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A brief survey on cognitive maps as humane representations

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A BRIEF SURVEY ON COGNITIVE MAPS AS HUMANE REPRESENTATIONS

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Abstract: Visualisation offers a huge potential for representing information and knowledge. A number of different proposals from diverse research areas have been over the time presented as techniques that may be used for sharing information and knowledge.
This paper briefly introduces such proposals by providing an introduction to cognitive maps as humane representations, as they provide in their alternative representations, a tool for information and knowledge sharing. The paper ends to suggest further research in order to develop graphical translations between those different representations.

keywords*: computer-human interface*

Introduction

A cognitive map is a mental map that supports navigation through the world. The concept was studied by people looking into the behaviour of animals when they moved from one location to another.

Concerning the knowledge that people need to have to move around, Thorndyke and Hays-Roth propose two types of knowledge: Route Knowledge and Survey Knowledge (Thorndyke and Hays-Roth, 1982):

- *Route Knowledge* is knowledge that results from getting around. If someone provides directions to his/her house, he/she is using Route Knowledge.
- *Survey Knowledge* is knowledge that enables us to understand the general spatial relationships that are involved. This is applied when we indicate that the house is north of the Museum.

Cognitive maps that are constructed by people as mental maps tend to be biased by the person constructing them. Such a mental map is a map that has been filtered by our personality. With it we can justify things that do not readily fit in our concept of the universe.

Mental maps are also related to images and concepts, and these, with the way individuals think about them: Damasio defends the identification of mental images with temporarily time-locked activity in multiple neural regions (people perceiving images for thinking purposes) (Damasio, 1994), and Clark includes the identification of concepts with distributed, context-dependent patterns of neural activity (Clark, 1993). These two perspectives provide support for the idea that such mental maps can be of help to identify and take advantage of concept and image representation for knowledge sharing support.

Mind Maps

Mind Maps were proposed by Buzan (Buzan, 1974). They are designed to help expand our mental capacities. The author asserts that Mind Maps can be used to promote clear thinking about concepts and ideas where relationships are visualised and manipulated in a more natural way than the case of the linear note taking. Buzan proposes a group of seven laws to develop Mind Maps: use images, use words, connected lines with associated words, one word per line, use colours and allow for creativity to take place (Buzan, 1974). The author also proposes a technique to develop Mind Maps called MMOST (the Mind Map Organic Study Technique). Two main sections comprise the MMOST technique: preparation and application. Each of these sections is divided into four additional sub-sections. Figure 1 presents an example of a Mind Map on the uses of Mind Maps (Buzan, 1974).

Mind Maps can be described as having a central word or concept. Around the central word it is possible to draw 5 to 10 main ideas that relate to that word. Taking each of those child words, and again drawing 5 to 10 main ideas to relate to each of those words (Buzan, 1974).

