Intelligent Computer-Assisted Instruction Systems

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ABSTRACT: *Computer–assisted instruction (CAI) has been in use for many years, bringing the power of the computer to bear on the educational process. Now artificial intelligence methods are being applied to the development of intelligent computer–assisted instruction (ICAI) systems in an attempt to create computerized "tutors" that shape their teaching techniques to fit the learning patterns of individual students.*

This paper provides some information and conclusions which author gained during analyzing and projecting of such systems.

1   INTRODUCTION

Artificial intelligence (AI) is concerned with the use of computers in tasks that are normally considered to require knowledge, perception, reasoning, learning, understanding and similar cognitive abilities.

There are two important ways how to implement intelligence from the computational point of view. One is based on symbolism, and the other, based on connectionism. The former approach (symbolic approach) models intelligence using symbols, while the later using connections and associated weights (subsymbolic approach). Evolving by different routes, they both have achieved many successes in practical applications.

Symbolic artificial intelligence provides techniques for flexible, non-numerical problem solving. These techniques include symbolic information processing, heuristic programming, knowledge representation, and automated reasoning. No other fields or alternative technologies exist with comparable capabilities. And nearly all complicated problems require most of these techniques. Systems that reason and choose appropriate courses of action can be faster, cheaper, and more effective and viable than rigid ones.

AI can be considered to be the top layer of control on the hierarchical road to autonomous machines and systems.

Important areas of AI application and research include:

- expert systems,
- natural language processing,
- computer vision,
- robotics,
- intelligent computer-assisted instruction,
- automatic programming,
- planning and decision support.

In artificial systems knowledge is most often provided through processes of hardware engineering and software programming.

2   LEARNING

Learning is defined as the acquiring of knowledge or skill, in a particular domain. This definition is related to human beings. In psychology, various generalized definitions of learning have been proposed, and many of them interpret learning as the change in behavior of a being, subject to a given situation, or as a sequence of his or her repeated experiences in that situation.

In AI, machine learning can be defined as the capability of an AI system to improve its performance over a period of time. This, of course, assumes the capability of the system to acquire new knowledge and

skills as well as its capability to reorganize the existing knowledge based on the newly acquired knowledge. Machine learning has already grown into a widespread research field devoted to the seeking of new learning methods and/or learning algorithms, as well as their implementations.

The history of machine learning is rather long and can be traced to the mid-1950s. However, the crucial research work in this field really started much later by introduction of a series of alternative learning concepts or learning strategies, such as

- learning from examples
- learning by analogy
- learning by search
- learning by matching
- learning by problem solving
- learning by discovery
- learning by parameter adjustment
- failure-driven learning
- strategy learning
- cennectionist learning

Learning can refer to either acquiring new knowledge or enhancing or refining skills. Learning new knowledge includes acquisition of significant concepts, understanding of their meanings and relationships to each other and to the domain concerned. The new knowledge should be assimilated and put in a menentally usable form before it can be called "learned". Thus, knowledge acquisition is defined as learning new symbolic information combined with the ability to use that information effectively.

Skill enhancement applies to motor skills, and to cognitive skills. One aspect of skill enhancement which distinguishes it from knowledge acquisition is the role which repetition and practice plays. Skill enhancement can be interpreted in biological terms as reinforcing a pattern of neural connections for performing the desired function.

3   BASIC PROBLEMS

Learning is one of several processes by which world knowledge and task knowledge become embedded in the computing modules of an intelligent system. In biological systems, knowledge is also provided by genetic and growth mechanisms. In artificial systems, knowledge is most often provided through processes of hardware engineering and software programming.

Going out from the model (that integrates knowledge from research in both natural and artificial systems), which consists of a hierarchical system architecture, then there are four system elements of intelligence: sensory processing, world modeling, behavior generation, and value judgment.

Through learning, the behavior generation system can acquire new skills, the world model can be updated, the sensory processing system can refine its ability to interpret sensory input, and new parameters can be instilled in the value judgment system.

Observations from psychology and neural net research suggest that there are at least three major types of learning: repetition, reinforcement, and specific error correction learning.

