

Towards using concept mapping for math learning

Introduction

Concept mapping is a technique for visually representing the structure of information - how concepts within a domain are interrelated. It is based on theories of meaningful learning which stress that learning new knowledge is dependent on what is already known. More specifically, new knowledge gains meaning when it can be substantively related to a framework of existing knowledge rather than being "processed and filed" in isolation according to more or less arbitrary criteria. Concept mapping supports the visualization of such conceptual frameworks and is an example for "mind tools" that may support learning [1]. We have started an initiative to integrate the collaborative modelling framework Cool Modes [2] with the adaptive tutoring system ActiveMath [3] with the aim of using concept mapping techniques for mathematics learning.

Cool Modes is a collaborative tool framework designed to support discussions and cooperative modelling processes in various domains. This is achieved through a shared workspace environment with synchronized visual representations. These representations together with their underlying semantics can be defined externally by plug-in visual languages and interpretation patterns, so-called "reference frames" [4]. We implemented a number of these reference frames for mathematical concept mapping which bridge the gap to ActiveMath. ActiveMath is a web-based, interactive learning system for mathematics that employs technology for enhancing learning with instruction as well as constructivist elements and is based on a semantic representation of mathematical knowledge.

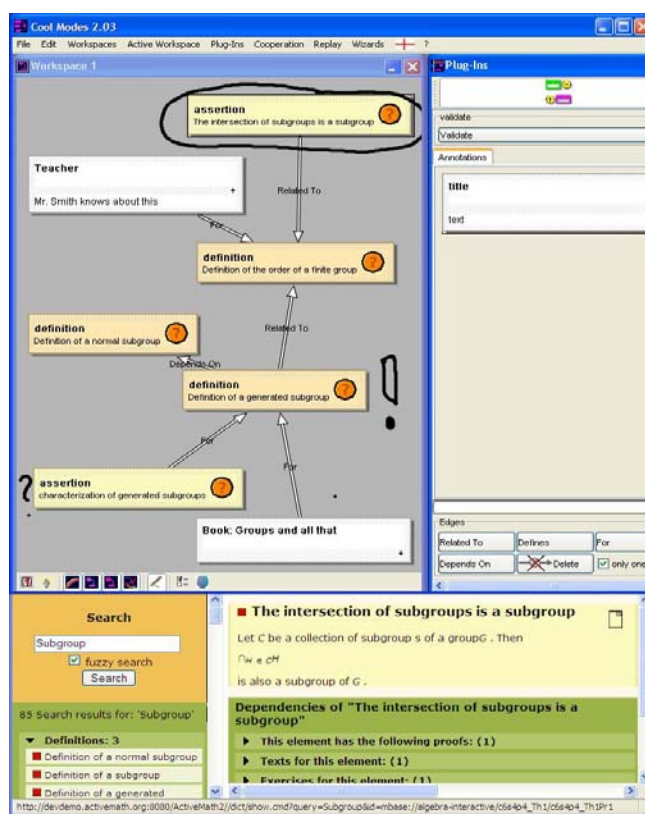


Figure 1: Screenshot

Usage scenarios

The integrated system is planned to be used in two different scenarios:

Concept Mapping Exercises: The learner is asked to create a concept map of his understanding of some part of mathematical knowledge, where some existing concepts and links can be provided as a starting point for the exercise (analogues to fill-in-blank text exercises). It will be possible to provide the learner with system feedback by matching the concept map with the underlying system knowledge representation.

Collaborative Concept Mapping: As Cool Modes has generic support for synchronous cooperation, learners will be able to discuss and integrate their individual concept maps of some mathematical topic into a single concept map that represents their joint understanding of the domain. The interesting part of this scenario is the coordination and negotiation of the different understandings of mathematical knowledge, which might be supported by the system.

System architecture

Cool Modes and its plug-ins are implemented in Java and can therefore be started on demand via Java WebStart from the ActiveMath web environment. Within the ActiveMath integration, Cool Modes offers three reference frames to the user: one for exercises, one for exercise authoring, and one for collaborative concept mapping. As visible in figure 1, the user interface consists of a workspace, where the concept map is edited, and a palette (one per reference frame), which provides the available objects and relations as well as controls for extra functionality, like validation of the map. An MBaseConnector class provides the interface to the semantic mathematical knowledge base MBase of ActiveMath, fetches the available items, like theorems and definitions, from the MBase and provides verification of the map.

