FROM CONCEPT MAPPING TO QUALITATIVE MODELING IN COGNITIVE RESEARCH

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Abstract. Concept maps can represent individual knowledge by the set of concepts and relations between them. The representation is fast, telling and natural, and besides the structural, relational knowledge that can be expressed by means of set of propositions (explicit knowledge), it is usually possible to find additional, hidden knowledge in the concept map structure (implicit knowledge). This hidden knowledge can be revealed by conversion of concept map texture into the evaluated cognitive maps and processing them. In this paper a way to perform such conversion is demonstrated on spatial concept mapping example.

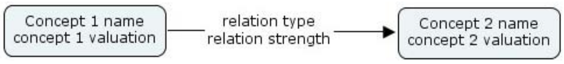
1 Introduction

Cognitive maps as there were introduced by Tolman in his study (Tolman 1948) has laid the basis for cognitive psychology research. Cognitive maps in cognitive psychology are considered as dynamical schemes inside human mind. They are parts of our reflection of physical world and participate on motivation to decision making and creating and changing our attitudes. Cognitive maps work not only as a "mental mirror" of a part of reality inside human brain, but also as an active tool for modification of our feelings and ideas about the world. First practical application of a cognitive map (in somewhat modified sense of the concept) comes from Axelrod (Axelrod 1976) and was applied as a modeling tool in politics. Cognitive map was defined as a system composed of the set of concepts and the set of causal relationships. Each concept may influence other concepts via causal relationships in positive or negative sense, and there are no interactions between independent concepts. A cognitive map is traditionally represented by a signed directed graph, where concepts of the cognitive map correspond to nodes of the graph and causal relationships correspond to arcs oriented from the cause concepts to the effect concepts. In contrast to relationships in concept map the sign and strength of causality in cognitive map are expressed by evaluating the arcs with numerical values. The extension of cognitive map – fuzzy cognitive map – was proposed by Kosko (Kosko 1986). Causal relationships and even concepts in fuzzy cognitive maps are accompanied by fuzzy sets or fuzzy systems (fuzzy logic was introduced by Zadeh (Zadeh 1965) as a tool for handling unsharp, unprecise or ill defined, "fuzzy" problems). This evaluation allows to express fine differences in causal relationships and to introduce partial activation of concepts instead of binary activation in classical cognitive maps. Fuzzy approach is at the same time close to human-like way of thinking and communication. Moreover, thanks to fuzzy approach, there is also possible to process verbal evaluations of concepts and relations directly ("computing with words"), as was proposed by Zadeh (Zadeh 1975).

2 Design of concept map from the controlled interview

To get complex personal knowledge concerning specific place, a controlled interview was used. Figure 1 shows some fragments of concept network inferred from recorded interviews that were concerned in evocation of one particular problem – to remember and describe personal experience about holiday stay by the seaside. Interviews were performed during the pilot phase of the research work on static and dynamic characteristics of cognitive maps. Diagram consists not only of common concepts (Sea, Village, Rock) and connections (is, has, offer), but also of quantified concepts (Visibility-excellent, Broad-quite, ...), indicating that there is a quantitative information in verbal form included here.

The information transcription from recorded interview to the concept map was formalized that the first row of the concept box holds concept name and the second row holds linguistic valuation of the concept. Similarly the relation type and strength (if located in interview) is entered into separate rows:



This convention makes use of export option of the concept map software (CmapTools) to code a map as a specifically structured text file. Structured text data are then convenient for further automatic analyzing and processing.

