A New Dimension of Knowledge Visualization for Reconstructing Thinking Process

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Abstract:

Knowledge visualization (KV) is an emerging field, which is firstly disciplinary proposed by Eppler in 2004. The main concern of KV research is not the mere convey of facts, but the transfer of people's insights, experiences, attitudes, values, expectations, perspectives, opinions and predictions, and enables someone else to re-construct, remember and apply these insights correctly. In the collaborative problem-solving process, to achieve smooth and efficient communication among the participants, knowing how others arrive at the conclusion is even more important than the conclusion itself. Several related KV methods of helping express people's thinking are introduced in this paper, and based on the discussion of these methods' limitations, a TPO (Thinking Process Organization) framework for reconstructing people's thinking process is proposed from a new dimension.

1 Introduction:

Working cooperatively with the support of computer techniques over the Internet to achieve some goal has turned out to be a ubiquitous trend, e.g., remote medical consultation, online product co-design, online book co-authoring. A majority of such collaborative processes need professional communication among the participators, thus a main concern of those processes is effectively facilitating the sharing of participators' insights, experiences, attitudes, expectations, perspectives, opinions, predictions, etc, so that they could reach the same understanding. People commonly express their minds in words in the form of text in order to sharing it with others, however, to different knowledge possessors, the same knowledge can be relatively easily articulated by some ones but difficult to express by some others; moreover, many of the knowledge senders usually don't spend much time in content organizing while writing, which often results in the lack of logic. On the other hand, to the knowledge recipients, plain textual material conveying complex ideas is frequently incomprehensible.

Paivio's Dual Coding Theory (DCT) has a basilic Principle: Recall/recognition is enhanced by presenting information in both visual (e.g. imagery) and verbal (e.g. language) form [1]. Research on visual imagery [2, 3] suggests that visual recall seems to be better than verbal recall. It is not clear how images are stored and recalled, but it is clear that humans have a natural ability to use images. Instructional psychology and media didactics investigate the learning outcomes of text-alone versus text-picture: [4] present different results in knowledge acquisition from text and pictures. A plenty of research work shows that people have the innate abilities to effectively process visual representations.

Despite a number of research contributions had revealed the potential value of using visual representations on knowledge management (KM), until the recent interest in KM on business community [5,6] brought attention to the effective portrayal and sharing of knowledge, the issue of knowledge visualization is really concerned. Knowledge Visualization (KV) as a relatively new subject is firstly disciplinary proposed by Eppler [7], based on Eppler's definition, knowledge visualization examines the use of visual representations to improve the creation and transfer of knowledge between at least two people.

Knowledge can be viewed, from the state of mind perspective, as the state of knowing and understanding [8]; therefore, different from information visualization and data visualization, knowledge visualization investigates human-human interaction rather than human-computer interaction, the role of IT is to provide access to sources of knowledge rather than knowledge itself. According to this standpoint, in this paper, the authors first give a short introduction to some existing KV tools, namely mind maps, cognitive maps and thinking maps.The limitations of these methods are discussed subsequently. Based on the discussion, the authors suggest a new research dimension called Thinking Process Organization (TPO) under the umbrella of KV, envisioning its primary framework to help bridge the knowledge recipients and senders by the way of organizing and structuring knowledge senders' thinking processes.

2 Some Existing Knowledge Visualization Methods: A Brief Survey

Eppler summarizes knowledge visualization methods into six types, namely heuristic sketches, conceptual diagrams, visual metaphors, knowledge animations, knowledge maps and scientific charts [7]. Although the existing KV methods so far have not been classified according to types of knowledge [8], each method still has its own specific application context and function on some kind of knowledge with certain characteristics. For example, Visual Metaphor [9] represents a new system by means of visual attributes corresponding to a different system which is familiar to the user and behaves in a similar way; and Knowledge Map [10] tangibly represents concepts and relationships of expertise in catalog which enables the users to find their desired concepts, and then retrieve relevant knowledge sources. In the remainder of this section, three useful KV methods used in different fields for support the communication by helping people express their thinking are briefly introduced.

2.1 Mind Map

Mind maps have been used for centuries, for learning, brainstorming, memory, visual thinking, and problem solving by educators, engineers, psychologists and people in general. A mind map is a diagram used to represent words, ideas, tasks or other items linked to and arranged radially around a central key word or idea. Figure1 shows an example of mind map.

