Rule-based Cognitive Modelling for Multimodal Intelligent Tutoring Systems

G. Manju and K.S. Anilkumar

Abstract--- *The work aims to build a rule-based multimodal Intelligent tutoring system. The interface is important as a communication medium. It acts as a problem-solving environment and provides support to student's learning. A good Interface is a mean of an external representation of the system's knowledge and instructional model. A good interface will anticipate the user's action, provide a high level of interaction and make use of metaphors, which in turn requires integration of various advanced technologies. Rule-based models can serve an important role in intelligent tutoring systems (ITS) development. The work focuses on building a multimodal geometry tutoring system. Geometry involves both verbal and visual modes of learning. It is a very good research area to explore multimodal interaction in an intelligent tutoring system.*

Keywords--- *Rule-based Cognitive, Multimodal Intelligent, Tutoring Systems.*

I. INTRODUCTION

The system will be designed to incorporate speech, gestures and natural language, etc in the tutoring system, among these, each one is a challenging area of research. The hand-free aspect of speech enables to incorporate of multimodality into the system, which in turn reduces ambiguity and increases the speed of interaction with the system[1]. While using speech as one of the modalities in a geometry tutoring system we can overcome the difficulties in speech processing by building a multimodal geometry tutoring system.

Another important concept in building an ITS is the selection of pedagogical strategies. From the studies so far done, only a few pedagogical strategies are now used in ITS. The multimodal tutoring system is designed to use constructivism as a learning strategy. The system is designed to work in a distributed environment [2]. The development of communication infrastructure can support the constructivist learning approach in distance learning, which in turn reduces the physical time constraints of learning.

II. MULTIMODAL INTERFACES

People usually include multiple modalities in face-to-face communication. For example, while talking to a person, one usually expresses his emotions in his face or uses his hands to give more emphasis to a particular point. Similarly, we can incorporate multiple modalities in HCI, such a speech together with pen gestures, etc. Multimodality in HCI focuses on including multiple modalities at computer input (text, voice, gestures) and output display (speech, visual display, gestures)[3]. The area of multimodality has expanded very much in the last 6-7 years due to accessibility for diverse user or usage context, performance stability, and robustness and expressive power and efficiency. The interface that depends on the keyboard and mouse has limited capability in the mobile

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computing device. But multimodal interfaces such as a combination of speech and gesture provide more natural interfacing technology for mobile computing.

III. INTELLIGENT TUTORING SYSTEMS

The evolution of new information and communication technology brought out some advancement in the field of education. The ITS incorporates knowledge about the domain/course, learner, teaching strategy and dialogue between tutor and learner. The ITS can adapt learner's skills and understanding capability. The main advantage is that an intelligent tutoring system can individualize the instructions based on learner's learning capability without human intervention [4]. If a student's problem-solving skill is poor in a particular domain, then the tutor can give more hints or can select some other pedagogical strategy for teaching the same concept.

The various components of an ITS *(Figure 3.1*) work together to produce an instructional system that can recognize patterns of leaner behavior and respond with instruction appropriate to those patterns [5]. This process is driven by knowledge representation in an expert model.

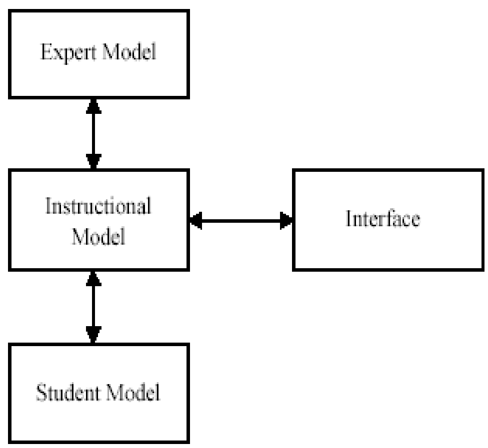

Figure 3.1: Intelligent Tutoring

I. System Components

Expert Model

The expert model is an organized database of the declarative and procedural knowledge in a specific domain. This geometry tutoring system helps the student in solving problems based on the congruence of two triangles. A rule based modeling is used to store knowledge about various triangles and theorems for checking congruency [5].

