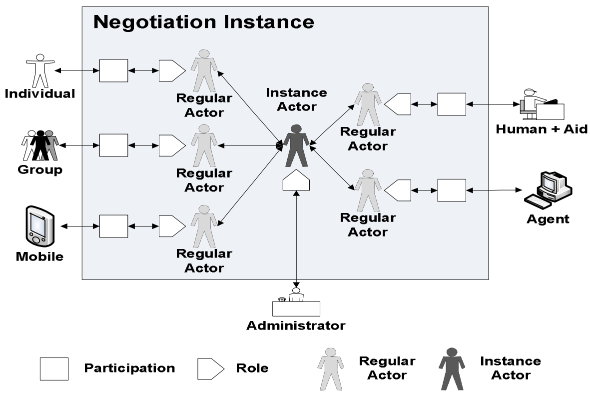

Fig. 1. Configuring a negotiation instance

4.3 Technological Layer

Both the analytical and synthetic perspectives deal with much with theoretical and conceptual content of a meta-artifact. The feasibility of the meta-artifact needs to be in line with more concrete or available materials, solutions or technologies. These issues need to be addressed from the technological perspective.

Motivation. Multiple objectives can be desirable from technological perspective. Optimality and efficiency are two frequently used criteria when building a system. The motivation behind the PROSPER system from the technical perspective is to use available frameworks, components, and software when building the system.

Structure. The PROSPER system uses Grails (http://www.grails.org) as its main framework in its development. Grails is a well-established web application framework. It supports both Java and Groovy as its main programming languages. Underlying the framework is the industrially tested frameworks of Spring (http://spring.io) and Hibernate (http://www.hibernate.org). Spring is famous for its robustness and flexibility to configure and provide beans by using the inverse of control techniques. Hibernate is an effective tool for object/relational mapping. A software package of Groovy parallel system, i.e., GPars (http://gpars.codehaus.org/) is used to implement the design pattern of actor. Activiti (http://www.activiti.org/) is used to be a business process engine. jQuery and jQuery UI (http://jquery.com/) are used on top of Groovy Server Pages shipped with Grails to enhance the usability.

The PROSPER system supports two types of users, i.e., administrators and regular users. Regular users are those who will participate in a negotiation instance. The system provides a set of system administration functions for administrators. Using these functions, an administrator can manage meta-components, create and deploy negotiation instances, and monitor the execution of negotiation instances. The creation of negotiation instances from meta-components is based on meta-data, including text and database. All actor objects are registered with the interaction service. All participation objects are registered with the participation service. Each of these two services holds a map, with which the names can be used to index the objects. The system structure is shown in figure 2.

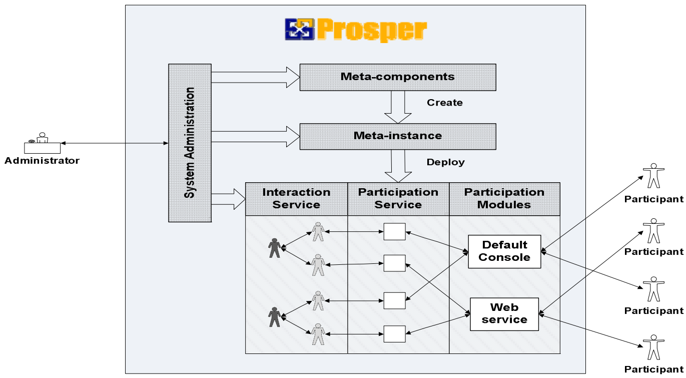

Fig. 2. The system structure of the PROSPER system

Behavior. The PROSPER system uses both database and text to store meta-data used to dynamically create objects. Text-based meta-data are saved in the form of JSON (JavaScript Object Notation, http://json.org). A software package is adopted to serialize objects into to JSON text. An example of the JSON text is presented in Figure 3. The text is a snippet of instance template. It includes some meta-component names that can be used by the system to iteratively look up the right classes, create components, assemble parts into an instance, and then set the parameters according to the meta-data. Each registered meta-component will have a name associated with a factory. The deserializaton process will use these names to look up factories and then produce the live objects. In addition to meta-component names, both businessCaseName and problemSpaceType are important fields that will determine which and what type of individual problem space will be created for individual participants.

```
{
"metaInstanceActorName": "defaultAlternativeOfferInstanceActor",
"businessCaseName": "TestingBilateralExample",
"params": "{heartBeatsPerRound:30}",
"participants": [
 {
  "name": "seller2",
  "metaParticipantActorName": "defaultAlternativeOfferParticipantActor",
  "participantParams": "{ }",
  "metaParticipationName": "AO_DEFAULT",
  "participationParams": "{heartBeatsPerResponse:3,
                          problemSpaceType:ADDITIVE_COMPENSATORY,
                          concessionCoefficient:0.5,
                          baseValue:0.2}",
  "caseParticipantName": "seller2",
  "contacts": "buyer1,buyer2",
   "side": "seller"
 },
 …
]
}
```

Fig. 3. An example of template for instance configuration

Instantiation. The PROSPER system has been implemented based on the social interaction theory. While detailed description would require much more space than allowed for this paper, Figure 4 shows an example negotiation instance and demonstrates some management functions of the PROSPER system.

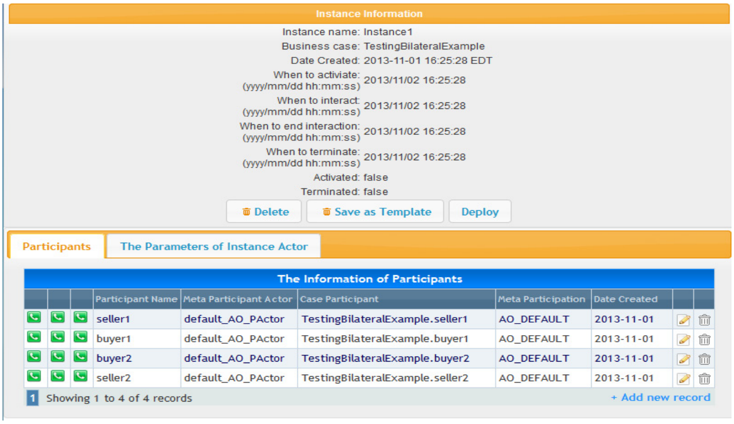

Fig. 4. The instance management functions of the PROSPER system

5 Conclusion

The modeling of negotiation is important as it may influence both how we see negotiation and how we can manage it. By borrowing two key notions, i.e., actor and role, from social interaction studies, the current work proposes an approach to model negotiation as social interaction. The notions of actor and role help to abstract negotiation into instances, which are able to bootstrap a diversity of configurations. By doing so, the functions of a ENSs can be simplified to focusing on the management of negotiation instances and related reusable meta-components.

References

1. Vahidov, R.: Design-Type Research in Information Systems: Findings and Practices. Information Sciences References (2012)
2. Kersten, G., Lai, H.: Electronic Negotiations: Foundations, Systems, and Processes. In: Kilgour, D.M., Eden, C. (eds.) Handbook of Group Decision and Negotiation, vol. 4, pp. 361–392. Springer, Netherlands (2010)
3. Kersten, G., Lai, H.: Negotiation Support and E-negotiation Systems: An Overview. Group Decision and Negotiation 16, 553–586 (2007)
4. Bichler, M., Kersten, G., Strecker, S.: Towards a Structured Design of Electronic Negotiations. Group Decision and Negotiation 12, 311–335 (2003)
5. Lomuscio, A.R., Wooldridge, M., Jennings, N.R.: A classification scheme for negotiation in electronic commerce. Group Decision and Negotiation 12, 31–56 (2003)
6. Kando, T.M.: Social interaction. The C. V. Mosby Company, Saint Louis (1977)
7. Kersten, G.E., Chen, E., Neumann, D., Vahidov, R., Weinhardt, C.: On Comparison of Mechanisms of Economic and Social Exchanges: The Times Model, Dagstuhl. Dagstuhl Seminar: Negotiation and Market Engineering (2006)
8. De Moor, A., Weigand, H.: Business Negotiation Support: Theory and Practice. International Negotiation 9, 31–57 (2004)
9. Kersten, G.E., Noronha, S.J.: WWW-based negotiation support: design, implementation, and use. Decision Support Systems 25, 135–154 (1999)

SAW-Based Rankings vs. Intrinsic Evaluations of the Negotiation Offers – An Experimental Study

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Abstract. In this paper we discuss the issue of evaluating the negotiation offers represented in a form of the complete packages and the negotiators' consistency in scoring such packages. We analyze the results of an experiment, in which the negotiators were asked to build the ranking of fourteen negotiation offers and then compare it with two predefined rankings obtained by means of SAW method. We verify how do the negotiators evaluate these SAW-based rankings and how they correspond to the negotiators' intrinsic ones. We discuss then both the negotiators' consistency in defining their preferences and the applicability of some formal methods in supporting them in such a definition.

Keywords: preference analysis, preference consistency, negotiation offer scoring system, unfolding analysis, SAW.

1 Introduction

Negotiation is a decision making process, in which at least two parties talk with one another in effort to resolve their opposing interests. Usually the negotiation involves a number of issues that needs to be discussed, so the decision problem that is faced by the negotiators is of multiple criteria. Therefore the negotiations are often supported by various multiple criteria decision making (MCDM) methods [2; 9; 11]. These methods are used to elicit the negotiator preferences and build the negotiation offer scoring system that helps negotiator to evaluate qualitatively the offers submitted during the negotiation process. The most popular MCDM technique widely used for eliciting the negotiators' preferences is the simple additive weighting (SAW), that stems from the fundamental notions of the multi-attribute value theory (MAVT) [5], and allows to build a value function over the negotiation issues and their options [7; 11]. However, one drawback of the SAW is, that while eliciting the preference it requires of the negotiator to assign the numerical scores directly to all the evaluated resolution levels within the negotiation template. Yet, the negotiators may not know how to interpret these scores and therefore misuse them while assigning them to the issues and options [4; 12]. Consequently, it may lead to the inconsistency between the

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evaluations generated by the scoring system obtained by means of SAW, and the subjective intrinsic preferences of the negotiators. There are some research studying the use and usefulness of SAW in negotiation support or the consistency of SAW rankings depending on various normalization procedures [3; 6], however, they do not focus on analyzing the if the SAW-based scoring systems are coherent and consistent with the negotiators intrinsic preferences.

This paper is a part of the bigger scientific project that focuses on building a new negotiation support system and identifying the formal tools for supporting the process of negotiation template design and evaluation in the ill-structured negotiation. In our earlier works we studied the usability of TOPSIS and fuzzy TOPSIS methods [8]. Here, we try to evaluate experimentally if the SAW algorithm can be effectively used as a supportive tool in describing precisely the negotiators' preferences. We use two SAW-based procedures, that differ in normalizing the issues' resolution levels. They are implemented to ease the process of analyzing the negotiators preferences by automatic generation of the options' ratings. The main goal of this paper is twofold: (1) we aim to analyze the usefulness of these two alternative SAW algorithms in generating the rankings of the negotiation offers, that we could use in developing the assessment capabilities of our NSS; and (2) we want to verify the consistency of the negotiators' evaluations of the SAW-based predefined rankings with their own rankings based on their intrinsic preferences and generated previously without any support mechanism.

The paper consists of three more sections. In section 2 we present these two alternative SAW algorithms we used for scoring the offers. In section 3 we describe the experiment we organized to verify the usefulness of SAW-based rankings and the consistency of the negotiators' preferences, while in section 4 we analyze the experimental results.

2 Two Alternative SAW Algorithms for Ranking the Offers

To release the negotiators from the tiresome process of evaluating the negotiation template we predefined two mechanisms for automatic scoring based on SAW. We used two scoring functions A and B that differ in the normalization procedures implemented to obtained the standardized values of issues' options, regarded as the options' ratings. The standard normalization formulas, different for benefit and cost issues, are used [10]. For scoring function A the normalization of the options of the benefit (cost) issue was conducted according to the following formula

$$z_{ij} = \frac{x_{ij}}{x_j^{asp}} \left(z_{ij} = \frac{x_j^{res}}{x_{ij}} \right), \tag{1}$$

where: x_{ij} is the option of the jth issue in the ith offer that is to be normalized, x_j^{asp} (x_j^{res}) is the negotiator's aspiration (reservation) level for the jth issue.

In the scoring function B the formulas for benefit (cost) issues are

$$z_{ij} = \frac{x_{ij} - x_j^{res}}{x_j^{asp} - x_j^{res}} \quad \left(z_{ij} = 1 - \frac{x_{ij} - x_j^{res}}{x_j^{asp} - x_j^{res}} \right). \tag{2}$$

These two scoring functions are implemented in the SAW algorithm, in which the aggregation function S assigns to each negotiation package P_i a score, being the linear combination of the vector of issues' and the normalized option values:

$$S(P_i) = \sum_j w_j \cdot z_{ij} \,, \tag{3}$$

where w_j is the weight of *j*th issue.

It should be noted, that in the scoring function B the global score of any package P_i that is comprised of the options worse than aspiration and better then reservation levels is in the range $\langle 0;1 \rangle$, while for scoring function A the range of the scores is not unitarized but depends on the aspiration and reservation packages defined in the negotiation template.

3 Experimental Setup

In our experiment, organized as an in-class assignment, eighty undergraduate students of international business and computer science took part. They fit the profile of the future users of our NSS, which is being designed to support the business negotiation/e-negotiation (e.g. in procurement). However, since no research has already been conducted to identify the characteristics of the true NSS users, we cannot conclude on the representativeness of the group of our responders.

The participants were asked to play the role of the negotiators and to conduct a prenegotiation analysis in the multiple issue business negotiation problem. They were presented the negotiation template, in which fourteen feasible negotiation packages were identified, each described by means of three negotiation issues, i.e. price, time of delivery and time of payment (Table 1).

Table 1. The negotiation template and the general preference information

Issue	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
1. Price (USD)	20	20	20	20	20	20	22	22	22	25	25	25	25	25
2. Time of delivery (days)	2	2	7	7	14	14	2	7	14	2	7	7	14	14
3. Time of payment (days)	3	20	3	20	3	20	7	20	7	7	3	7	3	20

For each issue the reservation and aspiration level was predefined: $x^{res} = (18, 2, 21)$ and $x^{asp} = (30, 20, 1)$, as well as the issues' importance was fixed (vector of weights $w = (0.8, 0.1, 0.1)$).

Each participant was asked then to build a strict ranking of the packages, taking into account the general preference information (assigning the rank of 1 to the most preferred package, and the rank of 14 to the least preferred one). Next the participants were proposed two alternative SAW-based rankings, obtained by means of the scoring functions A and B (see formulas 1-3). These two rankings, together with the accompanying ratings are shown in Table 2.

Table 2. The rankings and ratings of the packages for the SAW-based scoring system

Package	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}
							Scoring function A							
Rank	12	14	11	13	7	10	9	8	6	5	3	4	1	2
Rating	0.577	0.548	0.602	0.573	0.637	0.608	0.611	0.627	0.671	0.691	0.735	0.716	0.770	0.742
							Scoring function B							
Rank	11	14	10	13	9	12	7	8	6	5	2	3	1	4
Rating	0.223	0.138	0.251	0.166	0.290	0.205	0.337	0.299	0.403	0.537	0.584	0.564	0.623	0.538

Having analyzed the above rankings the participants had to evaluate each of them by assigning the score reflecting the ranking usefulness in ordering of the package according to their individual preferences. For the evaluation an ordinal 5-point scale was used (1 – very good, 2 – good, 3 – average, 4 – poor, 5 – very poor).

4 Results

4.1 Participants' Individual Rankings

There are 14! different rankings that may be identified for fourteen packages, however, in our experiment the negotiators built 60 of them: 47 orderings were unique (declared by one negotiator only), while 13 were repeated in declarations of at least two negotiators. The most frequently used (7 instances) was the ranking of the same order to the one obtained by means of scoring function B. These numbers may suggest that the respondents differ a lot in setting the ranks. To verify, if the dispersion of the individual evaluations over the ranks of each package is big, we conduct the unfolding analysis [1].

Analyzing the unfolding graph (Fig. 1) we see, that the numbers representing our respondents are clustered around the (0,0) point (an "ideal point"), which means that their rankings (vector of ranks) are quite a similar (the distances between them are short). To verify the high degree of agreement among the negotiators we determined the Kendall's W coefficient of concordance, obtaining $W = 0.8046$. The significance of the concordance measured by W was tested using the value of chi-square statistic

$$\chi_r^2 = m(n-1)W = 836.78, \tag{4}$$

where m is a number of respondents, and n – the number of packages.

For $\alpha = 0.0001$ and $m-1 = 79$ df we obtain $\chi_\alpha^2 = 134.49$, thus $\chi_r^2 > \chi_\alpha^2$. Hence, we may reject the hypothesis on the independence of the respondents' individual rankings, i.e. they rankings seem to be similar and quite homogenous.

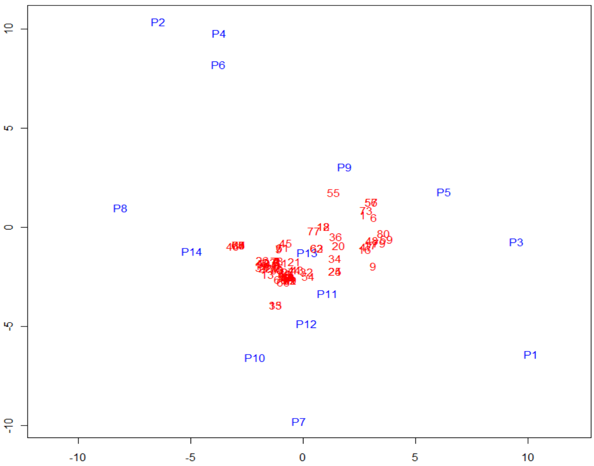

Fig. 1. The results of the unfolding analysis for negotiators (numbers) and packages (P_i)

This result indicates an important issue that should be taken into consideration while designing the assessment capabilities of NSS. Namely, the individual preferences of negotiators may be sometimes approximated by means of a group profile reflecting the ranking that describes a representative evaluation of packages within a particular group of negotiators. Such a group profile may be constructed on the basis of the unfolding graph too. As it is depicted in Fig. 1 the closest to the ideal point is the package P_{13}, the second closest is P_{11}, then P_{12}, P_{14}, $P_{9,}$ …. The graph indicates however, that the individual rankings differ, and, for instance, the negotiator number 55 considered the package P_9 to be the best (the distance between the point represented the negotiator 55 and P_9 is shorter than to any other P_i), while for the negotiator 35 the best is P_{12} and then P_{11}. Naturally, a group profile may be determined by using other notions too, e.g. the average or dominant ranks. What is interesting here, the dominant-based ranking is the same to the one obtained by means of scoring function B.

4.2 SAW-Based Rankings and Their Evaluation

We compared then the respondents' individual rankings with the ones obtained by means of scoring functions A and B and analyzed, how had the respondents evaluated the usefulness of these two functions. Scoring function A was evaluated positively (as being very useful or useful) by 40 participants (50%), while scoring function B – by 44 of them (55%). There was also very low percentage of the respondents that negatively evaluated each of these functions. The details of the scoring functions evaluations are presented in Table 3. Despite the high percentage of positive evaluations we decided to analyze how the rankings evaluations (o_A and o_B for ranking A and B respectively) correspond with the ones individually built by respondents at the beginning of the experiment. We used the Spearman's rank correlation coefficient (r_s) to measure the consistency of the respondents preference definitions with the predefined ranking A (r_{SA}), and the ranking B (r_{SB}).

Table 3. Distribution of the scoring function evaluations

Evaluation (o)	Scoring function A				Scoring function B			
	No. of respondents	Min $r_{SA}(k)$	Max $r_{SA}(k)$	Avg. $r_{SA}(k)$	No. of respondents	Min $r_{SB}(k)$	Max $r_{SB}(k)$	Avg. $r_{SB}(k)$
1 – very good	17	0.530	1.000	0.864	20	0.490	1.000	0.918
2 – good	23	0.591	0.982	0.881	24	0.466	1.000	0.868
3 – average	32	0.486	0.969	0.863	25	0.578	1.000	0.866
4 – poor	3	0.763	0.965	0.903	10	0.525	0.987	0.882
5 – very poor	5	0.648	1.000	0.909	1	0.618	0.618	0.618

As shown in Table 3, there are examples of evaluations that cannot be considered as reliable, e.g. there are respondent(s) that evaluated ranking A as very poor, however it is highly coherent with their own ranking they prepared on the basis of their preferences (maximum r_{SA} in this group is 1.0, while an average $r_{SA} = 0.909$). Therefore we defined 5 different types of inconsistency that may appear in our research for each of participants. We will consider the preferences of *k*th respondent to be inconsistent according to:

- Type I if: ($o_A(k) \in \{1,2\}$ and $r_{SA}(k) \in (0.4;0.7\rangle$) or ($o_B(k) \in \{1,2\}$ and $r_{SB}(k) \in (0.4;0.7\rangle$);
- Type II if: ($o_A(k) \in \{4,5\}$ and $r_{SA}(k) \in (0.9;1.0\rangle$) or ($o_B(k) \in \{4,5\}$ and $r_{SB}(k) \in (0.9;1.0\rangle$);
- Type III if: $o_A(k) = o_B(k)$ and $r_{SA}(k) \neq r_{SB}(k)$;
- Type IV if: $o_A(k) \neq o_B(k)$ and $r_{SA}(k) = r_{SB}(k)$;
- Type V if: ($o_A(k) < o_B(k)$ and $r_{SA}(k) < r_{SB}(k)$) or ($o_B(k) < o_A(k)$ and $r_{SB}(k) < r_{SA}(k)$).

Having analyzed the dataset we found the inconsistencies of at least one type for 42 respondents (52%), for 15 of them two types of inconsistency were identified at a time. The histogram in Figure 2 shows the numbers of the inconsistencies within each type defined above. The highest number of inconsistencies was observed for the Type V (32 respondents). It was exactly half of them (16 respondents) who considered ranking A to be better than B, however B was more similar to their own subjective ranking; while the remaining 16 respondents reckoned quite the opposite – that B is better than A despite $r_{SB}(k) < r_{SA}(k)$. There were 12 participants whose evaluation was classified as the inconsistency of Type II: six of them considered ranking A as poor or very poor, while the Spearman coefficient for their own evaluation compared to ranking A was extremely high ($r_{SA}(k) \in (0.9;1.0\rangle$), the remaining six of them revealed similar inconsistency in evaluation of ranking B. Another 8 participants revealed the inconsistent evaluations of Type I: five of them regarded ranking A to be very good or good, while the Spearman coefficient proved very weak correlation of this ranking and the their own one ($r_{SA}(k) \in (0.4;0.7\rangle$); the remaining three evaluated ranking B positively, while it does not fit their own one too much.

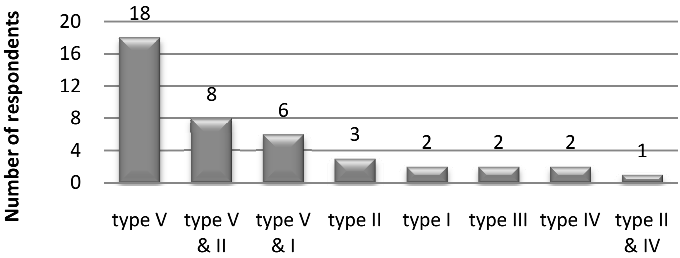

Fig. 2. Number of inconsistent respondents within each type of inconsistency

5 Conclusions

In this paper we analyzed the usefulness of SAW in defining the rankings of the negotiation offers and their consistency with the negotiators' preferences. The experiment we conducted was to prove the applicability of the SAW algorithm in the precise elicitation of the negotiator's preferences that could be used in the NSS we aim to design and implement. We found that:

- The SAW-based scoring systems, despite their disadvantages raised by some researchers [4; 12], are acceptable by the majority (from 50% to 55%) of the potential negotiators, who evaluate them positively as being good and useful tools (which confirms some earlier research [6]).
- More than half of the negotiators (52%) are inconsistent in evaluating and choosing the SAW-based rankings that fit their preferences. Most frequently the negotiators evaluated as a more useful (better) a particular predefined ranking that was more different from his own subjectively defined one (32 respondents). It questions SAW based scoring systems as being the tools that precisely describe the intrinsic preferences of the negotiators.
- The SAW-based rankings may be useful, however, if the group profile of the preferences should be determined to represent the negotiator's individual preferences. The ranking obtained by means of the scoring function B is the same to the one obtained by means of dominant rank in our group of the respondents, and is also very similar to the one determined by means of average ranks in the group.
- The unfolding analysis may be an effective tool that would allow to identify the groups of negotiators of the similar preferences and define their group profile ratings. Such an analysis may be applied for facilitating the process of preference elicitation in negotiation support systems operating on the electronic markets. Instead of following the tiresome and complicated algorithm of building an individual scoring system the negotiator's bargaining profile may be determined (e.g. using his business, psychological and demographical characteristics) and then the scoring system may be automatically suggested to the negotiator using the average or dominant ratings defined by other negotiators of similar profile in previous negotiations.

Our experiment proves that the problem of defining preferences, even for such a simple negotiation problem that consist of fourteen packages only, requires a special consideration and some support techniques that will explore the preferences in detail and result in scoring systems consistent with the negotiators intrinsic preferences. The classic SAW does not seem to be an effective tool here. It may be, however, that some modifications will improve the SAW-based approach in building the reliable and sound negotiation offers scoring systems. In our future work we will focus on testing the use and usefulness of the fuzzy SAW and developing its extensions, which would allow for determining the scoring system most coherent with the negotiators subjective and intrinsic preferences.

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References

1. Bennett, J.F., Hays, W.L.: Multidimensional unfolding: Determining the dimensionality of ranked preference data. Psychometrika 25(1), 27–43 (1960)
2. Brzostowski, J., Roszkowska, E., Wachowicz, T.: Multiple Criteria Decision Making Methods in Negotiation Support. Optimum 5(59), 3–29 (2012)
3. Chakraborty, S., Yeh, C.-H.: A simulation based comparative study of normalization procedures in multiattribute decision making. In: Proceedings of 6th Conference on 6th WSEAS Int Conf on Artificial Intelligence, Knowledge Engineering and Data Bases, Citeseer, pp. 102–109 (2007)
4. Forman, E.H., Selly, M.A.: Decision by Objectives. World Scientific Publishing, Singapore (2001)
5. Keeney, R.L., Raiffa, H.: Decisions with multiple objectives: preferences and value tradeoffs. Wiley, New York (1976)
6. Kersten, G.E., Noronha, S.J.: WWW-based negotiation support: design, implementation, and use. Decis. Support Sys. 25(2), 135–154 (1999)
7. Raiffa, H., Richardson, J., Metcalfe, D.: Negotiation analysis: The science and art of collaborative decision making. The Balknap Press of Harvard University Press, Cambridge (2002)
8. Roszkowska, E., Brzostowski, J., Wachowicz, T.: Supporting Ill-Structured Negotiation Problems. In: Barzdins, J., Bjorner, D. (eds.) Baltic Computer Science. LNCS, vol. 502, pp. 339–367. Springer, Heidelberg (1991)
9. Salo, A., Hämäläinen, R.P.: Multicriteria decision analysis in group decision processes. In: Handbook of Group Decision and Negotiation, pp. 269–283. Springer (2010)
10. Tzeng, G.-H., Huang, J.-J.: Multiple attribute decision making: Methods and applications. CRC Press (2011)
11. Wachowicz, T.: Decision support in software supported negotiations. J. Bus. Econ. 11(4), 576–597 (2010)
12. Wachowicz, T., Wu, S.: Negotiators' Strategies and Their Concessions. In: de Vreede, G.J. (ed.) Proceedings of The Conference on Group Decision and Negotiation 2010, pp. 254–259. The Center for Collaboration Science, University of Nebraska at Omaha (2010)

Making Sense of Intransitivity, Incompleteness and Discontinuity of Preferences

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Abstract. The starting point of modern social choice theory is the assumption that is the individuals are endowed with complete and transitive preference relations over the set of alternatives. Over the past 60 years a steady flow of experimental results has suggested that people tend to deviate from principles of choice stemming from the utility maximization theory. Especially in choices under risk, this behaviour is quite common. More importantly, this behaviour makes intuitive sense. The usual culprit, i.e. the source of this "deviant" behaviour, is most often found in the violation of transitivity or – under risk – of the monotonicity in prizes principle. We show that there are grounds for arguing that even the completeness principle as well as continuity of preferences may, quite plausibly, be violated.

1 Introduction

When faced with a choice between two options, say x and y, it is in a way natural to choose x if one prefers x to y. If the preference is known not only to the chooser but also to another person observing the choice, it is unlikely that the latter person is puzzled by the choice. Once the preference is known no further information is needed to explain the choice behaviour or to make it intelligible. Choosing the preferred option can be viewed as utility maximization in a straight-forward sense: since the preferred option possesses higher value to the chooser (by definition), then the observed behaviour clearly amounts to maximizing the value (utility) to the chooser. Extending this principle to situations involving more than two options requires more conditions on preference relations than completeness that is implicitly assumed above: for any two options, either one is preferred to the other or the other way around. Obviously, if there is no preference, the observed choice behaviour cannot be seen as utility maximization. With three or more options, the assumption of complete preference relations is not enough to characterize choice behaviour as utility maximization: it may well be that x is preferred to y, y preferred to z and z preferred to x. Hence, whichever option is chosen, there is an option that is preferred to the chosen one. Hence, the utility value of the chosen option is not maximal. A way to salvage the maximization principle is to impose the condition of transitivity

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on preference relations: for any three alternatives x, y and z, if x is preferred to y and y is preferred to z, then it must be that x is preferred to z.

Completeness and transitivity of individual preference relations have become the standard assumptions in decision theory (von Neumann and Morgenstern 2007; Savage 1954). Indeed, under certainty they guarantee the existence of a utility function that represents individual preferences and render preference-consistent behaviour equivalent to utility maximization. Under risk and uncertainty similar representation theorems have been proven, each including completeness and transitivity among the conditions guaranteeing the utility maximization (see e.g. Harsanyi 1977).

From its early days the utility maximization view (UM view, for short) has been challenged by experimental and other empirical evidence suggesting that choice behaviour often deviates from the principles of UM view. Since the representation theorems are not empirical findings but mathematical truths, the source of UM violations has been sought in the principles imposed on preference relations. The earliest violations were observed in choice behaviour under risk, i.e. situations where the experimental subjects make choices among lotteries or risky prospects involving probability mixtures of payoffs. Allais conducted experiments in the 1950's showing that not only do the subjects often deviate from the principles of UM view, but they do it in a systematic manner (see Allais 1979). Somewhat later Kahneman and Tversky built a theory of choice, prospect theory, on the foundations of what they saw as systematic deviations from UM view. They were followed by other similar constructs that aim at making sense of UM deviant regularities in empirical choice behaviour (e.g. Gilboa and Schmeidler 2001; Machina 1982).

In the following we first give a brief overview of the main types of UM violations discussed in the literature. It turns out that most of them are related to choices under risk or uncertainty. Moreover, the explanation of these types of violations is usually sought in the violation of monotonicity in prizes of risky prospects. Our aim to show that violations make sense in simpler settings, viz. under certainty, where cyclic preferences can be expected to emerge in multicriterion settings. Our main aim, however, is to show that UM view may fail in even simpler situations, viz. those involving only two alternatives. Since transitivity is not relevant in these circumstances, the culprit must be the completeness condition. We show by way of toy examples that under some circumstances it is plausible to expect that individual preference relations are not complete in the sense that an individual may quite plausible strictly prefer x to y and y to x. This could be viewed as a sort of explanation of the well-known preference reversal phenomenon (Lichtenstein and Slovic 1971).

