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A SURVEY ON APPLICATIONS OF FUZZY COGNITIVE MAPS IN BUSINESS AND MANAGEMENT

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Abstract. The aim of this article is to present a survey on applications of fuzzy cognitive maps to today's business management indicating its comparative advantages to conventional expert systems. Thus, a survey on FCM studies related to business and management is elaborated, marking down their evolution during the last decade. Various representative applications of fuzzy cognitive maps are illustrated in diverse areas of business management, such as e business, performance assessment, human resources management, planning and investment decision making processes.

Keywords: fuzzy cognitive maps; e business; performance assessment; management.

1. INTRODUCTION

Nowadays, due to constant change of business conditions, adaptability is considered a significant competitive advantage for an organization. To achieve this, practical problem solving in real time is necessary [1]. For the last 40–50 years all problems originated from business processes needed experts, in order to be solved in a realistic and cost-effective way. Unfortunately, practical problems can arise at any time and experts cannot always be available. However, their knowledge could be utilized at all times in certain problematic areas with the use of a well-designed expert system (ES).

ES constitute the most commonly applied branch of Artificial Intelligence (AI). An ES is in fact a computational program, which represents and analyzes an expert's knowledge in a specific area, so as to advise or solve problems in that field. It emulates human reasoning regarding a problem by performing a complex process for decision making in a problem domain. Expert systems, since their development have been providing us with effective solutions-answers in a variety of problems-questions that are difficult to handle using other traditional methodologies.

Various ES methodologies [2] have led expert systems to overcome their limitations regarding their rule-based nature. However, there is still a long way to go. ES development continues to be a time-consuming and expensive task. Additionally, they can solve complex problems in a very narrow area and it is not always easy for experts to communicate their domain-specific knowledge. ES are often mistrusted by their users, i.e. managers, who cannot get used to the idea that a computer program is going to decide instead of them. Managers seem to be fonder of tools for decision facilitation rather than automatic decision making.

It is a common truth that the success of business management lies in the consideration and provision of how a variety of factors interact between them. Today, the number of factors that must be taken into account for an effective business management has increased significantly, due to the highly dynamic business environment. Unfortunately, many times managers lack the ability of evaluating all the related factors, as they use to analyze and assess the impact of two to three factors simultaneously at best. It is very common for a business system to contain uncertain and fuzzy knowledge, due to the fact that most knowledge is expressed in terms of cause and effect. In addition, every business practitioner, i.e. expert, tends to have its individual point of view about effective business management. Fuzzy Cognitive Maps (FCMs) have come to fill that gap, as they are best suited for problems where experts have different opinions about a correct answer and they have the ability to model uncertain and fuzzy knowledge [51].

FCMs have comprised a tool used for decision facilitation in diverse scientific areas, such as medicine [67] and political science [68]. The purpose of this study is to review recent applications of Fuzzy Cognitive Maps in the domain of business. By doing that, it can be shown how FCMs can make life for managers a lot easier and it can be derived that

FCMs can constitute a useful tool for decision support in business management, too.

This paper has been organized in the following way. Section II gives a brief overview of Fuzzy Cognitive Maps, while Section III presents recent applications of them to various areas of business management. In Section IV a discussion on survey results takes place and the significant increase of FCM-related studies in business and management during the last decade is demonstrated. Finally, in Section V, some concluding remarks on Fuzzy Cognitive Mapping Technique are made.

2. A BRIEF OVERVIEW OF FUZZY COGNITIVE MAPS

Fuzzy Cognitive Maps (FCMs) is a modeling technique, arising from the combination of Fuzzy Logic and Neural Networks. Compared to conventional expert systems, FCMs have considerable advantages; they are dynamic feedback systems [5] and they can represent structured knowledge very easily, providing the higher level of abstraction needed in many cases [6]. FCMs constitute a useful tool, with which we take advantage and quantify the accumulated knowledge obtained through years of observing the operation and behavior of complex systems [7].

The term of "fuzzy cognitive map" was first used by Kosko [8] to illustrate a graphically signed directed graph with feedback, consisting of nodes and weighed arcs. The FCM's nodes represent the concepts used for describing system behavior. These nodes are interconnected by signed and weighted arcs, standing for the existing causal relationships between the concepts. In other words, the arcs describe the variation on the value of one concept when the value of an interconnected concept is being altered.

When concept C_j influences concept C_i, there is a w_{ji} arc which can take any value between -1 and 1, quantifying this way the correlation between the two concepts. w_{ji} can be:

- Positive ($w_{ji} > 0$) when there is a positive causality between C_j and C_i, i.e. an increase / decrease in the value of C_j brings an increase/decrease in the value of C_i respectively.

- Negative ($w_{ji} < 0$) when the causality is negative and increase/decrease of the value of C_j causes a decrease/increase of the value of C_i.

