Doctoral School of Regional and Business Administration Sciences

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Knowledge bases as a source of innovation

Doctoral dissertation summary

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1. Research question and knowledge background

In this dissertation, we address complex business dilemmas in which the problem can be solved by gathering and engineering the available knowledge. The focus on the experienced decision-maker or the expert who has the knowledge needed to make the decision, but he or she can achieve better results by properly systematizing the prior knowledge and transforming the tacit knowledge elements to explicit. Thus, the thesis is not about data or analysis of them but primarily about understanding human behavior and thinking. On the problem level of the dissertation we discuss two questions: *how to create new knowledge from this prior experience with the help of Knowledge-bases? How can these decisions catalyze new, innovative ideas?*

In the last few decades, extensive scientific literature was published on data-based decision support, we can talk about a big data-boom phenomenon, but these studies debate obviously much less about those cases when the appropriate “big data” are not available or not in sufficient quantities or qualities to make a decision. Yet, there are many cases like this, for example, SMEs or educational institutions, where it is still not typical to implement a sophisticated management information system which can provide data in order to support the work of decision makers in a strategic situation. By now this problem has also been published in one of the most prominent business journals, the Harvard Business Review with the title ‘Deciding how to decide’ (Courtney et al., 2013), or ‘How to make better decision with less data’ (Menon and Thompson, 2016). Concerning the Big Data hype in the last decade, decision makers should take James G. March’s hint (March, 1991) about the irrelevancy of data, saying that decision makers collect a large amount of data, which play a tiny role or even do not play any kind of role in their decisions. In almost every organization, we can find individuals, or we can call them experts, who own usable knowledge elements, even if only in a special topic, that can be acquired with the suitable method in order to apply them in a knowledge engineering process. But why would they share their knowledge with their organization? In the age of Motivation 3.0 (Pink, 2009) many people are definitely looking for professional challenge opportunities and those where their expertise, even without financial reward, is recognized. One of these people's professional drivers can be solving complex problems and being a part of a really important and useful thing. It is true for a development or a decision-making process. They own the intellectual capital of corporations and this knowledge can be applicable with benefits in decision situations. In order to motivate people in these processes where problem solving happens, it is essential to enable them to share their stories, viewpoints and aspirations. However, these personal perspectives can undoubtedly create opportunities for cognitive biases in decision making. The thesis of bounded rationality by Herbert Simon (Simon, 1957) states that, the results of our decisions depend on our human and environmental limitations and capacity, how and from where we collect data (quality of data) and how we process them. He says that the result will always be bounded and limited because decision makers will choose the first solution that meets their minimal decision criteria so it won't be the best, it can only be a satisfying one. The most significant differences compared to the classical economic models which emerged, the uprise of the discipline of behavioral economics was published by Thaler (Thaler et al., 2008) and Kahneman (Kahneman, 2011). Classical economic theories assume an unlimited cognitive capacity without cognitive biases or human weaknesses but when we examine the results of decision-making processes from the perspective of acceptance, we have to admit that the homo economicus exists without roots in reality as Sørensen said (Sorensen 1990). Instead, we should speak about humans (Thaler and Sunstein, 2008) with all these weaknesses but with intuition and two different ways of thinking as emotional intuition (thinking fast) and rational reasoning (thinking slow) (Kahneman, 2011), which can lead to the theory of the predictable irrationality (Ariely, 2008). According to Polányi's most cited work (Polányi, 1957), there is a part of our knowledge which can hardly be articulated or it cannot be at all, although this knowledge elements are as useful and value creating as the explicit ones. With the help of Knowledge Engineering, this tacit knowledge can be captured and involved in decision making.

Nowadays we talk about smart decisions a lot, but in these cases, we usually think that a smart tool will decide instead of us. In contrast, a smart tool just models the mindset of a smart decision maker, and it can immediately reflect the inconsistency of the decision maker's thinking if it occurs. Actually, when we talk about smart systems, we talk about tools which are able to follow and interpret our own way of thinking while a knowledge base is also built. Expert Systems were exactly like this when those had not been called "smart" as we call them today. As a proposition of the thesis, our assumption is that in similar dilemmas, the knowledge-base of a case could be efficiently used, which tends to confirm the usefulness of behavioral pattern recognition. In this thesis, we want to show how knowledge creation and knowledge exploration can contribute to innovation as its potential source.

