A Conceptual Model to Combine Creativity Techniques with Fuzzy Cognitive Maps for Enhanced Knowledge Management

P. Kaltenrieder, E. Portmann, N. Binggeli, and T. Myrach

University of Bern, Institute of Information Systems, Engehaldenstrasse 8, 3012 Bern, Switzerland
patrick.kaltenrieder@iwi.unibe.ch, edy.portmann@iwi.unibe.ch, nicolas.binggeli@iwi.unibe.ch, thomas.myrach@iwi.unibe.ch

Abstract. This chapter introduces a conceptual model to combine creativity techniques with fuzzy cognitive maps (FCMs) and aims to support knowledge management methods by improving expert knowledge acquisition and aggregation. The aim of the conceptual model is to represent acquired knowledge in a manner that is as computer-understandable as possible with the intention of developing automated reasoning in the future as part of intelligent information systems. The formal represented knowledge thus may provide businesses with intelligent information integration. To this end, we introduce and evaluate various creativity techniques with a list of attributes to define the most suitable to combine with FCMs. This proposed combination enables enhanced knowledge management through the acquisition and representation of expert knowledge with FCMs. Our evaluation indicates that the creativity technique known as mind mapping is the most suitable technique in our set. Finally, a scenario from stakeholder management demonstrates the combination of mind mapping with FCMs as an integrated system.

Keywords: Creativity techniques, fuzzy cognitive maps, knowledge management, stakeholder management, integrated systems

1 INTRODUCTION

Enhanced knowledge creation is a key factor in constantly improving knowledge management. Knowledge aggregation, representation, and reasoning (KR; e.g., see [8]) combine to create a form of knowledge management that is realized through intelligent information systems [52]. KR can be understood as a threefold process. Knowledge aggregation seeks to accumulate as much knowledge as possible (i.e., from different sources) into a knowledge base in which such knowledge is unified in a computer-understandable format (i.e., in which it becomes represented). After knowledge is acquired through aggregation and represented with formal techniques, KR allows for self-controlled reasoning as the second step in information systems

[27]. As a consequence, in this chapter, we use the term KR to describe the entire process of knowledge aggregation, representation, and reasoning.

Research associated with the Semantic Web is arguably the most active KR research area [20], [28], [46] (incl. Semantic Web ontologies, as RDF(S) or OWL). However, a major issue with conventional KR techniques is that knowledge can only barely be codified straightforwardly (or not at all) by non-experts, which impacts not only the Semantic Web but also knowledge management in general. Thus, a formal representation of knowledge frequently requires a profound understanding of knowledge engineering, computer science and/or logic. For this reason, technical laymen are largely excluded from providing knowledge [35]. In many key cases, experts in different fields (e.g., business and commerce, government, health, etc.) are such technical laymen and thus only able to formally codify their expertise by working in conjunction with KR specialists.

With this in mind, we propose a conceptual model to combine creativity processes with fuzzy cognitive maps (FCMs) to achieve knowledge aggregation by means of integrated systems [49]. Thus, we use creativity techniques as procedures to facilitate the decision-making process by utilizing the potential creative ability of each individual within a company [35], [42], [47], [48]. On the one hand, creativity techniques are often rather simple to grasp (and use) but difficult to acquire (and reuse) when the scope is more complex (e.g., in traditional KR). FCMs, on the other hand, may appear complex, and a direct usage in knowledge acquisition is somewhat unusual because laymen frequently do not understand the concepts underlying FCMs (or understand them only on an elementary level) [35]. FCMs are mental models in which the relations between individual parts can be used to compute the strength of the impact of these parts [32], [33].

Applying fuzzy logic [51], we combine the advantages of creativity processes with FCMs in such a manner that the fuzzy part of a cognitive map is able to address uncertainty, which occurs in human perception of the world [39]. In particular, during processes involving creativity—in which uncertainty may be high—certain questions may arise, such as the following: What exactly is meant by a concept? Why is one concept related to another? What is the most important part of a particular concept? These and other questions emerging during group creativity processes demonstrate the uncertainty of human perceptions of the world [39], [53].

We address this uncertainty by employing a threefold approach. First, we present creativity techniques and an introduction to FCMs. Second, we compare creativity techniques, select a particularly well-suited technique and combine it with FCMs. Additionally, because the comparison serves as the basis for the proposed conceptual model, we combine the models discussed in this chapter to generate an integrated system in the example of a stakeholder management use case.

In the next section, we introduce our KR process in more detail. We provide short explanations for each creativity technique we use, and the FCM concept is introduced. The third section evaluates the suitability of creativity techniques for creating FCMs. On the one hand, we demonstrate how expert knowledge might be aggregated, and on the other hand, we compare the suitability of various creativity techniques to combine with FCMs. Section four introduces our conceptual model. To this end, we present a scenario from stakeholder management from which we derive the necessary requirements for a possible to-be-completed implementation. We finish the chapter with a discussion that summarizes and offers suggestions for the future.

2 Background

First, we introduce the knowledge acquisition and representation process. Next, seven exemplary creativity techniques (i.e., five well-known and two more marginally known techniques) are presented; these techniques represent the full spectrum of available techniques. Eventually, FCMs are introduced as a form of knowledge representation.