2 A Review of Some UM Violations under Risk

The first serious attack on the UM theory was launched by Maurice Allais and carries nowadays the title of the Allais paradox. In his early experiments Allais confronted his subjects with the following pair of choices: (i) choose either r_1 or r_2, and (ii) choose either r_3 or r_4. All options except r_1 are risky. For example, r_2 is an option that results in payoff $5,000,000$ monetary units with probability 0.1, in payoff $1,000,000$ with probability 0.89 and in payoff 0 with probability 0.01.

$$r_1 = (1,000,000, 1.0)$$
$$r_2 = (5,000,000, 0.10; 1,000,000, 0.89; 0, 0.01)$$

$$r_3 = (5,000,000, 0.10; 0, 0.90)$$
$$r_4 = (1,000,000, 0.11; 0, 0.89)$$

Allais found that the majority of his subjects chose r_1 in (i) and r_3 in (ii). The majority choices contradict the UM theory regardless of the utility value assigned to the monetary values. To be more precise, the majority choice behaviour shows that they do not maximize the expected utility when choosing from risky prospects.

Some years later Ellsberg (1961) made somewhat similar observations. His setting, however, involves uncertainty, i.e. partially unknown probabilities of outcomes. The experimental subjects again make choices from two pairs of options: (i) either 1 or 2, and (ii) between 3 and 4. There are 90 balls in an urn. It is known that 30 of them are red, while the remaining 60 are either white or blue in unknown proportion. Option 1 gives the chooser \$100 if he draws a red ball from the urn, and nothing if the ball is either white or blue. Similarly for other options.

	colour (and number) of balls		
	red	white or blue (60)	
options	(30)	white	blue
1	\$100	\$0	\$0
2	\$0	\$0	\$100
3	\$100	\$100	\$0
4	\$0	\$100	\$100

Now, Ellsberg found that "[m]any people would choose 1 over 2, but 4 over 3. …[this] choice behaviour is clearly inconsistent with EU [expected utility] theory". Indeed, regardless of which utility values one assigns to payoffs, the type of behaviour cannot be of UM nature.

Strictly speaking, the experiments of Allais and Ellsberg do not address directly the completeness or transitivity assumptions of UM theory. Rather they purport to show – and, indeed, succeed in doing so – that the behaviour reported cannot be reconciled with one that ensues from EM *and* the assumption that people assign risky prospects utility values that are weighted averages of the utility values of the possible outcomes with weights equal to the probabilities of those outcomes. So, in principle it is possible that people do engage in UM, but resort to different utility calculus than the one envisaged in EU theory. Since in addition to completeness and transitivity only monotonicity in prizes is needed to render choice behaviour that follows preferences representable as EU maximizing (Harsanyi 1977), one of the three "axioms" (completeness, transitivity, monotonicity in prizes) has to the source of EU deviant behaviour. Most of the time since Allais' and Ellberg's experiments, the primary suspect has been the monotonicity in prizes condition, but transitivity was questioned as well.

A more direct way to assess the transitivity assumption is to ask the experimental subjects to make pairwise choices from a sequence of risky prospects. Tversky (1969) did just that. He confronted his subjects with the following sequence:

1. $(\$5.00, 7/24; \$0, 17/24)$
2. $(\$4.75, 8/24; \$0, 16/24)$
3. $(\$4.50, 9/24; \$0, 15/24)$
4. $(\$4.25, 10/24; \$0, 14/24)$
5. $(\$4.00, 11/24; \$0, 13/24)$

The expected values of payoffs increase from top to bottom (from value \$1.46 to \$1.83). The same is true for the probability of a non-zero payoff. Tversky found in his experiments that a sizable subgroup of his experimental subjects exhibited behavior whereby in adjacent pairwise choices, they preferred the prospect associated with higher maximum payoff (and smaller expected payoff), but in the comparison between the extreme prospects they preferred the one with the higher winning probability (and expected value). In other words, this group of individuals had a cyclic preference relation over risky prospects.

The preceding examples are but a (biased) sample of the vast literature that stemmed from comparing experimental observations with the theory of individual decision making. These examples have been chosen because in their context the term "paradox" has often been used. And for a good reason: not only do the observations deviate from the dictates of the theory, but those deviations seem to make intuitive sense. Hence, to the extent theory purports to portray rational behaviour, it seems that at least sometimes deviation from rationality makes sense. In what follows we argue that we do not need the risk or uncertainty modalities – as in the preceding examples – to end up in paradoxical choice situations. Consequently, we do not need to consider the specific conditions that pertain to risk and uncertainty modalities to end up with paradoxical yet plausible choice behaviour. Instead we may focus directly on transitivity and completeness conditions.

3 Intransitivity of Preferences

Three universities A, B and C are being compared along three criteria: (i) research output (scholarly publications), (ii) teaching output (degrees), (iii) external impact (expert assignments, media visibility, R& D projects, etc.)

crit. (i)	crit. (ii)	crit. (iii)
A	B	C
B	C	A
C	A	B

Assuming that each criterion is a roughly equal importance, it is natural to form the overall preference relation between the universities on the basis of the majority rule: which one of any two universities is ranked higher than the other is preferred to the latter. In the present example this leads to a cycle: $A \succ B \succ C \succ A \succ \ldots$. Hence, an intransitive individual preference relations can be made intelligible by multiple criterion setting and majority principle (cf. Fishburn 1970;Bar-Hillel and Margalit 1988).[1]

4 Incompleteness of Preferences

It is sometimes said that in social choice everything works nicely as long as the number of options is strictly less than three. The underlying idea then seems to be that the paradoxes begin with cyclic majorities. It can, however, be shown that voting paradoxes may be encountered in situations involving just two options. In what follows we consider two such paradoxes and provide a reinterpretation of them to show that in some situations it is entire plausible to encounter incomplete preferences.[2] Thereafter we take another look at an important theorem of Baigent (1987) to show that under a wide class of choice situations using nearly any plausible choice rule leads to "unstable" choices (see also Baigent and Eckert 2004; Baigent and Klamler 2004; Eckert and Lane 2002).

4.1 Ostrogorski's Paradox

A phenomenon known as Ostrogorski's paradox refers to the ambiguity in determining the popular preference among two alternatives (Daudt and Rae 1978). In the following we recast this paradox in an individual decision-making setting. The individual is to make a choice between two alternatives X and Y, e.g. candidates to a political office. There are three issues that are of primary importance for the office, say, foreign policy, social policy and educational policy. The individual uses 5 criteria in determining his/her favourite: relevant education (marked A, in the table), political experience on the issue (B), negotiation skills in the issue (C), substance expertise (D) and relevant political collaboration network (E). The following table indicates which candidate is preferable to

[1] Nothing new is asserted here: the point has been made some 60 years ago by May (1954). In fact, already in 1930's some authors doubted the general plausibility of preference transitivity on the basis of its symmetric part, viz. the indifference relation. Aleskerov and Monjardet (2002, 4) and Mongin (2000) provide more extensive discussions and further references on this point.

[2] Again, no claim for novelty is made is here. In fact, Aumann (1962) not only suggests the possibility of incomplete preferences, but builds a theory of utility maximization without the completeness condition.

the individual on each issue in terms of each criterion. Thus, e.g. candidate X has preferable (longer) experience in foreign policy than candidate Y.

issue	*issue 1*	*issue 2*	*issue 3*	*the criterion chooses*
crit. A	X	X	Y	X
crit. B	X	Y	X	X
crit. C	Y	X	X	X
crit. D	Y	Y	Y	Y
crit. E	Y	Y	Y	Y
issue-wise choice	Y	Y	Y	*overall choice* ?

Suppose now that the criterion-wise preference is formed on the basis of which alternative is better on more issues than the other. If all issues and criteria are deemed of equal importance, the decision of which candidate the individual should vote is ambiguous: the row-column aggregation with the majority principle suggests X, but the column-row aggregation with the same principle yields Y. Thus, the preference over X and Y appears to exhibit incompleteness: on the basis of row-column aggregation Y cannot be preferred to X and on the basis of column-row aggregation X cannot be preferred to Y. Hence, there is no preference relation between X and Y.

4.2 The Exam Paradox

The crux of Ostrogorski's paradox is the majority rule used in determining the "winners" of aggregation. A different type of rule is resorted to in a paradox, the exam paradox, that was introduced by Nermuth (1992). In the following we give it a somewhat different interpretation. Consider again an individual making a choice between two candidates or policy options, X and Y. The individual aims to pick the one that is closer to his/her ideal in issues $1, \ldots, 4$. X is located at the following distance from the voter's ideal point in a multi-dimensional space. The individual defines a total score of each alternative as the arithmetic mean of the issue-wise distances rounded to the to the nearest integer with values 0.5 rounded down to 0.

issue	1	2	3	4	average	score
criterion 1	1	1	2	2	1.5	1
criterion 2	1	1	2	2	1.5	1
criterion 3	1	1	2	2	1.5	1
criterion 4	2	2	3	3	2.5	2
criterion 5	2	2	3	3	2.5	2

X's competitor Y, in turn, is located in the space as follows.

issue	1	2	3	4	average	score
criterion 1	1	1	1	1	1.0	1
criterion 2	1	1	1	1	1.0	1
criterion 3	1	1	2	3	1.75	2
criterion 4	1	1	2	3	1.75	2
criterion 5	1	2	1	2	1.75	2

The score of X is smaller than that of Y suggesting that it is closer to the individual's ideal point. And yet, on 4 criteria out of 5 Y is closer to the individual's ideal point. As in Ostrogorski's paradox, there are good grounds for arguing that incomplete preference relations can be quite plausible.

4.3 A Reinterpretation of Baigent's Theorem

Consider an individual making a choice from a set of alternatives using some criteria (cost, performance, ...). Suppose that the individual occasionally makes mistakes in applying the criteria. A plausible desideratum for an individual choice rule is that *mistakes involving a small number of criteria should not result in larger changes in chosen alternatives than mistakes involving larger number of criteria.* This desideratum rules out instances where decision situations that are very close to each other result in choice outcomes that are further apart than instances where the situations differ substantially. The desideratum is called proximity preservation.

Theorem 1. *(Baigent 1987; Eckert and Lane 2002; Baigent and Eckert 2004; Baigent and Klamler 2004): anonymity and respect for unanimity cannot be reconciled with proximity preservation.*

In other words:

- No matter what rule one uses in combining criterion values into choices (as long as it is anonymous and satisfies Pareto), the choices made in "very similar" circumstances can be further apart than those made in different circumstances.
- The choices – given criterion measurements – may occasionally appear "chaotic".
- The result holds under metric representations of distances between "profiles"
- It also holds under considerably weaker assumptions concerning distance measures (Eckert and Lane)

The theorem – when interpreted in the multiple-criterion choice context – does not challenge completeness or transitivity of individual preferences, but calls into question the continuity of preferences, i.e. their representation by smooth utility functions. In other words, whenever the labeling of criteria does not matter for determining the choice and the Pareto principle is adhered to, there are situations in which the continuity is violated.

5 Conclusion

In the title of his article, Mongin (2000) asks whether optimization implies rationality. My aim here has been related, but more modest, viz. to find out whether reasonable choices can be made – and defended – when the formal preconditions of optimization are absent. The preceding discussion is also somewhat related to reason-based rationality as understood by Dietrich and List (2013). The message of this paper is that even though the standard assumptions of the UM theory are often quite natural, it is not at all irrational to have intransitive, incomplete and/or discontinuous preference relations. In fact, it may be quite reasonable to have them. All that is called for is that the choice involves several criteria and that the alternatives are multi-dimensional. Under these circumstances incomplete and intransitive preference relations may emerge in a systematic manner that is consistent with the maximization principle that underlies rationality in the standard theory of choice. In fact, intransitive and discontinuous preferences may emerge in a single-dimensional setting as was shown above.

References

1. Aleskerov, F., Monjardet, B.: Utility Maximization, Choice and Preference. Springer, Heidelberg (2002)
2. Allais, M.: The foundations of positive theory of choice involving risk and a criticism of the postulates and axioms of the American school. In: Allais, M., Hagen, O. (eds.) The Expected Utility Hypothesis and the Allais Paradox. D. Reidel, Dordrecht (1979)
3. Aumann, R.J.: Utility theory without the completeness axiom. Econometrica 30, 445–462 (1962)
4. Baigent, N.: Preference proximity and anonymous social choice. The Quarterly Journal of Economics 102, 161–169 (1987)
5. Baigent, N., Eckert, D.: Abstract aggregations and proximity preservation: and impossibility result. Theory and Decision 56, 359–366 (2004)
6. Baigent, N., Klamler, C.: Transitive closure, proximity and intransitivities. Economic Theory 23, 175–181 (2004)
7. Bar-Hillel, M., Margalit, A.: How vicious are cycles of intransitive choice? Theory and Decision 24, 119–145 (1988)
8. Daudt, H., Rae, D.: Social contract and the limits of majority rule. In: Birnbaum, P., Parry, G. (eds.) Democracy, Consensus & Social Contract. Sage, London (1978)
9. Dietrich, F., List, C.: A reason-based theory of rational choice. Nous 47, 104–134 (2013)
10. Eckert, D., Lane, B.: Anonymity, ordinal preference proximity and imposed social choices. Social Choice and Welfare 19, 681–684 (2002)
11. Ellsberg, D.: Risk, ambiguity, and the Savage axioms. Quarterly Journal of Economics 75, 643–669 (1961)
12. Fishburn, P.C.: The irrationality of transitivity in social choice. Behavioral Science 15, 119–123 (1970)
13. Gilboa, I., Schmeidler, D.: A Theory of Case-Based Decisions. Cambridge University Press, Cambridge (2001)

14. Harsanyi, J.C.: Rational Behavior and Bargaining Equilibrium in Games and Social Situations. Cambridge University Press, Cambridge (1977)
15. Lichtenstein, S., Slovic, P.: Reversal of preferences between bids and choices in gambling decisions. Journal of Experimental Psychology 89, 46–55 (1971)
16. Machina, M.: Expected utility analysis without independence axiom. Econometrica 50, 277–323 (1982)
17. May, K.O.: Intransitivity, utility, and the aggregation of preference patterns. Econometrica 22, 1–13 (1954)
18. Mongin, P.: Does optimization imply rationality? Synthese 124, 73–111 (2000)
19. Nermuth, M.: Two-stage discrete aggregation: the Ostrogorski paradox and related phenomena. Social Choice and Welfare 9, 99–116 (1992)
20. von Neumann, J., Morgenstern, O.: Theory of Games and Economic Behavior, Sixtieth Anniversary Edition. Princeton University Press, Princeton (2007)
21. Savage, L.: Foundations of Statistics. Wiley, New York (1954)
22. Tversky, A.: Intransitivity of preferences. Psychological Review 76, 31–48 (1969)

Preference Elicitation for Group Decisions

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Abstract. Groups engaged in a mutual activity often need assistance in order to reach a joint decision. However, the group members' personal preferences are often unknown and need to be collected. Querying for preferences can annoy the users. We suggest employing a voting mechanism that finds a winning item under incomplete settings. We present a practical method for eliciting the preferences, so that with a minimal amount of queries a winning item that certainly suits the group can be computed. The heuristic incorporates probabilistic assumptions on the users' preferences and was evaluated on a real world datasets as well as on simulated data, showing a saving in queries to users.

Keywords: Preference elicitation, social choice, decision support systems.

1 Introduction

Decision systems can assist group members to reach a joint decision. An example of such a task is to assist a group of friends who wish to find a restaurant for a dinner party. The process is easy when the group members state all of their personal preferences for the items in question (restaurants in this case). In this case a decision can be reached by picking the most preferred item. However, a requirement to state complete preferences for all items in question may be viewed as disruptive by the users as this can be difficult or time consuming.

Fortunately, as [7] show, not all user preferences are needed in order to reach a "winning item" i.e., an item that certainly suits the group's preferences and can be regarded as a group decision. We propose an incremental elicitation process that can be employed in order to reduce the number of questions that the users are asked in order to find a winning item. In this process, the users state only some of their preferences, and only when explicitly queried for them. Studies have shown it is easier for users to state opinions when the queries are pairwise [1]. Consider, for example an application trying to find a Sushi type most preferred by a group [6]. A user might find it easier to answer a question such as: "do you prefer this Sushi or that Sushi?" as opposed to "on a scale of 1 to 5, how would you rate this Sushi?" Pairwise comparison queries can be related to the Borda voting protocol, in which users are assumed to have a fixed ranked list of preferences for items.

We propose a practical pairwise comparison method for user preference elicitation. Since the method is incremental we do not assume users have actually taken the time

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to rate all options, but rather assume that they will be consistent in their choices. Thus, in our incremental method, a user and two items are selected and the user is queried for her preference between the two items. The goal is to find the best queries so that the winner is reached using a minimal amount of queries. When given a set of users and a set of items, the goal is to determine a querying policy that finds a necessary winner. While the users' true preferences are unknown to the voting center, we assume that the center does have some approximation as to their desires. A probability distribution of the users' preferences can be derived from the users' history of preferences or from other users' preferences on the items in question. See for example [8].

In this paper we propose a practical algorithm that uses a probabilistic method to guide preference elicitation and minimize the overall number of queries asked. The suggested approach (ENTROPY) considers the items' winning probabilities and consequently selects a query that maximizes the information gain. We perform an experimental analysis on a real world dataset and on simulated data. The results indicate that ENTROPY and can save queries to users and thus simplify the preference elicitation process and consequently the group decision process.

2 Related Work

Preference elicitation is practiced to some extent in the recommender systems domain [10] where a recommendation for a group is outputted, thus attempting to help the group reach a joint decision. The major differences are that we focus on minimal questions in the preference elicitation process and on finding an item that is necessarily a winner item according to the Borda protocol, rather than on the accuracy or fairness of the recommendation.

Previous work in the social choice domain addresses voting in systems with partial information. In [2] the communication complexity of various voting protocols is analyzed and upper and lower bounds for query amount are determined showing that for most voting protocols, in the worst case users should send their entire set of preferences. In [7] partial information is addressed, where users do not set the preferences for all candidates. They show how to compute the sets of possible winners and a set of necessary winners. These sets determine which candidates no longer have a chance of winning and which are certain to win. We adopted this approach to propose a systematic preference aggregation protocol in which the users do not need to send their entire set of preferences. We use this idea in order to reach a group decision.

Incremental elicitation of preferences has recently received attention, with various approaches employed on numerous existing goals. Like us, [12] also conduct a pairwise comparison of items. However, they approach each user once only, and their goal is to predict the rank of items under and not to output a recommendation or a winner.

Another approach is to define an incremental process in which either all users are queried for their rating on a selected item; or selected users are queried for their ranked list of preferences on all items [5]. We extend this work to find a winner using a minimum amount of queries by iteratively searching for the best query. In [11] users are incrementally queried for their ratings on items and the Range protocol is used to determine a winner. We differ from [5,11] in that the elicitation is performed using pairwise queries, thus making the algorithm more practical as explained in [1]. In [9] an incremental process of pairwise comparison is defined using the "minmax regret" concept. However, we suggest a user specific probabilistic model which considers the users past preferences and uses this information when selecting queries. Our probabilistic model is constantly updated as more information is revealed while [9] use a general model which is not updated specifically for each user.

3 The Preference Elicitation Model

Let us introduce an incremental elicitation model where user preferences are revealed one at a time, and the winner item is computed according to the Borda protocol. The process proceeds in rounds; at each round the voting center selects which user to query for pairwise preferences. The voting center aims to converge to a winning item using a minimal amount of queries. We use two assumptions valid for social choice: the environment is collaborative and users do not change their preferences during the preference elicitation process.

Let a set of users and a set of candidate items be denoted as $U = \{u_1, u_2, \ldots, u_m\}$ and $= \{c_1, c_2, \ldots, c_n\}$ respectivly. The Borda protocol assumes every user has a total order of ranked preferences on n items. The voting center translates the preferences into an ordered sequence of values with a decreasing value of 1: $\{n-1, n-2 \ldots 0\}$. Each value is uniquely assigned to one item only. The winning item is the one which maximum sum of scores.

In an incremental elicitation model, the voting center queries for user u_i's pairwise preferences; in response the user's preference between the two items is received. A pairwise query $q_{j,k}^i$ for user u_i's preference between candidates c_j and c_k has two possible responses: $q_j^i \prec q_k^i$ or $q_k^i \prec q_j^i$ meaning candidate item c_k is either preferred over candidate item c_j or vice versa. The set of responses is denoted O.

At the end of each round, one query response is added to O. As shown by [7], the set O does not need to be complete in order to find a winner: if an item c_j exists whose *Borda possible minimum* is bigger than the *Borda possible maximum* of all other items then c_j is a *necessary winner*. The *Borda possible maximum* of an item represents the highest possible score for an item based on the known preferences. When no preferences are known, the Borda possible maximum of item c_j is the maximum score $s_n = n - 1$ that any item can receive multiplied by the total number of members: $(n-1) \cdot m$. This score is received if all users will rank c_j as their most preferred item. The Borda possible maximum of c_j decreases in 1 for every user that states some other item is preferred over c_j: $q_j^i \prec q_k^i$. Consequently, the *Borda possible minimum* of an item is the lowest possible score of the item based on the known preferences. When no preferences are known, the Borda possible minimum score of a candidate item c_j is 0. This score increases in 1 every time a user states she prefers item c_j over some other item.

At the beginning of the elicitation process the users preferences for items are unknown, i.e., the voting center does not know the response to any pairwise query $q^i_{j,k}$. The voting center holds probabilistic information as to each user's preference between each pair of items. According to the preference probability, the voting center determines which query to execute (this is shown in the next section). One option is to hold the preference probability of each user for each $n(n-1)/2$ pairs of items. The advantage of this model is that the state space of the number of possible pairs per user is polynomial and the model can easily cope with a large amount of candidates. However, this option ignores the dependency between pairwise preferences. According to the Borda protocol: $p\left(q^i_j \prec q^i_k \,|q^i_k \prec q^i_l\right) \neq p\left(q^i_j \prec q^i_k \,|q^i_l \prec q^i_k\right)$.

In [4] it is recommended to consider this dependency and to hold a full list of probabilities for all order permutations. An example of a permutation distribution for 2 users and 3 items is given in Table 1. The pairwise preference probability of $c_j \prec c_k$ can be extracted by aggregating all the permutation probabilities where $c^i_j \prec c^i_k$. However, since n! is the amount of permutations, this model cannot cope with a large amount of candidates. Therefore, one must choose whether to tradeoff model complexity with model accuracy. In this paper we follow [7] and hold a complete set of permutation probabilities.

Formally, the permutation set is defined as $UC = \{uc_1, \dots, uc_{n!}\}$. User u_i 's permutation distribution, denoted by vc^i, is a discrete random variable, taking the values in UC. In table 1, $Pr\left(uc^1 = (c_3 \prec c_2 \prec c_1)\right) = 0.1$.

The model can be derived from the users' history of preferences or from other users' preferences on the items in question. See for example [8]. Deriving the permutation distribution is data specific; in the evaluation section we describe how the permutation distribution for the experiments data is derived.

Table 1. User permutation distribution example

users	$c_3 \prec c_2 \prec c_1$	$c_3 \prec c_1 \prec c_2$	$c_2 \prec c_3 \prec c_1$	$c_2 \prec c_1 \prec c_3$	$c_1 \prec c_3 \prec c_2$	$c_1 \prec c_2 \prec c_3$
u_1	0.1	0.1	0.2	0.3	0.2	0.1
u_2	0.2	0.2	0.2	0.2	0.1	0.1

4 The ENTROPY Heuristic

The goal of the elicitation process is to minimize the overall number of queries. Determining the next optimal query recursively depends on the order of the rest of the queries. There are an exponential number of such orders $(O(m \cdot n \cdot (n-1)^2)!)$ so finding the optimal minimal set of queries is intractable. Therefore, we propose a myopic approach for selecting the next user-item-item query trio. The heuristic relies on two assumptions: a user is able to submit her preferences when queried for them and transitive relation closure exists.

We approximate the item winning probability using a Monte Carlo algorithm [3] that uses sampling to estimate the winner. The Item Winning Probability algorithm proceeds as follows: for each user u_i, one permutation is sampled out of all possible user permutations UC. Once the permutations of all users are collected the winner is determined using the Borda protocol. These two steps are repeated γ times. Finally, the winning probability of each item is calculated as the number of times the winner was found is divided by the sample size γ.

```
Item Winning Probability Algorithm:
Input:
    U - the set of voters
    C - the set of candidate items
    UC - the set of possible permutations
Output:  winning probabilities array PrWin[n] for all j's
Initialize  winnerArray[n] ← 0
Initialize voterArray[m] ← 0
Repeat γ times:
    For each voter v_i ∈ V
            voterArray[i] ← sample a permutation from vc^i
    c_localwinner ← winner in voterArray
 winnerArray[localWinner] ← winnerArray[localWinner] + 1
    For each item c_j ∈ C
       Compute PrWin[j] ← winnerArray[j]/γ
```

The ENTROPY heuristic focuses on selecting queries that will maximize the available information in terms of entropy [13] at each stage. First, the information gain of each possible query is calculated. The information gain of a specific query is the difference between the prior and the posterior entropy of the probability to win of the item candidates given the possible responses to the query. The chosen query is the user-item-item query trio that maximizes the weighted information gain. The heuristic continues until a necessary winner is found. Ties in weighted information gain are broken according to the item positions in an increasing order of all items.

The entropy function is used in order to compute the query information gain. Given the item winning probabilities array $PrWin$, the entropy function is:

$$E(\text{PrWin}) = -\sum_{j=1}^{m} PrWin[j] log(PrWin[j]) \quad (1)$$

The posterior entropy is calculated for the probability winner vector that has been computed for the two possible outcomes of a query $q^i_{j,k}$ We use $E\left(\text{PrWin}\middle|q^i_{c_j \succ c_k}\right)$ to denote the entropy given user i prefers $c_j \succ c_k$. The information gain (IG) is the difference between the prior entropy of the local winner and the posterior entropy given that the response of an executed query $q^i_{j,k}$ is $c_j \succ c_k$:

$$IG\left(q^i_{c_j \succ c_k}\right) = \left(E(\text{PrWin}) - E\left(\text{PrWin}|q^i_{c_j \succ c_k}\right)\right) \quad (2)$$

The probability that user u_i prefers c_j over c_k $\mathrm{p}\left(q^i_{c_j \succ c_k}\right)$ can be calculated based on the prior permutation distribution. Thus we can compute the weighted information gain (WIG):

$$WIG\left(q^i_{j,k}\right) = IG\left(q^i_{c_j \succ c_k}\right) \cdot \mathrm{p}\left(q^i_{c_j \succ c_k}\right) + IG\left(q^i_{c_j \prec c_k}\right) \cdot \mathrm{p}\left(q^i_{c_j \prec c_k}\right) \quad (3)$$

The chosen query is the query that maximizes the weighted information gain.

5 Evaluation

The evaluation was performed on a real world dataset: Sushi [6] and on simulated data. We examined a scenario of 10 users who pick one Sushi type out of 4 different Sushi types. We set the initial permutation probability distribution to a Uniform distribution. Thus the initial permutation distribution is equal for all users. As more queries are answered, the distributions are updated for each user. Over time a unique permutation distribution pattern emerges for each user.

The heuristic was compared to a baseline RANDOM method that selects queries at Random. Since ENTROPY uses sampling, to accommodate for randomness each experiment was run 20 times. The γ parameter in the Item Sampling algorithm was set to 300, as above this number we did not detect a noticeable difference in results.

Using simulated data, we studied performance of different levels of heterogeneity within the group of users. A distinct winner item is an item who received a score which greatly varies from the other scores. In the same manner, a winner item with low distinction has a score which is just slightly higher than the scores of the other items. We defined 10 levels of group heterogeneity; these are displayed in Table 2.

Figure 1 displays a comparison between the heuristics on simulated dataset of size 5x5. Axis x presents a varying heterogeneity level. Axis y presents the amount of queries performed. It can be seen when the winner item is not distinct, ENTROPY has a bigger advantage over RANDOM. However, when the winner item is distinct, ENTROPY offers no real advantage. Also, the more distinct the winner item is, the less queries are needed in order to find the winner. All of the results are statistically significant, ENTROPY outperforms RANDOM with a 95% confidence interval according to a one tailed paired t-test.

For the Sushi dataset, the winner item is quite distinct. Still, ENTROPY outperforms the RANDOM heuristic. A summary of the amount of queries needed (and the standard deviation on 20 experiments) is presented in Table 3 for datasets of sizes 10x4 and 10x5.

We conclude ENTROPY should be considered for use, especially in cases where runtime is not an issue, user comfort is of importance and the winner item is not distinct.

Table 2. Defined heterogeneity levels for different settings

Heterogeneity level	Candidate items scores				
	c_1	c_2	c_3	c_4	c_5
1.25	16	15	15	15	14
2.5	17	15	15	14	14
3.75	18	15	14	14	14
5	19	14	14	14	14
6.25	20	14	14	14	13
7.5	21	14	14	13	13
8.75	22	14	13	13	13
10	23	14	13	13	12
11.25	24	14	13	12	12
12.5	25	13	13	12	12

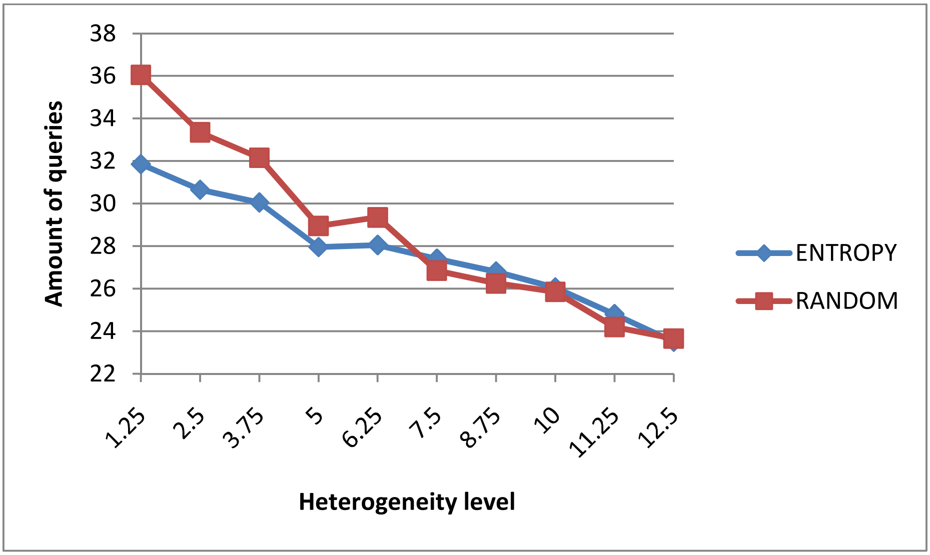

Fig. 1. A simulated dataset of size 5x5 with different heterogeneity levels

Table 3. Sushi dataset results comparison

Dataset	ENTROPY	RANDOM
10x4	33.8 ± 3.9	34.45 ± 4.4
10x5	67.3 ± 4.3	69.75 ± 4.4

6 Summary and Future Work

In this paper we presented a heuristic that attempts to minimize the overall amount of queries needed for finding a necessary winner for a group of users, thus assisting the users in reaching a joint decision. In an iterative elicitation process, users are queried for their preferences between two items. The process continues until a necessary winner item is found, this item is presented to the group as a recommended choice. The heuristics use probabilistic information of the users' preferences. Usually the permutation distribution for datasets does not readily exist. However, we demonstrated a realistic method for easily learning this distribution on a dataset. Experiments illustrate the superiority of the ENTROPY heuristic over a baseline RANDOM heuristic.

