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IMPLICIT KNOWLEDGE IN CONCEPT MAPS AND THEIR REVEALING BY SPATIAL ANALYSIS OF HAND-DRAWN MAPS

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Abstract. Concept maps represent a rich structure to store and picture information or knowledge in form of concept-to-concept relations. There are several methods proposed for concept map analysis, based usually on concept and relation comparison, topological analysis of the map and others. One of the traditional applications of concept maps is the evaluation of the student's knowledge, enabling to identify not only well understood knowledge, but also to reveal misunderstanding of some parts of the course topic. One of the not yet fully examined characteristics of hand-drawn concept maps seems to be the spatial layout of the map and its connection with the level of understanding to the diagrammatized topic. Possible relationship between the concept-to-concept distances and the level of subjective understanding of the subject domain will be presented as a new sight to hand-drawn concept maps analysis.

1 Introduction

There are several levels of information that can be preserved in the frame of the concept maps. Some of these chunks of information are being the subject of intensive study (hierarchy of concepts, overall structure of the map, relevance of propositions …) (Cañas, Leake, Maguitman, 2001), (Henderson, Yerushalmi, Heller, Kuo, 2003), (Leake, Maguitman, Reichhertzer, Cañas, Carvalho, Arguedas, Eskridge, 2004), but some are still out of the interest horizon of the research community. One of these still omitted sources of "hidden" information, coded in the structure of concept maps can be found in spatial layout of the concrete map.

In this contribution we shall focus on some interesting relations in spatial representation of hand-written concept maps – especially on relation between the frequency of links between concepts and their average distance. We hypothesize, that the distance between concepts is in inverse relation with the level of understanding or knowledge about these concepts links. Better understanding of the link should be expressed by more often use of it when drawing the concept map and by measurably closer placing connected concepts. On the other hand, there is in practice infinite number of possible layouts of the concept map. We can ask – why particular people choose just the only concrete concept map layout? What is their motivation? Can we better understand their knowledge?

2 Concept maps in students' knowledge evaluation

In the academic year 2004/2005, we have used concept mapping as a part of the exam test for students of Decision Support Systems (DSS) course at the Faculty of Informatics and Management. Students were instructed about concept maps at the beginning of the term, they worked with CmapTools software on seminars and were encouraged to cooperate in the long-term project – in creation of a common concept map about "What are Decision Support Systems?"

For the exam test purposes, ten typical concepts from the DSS domain were selected (DSS, OLAP, Data, Models, Data warehouse, Knowledge, Decision, Cognitive limit, Risk, Manager). Students were then asked to express (according to their knowledge) in the form of concept map only the most relevant or important relations between any pair of the concepts from the defined set. No other limitations (time for creation the map, layout nor size of the map) were stated.

Acquired hand-drawn individual concept maps were then used as one of the evaluation criteria – only number and relevance of expressed relational descriptions (links between concepts) were taken into the evaluation formula. There were about 140 individual concept maps with different structure, different evaluation and, especially, with different layout. As some characteristic patterns seemed to occur in many of these maps, we constructed some hypotheses concerning connection between spatial layout of the specific map and the level of knowledge about the visualized domain, and decided to provide deeper analysis to prove them. For the analysis purposes only 45 complete individual maps were randomly selected.

3 Concept maps and spatial maps

In the frame of our thinking we are determined not only by actual sensations, but to some degree also by our previous experience and by our knowledge. One can say, that knowledge were (and still are) very important for better orientation in the surrounding space we are living in. It was vital for human's survival to remember how to come back from hunting to the native cave or to his or her home village. As only small piece of the scene is visible in concrete time, there is a need for remembering and processing of spatial information in some way to enable orientation, way planning and way finding in different situations.

It is widely accepted that the incoming data are processed in our senses and mainly in our brain and spatial information is stored in a schematized form – cognitive map of the environment. Let's suppose that the near surroundings are usually the best known space, with very details and specialities, while far sites are less known and are characterized mainly by orientation points and can be replaced with schematic maps (Klippel, Richter, Barkowsky, & Freksa, 2005).

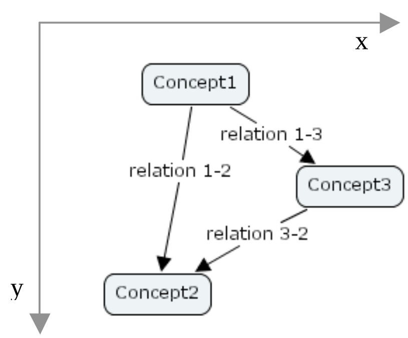
Concept mapping of some common domain can be compared to spatial mapping in terms of creating simplified and usually incomplete or in some way distorted image of the reality. Concept maps are also representing some kind of domain knowledge. They are characterized by simplification and standardization. In some aspects, concept maps can be considered as an equivalent of spatial and schematic maps for virtual, abstract conceptual spaces.