2.1 The Knowledge Acquisition and Representation Process

The goal of this research is to improve knowledge management by promoting the reuse and aggregation of expert knowledge by making it available in an electronic format with an integrated system. Previous research has implemented creative approaches regarding KR [19] (and likewise FCM [30], [39], [47], [48]), but our main focus is the direct combination of creativity techniques with FCMs (e.g., see scenario in section 4.1). To this end, we introduce a process of knowledge acquisition and representation (see Fig. 1).

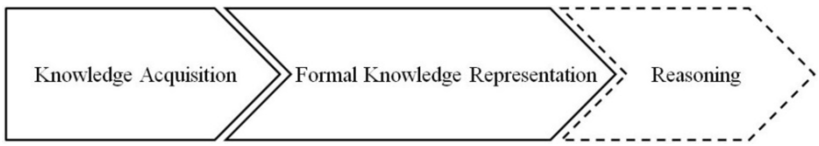


Fig. 1: The knowledge acquisition and representation process.

Expert knowledge is commonly acquired through creativity techniques. Thus far, over one-hundred such techniques have been introduced in the literature [23], [26], [41] following Osborn's [34] introduction of brainstorming.

After it is acquired, knowledge should ideally be formally represented. To describe this representation, we apply cognitive maps that allow a formal coding, storing, recalling, and, decoding of knowledge that was acquired in the previous knowledge acquisition step (e.g., see [36], [37]). Successfully representing knowledge enables an information system to actively process such knowledge instead of merely representing it (e.g., see [6], [29]). Structurally, this is typically accomplished with KR languages (i.e., both implemented and theoretical) that have been developed over the years [28], [46].

In the next section, seven creativity techniques [9], [11], [12], [14], [15], [34], [55] are introduced that have also been used in related research [19], [30]. Then, the concepts of cognitive maps [18], [43], [45] and FCM [32], [33] are introduced in greater detail.

2.2 Creativity Techniques for Knowledge Acquisition

It is not our goal to create an exhaustive list, nor an updated overview, of the creativity techniques currently available (e.g., see [41]). To enhance our understanding of creativity techniques, we instead consider seven techniques used in various research fields. We will later show which technique best fits our particular needs. In Table 1, these techniques are listed in alphabetical order:

Table 1: Seven creativity techniques.

Attribute Listing (see Crawford [11])	An attempt is made to improve a product by listing the various attributes of objects of study and recombining and altering these attributes with known elements (of other objects). [5], [11], [22]
Brainstorming (see Osborn [34])	This technique involves a two-step process: 1) Create and record ideas, following four principles: no judgment, exotic ideas are allowed, quantity before quality and using existing ideas to build on; 2) Evaluate the results (best after a break). [1], [5], [22], [39], [42]
Lateral Thinking (see de Bono [14])	Being creative means leaving the usual thinking patterns and thinking "around corners". This requires some training because humorous ideas are frequently only exaggerations of usual patterns. [13]
Mind Mapping (see Buzan [9])	Beginning with the main idea in the middle, a mind map is extended by adding branches to the core or to other branches; this map is read inside out with no distinct direction. Colors, numbers, and pictures can be used to connect different branches. [19], [22]
Morphological Panel (see Zwicky [55])	A morphological panel consists of the independent main attributes of the objects of study in the first column and possible solutions in the respective lines. Combining these solutions into a solution-chain, regardless of the column they originate, provides the outcome. [5], [22]
Six Thinking Hats (see de Bono [12])	The six hats with different colors stand for six mentalities. Participants can switch between mentalities by putting on different metaphorical hats. The colors stand for information and data, feelings and intuition, proposals and ideas, logical conclusions (one for, another against), and coordination of the discussion. [13]
Walt Disney (see Dilts [15])	Typically, one person takes three different positions in turns, to review or improve the initial idea. These are the positions of a dreamer, a realist and a critic. [16]

2.3 Representing Knowledge with Fuzzy Cognitive Maps

A successful KR-representation [6], [28], [29], [46] (e.g., as a cognitive map) can be actively processed by an information system (i.e., applying the knowledge) for improved knowledge management. The concept of cognitive maps was previously introduced by Trowbridge [44] but only became widely known when Tolman published his experiments with rats and mazes [43]. Axelrod introduced them in his description of social scientific knowledge [4], which is an approach later adopted by Kosko [32], who defined FCMs as uncertainty-extended enlargements of traditional cognitive maps (i.e., applying fuzzy logic [51], [54]).

Fuzzy logic enhances traditional true/false logic with the concept of partial truth, which is used for qualitative rather than quantitative judgments. Humans have a remarkable capability to reason and make decisions in an environment of uncertainty (e.g., with imprecision, incomplete information, and partial knowledge, truth, and class membership). The principal objective of fuzzy logic is to formalize and mechanize this capability [54]. Thus, fuzzy logic follows the way humans think and helps handle real-world complexities more efficiently (i.e., it allows for *more or less* true statements).