2. Problem space

As we compare the knowledge background based on the previous paragraphs as available knowledge to some relevant questions as the lack of knowledge, we receive some research gaps which can be summarized in the following problem spaces with four pillars and four levels. The skeleton of this thesis is based on two big topic streams: a) the future of the AI-based decision support systems, which will be examined through *"Domains of AI tools*" and "*Superintelligence*" and b) the applicability of these systems which will be investigated by a rule-based reasoning study as "*Smart decisions*" and a case-based example as "*R&D project evaluation*". All these sub-topics have a problem, tentative problem solving and finding levels and as a result of a discussion, we can finally get their conceptual model. In order to understand the future of AI-based systems, we investigated the problem of superintelligence as interpreted by Bostrom (Bostrom 2014) and the history of AI tools and we tried to explain how artificial intelligence will support - and not substitute – the working memory in decision making. This presumes the use of that kind of Knowledge-Based Systems which provide a high-level user experience in the interpretation and understanding of the result of the decision-making process. Our findings will present that when we identify the opportunities and limitations well, we can utilize the acquired knowledge from previous cases and it can lead to “experience mining” which is a new method based on the recognition of *cognitive patterns*. Using these cognitive patterns as an input for a Knowledge-Based System and applying a reductive reasoning on them, we can build a knowledge platform which is able to create new knowledge. As we followed the other topic stream, we aimed to prove the applicability of the Knowledge Acquisition and Knowledge-based Systems. We presumed that in those cases when the experts or decision makers' knowledge is available, we can support complex dilemmas effectively by Knowledge Engineering and Knowledge Acquisition. During this investigation, the question of how an innovative SME can be supported by a smart decision was defined as a third problem area. Our tentative solution was that Knowledge Engineering and rule-based reasoning will lead to a better quality and transparent result. Our findings were a mindset model and the decision maker's positive feedback about the process. Within the fourth problem area, we evaluated R&D projects at a university laboratory with experienced project managers and we built a knowledge-base from the projects as cases. The goals of this process were to know which aspirations the project managers have in these projects. As a result, a) we identified the most informative attributes and the logical rules between them, which show the relevant aspirations, b) tacit knowledge of the members of the project organization was transformed to adaptable explicit knowledge by systematizing the experience of the individuals.

3. Methodology

According to the classical distinctions of qualitative data collection methods our research is based on two of them: interviewing and case studies. Knowledge Acquisition is a process which happens step-by-step by interviews. Knowledge bases are built up with the help of experts or decision makers based on their experience by semi-structured, qualitative, in-depth individual interviews. This interview technique allows interviewees in the first part to tell their stories and thoughts in their own words and thus we can learn about the broader circumstances of the cases. Later with focused questions, we try to direct the words to the certain topics that have to appear in the knowledge base. First, in this part of the interview, we also allow the interviewee to use their own terms in the answers and we observe the extent to which they match those previously used by others. If they differ from the terms used earlier, we try to fine-tune and try to find out if the term we offer really has the same connotation for the interviewee. When we make sure it does, we record the answer with the term used in the knowledge base. When we see that there is a need to insert a new aspect or a value in our knowledge base, we try to find the appropriate place for the new element with the help of additional clarifying questions. We finish the interview when we are convinced that the interviewee had told all the relevant facts and circumstances and that all the elements were in the right place in the knowledge base. In case-based reasoning processes, we perform an interview one-by-one with each case provider as interviewees in the first part of the process. After this, we run the reasoning, evaluate the results and usually organize a workshop to introduce and validate the results for the participants. When we carry out a rule-based reasoning process, we usually work with only one decision maker and at least 3 or 4 occasions are needed. The interview script used is available in the first appendix of the dissertation.

4. Papers included and results

The main part of the dissertation consists of four papers related to the four problem areas. In the first study titled "Beyond 160 applications of an expert system: key to a better usability", we give an outline of our experience based on 160 applications of the proposed method and DSS. After a long time and beyond several applications, we believe that we got to know Expert Systems well, and we dare to form an opinion about what the key to a better usability and user experience of these systems is. The goal of this paper is to find the answer for the question: What influences the decision maker's understanding when presenting the results in a Knowledge-based Expert System? We assume that decision makers accept the outcome of a supportive process when they understand and feel that their own thinking is reflected in it. In the first part of the article, we tried to provide a comprehensive picture of the 160 applications in order to prove that our cases come from different problem domains and business fields but all of them are complex dilemmas, thus, these data set is relevant for drawing conclusions. Since this paper is a case study research, it is appropriate to observe and recognize some unique issues. During this research, the focus of our investigation was directed by only one special aspect of interest examined in details: how to understand and accept the result of the decision support more easily. According to the method, in the second part of the paper, we present some case studies individually, identifying the problem, demonstrating some interesting details and the results. Due to the applicability and functioning of the Knowledge-based Systems, we introduce examples for both case-based reasoning and rule-based reasoning. Concluding this paper, we found that the key to the better user experience is that if the result is not a difficult-to-understand interpretation of mathematical derivations with complex formulas, nor it is statistical data visualization obtained from hard management information. The findings confirmed our assumption that a properly designed model graph from which the relationships of the expectations and the logical rules can be clearly read supports the decision. Implications for reasoning and visualization of knowledge at the end of the paper can contribute to the field of knowledge representation and the development and design of Expert Systems.