In future work we plan to extend the evaluation. We also plan to search for an approximate winner and not a definite one and to experiment with the probabilistic information. If we relax the need to find a definite winner, the decision can be made even faster. Also, the more accurate the initial probabilities are, the fewer queries are needed to find a winner.

References

1. Balakrishnan, S., Chopra, S.: Two of a kind or the ratings game?Adaptive pairwise preferences and latent factor models. Frontiers of Computer Science 6(2), 197–208 (2012)
2. Conitzer, V., Sandholm, T.: Communication complexity of common voting rules. In: Proc. EC 2005, pp. 78–87. ACM (2005)
3. Fishman, G.: Monte Carlo: concepts, algorithms, and applications. Springer (1996)
4. Hazon, N., Aumann, Y., Kraus, S., Wooldridge, M.: On the evaluation of election outcomes under uncertainty. Artificial Intelligence (2012)
5. Kalech, M., Kraus, S., Kaminka, G.A., Goldman, C.V.: Practical voting rules with partial information. Auton. Agents Multi-Agent Syst. 22(1), 151–182 (2011)
6. Kamishima, T., Kazawa, H., Akaho, S.: Supervised ordering-an empirical survey. In: Proc. ICDM 2005, p. 4. IEEE (2005)
7. Konczak, K., Lang, J.: Voting procedures with incomplete preferences. In: Proc. IJCAI 2005 (2005)
8. Koren, Y., Sill, J.: OrdRec: an ordinal model for predicting personalized item rating distributions. In: Proc. of the Fifth ACM RECSYS, pp. 117–124. ACM (2011)
9. Lu, T., Boutilier, C.: Robust approximation and incremental elicitation in voting protocols. In: Proc. of AAAI (2011)
10. Masthoff, J.: Group recommender systems: Combining individual models. Recommender Systems Handbook, pp. 677–702 (2011)
11. Naamani Dery, L., Kalech, M., Rokach, L., Shapira, B.: Iterative voting under uncertainty for group recommender systems. In: Proc. RECSYS, pp. 265–268. ACM (2010)
12. Pfeiffer, T., Gao, X.A., Mao, A., Chen, Y., Rand, D.G.: Adaptive Polling for Information Aggregation. In: Proc. AAAI (2012)
13. Shannon, C.E.: A mathematical theory of communication. ACM SIGMOBILE Mobile Computing and Communications Review 5(1), 3–55 (2001)

On Developing a Web-Based Time Preference Elicitation Engine: Implications for E - Negotiations

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Abstract. In electronic negotiations, buyers and sellers are represented by negotiating agents and it becomes imperative for the negotiating agents to acquire user's preferences to be able to negotiate better. In this paper we present the design of a web based engine to capture a buyer's choices over time through a preference elicitation tool known as Time – Tradeoff sequence(TTO Sequence). Preferences thus elicited are used by buyer's electronic agents to negotiate price and date of movie tickets with cineplex owners. Further, we illustrate with an example that negotiation outcome is affected by the time-preference of the buyer.

Keywords: TTO Sequence, Electronic negotiations, Intertemporal choice.

1 Introduction

Buying and selling of products and services on the internet, termed as e-commerce, is growing rapidly every day. E-commerce operates on various types of models: B2B, B2C, C2B and C2C [10]. Of these models, B2C is of particular interest to us in this context. E-commerce is conducted on platforms known as e-marketplaces. Though e-marketplaces facilitate buying and selling of broad variety of goods and services, transacting in e-marketplaces require a great deal of human intervention at each stage of buying and selling. Several decision making stages that are part of the customer buying behaviour (CBB) are applicable to e-marketplaces as well. [15] have identified various stages of a customer buying behavior. However if a buyer has to manually execute these steps it would entail considerable effort on the part of the buyer in terms cost and time. These processes can be automated by using electronic agents to enhance a customer's buying experience [15, 12]. In this paper, we employ a web-based mechanism to elicit a buyer's choices over time, in other words time preferences. Buyer's time preferences so elicited will be used by electronic agents to conduct negotiations on behalf of the customer. The scope of this paper is restricted to web-based preference elicitation mechanism. The remainder of this paper is structured as follows: Section 2 presents background and motivation. Section 3 presents literature review on intertemporal choice and eliciting time preferences. The process flow chart describing the sequence of steps starting with preference elicitation and leading up to negotiation framework is discussed in Section 4, followed by web-based

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preference elicitation engine in section 5. Section 6 talks about implications and section 7 discusses conclusions and limitations.

2 Background and Motivation

This paper draws motivation from the work of [13] on e-negotiations for the purchase of movie tickets. We have modified the scenario considered by [13] to an online movie place where cineplex owners sell the tickets of forthcoming movies. These movie tickets are for screenings to be held on different dates beginning with the date of premiere. Prices of these tickets are to be determined through negotiations with customers.

Since both cineplex and customers pursue their own self-interests which might conflict with each other, negotiation can be a way to resolve this conflict of interest. A negotiation is a non-individual decision making process. It involves two or more parties that jointly determine outcomes of mutual interest or resolve a dispute via exchanging ideas, arguments, and offers. Parties thereby can be individuals, groups, organizations, or computer-based decision-making models like software agents [9]. In an agent-based setting, sellers and buyers are represented by electronic agents that negotiate or bid on their behalf in an e-marketplace. Negotiations performed by electronic agents are generally referred to as e-negotiations [2].

[12] have classified electronic agents, based on the role they play in an e-negotiation, as follows: 1. User profile agent, 2. Information agent, 3. Opponent profiling agent, 4. Proposer agent, 5. Critic agent, 6. Negotiator agent and 7. Mediator agent. In this paper, we focus primarily on the user profile agent and briefly cover the roles of proposer, critic and negotiator agents. The role of the user profile agent is to elicit user preferences, which will be used by other agents in the negotiation process. We propose the use of an elicitation scheme by the user-profile agent in learning a user's time preference. Further, we illustrate the elicitation and subsequent negotiation process for the purchase of movie tickets.

Empirical studies indicate that elements of a negotiating behaviour, such as initial bid price, concessions made in each round, are closely related to the negotiating parties' preferences [19]. Extending this argument to e-negotiations, [11] pointed out that the principal's (i.e., human) characteristics or preferences must be considered by electronic negotiation systems in order to be perceived as useful. On similar lines, [2] had argued that negotiation systems had not shown sufficient concern for user's needs and expectations. Few studies have integrated preference elicitation mechanisms with agent technology. For example, [18] provided AHP based mechanisms to consider human elements like goal and situational power in e-negotiations. AHP based mechanisms to elicit user preferences in C2B market context were discussed in [5] and [10].

In representing the buyer's utility, [13] have taken various factors into account like box office rank, distance from theater, movie genre, price and timeliness. In their paper, the utility of the movie tickets is a linear additive function of the individual utilities of these factors multiplied with their corresponding weights. This is because they have assumed that the preferences of individual attributes, for example price and time, are independent of each other. However, from the literature on time preference, the preferences among time and other factors are not independent and are usually represented by multiplicative functions (discussed in subsequent section). One may argue that additive utility functions can be a good approximation for multiplicative functions [3, 6]. Given that we employ a tool to elicit these preferences and a model to represent them, we need not make this approximation. In the next section, we discuss more on the choices made by the buyer over time (termed as intertemporal choices) and models to represent those intertemporal choices.

3 Intertemporal Choice and Eliciting Time Preferences

Intertemporal choice, as described above, is the decision involving trade-off between time and payoffs (cost or benefits). It relates to how a person discounts the utilities of these payoffs across different points in time. Intertemporal choices are represented by time discounting functions which value utility as a function of time. [16] gave the discounted utility model wherein the overall utility is discounted by the exponential time discounting function at rate π.

$$u(x,t) = u_x(x).e^{-\pi.t} \tag{1}$$

But this model fails to explain non-stationarity of intertemporal decisions. Stationarity means that preference over two delayed choices does not change if the delays are incremented by a constant amount. However, several experimental studies in the literature on intertemporal choice show non-stationarity of time preference [8]. In the context of movie tickets, if a person values a movie show today more than tomorrow, but values the show on 8th day more than 7th day, then he/she exhibits decreasing impatience. Decreasing impatience is due to diminishing sensitivity with respect to time [14]. On the contrary, if a person values a movie show tomorrow more than today, but values the show on 7th day more than 8th day, then he/she exhibits increasing impatience. Studies by [1] and [17] support the existence of increasing impatience. Therefore, this exponential discounting function should be replaced by $\varphi(t)$, a generic discounting function based on the impatience exhibited by the subject [14, 8, 4]. Based on [16] and the aforementioned literature on intertemporal choice, we plan to use the following time discounted utility function in this paper. A summary of discounting functions from time preference literature is shown in Table 1.

$$u(p,t) = u_p(p).\varphi(t) \tag{2}$$

Table 1. Time Discounting Models

Sno	Function Type	Function	Condition	Source
1	Exponential	$\varphi(t) = e^{-r.t}$		[16]
2	Hyperbolic	$\varphi(t) = (1+\alpha t)^{-\beta/\alpha}$	$\alpha,\beta > 0$	[14]
3	CADI I	$\varphi(t) = ke^{re^{-ct}}$	$r > 0, c > 0, k > 0$	[4]
4	CADI II	$\varphi(t) = ke^{-re^{-ct}}$	$r > 0, c < 0, k > 0$	[4]
5	CRDI I	$\varphi(t) = ke^{rt^{1-\delta}}$	$r > 0, \delta > 1, k > 0, 0 \notin t$	[4]
6	CRDI II	$\varphi(t) = ke^{-rt^{1-\delta}}$	$r > 0, \delta < 1, k > 0$	[4]

In the context of electronic negotiations, [7] have argued that φ(t) should represent the time-based discounting of goods/services. However [7] did not discuss a method to elicit the time preference of a buyer. We argue that a negotiating agent that can identify the time preference (impatience) of the buyer is in a better position to get a deal which is closer to the user's expectations. Therefore, it becomes pertinent for an e-agent to elicit the time preferences of the customer before beginning the negotiations for buying the movie ticket.

One way to incorporate these time preferences is the use of time trade off (TTO) sequence proposed by [1]. TTO sequence is a tool to capture the intertemporal choice. The two salient features of the TTO sequence are: firstly, it does not assume linear utility and hence does not violate the law of diminishing marginal utility. Secondly, it focuses on a single outcome i.e. in this case the movie ticket and therefore is not affected by violation intertemporal separability. TTO sequence consist of a series of questions asked to the customer to get the time points T_n and T_{n+1} with outcomes An and An+1 such that the outcome improvement $A_{n+1} - A_n$ is offset by the delay $T_{n+1} - T_n$. These time points help derive the discounting function which in turn is used to evaluate the overall utility of the proposed offer in a negotiation.

4 Process Flowchart

Once the tickets for an upcoming movie are made available on the e-marketplace, the user profile agent elicits the time preferences of the customer for that particular movie using the TTO sequence. It also elicits the initial and maximum price he/she is willing to pay for the movie ticket and the time frame (dates within which he/she wants to see the movie). Once the preferences have been elicited, user profile agent determines the customer's time-discounting function and its parameters by feeding responses from the TTO sequence to matlab curve fitting algorithm. The curve fitting algorithm tries to fit these responses in the time discounting functions mentioned in table 2. Function and its parameters with the best goodness of fit are selected and relayed to critic agent. Negotiation over price and date of screening is started. Negotiation follows an alternating offers protocol and is time bound. During the negotiation, critic agent evaluates the utility of the offer and directs negotiator agent to accept or reject the offer. Critic agent also calls the proposer agent to propose a counter offer if the negotiator agent rejects the current offer. We limit the discussion to web-based preference elicitation mechanism in this paper, represented by the shaded portion in Fig. 1. The elicitation mechanism is described in the following section.

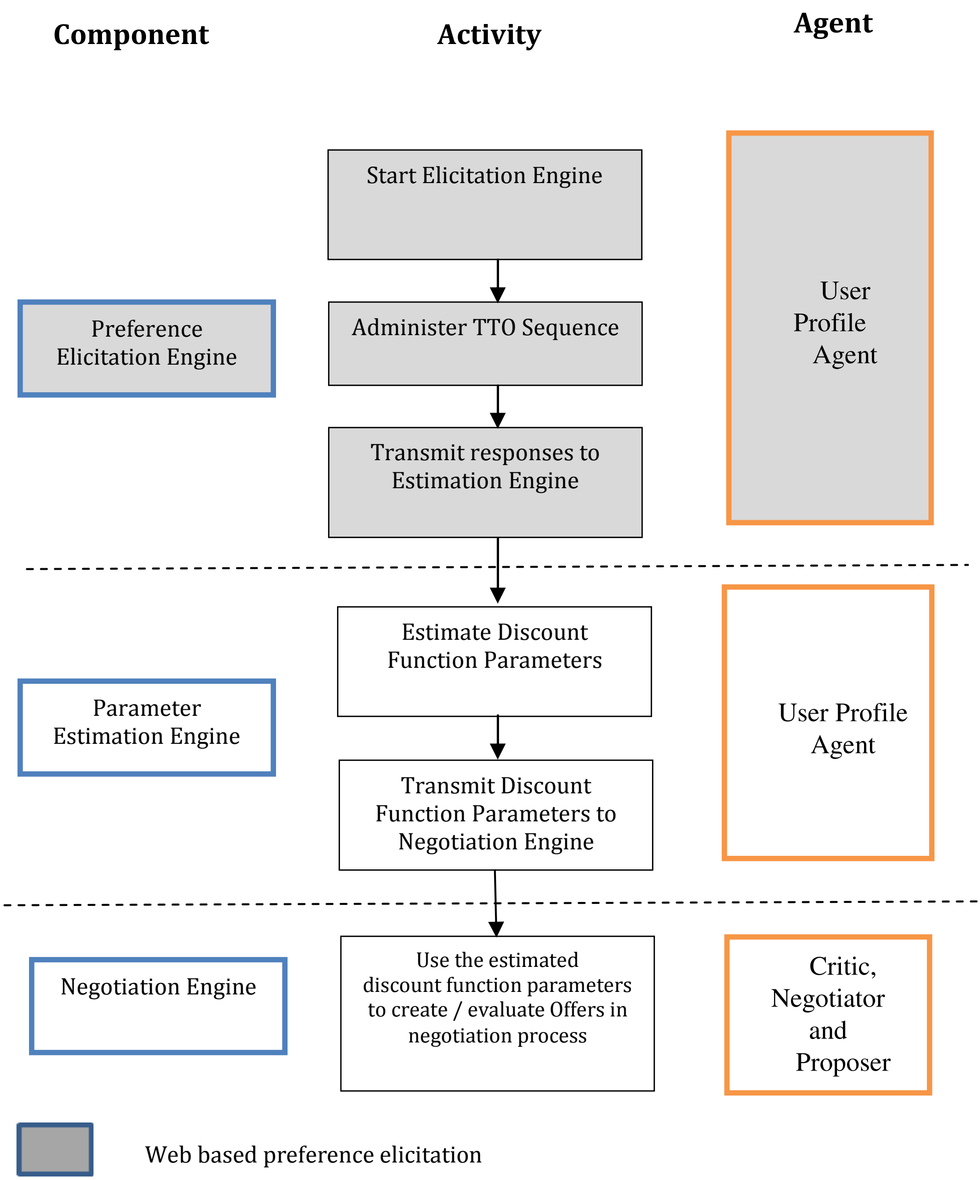

Fig. 1. Preference Elicitation Engine and Subsequent Negotiation

5 Web-Preference Elicitation Engine

The Elicitation engine consists of eight webpages residing on the Movie Place's web server. These webpages are displayed on user's machine on demand. The first web page introduces the user to iAgent – Movie Place's intelligent agent. The next page onwards the user responds to a series of questions termed as Time Tradeoff Sequence. The last page of the elicitation engine requests the user to wait while an offer is being negotiated with cineplex owner. The screenshots are as follows:

Screen 1

Screen 2

Screen 3

The broadway will be screening "The Wolf of Wall Street" the coming week.

Given a movie ticket of "The Wolf of Wall Street" for the premiere (Day 0) for a price of $10. On which day (more than 0) will you be willing to watch the movie for $7.

2

Submit

Screens 4,5,6,7

Given a movie ticket of "The Wolf of Wall Street" to be screened on day 2 (from the premiere-day 0) for a price of $10. On which day will you be willing to watch the movie for $7:

4

Submit

Given a movie ticket of "The Wolf of Wall Street" to be screened on day 4 (from the premiere-day 0) for a price of $10. On which day will you be willing to watch the movie for $7:

6

Submit

Given a movie ticket of "The Wolf of Wall Street" to be screened on day 6 (from the premiere-day 0) for a price of $10. On which day will you be willing to watch the movie for $7:

8

Submit

Given a movie ticket of "The Wolf of Wall Street" to be screened on day 8 (from the premiere-day 0) for a price of $10. On which day will you be willing to watch the movie for $7:

10

Submit

Screen 8

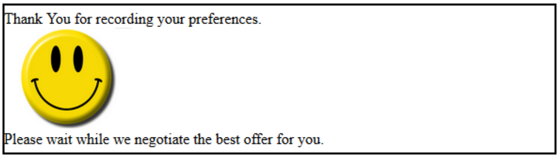

Fig. 2. Web based TTO Sequence

6 Implications

We use an example to illustrate the effect of time preference on the negotiation outcome. In this example we consider three different buyers: Buyer A, B & C with constant, decreasing and increasing time preference. In order to isolate the effects of time preference, we assume that users have similar preferences with respect to all other attributes of negotiation except for time preference (refer Table 2). Time preference of the user (impatience type) has been determined based on his/her response to TTO sequence. From the illustration, one can find that the outcome of the negotiation is different across buyers exhibiting different impatience types. For instance, the agreed price of $23.7 is the same across three users, the agreed time differs across buyers. The agreed time is day 10, 6 and 11 in the case of buyers with constant, decreasing and increasing impatience respectively. While the outcome utility is the same across the buyers, the constituents that make up the outcome utility are different among the three buyers. In summary, the web-based preference elicitation engine helps to negotiate and conclude offers that are closely related to the buyer's time preferences.

Table 2. Illustrative example on the effect of Time-Preference

Item	**Buyer A**	**Buyer B**	**Buyer C**
Elicitation			
Elicited Time Points	0,2,4,6,8,10	0,2,3,5,7,11	0,3,5,7,9,10
Impatience Type	Constant	Decreasing	Increasing
Modeling			
Function Parameters	d = 0.000 k = 1.000 r = 0.057	d = 0.213 k = 1.007 r = 0.092	d = -0.310 k = 0.999 r = 0.027
Negotiation			
Min Time	0 days (Premiere date)	0 days (Premiere date)	0 days (Premiere date)
Min Price	$10	10	10
Max Price	$100	100	100
Outcome Utility	0.55	0.55	0.55
Agreed Offer	**Day = 10, Price = $23.7**	**Day = 6, Price = $23.7**	**Day = 11, Price = $23.7**

Preference elicitation engine can be incorporated into any standard negotiation platform. From the illustration, one may observe that the negotiated outcome is contingent upon a buyer's time preference. The implication of using the engine is that it would lead to a better negotiation outcome, from the perspective of the buyer, which may eventually drive the successful adoption of e-negotiation platforms.

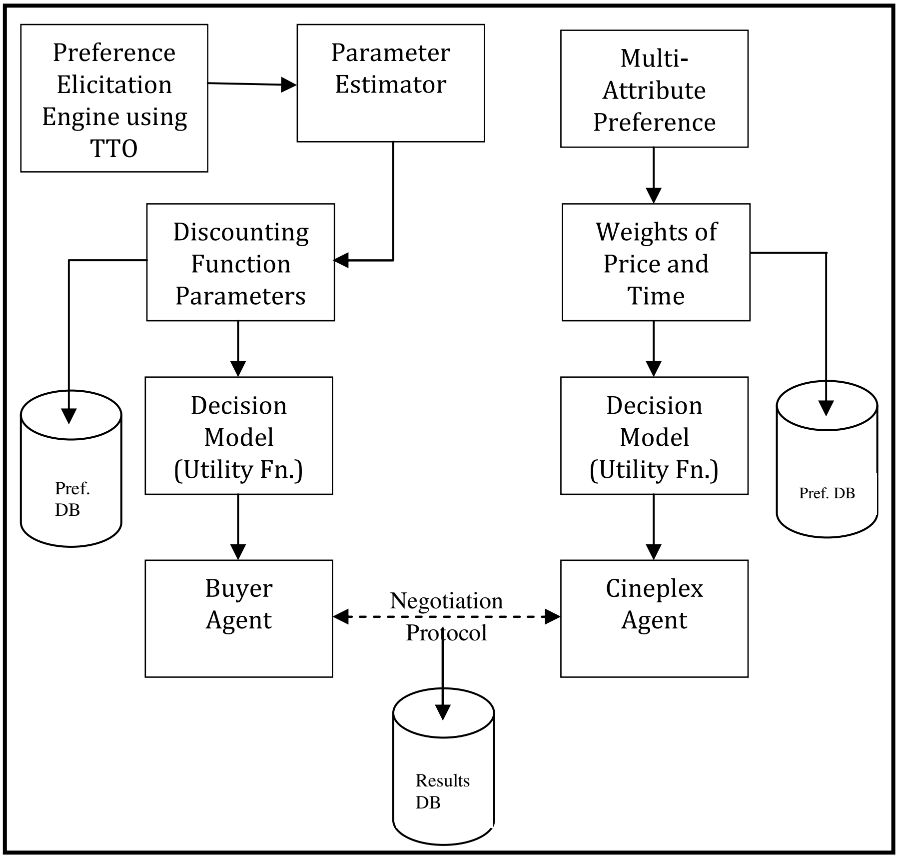

Fig. 3. Negotiation System Framework

7 Conclusions and Limitations

In this paper, we have proposed the use of a web-based elicitation engine that uses TTO sequences as a mechanism to identify a buyer's time preference. Further, we have shown a way to integrate the time preference in an agent-based negotiation by using time-discounting functions from the literature on time preference. Figure 3, presents a high level framework of an e-negotiation system for movie tickets with a web-based preference elicitation engine as part of our future work. While the proposed elicitation mechanism is step towards making the e-negotiation systems more representative of a buyer's preference, it adds towards overheads in time and computation in achieving a negotiated agreement. A way to justify the consumption of additional time and resources is an empirical investigation of acceptance of e-negotiation systems with the elicitation mechanism. Apart from TTO sequences, one might use other methods to elicit time preference. We leave the aforementioned limitations as future work.

References

1. Attema, A.E., Bleichrodt, H., Rohde, K.I., Wakker, P.: Time-tradeoff sequences for analyzing discounting and time inconsistency. Management Science 56(11), 2015–2030 (2010)
2. Bichler, M., Kersten, G., Strecker, S.: Towards a structured design of electronic negotiations. Group Decision and Negotiation 12(4), 311–335 (2003)
3. Bichler, M.: The Future of eMarkets: Multi-Dimensional Market Mechanisms. University Press, Cambridge (2001)
4. Bleichrodt, H., Rohde, K.I., Wakker, P.P.: Non-hyperbolic time inconsistency. Games and Economic Behavior 66(1), 27–38 (2009)
5. Chen, D.N., Jeng, B., Lee, W.P., Chuang, C.H.: An agent-based model for consumer-to-business electronic commerce. Expert Systems with Applications 34(1), 469–481 (2008)
6. Clemen, R.T.: Making Hard Decisions: An introduction to decision analysis, 2nd edn. Duxbury Press, Belmontm (1996)
7. Fatima, S.S., Wooldridge, M., Jennings, N.R.: An agenda-based framework for multi-issue negotiation. Artificial Intelligence 152(1), 1–45 (2004)
8. Frederick, S., Loewenstein, G., O'donoghue, T.: Time discounting and time preference: A critical review. Journal of Economic Literature 40(2), 351–401 (2002)
9. Gimpel, H., Jennings, N.R., Kersten, G.E., Ockenfels, A., Weinhardt, C.: Market engineering: A research agenda. In: Negotiation, Auctions, and Market Engineering, pp. 1–15. Springer (2008)
10. Huang, C.C., Liang, W.Y., Lai, Y.H., Lin, Y.C.: The agent-based negotiation process for b2c e-commerce. Expert Systems with Applications 37(1), 348–359 (2010)
11. Kersten, G.E., Lai, H.: Negotiation support and e-negotiation systems: an overview. Group Decision and Negotiation 16(6), 553–586 (2007)
12. Kersten, G.E., Kowalczyk, R., Lai, H., Neumann, D., Chhetri, M.B.: Shaman: Software and human agents in multiattribute auctions and negotiations. In: Negotiation, Auctions, and Market Engineering, pp. 116–149. Springer (2008)
13. Lee, K.C., Lee, H., Lee, N.: Agent based mobile negotiation for personalized pricing of last minute theatre tickets. Expert Systems with Applications 39(10), 9255–9263 (2012)
14. Loewenstein, G., Prelec, D.: Anomalies in intertemporal choice: Evidence and an interpretation. The Quarterly Journal of Economics 107(2), 573–597 (1992)
15. Maes, P., Guttman, R.H., Moukas, A.G.: Agents that buy and sell. Communications of the ACM 42(3), 81–93 (1999)
16. Samuelson, P.A.: A note on measurement of utility. The Review of Economic Studies 4(2), 155–161 (1937)
17. Sayman, S., Onculer, A.: An investigation of time inconsistency. Management Science 55(3), 470–482 (2009)
18. Sundarraj, R.P., Mok, W.W.H.: Models for human negotiation elements: Validation and implications for electronic procurement. IEEE Transactions on Engineering Management 58(3), 412–430 (2011)
19. Vetschera, R.: Preference structures and negotiator behavior in electronic negotiations. Decision Support Systems 44(1), 135–146 (2007)

Using Value Ranges to Reduce User Effort in Preference Elicitation

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Abstract. In the aim to decrease the user effort during the preference elicitation phase, we have studied the use of value ranges. We propose to allow the users to modify a reduced initial set of alternatives to easily report their preferences. We have investigated the consequences on the following steps of the decisional process. This is illustrated by examples taken in the search for common time slots for a meeting using an on-line group decision support system.

Keywords: Group Decision-Making, preference elicitation, range of alternatives, Decision Support System.

1 Introduction

Web-applications provide new supports for Group Decision Making (GDM), like on-line voting systems. However, these tools strongly constrain the way the preferences are provided by the participants, what can lead to great user effort. Suppose that you have to schedule a meeting with your colleagues. You can say: “Any date between the 13rd and the 17th is right for me”, instead of making the list: “It’s right at any date among the 13rd, the 14th, the 15th, the 16th and the 17th”. Although the dates are discrete values, their expression using ranges is easier than with long lists of values, which are although what a scheduling application would require. Similarly, suppose that you have to plan a one-hour long meeting tomorrow. You can say: “Any hour between 1 PM and 5 PM is right for me”, instead of making the list: “It’s right at any hour among 1 PM, 1:30, 2:00, 2:30, 3:00, 3:30, 4:00”. This is an example in which the continuous expression is preferable when, like time, the objects are intrinsically continuous. However using range of values requires to adapt the computing algorithm. For example, in the case where one of the group member gives her preference for any hour between 1.5 PM and 3.5 PM, while another one prefers between 1 to 3 PM and 4 to 5 PM, the difficulty is to aggregate the preferences reported as continuous alternatives to make the group decision.

In the aim to decrease the user effort during the preference elicitation phase, we have studied the use of alternatives described as ranges of values in the context of group decision-making. This is illustrated by examples taken in the search for common time slots for a meeting using an on-line decision support

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system. The format of our paper is as follows: in Section 2, we present some related works and the hypotheses of our study. In Section 3, we define the problem and propose how the continuous alternatives can be handled throughout the decision-making process. Our proposition is illustrated in Section 4 by two application cases related to two different decision needs contexts.

2 Related Work and Hypotheses

GDSS users do not want to spend time and effort when it is not necessary [10]. One of the user effort components is the size of the set of alternatives [1]. Our aim is to reduce this size in using aggregated alternatives when the user is indifferent among a range of values. The preference information on alternatives provided by the users can be represented in different formats: utility values, preference orderings, multiplicative preference relations, fuzzy preference relations... In this study, we choose to consider only utility values. Our purpose is thus different from the works in the field of the fuzzy preference relations [9]. Indeed, the intervals are commonly used to represent and compute the preference relations between discrete alternatives, on the base of the fuzzy preferences given by the decision-makers [11]. Fuzzy preferences are used to handle the cases when a decision-maker can not report precisely his preference of an alternative to another one. Despite the similar aim to facilitate the preference elicitation, we differ in that we use the intervals to represent the alternatives and not the preference relations; the ranges of values will be used only to gather alternatives having the same utility value for the user.

The elicitation and aggregation problems in the context of choosing a range of values from multiple agents' most-preferred ranges of values has already been studied in diverse domains, as in [7] for assignment problems where specific information is inferred using global knowledge, or [6] for soft constraint problems where some of the preferences may be unspecified. Our aim is essentially practical, in that we want to evaluate the difficulties encountered in developping a group decision system based on ranges of values instead of the usual discrete alternatives. Moreover, and differently from [4] in which the focus is on the sufficient conditions to encourage the agents to answer truthfully, we make the hypothesis that the DSS is sufficiently secured to allow the agents to give their preferences in a total privacy, i.e. none of them knows the preferences of the others. The user is supposed to give a full evaluation of the ranges he has defined and the focus is on the facility for him to report preferences. Finally, the problem handled in this study is to support GDM, via an on-line tool, but without using additional communication methods or support to negotiation (see [3] for a recent related study).

3 Decision-Making with Continuous Alternatives

We examine the case of a group $\mathcal{M} = \{\mathbf{m}_1, \ldots, \mathbf{m}_n\}$ of decision-makers, or "agents", that has to make a decision $\mathbf{d} = [\underline{d}, \overline{d}]$ with a given constraint on the width $\text{wid}(\mathbf{d}) = |\overline{d} - \underline{d}| = \delta$, e.g. representing the begin and end times of a meeting. We make no assumption on the criteria on which the agents evaluate the alternatives: each agent m is supposed to have her/his own utility function u_m, whose details are unknown from the others. To reduce the user effort, we propose to reduce the number of alternatives to be evaluated by the user. The principle is to group, as often as possible, the alternatives having the same value for the user. The proposed decision-making process (called *EGDM* for *user Effortless GDM process*) includes these steps:

1. Proposition of the initial ranges of alternatives
2. Preference elicitation with modification of the initial set
3. Unification of the modified alternative sets
4. Preference aggregation

3.1 Proposition of the Initial Ranges of Alternatives

Let $\mathcal{R}$ be the initial set of feasible alternative ranges. Each range of alternatives is represented by an interval $\mathbf{a} = [\underline{a}, \overline{a}]$ of real numerical values. When its width $\text{wid}(\mathbf{a})$ is greater than the decision width, one range can group multiple decision possibilities. In the example case of the meeting, the initiator of the meeting provides a set of possible time slots, possibly longer than the wished duration for the meeting. We assume that the ranges are distinct and we define the domain of $\mathcal{R}$ as $\text{dom}(\mathcal{R}) = \{x \in \mathbb{R} \,|\, \exists! \mathbf{a} \in \mathcal{R},\, x \in \mathbf{a}\}$.