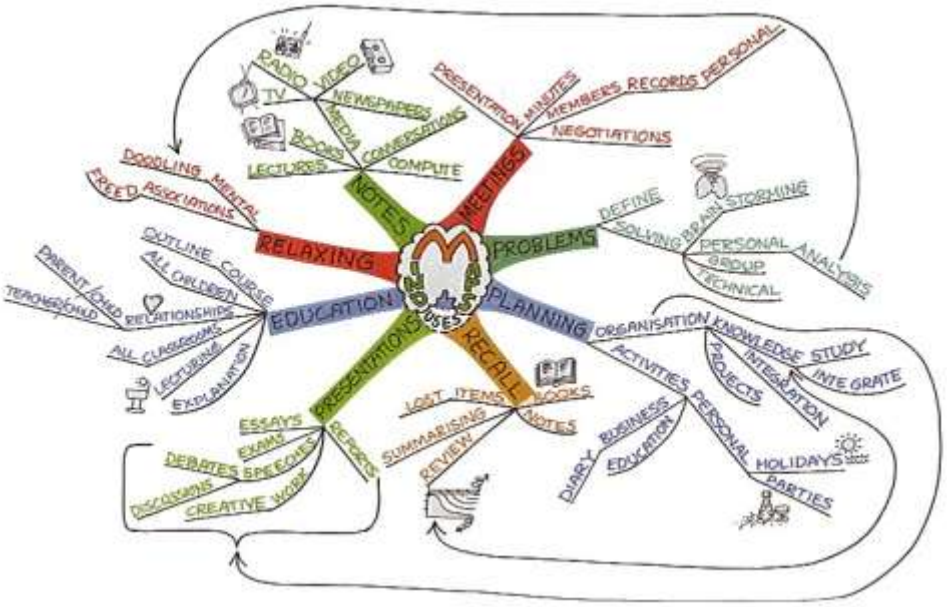

Figure 1: A Mind Map on the uses of Mind Maps (Buzan, 1974)

Concept Maps

Concept Maps provide a visual representation of knowledge structures and argument forms. They provide a complimentary alternative to natural language as a means of communicating knowledge (Gaines and Shaw, 1995).

Concept Maps are diagrams that help students see how words or concepts are related to one another. In most cases, Concept Maps begin with a brainstorming session in which students are encouraged to make associations with the main topic or concept presented. Students are actively engaged in using their prior knowledge, as well as new concepts and experiences that have been provided, to develop Concept Maps, both individually, or in small groups.

Novak and Gowin develop the concept mapping technique (Novak and Gowin, 1984). This work was based on Ausubel's ideas that stressed the importance of prior knowledge in learning new concepts (Ausubel, 1963). Novak and Gowin add that meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures (Novak and Gowin, 1984).

Concept Maps have been widely applied for education in evaluating students learning (Gaines and Shaw, 1995). Figure 2 presents one example of such Concept Maps from (Novak and Gowin, 1984). Because Concept Maps have any number of concepts they often require a network representation.

A further example of Concept Maps is proposed by Toulmin who developed a theory of scientific argument based on them (Toulmin, 1958).

As defended by Kommers and Lanzing, concept mapping is a method to regulate the ratios between fragmentation/coherence and cognitive overhead/flexibility during the student's browsing of hypermedia documents (Kommers and Lanzing, 1997). The same authors add that Concept Maps can be used as:

- *a Design method* to be used as a structural scaffolding technique for the development of hypermedia;
- a Navigation device for students who need orientation while they explore information domains such as hypermedia documents;
- *a Knowledge elicitation technique* to be used by students as they try to articulate and synthesise their actual states of knowledge in the various stages of the learning process;
- *a Knowledge assessment* tool to enable students to diagnose their own level of understanding and to detect misconceptions.

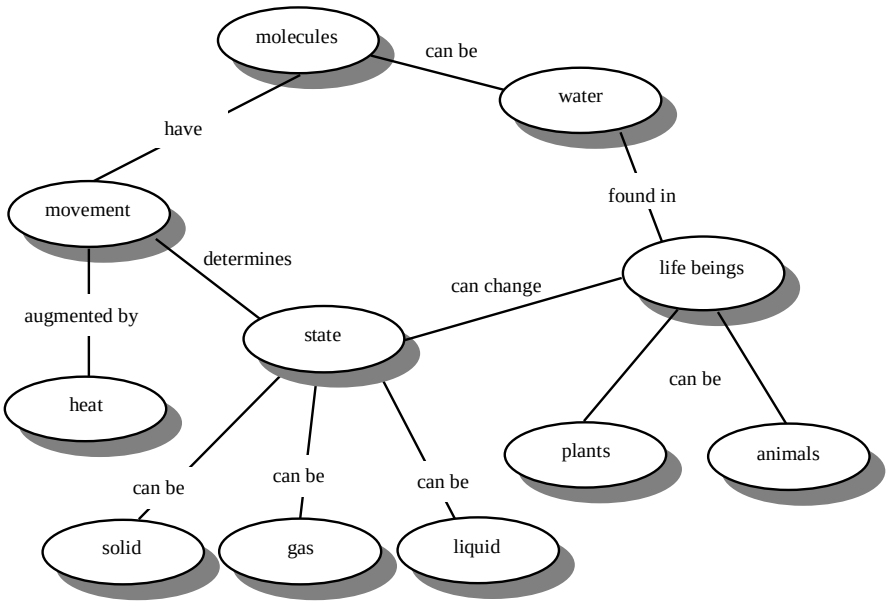

Figure 2: a Concept Map example from (Novak and Gowin, 1984)