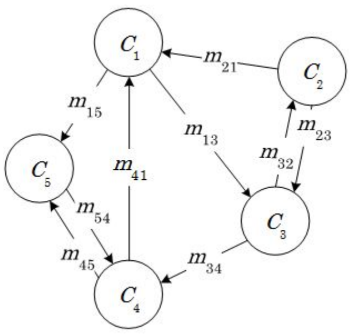
FCMs may also use a linguistic approach to represent fuzzy causality. Fuzzy logic thereby allows degrees of truth with a range [negative, positive] (or [0, 1]|[-1, 1]). When linguistic variables are used, degrees may be managed by specific functions (e.g., see [25]). As a result, linguistic variables (incl. *usually, slightly, a little* etc.), can be determined.

Therefore, FCM shifted from representing fuzzy causality to representing qualitative system dynamics behavior (i.e., it was used as an alternative to cognitive maps for modeling social systems [10] and for reasoning [35], [50]).

To enhance the technical understanding, we present an operable definition of FCM in the next section.

2.4 Definition and Properties of a FCM

According to Groumpos [25], a FCM consists of key factors or characteristics of the system as concepts (i.e., concepts are goals, states, variables, outcomes, etc.), which are called nodes $C_1,\ldots,C_n$, and the adjacency matrix M, which represents the connections between the concepts. The element m_{kl} of the matrix shows the weight of the edge connecting C_k and C_l, i.e., the degree of the causal relationship. Fig. 2 shows an example with *n*=5.



$$\begin{pmatrix} 0 & 0 & m_{13} & 0 & m_{15} \\ m_{21} & 0 & m_{23} & 0 & 0 \\ 0 & m_{32} & 0 & m_{34} & 0 \\ m_{41} & 0 & 0 & 0 & m_{45} \\ 0 & 0 & 0 & m_{54} & 0 \end{pmatrix}$$

Fig. 2: An example of a fuzzy cognitive map with an adjacency matrix.

Typically, the concepts have values in [0, 1] or [-1, 1]. Because it is a fuzzy cognitive map, the weights m_{kl} lie in the real interval [-1, 1]. The causality between C_k and C_l can be positive ($m_{kl} > 0, C_k$ increases C_l), negative ($m_{kl} < 0, C_k$ decreases C_l) or neutral (i.e., no relationship, $m_{kl} = 0$). Note however, that M is not required to be symmetric ($m_{kl} \neq m_{lk}$ in general) or to have the diagonal entries equal zero (e.g., see [7], [31]).

A FCM describes a dynamic system, which indicates that the matrix should also evolve. Following Salmeron [38], consider $\vec{C}^0 = (C_1^0 \ \ldots C_n^0)$ as the initial state vector of the concepts (i.e., by time step 0). The state vector at time step t is computed by $C_i^t = f\left(k_1 C_i^{t-1} + k_2 \sum_{j=1}^{n} m_{ji} C_j^{t-1}\right)$, where f stands for an activation function that maps the value of the concept back to its initial interval (e.g., a sigmoid function $f(x) = \frac{1}{1+e^{-\lambda x}}$ for [0,1], where $\lambda > 0$ determines the steepness of the function, or the hyperbolic tangent for [-1,1]). k_1 and k_2 are proportions of how this sum is weighted as used in [25] (in the following $k_1 = k_2 = 1$). To simplify the notation, the above formula may be expressed as follows [38]: $\vec{C}^t = f\left(\vec{C}^{t-1} + \vec{C}^{t-1} M\right) = f\left(\vec{C}^{t-1}(Id + M)\right) = f\left(\vec{C}^{t-1} M^{new}\right)$ where Id is the nxn-identity-matrix, and M^{new} is the matrix M in which m_{ii} is replaced by $m_{ii} + 1$.

This iteration has three possible outcomes, depending on the initial state vector [31]: Reaching a fixed point $\vec{C}^{fix}$ with $f(\vec{C}^{fix} M^{new}) = \vec{C}^{fix}$, falling in a cyclic repetition of the same state vectors or proceeding chaotically (i.e., randomly taking on new values in each iteration step).

As Boutalis et al. [7] showed, there are certain conditions on M^{new} for both of the described activation functions, such that the iteration converges (i.e., it reaches a fixed point) for every initial state vector.

Multiple FCMs can be aggregated into a new FCM by combining the matrices (e.g., see [25]). Assume there are N different FCMs. Each has a corresponding matrix, M_i. Then, $M^{Aggr} = F\left(\sum_{i=1}^{N} M_i\right)$, where F is typically (again) a type of sigmoid function to assure that the matrix entries remain in the interval [-1, 1] or only the mean of the entries [31]. This obviously works only if the FCMs consist of the same concepts (i.e., the matrices have identical dimensions and related entries). Furthermore one can add a credibility factor d_i to each FCM_i and add therefore a certain weighting, which results in a new $M^{Aggr} = F\left(\sum_{i=1}^{N} M_i d_i\right)$.

If the concepts of the FCMs are disjointed, a component-wise summation of the entries is false because they describe different relations. Given every FCM_i has n_i concepts, then each corresponding matrix M_i is $n_i x n_i$-dimensional. However, the concepts are disjointed such that the aggregated FCM has $z = \sum_{i=1}^{N} n_i$ different concepts and therefore a zxz-matrix. $M^{Aggr} = \begin{pmatrix} M_1 & 0 & 0 & 0 \\ 0 & M_2 & 0 & 0 \\ 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & M_N \end{pmatrix}$

The cases in which the FCMs have some (but not all) concepts in common are a combination of the two cases presented. The sum is built where the concepts are identical and the matrices extended in the upper way where they are disjointed.