3.2 Preference Elicitation

In the decision process, the preference elicitation step results in the set of the agents' preferences regarding the alternatives. We will focus on a cardinal evaluation of the (ranges of) alternatives, rather than pairwise comparisons. Let $u_m(x) \in [0, 1]$ be the utility of the alternative x for the agent m. We extend the notation to the ranges: when all the alternatives in the range $\mathbf{a} \in \mathcal{R}$ have the same utility, this is noted $u_m(\mathbf{a})$. The agent m prefers the range $\mathbf{a}$ to the range $\mathbf{b}$ iff $u_m(\mathbf{a}) > u_m(\mathbf{b})$.

With ranges of alternatives, the main purpose of the preference elicitation is to allow each agent to divide the proposed ranges according to his preferences. Suppose that an agent has already a meeting planned at 14:00 until 15:00, then the proposed range $[13.5, 16.5]$ must be divided into $[13.5, 14]$, $[14, 15]$ and $[15, 16.5]$ to enable to report $u([14, 15]) = 0$. Indeed, given a range $\mathbf{a}$, each agent may want to distinguish the subsets of $\mathbf{a}$ that have distinct utilities. We propose to give the possibility to "split up" any range according to the utility of its parts. When a range $\mathbf{a}$ is divided to distinguish a part $\mathbf{b} \subseteq \mathbf{a}$ such as $u(\mathbf{b}) \neq u(\mathbf{a} \setminus \mathbf{b})$, $\mathbf{a}$ is replaced by the new ranges $[\underline{a}, \underline{b}]$, $\mathbf{b}$ and $[\overline{b}, \overline{a}]$. This enables to report the value of $u(\mathbf{b})$, distinct from $u([\underline{a}, \underline{b}])$ and $u([\overline{b}, \overline{a}])$. Note that the part $[\underline{a}, \underline{b}]$ (resp. $[\overline{b}, \overline{a}]$) can be reduced to an empty interval when $\underline{a} = \underline{b}$ (resp. $\overline{b} = \overline{a}$).

The partition process (see Algorithm EGDM, lines 1 to 4) is repeated until no more distinction is needed between parts of the alternative ranges. Each agent m can thus change the initial set $\mathcal{R}$ into a new set $\mathbf{P}_m$ using this partitionning process. She provides the value of $u(\mathbf{a})$ for every $\mathbf{a}$ in $\mathbf{P}_m$. Since each agent creates her specific resulting set of alternative ranges, the difficulty is then to aggregate the potentially different sets issued from the preference elicitation phase.

3.3 Unification

The decision-making requires to aggregate the profiles of the agents. However, based on his individual preferences, each agent has a specific partitioning of the alternatives. The partitions must thus be unified before any aggregation of the profiles. The unification consists in two steps: (i) to define an aggregated set on the base of the individual partitions; (ii) to extend each agent's preferences to the alternatives that come from the others' partitions. The first step is a very simple union (called $\mathcal{A}$) of the partitions created by the agents (see EGDM, lines 5-9), with removal of the duplicates and those not respecting the required width. The second step requires to examine how to extend the agents' evaluation to the other alternatives, in order to avoid to go back to the preference elicitation process. The evaluations that have been given cover the whole domain of values (dom($\mathcal{R}$)), that means there is no real uncertainty on the preferences: for every agent m and every alternative range $\mathbf{a} \in \mathcal{A}$, there are ranges in $\mathbf{P}_m$ that overlap $\mathbf{a}$ and which union includes $\mathbf{a}$. We assume the utility of these ranges can be used to compute an estimated utility for $\mathbf{a}$ (comp-u$_m(\mathbf{a})$).

For instance, if the agent m has given the following evaluations: $u([9, 10.5] = 0.5$ and $u([10.5, 11.5]) = 1$, how can we determine the values m would have given to $u([9, 10])$ and $u([9, 11])$? Since $[9, 10] \subseteq [9, 10.5]$, its extended utility value is logically the same as the utility of $[9, 10.5]$: $\forall \mathbf{a} \in \mathcal{R} \setminus \mathbf{P}_m$, comp-u$_m(\mathbf{a}) = u_m(\mathbf{b})$ if $\exists \mathbf{b} \in \mathbf{P}_m,\ \mathbf{a} \subseteq \mathbf{b}$. But, for $[9, 11]$, the answer is not as straightforward.

Several methods exist to tackle this problem [5]; here are two examples: a cautious method would be to estimate the missing value using the lowest value of its parts, using comp-u$_m^{min}(\mathbf{a}) = \min u_m(\mathbf{b})$ with $\mathbf{b} \in \mathbf{P}_m$ and $\mathbf{b} \cap \mathbf{a} \neq \emptyset$. For the above example: comp-u$_m([9, 11]) = 0.5$. Another method woud be to use an additive function as: comp-u$_m^{\text{wsum}}(\mathbf{a}) = (\sum_b u_m(\mathbf{b})\text{wid}(\mathbf{b} \cap \mathbf{a}))/S$, with $\mathbf{b} \in \mathbf{P}_m$ and $\mathbf{b} \cap \mathbf{a} \neq \emptyset$, $S = \sum_b \text{wid}(\mathbf{b} \cap \mathbf{a})$. With $[9, 11]$, this gives comp-u$_m([9, 11]) = (1.5\, u([9, 10.5]) + 0.5\, u([10.5, 11.5]))/2 = 0.625$. These are only examples of the methods that can be used at this step. The function used to estimate the missing values must be selected according to the application context (see Section 4). At the end of this step (see EGDM, lines 10-15), every preference pref$(m, \mathbf{a})$ is known for any $m \in \mathcal{M}$ and any $\mathbf{a} \in \mathcal{A}$, with pref$(m, \mathbf{a}) = u_m(\mathbf{a})$ if $\mathbf{a} \in \mathbf{P}_m$, comp-u$_m(\mathbf{a})$ otherwise.

3.4 Aggregation

Once the values are given for all the ranges and all the agents, they can be aggregated to provide one or several decision recommendations. As for the estimation step, the choice of the aggregation function must be based on the constraints of the application domain or context. For example:

- when the widest consensus must be found, it is preferable to select a function that assure to maximize the satisfaction of the less satisfied agent, like in: $\mathrm{f}_{\mathrm{agreg}}^{\mathrm{maxmin}}(\mathcal{A}, \mathrm{pref}) = \arg\max_{\mathbf{a}\in\mathcal{A}} \min_{m\in\mathcal{M}} \mathrm{pref}(m, \mathbf{a})$;
- when a satisfaction threshold is imposed, the selected function can be: $\mathrm{f}_{\mathrm{agreg}}^{\theta}(\mathcal{A}, \mathrm{pref}) = \{\mathbf{a} \in \mathcal{A} | \mathrm{pref}(m, \mathbf{a}) > \theta,\ \forall m \in \mathcal{M}\}$;
- when the most important is to maximize the global utility, the function can be: $\mathrm{f}_{\mathrm{agreg}}^{\mathrm{sum}}(\mathcal{A}, \mathrm{pref}) = \arg\max_{\mathbf{a}\in\mathcal{A}} \sum_{m\in\mathcal{M}} \lambda_m \mathrm{pref}(m, \mathbf{a})$, with λ_m, the priority of the agent m in the decision.

In addition, when the resulting set contains more than one alternative, secondary functions can usefully complete the selection, e.g. $\mathrm{f}_{\mathrm{agreg}}^{\mathrm{maxmin}}$ used to select the "less worst" solutions among the results given by $\mathrm{f}_{\mathrm{agreg}}^{\mathrm{sum}}$. When a resulting alternative **d** is wider than what is required, **d** includes several narrower and equivalent alternatives. One of them can thus be randomly selected after discretization.

Algorithm 1. EGDM: the proposed user Effortless GDM process

Input: A finite ordered set $\mathcal{R}$ of alternative ranges
Input: A finite set $\mathcal{M}$ of agents
Input: A real number δ, the required width for the selected alternatives
Input: A function to extend the utility values comp-u
Input: An aggregation function $\mathbf{f}_{agreg}$
Output: A finite ordered set of alternatives $\mathcal{D}$

`// Preference elicitation`
for $m \in \mathcal{M}$ **do**
    $\mathbf{P}_m \leftarrow m.$PARTITION$(\mathcal{R})$ `// action of the agent`
    for $\mathbf{a} \in \mathbf{P}_m$ **do**
        $u_m(\mathbf{a}) \leftarrow m.$EVALUATE$(\mathbf{a})$ `// action of the agent`

`// Unification of the partitions`
$\mathcal{A} \leftarrow \emptyset$ `// resulting unified set`
for $m \in \mathcal{M}$ **do**
    for $\mathbf{a} \in \mathbf{P}_m$ **do**
        if $((\mathbf{a} \notin \mathcal{A})$ *and* $(\mathrm{wid}(\mathbf{a}) \geq \delta))$ **then**
            add $\mathbf{a}$ to $\mathcal{A}$

`// Estimation of the missing preferences`
for $m \in \mathcal{M}$ **do**
    for $\mathbf{a} \in \mathcal{A}$ **do**
        if $((\mathbf{a} \in \mathbf{P}_m)$ **then**
            $\mathrm{pref}(m, a) = u_m(a)$
        else
            $\mathrm{pref}(m, a) = \text{comp-u}(a, u_m, \mathbf{P}_m)$

`// Preference aggregation`
$\mathcal{D} \leftarrow \mathbf{f}_{agreg}(\mathcal{A}, \mathrm{pref})$
return $\mathcal{D}$ `// set of selected alternatives`

4 Illustrative Example and First Evaluation

The process has been applied to the case of a poll, in the aim to find a time for a one hour-meeting. There are 5 participants and 3 feasible ranges are proposed: from 9:00 to 11:5, from 14:00 to 15:00 and from 17:00 to 19:00. To be able to list all the one-hour alternatives in the proposed time periods with a discretization every 30mn would have required to present eight alternatives ($\{[9, 10], [9.5, 10.5]...\}$, etc.). Each participant has the possibility to split the proposed ranges when he/she wants to differentiate parts having distinct utilities. The utility values have been restricted to the three usual tags “No”, “If necessary” and “OK”, coded as 0, 0.5 and 1. Table 1 shows the results from the preference elicitation phase: the participant m_1 divides $[9, 11.5]$ according to her evaluation in three distinct parts, while the participant m_2 splits it in two, etc.

Table 1. The initial ranges and the profiles of the decision-makers ($m_1, \ldots, m_5$)

initial set	m_1		m_2		m_3		m_4		m_5	
	$\mathbf{P}_{m_1}$	u_{m_1}	$\mathbf{P}_{m_2}$	u_{m_2}	$\mathbf{P}_{m_3}$	u_{m_3}	$\mathbf{P}_{m_4}$	u_{m_4}	$\mathbf{P}_{m_5}$	u_{m_5}
$[9, 11.5]$	$[9, 10]$	0	$[9, 10.5]$	0	$[9, 11.5]$	0	$[9, 11.5]$	1	$[9, 9.5]$	0.5
	$[10, 11]$	1	$[10.5, 11.5]$	1					[9.5,11]	1
	$[11, 11.5]$	0.5							[11,11.5]	0
$[14, 15]$	$[14, 15]$	1	$[14, 15]$	0.5	$[14, 15]$	1	$[14, 15]$	0	$[14, 15]$	0.5
$[17, 19]$	$[17, 19]$	0	$[17, 19]$	0	$[17, 18]$	1	$[17, 19]$	0	$[17, 19]$	0
					$[18, 19]$	0				

With this example, we can carry out a first evaluation. In usual GDSS studies, the evaluation aims at measuring the impact of the system in terms of decision time, decision quality, and decision satisfaction [2]. According to our aim, we have added a fourth criterion, which is the user effort:

- the *decision time* criterion is defined as the time required to achieve the whole decision-making process, from the definition of the alternatives (here, the intial ranges) to the proposition of solutions.
- the *decision quality* criterion is defined as the fitness of the decision regarding the group objective. In the next section, two cases with distinct objectives are presented; they are evaluated using specific indicators.
- the *decision satisfaction* criterion is defined as the fitness of the decision regarding the individual preferences. The median utility value of the selected alternative is taken as an indicator of this satisfaction.
- the *user effort* includes the definition of the initial alternatives and the preference elicitation activities. This criterion is linked to the other criteria as the part of the decision time that is dedicated to provide input data (options and preferences) to the DSS, and as the part of the quality of the system concerned by interaction and use.

The *decision time* includes both the time required to define the alternatives and the preferences, and the time for the system to compute the decision. The computing parts of the EGDM method, i.e. unification, evaluation of missing values and aggregation, are time consuming when the users have very distinct partitions and/or provide numerous details on each proposed range. In such cases, the "extensive" method, i.e. asking the agents to evaluate every possible alternative, is more appropriate. Besides, we consider that computing time is negligible regarding the time for the user to perform actions. As a consequence, the decision time is correlated to the user effort (see in the following). In this small example, the decision time is equivalent for the EGDM and the extensive methods.

Regarding the *decision quality* and *decision satisfaction* criteria, two cases with distinct aims are investigated, requiring distinct choices to unify and aggregate the profiles.

Case 1. In this first case, the aim is to plan a meeting with the persons who are available, with no priority among the participants. Within this context, the missing values are estimated from the known evaluations using the weighted-sum approximation function method described previously. The results provided by the $\mathrm{f}_{\mathrm{agreg}}^{\mathrm{sum}}$ function with $\lambda_m = 1\,\forall m$, with a further selection using $\mathrm{f}_{\mathrm{agreg}}^{\mathrm{maxmin}}$ if necessary, fit the characteristics of the expected decision. One resulting alternative is provided in this case: $[10, 11]$. The *decision quality* is measured by the sum of the utilities for the selected alternative and equal to 3.5/5. The *decision satisfaction* is measured by the median utility for the selected alternative and is equal to 1 in this case.

Case 2. In the second case, the principle is to gather as many participants as possible for the meeting. With the hypothesis that a value of 0 given to an alternative means that the participant will not be able to make himself available, the estimation of the missing evaluations are based on the "cautious" method described above. The chosen aggregation function is then $f_{agreg}(\mathcal{A}, \mathrm{pref}) = \arg\max_{p\in\mathcal{A}} |\{m \in \mathcal{M} \mid u_m(p) > 0\}|$. Applied, on the data of the example, this function gives the alternative $[14, 15]$ as the best result. The *decision quality* is measured by the number of expected participants to the meeting at the selected time, i.e. the number of utility values greater than 0 for the selected alternative, and is equal to 3/5 in this case. The *decision satisfaction*, measured as previously, is equal to 0.5 in this case.

Table 2 gives an evaluation based on the *user effort* criterion. The results show a reduction of the user effort with EGDM. However, the benefit of using value ranges depends mainly on two factors: the difference $(|\mathcal{A}| - |\mathcal{R}|)$, which represents how much the size of the initial set of alternatives is reduced using intervals, and this depends on the discretization (e.g., results would be different

Table 2. User effort in the context of the example

User effort indicators		EGDM	extensive method
size of the initial set		3 ranges	8 alternatives
number of items to evaluate	total	21	40
	average per agent	4.2	8
number of splitting actions	total	6	0
	average per agent	1.2	0

with a 15mn precision) and on the expected result width (e.g., with a 2 hour meeting); the difference $(|\mathcal{M}||\mathcal{A}| - \sum_{m \in \mathcal{M}} |\mathbf{P}_m|)$, which represents how much the users have precise preferences regarding parts of the proposed ranges.

5 Conclusions

This paper presents EGDM, a practical approach based on ranges of alternatives, to reduce the user effort during preference elicitation in the context of an online GDSS. We have proposed, in a first phase, to allow the users to modify a reduced initial set of feasible alternative ranges to easily report their preferences. Then, we have investigated how the resulting partitions of the alternative set can be unified and how the missing preferences can be deduced to complete the elicited ones. Examples of solutions have been proposed to show how the proposition can be adapted to the decisional needs. However, the consequences of the assumptions made must be assessed in relation to the literature about interval orders, e.g.[8], and much work remains to define precisely the possible application contexts and the adequation to more complex situations.

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References

1. Avesani, P., Susi, A., Zanoni, D.: Collaborative case-based preference elicitation. In: Ali, M., Esposito, F. (eds.) IEA/AIE 2005. LNCS (LNAI), vol. 3533, pp. 752–761. Springer, Heidelberg (2005)
2. Barkhi, R., Kao, Y.-C.: Evaluating decision making performance in the GDSS environment using data envelopment analysis. Decision Support Systems 49(2), 162–174 (2010)
3. Druckman, D., Mitterhofer, R., Filzmoser, M., Koeszegi, S.: Resolving impasses in e-negotiation: Does e-mediation work? Group Decision and Negotiation, 1–18 (May 2013)
4. Farfel, J., Conitzer, V.: Aggregating value ranges: preference elicitation and truthfulness. Autonomous Agents and Multi-Agent Systems 22(1), 127–150 (2011)
5. Fishburn, P.: Preference structures and their numerical representations. Theoretical Computer Science 217, 359–383 (1999)
6. Gelain, M., Pini, M.S., Rossi, F., Venable, K.B., Walsh, T.: Elicitation strategies for soft constraint problems with missing preferences: Properties, algorithms and experimental studies. Artificial Intelligence 174(3-4), 270–294 (2010)
7. Mousseau, V., Slowinski, R.: Inferring an ELECTRE TRI model from assignment examples. J. of Global Optimization 12, 157–174 (1998)
8. Nakamura, Y.: Real interval representations. J. of Mathematical Psychology 46(2), 140–177 (2002)
9. Orlovsky, S.A.: Decision making with a fuzzy preference relation. Fuzzy Sets and Systems 1, 155–167 (1978)
10. Pommeranz, A., Broekens, J., Wiggers, P., Brinkman, W.-P., Jonker, C.: Designing interfaces for explicit preference elicitation. UMUAI 22(4-5), 357–397 (2012)
11. Xu, Z., Cai, X.: On consensus of group decision making with interval utility values and interval preference orderings. Group Decision and Negotiation 22(6), 997–1019 (2013)

Conflict Analysis between Environment Protection and Economic Development Based on GM-DEA Theory

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Abstract. In any country or region undergoing social and economic advancement, coordinating the consumption of resources and environment with economic development inevitably becomes a major issue. Based on the combination of data envelopment analysis and grey system forecasting theory, this paper establishes a "grey model-data envelopment analysis" (GM-DEA) pre-evaluation model and extends the pre-evaluation ability of temporal sequence DEA. We take the resource, environment and economy system of Jiangsu Province as an example, then measure and analyze the coordination of the resource-environment-economy (REE) system of Jiangsu from 1997 to 2014 quantitatively. This paper introduces useful methods for optimizing the coordination among the REE system. The results show that the coordination declines at first and then rises slowly from 1997 to 2014 and there is a large fluctuation and weak stability. The evaluation results and related suggestions are provided in this paper.

Keywords: Conflict analysis, Resource, Environment, Economy, Coordination, Data envelopment analysis, Grey model.

1 Introduction

The rapid development of the economy and increased social demands place considerable pressure on resources and the environment. Therefore, coordinating resource, the environment and economic development is an inevitable problem for humanity and, therefore, an important research topic.

In past years, Jiangsu placed a great emphasis on economic development but paid little attention to resource consumption and environmental protection. The conflict between economic development, and resource consumption and environmental protection has become more and more prominent. During the period of "The Tenth Five-Year Plan", Jiangsu energy consumption growth rate exceeded the GDP growth rate by 1.5 percent in 2003, and in the years 2004 and 2005, the growth rate of energy consumption was also higher than that of GDP. Although Jiangsu has made some

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effort with regard to environmental protection, the task of keeping the economy booming while using resources responsibly and protecting the environment is still difficult for Jiangsu.

In recent years, the amount of research concerning coordination between resource, environmental protection and economic development has greatly increased. Ke & Li (2005) studied the regional coordination between the resource-environment and economy of China in 2003 using DEA theory and the optimal partition clustering analysis method. Zhang & Li (2009) established a typical econometric model of environmental index with per capita GDP based on the economic and environmental data for Jiangsu. Liang (2009) evaluated the coordinated development of the economy and environment of Shandong using principal component analysis and regression analysis. Tong & Wu (2010) built a panel model according to the economic and environmental data of 13 cities in Jiangsu from 2003 to 2007. Hou (2011) showed that the environmental and economic development of Dongying City is disordered based on calculating the coordination degree of economic development and industrial structure in the city. Yu et al. (2012) used the DEA model to evaluate the environmental quality and economic development of Hainan from 1998 to 2007.

The research methods pertaining to coordination of the REE system are various. However, not enough research has been carried out. There are few research results regarding this issue for Jiangsu and different ways to determine the weights of the valuation index. Furthermore, the evaluation object is limited to single sectional data or historical data. In this paper, resource and environment are used as inputs of the system and economic development as output to calculate the coordination. This paper uses the DEA model to analyze the coordination of the REE system in Jiangsu province. Because of the lack of sample data, this paper uses the grey theory model, GM(1,1). First, for combining assessment and prediction, we construct a GM-DEA pre-evaluation model. Second, we use the built model to analyze the effectiveness of the system. Then, we analyze the changes and trends of the coordination and provide suggestions for improvement.

2 Research Methodologies and Models

2.1 Data Envelopment Analysis

Data envelopment analysis (DEA) is a linear programming method which deals with multiple inputs and outputs without pre-assigning weights between variables (Charnes et al. 1987). It can form an efficient frontier which “envelopes” data and separates efficient units from inefficient units (Wei 2004). This paper chooses two classical models of DEA to evaluate the coordination.

2.1.1 C^2R Model

Suppose there are n peer DMUs and we need to evaluate the efficiency of them. For DMU_0, we can build a regional C^2R model as the maximum of the ratio of weighted outputs to weighted inputs subject to the condition that similar ratios for every DMU are less than or equal to unity[7], shown in formula (1).

$$\begin{cases} \max \theta = \dfrac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{i0}} \\ s.t. \dfrac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, j = 1,2,\Lambda,\text{n}; u_r, v_i \ge 0; i = 1,2,\Lambda,m; r = 1,2,\Lambda,s \end{cases} \tag{1}$$

where x_{ij}, y_{rj} are the known inputs and output of *j*th DMU, v_i, u_r are variable weights decided by the solution of this problem.

$$\begin{cases} \min \theta \\ st \sum_{j=1}^{n} \lambda_j X_j + S^- = \theta X_0 \\ \sum_{j=1}^{n} \lambda_j Y_j - S^+ = Y_0 \\ \lambda_j \ge 0; j = 1,2,\Lambda,n; S^- \ge 0, S^+ \ge 0 \end{cases} \tag{2}$$

Second, applying the Charnes-Cooper transformation to the C^2R model and then converting it into dual programming, we obtain the final C^2R model shown in formula (2). There are *m* inputs and *s* outputs for DMU. $X_j=(x_{1j}, x_{2j}, \ldots, x_{mj})^T$, $Y_j=(y_{1j}, y_{2j}, \ldots, y_{sj})^T$. θ is the final efficiency of DMU_0. λ_j is a constructed mix proportion of DMU_j relative to DMU_0 among DMUs. S^- and S^+ stand for the slack variable of input and output, respectively.

This model can be explained as follows: 1. When $\theta = 1$ and $S^{-0} = S^{+0} = 0$, DMU_0 is referred to as DEA efficient, i.e., to DMU_0, for original input, output has achieved the optimal value in a system made up of *n* DMUs. 2. When $\theta = 1$ and $S^{-0} \ne 0$ or $S^{+0} \ne 0$, DMU_0 is referred to as weak DEA efficient. 3. When $\theta < 1$, DMU_0 is referred to as DEA invalid, i.e., this DMU has a poor performance of input and output.

For an invalid DMU, we can project it to the frontier and obtain the sub-point, which is also the target value of this DMU. Suppose the original point is (X_j, Y_j), the sub-point is (X_j', Y_j'), then $X_j' = \theta X_j - S^{-j}$, $Y_j' = Y_j + S^{+j}$. $\Delta X_j = X_j - X_j' = (1-\theta) X_j + S^{-j}$, and $\Delta Y_j = Y_j' - Y_j = S^{+j}$ are the amount of input redundancy and output deficiency, respectively. We define the input redundancy rate as $\Delta X_j / X_j$, and the corresponding output deficiency rate as $\Delta Y_j / Y_j$.

2.1.2 BC^2 Model and Return to Scale

C^2R has constant return to scale, while BC^2 has variable return to scale. The BC^2 model is derived by adding one constraint, $\sum_{j=1}^{n} \lambda_j = 1$, to the C^2R model. Its efficiency value is pure technical efficiency (PTE) value. We can obtain the scale efficiency value according to the formula $SE = TE / PTE$.

2.2 Grey System Forecasting GM(1,1)

Grey system theory takes a “small sample, poor information” uncertain system as the research object. Grey forecasting can generate and process raw data using a sequence operator according to our recognition of the system, build a model and make scientific predictions about the future state (Liu et al. 2010). Considering that this study will deal with related data and we may face the problem of limited data, we choose the GM(1,1) model of grey system theory for prediction.

GM(1,1) converts the original sequence to a generated sequence first, and then uses the curve fitting method to establish a dynamic model. Finally, we deoxygenize the new model and obtain the grey prediction of the original sequence. Specific steps are as follows: 1. Accumulate and generate the sequence based on the original sequence, $X^{(0)}=(x^{(0)}(1),x^{(0)}(2),\cdots,x^{(0)}(n))$, and get $X^{(1)}=(x^{(1)}(1),x^{(1)}(2),\cdots,x^{(1)}(n))$, where $x^{(1)}(k)=\sum_{i=1}^{k}x^{(0)}(i),k=1,2,\cdots,n$. 2. Carry out the closing average generation to $\mathbf{X^{(1)}}$. Let $z^{(1)}(k)=0.5x^{(1)}(k)+0.5x^{(1)}(k-1)$. We have $Z^{(1)}=(z^{(1)}(2),z^{(1)}(3),\cdots,z^{(1)}(n))$. Let $B=\begin{pmatrix}-z^{(1)}(2) & 1\\ -z^{(1)}(3) & 1\\ \cdots & \\ -z^{(1)}(n) & 1\end{pmatrix}$ and $Y=\begin{pmatrix}x^{(0)}(2)\\ x^{(0)}(3)\\ \cdots\\ x^{(0)}(n)\end{pmatrix}$. 3. The corresponding differential equation is $\frac{dx^{(1)}}{dt}+ax^{(1)}=b$, where a and b are model parameters; -a is the development coefficient and b is the grey action. Estimate parameter $\hat{a}=[a,b]^T$ with the least squares estimating method and get $\hat{a}=(B^TB)^{-1}B^TY$. 4. Obtain the time response function sequence $\hat{x}^{(1)}(k+1)=(x^{(0)}(1)-\frac{b}{a})e^{-ak}+\frac{b}{a}$, $k=0,1,\cdots,n$. According to $\hat{x}^{(0)}(k+1)=\hat{x}^{(1)}(k+1)-\hat{x}^{(1)}(k)$, we get the prediction model of the original sequence: $\hat{x}^{(0)}(k+1)=(1-e^{a})(x^{(0)}(1)-\frac{b}{a})e^{-ak},k=1,2,\cdots,n$, where $\hat{x}^{(0)}(1)=x^{(0)}(1)$. 5. Error checking. Calculate the residual error of each term in the sequence $\varepsilon(k)=x^{(0)}(k)-\hat{x}^{(0)}(k)$. For $k\le n$, $\Delta_k=\left|\frac{\varepsilon(k)}{x^{(0)}(k)}\right|$ stands for simulated relative error of the k point, and $\bar{\Delta}=\frac{1}{n}\sum_{k=1}^{n}\Delta_k$ is called the average relative error. Given a threshold, α, we can evaluate accuracy according to average relative error by observing whether $\bar{\Delta}$ is less than α. Accuracy class is given in Table 1.

Table 1. Error Precision Grade

Given threshold α	0.01	0.05	0.10	0.20
Accuracy class	Level 1	Level 2	Level 3	Level 4

2.3 GM-DEA Model

If a system consists of several units, it is suitable to use the DEA model to evaluate the DMU's efficiency. However, DEA cannot make predictions. This paper introduces the idea of combining grey prediction with DEA evaluation and constructs a GM-DEA pre-evaluation model in which temporal sequence DEA expands *q* periods. Consider time response sequences $\hat{x}^{(0)}(k+1)=(1-e^{a})(x^{(0)}(1)-\frac{b}{a})e^{-ak}$ in GM(1,1), which have final prediction function, and the constraints of system inputs and outputs, namely restrictions on X_j and Y_j. According to the C^2R model we know there are m+s equations, *m* inputs, and *s* outputs. Add this constraint to C^2R as constraint conditions, and make *q* period forecasting data. Then, the GM-DEA pre-evaluation model is:

$$\begin{cases} \min \theta \\ st \sum_{j=1}^{n+q} \lambda_j x_{ij} + s_i^{-j} = \theta x_{i0} \\ \sum_{j=1}^{n+q} \lambda_j y_{rj} - s_r^{+j} = y_{r0} \\ x_{ik} = \hat{x}_i^{(0)}(\mathrm{k}) = (1-e^{a_i})(\mathrm{x}_i^{(0)}(1) - \frac{b_i}{a_i})\mathrm{e}^{-a_i(\mathrm{k}-1)} \\ y_{rk} = \hat{y}_r^{(0)}(\mathrm{k}) = (1-e^{a_r})(\mathrm{y}_r^{(0)}(1) - \frac{b_r}{a_r})\mathrm{e}^{-a_r(\mathrm{k}-1)} \\ \lambda_j \geq 0,\ \mathrm{s}^{\pm} \geq 0,\ j=1,2,\cdots,\mathrm{n}, n+1, n+2,\cdots, n+q \\ \mathrm{i}=1,2,\cdots,\mathrm{m},\ \ \mathrm{r}=1,2,\cdots,\mathrm{s},\ \ k=n+1,n+2,\cdots,n+q \end{cases} \tag{3}$$

where meanings of variables are similar to those of C^2R. X_{ik} and Y_{rk} are the predicted data of *q* period; $-a_i$, $-a_r$ are the development index of the prediction equation; b_i, b_r are grey actions of X and Y.

This model increases the pre-evaluation ability in temporal sequence DEA. It can evaluate existing evaluation units and also pre-evaluate future effectiveness of a REE system. However, it should be known that this model is only for time series and we use time response function whose predicted data have reasonable relevant accuracy to construct the model. In particular, when the number of the DMU and index makes it unsuitable to use the classic DEA model, this method can satisfy the requirements of DEA by extending the amount of DMU.

3 Coordination Evaluation of REE System in Jiangsu

3.1 Determination of Decision Making Units and Index

This paper takes the REE system of Jiangsu for the years from 1997 to 2014 as DMUs to evaluate coordination. As such, there are 18 DMUs, namely, the year 1997 is DMU1, the year 1998 is DMU2 and so on. And the years 2012 to 2014 are units of pre-assessment. As we want to evaluate coordination of environment and economy, and strong coordination means less resource consumption and environmental damage costs but great economic development, therefore, we can use resource consumption and environmental damage as inputs in DEA, and economic development as output. According to correlation studies, we select total energy consumption and annual water supply as resource consumption, industrial wastewater, industrial emissions, and industrial solid waste discharge, which can reflect the total damage to the environment, as indicators of environmental damage, and Jiangsu's GDP, which can reflect economic development, as output. The index system is shown in Table 2.

Original data is from the 1998-2012 China Statistical Yearbook, Statistical Yearbook of Jiangsu Province, China's Environmental Statistical Yearbook and China Energy Statistical Yearbook.

