Developing an Intelligent Tutoring System that has Automatically Generated Hints and Summarization for Algebra and Geometry

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ABSTRACT

Intelligent tutoring systems (ITSs), which provide step-by-step guidance to students in problem-solving activities, have been shown to enhance student learning in a range of domains. However, they tend to be preestablished and cannot supply the tutoring function immediately from the diverse mathematical questions. The MITSAS (multiagent intelligent tutoring system after school) is a web-based ITS in algebra and geometry with a natural language interface which is designed to extract the hint and summarization from the detailed solving answer automatically. In this paper, its Design principles and functionality is analysed firstly. Then, the framework including the natural language understanding agent, automatic modelling agent and automatic problem-solving agent are discussed in the following in order to support the real-time problems solution. Next, the methods for automatically extracting tutoring function such as hint and summarization is given based on the difficulty of knowledge components and the type of problem acquired from the detailed answer. Finally, the effectiveness of MITSAS at improving the Chinese Students’ learning gain is shown by an experiment conducted in junior school.

Keywords: Hint Stepwise, Intelligent Tutoring System, Problem-Based Learning, Summarization

INTRODUCTION

Web-based ITS is gaining popularity with the advances of information technology and artificial intelligence. In ITS, the agent or set of agents can be modeled to perform pedagogical or tutoring tasks. The interactions among these agents and students include instructing, evaluating feedback from students, mining the characteristics of students, solving problems
and effectively tutoring with hint. Thus, these agents have to be able to both instruct and tutor at the same time and also have the ability to cope with disparate learning environments adaptively.

As early as 1956, research by Prof. Benjamin Bloom and others demonstrated that students who receive one-on-one instruction perform two standard deviations better than students in traditional classrooms (Bloom, Engelhart, Murst, Hill, Drathwohl, 1965). That is, the average tutored student performed as well as the top 2% of those receiving classroom instruction. Furthermore, research on prototype systems indicates that students taught by ITS generally learn faster and translate the learning into improved performance better than classroom-trained participants. In the 1990’s, references (Lynnette Taylor, 1999; Wood, Underwood, Avis, 1999; Underwood, Cavendish, Dowling, Fogelman, Lawson, 1996) conducted a formal evaluation of a two year trial of two Integrated Learning Systems in United Kingdom schools. It was shown that the systems could improve learning performance significantly.

Based on the learner model, ITS tailor instructional strategies, in terms of both content and style, and provide explanations, hints, examples, demonstrations and practice problems as needed. The results that there were high learning gains for both the effectiveness of the human teachers and the computer-based hinting e-learning system even without the use of adaptive and personalization capabilities were given in literature (Muñoz-Merino, Kloos and Muñoz-Organero, 2011; Henk, Harskamp, Suhre, and Goedhart, 2009; Suebnukarn & Haddawy, 2006). Some examples of hinting tutors are Andes (VanLehn et al., 2005), SIETTE (Guzman & Conejo, 2005), PACI (Aleven, Koedinger, and Cross, 1999), or AgentX (Martin, & Arroyo, 2004). In web-based learning environments for mathematics, such as Assimtments (Razzaq, Heffernan, Feng, and Pardos, 2007) and ActiveMath (Melis, Andre’s, Bu’denbender, Frischauf, Goguadze, Libbrecht, Pollet, and Ullrich, 2001), they generally supply richer client functions such as hint than HTML- and Javascript-based interfaces based on Flash’s ActionScript programming capabilities. The Mathtutor (Aleven, McLaren, and Sewall, 2009) offers detailed, interactive, step-by-step guidance with problem solving, individualized problem selection, detailed reports of student performance for teachers, parents, etc. on the basis of cognitive model. Cognitive Tutors provide individualized support for guided learning by doing (Anderson, Corbett, Koedinger & Pelletier, 1995; Koedinger, & Aleven, 2007) with context-sensitive hints and instruction to guide students towards reasonable next steps.

However, most of these ITSs ignore the summarization of the knowledge and methods for solving problem. Both hints and summarization are common way to help student solve problem for human tutor. Summarization is conducive to the students to construct the abstract relation of knowledge.

Furthermore, most of these ITSs, whether Mathtutor or cognitive tutor, with can only give the hints and instruction to the problems built in the system. However, the students could encounter wide range of different problems while learning or finishing homework out of class in natural language form. When they encounter questions and inquire questions from ITS, the hints to these problems cannot be obtained from these ITSs, owing to the absence of the automatically solving and the natural language understanding for the arbitrary problems.

In this paper, a web-based ITS called MITSAS is involved in algebra and geometry. The development language was the intelligent reasoning language Jess (the Java version of Clips). The system can solve the problems inquired by the students within five minutes based on the natural language understanding and the automatically solving problems. The main purpose designed the system is to give the hints stepwise and summarization of the inquired diverse problems automatically extracted from the reasoning procedures in order to improve the tutoring quality and the learning gain out of class. However, the system does not support the student solutions directly, they have to solve the problems on paper under the help of the hints.
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