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Self-Organizing Maps and Constructive Learning

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Abstract

In this article, the use of the self-organizing map (SOM) is approached on the basis of current theories of learning. Possibilities of computer and networked platforms that aim at helping human learning are also inspected. It is shown how the SOM can be considered a model of constructive learning. The area of constructive learning is outlined and two cases of using the self-organizing map in computer supported learning environments are presented.

Keywords

Self-Organizing Map, SOM, constructive learning, cognitive models, memory models

Introduction

The phrase computer-aided learning earlier referred to systems that helped the users in memorizing "facts". Moreover, the cognitive models of learning have often been based on a plain computer metaphor in which learning is viewed as memorizing. In this article, we focus on the constructivistic point of view considering human problem-based learning: We also point out how the Self-Organizing Map [1] appears to provide a more realistic model of certain aspects of human learning than many alternative models. After the theoretical discussion we present how the self-organizing map could be used in computer supported co-operative learning environments.

Self-organizing map

The self-organizing map (SOM) [1] is a widely used artificial neural network model. In the SOM learning process is *unsupervised*: no a priori classifications for the input examples are needed. The learning process is based on similarity comparisons in a continuous space. The result is a system that associates similar inputs close to each other in the two-dimensional grid called the map. The input may be highly complex multidimensional numerical data. Recently, the SOM has also been used for the analysis and visualization of symbolic and text data [2,3].

Constructive approach

During the past two decades, a constructive approach to learning and knowledge has become dominant in educational psychology. Learning is viewed as an active, constructive process rather than a passive, reproductive process (e.g., [4]). Students are portrayed as intentional individuals who are primarily responsible for their own learning.

In order to become experts, it is necessary for students to construct qualitative models that are essential for a deep structural understanding of their own field [5]. These conceptions are based on domain-specific knowledge, but in addition to single facts, they consist of concepts, propositions and theories [6]. The structural organization of the domain-specific knowledge base essentially differentiates between novices and experts, and cognitive development requires the reorganization of domain-specific knowledge structures [7,8].

The novice/expert shift involves psychological resistance and a gradual restructuring of the novice's belief system [9]. Individuals construct certain entrenched beliefs that are based on their everyday experience and, depending on the domain, the knowledge acquisition process requires a revision of some of those beliefs and their replacement with a new explanatory structure. This process may be called *conceptual change* [10].

In current cognitive learning theory, three core conceptions may be identified [11]. The first concept, *constructivity,* is the idea that knowledge and cognitive strategies are constructed by the learner, and that learning involves qualitative restructuring and modification of schemata, rather than just the accumulation of new information in memory. The second concept, *active epistemology,* is closely related to constructivity, but refers specifically to beliefs about the learner's role in the learning process. *Mental representation* is the third core concept. In cognitive learning theory, performance on problem-solving tasks and students' explanations of such tasks are most often accounted for by the nature of their mental representations and also by their prior knowledge. Moreover, representations are highly situational [12] and knowledge is socially shared and constructed [13,14].

Modeling constructive learning

The epistemological theories of knowledge have traditionally been based on predicate logic and related methodologies and frameworks. The basic assumption is that the world consists of objects, events and relationships. The language and the conceptual structures and then supposed to reflect rather straightforwardly this ontological structure. Learning has been seen as a means to memorize the mapping from the epistemological domain (to put it simply: words) into the ontological domain (objects, events and relationships). This view has been dominant at least partly because of the consistent formalization of the theory through the use of symbolic logic. Moreover, the use of the von Neumann computer as the model or metaphor of human learning and memory has had similar effects and has strengthened the idea of the memory as a storage of separate compartments which are accessed processed separately and which are used in storing and retrieving information more or less as such. In the philosophical discourse, there have been several opposing views (e.g. [9]) but there have been little means to model or formalize these ideas before connectionist models.

In cognitive science constructivists have questioned the idea that the origin of knowledge is outside human beings. Instead, they find that knowledge is a human construction. The so-called "flat ontology" implies that one's view of reality emerges directly from sensory data, without the need for any intervening cognitive mechanism. However, the flat ontology appears to have no empirical support [5].

Self-organizing map can also be considered as a memory model. It is dynamic, associative and consists of elements that can also be called adaptive prototypes. Inputs are not stored as such but comparison is made between the input and the collection of prototypes. The closest prototype of the input is adapted towards the input. The same operation is also conducted for the neighboring prototypes, which gives rise to the topographical order on the map. Thus, the adaptation process in the self-organizing map algorithm is based on the principle that what already exists in the system also influences the learning result.

Considered superficially, one could claim that modeling learning phenomena through the use of the self-organizing map would be mentalistic. However, it is possible to construct a model in which a number of autonomous map-based agents interact in such a way that they perform social construction of knowledge and find intersubjective epistemological agreements [15].