Table 2. Coordination Evaluation Index of REE System

System Inputs	Resource consumption	Total energy consumption (Ten thousand tons of standard coal)
		Annual water supply (Ten thousand cubic meters)
	Environment inputs	Industrial wastewater (Ten thousand tons)
		Industrial emissions (Million cu.m)
		Industrial solid waste discharge (Ten thousand tons)
System Output	Economic development	Jiangsu's GDP (One hundred million yuan)

3.2 GM-DEA Model and Results Analysis

Because the data of later years differ greatly from those of earlier years, we select data from 2001 to 2011 to forecast. Using GM, we can establish the time response function for each index. For Jiangsu's GDP, a=0.1651, b=8658.4674, and time response function is $\hat{y}^{(0)}(k+1)=9420.89e^{0.1651k}$, where $\hat{y}^{(0)}(1)=9456.84$ is the original value. Then, we get $\hat{y}^{(0)}(1),\cdots,\hat{y}^{(0)}(11)$. By calculating the residual error and average relative error, we have $\overline{\Delta_6}=2.46\%$. So, accuracy of average relative error is at Level 2. In the same way, we get average relative error of other indicators: $\overline{\Delta_1}=7.08\%$, $\overline{\Delta_2}=3.56\%$, $\overline{\Delta_3}=4.69\%$, $\overline{\Delta_4}=9.77\%$, and $\overline{\Delta_5}=6.46\%$, which are shown in Table 3. Their errors are at Level 2 or Level 3. Accuracy of errors is acceptable. Therefore, time response functions of indexes shown in Table 4 can be used to predict index data.

Table 3. Average Relative Error of Index

Index	Input1	Input2	Input3	Input4	Input5	Output1
Average relative error (%)	7.08	3.56	4.69	9.77	6.46	2.46
Accuracy class	Level 3	Level 2	Level 2	Level 3	Level 3	Level 2

Table 4. Time Response Function of Index

Index	Time response function
Total energy consumption	$\hat{x}_1^{(0)}(k)=10509.2327e^{0.1017(k-1)}$
Annual water supply	$\hat{x}_2^{(0)}(k)=369449.1127e^{0.0274(k-1)}$
Industrial wastewater	$\hat{x}_3^{(0)}(k)=265687.8338e^{-0.0014(k-1)}$
Industrial emissions	$\hat{x}_4^{(0)}(k)=11319.5551e^{0.1274(k-1)}$
Industrial solid waste discharge	$\hat{x}_5^{(0)}(k)=3671.7554e^{0.1045(k-1)}$
Jiangsu's GDP	$\hat{y}_1^{(0)}(k)=9420.89e^{0.1651(k-1)}$

Table 5. DEA Efficiency Scores for Each Year

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005
DMU	1	2	3	4	5	6	7	8	9
crste	0.749	0.724	0.679	0.694	0.522	0.546	0.626	0.62	0.678
vrste	1	1	1	0.994	1	0.977	0.927	0.9	0.92
cale	0.749	0.724	0.679	0.698	0.522	0.559	0.675	0.689	0.737
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
DMU	10	11	12	13	14	15	16	17	18
crste	0.643	0.812	0.903	0.925	0.977	0.87	0.927	0.963	1
vrste	0.79	0.864	0.947	0.96	1	0.941	0.941	0.968	1
cale	0.814	0.939	0.954	0.963	0.977	0.925	0.985	0.995	1

Table 6. Input Redundancy Rates of Each Year

	Year	1997	1998	1999	2000	2001	2002	2003	2004	2005
Input redundancy rate %	DEA score	0.749	0.724	0.679	0.694	0.522	0.546	0.626	0.62	0.678
	Energy consumption	59.12	56.63	53.89	51.43	47.93	46.02	44.99	46.26	47.02
	Water consumption	87.25	86.87	85.14	84.15	81.36	81.77	78.58	74.97	68.81
	Waste water	30.68	88.25	87.6	86.28	88.7	86.13	83.72	81.57	79.68
	Waste gas	25.08	27.59	32.09	30.65	47.84	45.35	37.41	38.02	32.22
	Waste solid	53.68	55.78	53.07	50.1	52.83	50.48	43.37	43.1	42.74
	Year	2006	2007	2008	2009	2010	2011	2012	2013	2014
Input redundancy rate %	DEA score	0.643	0.812	0.903	0.925	0.977	0.87	0.927	0.963	1
	Energy consumption	43.27	39.26	31.85	28.93	21.4	12.95	11.92	6.15	0
	Water consumption	69.85	62.36	53.03	49.76	43.82	32.6	24.07	12.86	0
	Waste water	75.49	68.66	61.42	56.45	49.15	35.44	28.32	15.34	0
	Waste gas	35.68	18.8	9.67	7.55	2.32	24.98	7.26	3.7	0
	Waste solid	46.44	37.3	28.91	23.93	19	16.91	11.42	5.88	0

According to the time response function, equation (3), and letting q=3, we get the DEA relative efficiency value of each year using DEA software Deap2.1 and the input-oriented model. The final efficiency scores are shown in Table 5, where crste means CCR value, vrste means BCC value, scale means scale efficiency. Input redundancy rates are shown in Table 6, the trend of efficiency value is shown in Figure 1.

Table 5 shows that only DMU18 is efficient, which means that this year needs relatively less resource consumption and environmental damage costs to obtain more economic development. The efficiency values range from 0.522 to 1, indicating that the overall efficiency fluctuates greatly. Scale efficiency decreases at first and then increases, showing a U-shaped trend. Now, look at the pure technical efficiency.

The scores of 2006 and 2007 are 0.79 and 0.864, respectively. We can conclude that these two years have poor technological progress with respect to improving production and economic efficiency, i.e., there is a lack of investment in science and technology.

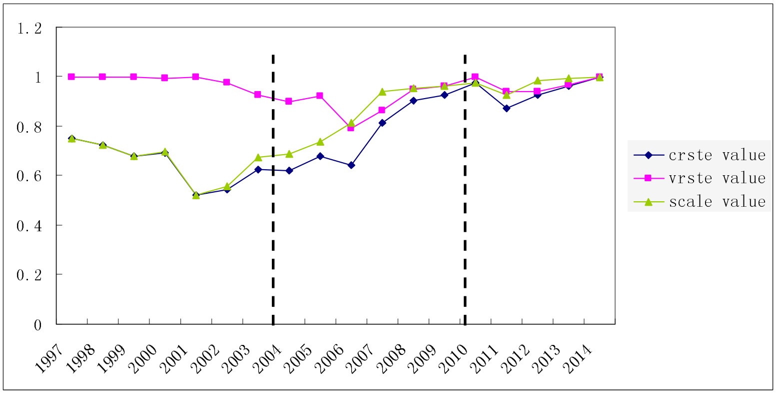

Fig. 1. Trend Chart of Each Unit Efficiency

Based on the overall efficiency situation shown in Figure 1, we can divide the dynamic change of coordination from 1997 to 2014 into three stages: 1997-2000, 2001-2006, and 2007-2014.

In the first stage, the efficiency value is between 0.679 and 0.749, which is within the moderate scope of coordination. Based on the input redundancy rate, we know the overall redundancy rate is large, and energy consumption and water consumption are up to more than 80%, which makes DEA invalid. In this stage, the economic development of Jiangsu is relatively slow, and the technical level of production can meet the needs of economic development. In the early period, economic development is still in a situation of extensive mode of growth, and economic development mainly relies on the pushing of consumption of resources and environment. Therefore, the degree of scale invalidity is large, which causes DEA to be invalid.

In the second stage, the comprehensive efficiency value is at a minimum on the whole, fluctuating between 0.522 and 0.678. The lowest year is 2001, in which more than 80% of water resources are in severe underutilization. Nearly 50% of energy consumption could not fully promote economic development. Waste gas and solid waste emissions redundancy are about 50%. In general, large resource consumption and wastewater and solid waste emissions are the main reasons for invalidity. This stage is at the period of "The Tenth Five-Year Plan" and Jiangsu is in the phase of vigorous economic development but with less investment in science and technology. However, due to limited development, production levels and technology cannot adequately meet the demand of rapid economic development. Simultaneously, the wastage of the environment caused by rapid economic development exceeds the bearing capacity of the environment. Because of these phenomena, the efficiency score in this stage is at a lower level and DEA invalid gradually changes from the first stage caused by scale inefficiency unilaterally to the stage caused by both scale and technical inefficiency.

The third stage is 2007-2011 and 2012-2014. In the first period, CRS value ranges from 0.812 to 0.977. From input redundancy we know that large water consumption and wastewater emissions are the main reasons for invalidity. The efficiency value in this stage is in a good condition and in a rising trend. We can conclude that intensive economic development has certain implications.

The data demonstrate that the mode of economic development of Jiangsu has been greatly changed compared with that of the early years. In the pre-assessment years of 2012-2014, pure technical inefficiency is stronger than scale inefficiency. According to Table 6, redundancy of energy consumption and solid waste is around 11%, and exhaust emissions has a better condition of 7.26%. There is a slight improvement in the year 2013. The redundancy rate is about 50% of that in 2012. According to the current trend, the year 2014 is relatively good. However, Figure 1 shows that though coordination of REE in recent years has been good, it is still not stable, especially for fluctuations caused by pure technical efficiency. Therefore, for the year 2013, we need to pay more attention to the utilization efficiency of water resources. For instance, we can improve water recycling and use water multi-purposely. We should also strengthen the protection of the water environment. At the same time, more support should be provided to science and technology to improve the efficiency of technology.

4 Conclusion

This paper constructs the GM-DEA pre-evaluation model which is applied to evaluate the coordination of the REE system of Jiangsu, China. The results show that the overall coordination in Jiangsu declines at first and then rises slowly over the past 17 years and has large fluctuations. Though coordination in recent years has improved, its technical efficiency is still unstable. And, the problem that the utilization rate is not high still exists in resource consumption, mainly in the use of water resources. Environmental damage is mainly embodied in emissions of industrial wastewater, causing pollution of the water environment.

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References

[1] Ke, J., Li, C.: Coordinated development research of resource, environment and economy in regions of China based on DEA cluster analysis. China Soft Science 2, 144–148 (2005)

[2] Zhang, J.Z., Li, H.: Relationship between economic growth and environmental pollution in Jiangsu province. Journal of HeHai University (Natural science edition) 37(1), 119–124 (2009)

[3] Liang, Z.H.: Coordinated development evaluation of economic environment system in Shandong province. Resources Development and the Market 25(2), 138–140 (2009)

[4] Tong, T.T., Wu, G.: Regional economy and environment coordinated development research. Resources and Industry 12(5), 142–145 (2010)

[5] Hou, Z.Z.: Coordination degree evaluation of ecological environment and economic development in Dongying city, Shandong province. China Population Resources and Environment 21(7), 157–161 (2011)

[6] Yu, H.M., Xiao, M., et al.: DEA validity evaluation of environmental quality and economic development of Hainan province. Industrial Safety and Environmental Protection 38(6), 68–70 (2012)

[7] Charnes, A., Cooper, W.W., Rhodes, E.: Measuring the efficiency of decision making units. European Journal of Operational Research 2(6), 429–444 (1978)

[8] Wei, Q.L.: Data envelopment analysis. Science Press, Beijing (2004)

[9] 魏权龄：数据包络分析. 北京：科学出版社 (2004)

[10] Liu, S.F., Dang, Y.G., et al.: The grey system theory and its application. Science Press, Beijing (2010)

[11] 刘思峰，党耀国等灰色系统理论及其应用. 北京：科学出版社 (2010)

Analysis of Data from a Corporate Prediction Market

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Abstract. Although some companies, such as Google, Best Buy and GE have generated and used prediction markets internally there has been limited investigation of real world use of prediction markets. Accordingly, the purpose of this paper is to investigate three issues associated with real world data derived from corporate use of prediction markets.

Keywords: Corporate Prediction Markets, Group Decision Support System.

1 Introduction

Recently, there has been substantial interest in gathering the so-called "wisdom of the crowd" (Surowiecki 2004). Accordingly, some firms have made use of prediction markets internally, including Google (Cowgill et al. 2008), Microsoft (Berg 2007) and GE (Spears et al. 2009). Prediction markets, generally accepted as part of so-called "social media" and "web 2.0" (e.g., Chui et al. 2009 and Consensus Point 2010), introduce "stock markets" into corporations in an effort to gather knowledge and information from participants, typically, employees. Stocks, such as "project X will be completed by June 1" are traded among participants in order to establish estimates of the probability of such events.

1.1 Purpose of This Paper

Although prediction markets have been around for a number of years, the actual use of prediction markets internally for business decision making has been a relatively recent and apparently limited phenomena in corporate environments (Nocera 2006). Further, there has been limited analysis of actual corporate markets and limited access to actual corporate data use of prediction markets. Accordingly, there has been limited academic discussion of actual corporate use of such systems and little analysis of their actual use in corporate settings.

As a result, the purpose of this paper is to investigate some characteristics of corporate prediction markets drawing on actual data derived from a well-known company that has used prediction markets, Best Buy. The data does not come from an academic experimental market or academic experiments, but instead comes directly from their corporate environment. Accordingly, this paper investigates real world data and analyzes relationships among the resulting variables.

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In particular, the purpose of this paper is to analyze the unique trader participation of two different employee groups ("corporate" and "retail") on three different types of prediction market problems (corporate, retail and fun). This analysis provides a number of findings, including evidence that

- The two groups' participation in different markets is highly correlated, suggesting similar interests, similar information availability or similar market artifacts.
- The two groups have statistically significant different mean numbers of trades suggesting different trading patterns by the two different groups.
- Some "fun" markets did not draw or interest potential participants, suggesting that companies need to clearly determine which "fun" markets provide the best opportunity for users to engage prediction market use.

1.2 Outline of This Paper

Section 1 of this paper has briefly introduced the notion of prediction markets, motivated the paper and discussed the purpose of the paper. Section 2 summarizes the available data and the company, Best Buy. Section 3 analyzes some previous research involving corporate prediction markets. Section 4 investigates three findings related to the analysis of the data. Section 5 briefly summarizes the paper.

2 Best Buy's "Tag Trade" and the Prediction Market Data

The prediction market analyzed in this paper was developed by Best Buy. Best Buy is a well-known firm that has pursued a range of emerging technologies to improve information flow and decision making. For example as noted by Dvorak (2008) "Best Buy's chief executive … encourages experiments … that seek to drive decision-making down the corporate ladder and information up toward the top."

2.1 Background on Best Buy[1]

Headquartered in Richfield, Minnesota, Best Buy is a large retailer with stores located in the United States, Europe, Canada and China. Although Best Buy has had operations in the United Kingdom and Europe, those investments have been closed or sold.

Best Buy operates as a physical retailer and through e-commerce. Best Buy offers a wide range of consumer products, typically related to technology, including audio, video, phones and computers. Best Buy is extremely price competitive. For example, over the Christmas holidays in the United States in 2013, Best Buy implemented a strategy of a low price guarantee through Christmas. Best Buy allows trade-in of electronics and has a strong credit card presence.

Best Buy is famous for their "Geek Squad,"[2] that allows buyers to ask questions about their technology purchases. For example, the Geek Squad can help computer

[1] http://finance.yahoo.com/q/pr?s=BBY

[2] http://www.bestbuy.com/site/Electronics/Geek-Squad/pcmcat138100050018.c?id=pcmcat138100050018

owners remove viruses and other concerns. As a result, Best Buy is not just known for the sale of technology and entertainment-based equipment, but also for their subsequent service of that equipment.

2.2 Best Buy's Use of Prediction Markets (Dvorak 2008)

Best Buy has used a prediction market referred to internally as "Tag Trade." As many as 2,100 employees have chosen to be a part of the prediction markets. Traders are given one million dollars of an internal currency to trade. As noted by different observers at Best Buy, reportedly, in some cases, the prediction markets have been more accurate than the official forecasts. In one case, prediction markets were 99.4% accurate 4 months prior to a holiday prediction.

2.3 Data

The data in this study was generated by Best Buy[3]. There were two groups of participants: corporate and retail. Retail included store, district and regional management from a sales district in the upper Midwestern United States. Corporate traders were drawn from the corporate office. In the study there were 159 total traders participating, with 79 from "corporate," and 80 from "retail." There were 196 registered traders, with 97 from corporate and 99 from retail. As part of the prediction market, Best Buy captured the unique number of traders both by day/date and by market stock, for the two different groups of employees.

The data used in this study is "researcher neutral," in that Best Buy developed the data independent of the researcher, for their own uses. This has at least four implications. First, we take the data as an indicator of the firm's interest in the activities described by the data; otherwise they would not have developed it and analyzed it. Second, such internal data is not usually made available to researchers. As a result, this data provides a relatively unique opportunity to glimpse the use of Best Buy's prediction market system. Third, since the data is developed by a firm about their own internal system it has substantial external validity. Fourth, the data "is what it is," in that there is no going back to get additional data or different data. For example, we may have been interested in daily price data or number of trades, but the data primarily consists of information about the number of unique traders along a number of dimensions, along with aggregated trading information.

3 Background: Markets, Prediction Markets and Corporate Prediction Markets

3.1 Economic Basis of Markets

Corporate prediction markets differ from traditional approaches that focus on gathering knowledge and information from corporate experts, and instead make use of the so-called "wisdom of the crowds" (Surowiecki 2004), gathering knowledge that is

[3] Data is available from the author.

broadly distributed among the employees. This approach is consistent with economic theory. For example, as noted by Hayek (1945) "…knowledge (is) not given to anyone in its totality." Instead "…the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form, but solely as the dispersed bit of incomplete and frequently contradictory knowledge which all the separate individuals possess." Prediction markets work to aggregate dispersed knowledge in the form of prices that are used to anticipate (predict) economic events.

In addition, prediction markets are based on the notion of efficient markets. In a path-breaking analysis, Fama (1970) indicated that ''prices at any time fully reflect all available information.'' As a result, theory suggests that we can gather expectations that fully reflect all available information in the form of market prices.

3.2 Prediction Markets

In contrast to investment markets, such as the New York Stock Exchange, internal corporate prediction markets are markets aimed at developing predictions about future events. For example the Hollywood Stock Exchange (HSX.com) is an open market that uses a market format to forecast movie revenues.

3.3 Prediction Markets as a Group Decision Support

Prediction markets are a market-based approach to group decision support systems. Prediction markets use broad-based participation, typically from within a company to gather and aggregate information, typically about some event, using a market mechanism that ultimately is captured in a price associated with that event. As with other group decision support approaches, internal corporate prediction markets are technology-based and dependent on participants being networked together through the markets. Further, the markets must respond in a timely manner and allow trades be completed without technical difficulties.

4 Expectations, Analysis and Findings

This section summarizes expectations, analyzes and findings regarding three different issues: the relationship between the number of traders in the two groups and the markets that they participate in, the average number of trades that the two different groups made and some limitations of the use of so-called "fun" markets to gain participation.

4.1 Number of Traders in Different Markets by Group

The correlations between the two groups of corporate and retail traders, for all markets and for each individual market types (corporate, retail and fun), are summarized in table 1. Each of the correlations between the two trader groups, in total and by market are statistically significant.

Table 1. Correlation between Number of Unique Traders in Corporate and Retail by Market Type

Type	Number	Correlation	Significance
All	45	0.828	0.0000001
Corporate	24	0.793	0.000002
Fun	12	0.891	0.00005
Retail	9	0.923	0.0002

These results suggest a strong relationship between the two different groups and the markets that they trade in. This result could suggest information flows between the two different groups, either formally or informally, that result in mitigating asymmetries of information between the two groups. Alternatively, it could be an indication of general interest in the markets chosen by the company.

4.2 Group Trading Behavior

With our data, there are multiple internal groups involved in the markets. This is not unusual in corporate settings. For example, there may be multiple functional groups, such as marketing, finance and operations. Alternatively, the groups may be based on the business, such as at Best Buy, where the groups were based on operations: retail and corporate. An important question in designing markets is whether the trading behavior for the two groups is similar. The existence of aggregated trading data allows us to investigate the similarity of trading behaviors between the two groups.

One approach to studying that relationship between trading behaviors of groups is to determine whether or not the mean numbers of trades of the two groups are different than each other. As a result, the mean numbers of transactions, per group were investigated as a measure of the trading behavior in each of the two groups. In order to determine the statistical significance of the difference of the means requires an estimate of the standard deviation, that was not provided with the data. The original disclosures only included the mean, median, low number of transactions and the highest number of transactions. Accordingly, an estimate of the standard deviation was required to estimate statistical significance.

Recently researchers (Hozo et al. 2005) have provided guidance as to estimation of the standard deviation, for sample sizes greater than 70, as the range divided by 6. Since our data has 79 retail participants and 80 corporate participants we can use their result to generate an estimate of the standard deviation, in order to determine whether the means are statistically significantly different than each other. Using that formula, we can estimate that the two means are statistically significantly different than 0 at better than the .01 level. These results are summarized in table 2. Accordingly, that the two different groups appear to have substantially different mean numbers of trades, suggesting important differences between the two groups. This suggests that market designers take these differences into account in their design of prediction markets.

Table 2. Mean Number of Transactions per Trader

	Mean	Median	Minimum	Maximum	Estimated Standard Deviation
Corporate	94.304	24	2	1213	201.833
Retail	35.625	21	2	288	47.667

4.3 Fun Markets

In corporate prediction markets there seems to be a common thought, that sports and entertainment stocks are used as a basis to "drive participation" (e.g., Coles et al. 2007) by creating "fun" markets. As noted in table 1, the Best Buy data contained 12 different "fun" markets. However, companies generally don't really care if users participate in the fun markets but they do want the fun markets to appeal to potential market participants, so that they get used to and use the prediction markets.

An analysis of the data, suggests that some fun markets are "more fun" than other markets. Further, some fun markets appear not to draw or interest participants. If that is true then including some of the markets to draw users is problematic and does not accomplish its goal. As a result, the fun markets were analyzed to see if there was a difference in the number of unique traders that participated in the different markets.

Best Buy generally used both sports and entertainment markets. The analysis did find that there was more interest in "entertainment" rather than "sports" for both of the groups in the sample (table 3, panels A and B). For example, the average number of unique traders in the four sports markets of PGA (Professional Golf Association) and NBA (National Basketball Association) were statistically significantly different than all of the other "fun" markets at the .01 level (Table 3 – Panel A). Although there is controversy as to whether NASCAR (National Association for Stock Car Racing) is a sport or entertainment,[4] the numbers of unique traders of the five sports markets (PGA, NBA and NASCAR) were statistically significantly different than the "entertainment" stocks at the .05 level (Table 3 - Panel B).

The results here indicate that market developers should know their participants and chose the "fun" markets accordingly. In this case, the results suggest that the number of participants for both retail and corporate interested in sporting events compared to entertainment was substantially different. If the goal is to get a large number of participants into each of the fun markets, then those fun markets would need to be chosen carefully as part of the market design.

Alternatively, perhaps it is most important to have a "portfolio" of different fun stocks, designed to ensure that all participants have particular interest in at least one market that interests them, in order to draw them in as participants to other types of markets. As a result, companies need to clearly determine which fun markets to use to their advantage.

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[4] For example, http://www.autoweek.com/article/20120822/nascar01/120829955

Table 3. – Number of Unique Traders in Fun Markets

Panel A – PGA and NBA vs. All Else Fun

Population	Total	Total	Retail	Retail	Corporate	Corporate
Measure	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
PGA + NBA	20.75	6.898	7.50	2.082	13.25	5.188
All Else Fun	56.50	14.036	26.75	6.924	29.75	8.058
Significance of Difference of Means	0.01		0.01		0.01	

Panel B – Sports vs. All Else Fun

Population	Total	Total	Retail	Retail	Corporate	Corporate
Measure	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
Sports	29.20	19.817	12.00	10.223	17.20	9.910
All Else Fun	55.57	14.773	26.29	7.284	29.28	8.514
Significance of Difference of Means	0.05		0.05		0.20	

5 Summary and Extensions

This paper has examined some aspects of data deriving from a prediction market. Both the data and a companion paper, that empirically analyzes additional issues, are available from the author.

References

1. Berg, H.: Prediction Markets at Microsoft, Prediction markets Conference, Presentation at the University of Kansas (2007), `http://people.ku.edu/~cigar/PMConf_2007/HenryBerg(Prediction Point%20KC%20071101).pdf`
2. Berg, J., Rietz, T.: Prediction Markets as Decision Support Systems. Information Systems Frontiers 5(1) (January 2003)
3. Berg, J.E., Nelson, F.D., Rietz, T.A.: Prediction Market Accuracy in the Long Run. International Journal of Forecasting 24(2), 285–300 (2008)
4. Chui, M., Miller, A., Roberts, R.: Six Ways to Make Web 2.0 Work (February 2009), `http://www.boulderdowntown.com/_files/docs/six-ways-to-make-web-2-work.pdf`

5. Coles, P., Lakhani, K., McAfee, A.: Prediction Markets at Google. Harvard Business School Press, N9-607 088 (March 2007), http://stanford2009.wikispaces.com/file/view/HBSGooglePMCase.pdf
6. Consensus Point, Web 2.0 has Arrived and Social Predictive Analytics is Web 2.0 (2010), http://www.consensuspoint.com/prediction-markets-blog/tag/web-2-0
7. Cowgill, B., Wolfers, J., Zitzewitz, E.: Using Prediction Markets to Track Information Flows: Evidence from Google (January 2008), http://www.weigend.com/files/teaching/stanford/2008/readings/PredictionMarkets%2520CowgillWolfersZitzewitz2008.pdf
8. Dvorak, P.: Best Buy Taps Prediction Market. Wall Street Journal (September 16, 2008)
9. Fama, E.F.: Efficient capital markets: A review of theory and empirical work. Journal of Finance 25(2), 383–417 (1970)
10. Hayek, F.: The use of knowledge in society. The American Economic Review 35, 519–530 (1945)
11. Hozo, S.P., Djulbegovic, B., Hozo, I.: Estimating the Mean and the Variance from the Median, Range and the Size of the Sample. BMC Medical Research Methodology 5(13) (April 2005), http://www.biomedcentral.com/1471-2288/5/13
12. Manski, C.: Interpreting the Predictions of Prediction Markets. Economics Letters 91(3), 425–429 (2006)
13. Nocera, J.: The Future Divined by the Crowd, p. B1. The New York Times (March 11, 2006)
14. Surowiecki, J.: The Wisdom of Crowds. Random House (2004)

An Integrated Decision Support System Framework for Strategic Planning in Higher Education Institutions

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Abstract. Strategic planning models and information provision for decision-making in complex strategic situations are frequent subjects for scientific research. This research deals with the problem of supporting strategic planning decision-making in public higher education (HE) institutions by designing a Decision Support System (DSS) to be used by HE decision makers in implementing their strategic planning process, considering that the DSS would be anchored in on all databases of the institution's information systems. This paper adopts a model for the strategic planning process, advocates the incorporation of technologies of participation (ToP) and introduces a collaborative framework for the planning activities at the different institutional levels to develop the institution's strategic plan using a bottom-up approach. Based on the strategic planning process model, a DSS framework is proposed and decision support methods are suggested for the different modules of the DSS. The DSS provides intelligent support (on the individual, group and organizational levels) to strategic planning decisions in all stages of the process. By utilizing this DSS, it is possible to create better conditions for implementing the objectives of the future-oriented activity of the institution.

Keywords: Strategic Planning, Higher Education, Technology of Participation, Decision Support Systems, Group Support Systems, Collaborative frameworks.

1 Introduction

"*In today's competitive higher education atmosphere it is critical to strategically develop approaches for the improvement and growth of systems, services, and strategy*" [1]. Therefore, it is the complexity and uncertainty of higher education's future in a briskly changing world that will position the foundation for the challenges facing HE institutions ahead. The main challenges are: the competition for scarce resources; an absence of a strategic systems approach to planning in order to understand the changing marketplace and identify opportunities, threats, internal strengths and weaknesses; and the shift in faculty and student's pursuit of greater participation in decision-making and a robust culture of transparency [2] [3].

The application of strategic planning, which is rooted in the military theory and has been adapted as a tool for businesses, in HE institutions allows the institution to: (i) devise a realistic framework for determining the process a university should take in achieving its stated and desired future; (ii) embrace continuous innovation and quality

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improvement; (iii) establish goals and priorities; and (iv) involve key implementers and stakeholders in defining the strategic direction of the institution. The key element of strategic planning is to achieve competitive advantage, in order to obtain qualified students and resources and provide quality programs. The institution's strategic plan should reflect assessment and evaluation of educational activities, learning outcomes, research and postgraduates, admission and grants, student services, human resources, financial stability, governance and administration, institutional effectiveness, cooperation with national and international HE institutions and compliance with accreditation requirements [4].

Technology of Participation planning was recognized internationally in the mid 80s when introduced by the Institute of Cultural Affairs (ICA). The approach used by ICA is a structured planning process, which incorporates group facilitation methods into productive action, and concrete accomplishments that enables a group to come to a common vision and create a "*participant-owned*" plan that deals with the realities blocking the group [5] [6]. Figure (1) illustrates a "spiral strategic thinking" model that provides leaders with a way to engage an entire group in a thought process that produces a participatory practical vision and leads to commitment and action [7]. Adopting a participatory culture requires new attitudes, tools and methods. The design of customized applications building up on the ToP strategic planning approach, brings high levels of participation to the decision-making process, cultivates the collective ideas that generate the spirit of commitment and fosters creativity and innovation.

Fig. 1. Strategic Thinking Model [7]

Literature review reveals gaps in educational strategic planning. Though, much has been written on the importance of strategic planning in HE, it is not clear how these practices are fully realized on public universities campuses. And how computerized decision support can be used for implementing strategic planning decision-making processes. "*Recent analysis on decision support and expert systems has shifted from considering them as solely analytical tools for assessing best decision options to seeing them as a more comprehensive environment for supporting efficient* *information processing based on a superior understanding of the problem context*" [8]. The use of DSS for strategic planning in HE allows utilization of quantitative models and qualitative knowledge to solve semi and unstructured problems and provide users with various options and scenarios to make future projections of decision variables. It can also provide coordination among a large number of participants from the different institutional levels through group decision support and collaborative frameworks. Nevertheless, evidence of widespread use of DSS's for strategic planning in HE institutions is hard to come by.

2 Adopted Strategic Planning Process

Literature demonstrates similarity and overlap among the proposed steps or phases of the strategic planning process. Based on models from literature [9] [10] [11] [12], we introduce a process model, which: (i) goes through the full process; (ii) uses a systems planning approach to define the steps with each step providing input to the next; (iii) groups steps into stages; (iv) defines a "*review stage*", the strategic direction; and (v) reflects the continuous nature of the process that requires constant assessment, evaluation and adjustments to any of the stages by linking these stages as shown in figure (2). A short description of each step is provided:

Step 0: Plan to plan: Preparations for strategic planning include: (i) description of the planning process, the time period covered by the strategic plan, how often the strategic plan is to be updated and how the planning process is to move forward; (ii) how the stakeholders can be involved in planning efforts; and (iii) analysis of data collected through questionnaires, personal interviews or public documents.

Step 1: Clarifying Values and Guiding Principles, Defining Mission and Vision statements: The written values and guiding principles might for instance be summarized by words such as integrity, teamwork, pride, honor, persistence, commitment, and accountability. In the formulation of mission and vision statements, variables such as the reason for being of the institution, its environment, resources, objectives, fields of service, and the needs the institution aims to address should be taken into consideration. The accountability of an institution should provide evidence of compliance to its mission, vision and values in both operations and assessments.

Step 2: *Identifying Strategic Goals and Objectives:* Defining specific and measurable goals and objectives, based on goals provided by the functional units' plans.

Step 3: Environmental Scanning: It includes analysis and evaluation of both internal and external environments to help to align the strengths and weaknesses of the institution with opportunities and threats in the environment (SWOT analysis).

