COLLABORATIVE CONCEPT MAPPING AT THE TABLETOP

TECHNICAL REPORT 657

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JULY, 2010
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ABSTRACT
Concept mapping is a technique where users externalise their conceptual and propositional knowledge of a domain in a way that can be readily understood by others. It is widely used in education, so that a learner’s understanding is made available to their peers and to teachers. There is considerable potential educational benefit in collaborative concept mapping, and the tabletop is an ideal platform for this. This paper describes Cmate, a tabletop collaborative concept mapping system. We describe its design process and how this draws upon both the principles of concept mapping and on those for creating educational applications on tabletops.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. - Graphical user interfaces, Input devices and strategies, Interaction styles, Screen design.

General terms: Design, Human Factors

Keywords: Information interfaces and presentation, Interaction styles.

INTRODUCTION
Concept mapping is an important educational technique that provides an excellent means for a learner to externalise knowledge of a particular domain and to get meaningful understanding of new information [1]. Moreover, concept maps are metacognitive tools that foster the development of strategies for organising knowledge, and facilitating communication of understanding [2]. They basically include: the concepts of the domain; propositions, indicated by a labelled line linking two concepts; and use of layout, with the most general concepts at the top, more specialised ones lower and similar concepts at the same level and close to each other. Propositions are the key elements of concept maps because each one shows the learner's conception of the relationship between a pair of concepts [3]. An example is shown in Figure 1, where the most general concept is Plants and this is in three propositions, Plants have Roots, Plants have Leaves, Plants have Stems, and the concepts Roots, Leaves and Stems are less general than Plants and at a similar generality level to each other. Strong results indicate that concept mapping, used as a tool for guiding education combined with cooperative learning, helps students to integrate new information with previous theoretical knowledge [4] and to make tacit and private knowledge public [2]. Novak’s research also indicates that building concept maps in a collaborative environment leads to greater learning and superior maps. Multi-touch tabletops appear to have the potential to encourage collaboration, affording fluid interaction and improved access to information [5], important characteristics in educational contexts.

We are exploring learner support for building concept maps on a tabletop. Concept mapping is a cognitively demanding task. This means that one valuable approach for making use of the tabletop for concept mapping involves two stages. In the first stage, students use an existing, validated desktop concept-mapping tool to construct individual maps. The learner would then come to the table to discuss these, identifying the similarities as well as the differences. This might mean that one person changes their mind, altering their own map. At other times, the learners may not be able to agree. For example, in a biology task, one student’s map may have the proposition “a whale is a mammal” while another student may have the proposition “a whale is a fish”. One might convince the other to change, or they may agree to disagree. We aim to create a tabletop interface that can support this process.

We present Cmate (Concept Mapping at an Adaptive Tabletop for Education), an interface designed to support learners in a form of discussion based on comparing personal understanding as captured in personal concept maps. Our design and its evaluation draws on principles of concept mapping, rethinking the usual interfaces to address the limitations and affordances of tabletops, to design an interface that should allow the users to focus...
Our system, Cmate, aims to afford a new form of learning environment that helps learners and their teachers gain a clearer understanding of the learner's knowledge and misconceptions. The foundation of our approach is to support learners in discussion about their individual concept maps, to identify areas of consensus and disagreement. We support this by maintaining each individual's map as well as the collaboratively created group map.

We illustrate the key features of the project in a scenario: let us have two learners, A and B. They are requested to build personal concept maps about a topic using its personal ontology about a particular topic. These initial concept maps can well be constructed using pencil and paper or applications such as VCM [12] and CmapTools, that export the concept maps using flat files or CXL (Concept Mapping Extensible Language) format. The next step is to enrich the concept mapping building process through collaborative actions performed at a tabletop; in this point is when Cmate enters the scene. The individual concept maps A and B are preloaded into Cmate. When the interface is first launched two *rosizable* user menu copies, two *black holes* to delete components [14] and a concentric blank work area is presented to the users. A *user menu* has two kinds of buttons: *colored buttons* and correspondent *labeled buttons*. Colored buttons are for drawing and are related with a particular user layer (see Figure 2, yellow and orange) and there is one that is related with the group layer (red button). Now learner A decides to add a concept that he used during the individual construction phase; he can perform this action by picking its color and then drawing a circular gesture, similar to a number 6, on the screen. After the gesture is recognized, a personalized *rosizable* list of concepts appears. Then, Learner A selects a concept. In this way both users could add its personal concepts and linking words by drawing a line between two different concepts. In this way, both learners can add concepts and linking words in the same interface but in three different layers: one for each user, and an additional for the concepts and propositions in which both users are agree. Finally, Learner A selects the *labeled button* (with the title *Learner 1* in figure 3) from the *user menu* to highlight the links and propositions he added. The correspondences between both concept maps are indicated in red lines. Then Learner A picks the button with the label *all* to see the general layer for having a broad idea of the whole topic. As a result, learners A and B merge their concept maps unifying the similarities between them but presenting in different layers the differences.