- Zero ($w_{ji} = 0$) when there is no influence of concept C_j to concept C_i.

The bigger the absolute value of w_{ji} it is, the stronger the influence of C_j to C_i will be, in a direct (positive causality) or an inverse way (negative causality).

In a conventional FCM, the value of each concept is computed, taking into account the influence of other concepts to the specific concept [9], by applying the following mathematical procedure:

$$A_{i_{(k+1)}} = f(k_2 \cdot A_{i_{(k)}} + k_1 \cdot \sum_{\substack{j \neq i \\ j=1}}^{N} A_{j_{(k)}} \cdot w_{ji}). \qquad (1)$$

In equation (1), $A_{i_{(k+1)}}$ is the value of concept C_i at time $k+1$, $A_{j_{(k)}}$ is the value of concept C_j at time k, w_{ji} is the weight of interconnection between concepts C_j and C_i and f is the sigmoid threshold function.
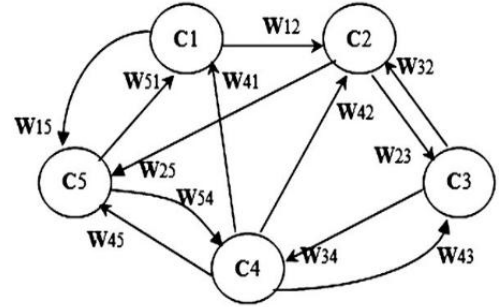

Fig 1. A Simple Fuzzy Cognitive Map

3. APPLICATIONS IN BUSINESS AND MANAGEMENT

Considering the abovementioned favorable features of the FCMs, besides the overall increase of FCM-related studies [10], we have observed that there has been also an increasing amount of literature on business and systems management in the recent years. In this work, we attempt to mark down FCM studies related to business and management and illustrate some interesting applications of them.

Several studies have succeeded in measuring and assessing business performance. Chytas et al. [11] managed to develop a new proactive balanced scorehand methodology with the aid of FCMs, which were used for quantifying the imprecise causal interrelationships of key performance indicators, so as to adjust performance goals. Of

course, it is not the only study which makes use of FCMs, in order to model and analyze business performance metrics [12]. In another work, FCMs were implemented in strategy maps, eliminating their drawbacks and providing them with competitive advantages in terms of flexibility and simulated scenarios. Results of case studies showed that the developed system could emulate effectively experts' predictions [13]. FCMs are used as a performance modeling tool for the implementation of business performance re-engineering methodology, in order to simulate the operational efficiency of complex, imprecise functional relationship and quantify the impact of BPR activities to the business model [14].

FCMs have found a great applicability in the planning process, too. Lee et al. [15] employed FCMs to industrial marketing planning. By integrating agent and FCM technology, they managed to overcome the conventional FCMs' limitations in marketing planning. Hence, experts' opinions from different functional departments were integrated and complex, ambiguous causalities among the related variables were quantified, allowing this way a systematic what-if analysis to be carried out, in order to compare various scenarios. Comparison and evaluation of different scenarios is done in another work too [16], in which FCMs are applied to enterprise resource planning, modeling maintenance risks. With the help of FCMs, ERP practitioners highlight the most important factors and are able to handle the maintenance risks more effectively. Kardaras and Karakostas [17] used FCMs as a supplement to the strategic planning of information systems. This way, it could be much easier for planners to label specific IT projects and evaluate their impact on an organization. Regarding business informatics, an interesting work was that, which proposed augmented FCMs for modeling LMS critical success factors, in order to discern the necessary activities for success [18].

FCMs have also addressed the growing need to assess investment decision-making processes. Irani et al. [19] managed to shed light upon the often cloudy evaluation of IS investments by identifying, classifying and correlating the factors that affected more the IS investment evaluation with the related knowledge components. As a result, an analysis of knowledge-based decisions in the IS evaluation investment area took place. In 2004, Koulouriotis [20] assigned FCMs to emulate investors' reasoning process, as a means for stock prediction.

Human Resources Management has also been implemented with the fuzzy cognitive mapping technique. Xirogiannis et al. [21] attempted to model the operational efficiency of HRM activities and their impact to shareholder satisfaction. Thus, the effects of HR practices to the overall shareholder value were clearly illustrated. In another work, Motlagh [22] investigated HRM influence to Six Sigma projects implementation. The critical factors were identified, so managers knew where should focus, in order to achieve better organizational performance as far as HRM is concerned. Last but not least, FCM applications, such as modeling core value systems [23] and relationship management [24] enable possible detection of conflicts among colleagues, doing in this manner, the work of HRM much easier.