Concept definition mapping

The strategy, proposed for developing student vocabulary, provides an illustration – mapping – of the attributes of key concepts (Schwartz, 1988). Students are asked to think beyond the essentials of what a word is and what it is not. The use of the Concept Definition Mapping promotes the analysis of a word from multiple perspectives. This strategy is aimed to foster students' understanding of semantic relationships between words while aiding in their recall. Figure 3 presents an example of a Concept Definition Mapping.

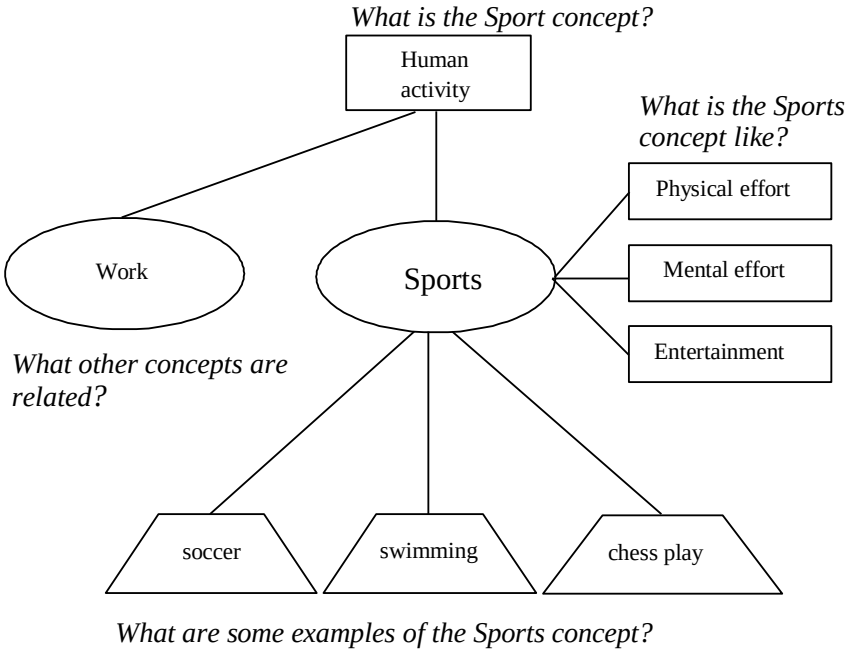

Figure 3: a Concept Definition Mapping example

To use this technique the following steps should be followed:

1. Propose an initial Concept Definition Map;
2. Discuss the questions that the Concept Definition Map should answer: What is it? What is it like? What concepts are related? What are some examples of it? What are its essential characteristics? What makes it different?;

3. Use additional familiar vocabulary terms to complete the Concept Definition Map;
4. When the map is finished, ask for a complete definition of the concept;
5. Allow for continuous map improvements along with the learning process related to the concept.

Semantic Maps

Semantic Maps are a strategy for graphically representing concepts. Semantic Maps portray the schematic relations that compose a concept. It assumes that there are multiple relations between a concept and the knowledge that is associated with the concept. Thus, for any concept there are at least these types of associations:

1. class: the order of things (selection) the concept falls into;
2. property: the attributes that define the concept;
3. example: exemplars of the concept.

Semantic Maps are used also to identify techniques that describe a variety of strategies designed to show how key words or concepts are related to one another through graphic representations (McAleese, 1998). These techniques are also known as idea mapping or word webbing. Mapping can be used for teaching vocabulary, for textual patterns of organisation, for improving note taking and for creative thinking skills. For teaching vocabulary, learners are asked to create their own unique semantic networks of association with a given text. Figure 4 shows an example of the use of Semantic Maps, given by (Zaid, 1995).