The self-organizing map can be used in visualization of conceptually rich and complex phenomena. Through constructive theory it becomes apparent that there can be many and different interpretations and points of view towards an area of discussion. This kind of the subjectivity and intersubjectivity of interpretation may be visualized by using self-organizing maps [16].

Maps for learning environments

In the following two cases of using the self-organizing map in problem-based learning processes are considered. An example of building a map of conceptually rich area, namely that of cinematography, is presented. The process of inquiry learning process supported by the use of the self-organizing map is also considered.

Map of cinematographic concepts

The cultural and economical areas of cinematographic expression and the production of films have been conceptualized rather extensively. However, for a student of those areas, a problem may be that the relationships between the concepts may be difficult to realize. A map of 199 cinematographic concepts from the original idea into the final distributed film product was produced [17]. Analyzing this kind of maps may give relevant information about the filmmaking process: how the concepts actually link with each other.

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Figure 1. A map of cinematographic concepts based on input by a first year student.

A map based on first year film student's answers was also created (see Figure. 1). First, he was asked to draw a mind-map about the concept "film". Second, those 25 concepts were collected from the mind map. The student was asked to provide values according the method explained earlier in this article. The result gives a picture how the student has conceptualized the filmmaking process in his studies. A related web-based environment on filmmaking is accessible at the site http://www.mlab.uiah.fi/elokuvantaju/

Future Learning Environment

In problem-based inquiry learning process information is treated as something that needs to be explained. Instead of direct assimilation of the information students should construct knowledge through solving problems in communities [18,19]. By simulating culture and practices of expert communities, such as scientific research community or software/product development teams, the students may engage themselves in problem and explanation-driven inquiry. To guide the student's inquiry learning process the collaboration in form of dialogue can be carried out by using knowledge object*s* such as problems, hypotheses, theories, explanations or interpretations [19,20].

An example of an a practice in which one formulates a theory of teaching-and-learning that can be shared with the students in order to facilitate their efforts [21] is CSILE (Computer-supported Intentional Learning Environments; [22,23]).

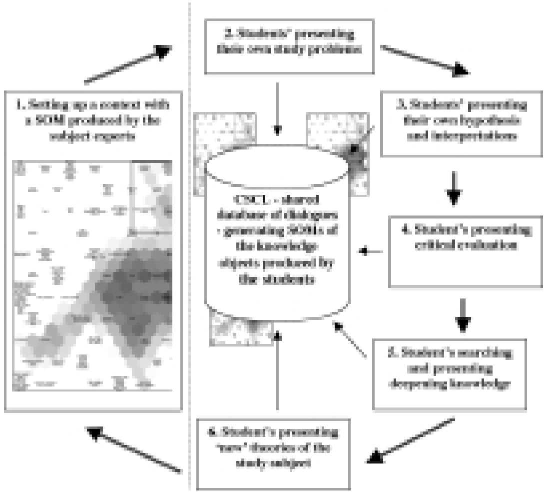

Figure 2. Elements of inquiry learning [19] and use of CSCL and SOM in the process

The recent Computer Supported Collaborative Learning (CSCL) tools such as FLE (Future Learning Environment, see http://www.mlab.uiah.fi/fle/) and Knowledge Forum, support collaborative building of knowledge and guided inquiry learning. With SOMs the use of the CSCL tools could potentially be made even more effective. In Figure 2, an inquiry learning process using CSCL-tools and SOMs is presented.

Teacher or supervisor may create the context by presenting the SOM of the area under consideration. The SOM of the context can be based on domain experts' interpretation of the conceptual relations in the field. The SOM of the context may present wider view to the study subject by presenting related subjects and concepts close to the main area interest.

Discussion

All aspects of inquiry learning process, i.e. setting up research problems, constructing one's own working theories, searching for new scientific information, can be shared with fellow students by using CSCL shared database. The knowledge-objects, for instance in form of notes, can be produced as a dialogue so that each note is commenting and linked to each another. The metadata of each note contains information indicating who is the author, what is the category of inquiry defined by the author, and on which note it is referring to. Different self-organizing maps (SOM) can be generated based on this metadata and the written information in the subject and body of the notes. The SOMs may indicate which direction students should continue so as to span the whole area under investigation. The students and the tutors may also compare the SOM generated by the experts and the SOMs constructed by the students during the inquiry learning process. Finally, the students' SOM constructed collaboratively can be included in the experts' SOM and this new SOM can then be used as a new context of the students' next course.

Future research with practical experiments will show how effective the use of the SOMs will be from the point of view of student learning. They provide promising possibilities for visualizing and making the conceptual change overt. What has already been shown is that the SOM constitutes a useful framework for modeling central concepts of constructive learning.

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