As a conclusion of thinking about the future of AI tools and superintelligence, we published a conceptual paper about a knowledge platform with the title "Collaborative Knowledge Platform: when the Learning Route provides data for the Knowledge-based Expert System". In this paper, we present a concept of how to build artificial intelligence into knowledge-based systems in order to accomplish experience mining. According to this concept, superintelligence creates the possibility to build a knowledge-based platform in which users can search in each other's knowledge, based on a logical rule-based recommendation, going beyond the solutions of the currently used recommendation systems.

Compared to other similar systems, the fundamental difference in this platform is that usage statistics are not primarily analyzed and it does not try to offer content based on simple tagging (such as webstore systems) but tries to map the knowledge of the user based on logical rules and taxonomy and it suggests elements according to that. This platform seeks to make collaboration more efficient by trying to bring the users to a common level of understanding, where every term and phrase has the same connotation for the users. In this conceptual paper, we present the high-level architecture of the platform and how a special AI-based element can be built in, which enables the continuous incremental knowledge engineering of the incoming knowledge elements.

In the paper titled "R&D project evaluation at a university with Knowledge Acquisition" we show the results of our research in a university laboratory. In this paper, our goal was to illustrate the process by which we built the knowledge base of experience of R&D projects and the final results of the evaluation. In an earlier conference paper (Tóth-Haász et al. 2019), we presented some partial results of the research but in this study we expanded them with an important aspect. The results of the case-based reasoning directed our attention to the difference between projects in industrial environment and in a university laboratory so we started to investigate this topic. In the first part, we consider the relevant literature based on the topics of R&D projects in university laboratories focusing on the researching attitude and academics' motivations, as well as project evaluation methods concentrating on success factors, and finally some thoughts from the field of decision sciences as KA trends and techniques. In this study, we highlight the difference in terms of goals and management between the industrial R&D projects and academic ones. Our findings show that at universities, a reversed process occurs thanks to the *Homo Academicus'* motivation and aspirations (Bourdieu 1988), thus in these cases, we can actually talk about D&R projects. This means that in the first part of the project, a development required in order to solve a semi-structured problem, generally initiated from an industrial organization or a laboratory and after that, due to the *Homo Academicus'* scientific curiosity, a research is also launched. In addition, although it seems self-evident that the commitment and passion of project managers is a key success factor of any project, this is especially true for the success of reverse D&R projects in university laboratories. The main objective of this research was to find the most informative attributes in the examined projects and the logical relationship between them. As a conclusion, we found the three most relevant expectations and three logical rules that can be articulated with them. As far as the research fields concerned, the goal of this paper is to give different understandings of the presented approach of project evaluation and to contribute to the body of management of intellectual property.

In another conference paper the results of the decision-making support of a complex business dilemma were presented with the title "If…then scenarios: smart decisions at SMEs". In this case study, the CEO of a high-tech SME was supported in his decision on where to place the new business unit of the company. As it was described in the knowledge background part, first we had to know the “story” of the dilemma in order to build the appropriate narrative. So, we started a consulting process during which we learned about the company's background, circumstances and the future plans of the managing director. He had definite ideas and had already tried to think through many aspects of the situation. This is the essence of smart decisions: only an experienced decision maker can be supported in this way, since AI-based systems cannot substitute the necessary knowledge or intelligence in the process if it was originally missing, it can only help to systematize the existing knowledge. As an outcome of the first part of the process, we gathered 21 attributes and their values in this manner, so we can say that our knowledge-base is sophisticated enough to get a rule-based graph. This graph can be the starting point of that tentative fine-tuning process by which we try to articulate the rules between the elements of the graph.

Finally, 231 rules were uttered during the meetings and the rules were refined step by step until no inconsistent elements remained. The result of the rule-based reasoning brought that alternative which the decision maker originally wanted to choose, so it was not difficult for him to accept the result.

Author’s publications on the topic

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Tóth-Haász, G., Baracskai, Z., Dory, T. (2019) Understanding aspirations: R&D project evaluation by Knowledge Based Systems. *37th International Scientific Conference on Economic and Social Development - "Socio Economic Problems of Sustainable Development, Baku 13-14 February (Book of Proceedings).*

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