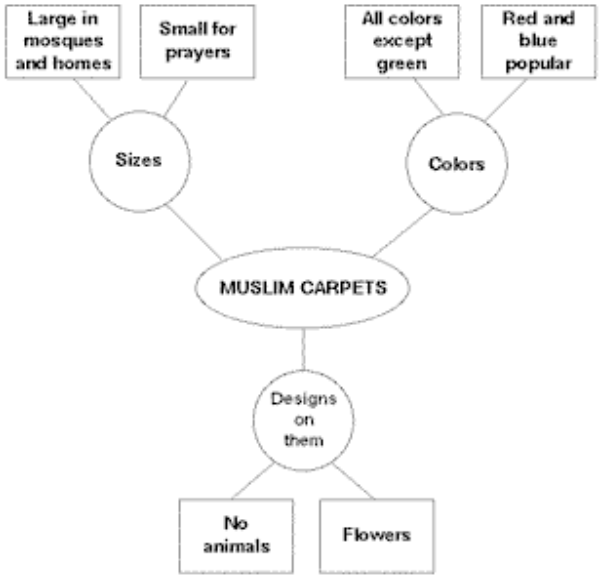

Figure 4: example of a Semantic Map about Muslim Carpets (Zaid, 1995)

A general procedure to develop a Semantic Map is by having a group discussion. In a situation like this, it is almost inevitable that the three types of concept associations – class, property and example – will emerge.

The major purpose of a Semantic Map is to enable students to organise their prior knowledge into formal relations and thus provide themselves with a basis for understanding what they are about to read and study. Comprehension can be thought of as the elaboration and refinement of prior knowledge. Semantic Maps provide a graphic structure of knowledge to be used as the basis for organising new ideas as they are understood (McAleese, 1998).

Within the Artificial Intelligence field, a similar Semantic Map representation is known as Semantic Networks. A Semantic Network focuses on the graphical representation of relations between elements in a domain. It is a non formal knowledge representation (Findler, 1979).

Hanf was among the first to propose the development of a Semantic Map procedure designed to improve the teaching of study skills (Hanf, 1971). However, the notion of Semantic Maps is older and based on Ausubel who claimed that background information was a necessary prerequisite to the addition of new concepts and vocabulary (Ausubel, 1963).

Ausubel asserts that when individuals are presented with new concepts, these concepts will not be explicitly understood until they are linked in a meaningful way to pre-existing concepts (Ausubel, 1963). Similarly, reading theorists have likened the process of reading comprehension to relate the new and the unknown (Pearson and Johnson, 1978).

Gathering the several uses of Semantic Maps it is possible to consider them as:

- *a technique for increasing vocabulary and improving reading comprehension;*
- *a means of improving the teaching of study skills;*
- *a framework for identifying the structural organization of texts;*
- *a means of teaching critical thinking skills;*
- *an assessment technique;*
- *a computational scheme to support reasoning in intelligent systems.*

During the process of developing Semantic Maps, it is possible to identify what is in and what is outside of students level of awareness with regard to core ideas and supporting details (Fleener and Marek, 1992). This can provide diagnostic information, which can help lead a group in an appropriate direction. The final phase of Semantic Maps development comes when students are asked to recall the details of a text and to discuss and graph new information onto their pre-existing maps.

Fleener and Marek assert that Semantic Maps are useful for evaluating students' increase in understanding throughout the learning cycle. They go on to state that the identification of misunderstandings early on allows teachers to redirect students misconceptions. As an assessment tool, Semantic Maps revealing beyond students' perceptions also allow to relate misunderstandings of core ideas, concerning the three phases of the learning cycle – exploration, conceptual invention, and expansion – (Fleener and Marek, 1992).

Semantic mapping for concept formation

Semantic Maps are also used as visual tools to encourage readers to access their prior knowledge regarding concepts, to examine and understand components of new concepts, and to relate them to previous knowledge, for concept formation. A method for using Semantic Mapping for Concept Formation might be as follows:

1. write the subject or concept in the middle of a chart;
2. students brainstorm and record a list of related words – the bigger this list is, the better;
3. group the words into categories in the form of a web or map;
4. explain the reasoning behind word groupings to the group of students.