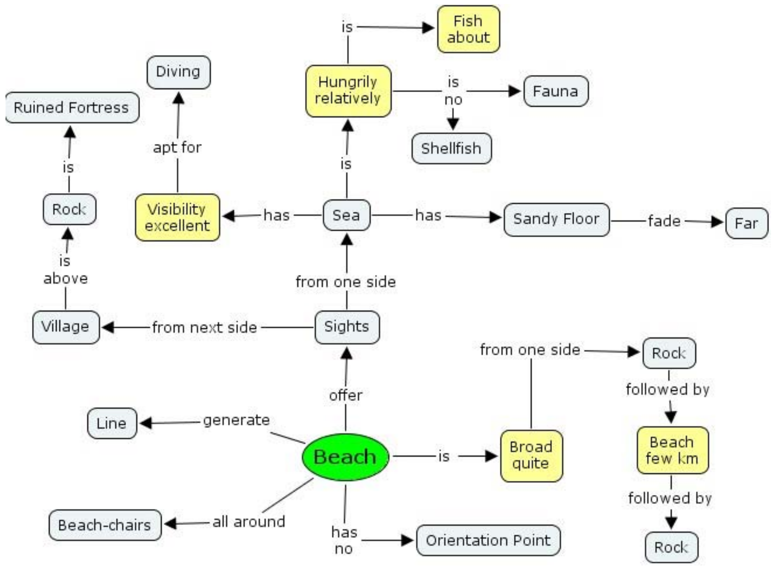


Figure 1. Space focused concept map concerning the place of holidays stay obtained through the controlled interview transcription.

Representing the interview by concept map is fast, telling and natural. For better understanding it is possible to highlight specific concepts by shape or colour, but our intention is to extract "hidden" dynamic knowledge from the concept map and embody it into the (fuzzy) cognitive map structure.

3 Finding pieces of knowledge in concept maps

The knowledge in concept maps is mostly presented in form of relations between the concepts (Novak and Gowin 1984) – as propositions (SEA is HUNGRILY, SEA has SANDY FLOOR). Since relations between nodes within (fuzzy) cognitive maps are established by (fuzzy) rules, it is vital to rebuild the concept structure and to add new causal relations.

There is a range of possible cognitive representations of concept maps, but only some of them make sense. From the particular concept map in Figure 1, new relations between concepts can be derived as follows:

- If the BEACH is broad, then there is no ORIENTATION POINT
- If the BEACH is broad, then there are many BEACH-CHAIRS
- If the SEA is hungrily, then the VISIBILITY is *excellent*
- If the VISIBILITY is excellent, then DIVING is fine
- If the SEA is hungrily, than there is no FAUNA
- If the FAUNA is poor, than DIVING is less fine
- If BEACH-CHAIRS are all around, than VISIBILITY is getting worse

The cognitive map representing the very derived set of rules is illustrated in Figure 2. Fuzzy values characterizing strength or importance of component causal relations can be obtained either from explicit data included in the source concept map or from additional questions, expert databases, or other sources (semantic nets, etc.). In our research we started with utilizing expert analyses and additional questions in evaluating strength between concepts, but future steps will be focused to earn the computerized support of the task. In the present time, numerical values were assumed from the standard fuzzy cognitive model to assess both relations and concepts.

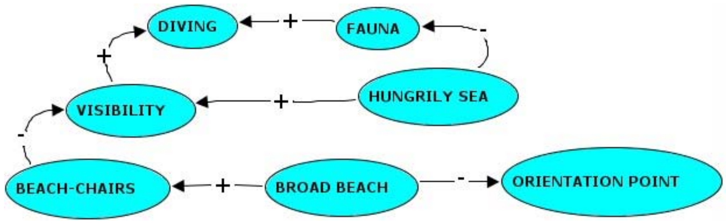


Figure 2. Cognitive map $\mathbf{FCM}_{SEA}$ based on rules extracted from the concept map on Figure 1

4 Processing the fuzzy cognitive map model

Fuzzy cognitive maps are typically recorded in form of tables or matrices of relations between concepts. Their benefit lies in their capability to represent dynamic systems that can evolve in time. In principle we follow the evolution of the model in discrete time steps as a sequence of state vectors $\mathbf{C}_t$. The future state of the model depends on present state and on relations between concepts:

$$\mathbf{C}_{t+1} = f(\mathbf{C}_t\mathbf{E}),$$

where **E** is a n×n connection matrix and f is a threshold function (we have used f(x) = x for x∈(0,1), f(x) = 1 for x ≥ 1, and f(x) = 0 for x ≤ 0).

For the cognitive map from Figure 2 the estimated causal relation strengths are listed in Table 1.