Step 4: Strategic Analysis: Formulating strategies is an interactive, dialectical process that requires nonstandard thinking and creativity. The process of strategy making is continual, takes place in real time, and involves generating strategic alternatives, defining and integrating the evaluation criteria, analysis and evaluation of strategic alternatives and finally, strategy decisions. The strategic planning units provide the information on possible ways to implement the goals to the strategic planning office, where the processes of strategic analysis of the institution are centralized.

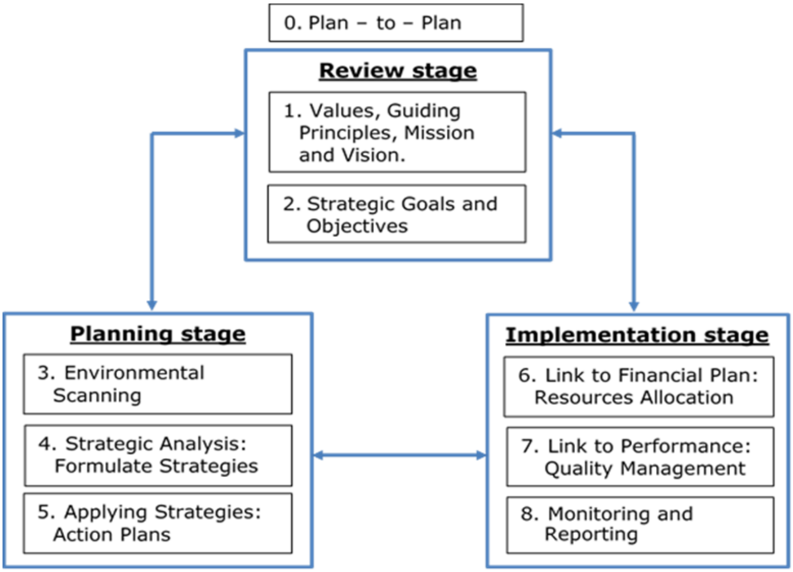

Fig. 2. Strategic Planning Process in HE institutions

Step 5: Action Plans: Action (operational) plans are very detailed plans that execute specific strategies that will lead the organization closer to the goals and objectives identified in step 2. Without specific strategies and action plans, developed at the functional unit level, the strategic plan tend to be little more than a vision statement of what the institution wishes to become without any concrete strategies to get it there.

Step 6: Link to Financial Plan - Resource allocation: This is an important step in the strategic planning process because it is the only way to make sure that adequate funding is available for the institution to achieve its goals and objectives.

Step 7: Link to Performance - Quality management: The action plans contribute to the link between strategic planning and performance management. The individual goals and objectives, developed by the institution's functional units, should become the foundation of the performance management system.

Step 8: Monitoring and Reporting: Including record and controlling of the action plans' implementation, analysis and evaluation of the results of the action plan implementation and using the results of the analysis and evaluation. That enables the institution to adjust strategies as needed, to evaluate progress, and to reward the accomplishment of goals and objectives [13] [14].

3 Strategic Planning Activities at Different Institutional Levels

The coordination of strategic planning activities at the different institutional levels is done by integrating goals and resource requests from individual plans of the functional units of the institution, in order to ensure their compatibility with the strategic goals and financial plan of the institution. Figure (3) presents a collaborative framework for development of the integrated strategic plan in a public university

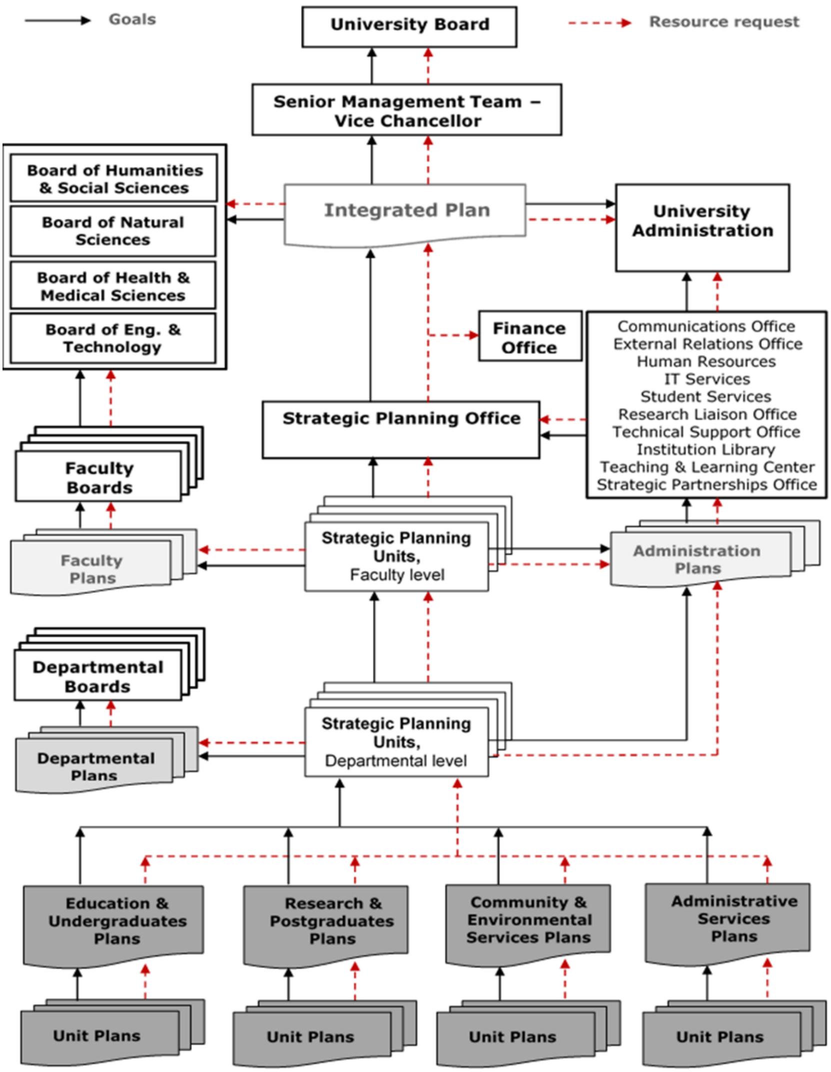

Fig. 3. Framework for Strategic Planning Activities at institutional levels

campus, which is based on a common organizational structure for public universities and is designed to address issues that arise from the lowest institutional level.

In our framework, the institution's strategic planning office and institutional levels' strategic planning units are presented as permanent entities providing a broad support for the strategic planning process, with the following responsibilities: (i) facilitating the process by scanning and monitoring the environment; (ii) assisting the functional units of the institution in developing goals and strategies; (iii) defining the roles of the institution's boards, authorities, and functional units; and (iv) developing the strategic plan document and setting timelines and criteria for evaluating and implementing the plan. The lowest institutional level is the unit level, which is a functional unit, a committee, an academic program, a research center or an administrative unit within a department. The unit's plans demonstrate the different programs and projects implemented within the unit and can be categorized into: Education, Research, Community services and Administrative services plans. The strategic planning units on the departmental level are responsible for developing the departmental plans based on goals and resource requests from the units' plans. The same for the strategic planning units at the faculty level by receiving the departments' plans. The scientific boards integrate and approve the faculties' plans. Administrative plans are integrated based on administrative plans from the departmental and faculty levels and offices of the university administration. The university's strategic planning office develops the integrated plan building up on the faculty and departmental levels' plans to be approved by the university board.

4 DSS Framework

The main components (modules) of the strategic planning DSS can be derived from the proposed strategic planning process model and are described as follows:

Module 1: Strategic Direction: (Tasks: Step 1 & Step 2)

Mode of decision support: Group support and Expert support. *Methods:* [ToP facilitation methods – Collaborative Visioning for Strategic Planning – Goal structuring methods]. *Participants:* University board, scientific boards, faculty boards and departmental boards (including representatives of stakeholders).

Module 2: Environmental Scanning: (Tasks: Step 3)

Mode of decision support: Group support. *Methods:* [methods for information gathering, analyzing and interpreting – Delegation Technologies – intelligent scanning approaches]. *Participants:* Strategic planning office, strategic planning units and the institution's functional units.

Module 3: Strategic Analysis: (Tasks: Step 4)

Mode of decision support: Individual decision support and expert support. *Methods:* [Strategic options development and analysis SODA – Strategic Choice Approach – Robustness decision-making – Scenarios – Futures matrix - Normative Forecasting – Multi-criteria decision Analysis]. *Participants:* Strategic planning office and strategic planning units.

Module 4: Implementation: (Tasks: Step 5 & Step 6 & Step 7)

Mode of decision support: Individual, Group decision support and expert support. *Methods:* [Methods of collective decision-making – Quality management frameworks – Financial planning models – Resource allocation models – Enrollment models]. *Participants:* Strategic planning office, Finance Office and the institution's functional units and quality assurance units.

Module 5: Monitoring and reporting: (Tasks: Step 8)

Mode of decision support: Individual, Group decision support and expert support. *Methods:* [Project management methods – Performance evaluation models – Criteria definition methods – Methods of multi-criteria evaluation – Ranking methods]. *Participants:* Strategic planning office and strategic planning units.

Through the suggested decision support methods for the different modules of the DSS, we can integrate data, modelling, simulation, analytical capabilities, environmental scanning information and experts' knowledge to provide the institution's decision-makers with hindsight, insight and foresight.

Figure (4), provides the standard structure of the DSS components and their integration. We consider that the DSS database is fed from all databases of the institution's information systems (educational, research, administrative services, human resources, finance, e-learning portal … etc.). The model base of the DSS integrates different quantitative models, which enables the DSS to support decision-making regarding the institution's strategic decision variables (mission, vision, strategic goals, constituencies, resources, and governance and quality management procedures). The DSS knowledge base will contain the formal ontology of a higher educational system, definition of the roles, relationships and interactions among participants (analysts, experts, and decision makers) questionnaires, model variables and meta-knowledge (justification/explanation).

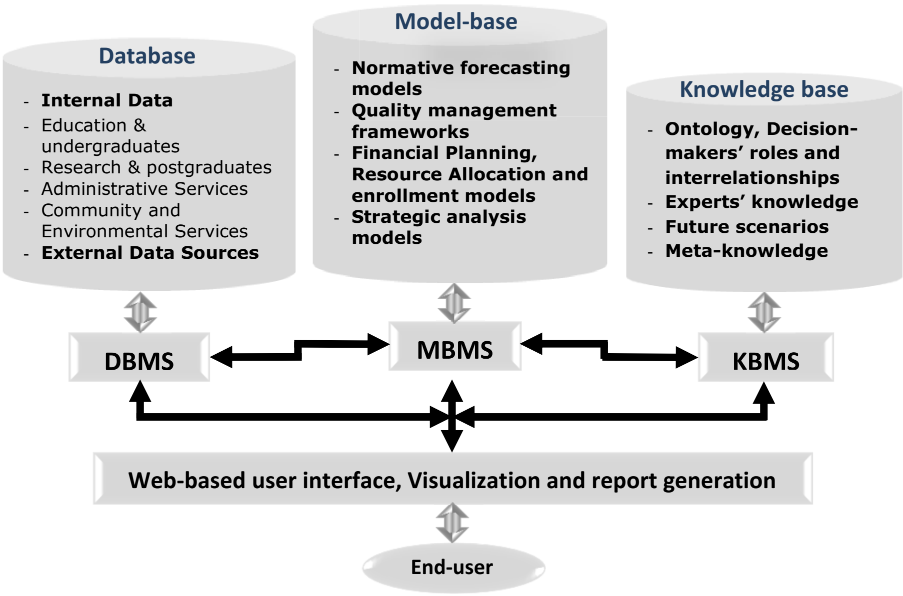

Fig. 4. DSS Structure

5 Defining Mission and Vision Statements, a Sample Model

The process of defining mission and vision statements in HE requires collaboration among participants from the University board, scientific boards, faculty boards and departmental boards (including representatives of Faculty, employees and students). In order to allow participation of these large, asynchronous and distributed groups, a dynamic workflow is required, which should consist of relatively independent modules that can be iterated through as the group moves from the beginning of the brainstorming stages to the end reaching to the goal of the collaborative work. That reflects the ToP strategic planning approach adopted in this research. A Group Support System (GSS) is proposed here to achieve this end. It is designed in a manner similar to the notion of thinkLets in the collaboration engineering approach introduced in [15]. An intelligent support to the GSS, based on the Participant-Driven GSS approach [16], is that the system itself has thresholds identified and set to automatically route participants to different modules as they log into the system. In addition the system can analyze the behaviour and productivity of the participants within the different modules of the system.

Figure (5) illustrates the modules of the GSS: *Brainstorming*, allows users to input ideas to the system and to perform peer- reviewing of ideas; *Evaluating brainstorming ideas*, allows participants to judge and sort ideas; *Clustering*, categorizing brainstorming ideas; *Reviewing clusters*, refining clusters (determine if any need to be split or consolidated); *Naming clusters*, providing names or labels for identified clusters; and *Rating clusters*, allows participants to evaluate and rank clusters. Each module of the GSS represents a basic collaborative activity that the group needs to complete in order to achieve the end goal of the collaborative efforts. In this manner, each user can contribute to the overall goal of the group.

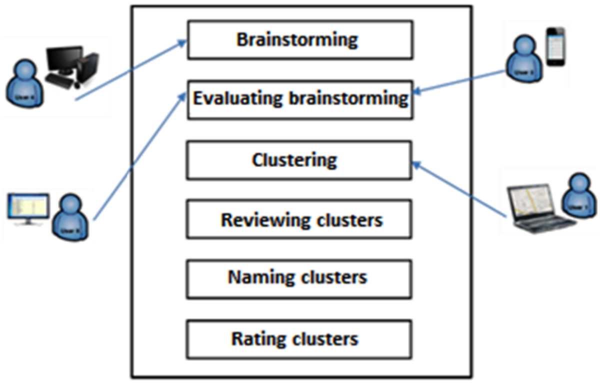

Fig. 5. GSS for defining mission and vision statements - Modular design

6 Conclusion

This research forms a basis for more focused future researches on designing the different modules of the DSS that implement the suggested decision support methods. Through this DSS, we will design several decision models and explain the criteria for selection of a best fit model for each of the strategic planning steps.

Our proposed strategic planning process model and the collaborative framework have the potential to contribute to the application of strategic planning in HE institutions. The final section presented and discussed a specific sample model or subcomponent of the system where Technology of Participation is incorporated in order to involve the institutions' decision-makers and stakeholders.

The development and integration of a strategic DSS with the university's information communications technology (ICT) systems will attain a reduced cost and time needed to resolve key issues of complex strategic decisions. The framework of the DSS is under further development and improvement. Preparations are underway to implement and test the different modules of the DSS using a case study.

References

[1] Rowley, D.J., Lujan, H.D., Dolence, M.G.: Strategic change in colleges and universities: Planning to survive and prosper. Jossey-Bass, San Francisco (1997)

[2] Hubbell, L.L.: Quality, efficiency, and accountability: Definitions and applications. New Directions for Higher Education 40, 5–13 (2007), doi:10.1002/he.276

[3] Paulsen, M.B., Smart, J.C. (eds.): The finance of higher education: Theory, research, policy & practice. Agathon Press, New York (2001)

[4] Rowley, D.J., Sherman, H.: From strategy to change: Implementing the plan in higher education. Jossey-Bass, San Francisco (2001)

[5] Spencer, L.: Winning Through Participation: Meeting the Challenge of Corporate Change with the Technology of Participation. Kendall/Hunt, Dubuque (1989)

[6] Staples, B.: Transformational Strategy: Facilitation of ToP Participatory Planning (2013)

[7] Website: `http://top-facilitators.com/`

[8] Gupta, J., Forgionne, G., Mora, M.: Intelligent Decision-Making Support Systems (i-DMSS): Foundations, Applications and Challenges. Springer, NY (2006)

[9] Dooris, M., Kelley, J., Trainer, J.: Strategic planning in higher education. New Directions for Institutional Research 123, 5–11 (Fall 2004)

[10] Trainer, J.: Models and tools for strategic planning. New Directions for Institutional Research 123, 129–138 (2004)

[11] Yow, D.A., Migliore, R.H., Bowden, W.H., Stevens, R.E., Loudon, D.L.: Strategic planning for collegiate athletics. The Hawthorn Press, Inc., New York (2000)

[12] De Vivo, S.B.: The strategic planning process: An analysis at two small colleges (2008), `http://repository.upenn.edu/dissertations/AAI3310485`

[13] Bryson, J.M.: Strategic planning for public and nonprofit organizations: A guide to strengthening and sustaining organizational achievement. Jossey-Bass, San Francisco (2011)

[14] Taylor, J.S., Miroiu, A.: Policy-making, strategic planning, and management of higher education. Papers on Higher Education. UNESCO-CEPES, Bucharest (2002)

[15] Briggs, R.O., De Vreede, G.J., Nunamaker Jr., J.F., Tobey, D.: ThinkLets: achieving predictable. repeatable patterns of group interaction with group support systems (2001)

[16] Helquist, J., Kruse, J., Adkins, M.: Participant-Driven Collaborative Convergence (2008)

On Facilitating Group Decision Making Processes with VIP Analysis

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Abstract. This paper summarizes a research path in the area of Multicriteria Decision Aiding (MCDA) in order to propose, test and refine an implementation model of a decision support process that uses *VIP Analysis* Software (Variable Interdependent Parameters Analysis). This path followed an Action Research methodology, based on interventions in three organizations. The results of this research guide decision facilitators on how to use the system and the use of cognitive maps as problem structuring method.

Keywords: MCDA, group decision, VIP Analysis, Cognitive Maps, MAUT, Action Research.

1 Introduction

VIP Analysis is a multicriteria decision support software used to evaluate a discrete set of alternatives in choice problems [1], based on the additive model for the aggregation of value functions. Its main characteristic is that it does not require the decision makers to indicate precise values for the trade-offs between different criteria. Rather, it can accept imprecise / partial information on the criteria weights (namely rankings, intervals and other linear constraints). VIP Analysis may be used to discover robust conclusions, i.e. those that hold for every accepted combination of the weights, and to identify which results are more affected by the imprecision.

The literature on MCDA software usually presents their main characteristics, often based on illustrative data. But this does not inform the decision facilitators (analysts, helpers) on what works best when using such software. To develop an implementation model to VIP Analysis, three interventions were conducted in organizations to test and refine a proposed model that uses cognitive maps, as a problem structuring method, followed by Multiattribute Utility/Value Theory (MAUT) supported by the VIP Analysis software.

1.1 The Research Method

The investigated problems were addressed in a constructivist approach, which acknowledges the learning of the actors during all the stages of the decision support process.

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The processes of investigation and resolution of decision problems in these organizations were conducted using the Action Research (AR) method. AR is a strategy for researching social systems in which the researcher acts to change the system while researching the impacts of such changes to generate knowledge [2]. In these studies, AR enabled the improvement of the originally proposed process allowing these organizations to use a decision support tool and allowing the researcher to deepen her knowledge through her performance as a facilitator in these interventions.

Montibeller [2] and Belton [3] highlight the AR method as the most suitable to research in the area related to multicriteria decision support interventions, because of its characteristic of knowledge sharing between researchers and actors of the decision problem. For Belton and Stewart [4], only through AR an implementation of an MCDA method can be genuinely investigated. Eden and Huxham [5] stressed the importance of documenting all the important information in interventions that use AR as a method of generating an active reflection on the results, bringing out new theories and providing relevant information for future interventions.

The activities of this research were developed within two cycles of activities that occurred simultaneously in an investigation by the AR method, according to McKay and Marshall [6], as presented in Fig. 1.

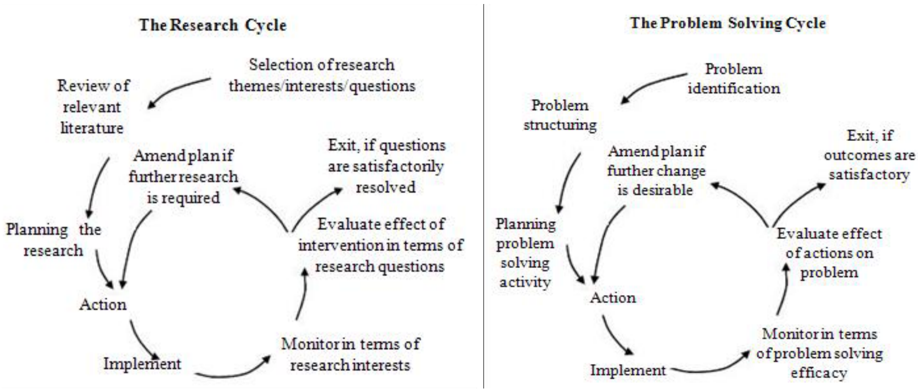

Fig. 1. Research and Problem Solving Cycles (Adapted from Mckay and Marshall [6])

In the Research Cycle the researcher used the AR method and in the Problem-Solving Cycle she used Cognitive Maps in the problem structuring phase (see Fig. 1), when the criteria and alternatives of the problem were defined, MAUT and VIP Analysis (in the Action phase of the Figure 1). The activities of these two cycles are detailed in Ventura [7].

2 The Interventions

All the three organizations studied faced choice/selection decision problems, in which compensation between criteria was considered acceptable and alternatives were considered comparable, which can be analyzed by VIP Analysis [1]. To perform this research, problems with different types of variables (quantitative and qualitative) and different ways of structuring cognitive maps (individual cognitive map, group shared cognitive map and aggregate group members cognitive map) were selected and studied.

The interventions followed the same sequence of steps:

a) Gathering information about the problem to be analyzed;
b) Training de decision makers about cognitive maps, MAUT and VIP Analysis;
c) Building a cognitive map, according to Eden [8], to structure the discussion about the evaluation criteria, and selecting those that will be used;
d) Establishing, for each criterion, how the performance of the alternatives will be assessed, defining a scale of performance levels and their respective descriptions (descriptors of impact);
e) Eliciting value functions that translate performance into value, and ordinal information about scaling coefficients (by eliciting a ranking of swings);
f) Defining the alternatives and assessing their respective performance on each criterion's value scale;
g) Using VIP Analysis software to obtain conclusions about the global value of each alternative and value differences between different alternatives.

2.1 The First Intervention

A first intervention was carried out in Topatlantico, a Portuguese network of travel agencies and was reported in Ventura et al [9]. The company intended to expand its activities in Portugal by opening a new travel agency in a given region. It was necessary to select a location with good potential of demand for their products and services, to ensure the return on investment. The actors involved were the Decision Makers (DMs), the company's administrator (in the initial and final stages) and a regional director of the company, as well as the researcher.

Following steps *a)* to *g)* one alternative was identified as being the most suitable. The DMs however preferred another alternative, which led the researcher to revise the original inputs on the relative importance of the criteria. This led to a new ranking headed by a third alternative, which the DMs realized was now their preferred one.

From this intervention the researcher learned the importance of actively suggesting testing different input scenarios. She also concluded that in the later stages of the process the DMs no longer remembered the training they had received at the outset of the intervention. Thus, in subsequent interventions training on a particular tool would be delivered only at the stage in which the tool would be used.

2.2 The Second Intervention

The second intervention, reported in Ventura et al [10], occurred in Federal University of Alagoas – UFAL, the largest public institution of higher education in the State of Alagoas (Brazil). The decision problem was to choose one of the options proposed by the Ministry of Education and Culture of Brazil concerning the use of the National Secondary Education Examination, in UFAL's student admission process. A decision group of four DMs was formed to recommend one alternative (a set of five alternatives had been defined previously), aided by the researcher.

Contrarily to the first intervention, this problem involved qualitative criteria. For this, the researcher learned that it was very important to use in step *d)* clear descriptors for performance levels such as “reasonable”, “good”, or “excellent”. The evaluation of the alternatives on such scales was a direct consequence of the consensus reached on what each performance level amounted to.

Another difference in this second intervention was that the cognitive map in step *c)* would be built by a group, whereas in the first intervention it was built by just one DM (although later approved by the other DM). In group decision processes, one can choose to produce cognitive maps of each group member and then aggregate them into a single map, called “aggregating mode” [14] or to develop as a group a single map that represents the group consensus about the problem at hand, called “sharing mode” [14]. In this case only one map was developed because none of the DMs considered having a complete and detailed description of the problem.

The development of a single map for the group is a faster process and very interesting from the aspect of group interaction. However, there is an increased risk of occurrence of groupthink [11] which may affect the use of the map as a tool for decision support. Groupthink is a phenomenon that occurs when peer pressure or a strong will to reach a consensus leads a group to ignore information, deteriorate reality testing, and sometimes even moral judgment, while being (over)confident about their outputs. To mitigate the risk of occurrence of these effects and to ensure a better development of the cognitive map, the researcher called the group's attention to each of these points, especially encouraging them to seek more information about the problem and not just stopping to analyze the information they initially had.

The researcher also tried to minimize the influence of the group’s leadership and the pursuit of cohesion. She could act this way because the AR method allows her to act as a facilitator, supporting the decision process and trying to drive it as well as possible, which might not occur when using another scientific method.

Recognizing that there is a practical difficulty in evaluating the effectiveness of group processes and therefore the quality of their cognitive map, Montibeller Neto [12] recommends an indirect evaluation of effectiveness through observation of symptoms associated with groupthink or team think. Based on this recommendation, the researcher used the technique of observation to assess if this intervention had any symptom of groupthink or team think, according to Neck and Manz [13], based on a thorough Yes/No/Maybe checklist of potential symptoms, prepared beforehand.

With this intervention the researcher concluded that there is not necessarily a link between groupthink and a poor representation of the cognitive map. This depends on the attitudes of the group leader and how the process is developed by the researcher.

The use of cognitive map as a problem structuring method and MAUT to develop value functions demonstrated to be a good choice to structure decision problems to be evaluated by VIP Analysis. However it was necessary to analyze the use of a group cognitive map in aggregation mode [14] to define what mode is better to use in this process. This was done in the next intervention, which was also the next “round” of the two AR cycles of this study.

2.3 The Third Intervention

With this intervention, a new round on the Problem Solving Cycle of the AR method (Figure 2) was restarted. It was also a group decision problem, but in a different company, Net Services, a private company that offers TV, internet and voice services through optical cable. The company wanted to decide which strategic project to compete in the market should have higher priority. As in the previously reported intervention, the alternatives were already defined before the intervention of the researcher. The projects to be analyzed were the digitalization of the signal on cable (P1), the codification of this signal (P2) and the expansion of the company (P3) in the country (for details, see [7]).

In this intervention the group's cognitive map was obtained by aggregation of individual maps constructed by four DMs, aided by the researcher (Fig. 2). Ensslin et al [15] consider that the development of individual cognitive maps for later aggregation and congregation is the best way to build a cognitive map of the group.

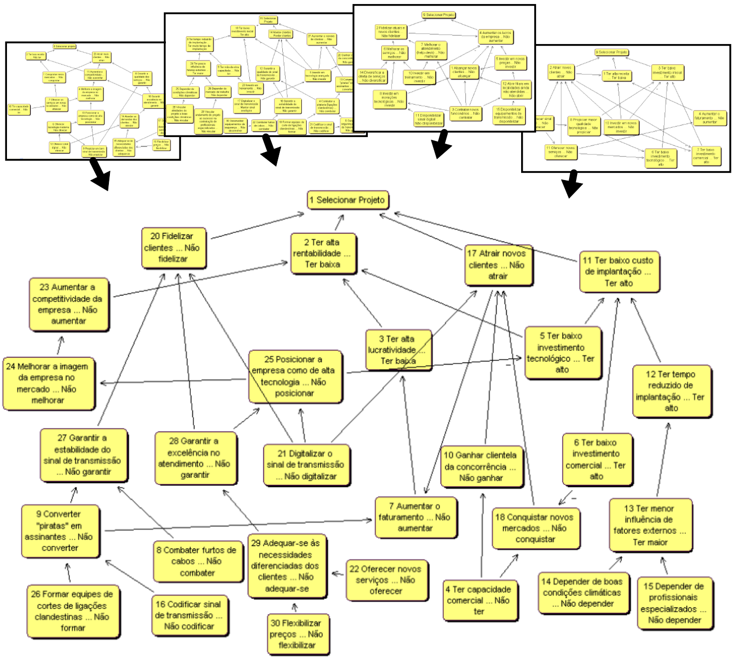

Fig. 2. Cognitive map for the third intervention, obtained by aggregation

The process of facilitating support group decision using individual cognitive maps for later aggregation allowed the researcher to learn and to compare this method with the development of a single cognitive map group, which occurred in previous intervention. Although there is an increased risk of groupthink occurs, the researcher believes this risk can be managed and that the development of a single cognitive map by the group is more effective and reflects better the thinking together, because is enriched through the interaction of all participants.

As in previous interventions, after modeling the cognitive map, the criteria of the problem were constructed using descriptors of impact and value functions. Four criteria were identified: two qualitative ones (possibility of attracting new customers and customer retention capacity) and two quantitative ones (estimated project monthly revenue and estimated cost of the investment).

After that, the researcher and the group began the process of using the VIP Analysis software, which was preceded by the training of the DMs on this tool. The DMs valued the complementarity of the different approaches offered by VIP Analysis software for the evaluation of alternatives, namely the pairwise confrontation (allowing the conclusion that there was one dominated alternative) and value ranges (Fig.3). Although the DMs did not have to indicate the weights (scaling constants) for the value functions, but only a ranking of these weights, one of the options (not only dominated the second one, it was clearly superior to the third alternative. The group chose the alternative indicated by the system (P1) and manifested its intention to continue using it to support future decision problems.

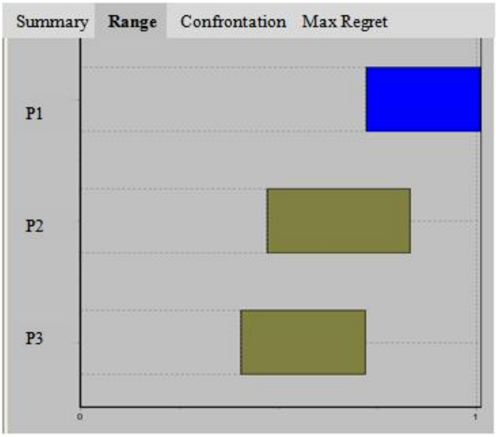

Fig. 3. VIP Analysis Range Map, displaying the minimum and maximum value each project can reach given the specified ranking of the value function weights (adapted from Ventura [7])

3 Conclusions

The Research Cycle and Problem Solving Cycle of AR method (Fig. 1) was followed in all three interventions. Rectifications of the research plan and the activity plan were done at the end of the first two interventions and at the end of the third intervention a reflection was carried out on both cycles considering the goals set at the beginning of the work had been achieved, with satisfactory results.

The fact that VIP Analysis not requires DMs to specify exact values for the weights facilitated the process, because DMs only needed to indicate the order of importance of the value functions. The initial purposes of this study were achieved: developing an implementation model for the process of decision support using the VIP Analysis software, understanding and describing the main difficulties encountered when using these methods and techniques in the organizations studied, supporting the process of decision making of the studied organizations, promoting the sharing of knowledge about all the methodologies and techniques selected for this work.