Repetition learning occurs due to repetition alone, without any feedback from the results of action. For this type of learning the gain function g is a small positive constant. This implies that learning takes place solely on the basis of coincidence between presynaptic and postsynaptic activity. Much more powerful learning effects can be obtained with reinforcement learning. Reinforcement learning incorporates feedback from the results of action. In reinforcement learning, the learning gain factor g(t) varies with time such that it conveys information as to whether the evaluation computed by the value judgment module was good (rewarding), or bad (punishing). Reward reinforcement learning in the behavior generation system is a form of positive feedback. Punishing reinforcement, or error correcting, learning occurs when g(t) is negative, i.e., punishing.

Error correction learning is a form of negative feedback. With each training experience, the amount of error is reduced, and hence the amount of punishment. Error correction is therefore self limiting and tends to converge toward a stable results.

In specific error correction, sometimes called teacher learning, not only is the overall behavioral result g(t) known, but the correct or desired response of each output neuron is provided by a teacher. Thus the precise error for each neuron is known.

Teacher learning tends to converge rapidly to stable precise results. Teacher learning is always error correcting. The teacher provides the correct response, and anything different is an error. Therefore, g(t) must always be negative to correct the error.

Teacher learning may also be used for task skill learning in cases where a high level behavior generation module can act as a teacher to a lower level behavior generation module, i.e., by providing desired output responses to specific command and feedback inputs.

4   COMPUTER-ASSISTED INSTRUCTION SYSTEMS

Computer–assisted instruction has been in use for many years, bringing the power of the computer to bear on the educational process.

Early CAI programs essentially imitated previously existing instructional materials. For example, a common CAI technique mirrors a method called programmed instruction. In a programmed instruction text, students read brief instructional material and then are presented with short questions to test their comprehension. Students turn to different pages of the book, depending on their answers to the questions, so that each student effectively "programs" a different path through the material based on individual comprehension abilities.

The CAI technique based on programmed instruction is known as frame-based CAI. In frame-based CAI, a student responds to problems presented by computer. The computer is programmed to react differently to possible student responses. If the student's answer is correct, for example, the computer might display remedial material and then pose a simpler problem.

The effectiveness of frame–based CAI program depends entirely on how well it is designed. Although many successful programs have been developed, frame–based CAI programs use computers simply as electronic "page–turners".

5   INTELLIGENT COMPUTER-ASSISTED INSTRUCTION SYSTEMS

Adding AI techniques to CAI results in an effective, new instructional method called Intelligent Computer-Assisted Instruction. The goal of ICAI is the development of instructional materials that actually analyze a student's performance in order to develop individualized tutoring strategies.

The main components of an ICAI system are:
- problem–solving expertise,
- student model, and
- tutoring module.

The problem–solving expertise component of an ICAI program contains the knowledge that system tries to impart to the student. This expertise is represented with techniques similar to those used in the knowledge base of an expert system. In fact, this component can be thought of as a specialized expert system that contains expertise in domain of the ICAI program. The student model, a representation of the student's understanding of the domain, is an important element of ICAI. If a student is experiencing difficulty with certain material, the student model analyzes the student's performance to ascertain the specific causes of the problem. By identifying response patterns, the student model determines the student's misconceptions and discovers the exact causes of erroneous reasoning.

Once the student model has determined the causes of a student's problem, an ICAI program decides how to correct the problem. The component of the program that selects the strategies for presenting tutorial information to students is called the tutoring module. Various strategies may be used to ensure that students understand both the causes of their errors and the actions necessary to correct them. A tutoring module generally incorporates natural language processing techniques to communicate at the level of each individual student.

6   CONCLUSIONS

An intelligent computer-assisted instruction program analyzes a student's performance and develops individualized tutoring strategies to identify and correct learning problems.

ICAI is the area of AI research with the goal of creating training programs that can analyze a student's learning pattern and modify their teaching techniques accordingly.

Intelligent CAI systems may produce one of the most dramatic changers of all . Systems that will enable students to ask questions and receive insightful answers may begin to overcome the barriers of instruction by machines. Computer systems that model the student based on his or her response can gear instruction to the student's level of ability and interest, something not easily done in a conventional classroom.

To truly learn is to digest and make the material one's by updating one's internal models and using them in new applications. Real-time interaction with a computer providing immediate feedback and individual guidance is particularly appropriate to this goal.

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