3.1 How to measure spatial characteristics of a concept map?

Spatial arrangement of the concept map can be analyzed from different points of view. In our approach, we focused to normalized distances between concepts within a concept map computed from coordinates of individual concepts as:

$$d(C_i, C_j)_{norm} = \frac{|C_i - C_j|}{|C_x - C_y|_{\max}} ,$$

where $|C_x - C_y|_{max}$ means the maximal distance between linked concepts in the concept map.



			x_{Ci}	y_{Ci}			x_{Cj}	y_{Cj}	$\|C_i - C_j\|$	$d(C_i, C_j)_{norm}$
Concept1	relation 1-2	Concept2	130	160	120	222	103	310	152,41	**0,9698**
Concept1	relation 1-3	Concept3	130	160	185	196	240	233	132,02	**0,8401**
Concept3	relation 3-2	Concept2	240	233	175	267	103	310	157,16	**1,0000**

Figure 1. Concept map and corresponding normalized distances between concepts based on Lifemap export from CmapTools.

For graphical representation of concept maps there are standard schemes and tools, based on the theory of Prof.. Novak and his co-workers (Novak & Gowin, 1984; Novak & Cañas, 2006).

3.2 *Collecting and preprocessing raw data*

Selected hand-drawn concept maps, captured from student's tests were converted (in the scale 1:1) into the electronic form by modifying a template concept map in CmapTools environment. The electronic concept maps were then exported to the LifeMap format – as the set of relations with x-y coordinates of particular concepts, and by use of simple application distances and normalized distances of linked concepts were computed (as it is shown in Figure 1).

A typical design of the individual hand-drawn map, copied to electronic form, can be seen in Figure 2.

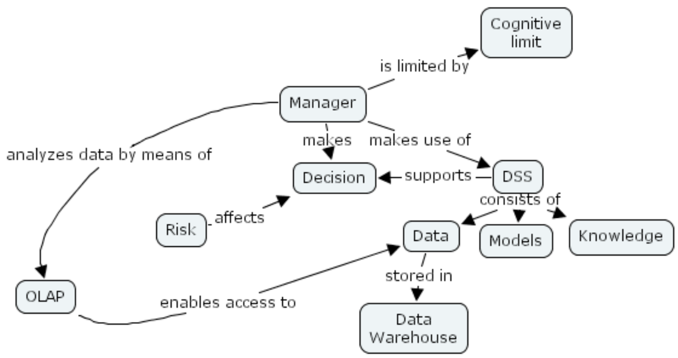


Figure 2. Student concept map redrawn to electronic form (CmapTools)

While links between concepts are usually interpreted as logical connections between concepts and are considered as one of important knowledge indicators, physical distances in hand-drawn maps layout seem not to follow this interpretation. As an example, the relation "Manager – analyzes data by means of – OLAP" can be taken attention to. In our example, students had often expressed the relation between concepts "Manager" and "OLAP" (they had some general knowledge about that concepts), but in other part of the exam test they frequently did wrong when selecting the correct answer to the characterization of the concept "OLAP" in multiple choice question (their understanding of the meaning of the concept was somewhat weak).

3.3 *Source and sink concepts*

First analysis of individual hand-drawn concept maps was focused to identify concepts with most outgoing (sources) and most incoming (sinks) links. It was no surprise to get a result identifying concepts "Manager" and "DSS" as outstanding sources of links, but there were no typical "sink concept" in analyzed maps.

3.4 *Connections and distance – knowledge or understanding?*

Having computed normalized distances between concepts within individual concept maps it was possible to compare spatial characteristics of these maps. When concepts were ordered according to number of outgoing links, we tried to prove our hypothesis, that concepts that are more often linked are in average closer, too. Some results for first (according to the number of connections) three concepts of our example are shown in Figure 3. The x-axis shows the number of concepts that are in general connected with the particular concept, and chart curves mean (a) cumulative number of links (black) and (b) normalized average distance between corresponding pairs of linked concepts (grey).

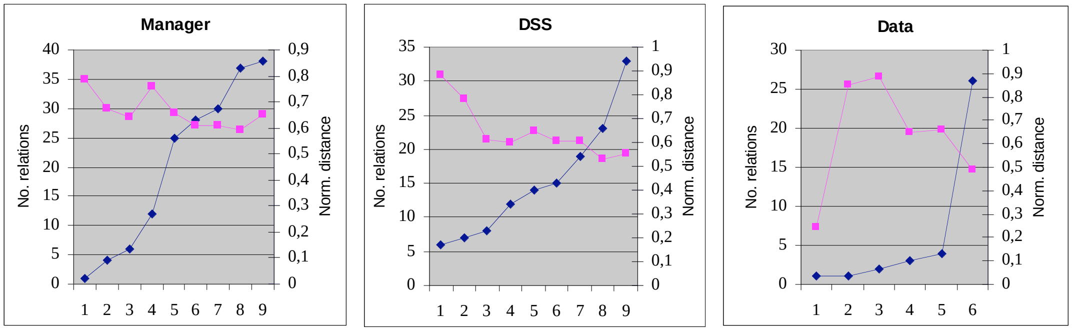


Figure 3. Cumulative number of links and normalized average distances of particular concepts

4 Summary

Analyzing students' hand-drawn concept maps we can identify many important indicators for evaluation of the quantity and quality of their knowledge. Number of relational links between concepts, accuracy of their characterization, complexity of the concept map belong to standard results.

Presented interpretation of the distance between concepts in hand-drawn concept maps can extend our scope to evaluate level of knowledge expressed in these maps and help to identify weaker points in concept map author's knowledge.

The research will continue by processing new data from present academic year students' concept maps and by verification of pertinency and usability of the concept map analysis method in other domains.

5 Acknowledgements

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