The model proposed in this study sought to be pragmatic and therefore used field experiments that enabled the testing of methods, techniques and tools that were used in real situations experienced in the organizational environment. As a social experiment, however, interventions throughout this work may not be reproduced as would be the case of laboratory experiments. The final implementation model can be summarized as follows:

- Use of cognitive maps in sharing mode to structure the problem (the researcher considered the sharing mode better than the aggregating mode because the sharing mode provides more interaction between the DMs), to derive a set of evaluation criteria.
- Use of group dynamics strategies to develop creativity and minimize groupthink (because the use of a sharing mode to construct the cognitive maps entails this risk)
- Training of the DMs in the tools to be used, which should occur at the stage each tool will be applied, unlike the initial proposal for intervention, in which DMs receive training on all the tools at the beginning of the work.
- For qualitative criteria, use of a clear verbal description that all DMs agree on for each value on the scale.
- Use of VIP Analysis to obtain conclusions without specifying a precise value for the criteria weights, using a sensitivity analysis of the constraints to increase the confidence in the conclusions.

The implementation model proposed for the VIP Analysis system presented in this study has some limitations: it needs a facilitator, it does not cover the revision phase of the decision making process, it requires availability of time, and it requires face to face meetings of the actors involved in the decision making group.

It is hoped that the reports of these three interventions, as well as its conclusions, may raise improvements to the VIP Analysis software and can provide a previously tested implementation model to ease the utilization of this tool by its users.

Future studies may analyze the continued use of the methodologies and techniques used in this study in other decision problems. In particular, it would be interesting to perform an AR study of a sequence of decision problems faced by the same team of DMs, or faced by different teams within the same organization.

Although this study presented some suggestions to minimize the symptoms of groupthink in the development of cognitive maps (performing group dynamics, guidance of the facilitator to participants) it is recommended to develop a model for facilitating these processes in future interventions in order to ensure greater efficiency in the structuring phase of decision problems.

Future research could also investigate the possible cultural factors that should be considered in applying the VIP Analysis or other decision support systems, repeating the investigation in different cultures and also evaluating possible behavioral differences of the decision makers of public and private organizations.

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References

1. Dias, L., Climaco, J.: Additive Aggregation with Variable Interdependent Parameters: The VIP Analysis Software. Journal of Operational Research Society 51, 1070–1082 (2000)
2. Montibeller, G.: Action Researching MCDA Interventions. In: 49th British Operational Research Conference, pp. 106–123. OR Society, Edinburg (2007)
3. Belton, V.: The Need for Interaction and Integration. Journal of Multicriteria Decision Analysis 6, 127–128 (2001)
4. Belton, V., Stewart, T.: Multiple Criteria Decision Analysis. Kluwer Academic Publishers, UK (2002)
5. Eden, C., Huxham, C.: Action Research for Management Research. Journal of Management 7, 75–86 (1996)
6. Mckay, J., Marshall, P.: The Dual Imperatives of Action Research. Information Technology & People 14, 46–59 (2001)
7. Ventura, A.: Aplicação do método action research ao processo de apoio à decisão com uso do sistema VIP analysis. PhD Thesis, University of Coimbra (2013), `http://hdl.handle.net/10316/22052`
8. Eden, C.: Cognitive Mapping. European Journal of Operational Research 36, 1–13 (1988)
9. Ventura, A., Dias, L., Clímaco, J.: Using Action research on the process of decision support with VIP Analysis software. In: Respício, A., Adam, F., Phillips-Wren, G., Teixeira, C., Telhada, J. (eds.) Bridging the Socio-technical Gap in: Decision Support Systems - Challenges for the Next Decade. IOS Press, Amsterdam (2010)
10. Ventura, A., Dias, L., Clímaco, J.: Developing an implementation model to VIP Analysis Software by using Action Research. In: de Almeida, A.T., Morais, D.C., Daher, S.F.D. (eds.) Group Decision and Negotiation 2012, Proceedings, vol. II, pp. 301–315. Editora Universitária UFPE, Recife (2012)
11. Janis, I.: Groupthink. Houghton Mifflin, Boston (1982)
12. Montibeller Neto, G.: Mapas Cognitivos: Uma Ferramenta de Apoio à Estruturação de Problemas. Dissertação de Mestrado da Universidade Federal de Santa Catarina, Florianópolis (1996)
13. Neck, C., Manz, C.: From groupthinking to teamthinking: toward the creation of constructive thought pattern in self-managing work teams. Human Relations. 47, 929–951 (1994)
14. Belton, V., Pictet, J.: A framework for group decision using a MCDM model: sharing, aggregating or comparing individual information. Journal of Decision Systems 6, 283–303 (1997)
15. Ensslin, L., Montibeller Neto, G., Noronha, S.: Apoio à Decisão – Metodologias para estruturação de problemas e avaliação multicritério de alternativas. Editora Insular, Florianópolis/Brasil (2001)

The Network Perspective of Supply Chain Risks to Support Group Decision Making in Fast Moving Consumer Goods in Middle East Region

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Abstract. Supply chain businesses are facing new challenges due to many events that recently took place in the Middle East Region that directly affects supply chain performance. Yet, managers lack insights in the development of effective performance measures and metrics needed to test and reveal the viability of strategies needed to make effective decisions before perils become more complicated. The main objective of this study is to have a network view to all factors causing vulnerabilities to the stakeholders in the entire chain. This can be done after identifying and prioritizing the critical factors and Key Performance Indicators in the Fast Moving Consumer Goods industry in the Middle East Region in order to proactively design and build resilience in supply chains. For this reason this study is considered as highly explorative. Therefore, the research methodology for this study comprises two purposeful components, namely; in-depth interviews combined with an analytic network process.

Keywords: Supply Chain Risk Management, Resilience, Supply Networks, Fast Moving Consumer Goods, Decision Support, Vulnerabilities.

1 Introduction

Where can things go wrong in supply chains (SCs)? This deceptively simple question has fascinated researchers for a long time. The question in fact forms the basis of supply chain (SC) risk management. Any factor that is likely to disrupt the procurement, production, or delivery of goods or services constitutes a SC risk. It is therefore imperative that a prior assessment of the factors that could pose a risk to the SC be conducted and contingency plans developed at strategic, tactical, and operational levels to monitor and mitigate those risks. Failing in detecting the risk factors affecting the entire network may inevitably affect SC performances [1].

The first challenge to managing SC risks lies in various sources of risks and complex interrelationships between the risks at various levels in SC. The types of risk affecting any SC network depend on the configuration of the supply network and the

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type of relationships between SC partners. All SC partners have their unique organization characteristics, industry nuances and their role in supply network [2]. Thus, not all risks have the same level of consequence to the supply network. Such a network of relationships is very much vulnerable to disruptions of all sorts ranging from internal to inter-firm and to external turbulences. The complexity of the supply network makes it difficult to elaborate a risk management model that can consider at the same time all the risk factors affecting a network. Over-reaction, unnecessary interventions, second guessing, mistrust and distorted information throughout a SC increase the risks within the network [3]. A second challenge of SC risk management is the evolving nature of SC performance indicators. Efficiency and responsiveness continue to be key performance indicators of SC; resilience has been added to the lexicon for SC performance indicators. Resilience is described as the ability to withstand and recover from disruptions. An important attribute for resilience is the ability of a system to return to its original state or move to a new, more desirable state after being disturbed through flexibility and agility [4] [5]. Creating resilient SCs requires a deep understanding of factors that could disrupt the SCs and contingency plans to mitigate them. One major drawback of this approach is that the SC resilience is built on passive rescue and recovery thinking. However, the proactive resilience is considered as the inevitability of change and tries to create a system that is capable of adapting to new conditions and necessities [6]. Thus, there is a need to understand more fully what drives vulnerability within SCs.

The purpose of this study is to explore how current practice managers employ SC risk management; not only from isolated aspects but from wider network perspective. This paper is organized as follows: First, a literature review related to the SC network design in the Fast Moving Consumer Goods (FMCG) is presented. Next, the articulation of the main network interactions within the FMCG SC context and pointing out the risks associated. After that, a proposed network view of risks within the context of FMCG is presented, pointing out the main network interactions between different partners within the network alongside their relation to support group decision making.

2 Fast Moving Consumer Goods Interactions and Risks Associated

SC risk appears as any event that might affect this movement and disrupt the planned flow of materials, information and fund. Moreover, unexpected changes constantly occur on all levels; on strategic levels through globalization, introduction of novel technology, mergers and acquisitions, volatile markets, and on operational levels through demand fluctuations, and events such as late arrival of in-bound material, machine equipment breakdown, and quality problems. However, the same disruption can have very different implications depending on how SCs are designed and planned for such an event. There is, therefore, a need to understand more fully what drives vulnerability within SCs. The problem is that many SCs leave risk management and business continuity to security professionals, business continuity planners or insurance professionals. Building a resilient SC should be a strategic initiative that changes the way a SC operates and that increases its competitiveness [4].

An increasingly important unit of analysis for understanding SC Management is the relationship between SC entities. Relationships can be defined in a myriad of ways and include several key components including collaboration and integration among involved participants. Some of the more frequently discussed challenges of these relationships include trust and information sharing. Nearly all SC Management decisions are affected by issues relating to trust within the SC partners. This makes it very difficult to create effective decisions regarding disruption, which is a necessary component of a SC strategy [7]. Pre-selecting a SC strategy it is necessary to identify the sources of uncertainty associated with each echelon in the SC network and select the best way of reducing this level of uncertainty. However, such work does not consider issues regarding decision-making support mechanisms. Many authors divide decision-making environments into three categories: certainty, risk, and uncertainty [8]. In certainty situations, all parameters are deterministic and known, whereas risk and uncertainty situations both involve randomness. In risk situations, there are uncertain parameters whose values are governed by probability distributions, which are known by the decision maker. In uncertainty situations, parameters are uncertain, and furthermore, no information about probabilities is known. In both situations, the goal is generally to find solutions that perform well under a variety of realizations of the uncertain parameters [7].

Based on the literature review on related work on SC risks, vulnerability and resilience, existing work has focused mostly on minimizing the negative consequences of risks and recovering the SC operations after failure. The SC resilience is built on passive rescue and recovery thinking. The literature has not adequately addressed the issue of how to design and build resilience in supply networks to support group decision making, so that risks affecting the whole supply network are proactively prevented pre-event instead of post-event rescue and recovery. A conceptual framework was built upon previous research, drawing from a number of reviews of factors that and aims to develop a network view of the risks affecting the SC to be further incorporated with The Proactive Performance Measurement for Supply Chain Resilience Framework (2PM-SCR) framework pre-developed by the authors to facilitate SCs to proactively anticipate disruptions and help in their preventing; thus opening visible channel for SC group decision makers [9].

The current problems explain that SC managers in the Middle East Region (MER) have a narrow vision regarding the global economy in terms of SC strategies. This misleads them to missing the broad vision to the risks that are internal to their SC network, but external to their organizations. For example, the sudden changes such as the Arab Spring revolutions has affected all the SC network causing increases in the prices of goods and services for important stakeholders such as customers. This wouldn't have happened if SC managers had a strategic long term view within the context of the network risks.

Accordingly, this is what this research aims to raise; the strategic importance of having a blue print to resilience in the MER which would help managers to employ effective decision making to mitigate SC vulnerabilities in anticipation of disruption through focusing on their internal capabilities. The literature has not adequately addressed the issue of how to design and build resilience in SC, so that SC risks are proactively prevented pre event instead of post event rescue and recovery [9].

3 Research Design and Methodology

The research design provides a guideline to the development and evaluation of a proactive SC resilience model from a network perspective exploring how the current practice managers employ for implementing SC Risk Management to proactively anticipate disruptions and effectively make group decisions prevent failure occurring.

Arab spring is making significant impact on the economic deterioration across the region; thus, little has been discussed in this area with regards to SC decisions. Grounded Theory methodology will be employed as a qualitative research methodology which allows the exploration of concepts, identification of relationships in raw data. Grounded theory is the ability to handle a complex phenomenon that is mainly affected by human perceptions such as risk management which is needed for developing multiple concepts and their linkages [10]. A case study as research strategy is considered in this work. This strategy helps to generate answers to ‘how’, ‘what’ and ‘why’ questions through providing a rich understanding of the real environment [11].

3.1 Methodology for the Model Development

In order to implement the vulnerability and capability constructs of the SC Resilience framework, detailed constructs must be created. The theoretical structure will be extended using empirical data in a systematic method. The pre-developed 2PM-SCR is a framework for categorizing the risks in terms of their driver factors in order to assess the overall impact on the performance of the SC. The framework identifies the main causes of vulnerabilities that can arise from 3 main reasons; (1) internal from the company itself, (2) external to the company but internal within the SC, and (3) from the external environment such as political changes or economic crises. The 2PM-SCR conceptual framework has not addressed the risk factors that are external to companies but internal to a SC, which means that risk factors that are internal to one SC partner could have severe consequence to other partners. When we look at SC vulnerability, we have to look at all types of risks (internal and external) in the whole SC and especially the interdependence between risk factors in difference partners. Since the FMCG industry have short shelf life, extensive distribution networks and need horizontal collaboration, this gives us more reasons to consider the risks from a network perspective rather than an isolated view focusing on the supply network perspective, looking at the risk network, proposing relevant strategies to create resilient supply network in FMCGs.

3.2 Data Collection Method and Analysis

In-depth interviews as data collection techniques will be employed in order to validate the conceptual framework 2PM-SCR. Further, a focus group interview is also considered in order to strengthening the result collected from the previous methods proposed.

Selecting participants who can provide meaningful data on multiple incidents is critical for grounded theory; thus, the three managerial levels are considered in this study to gain an insight into different managerial practices. Pre-planned core questions for guidance for the empirical study would be prepared based on the literature giving the opportunity for the managers to elaborate or provide more relevant information. [11]. Apart from the interviews, a focus group will be conducted allowing interactive discussions and interactions between the selected SC managers in order to explore further the general nature of comments from different individuals.

The process of data analysis begins with the categorization and organization of data in search of patterns, critical themes and meanings that emerge from the data. A process sometimes referred to as open coding is commonly employed whereby the researcher identifies and tentatively names the conceptual categories into which the phenomena observed would be grouped [10]. The goal is to create descriptive, multi-dimensional categories that provide a preliminary framework for analysis. Furthermore, Data analysis will incorporate the analytic network process (ANP) which is considered being useful to solve decision problems considering multiple criteria integrating both qualitative and quantitative data for providing a more generalized model incorporating all the components interconnected to each other capturing both interaction and feedback within clusters of decision elements (inner dependence) and between clusters (outer dependence) by offering a pairwise comparisons taking into account the data collected from the expert judgments through interviews deriving priority scales [12].

4 The Network View of Risk Framework and Decision-Making

The FMCG SC network comprises several stakeholders through the upstream operations to the downstream operations, starting from the suppliers who are responsible to send the raw materials to the SCs, and ends by the delivering the required products to end consumers. As shown in Figure 1, through the whole network of operations, there are considerable risks confronting each echelon within the supply network. These risks arise form unexpected events that disrupt the flow of materials on their journey from initial suppliers through to final customers that constitute harmful risks affecting the whole network. Suppliers' strategies may target other objectives that hardly meet the other stakeholders' strategies, which negatively affect the flow of the chain. Additionally, there are also some other risks associated to the manufacturing operations, which may also impact the whole flow of the materials inside the chain. This ambiguous strategies result in floundering in the interests of each stakeholder within the network, as each work with his own strategy and policies, regardless whether this strategy is convenient to others or not. Consequently this affects the whole flow and echelon inside the supply network causing.

When making decisions in SC it is important to focus beyond the firm's boundaries to include the impact of and on other SC members [8]. Incentives need to be formulated, so that when companies try to maximize returns, they also maximize the performance of the entire SC. Therefore, it is crucial for a company to try to predict the possible behavior of the SC partners depending on the incentives [13].

The rational decision-making process would help the decision-maker to logically process all information that needs to be considered when making a strategic decision in SC. The decision will probably affect other SC members; therefore different stakeholders can help the decision-maker to get a better understanding of how the decision will affect other SC members, and to try to predict their possible behavior [13]. The 1st step is to address different types of risks that may arise in each stage in the network. This only can be done through visibility and knowledge sharing. After that mapping all the affected SC members and select the decision maker in each organization each of them representing different types of concerned stakeholders. These decision makers will identify the strategic decision criteria to ensure that the SC objectives are aligned with their organizations' strategies to set the decision criteria in accordance with the overall SC objectives and this would then help in generating possible alternatives that could succeed in overcoming risks affecting the supply network [14]. These alternatives must be evaluated each by each stakeholder to select the alternative that is most aligned with the whole chain objectives.

Mapping this research into SC setting suggests that business professionals, when faced with high levels of SC complexity apply cognitive processes and managerial tools such as information systems to reduce the high levels of complexity into a more tractable level of perceived SC decision-making complexity that can be tackled by managers. In their study of human cognitive decision-making processes [13]. Human abilities, which are anchored in human cognitive processes gained through natural intellect, experience, training, and/or consultancy, are thought to mitigate SC decision-making complexity while taking decisions regarding risk mitigation. When faced with a difficult problem, cognitive processes often allow humans to effectively and efficiently discard poor alternatives and focus attention on a smaller set of alternatives that can potentially lead to a satisfactory although not necessarily optimal solution. A clear understanding of the business, processes, systems, and risks both within and across the firms, helps them manage SC complexity [14].

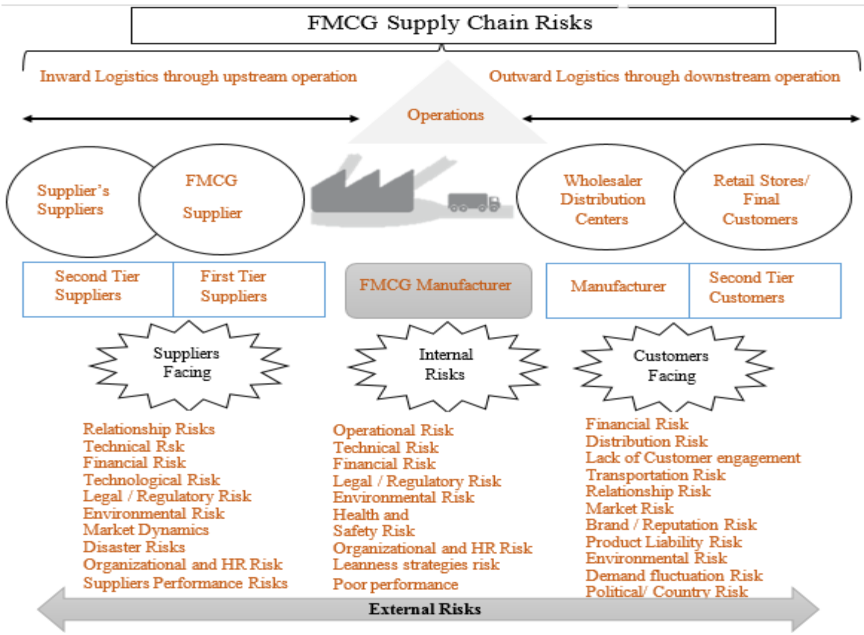

Fig. 1. The Network View of Risk Framework

5 Conclusions and Further Work

The key elements of SC resilience and the relationships among these elements, the links between risks and implications for SC management, and the methodologies for managing these key issues have not been well understood. Little theoretical justification exists for current SC resilience models that confirm the emerging state of this topic and its effect on the decision making process. It was obvious from the reviewed literature that the main focus is on the reactive part of the definition of the resilience definition, in the essence of how the supply will chain respond to any disruptions by maintaining its structure and functions. So research gap appeared in how to make resilience proactive by being able to sense the market dynamics and potential risks, in order to be able to lead the change instead of coping with the change. Taking account of each network separately helps providing interesting but not sufficient information to make the right group decision across the supply network in full knowledge of causes and consequences. The SC dimensions and decision-making necessary to highlight preventive or corrective approaches involve working in a collaborative mode.

This paper focuses on the exploration of the resilience of supply networks against disruptions and provides implications for SC managers on how to construct a resilient supply network from the perspective of complex network topologies, by mapping the different stakeholders and identifying the risks that affect each echelon in the network, further in order to be able to identify the missing links in the chain, and thus, make effectively group decisions in preventing failure occurring in the supply network operations. Managing human cognitive abilities including culture and risk awareness has to be further investigated in the MER. SC managers must build the strategic resilience for any sudden changes that would cause disruption to their normal operations in the MER. The Ministry of Industry has to give a full support to the organizations working in the logistics and SC sector.

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References

1. Gaonkar, R.S., Viswanadham, N.: Analytical framework for the management of risk in supply chains. IEEE Transactions on Automation Science and Engineering 4, 265–273 (2007)
2. Zsidisin, G.A., Melnyk, S.A., Ragatz, G.L.: An institutional theory perspective of business continuity planning for purchasing and supply management. International Journal of Production Research 43(16), 3401–3420 (2005)
3. Childerhouse, P., Aitken, J., Towill, D.R.: Analysis and design of focused demand chains. Journal of Operations Management 20(6), 675–689 (2002)

4. Sheffi, Y.: The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage. MIT Press, Cambridge (2005)
5. Peck, H., et al.: Creating resilient supply chains: a practical guide. Centre for Logistics and Supply Chain Management. Cranfield School of Management (2003)
6. Dovers, S., Handmer, J.: Uncertainty, sustainability and change. Global Environ. Change 4, 262–276 (1992)
7. Tomlin, B.: On the value of mitigation and contingency strategies for managing supply-chain disruption risks. Management Acience 52, 639–657 (2006)
8. Rosenhead, M.J., Elton, M., Gupta, S.K.: Robustness and optimality as criteria for strategic decisions. Oper. Res. Quart. 23(4), 413–430 (1972)
9. Soliman, K., Liu, S., Song, D.: Building Resilient Supply Chain in the Fast Moving Consumer Goods Industry in the Middle East Region. In: The British Academy for Management Conference (BAM), 27 (2013)
10. Strauss, A., Corbin, J.: Basics of qualitative research: Techniques and procedures for developing grounded theory, 2nd edn. Sage, Thousand Oaks (1998)
11. Saunders, M., Lewis, P., Thornhill, A.: Research Methods for Business Students, 5th edn. FT Prentice Hall, Harlow (2009)
12. Saaty, T.L., Vargas, L.G.: Decision Making with the Analytic Network Process. Springer, New York (2006)
13. Stank, T., Davis, B., Fugate, B.: A strategic framework for supply chain oriented logistics. Journal of Business Logistics 26(2), 27–45 (2005)
14. Lee, H.L.: The triple-A supply chain. Harvard Business Review 82(10), 102–112 (2004)

A Distributed Decision Making and Propagation Approach for Trust-Based Service Discovery in Social Networks

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Abstract. With the emergence of social networks, users show the willingness to use them to find and offer services. A problem arises when the number of available services is increasing and no means to distinguish between two or many providers offering the same service. To overcome this issue, we propose a trust measure defined as the combination of two dimensions namely *sociability* and *expertise*. This measure allows to discover trustworthy providers with good services satisfying the requester's needs. The problem increases when no central control can be fixed due to the distributed nature of social networks. To address that, our work advocates a distributed agent-based service discovery approach where each user is represented by an agent that acts on behalf of him to achieve the service discovery task. The propagation process within the social network is ensured by means of a *referral system* wherein agents communicate and evaluate *referrals* based on a distributed knowledge and a decentralized decision-making.

Keywords: Service Discovery, Multi-Agent Systems, Social Network, Trust, Referral Systems.

1 Introduction

Service-oriented architecture has been adopted in modern distributed environments and recently in *social networks* that act as a platform for gathering information and services [1,2]. In such networks, the important number of agents offering services with same functionalities increases the problem of finding *trustworthy providers* and *good services* to satisfy service requester preferences. In general, service discovery and selection approaches are based on finding good services in terms of functional as well as non-functional properties such as QoS (e.g. availability, reliability, ...) and are usually done using quality-driven techniques that ignore the contribution of both the social aspect and the characteristics of the environment. In this paper we present a *distributed decision making and propagation approach for trust-based service discovery in social networks* that addresses these two challenges. First, a service requester prefers providers that not only propose good services but also that can be trusted before using their services. For example, when searching for babysitting service in a social network,

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the requester agent would grant more trust to a family member rather than a friend, still less to a colleague to look after his/her child. Such trust consideration influences the agent's decision making when choosing a counterpart to interact with. In the present work, trustworthiness towards service providers and their services is evaluated over two dimensions: sociability and expertise. High sociability gives an indication about service provider confidence and high expertise gives rise to good services. Second, locating trustworthy providers with good services often involves the requester social acquaintances and may requires the involvement of other agents in the social network. Agents can help each others to find relevant services by recommending trustworthy providers that have been useful to them. To discover trustworthy service providers and recommenders[1], we rely on *referral system*. In the next section we present related work on referral systems, and on service discovery with trust. Section 3 overviews our referral approach and the main concepts used in this work. Section 4 present trust computation to evaluate the trustworthiness of providers and their offered services. Section 5 discuss implementation and evaluation aspects of our work. Section 6 gives the conclusion and the ongoing work.

2 Related Work

To discover trustworthy providers with good services, our approach uses a referral system. A referral system is a MAS in which agents represent users and they cooperate by giving, pursuing and evaluating *referrals* [3]. In [3], a referral system is used for searching social network with a centralized decision-making. The requester's agent collects all possible referrals and decides to continue the search by contacting some of the suggested referrals. However, due to the distributed characteristic of the social network, it is not possible to gather all information by a single agent and make thereafter a trust evaluation. To cope with this issue, a later work described in [4] introduces decentralized search algorithms in networks using homophily and degree disparity. Their algorithms have been designed for searching peer-to-peer distributed networks. However, despite enhancements in decision making and searching, some social network features are missing as for example the multi-relation aspect of social networks or the trust consideration between individuals. Basically, trust is an important feature that can be used to enhance service discovery as well as to manage interactions between agents. For Web service discovery, many approaches have investigated trust in the perspective of expertise [6,7]. The trust in expertise dimension is concerned with the evaluation of past interactions between users and services. For instance, Li et *al.* [6] capitalizes on users' feedbacks including ratings, opinions and relevant comments after use to calculate service reputation. Another recent work proposes in [7] an approach for using quality of past experiences as a criterion for web service selection, including an analysis of the different influence factors that may affect the perceived quality of the end-user. In spite of the value added

[1] Recommenders are agents that do not have useful services but may be well connected and help by proposing pertinent referrals.

of these retrieved information to evaluate trust between agents, trust in expertise dimension is insufficient to make a significant evaluation. Usually, in MAS the trust between two agents is based on another dimension called the trust in sociability. In this regard, we can find some interesting approaches that study trust from this point of view. We retain the works of Castelfranchi et *al.* [5] and Sabater et *al.* [8]. In [5], authors claim that the notion of trust is crucial in agent's theory and in MAS. An agent must trust another agent to delegate a task. Trust model is based on the expertise of this other agent regarding the task (viz. core trust) and on its willingness to achieve this task (viz. reliance). In [8], Sabater et *al.* propose a model for reputation called REGRET that allows to take into account the social dimension. In another work [9], Bansal et *al.* evaluate providers' trustworthiness based on the centrality degree that gives an indication about their prestige in the network. However, it is a poor definition of trust, since it just refers to one measure, the centrality degree. In this work, we do not consider a fixed central agent but we promote agents to cooperate in order to locate trustworthy providers with good services based on a distributed knowledge concerning acquaintances' expertise and established with a decentralized decision-making. We distributed the referral system by spreading out the query among agents with respect to the social network topology.

3 Our Approach

3.1 Concepts Definition

Social Networks. We consider a particular kind of complex networks, the multi-relation social network which takes into account the semantic aspect of the relationship linking two nodes. The relationships can be of different types. For example, if we consider two types, R_1 can be a friend relationship and R_2 can be a partner relationship.

Definition 1. *Given a set V of agents and a set R of types of symmetric relationships with $R = \{R_1, R_2, ..., R_r\}$, a multi-relation social network (MRSN) is a connected undirected graph $G = (V, E)$, in which each $E_i \subset E = \{E_1, E_2, \ldots, E_r\}$ is the set of edges with respect to the i-th relationship. In other words, an edge $(a_k, a_j) \in E_i$ represents a social relationship of type R_i between a_k and a_j.*

In the MRSN graph, the notion of neighborhood of an agent can be expressed as follows:

Definition 2. *Given an MRSN graph $G = (V, E)$, the neighborhood of an agent a_k regarding a type of relationship $R_i \in \{R_1, R_2, ..., R_r\}$, denoted $N_{R_i}(a_k)$, is defined as $N_{R_i}(a_k) = \{a_j \in V \mid (a_k, a_j) \in E_i\}$.*

In the MRSN, each agent a_k cooperate with a subset of agents, called SA_k, that represents a_k's local view in the MRSN such as $SA_k = \bigcup_{R_i} N_{R_i}(a_k)$.

Services. A service is described in terms of functionality, inputs and outputs.

Definition 3. *A service s is a triplet (in, out, f) where in is a set of inputs, out is a set of outputs and f is a functionality.*

User needs. A user communicates his needs by expressing a set of requirements and constraints on the requested services.

Definition 4. *A query Q is a quadruple (F, C, U, α) where $F = \{s_1, s_2, ..., s_l\}$ are required services, $C = \{c_1, c_2, ..., c_r\}$ is a set of global constraints fixed over services, $U : R \rightarrow \mathbb{N}$ is an utility function expressing user's preferences over relationship types, and $\alpha \in [0, 1]$ is a trust threshold.*

3.2 Approach Description

The main goal of our work is to propose a distributed approach using a referral system for trust-based service discovery in social networks. Initially, the user communicates his needs to his associated agent a_k, *the requester agent*, which launches the discovery process in the MRSN. An agent a_k is equipped with a bounded set of offered services S_k and it keeps in a dedicated data structure called Personal Interaction Table PIT_k information concerning its acquaintances. Each record in PIT_k contains the following elements: an acquaintance agent $a_j \in SA_k$, the set of social acquaintances SA_j of a_j and the set of services S_j provided by a_j. Before propagating the query, a_k has to determine which agents of its SA_k to address by evaluating their trustworthiness. Trust evaluation is performed using the structure of the graph, user's preferences and information stored in the PIT_k. Once a trustworthy agent $a_j \in SA_k$ receives the query, it checks if one of its offered services S_j matches user's needs F given his constraints C. Agents which are able to offer a service are called *service providers* whereas, those that do not have suitable services are called *recommenders.* Using the same principle of searching, each contacted agent (recommender or provider) acts autonomously and decides locally to continue or not the search by propagating the query in its SA_j without coming back to the requester agent. This way of progressive propagation is the main mechanism of referral systems in which the diffusion of the search is ensured via navigation in the graph.

4 Trust Computation

Trustworthiness is evaluated over two dimensions: sociability and expertise. High sociability indicates relevant providers and good recommenders, and high expertise gives rise to good services.

4.1 Trust in Sociability

Trust in sociability (ST) evaluates the social trustworthiness that an agent a_k may have towards an agent a_j. Based on the analysis of the MRSN graph and the extracted information, three measures are computed (see [10] for more details).