Figure 1 A student's summary of the Cosmological Argument in mind map form [11].

The foundation structures for Mind maps are suggested by Tony Buzan as follows [12],

1 Start in the center with an image of the topic, using at least 3 colors.

2 Use images, symbols, codes, and dimensions throughout your Mind Map.

3 Select key words and print using upper or lower case letters.

4 Each word/image must be alone and sitting on its own line.

5The lines must be connected, starting from the central image. The central lines are thicker, organic and flowing, becoming thinner as they radiate out from the centre.

6 Make the lines the same length as the word/image.

7 Use colors – your own code – throughout the Mind Map.

8 Develop your own personal style of Mind Mapping.

9 Use emphasis and show associations in your Mind Map.

10 Keep the Mind Map clear by using radial hierarchy, numerical order or outlines to embrace your branches.

2.2 Cognitive map

The term “cognitive map” is originally coined by the psychologist Edward Tolman [13] to indicate the mental representation of routes and paths through the environment used by people and rats. To Tolman a cognitive map was a geographical map in the mind. From the late 1970s, Eden began to use the term “cognitive map” in a quite different sense in OR to describe the task of mapping a person’s thinking about a problem or issue [14].A cognitive map is the representation of thinking about a problem that follows from the process of mapping. The maps are a network of nodes and arrows as links, where the direction of the arrow implies believed causality. Cognitive maps are usually derived through interviews, and so they are intended to represent the subjective world of the interviewee. Figure 2 gives an example of cognitive map.

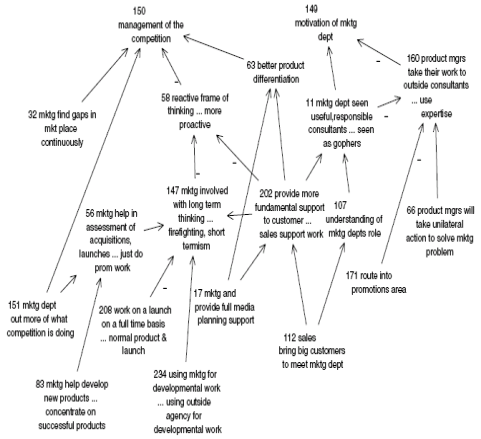

Figure 2 Part of a cognitive map [14]

2.3 Thinking Maps

Thinking Maps is a language for learning created by Dr. David Hyerle[15] founded on Upton Model[16] in 1988. It has been proved to be effective in improving teaching quality by helping teachers and students represent what they are thinking. There are eight Thinking Maps, based on fundamental cognitive skills: circle, bubble, flow, brace, tree, double bubble, multi-flow, and bridge.

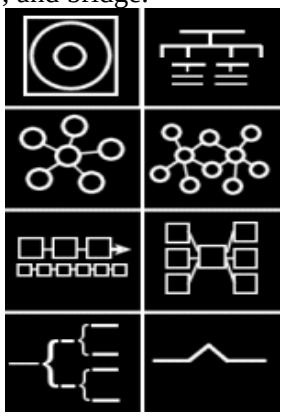

Figure3 Eight Thinking Maps [15]

- These maps are used for representing the thinking processes:
- The Circle Map is used for defining context (e.g. a thing or an idea)
- The Bubble Map is designed for the process of describing attributes.
- The Flow Map is based on the use of flowcharts. It is used by students for showing sequences, order, timelines, cycles, actions, steps, and directions.
- The Brace Map is used for identifying the part-whole, physical relationships of an object.
- The Double Bubble Map is used for comparing and contrasting two things;
- The Tree Map enables students to do both inductive and deductive classification.
- The Multi-Flow Map is a tool for seeking causes of events and the effects.
- The Bridge Map provides a visual pathway for creating and interpreting analogies (the process of identifying similarities between relationships).

2.4 Limitations of existing methods

(1) Tracking Complex Thinking Process
The previously-discussed methods provide useful tools to visualize how people think. As for Cognitive Maps, its formal basis derives from personal construct theory [17] and the means/ends analysis is the most often used

method in the mapping process [18]. Thus cognitive maps of problem situations are usually large and interlaced network containing more than one "head" (goal node). Tracking people's thinking process through the complicated mapping network to obtain the point needs some professional skills. Actually, the real thinking process of human is very complex. Human's thinking is not straightforward linear process, especially for the solving of complex problems. Towards the collaborative problem-solving issues, visualizing the participators' complete thinking processes often involves much redundant information which likely negatively influences recipients' understanding.