To approach our goal of combining creativity techniques with FCM, we introduce different criteria to measure the suitability of combining the presented creativity techniques with FCMs.

3 Comparison of creativity techniques for FCM generation

Our approach is not the first to introduce creativity techniques into FCMs [19], [30], [39], [47], [48]. For instance, Van Vliet et al. [47], [48] and Sharif and Irani [39] employ FCMs for scenario development and Xirogiannis et al. [50] use FCMs for decisional support. Eppler focuses on comparing different visualization techniques and their complementary use [19]. Kontogianni et al. use different methods (incl. creativity techniques) as preliminary to creating FCMs [30]. Although these authors mention creativity techniques in their approach, they do not focus on them. Thus, our main focus is to create a model to import existing expert knowledge into FCMs when the knowledge was gained explicitly with creativity techniques. By this means, we intend to make expert knowledge computer-understandable to improve knowledge management in an integrated system. Thus, knowledge can become reusable and better able to be spread across business departments and units (cf. 4.1). To the best of our knowledge, this particular combinative approach has not been researched until now.

We compare the seven creativity techniques discussed above to combine with FCMs. First, we explain the basis upon which combining creativity techniques with FCMs might be executed. To this end, we define attributes to measure the suitability of creativity techniques for possible combining with FCMs. Second, we evaluate the techniques and rank them. Third, we present a general approach to combine creativity techniques with FCMs. Finally, we combine our highest-ranked creativity technique with FCMs.

3.1 Attributes to Measure the Suitability of Combining Creativity Techniques and Fuzzy Cognitive Maps

At this point, we introduce a selection of important attributes to compare creativity techniques for their suitability in combining with FCMs. To this end, we use Portmann and Pedrycz's knowledge aggregation, representation, and reasoning framework [37] as well as its enhancement [36] as the basis of our model. To determine which of the seven creativity techniques might be the best fit for transformation into FCMs, we require evaluation criteria. As with our research, we follow a human-centered design approach for this purpose (e.g., see [24]).

Human beings differ in the manner in which they perceive the world (e.g., understanding, interpreting, describing, or sharing knowledge). On the basis of their experiences, humans construct conceptual models (i.e., beliefs and values) that are neither consistent nor monolithic [17]. Such issues appear particularly frequently in creativity processes [49]. As a result, there are as many alternative models as humans, and no person is justified in believing that they have the correct understanding of the world [17].

With this user-centered design view in mind, and based on criteria used by Eppler [19] and Kosko [32], we understand that the attributes in Table 2 are most relevant:

Table 2: Comparison Criteria.

Visualization ability: To transform the creativity technique into an FCM, it is useful if the creativity technique can be depicted visually because FCMs are visualizations.
Output/comparable objects: As the visualization property, this attribute follows from the definition of FCMs. In a simple FCM, there are no unrelated subparts, and every object must therefore be connectable to another one [37].
Modifiability/Extensibility: Eppler [19] compares the macro structure adaptability and the extensibility of the methods. We have to be able to adapt not only the macro structure of the creativity technique but also the connections and the form of the items. This requirement likewise follows from the attribute *output/comparable items*. Moreover, it should be possible to add further relations or to simplify the model, depending on the complexity of the initial creativity technique.
Suitable for complex problems: Eppler [19] compares the application context of the different methods. We want to allow the model to be used in different contexts at different levels of knowledge, as occurs when experts and laymen collide [30]. Therefore, the creativity technique has to be able to address complex problems or systems with much information.
Uniformity: The existence of core design rules or guidelines for the creativity technique [19] are preferable because dependency on users makes it difficult to generally transform the creativity technique.
Methodology: We are interested in the questions as to whether the aim of the creativity technique is to create new ideas or to find solutions for an existing problem to decide if the transformation to a cognitive map (and ultimately to a FCM) is useful. This attribute is similar to that of Eppler, who compares the main function or benefit of creativity techniques [19].

3.2 Evaluation of the Creativity Techniques

In this section, we evaluate (within our research group) how well these creativity techniques interact with FCMs. Table 3 shows our evaluation scale. Note that there might be dependencies between different attributes, but we evaluate each attribute separately. An influence between attributes might yet be possible. To guard against this, we use a fuzzy approach for our evaluation from the beginning (e.g., see [2], [3]) because absolute conformity of the creativity technique to the chosen attributes is not possible.

In Table 4, we present the evaluation of the creativity techniques by the attributes we defined in the previous section. The creativity techniques are arranged in the first line and the attributes in the first column. The order of the attributes is based top-down on their weight for combination suitability. Using a fuzzy scale [2], [3] (i.e., a large star represents excellent applicability and a little star inapplicability or very poor applicability), each creativity technique was evaluated with respect to how well it performs in the respective attribute. The total size of the stars, in the end, was responsible for the final ranking. The evaluation of our adapted attributes is thus stable with Eppler's comparison [19].

Table 3: Evaluation Scale.