Figure 5 presents an example of a Concept Mapping for Concept Formation. The group discussion is critical to building understanding and provides a solid foundation for the reading that will follow.

Every individual has a chance to compare with others its notions while gathering further background knowledge. Discussion is also valuable as an opportunity to fill in knowledge gaps or to attempt to eliminate misconceptions about the topic.

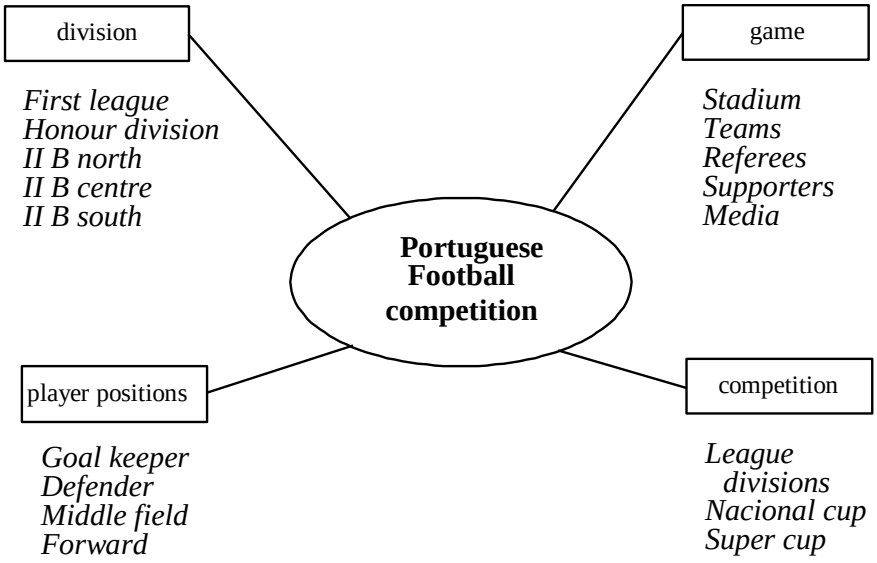

Figure 5: Semantic Mapping for Concept Formation example

Knowledge Maps

A Knowledge Map can be defined as a visual representation of a knowledge domain according to criteria that facilitate the location, comprehension or development of knowledge. Knowledge mapping is a systematic approach to improve the understanding of knowledge through visualisation. This may include the previous types of maps already introduced.

A Knowledge Map represents concepts and their relationships (such as a hierarchy, a taxonomy or a network). It is a navigational aid that enables a user to position him/herself on the desired concept and follow links to relevant knowledge sources. It models explicit information about peoples' processes, and their information objects, and the relationships between them.

Hall defines Knowledge Maps as a method of displaying text in a two dimensional, spatial, node link network. The same author states that one of the basic assumptions of the model is that structural properties of the map format activate spatial processing channels which during subsequent retrieval, the structural information stored within spatial schemas can act to cross reference detailed information during recall (Hall, 1996).

Hall shows that Knowledge Maps can be an effective tool for enhancing acquisition of text materials relative to a more traditional format (like text) and concludes by saying that objective cognitive outcomes are mirrored in student subjective rating of concentration and motivation, showing that affective outcomes could also be considered (Hall, 1996).

Kesik proposes Knowledge Mapping as a process rather than a content. He adds that science is knowledge, and that science extends in a knowledge landscape like land in a geographic landscape. The same author asserts that order is funded in patterns, patterns in similarity, similarity in likeness, and likeness by comparing perspective; if these do not fit in to our patterns we seek to explain, to understand, and to know why not or why for (Kesik, 1996).

Kesik defends that maps can be considered both descriptive tools and prescriptive guides which may be referred to as a tool-guide function. A Knowledge Map is a representation of what we know of science. It provides a recording of the patterns that have been recognised and in turn situates these patterns as elements to expand patterns. As maps can serve both as a descriptive tool and a prescriptive guide, they are unique resources to help to know what to know when we do not know what to know (Kesik, 1996).

