Razmišljanja

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Constructivist Learning Theory as a Link between Artificial Neural Networks and Intelligent Tutoring Systems

Konstruktivistična teorija učenja kot vez med umetnimi nevronskimi mrežami in inteligentnimi mentorskimi sistemi

V članku je predstavljena teoretična razprava o možnostih povezovanja umetnih nevronskih mrež in inteligentnih mentorskih sistemov v primeru uporabe konstruktivistične teorije učenja. Moja predpostavka je, da se povezava lahko vzpostavi prek študentskega modeliranja. Prvi vidik vzpostavite povezave je prek uporabe nevronskih mrež za simulacijo študentovih kognitivnih procesov, medtem ko je drugi prek uporabe nevronskih mrež študentskega razvrščanja.

1 Introduction

The object of my study is the application of artificial neural networks (ANN) in education, more precisely the use of ANN for implementation of intelligent tutoring systems (ITS). My ideas about exploring the possibility of linking ANN and ITS using constructivist learning theory are a result of the fact that constructivist learning theory is used as a basis for the organization of learning using ITS.

2 Constructivist Learning Theory

Constructivism is not a theory about teaching; it is an epistemological position (Boulton, 2002, p 3). In using constructivist learning theory, we are trying to explain how we gain our experiences of our environment by learning.

The main assumption of the constructivist learning theory is that learners actively construct their knowledge. We do not learn about our environment in an objective manner. Instead, we experience our environment, i.e. we interpret new knowledge using our previous experiences. By means of our previous experiences, we give meaning to new knowledge.

3 Constructivist Approach to Learning Using ITS

For a long period, the main activity in the classroom was teaching. This way of working with students is based on the objectivist view of the world. The main characteristic of the objectivist world view is that objects exist independent of subjects. Therefore students need to learn objective truths. Communication between student and teacher is mainly one-way, i.e. the teacher provides the student only with information that student needs to learn; the student is passive.

Although teachers still use that approach to the teaching, working with students is currently more often based on constructivist learning theory. Because students need to be active if they want to learn, emphasis has moved from teaching to learning. Communication between student and teacher becomes two-way process. The primary goal that teacher must achieve is motivating the student to think about a problem. When the student tries to solve the problem, questions about the problem will arise. The teacher must provide the student with information that student can understand and, as a result of understanding, use to solve the problem. This kind of work with student demands an individual approach, because communication between student and teacher must be adapted to student's previous experiences.

ITS is based on the idea of an individual approach to a student. An intelligent tutoring system is a computer program that uses the techniques of artificial intelligence to model an individual student's knowledge and to adapt the teaching process to the needs of that student (Oberem).

The constructivist approach to ITS based learning began to dominate in the mid-1980s. The difference between earlier approaches, i.e. behaviorism and information processing theory, and the constructivist approach is in the fact that the constructivist approach emphasizes understanding of the process with which students construct their knowledge. Hence, modeling the students' knowledge includes not only results of monitoring students' behavior, but also the results of inferences about student's cognitive abilities, motivation, interests etc. on the basis of student's behavior. Using results of such modeling, the system adapts presentation of knowledge to the individual student. Thereby, the system does not try to force a student to learn the lessons in some specific order. Instead of that, environments are used in which students can learn by exploration. The purpose of student modeling is to provide help to the student in his exploration of knowledge, because without guidance he can skip some important topics which form the basis of the domain. However, it is up to the student to choose acceptable path of gaining his knowledge.

The first constructivist oriented model of ITS was made by Wenger (Urban-Lurain, 1996). He sees ITS

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as knowledge communication tool. Although, components of his model of ITS were the same as components of earlier models of ITS, the difference was in the way he implemented those components. The components of ITS are: domain expertise, student model, pedagogical expertise and interface.

Domain expertise includes domain knowledge which is presented to the student; it is also used for the examination of the student's knowledge. The domain is dynamically organized, i.e. it contains not only information but also a set of rules which are used to create set of acceptable answers. Therefore, the student is allowed to give the answer which is in accordance with the way he constructed his knowledge.

The student model is used as a basis for the individualization of learning. According to Self, student modeling is the process of creating and maintaining student models. It is divided into the design of two different but tightly interwoven components: (i) the student model that, in its simplest form, is a data structure that stores information about the student; (ii) the diagnostic module that performs the diagnostic process that updates the student model (Stathacopoulou *et al*, 2004). The student model contains information about the student's behavior gathered during his interaction with the system. However, the student model also includes information about the student's characteristics which are results of the inference on the basis of student's behavior. Which type of data will be gathered depends on the availability of data and on the purpose of the ITS.

Pedagogical expertise has two roles: diagnostic and didactic. Wenger thinks that the diagnostic process must be performed on three levels. At the behavioral level, the subject of the diagnosis is the student's behavior. At the cognitive level, information about student's behavior is used for inferring the student's knowledge, and at the individual level information is gathered about student's personal characteristics, his motivation etc. Results of the diagnostic process are incorporated into the student model. The didactic role of the pedagogical expertise is to choose an adequate teaching strategy adjusted to student's individual characteristics.