Rank	Meaning
☆	Excellent applicability
☆	Good applicability
☆	Applicability
☆	Limited applicability
☆	Inapplicability / very poor applicability

Table 4: Evaluation of the creativity techniques.

Attribute/ technique	Attribute Listing	Brain-storming	Lateral Thinking	Mind Mapping	Morpho-logical Panel	Six Thinking Hats	Walt Disney
Visualization ability	☆	☆	☆	☆	☆	☆	☆
Output/ comparable objects	☆	☆	☆	☆	☆	☆	☆
Suitable for complex problems	☆	☆	☆	☆	☆	☆	☆
Modifiability/ extensibility	☆	☆	☆	☆	☆	☆	☆
Uniformity	☆	☆	☆	☆	☆	☆	☆
Methodology[1]	p, i	p, i	p, i	p, i, k	p, i	p, i, k	p, i
Rank	**3**	**4**	**7**	**1**	**2**	**5**	**6**

[1] Our scale is not applicable for this attribute, therefore we evaluate whether the creativity technique can be used to solve problems (p), to create ideas (i), and/or to mediate knowledge (k).

3.3 Combining Mind Mapping with FCMs

The combination of creativity techniques with FCMs has previously been researched, albeit only to a limited extent. On the one hand, Kontogianni et al. use the association of a specific creativity technique with FCM [30]. In this manner, they detail mind mapping and cognitive mapping as primary steps toward FCMs. They state a clear evolution from the different methodologies, which culminate in FCMs. In their research, mind mapping is a first step toward FCM, and not a method to combine directly with FCMs. Additionally, they do not relate to mind mapping as one of several creativity techniques. On that account, they do not generally combine creativity techniques with FCMs. Eppler, on the other hand, uses mind mapping for his comparison [19] in which he implements mind mapping for complementary usage, together with (all) the other methods presented in his paper. In so doing, Eppler does not compare visualization methods with FCM. Van Vliet et al. [47], [48] employ scenario development with FCM and develop stakeholder scenarios with FCM that use different creativity techniques (e.g., brainstorming and spidergrams), which lead to FCMs. They do not specifically combine general creativity techniques with FCM, but use brainstorming and spidergrams as input for the FCMs.

As far as we know, there is no previous research that builds a direct combination involving creativity techniques and FCMs. As shown in Table 4, there are more or less suitable creativity techniques for combination with FCM. However, our evaluation shows that mind mapping is likely the most suitable creativity technique we studied to combine with FCMs.

The choice of mind mapping as the best creativity technique for such a combination seems natural and is backed by Kontogianni et al. [30] and Eppler [19]. There are similarities between mind mapping and FCM, which do not exclude the use and the combination of mind mapping with FCM. Based on our finding, it is our goal to combine these methods into a conceptual model.

The advantage of mind mapping in combination with FCMs brings businesses new possibilities to aggregate and represent expert knowledge (e.g., in stakeholder management). On the one hand, its relative simplicity and intelligibility makes mind mapping a powerful tool to gather expert knowledge, but the representation and reuse of knowledge is limited to a specific case. On the other hand, FCMs are not easily understandable for technical laymen, but their technical capabilities make them valuable for KR. These key features of both mind mapping and FCM make them perfect candidates for a combination because the respective disadvantages are eliminated by this combination.

4 Deploying the conceptual model

First, we present our conceptual model and use a scenario to better explain it. Second, we simulate the scenario by going through each of its phases step-by-step. Finally, we present requirements for the scheduled instantiation of our model. To this end, we will follow the lex parsimoniae, which, as a preliminary point, suggests that we should tend toward simpler solutions until some simplicity can be traded for increased explanatory power.

4.1 Stakeholder Management Scenario

This section focuses on a scenario to illustrate our conceptual model for improved knowledge management in the context of stakeholder management. We intend to enrich the current literature on company stakeholder responsibility [21] with our research (i.e., on information integration). We present a scenario of an FCM-integrated mind-mapping technology used at stakeholder workshops of a medium-sized company. This scenario results from Portmann and Kaltenrieder, who use FCMs as granular knowledge bases that can be used for purposes of company stakeholder responsibility [36].

The participants (non-governmental organizations NGOs) of the first workshop are divided into three groups and given separate tasks. The groups must think about the past (i.e., group #1), present (i.e., group #2) and future (i.e., group #3) challenges of sustainable production.

Mind maps are used to record the thoughts and challenges of the groups. The participants must approximate the challenges they discuss by weighing them on a given scale.

In the afternoon, a member of each group must present the results. After a break, the moderator shows the top five challenges of sustainable production they gained, ranked by their individual weights (e.g., negligible, potential, important, crucial) using fuzzy scales. At the end of the workshop, all participants receive an overview of all the challenges mentioned in the workshop.

A week later, there is a similar workshop with other participants. After the afternoon break, the top five challenges discussed by the groups are re-presented. Additionally, this time, the moderator shows the overall top five challenges addressed by both workshops.

The workshop is held five times (NGOs, think tanks, politicians, local authorities, and shareholders). In the end, the top five challenges (incl. the weights of all the involved stakeholder groups) are known.