Student Model

The student model, which encompasses both the learner's knowledge and behavior as he or she interacts with the ITS. It acts as a guidance system that helps to lead the student through the domain's knowledge. The instructional model uses the student model to recognize errors, generate explanations or advice, generate problems, and control learning progress while solving the problem. The ability of an ITS is characterized by its capacity deliver appropriate individualized instruction to a student depends on the information held about the student in the student model.

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Instructional Model

The instructional model contains knowledge for making decisions about tutoring tactics. The main tutoring tactics used is providing appropriate hints to the learner.

Interface Model

The human-computer interface continues to be an important area of research in Computer Science. A good interface will anticipate the user's actions, be consistent, provide a high level of interaction. The interface is important as a communication medium, as a problem-solving environment that supports the student in learning, and as an external representation of the system's expert and instructional models [6]. To increase the bandwidth of Human Computer Interaction, the incorporation of advanced technology such as speech recognition and synthesis, computer vision, gesture recognition, etc are required.

IV. GEOMETRY TUTORING SYSTEM– A MULTIMODAL INTERFACE APPROACH

The aim is to build a distributed tutoring system for solving Euclidean geometry based problems that uses the theorems based on the congruency of triangle. It also evaluates the proof entered by the student. The input to the tutor is a problem statement and problem figure. And the student can enter the solution steps either by typing or by speaking or by the combination of speech and pen gestures and the tutor helps him to solve the problem by giving appropriate hints.

Figure. 4.1 presents the basic structure of the system architecture, using the main components used in this application.

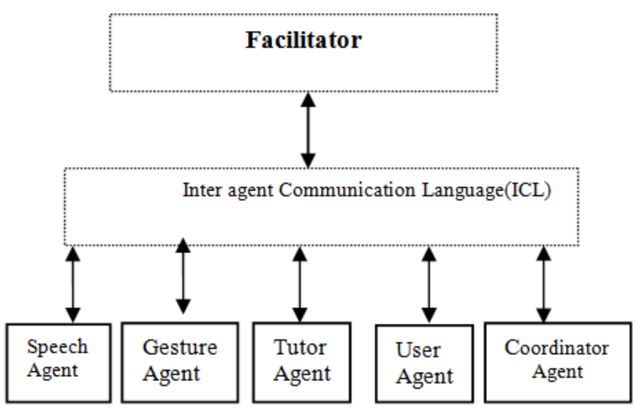

Figure 4.1: System Architecture

Speech Agent: Recognizes the text\speech generated by the user. The text generated by the user is parsed according to a semantic grammar. Currently, the speech agent is designed to handle a limited vocabulary. Later it can be extended to understand a large vocabulary or grammar. Each utterance of the student is time stamped. Voice recognition software is use for speech recognition.

Gesture Agent: This agent recognizes the pen gestures associated with the user's utterance. The gestures generated by the user are also time stamped. A back propagation neural network is trained for gesture recognition.

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Coordinator Agent: This agent unifies speech and gesture-based on timestamp. This unification is needed for this application since it is required to determine that a given piece of gesture input is compatible with a given piece of utterance and if compatible, combines them to a single result to be interpreted by the system. The coordinator identifies the overlapping gestures and speech and combines them for better recognition

Tutor Agent*:* This agent solves the problem and interacts with the student. The tutoring agent has a figure analyzer, a problem statement analyzer, a theorem prover, and an answer analyzer. The block diagram is shown in Figure 4.2