(2) Lack of the macro-level organizational structure

Thinking Maps provides rich cognitive model for people to express their thinking. It looks powerful, but we can still feel something is lacking. The relatively basic cognitive models enable Thinking Maps' advantages in portraying objective things/world. Although it is successful in aiding elementary/junior high school teaching and learning, due to the lack of macro-organizational structure, it seems powerless in express complex ideas.

(3) No prominent focus

Compared with Cognitive Maps, the form of Mind Map appears to be much more flexible and casual: there is no restriction for the center image choosing; the mapping lines go as far as the thinking goes. However, for the collaborative problem-soling or decision-making problems, seeking the unsorted nodes on the radial hierarchical graphic helps little with catching the main idea.

3 Primary considerations on TPO framework

3.1 Primary considerations

We propose TPO for the sake of facilitating structured knowledge transfer and communications. The argument is that the real process of human thinking is essentially connectionist and to some extent even messy. The direct mapping of the real thinking process, thus, does not surely facilitate communications and knowledge sharing. Instead, a means to systematically re-construct the thinking process is needed to help the recipients get the sender's entire logical thinking structure.

The TPO framework has a two-layer logical structure: fundamental thinking patterns layer, and macro-organizational layer. People's cognitive patterns will be investigated from the perspective of cognitive psychology, and the basic thinking patterns will be collected out as the construction units of TPO. We believe that when those thinking patterns are organized in some forms, the efficiency that people reconstruct the thinking process can be substantially enhanced. In TPO, a pyramid structure is used to structure the basic units on the macro-organizational layer.

3.2 Foundation structures and rules of TPO framework

The structure characteristics of TPO are briefly depicted as follows:

1 Primitive constructs: nodes and directed edges. Nodes can be words, paragraphs, even documents or images, etc; directed edges indicate some relation.

2 Each diagram must has a start node which must be the ultimate conclusion (prediction/ opinion/ expectation, etc)

3 Nodes and directed edges are linked into a hierarchical pyramid network.

4 A node can have one or more in-arrows from its sub-nodes and at most one out-arrow to its super-node (the start node can only have in-arrows connected with it).

5 Nodes which have out-arrow to the same super-node form a "group"; the order of the nodes in same group is constrained by some cognitive logic.

6 Different cognitive logics are indicated by different colors, thus nodes in same group must have the same color frame. Fill the corresponding color in the frame if the nodes need to be stressed.

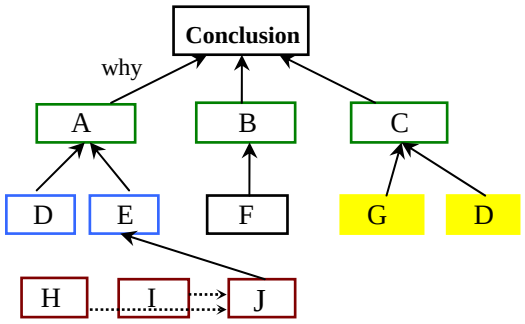

Figure 4 Foundation structures of TPO framework

A simplified TPO diagram (Figure 4) is drawn to illustrate the foundation structures of TPO framework. As we can see, the conclusion is supported by A, B and C; node F has no in-arrows, so F is taken for the "fact" or some conclusion that is generally accepted; that there are two same D in this diagram exemplifies why one node can at most have one out-arrow to its super-node: the logical order is D→E in D, E group, but in G, D group the logical order is G→D; node G and D are colored yellow to highlight what we want to emphasize; H, I, J group gives an example of deductive logic: (H: major premise, I: minor premise, J: conclusion).

It can be seen from the TPO diagram that recipients could seize the crucial "conclusion" part (the start node) in no time. And then, led by the organized hierarchical diagram, recipients would easily obtain the overall ideas of senders, which may inspire the reconstructing of senders' thinking processes.

4 Conclusion

This paper has introduced a variety of methods of KV, and further discusses their limitations. Based on the analysis, the TPO framework is proposed from the dimension of "thinking process organization". By analyzing and comparing, the author considered that TPO has advantages in facilitating knowledge transfer in collaborative problem-solving process.

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