The software used is a combination of a creativity technique (i.e., mind mapping) and the concept of FCM. Thanks to this software, users will be capable to acquire and (re-)use expert knowledge that is spread around various stakeholders and therefore to improve their knowledge management. New inputs to specific questions are gained by organizing workshop sessions and by asking the same type of questions to workshop participants. The software will store and aggregate all answers and give users valuable information (incl. the weightings) working as an intelligent information system.

4.2 Conceptual Model

This section is dedicated to our conceptual model. Fig. 3 shows the process explained in the scenario. Expert knowledge is acquired by multiple mind-mapping sessions (incl. the individual weights) to improve knowledge management. These sessions are then aggregated and transformed into $\sum FCM_i$. As described earlier, the automatic reasoning is not part of our current model. The technical functionality of the conceptual model is shown in (1).

$$MindMapping_i^w \xrightarrow{W} FCM_i \xrightarrow{Aggr.} \sum FCM_{1,...,N}^{Aggr.} \qquad (1)$$

Knowledge is acquired and aggregated by gaining expert knowledge with mind-mapping sessions (MindMapping_i). The assigned weighting (*w*) is included from every session. The next step is the transformation from knowledge aggregation into knowledge representation. The information gained will be implemented into a FCM (FCM_i) by applying a wrapper *W* (i.e., a technique that extracts content and translates it into a relational form). The FCM_i then represents all available weighted knowledge from this specific mind-mapping session. This procedure whereby knowledge is gained through mind mapping and transforming it into FCM will be repeated as frequently as desired. In the end, all FCMs are aggregated to create an integrated FCM ($\sum FCM_{1,...,N}^{Aggr.}$) as mentioned in 2.4 above. This approach is based on Portmann and Pedrycz [37] and Portmann and Kaltenrieder [36].

To instantiate the proposed model in a prototype (i.e., intelligent information system), we are currently working on the requirements of our model (e.g., business, design, and engineering).

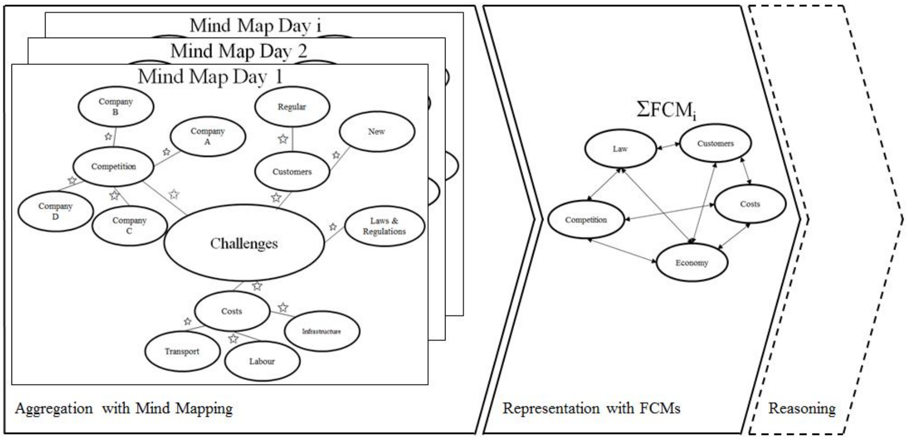


Fig. 3: Conceptual Model.

4.3 Requirements for an implementation of the Model

The requirements to develop and possibly implement an intelligent information system can be divided into three main categories; technical, design, and usability requirements. These requirement categories are tightly intertwined, and we can therefore try to allocate each into the category in which it has the strongest impact. Certain general requirements can be gathered from the evaluation attributes of the creativity techniques that are required by our model: *Visualizing ability, a measurable output* and *comparable objects*, *modification and extensibility*, *suitability to solve complex problems*, and *uniformity*. Additionally, the *possibility to personalize* the model is important because users of the model must be able to implement their own ontologies to specify and define their desired questions.

There are crucial technical requirements in this process, such as the *interface to other software* (e.g., a content management system CMS), the *ability to detect grammatical mistakes*, and *usage of a fuzzy scaling* to enable weighting of the gathered knowledge. The design of the model must be functional and contain high usability for the users. It should be based on current software standards to facilitate comprehensibility.

Therefore, the most important requirement with respect to usability is that the user interface must be highly usable for both the experts acquiring knowledge and for the users working directly with the model.

Our next research steps, however, will include more detailed requirements to enhance the conceptual model and to thus enable the features presented in the scenario.

5 Discussion

This chapter introduced a conceptual model that combines creativity techniques with FCM for purposes of knowledge management in an integrated system. Seven creativity techniques and their historical backgrounds were presented, and the concept of FCM was introduced. We evaluated the possible suitability of the presented techniques, which is why we defined several attributes. The evaluation culminated in the selection of the most suitable creativity technique (i.e., mind mapping). Based on this evaluation, we introduced our conceptual model that transforms mind maps and aggregates them into FCMs. To support intelligent information integration, this model is the first step in realizing a software prototype outlined in the scenario. This study has limitations that will be addressed by future research. For instance, our subjective selection of the seven creativity techniques and the choice of attributes to evaluate the suitability of the combination of the creativity techniques is certainly a limitation. The evaluation of additional creativity techniques for their suitability goes hand-in-hand with verifying attributes, and further research would be valuable. A prototype of the conceptual model is currently in the early stages of development.