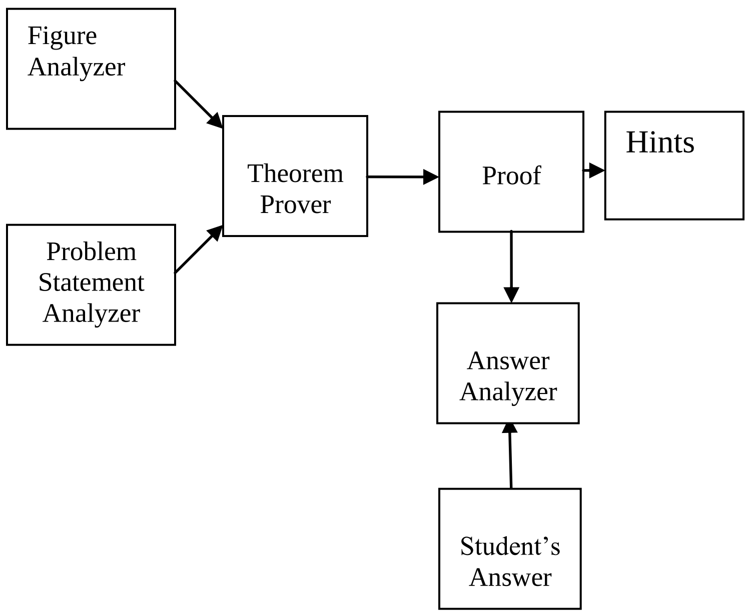

Figure 4.2: Components of Tutor

a. Figure Analyzer: A logic figure is constructed from the given problem figure which assigns a logical representation to each element in the figure. For example triangles QPR, QPS is assigned the logical name t1, t2, the edges PQ & QS is assigned the logic representation e1,e2 and the logical name a1,a2 is assigned to the angle QPR and QPS. It also stores the relationship among elements (e.g. a1 is the angle formed by e1 and e5).

b. Problem Statement Analyzer: It constructs a lexicon of various elements from the figure. The lexicon contains the element and a tag. For example this component identifies the element <PQR from the given figure and assigns it a tag <angle>. Likewise, the element PQ is assigned a tag <side>. The statement (problem statement or student's answer) given to the Problem Statement Analyzer is tokenized and tagged. Then a geometry parser parses this tagged statement to identify the geometric representation contained in the statement. Once a geometric representation is identified it is converted to a logical representation. This logical representation is used in further procedures. For example the text "AB =BC" or "AB equal to BC "matches to the pattern <side><=><side>. And it is converted to a logical representation eq(e1,e2).

c. Theorem Prover: The Theorem Prover constructs an initial problem state from the figure. Then it applies each fact to the current problem state and a new problem state is constructed. And inferences are drawn by applying rules

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to various elements of the problem state. These rules check whether a particular theorem can be applied to the current problem state. This application checks whether a particular theorem of congruency of a triangle (like SSS, SAS, ASA etc.) can be applied to the current state. New facts are derived from the inference drawn. These new facts are again applied to the problem state. This procedure is repeated until a solution is found or a state is reached where it is not possible to proceed further due to the lack of enough facts to prove the problem. One major aspect of problem-solving is that it uses monotonic reasoning. An inference drawn by applying one fact will not become false by the application of other facts.

d. Answer Analyzer: This part will analyze the proof entered by the student and compared it with the proof generated by the theorem prover. The Problem Statement Analyzer analyzes the student answer to find geometric represesntation relevant to the proof. Once a geometric representation is found in the proof entered by the student, it generates corresponding logical representation. This logical representation of the steps entered by the student is compared with the goal generated by the theorem prover. The answer analyzer always checks whether the student has identified all the facts supporting a particular step before writing the step.