The student communicates with ITS using an interface. In accordance with constructivist learning theory, the interface is designed to allow the student to be as active as possible. One form of active learning is learning by exploration. However, during the process of learning by exploration, we need to provide some basic guidance to the student so that he does not skip important topics which form the basis of the domain. Wenger recommends inclusion of a discourse model as a part of the interface. The purpose of the discourse model is to deal with ambiguity in the student's answers. The interface is also used for gathering information about the student.

4 How can we apply constructivist learning theory to ANN?

ANN is an imitation of a human brain, although considerably simplified. Therefore, ANN share the same approach to learning as humans, i.e. ANN also learn through examples. Consequently, constructivist learning theory is also applicable to ANN learning.

Honkela (2005) thinks that Kohonen's self-organizing map is a good example of ANN, which can be used to explain application of constructivist learning theory to ANN. A self-organizing map is based on unsupervised learning. That means that the network learns through work, i.e. the process of training the network is not separated from the process of using network, which is the case when we use supervised learning. An unsupervised network, therefore, can adapt its knowledge in accordance with new situations.

During the construction of the self-organizing map, a parameter vector, which contains the same number of parameters as input pattern, is assigned to each unit (artificial neuron). Initial values of the parameters can be set randomly or on the basis of a specific rule. Input pattern is sent to all units in the network and is compared with the parameter vector of each unit on the basis of a predefined rule. As a result of the comparison, the unit whose parameter vector is most similar to the input pattern is obtained. Only that unit and its neighboring units have the right to learn, i.e. to change their parameters, so that parameter values can be even closer to the parameter values of the input pattern. That approach to learning is based on the idea that similar input patterns activate the same area in the network, whereas different types of patterns activate different areas in the network. Thereby, the network performs classification; organizing its knowledge into the categories. Using classification, the network is trying to put its knowledge into the order; therefore, doing the same thing that humans do.

During the process of learning, the self-organizing map relies on its existing knowledge, i.e. parameter vectors of units. New knowledge, i.e. input patterns, are incorporated into existing knowledge structures by computation. Computation implies comparison of new knowledge with knowledge which network already has. On the basis of the results of the computation, the network adapts its knowledge by changing parameter values. Humans actively construct their knowledge in the same way. We associate new knowledge with existing knowledge by thinking, and in that manner we adapt our knowledge.

5 Link between ANN and ITS

We can link ANN and ITS using constructivist learning theory through student modeling. From the aspect of ITS, we are trying to model a student's knowledge, and we can do that by simulating the student's cognitive processes or by classifying students on the basis of their behavior. In the practice, both tasks are realizable using ANN.

ANN actively construct their knowledge and, because of that, we can use them for simulating a student's cognitive processes; more precisely, for establishing whether the student correctly constructs concepts. An example of simulation is an ANN that is trained to perform subtraction for the purpose of prediction of a student's responses and errors (Mengel, Lively, 1992). They used a back-propagation network and trained it using data which represents correct subtraction and different sorts of mistakes that students made when they perform subtraction. This network can predict student's results,although its prediction are not correct in 100% of cases. The success of the network's prediction, however, depends on the chosen network architecture, learning algorithm, structure of the network and training examples. All parameters must be optimal for the greater success of the network. For the task of modeling students' cognitive processes, I think that unsupervised networks are a better solution for the purpose of modeling students' cognitive processes than the previously mentioned supervised one. For example, Kohonen's self-organizing map can learn about the student during the entire learning session, and consequently can adapt to student. Therefore, it will exhibit better prediction results. However, a supervised network is trained in advance and cannot learn during the student learning session, so we need periodically to update network's knowledge about student performance.

ANN can also be used for observing changes in the process of concept construction that occur as a result of student development, i.e. as a result of passing through stages of development. Constructive neural networks have been proven to be adequate for that task. They are sufficiently specific that they can change their structure as a part of a learning process. Therefore, networks can initially have simple structures, which allows them limited possibilities of concept construction and problem solving. Through learning, the networks extended with additional units, which allows more complex capabilities of concept construction and problem solving. Changes that networks exhibit are like changes that students exhibit as they go through development stages; just as with networks, students can also solve more complex problems when they reach higher development stages.

Using ANN for classification of students also has an important role. Because we can only gather information about student behavior, it is important to find a way to make inferences the student knowledge. A difficult part of that task is to determine which elements of student behavior characterize their processes of concept construction. The task of ANN is to infer student characteristics that interested us on the basis of chosen student behaviors. We can than use another ANN to infer the quality of overall student concept construction on the basis of the set of student characteristics. An example of ANN classification use is for determination of student learning style. Hence, using information about the amount of time spent for reading theory and about the number of false attempts to find a solution, a student could be classified as person with studious or superficial approach to the learning.

Generally, classification of students is part of the basis of all tutoring situations. Teachers always evaluate their students, e.g. their previous knowledge, their motivation etc, and use that information to adjust their teaching to the students.

6 Conclusion

Constructivist learning theory can be used as a valid basis for establishing connections between ANN and ITS. In this paper, I have shown that a connection could be established through student modeling. In accordance with constructivist learning theory, the objective of student modeling is to model student knowledge for the purpose of understanding how the student constructs his knowledge. ANN learn the same way as humans, i.e. they construct its knowledge, and that characteristic makes them suitable for student modeling.

One idea for future work is to examine the possibilities of practical application of ANN for simulating student's cognitive processes and for student classification.

7 References

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