References

1. Aiken, M., Vanjani, M. and Paolillo, J.: A comparison of two electronic idea generation techniques. Information & Management, Vol. 30(2) (1996) 91-99
2. Araujo, E. and Myahira, S.A.: Unidimensional fuzzy pain intensity scale. In: IEEE International Conference on Fuzzy Systems, Hong Kong (2009) 185-190
3. Araujo, E. and Myahira, S.A.: Tridimensional fuzzy pain assessment. In: IEEE International Conference on Fuzzy Systems, Taipei, Taiwan (2011) 1634-1639
4. Axelrod, R.M.: Structure of decision: The cognitive maps of political elites. Princeton University Press, Princeton (1976)

5. Barrett, F.D.: Creativity techniques: Yesterday, today, and tomorrow. Advanced Management Journal, Vol. 43(1) (January 1978) 25-35
6. Berners-Lee, T., Hendler, J. and Lassila, O.: The semantic web. Scientific American Journal, Vol. 284(5) (2001) 28-37
7. Boutalis, Y., Kottas, T.L. and Christodoulou, M.: Adaptive Estimation of Fuzzy Cognitive Maps with Proven Stability and Parameter Convergence. In: IEEE Transactions on Fuzzy Systems, Vol. 17(4) (August 2009)
8. Brachman, R.J. and Levesque, H.J.: Knowledge Representation and Reasoning. Morgan Kaufmann, San Francisco (2004)
9. Buzan, T.: Use both sides of your brain. Dutton Books, New York (1976)
10. Carvalho, J.P.: On the semantics and the use of fuzzy cognitive maps and dynamic cognitive maps in social sciences. Fuzzy Sets and Systems, Vol. 214 (2013) 6-19
11. Crawford, R.P.: The techniques of creative thinking. Hawthorn Books, New York (1954)
12. de Bono, E.: Six thinking hats. Little, Brown and Company, Boston (1985)
13. de Bono, E.: Exploring patterns of thought…serious creativity. Journal for Quality and Participation, Vol. 18(5) (1995) 12-18
14. de Bono, E.: Lateral thinking: Creativity step by step. Harper & Row, New York (1970)
15. Dilts, R.: Strategies of genius volume I: Aristotle, Sherlock Holmes, Walt Disney, Wolfgang Amadeus Mozart. CA: Meta publications, Capitola (1995)
16. Dilts, R.: Walt Disney, Strategies of Genius (1996) [Online] Available: http://www.nlpu.com/Articles/article7.html
17. Dimitrov, V. and Russell, D.: The Fuzziness of Communication: A Catalyst for Seeking Consensus. In: Fell, L., Russell, D. and Stewart, A. (Eds.): Seized by Agreement, Swamped by Understanding (1994) [Online] Available: http://www.pnc.com.au/~lfell/fuzcom.pdf.
18. Eden, C.: On the nature of cognitive maps. Journal of Management Studies, Vol. 29(3) (1992) 261-265
19. Eppler, M.J.: A comparison between concept maps, mind maps, conceptual diagrams, and visual metaphors as complementary tools for knowledge construction and sharing. Information Visualization, Vol. 5(3) (2006) 202-210
20. Barr, A. and Feigenbaum, E.A: The Handbook of Artificial Intelligence. HeurisTech Press, Stanford, California (1981)
21. Freeman, R.E., Velamuri, S.R. and Moriarty, B.: Company Stakeholder Responsibility: A New Approach to CSR. Business Roundtable, Institute for Corporate Ethics, Bridge Paper (2006) [Online] Available: http://www.corporate-ethics.org/publications/bridge-papers/
22. Geschka, H.: Kreativitätstechniken und Methoden der Ideenbewertung. In: Sommerlatte, T., Beyer, G. and Seidel, G. (Hrsg.): Innovationskultur und Ideenmanagement – Strategien und praktische Ansätze für mehr Wachstum. Symposium Publishing GmbH, Düsseldorf (2006) 217-249
23. Geschka, H. and Lantelme, G.: Kreativitätstechniken. In: Albers, S. and Gassmann, O. (Eds.): Handbuch Technologie- und Innovationsmanagement. Gabler, Wiesbaden (2005) 285-304
24. Greenhouse, E.S.: Human-centered design. Livable New York Resource Manual (2012) [Online] Available: http://www.aging.ny.gov/LivableNY/ResourceManual/DemographicAndSocialTrends/I9.pdf.
25. Groumpos, P.P.: Fuzzy Cognitive Maps: Basic Theories and Their Application to Complex Systems. In: Glykas, M. (Ed.): Fuzzy Cognitive Maps: Advances in Theory, Methodologies, Tools and Applications. Springer Verlag, Berlin Heidelberg (2010)