As far as e-business is concerned, Miao et al. [25] integrated Intelligent Agents into Fuzzy Cognitive Mapping, creating the tool of Fuzzy Cognitive Agents, in order to support e-commerce applications. That new approach enabled personalized recommendations based on the online user's preferences, common preferences of other users in general and expert's knowledge. Hence, they addressed the difficulty of many users, who cannot determine what they really want, when visiting electronic commerce web-sites. Also, Lee and Ahn [6] combined FCMs and structural equation modeling for control design support of an e-commerce web based system (ECWS), in order to achieve high ECWS performance. The FCM's fuzzy edges facilitated the representation of environmental factors, controls, implementation, and performance in ECWS, while the structural equation modeling defined the complex causal relationships among factors. In another publication, Xirogiannis and Glykas [26] used FCMs as a means for a causal representation of dynamic e-business maturity indicators. They showed how FCMs can work as a supplement to strategic change projects, by modeling complex strategic models and quantifying the impact of strategic changes to the overall e-business efficiency.

Other worth to be mentioned applications follow. Nasserzadeh et al. [27] used FCM modeling, in order to assess customer satisfaction, a competitive advantage in today's societies, in the sector of banking industry. The Delphi methodology, which included feedback reports for everyone, was exploited for easier consensus among the experts. The resulting FCM was capable of evaluating a bank's capacities for attracting new customers and increase customer satisfaction rate. Irani et al. [28] used fuzzy cognitive mapping to investigate the relationship between knowledge management and organizational learning. They showed that a relationship between them did exist and the constructed FCM helped them to identify

factors, with which a company could evolve to a learning organization. Wang et al. [29] used structural equation model as a supplement to FCM, in order to define the complex causal relationships among factors in a hotel environment. The constructed FCM enlightened the often cloudy context of building competitive advantages in the hotel industry and it enabled a systematic what-if analysis to be carried out, in order to compare various possible scenarios in reality. FCMs were applied in the complex sector of retail industry, too. They led to a better implementation of collaborative planning, forecasting and replenishment (CPFR) approach, as they highlighted the related factors for CPFR success [30].

4. DISCUSSION ON SURVEY RESULTS

In reviewing the literature, it has been observed that FCMs, have strong and weak points. They are flexible, adaptable and they can model very well semi-structured or unstructured knowledge. Nevertheless, they contribute to the problem solving process only by evaluating the alternatives of a scenario, thus, not absolving the manager from making the actual decision. The preceding features suggest that FCMs cannot be utilized in all kinds of problems. They are preferred in unstructured cases, where they can provide managers with very good results without the ethical implication of human replacement.

Table
Recent FCM Studies in Business & Management

Year	Number of FCM-related studies in Business & Management		
	Studies	*Journals & Book Chapters*	*Conferences*
2004	8	5	3
2005	1	0	1
2006	5	2	3
2007	7	5	2
2008	9	3	6
2009	12	5	7
2010	20	16	4
2011	20	11	9
2012	15	12	3
2013	22	15	7

Through an extensive survey and classification of FCM published studies across the internet, last decade's FCM applications in business and management are marked down in Table. There has been a steady increase in the number of FCM-related studies in this field, as it can be seen in Table. In particular, FCM studies regarding Business & Management in 2013 were almost tripled compared with those ten years ago. Considering the above-mentioned, it is clear that FCM application in business and management has gained a considerable interest over the last ten years.

5. CONCLUSIONS

Nowadays successful decision making usually requires complicated mathematical models. Business problems are no exception to this rule, as they are characterized by controversial theories and mathematical solutions, if any, with complex equations and formulas. These difficulties have led to an extensive use of expert systems to problems of this domain, thanks to their capability of taking advantage of experts' domain-specific knowledge and emulate their inference in a very narrow area. This study set out to demonstrate various applications of Fuzzy Cognitive Maps to business management.

FCMs have been proven through literature, as a very useful cognition tool to identify and assess the key-factors of a variety of business issues. However, FCM technique cannot act as a panacea for solving business problems as it depends upon several assumptions, such as the existence of only symmetric or monotonic causal relationships. A lot of effort has been made for conventional FCMs to overcome their drawbacks either by using various supplements, or by advancing FCM theory and learning. Despite their drawbacks though, the increasing number of FCMs' applications not only in various aspects of business, but also in diverse scientific fields, seems quite promising. Hence, more research on FCMs is expected in the future, so as to evolve even more, leaving their limitations behind.

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МЕТАДАННЫЕ

Аннотация: Целью данной статьи является представить обзор существующих на сегодня приложений нечетких когнитивных карт управления бизнесом, определяющие свои сравнительные преимущества в традиционных экспертных системах. Таким образом, был составлен обзор исследований НКК, связанных с бизнесом и управлением, показана их эволюция на протяжении последнего десятилетия. Различные представительные приложения нечетких когнитивных карт проиллюстрированы в различных областях управления бизнесом, таких как электронный бизнес, оценка эффективности, управление людскими ресурсами, планирование и инвестиционные процессы принятия решений.

Ключевые слова: нечеткие когнитивные карты; электронный бизнес; оценка эффективности; управление.

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