Our approach at this first stage is to enable small groups of learners to externalise their knowledge, reflect on the similarities and differences with other learners’ propositions and solve the conflicts in a manner that could lead them to better learning outcomes. Through this strategy we also leave freedom in the selection of concept and linking phrases maintaining the concept mapping *Novakian style* that gives this tool its usefulness in education settings and gives Cmate a balance between flexibility and formalism [15].
IMPLEMENTATION

Cmate has been written in Python and OpenGL using PyMT, an open source library for developing multi-touch applications which offers a wide spectrum of tools such as gesture recognisers, layouts, sliders and containers. The application is hardware independent but has been tested in multitouch tabletops. Implementing applications based on these libraries allows users to manipulate unlimited number of widgets in parallel on the same tabletop interface.

The design of our tool is firstly oriented by the following concept mapping guidelines: 1) concept maps have a hierarchical structure and the root concept represents the topic of the map; 2) concepts and linking phrases are as short as possible, 3) a concept map is a representation of individual understanding of a topic [15].

We now describe the features of the system in detail, explaining its structure in terms of underlying software and the way in which it is used. Scott et.al. [8] suggest guidelines to build a tabletop system that encourages collocated collaborative work. We addressed some of this guidelines, and adapted the heuristics given by Nielsen [6] and Apted et.al. [7] to design and implement our interface. We also describe below the features that are related with each guideline:

• **Consideration for arrangement of users** [8]. Users using Cmate are able to view and interact with the table at any position. Cmate is not a non-oriented interface because of the nature of concept mapping itself. But a new paradigm for hierarchical structure was implemented. We choose a concentric hierarchy in which the most centered concept is the best representative of the topic of the map. Also we added some circular lines as a reference for users to arrange the concepts that should share the same hierarchical level. Following the design guidelines given in [7, 8] every single component of the interface is presented in the best orientation given the adequate gesture to add a concept and all other components can be reoriented at once by touching the blank spaces of the screen or by manually rotating particular components.

• **Support simultaneous user actions** [8]. One of the main drawback in research made to discover the benefits of tabletops in collaborative work is that is not easy to find the equilibrium between the individual spaces allowed by concurrently multitouch tabletops, and the integration of collaborative activities in a shared way; this issue can be noticed in [10]. Cmate is natively supporting multitouch interactions given the adequate hardware, but offers a sort of personal space in form of a personal layer. Users are encouraged to take turns while adding personal concepts or connection links, but they could be working simultaneously while working in the general layer. Through this approach the group could decide between both focusing on explaining the subject of matter or to solve the agreements and conflicts between their ideas.

• **Support transitions between tabletop collaboration and external work** [8]. As described above in the scenario, our application allows using previously generated files as the source of the ontology of the group concept map. For now we avoided to use a keyboard, physical nor emulated, for maintaining the interface as simple as possible [6].

![Figure 3: Visualisation of 2 merged concept maps using Cmate. In this case, the concept map from Figure 1 is highlighted and enriched by the combination of a second concept map.](image-url)
tons and labels to be suitable to all kind of people. All menus in the application are surrounded by wide areas for rostizing them [14].

- **Manage interface clutter** [7]; we took the black hole idea from[14]. In this way we match the abstract idea with the real world to disappear concepts or propositions that fall in the metaphoric black hole. Also we use personalised gesture based lists to add new elements to the interface as required.

**EVALUATION**

We conducted qualitative usability inspections to analyse the system using a think aloud formative evaluation. We included four expert users in order to see how a user comprehends the different layer levels to represent concept maps using personal ontologies and, at the same time, building a common and accurate concept map.

As a result of the exercise we obtained valuable feedback pertinent to the usability of our system. The users were motivated and explored all the characteristics that the interface offers. They expressed that the interface helped them to merge their ideas in form of propositions and visualise their personal work in context of the collaborative work performed by the group. Users detected a heavy load of work by deleting components using the black hole; consequently, we have to extend the use of gestures for eliminating components, and even better, for all repetitive actions. Also, the presence of two user menu copies, a complex component, originated confusion about the functionality of the buttons for drawing personal concepts and linking words. Finally, we were suggested to provide feedback after pressing a button and improve the system to reorient the concept map elements and the entire concept map at once based on how real negotiation occurs in real life round table discussions.

**CONCLUSIONS**

We have constructed Cmate, a system for visualise multiple concept map representations and, at the same time, build a more accurate and precise shared concept map through active collaborative work and group agreement and disagreement resolution on the similarities and differences between the personal concept maps.

In the future, the application can use the Mimio Capture pen system or the DiamondTouch for implementing logging mechanisms of every action that is performed during the concept mapping process to support perform further educational research. The nature of concept mapping makes our application suitable for many learning fields such as, science, history, express opinions and personal experiences or even for learning a new language. Also we will devise specific heuristics for this user interface and consider the inclusion of more natural gestures for performing actions, add a keyboard input interface and tackle the observations obtained in the qualitative evaluation.

**REFERENCES**