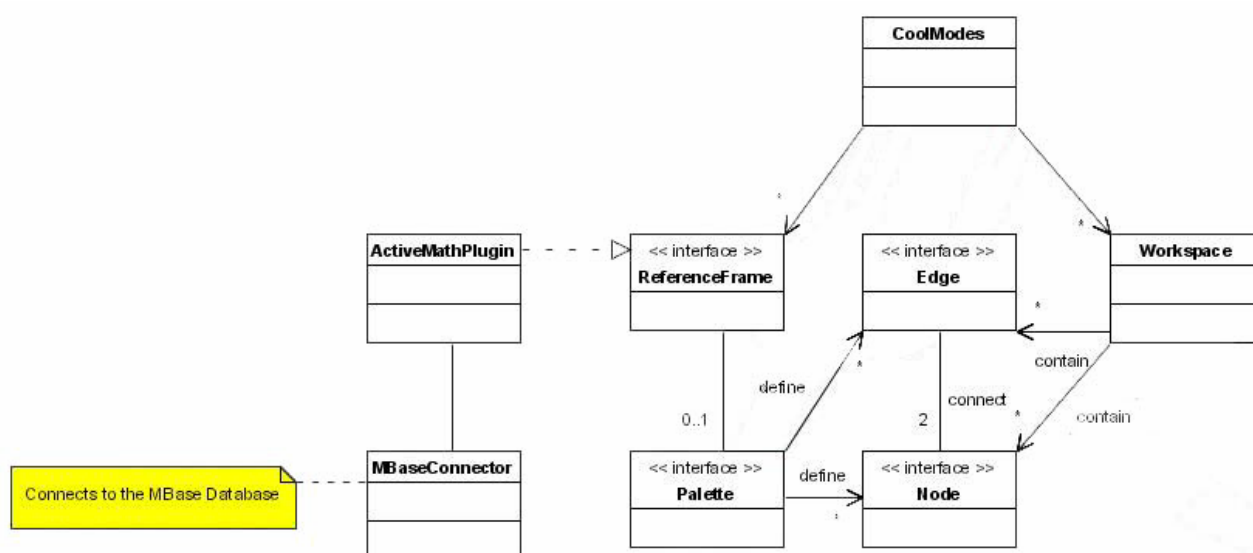


Figure 2: System architecture

First prototypes of the three reference frames have been implemented and tested on Workstations, Tablet PC's and interactive whiteboards. All mathematical items from the ActiveMath system, i.e. definitions, theorems, examples etc. can be used as nodes in the concept map by simply dragging them from the browser and dropping them into the workspace. Furthermore, annotation nodes are available where the learner can edit headline and body, for example to make annotations or refer to books etc. Handwriting nodes are also planned to facilitate interaction with Tablet PC's. Edges of the type "for", "related to" and "depends on" can be created between nodes. The concept map can be validated against the semantic knowledge representation with a preliminary simple mechanism: each edge between two mathematical items is checked against the database whether this relation exists there. If not, it is highlighted with a question mark.

Further work

We faced both technical and conceptual problems in implementing the prototypes. From the technical point of view, drag&drop support in different operating systems posed problems, as the rendering of the concepts in nodes (mathematical formulae), and the restriction that each concept should be available in a workspace only once. Other problems concerned system integration— however, most of these technical issues are solved. On the conceptual side, it seems still unclear exactly what kinds of nodes and edges are useful and needed by the learner, as well-known techniques like concept mapping are interlinked with entities from a particular domain, mathematics.

There are two main topics to investigate: Concept mapping exercises and computer supported collaborative concept mapping. For the exercises, the pedagogic usefulness of the proposed exercise types has to be evaluated, and for the collaborative use case, we would like to investigate in how far the computer with a semantic representation of the domain knowledge can support groups of learners in their concept mapping tasks. Tracking and analysis of interaction data, both from exercises and collaborative sessions, may provide valuable information for the user model of the tutoring system, but it is still unclear what information is useful for the user model and how it can be used.

References

- [1] Jonassen, D.H. (1992). What are cognitive tools?. In Kommers, P.A.M., Jonassen, D.H. & Mayes, J.T. (Hrsg.), *Cognitive tools for learning*. Berlin: Springer Verlag.
- [2] Pinkwart, P., Hoppe, H.U., Bollen, L. & Fuhlrott, E. (2002). Group-Oriented Modeling Tools with Heterogeneous Semantics. In Cerri et al (eds.): *Lecture Notes in Computer Science 2363, Intelligent Tutoring Systems*, pp. 21-30. Springer.
- [3] Melis, E. et al. (2001). ActiveMath: A Generic and Adaptive Web-Based Learning Environment, *Artificial Intelligence in Education*, vol 12, no 4, winter 2001.
- [4] Pinkwart, N. (2003). A Plug-In Architecture for Graph Based Collaborative Modeling Systems. In Hoppe, Verdejo & Kay (eds.): *Shaping the Future of Learning through Intelligent Technologies. Proceedings of the 11th Conference on Artificial Intelligence in Education*, pp. 535-536. Amsterdam, IOS Press.

Jörg Müller

ActiveMath Group
German Research Center for Artificial Intelligence
Saarbrücken, Germany
joerg.mueller@dfki.de

Martin Mühlenbrock

ActiveMath Group
German Research Center for Artificial Intelligence
Saarbrücken, Germany

Niels Pinkwart

Collide Research Group
Duisburg University, Germany