- *Social Position Measure (SPo).* It is computed based on the centrality degree of an agent a_j in order to give an indication about its social power.

$$SPo(a_j) = \sum_{i=1, \forall a_l \in SA_j}^{|R|} w_i \ . \ b^i(a_j, a_l)$$

where w_i is the weight of the relation R_i computed as $\frac{1}{U(R_i)}$; and $b^i(a_j, a_l) =$ 1 iff a_j and a_l are directly connected with an edge of a relation type R_i, 0 otherwise.
- *Social Proximity Measure (SPr).* It is a distance metric between a pair of agents (a_k, a_j), defined by the average cost of their path.

$$SPr(a_k, a_j) = \frac{\sum_{l=1}^{d} U((a_l, a_{l+1}))}{d}$$

where $U((a_l, a_{l+1}))$ is the cost of the edge $(a_l, a_{l+1}) \in path$ given by the utility function U regarding the requester agent preferences.
- *Neighborhood Similarity Measure (NS).* The neighborhood similarity between two agents is computed based on the comparison of their social acquaintances within the MRSN graph.

$$NS(a_k, a_j) = \sum_{i=1}^{|R|} w_i \ . \ \delta^i(a_k, a_j) \quad with \quad \delta^i(a_k, a_j) = \frac{1}{1 + jac^i}$$

where $w_i = \frac{1}{U(R_i)}$ and $jac^i = \frac{y_i + z_i}{x_i + y_i + z_i}$ is the *Jaccard distance* between a_k and a_j according to the relationship R_i such as $x_i = |N_{R_i}(a_k) \cap N_{R_i}(a_j)|$, $y_i = |N_{R_i}(a_k)| - x_i$, $z_i = |N_{R_i}(a_j)| - x_i$.

After computing these measures, a vector M_j associated with each agent a_j is defined as $M_j = (SPo(a_k), SPr(a_k, a_j), NS(a_k, a_j))$. Considering the vectors of all acquaintances, a matrix $M = (M_{jt}, a_j \in SA_k \ and \ 1 \leq t \leq 3)$ is built. $ST(a_k, a_j)$, is then computed using a Simple Additive Weighting technique:

$$ST(a_k, a_j) = \sum_{t=1}^{3} \lambda_t \ . \ M'_{jt}(a_k, a_j)$$

where $\lambda_t \in [0, 1]$ and $\sum_{t=1}^{3} \lambda_t = 1$. λ_t represents the weight of the tth social measure; and $M' = (M'_{jt}, a_j \in SA_k \ and \ 1 \leq t \leq 3)$ is the matrix of vectors obtained after the scaling phase which transforms every measure value of M_{jt} vector into a value M'_{jt} between 0 and 1.

4.2 Trust in Expertise

A good agent should not only be socially trustworthy but also sufficiently expert. Inspired from [7], we define trust in expertise ET of an agent a_j based on three attributes:

- *Usability*: is the percentage of successful use of an agent's service s_{jl} compared to the other services it offers: $Us(s_{jl}) = \frac{Nb_{success}(s_{jl})}{\sum_{l=1}^{m} Nb_{success}(s_{jl})}$ where $Nb_{success}(s_{jl})$ is the number of successful executions of s_{jl}.
- *Reliability*: is the probability that a service s_{jl} is operational at the time of invocation: $Re(s_{jl}) = \frac{Nb_{success}(s_{jl})}{Nb_{invoc}(s_{jl})}$ where Nb_{invoc} is the number of invocations of s_{jl}.
- *Evaluation rate*: is the quality of a service s_{jl}. Once a service s_{jl} is successfully used by an agent a_k, an evaluation $\nu \in [0, 1]$ is attributed to this service. We designate by $Eval_x(a_k, s_{jl})$ the average rating of the quality of s_{jl} for x uses.

$$Eval_x(a_k, s_{jl}) = \begin{cases} 1 & \text{if} \quad x = 0 \\ \frac{Eval_{x-1}(a_k, s_{jl}) * (x-1) + \nu}{x} & \text{otherwise} \end{cases}$$

Trust in expertise $ET(a_k, a_j)$ measures, the ability of a_j to meet the expectations of a_k. It's an overall score established on the basis of the three aforementioned attributes and over the total m services offered by a_j.

$$ET(a_k, a_j) = \frac{\sum_{l=1}^{m} (Us(s_{jl}) \times Re(s_{jl}) \times Eval_x(a_k, s_{jl}))}{m}$$

4.3 Global Trust

The global trust $Trust(a_k, a_j)$ that an agent a_k has for an agent a_j is a weighted sum that depends on the expertise as well as on the sociability of a_j.

$$Trust(a_k, a_j) = w \times \ ST(a_k, a_j) + (1 - w) \times \ ET(a_k, a_j)$$

5 Experimental Results

We developed a prototype using Java 1.7 and the Jade[2] multi-agent platform. The MRSN graph data was stored in a GML format[3]. All experiments were run on a 3.1GHz Core(TM) i5-2400 running windows 7, with a 8Go of RAM. Simulations were done over 11 instances of MRSN graph randomly generated. The number of agents varies from 500 to 10000. Each instance contains 3 types of relationship and the requester preferences over relationships types are equal to $U(R1) = 1$, $U(R2) = 2$, $U(R3) = 4$. In this case, we suppose that the requester agent prefers twice more the first relationship than the second one. This allows to favor paths in the MRSN graph that uses the minimum number of different kind of relationships regarding the requester agent preferences. In order to decide whether an agent is trustworthy or not, we use a trust threshold $\alpha \in [0, 1]$. We evaluate our model by computing the percentage of discovered providers

[2] Telecom Italia Lab. JADE 4.3 `http://jade.tilab.com/`

[3] Graph Modeling Language, 1997, `http://www.fim.uni-passau.de/en/fim/faculty/chairs/theoretische-informatik/projects.html`

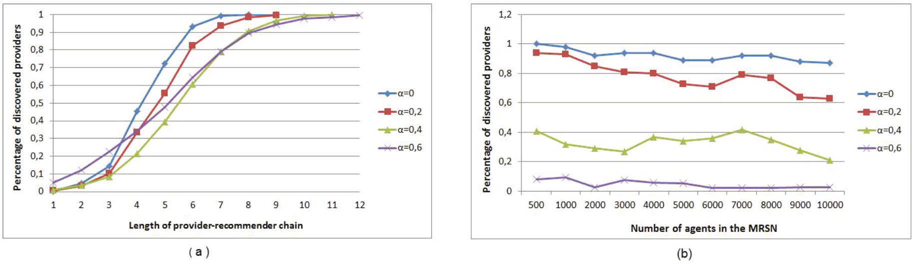

Fig. 1. Percentage of discovered providers as a function of: (a) the length of provider-recommender chain (b) trust threshold

(see figure 1 (a) and (b)). Services were also randomly distributed among agents thus, each agent in the graph may be a potential provider depending on the requested service. For sake of simplicity, we suppose for all experiments that the requester agent needs only one service s at a time.

5.1 Effect of the Provider-Recommender Chain Length

First, we study how the number of discovered providers is dispersed in the MRSN in terms of provider-recommender chain length for a given requester agent query. Using the trust measure, we compute the percentage of discovered providers (averaged over all graph instances) for different ranges of length. Now, let us look at figure 1(a); this figure displays the providers' dispersion for different trust threshold. For each threshold value, the average number of discovered providers tends to level off once the length reach a certain point. There is a trade-off between the chain length and the number of discovered providers: there is seven times more chances to find a trustworthy provider in a chain length equal to 7 than in chain length equal to 3 (from 14% to 80%). We noticed also that for values of α greater than 0.4, trustworthy providers are discovered relatively far away from the requester. This indicates that many of discovered providers are weakly connected to the service requester and require a long chain of recommenders to be reached. Following these results, we can consider the length of the provider-recommender chain as a parameter and then adjust it with a upper boundary. Setting a maximum length to 6 gives us the possibility to control the scope of search which would substantially limit the computation costs.

5.2 Effect of Trust Threshold

Second, we investigate the impact of trust threshold on the discovery process. We compute the percentage of discovered providers while varying trust threshold as depicted in figure 1(b). For $\alpha = 0$, almost all providers are discovered. This is equivalent to an exhaustive search that takes into account only the functional aspect of the provider and ignores its social aspect. Besides, we noticed that the more important α's value is, the smaller the percentage of discovered providers is. This is justified by the fact that finding a provider which fulfills functional aspect with high trust expectations is difficult to guarantee. For high values of α, agents explore less search space in the MRSN which reduces the number of discovered providers.

6 Conclusion and Future Work

In this work, we presented a distributed approach for trust-based service discovery to satisfy user's needs in social networks. Trustworthiness towards service providers and their services is evaluated over two dimensions namely sociability and expertise. The discovery process is done by a distributed referral system that spreads out the query among agents with respect to the social network topology. As future work, we plan to compare our service discovery approach with a non trust-based one. By means of simulation, we would like to evaluate the impact of our social trust at agent-decision making during interaction and thereafter the quality of the underlying service discovery. Also, we intend to explore the extension of our model to perform a service composition built upon a coalition formation of trust-based discovered services.

References

1. Maamar, Z., Santos, P., Wives, L., Badr, Y., Faci, N., de Oliveira, J.: Using social networks for web services discovery. IEEE Internet Computing 15, 48–54 (2011)
2. Gross, R., Acquisti, A.: Information revelation and privacy in online social networks. In: ACM Workshop on Privacy in the Electronic Society, pp. 71–80. ACM (2005)
3. Yu, B., Singh, M.P.: Searching social networks. In: AAMAS, pp. 65–72. ACM (2003)
4. Simsek, O., Jensen, D.: Decentralized search in networks using homophily and degree disparity. In: 19th International Joint Conference on Artificial Intelligence, IJCAI 2005, pp. 304–310. Morgan Kaufmann Publishers Inc. (2005)
5. Castelfranchi, C., Falcone, R.: Principles of trust for mas: Cognitive anatomy, social importance, and quantification. In: 3rd International Conference on Multi Agent Systems, ICMAS 1998, pp. 72–79. IEEE Computer Society (1998)
6. Li, M., Hua, Z., Zhao, J., Zou, Y., Xie, B.: Arima model-based web services trustworthiness evaluation and prediction. In: Liu, C., Ludwig, H., Toumani, F., Yu, Q. (eds.) Service Oriented Computing. LNCS, vol. 7636, pp. 648–655. Springer, Heidelberg (2012)
7. Lalanne, F., Cavalli, A., Maag, S.: Quality of experience as a selection criterion for web services. In: 2012 Eighth International Conference on Signal Image Technology and Internet Based Systems (SITIS), pp. 519–526 (2012)
8. Sabater, J., Sierra, C.: Regret: a reputation model for gregarious societies. In: Castelfranchi, C., Johnson, L. (eds.) 1st International Joint Conference on Autonomous Agents and Multi-Agent Systems, pp. 475–482. ACM Press (2002)
9. Bansal, S., Bansal, A., Blake, M.: Trust-based dynamic web service composition using social network analysis. In: IEEE International Workshop on Business Applications of Social Network Analysis, pp. 1–8 (2010)
10. Louati, A., El Haddad, J., Pinson, S.: Trust-based service discovery in multi-relation social networks. In: Liu, C., Ludwig, H., Toumani, F., Yu, Q. (eds.) Service Oriented Computing. LNCS, vol. 7636, pp. 664–671. Springer, Heidelberg (2012)

Semantic Web Tools and Decision-Making

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Abstract. Semantic Web technologies are intertwined with decision-making processes. In this paper the general objectives of the semantic web tools are reviewed and characterized, as well as the categories of decision support tools, in order to establish an intersection of utility and use. We also elaborate on actual and foreseen possibilities for a deeper integration, considering the actual implementation, opportunities and constraints in the decision-making context.

Keywords: Semantic Web, Decision-making, Web evolution.

1 Web Evolution

Web 1.0 is known as an early stage of the conceptual evolution of the World Wide Web, where users simply acted as publishers and consumers of content, as webpage information was closed to external editing. Rather than a specific technology update or specification, Web 2.0 core was a transformation in the way web pages were made and used, adding a multitude of users responsible for all information management activities.

Traditional group decision-making presents a "top down" approach, usually designed to deliberately guide the interactions of groups in decision-making processes, while in social software users, in the public internet, generate the content and define both the rules and reasons for usage [9], constituting a "bottom-up" approach.

The term Semantic Web [6], considered by many an evolution of Web 2.0 – hence the term Web 3.0 [18] – means a set of technologies that includes ontologies, software agents and rules of logic. These technologies can greatly improve the ability to connect and automatically organize the content of information spread across multiple pages or sites [17]. In this paper, we will make a brief initial review of the general objectives and technologies proposed with the implementation of the Semantic Web, which we will later combine with its actual implementation, opportunities and constraints within the context of decision-making.

2 Semantic Web Technology

According to [6], the Semantic Web will enable machines to comprehend semantic documents and data, not human speech and writings. Moreover, the Semantic Web, in naming every concept using a URI (Uniform Resource Identifier), should express,

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seamlessly, new concepts that people invent. The base of Web 3.0 for exposing data to applications is the Extensible Markup Language (XML), which lets everyone create their own tags. Scripts, or programs, can make use of these tags in sophisticated ways, but the script writer has to know for what the page writer uses each tag.

Meaning is expressed by Resource Description Framework (RDF), which encodes it in sets of triples that use URIs to name the relationship between things as well as the two ends of the link [6], allowing structured and semi-structured data to be mixed, exposed, and shared across different applications. The resulting linking structure forms a directed, labeled graph, which is the easiest possible mental model for RDF which is often used in easy-to-understand visual explanations.

With SPARQL (a recursive acronym for SPARQL Protocol and RDF Query Language), a query language for RDF data, applications can access native graph-based RDF stores and extract data from traditional databases [16]. SPARQL intends to integrate disparate databases (domain-limited or specific databases – relational, XML, HTML, etc.) so that one query spans (seamlessly and on-the-fly) through several datasets to deliver targeted results [18], also referred as Linked Data.

On the Semantic Web, vocabularies or ontologies define the concepts and relationships (also referred to as "terms") used to describe and classify terms that can be used in a particular application, characterize possible relationships, and define possible constraints on using those terms. The most typical kind of ontology for the Web has a taxonomy and a set of inference rules, which defines classes of objects and relations among them [6]. Web Ontology Language (OWL) and RDF are much of the same things, but OWL is a stronger language with greater machine interpretability than RDF. OWL is built on the top of RDF but comes with a larger vocabulary and stronger syntax than RDF [24], being the basis for implementing inference techniques on the Semantic Web.

Inference rules in ontologies can be characterized by discovering new relationships among terms. Although the computer doesn't truly "understand" any of these relationships, it can manipulate the terms much more effectively in ways that are useful and meaningful to the human user [6]. Inference is also intended to improve data integration and handle possible data inconsistencies on the Web, by seamlessly analyzing data content.

In spite of the earlier vision for a future with Web 3.0 [6], the problem is that a complete re-annotation of the Web is a massive undertaking. As an alternative, many researchers take a very different approach to the Semantic Web. Rather than calling for an overhaul of Web formats, and the massive effort of using Semantic Web tools (not to be expected), they are building software agents that can better understand web pages, as they exist today. Instead of waiting for additional information and for more "machine-understandable" web pages, the alternative is developing improved software agents for Information Retrieval and Natural Language Processing.

Natural Language Processing/Programming (NLP) is a field of computer science, artificial intelligence, and linguistics that regards the interactions between computers and human (natural) languages. NLP and Information Extraction (IE) seek to deduce rules or a domain model out of texts. The knowledge base they hope to extract is frequently designed to drive an expert system or case-based *reasoner* [10] or knowledge-driven decision support systems.

Information extraction identifies specific pieces of information (data) in a unstructured or semi-structured textual document (e.g. a webpage) and transforms unstructured information into a corpus of documents or web pages into a structured database [1].

In artificial intelligence, an intelligent agent (IA) is an autonomous entity, which observes through sensors and acts upon an environment using actuators and directs its activity towards achieving rational goals [27]. Intelligent agents may also learn or use knowledge to achieve their goals, ranging from very simple or very complex (a thermostat is an intelligent agent, as is a human being, as is a community of human beings working together towards a goal, as described in [12]). Nevertheless, the effectiveness of such software agents can only achieve its full potential when more "machine-readable" Web content and automated services (including other agents) become available.

3 Decision-Making and Semantic Web

The Semantic Web has implications for decision-making support, namely filled and unfulfilled promises derived from the earlier vision of the Semantic Web and research opportunities.

We can accept the categories of decision support tools as [4;5] established, based on their main objectives: *Personal Decision Support Systems* (PDSS); *Group Support Systems* (GSS); *Negotiation Support Systems* (NSS); *Intelligent Decision Support Systems* (IDSS); *Knowledge Management-Based DSS* (KMDSS); *Data Warehousing* (DW); and *Enterprise Reporting and Analysis Systems* (ER)[1].

[7] stands that the Semantic Web data can be utilized in several ways to process and share information, namely in DSS context: (1) *Information integration*; (2) *Information filtering and selection*; (3) *Information extension, exploration, and explanation*; (4) *Information interpretation, event detection, and prediction*; (5) *Information tracking and post-event analysis*; (6) *Models and model evolution*; and (7) *Sharing decisions*.

Table 1. Intersection of the Semantic Web and Decision Support

		Decision support tools						
		PDSS	*NSS*	*GSS*	*IDSS*	*DW*	*KMDSS*	*ER*
Semantic Web	*RDF*	1, 3, 7	1, 3, 7	1, 3, 7	1, 3, 7	1, 3	1, 3, 7	1, 3
	XML	1, 3, 7	1, 3, 7	1, 3, 7	1, 3, 7	1, 3	1, 3, 7	1, 3
	Ontologies	3, 5, 6	3, 5, 6	3, 5, 6	3, 5, 6	3, 5, 6	3, 5, 6	3, 5, 6
	Inf. rules	4	4		4		4	4
	Query	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3	2, 3
	NLP		2	2	2, 4	2, 4	2, 4	2, 4
	Agents		2, 3, 4, 7	2, 3, 4, 7	2, 3, 4, 7	2, 3, 4	2, 3, 4	2, 3, 4

The feature categories span across the different DSS and Semantic Web tools (presented in section 2), even though they are not always present or bear the same importance. We can match the utility of each semantic web tool to information processing and sharing against each decision support tool category and the intersection of tools and feature categories is depicted in Table 1.

[1] Which include enterprise focused DSS, namely executive information systems (EIS), business intelligence (BI), and more recently, corporate performance management systems (CPM).

DSS can be viewed from several different perspectives [4;25;29] and we can trace them to Web evolution, according to their intrinsic purposes, as represented in Table 2. It is easy to realize that PDSS are much more related with producing content than disseminating such content, while NSS and GSS naturally involve a multitude of users (even though bearing different objectives). Knowledge-driven and Data-driven DSS can benefit the most from Semantic Web features, as it provides enhanced content relationships with the possibility for greater retrieval accuracy.

Table 2. Web stages and their adequacy regarding decision-making tools

[25]	[4;5]	Web		
		1.0	**2.0**	**3.0**
Model-driven	PDSS	+ + +	+	+
	NSS	+ +	+ + +	+ +
Communications-driven	GSS	+ +	+ + +	+ +
Knowledge-driven	IDSS	+ +	+	+ + +
	KMDSS	+ +	+ +	+ + +
Data-driven	DW	+ +	+	+ + +
	ER	+ +	+	+ + +

+ + + *Excellent fit*
+ + *Adequate fit*
+ *Poor fit*

Regarding the creation of information, and contrarily to the traditional group decision-making "top-down" approach usually involving small groups, Web 2.0 stands for a "bottom-up" approach where information is produced by mass collaboration of people that create, update and share knowledge on a regular basis [14], which constitutes a very distinct approach from PDSS. The use of *folksonomies*, ontologies, software agents and social classification of information relevance (through registered classifications performed by past information users, according to their perceived relevance) provide an opportunity for a larger spectrum of possibilities in searching and recovering relevant information [2]. Compared to ontologies, *folksonomies* offer greater flexibility and adaptability in organizing information and users do not need to agree on a detailed tag hierarchy and taxonomy, though it implies that each user can create a separate set of tags that would then need to be disambiguated, using specific ontologies to be created or a combination with existing ontologies. *Folksonomies* may also suffer from ambiguity regarding the meaning of the tags and lack of semantics, for example, synonyms. Moreover, a coherent categorization scheme when using *folksonomies* can become difficult to achieve, because their contributors do not operate under a centralized controlling vocabulary, though empirical work shows the emergence of stable collective consensus around the categorization of information driven by tagging behaviors [26].

According to the Technology Acceptance Model and its extensions [31], and in spite of the fact that people seamlessly create and disseminate information through social media, the intention to individually add any further annotations to contents seems compromised (at least until they have better tools to do so). Thus, the use of software agents and NLP seems appropriate to perform an automatic processing of the dynamic and massive amount of information encompassed in social media at least until technology takes full advantage of *folksonomies*.

The unstructured nature of decision-making, especially its early stages [30], is very well suited for the *ad-hoc* nature of social networking. During the intelligence phase, in spite of the fact that Semantic Web cannot be viewed as a decision-modeling technology to improve decision *per se*, it can be seen as an enhanced possibility for integrating data [20] and revealing implicit information than usually would remain undiscovered, thereby resulting in sub-optimal decisions [21].

Semantic Web technologies can be exploited to the advantage of DSS, namely by applying Information Extraction (IE) to populate Semantic Web datasets and to perform the automatic detection of arguments within group discourse (and from external data), for later analysis by a DSS. Interconnecting users' contributions would enrich and produce a much more accurate information to be used in the intelligence phase. Nevertheless, the creation of *folksonomies* lack tools that can make this a seamless work (or at least very simplified or intuitive), making it a time-consuming task.

During the design phase, structured versions of a group discourse allow a better understanding of the expressed points of view. However, Social Media does not favor this latter type of structure or the generation of tags that can explicitly define used concepts, applied values or any types of quantitative or qualitative parameters. Accordingly, the use of XML/RDF to structure the produced meeting content could alleviate this problem. Nevertheless, the generation of *tagged* content, which would be of enhanced utility in decision-making, requires computer skills that cannot be expected from all participants in all decision meetings and, as in the intelligence phase, the creation of such structured content also constitutes a time-consuming task.

There is a need for ontologies that are suitable for representing *informal* Social Web arguments and ontologies that map between the social world and the argumentative world [28]. Nevertheless, Social Media are understood as failing the criterion of "argumentative discussions", as the argumentation support of general Web 2.0 tools is considered to be peripheral [28]. The writing style commonly used in these platforms has a pattern out of the ordinary that sometimes makes it incomprehensible to those who are not part of the conversation and/or culture/context, thus making it very hard to make it "machine-understandable"[8;15]. Another problem (described in [19]) is the fact that a dialogue can be written in more than one language (code-mixing[2]). As users can also omit much of the speech, this means that data is possibly tangled, incomplete and sometimes error-prone. Even harder to grasp, are the artifices of language, which help to define how these interactions and respective arguments do come out. Herein lays the challenge to achieve its capture in order to be used by "machines". One way of doing this is by using formal models that capture arguments and convert implicit (concealed in discussions) to explicit knowledge [22].

In spite of the earlier considerations and knowing that RDF triples consist of text encompassing relations between described entities, we can argue that Semantic Web tools will be able to transform the representation of a simple (unstructured) text into a representation that follows or is supported by one or more argumentation models. Such process would follow: (1) the establishment/extraction of a taxonomy of elements contained in the text/speech; (2) the development of a specific ontology or use of existing ontologies to relate the elements included in the taxonomy; (3) the development of ontologies according to the intended argumentation models; (4) the combination of steps (2) and (3).

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[2] Where lexical items and grammatical features from two languages appear in a sentence.

The revelation of implicit attributes or argumentative properties could be achieved by IE/NLP techniques that could also build and associate different ontologies containing rules of the argumentative association derived from semantic terms (e.g. terms such as "in support of", "against", "in favor of", etc.). These processes combine the ease of use of Social Media for presenting, discussing and narrowing ideas (Intelligence and Design phases), while using Artificial Intelligence (AI) tools (IE/NLP in particular) to structure the produced content[3] and, thus, leading to the choice phase. This would be done by enabling a richer and more structured visualization of the speech[4], namely by presenting the information according to different models of argumentation.

In the choice phase, many DSS applications use ontologies and rules as a means for making the DSS "intelligent" by adopting the emerging Semantic Web standards for knowledge representation [7]. According to [13], the use of ontologies can facilitate collaboration, by providing a unifying multiple-criteria decision analysis/aiding (MCDA) decision knowledge skeleton that can be used as a common and shared reference for a collaborative process. In addition, the deployment of Service Oriented Architectures (SOA), enhanced by Semantic Web technologies for sharing and accessing data, can apply Semantic Web technologies in peer-to-peer networks, for facilitating offers in negotiation scenarios [11].

Semantic Web tools, namely ontologies, could also be applied to provide a follow-up on decisions after they are taken. This could become an excellent source for decision reconstruction [3] and evaluation of the implemented choice. Unfortunately, the pervasiveness of ontologies in the Web, is not yet a reality, as their creation involves a top-down process, which constantly requires disciplinary experts checking the evolution of the ontologies [23].

4 Final Remarks

We concluded the greatest obstacle to actual arrival of the Semantic Web mostly relies on the technologies that have to come together in order to make it a seamless. Nevertheless, Semantic Web and decision-making possess many connection points, namely regarding decision-making phases, which are worthy to explore and develop (Table 3).

Some argue that it is unrealistic to expect busy people and businesses to create enough metadata to make the Semantic Web work. The simple tagging used in Web 2.0 applications lets users spontaneously invent their own descriptions, which may or may not relate to anything else. However, the solution to this problem may simply rely on better tools for creating metadata, like the blog and social-networking sites that have made building personal websites easy.

The first step towards a real Semantic Web-based decision-making environment is making data accessible through queries. The second step towards Semantic Web-based decision-making seems to be ontology mapping, as the amount of public available ontologies increases steadily and as the Semantic Web grows (even some argue its rhythm is not fast enough).

[3] Even though manual/human intervention is expected at some extent.

[4] For which visualization analytics and tools are complementary to Semantic Web tools.

It is easy to understand that a broader or generalized Semantic Web integration in the decision support community is still a work in progress.

Table 3. Semantic Web and the decision-making process

	Decision process			
	Intelligence	*Design*	*Choice*	*Implementation and evaluation*
Opportunities	- Data integration and interoperability	- Enhanced structuring and argument representation of collaborative discourse	- Collaborative MCDA - Facilitating offers in negotiation scenarios	- Follow-up on decisions
Constraints	- Requires specialized computer skills - Needs seamless tools	- Requires specialized computer skills - Perception of utility - Needs seamless tools	- Requires specialized knowledge	- Ontologies are not web-pervasive - Requires specialized knowledge

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References

1. Acharya, S., Parija, S.: The Process of Information Extraction through Natural Language Processing. International Journal of Logic and Computation (IJLP) 1(1), 40–51 (2010)
2. Antunes, F., Costa, J.P.: Integrating decision support and social networks. Advances in Human-Computer Interaction 2012, 1–10 (2012)
3. Antunes, F., Costa, J.P.: A decision reconstruction support model. International Journal of Information Technology & Decision Making 12(2), 309–333 (2013)
4. Arnott, D., Pervan, G.: A critical analysis of decision support systems research. Journal of Information Technology 20, 67–87 (2005)
5. Arnott, D., Pervan, G.: Eight key issues for the decision support systems discipline. Decision Support Systems 44, 657–672 (2008)
6. Berners-Lee, T., Hendler, J., Lassila, O.: The semantic web, pp. 34–43. Scientific American (2001)
7. Blomqvist, E.: The Use of Semantic Web Technologies for Decision Support - A Survey. Semantic Web, Pre-Press, 1–25 (2013)
8. Bodomo, A.B.: Computer-Mediated Communication for Linguistics and Literacy: Technology and Natural Language Education. Information Science Reference. Hershey, New York (2010)
9. Boyd, D.M.: The significance of social software. In: Burg, T.N., Schmidt, J. (eds.) Blog Talks Reloaded. Social Software - Research & Cases, pp. 15–30. Books on Demand GmbH, Norderstedt, Germany (2006)
10. Cowie, J., Lehnert, W.: Information Extraction. Communications of the ACM 39(1), 80–91 (1996)
11. Du, T.C.: Building an automatic e-tendering system on the Semantic Web. Decision Support Systems 47(1), 13–21 (2009)
12. Franklin, S., Graesser, A.: Is it an Agent, or just a Program?: A Taxonomy for Autonomous Agents. In: Proceedings of the Third International Workshop on Agent Theories, Architectures, and Languages, Budapest, Hungary, August 12-13, pp. 21–35. Springer (1996)

13. Gaševic, D., Djuric, D., Devedžic, V.: Model driven engineering and ontology development. Springer, Berlin (2009)
14. Gehrke, N., Wolf, P.: Towards Audit 2.0 – A Web 2.0 Community Platform for Auditors. In: Proceedings of the 43rd Hawaii International Conference on System Sciences (CD-ROM), January 5-8. Computer Society Press, Kauai (2010)
15. Georgalou, M.: "Pathfinding" Discourses of Self in Social Network Sites. In: Taiwo, R. (ed.) Handbook of Research on Discourse Behavior and Digital Communication: Language Structures and Social Interaction, pp. 39–62. IGI Global, Hershey, New York (2010)
16. Hendler, J.: Web 3.0 Emerging. Computer 42(1), 111–113 (2009)
17. Kousetti, C., Millard, D.E., Howard, Y.: Study of Ontology Convergence in a Semantic Wiki. In: Proceedings of the WikiSym 2008 International Symposium on Wikis Porto, Portugal, September 8-10 (2008)
18. Lassila, O., Hendler, J.: Embracing "Web 3.0". IEEE Internet Computing 11(3), 90–93 (2007)
19. Muysken, P.: Bilingual Speech: A Typology of Code-mixing. Cambridge University Press (2000)
20. Necula, S.-C.: Discussions on semantic-based in decision support systems. In: Proceedings of the 5th European Conference on European Computing Conference (ECC 2011), April 28-30, pp. 193–197. World Scientific and Engineering Academy and Society (WSEAS), Paris (2011)
21. Necula, S.-C.: Implementing the Main Functionalities Required by Semantic Search in Decision-Support Systems. International Journal of Computers, Communications & Control (IJCCC) 7(5), 907–915 (2012)
22. Nonaka, I., Takeuchi, H.: The Knowledge-Creating Company. Oxford University Press, New York (1995)
23. Padula, M., Reggiori, A., Capetti, G.: Managing Collective Knowledge in the Web 3.0. In: Society, I.C. (ed.) Proceedings of the INTERNET 2009, First International Conference on Evolving Internet, Cannes/La Bocca, French Riviera, France, August 23-29 (2009)
24. Pattal, M.M.I., Yuan, L., Jianqiu, Z.: Web 3.0: A real personal Web! More opportunities & more threats. In: Proceedings of the Third International Conference on Next Generation Mobile Applications, Services and Technologies, September 15-18, IEEE Computer Society Press, Cardiff (2009)
25. Power, D.J., Sharda, R., Kulkarni, U.R.: Understanding Decision Support Systems for Global Enterprises. In: Decision Support for Global Enterprises, pp. 3–14. Springer US (2007)
26. Robu, V., Halpin, H., Shepherd, H.: Emergence of consensus and shared vocabularies in collaborative tagging systems. ACM Transactions on the Web (TWEB) 3(4), Article 14 (2009)
27. Russell, S.J., Norvig, P., Artificial Intelligence, A.: Modern Approach. Pearson Education, Inc., Upper Saddle River (2010)
28. Schneider, J., Groza, T., Passant, A.: A review of argumentation for the Social Semantic Web. Semantic Web 4(2), 159–218 (2013)
29. Turban, E., Aronson, J.E., Liang, T.P.: Decision Support Systems and Intelligent Systems. Pearson Education Inc., New Jersey (2005)
30. Turban, E., Liang, T.-.P., Wu, S.P.: A Framework for Adopting Collaboration 2.0 Tools for Virtual Group Decision Making. Group Decision and Negotiation 20, 137–154 (2011)
31. Venkatesh, V., Davis, F.D.: A Theoretical Extension of the Technology Acceptance Model: Four Longitudinal Field Studies. Management Science 46(2), 186–204 (2000)

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