Topic Maps

Topic Maps and Knowledge Maps are related, but not equivalent, concepts. A Topic Map is a particular type of Knowledge Map, one that describes a semantic network of relationships between concepts. Topic Maps are an ISO standard for describing knowledge structures. Topic Maps allow us to (Logan, 2000):

- *represent* objects and provide a way of navigating them;
- *enable* the structuring of unstructured information;
- *deploy* information sets in different environments with different requirements.

Topic Maps enable users to capture knowledge about information resources: what is in them, where they are and how to reach them. The Topic Map paradigm is a technology that can be used to improve access to information. According to the Gartner Group, Topic Maps will be an adopted technology for the use of portal and search engines (Logan, 2000).

The international standard for Topic Maps (ISO/IEC, 1999) defines Topic Map syntax. It allows the creation of a model for an area of knowledge. The model takes the form of an XML document-type definition. A Topic Map works by layering associated information over an information set. It is a knowledge representation paradigm that allows knowledge structures to be modelled and then linked to information sources.

The strength of Topic Maps is that they allow indexing and data modelling information to be maintained separately from the information that is indexed or modelled (Logan, 2000). Every user can therefore have a particular Topic Map representing a view into the data (Pepper, 1999).

Topics have a flexible definition: they can be anything that the user is interested in and their subject is what they are about. Topics also have names, which identify them for their users. Names are declared, much like data values for variables. Topics become the constituent parts of Topic Maps. They can be thought of as multidirectional links, pointing to all of their occurrences. The idea is that the link will aggregate everything about a given subject. Topics and their links are networks of meanings defined by the user (Biezunski, 1999).

Topic Maps are groups of named information objects around topics and the relationships between them. These relationships are called associations. The topics and their associations form networks when they are parsed. The links between the nodes of the network can be traversed to find related information and used to create networks of knowledge and information (Biezunski, 1999).

Topic Maps are not constrained by a particular structure. They may be object-oriented, hierarchical, ordered or unordered. Any number of Topic Maps can be designed to work with the same set of information resources, stored in any structured or unstructured format. Among potential uses of Topic Maps are: online navigational aids, virtual documents, filtering information for specific users and uses, and information structure support.

Maps extensions and related 3d visualisations

A number of systems use some kind of Knowledge Map to support knowledge sharing and collaborative learning activities. Among these are:

- Kmap, a general Concept Mapping tool that supports collaborative learning through the World Wide Web (Gaines and Shaw, 1995);
- KSE (Knowledge Sharing Environment) which is a system of information agents for organising, summarising and sharing knowledge from a number of sources. In KSE, users are organised into user groups or communities of interest (Davies et al., 1998);
- Semio solution – a software technology for information categorisation and retrieval. It is based on constructing and developing a taxonomy based on lexical tools (Semio, 2001);
- TheBrain – a non-hierarchical knowledge management software producing a 3D visual map. The software maintains relationships between issues in a dynamic manner, and URLs associated with a particular issue is displayed in a web-browser when the issue is made as the focus of attention. (TheBrain, 2001);
- MindManager – an implementation of Mind Maps that allow the collaborative development of thoughts and ideas (MindManager, 2001);
- WordNet – an on-line lexical database developed on the basis of contemporary psycholinguistic theories of human lexical memory (WordNet, 2001);
- ThinkMap – a browser for exploring WordNet based thesaurus, using a Java-enabled spatial map, the Visual Thesaurus (ThinkMap, 2001);
- Storyspace – a tool designed for hypertext writers. Provides maps and views to help writers create, organise, and revise (Storyspace, 2001).

Final remarks

Visualisation offers a lot of potential for representing the structure of knowledge for sharing and integration with "real world" data. This paper introduces several strategies to represent and share knowledge and provides an attempt to classify different and alternative representations for such visuals normally designed as semantic maps. The paper also proposes that although those representation provide similar results, they use different strategies for their development and for that, they serve diverse goals and each one has its own application space.

As a result, further research is needed not for providing a unique and definitive technique, but to integrate those different representations by proving graphical translations among them in order to provide a more humane representation for information and propose knowledge as composite concepts and represent it as semantic maps for sharing use.

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