	HUNGRILY SEA	VISIBILITY	DIVING	FAUNA	BROAD BEACH	ORIENTATION POINT	BEACH-CHAIRS
HUNGRILY SEA		**+0.6**		**+0.2**			
VISIBILITY			**+0.7**				
DIVING							
FAUNA			**+0.8**				
BROAD BEACH						**-0.3**	**+0.6**
ORIENTATION POINT							
BEACH-CHAIRS		**-0.5**					

$$\mathbf{E} = \begin{bmatrix} 0 & +0.6 & 0 & +0.2 & 0 & 0 & 0 \\ 0 & 0 & +0.7 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & +0.8 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -0.3 & +0.6 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -0.5 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Table 1: Relations between concepts in fuzzy cognitive map $\mathbf{FCM}_{SEA}$ from Figure 2 and corresponding connection matrix **E**.

For initial state $\mathbf{C}_0$=[1 0 0 0 1 0 0] and on the assumption that both concepts HUNGRILY SEA and BROAD BEACH are time-invariant, we get the sequence of states:

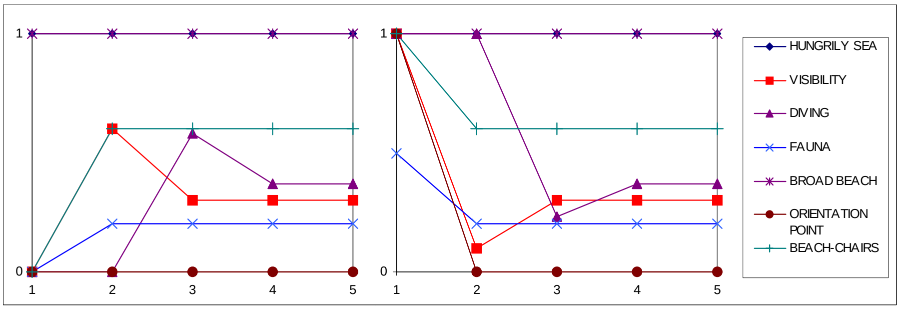
$\mathbf{C}_1$=[1 0.6 0.00 0.2 1 0 0.6],
$\mathbf{C}_2$=[1 0.3 0.58 0.2 1 0 0.6],
$\mathbf{C}_3$=[1 0.3 0.37 0.2 1 0 0.6],
$\mathbf{C}_4$=[1 0.3 0.37 0.2 1 0 0.6], etc.

The interpretation of the cognitive map model based on the record of its dynamical activity may be as follows: hungrily sea with poor fauna but with good visibility and broad beach can attract tourists. After some initial stabilization of the system good diving conditions will be achieved. However, the increase of other tourist activities (beach-chairs) makes the visibility in the sea worse, which decrease the attractivity of the place for potential divers (Figure 3a)).

Beginning the simulation of behavior of the fuzzy cognitive map $\mathbf{FCM}_{SEA}$ for substantially different initial state $\mathbf{C}_0$=[1 1 1 0.5 1 1 1], different transition states but identical stable state will be gained:

$\mathbf{C}_1$=[1 0.1 1.00 0.2 1 0 0.6],
$\mathbf{C}_2$=[1 0.3 0.23 0.2 1 0 0.6],
$\mathbf{C}_3$=[1 0.3 0.37 0.2 1 0 0.6],
$\mathbf{C}_4$=[1 0.3 0.37 0.2 1 0 0.6], etc.

Now the supposed initial state of the model picture some “overload” of the environment exploitation that leads to radical decrease of conditions (visibility), so the diving activities drop to very low level. Anyhow, continuing the evolution the model can reach the stable state that may be identical (or different owing to internal relations of the particular model) to other initial states outgrowth (Figure 3b)).



a) b)

Figure 3. The evolution of states of the fuzzy cognitive map $\mathbf{FCM}_{SEA}$ a) for initial state $\mathbf{C}_0$=[1 0 0 0 1 0 0] and b) for initial state $\mathbf{C}_0$=[[1 1 1 0.5 1 1 1]

5 Summary

Concept maps and cognitive maps look very similar, but they represent knowledge in fairly different way. The ambition of the article was to refer our approach aimed to obtaining implicit knowledge by rendering concept map and by constructing and analyzing corresponding fuzzy cognitive map. Although the presented model was very simple, it is evident that some sensible dynamical processes can be revealed in concept descriptions of real situations.

6 Acknowledgements

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