26. Grube, P.P. and Schmid, K.: Selecting creativity techniques for innovative requirements engineering. In: Multimedia and enjoyable requirements engineering - beyond mere descriptions and with more fun and games. Third International Workshop, Barcelona (2008) 32-36
27. Hayes-Roth, F., Waterman, D., and Lenat, D.: Building Expert Systems. Addison-Wesley, München (1983) 6-7
28. Hitzler, P., Krötzsch, M. and Rudolph, S.: Foundations of Semantic Web Technologies. Chapman & Hall/CRC, Boca Raton (2010)
29. Kaufmann, M., Wilke, G., Portmann, E., and Hinkelmann, K.: Combining Bottom-up and Top-down Generation of Interactive Knowledge Maps for Enterprise Search. Accepted for the International Conference on Knowledge Science, Engineering and Management, (2014), Sibiu, Rumania
30. Kontogianni, A.D., Papageorgiou, E.I. and Tourkoalias, C.: How do you perceive environmental change? Fuzzy cognitive mapping informing stakeholder analysis for environmental policy making and non-market valuation. Applied Soft Computing Journal, Vol. 12(12) (2012) 3725-3735
31. Kosko, B.: Fuzzy Engineering. Prentice Hall, New Jersey (1997)
32. Kosko, B.: Fuzzy cognitive maps. International Journal of Man-Machine Studies, Vol. 24(1) (1986) 65-75
33. Kosko, B.: Neural networks and fuzzy systems: A dynamical system approach to machine intelligence. Prentice-Hall International, Englewood Cliffs (1992)
34. Osborn, A.F.: Applied imagination: Principles and procedures of creative problem solving. Charles Scribner's Sons, New York (1953)
35. Papageorgiou, E.I. and Kontogianni, A.D.: Using fuzzy cognitive mapping in environmental decision making and management: A methodological primer and an application. In: Young, S. (Ed.): International perspectives on global environmental change. InTech, Germany (2012) 427-450
36. Portmann, E. and Kaltenrieder, P.: The Web KnowARR Framework: Orchestrating Computational Intelligence with Graph Databases. In: Pedrycz, W. and Chen, S.M. (Eds.): Information Granularity, Big Data, and Computational Intelligence. Springer Verlag, Berlin Heidelberg (2015) 325-346
37. Portmann, E. and Pedrycz, W.: Fuzzy Web Knowledge Aggregation, Representation, and Reasoning for Online Privacy and Reputation Management. In: Papageorgiou, E.I. (Ed.): Fuzzy Cognitive Maps for Applied Sciences and Engineering. Springer Verlag, Berlin Heidelberg (2014) 89-105
38. Salmeron, J.L.: Fuzzy Cognitive Maps for artificial emotion forecasting. Applied Soft Computing, Vol. 12 (2012) 3704-3710
39. Sharif, A.M. and Irani, Z.: Exploring fuzzy cognitive mapping for IS evaluation. European Journal of Operational Research, Vol. 173(3) (2006) 1175-1187
40. Siau, K.L.: Electronic creativity techniques for organizational innovation. The Journal of Creative Behavior, Vol. 30(4) (1996) 283-293
41. Smith, G.F.: Idea-generation techniques: A formulary of active ingredients. The Journal of Creative Behavior, Vol. 32(2) (1998) 107-134
42. Summers, I. and White, D.E.: Creativity techniques: Toward improvement of the decision process. Academy of Management Review, Vol. 1(2) (1976) 99-107
43. Tolman, E.C.: Cognitive maps in rats and men. The Psychological Review, Vol. 55(4) (1948) 15-64
44. Trowbridge, C.C.: On fundamental methods of orientation and imaginary maps. Science, Vol. 38(990) (1913) 888-897

45. Tversky, B.: Cognitive maps, cognitive collages, and spatial mental models. Spatial information theory: A theoretical basis for GIS. Lecture notes in Computer Science, Vol. 716 (1993) 14-24
46. Van Harmelen, F., Lifschitz, V. and Porter, B.: Handbook of Knowledge Representation. Elsevier, Amsterdam/Oxford (2008)
47. Van Vliet, M., Kok, K. and Veldkamp, T.: Linking stakeholders and modellers in scenario studies: The use of Fuzzy Cognitive Maps as a communication and learning tool. Futures, Vol. 42(1) (2010) 1-14
48. Van Vliet, M., Kok, K., Veldkamp, A. and Sarkki, S.: Structure in creativity: An exploratory study to analyse the effects of structuring tools on scenario workshop results. Futures, Vol. 44(8) (2012) 746-760
49. Whiting, C.S.: Creative Thinking. Reinhold, New York (1958)
50. Xirogiannis, G., Stefanou, J. and Glykas, M.: A fuzzy cognitive map approach to support urban design. Expert Systems with Applications, Vol. 26(2) (2004) 257-268
51. Zadeh, L.A.: Fuzzy sets. Information and Control, Vol. 8(3) (1965) 338-353
52. Zadeh, L.A.: Some reflections on soft computing, granular computing and their roles in the conception design and utilization of information/intelligent systems. Soft Computing: A fusion of foundations, methodologies and applications, Vol. 2(1) (1998) 23-25
53. Zadeh, L.A.: From computing with numbers to computing with words—from manipulation of measurements to manipulation of perceptions. Int. J. Appl. Math Computer Sci, Vol. 12(3) (2002) 307-324
54. Zadeh, L.A.: Is there a need for fuzzy logic? Information Sciences, Vol. 178 (2008) 2751-2779
55. Zwicky, F.: Entdecken, Erfinden, Forschen im morphologischen Weltbild. Droemer/Knaur, München/Zürich (1966)