The theorem prover uses the forward reasoning technique. This application uses the generate-and-test technique for solving the problem. In this strategy, the algorithm first generates a possible solution. Then test to see if this is the actual solution by comparing this with the goal states. This process is repeated until a solution is found. The algorithm used by the theorem prover is

1. Evaluate the current problem state and identify the facts. If there is a fact equal to goal state the return and exit.
2. Repeat the steps until no facts are to be applied.
   a) Select a fact that has not been applied to the problem state and apply the fact to produce a new problem state.
   b) Evaluate the new state.
      1) If there exists a fact equal to the goal, then return and exit.
      2) If the goal is not reached make the new problem state as current problem table

V. INTERFACE

The application uses a multimodal interface for interaction. It combines speech/text with some pen gestures. Here both the student and teacher can alternate visual and verbal strategies. The student's understanding will be greater if a geometric rule is explained with a picture. For example, to refer to a particular angle A of a triangle ABC, the system an highlight the angle A while saying 'ANGLE A EQUAL TO 90^0 '

Designing a high bandwidth interface will result in better diagnosis of the learner's level The main function of a tutor is to evaluate the student and depending on his understanding move to the next tutoring steps, which can be either selecting a new problem or giving hints to the learner. For example, the student can say 'ANGLE ABC' while pointing to the angle B of triangle ABC. If the information from both speech (ANGLE ABC) and gesture (pointing a location) doesn't match means, the student is confused with the naming convention of specifying three angles of a triangle.

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The student can either use speech or a combination of speech and pen gestures. Instead of saying " PQ=RS ", he can say "PQ equal to <pointing_gesture>" while pointing to the edge RS on the problem figure or can say " <pointing_gesture> this equal to this <pointing_gesture>" or can draw various gestures. The coordinator agent combines the speech and overlapping gestures and identifies the element pointed by the student. Which is then translated into the geometric statement " PQ = RS ". Fig. 6 shows a sample screenshot of the theorem prover.

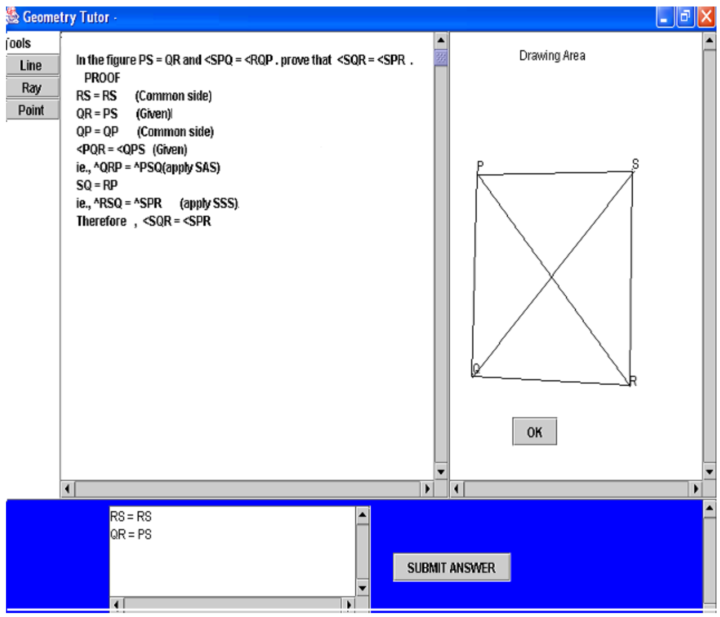

Figure 5.1: A sample screenshot

VI. Conclusion

Geometry is an interesting domain to investigate multimodal interaction. We can use multimodality to increase the bandwidth of an Intelligent Tutoring System and can use this increased bandwidth in geometry tutoring system effectively to contribute better understanding. This representation provides support to learning.

VII. Future Work

Currently, the system handles only limited vocabulary and gestures. This can be extended to include a large vocabulary and more complex gestures. This tutoring system compares the student answer with the proof generated by the system and gives error messages as feedback. The tutoring system can act as a learning companion. This system can be extended in way that two or more students can collaboratively solve particular geometry problem and the tutoring system can assist them if needed. All these interactions are through a multimodal interface.

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