A Multimedia Tool for Teaching Geometry at Schools

Nikos Alexandris, Maria Virvou, Maria Moundridou
Department of Computer Science,
University of Piraeus
80, Karaoli and Dimitriou St.,
Piraeus, Greece
E-mail: {alexandr | mvirvou | mariam}@unipi.gr

This paper describes the work-in-progress of a collaboration project for the development of educational multimedia software. The project involves four partners both from academic and industrial sites and is funded by the Ministry of Education of Greece. The final product is going to be tested and evaluated in 60 state schools which are all going to be connected in a network. Among the development partners, there are two national Universities, the Greek Mathematical Society and a software house company. The content of this paper describes the design of the final product and focuses mainly on the work undertaken by the University partner where the authors belong (University of Piraeus) which is mainly the incorporation of intelligence into the system.

The main objective of this project is to create educational software that is going to be useful to teachers and students in high school classrooms and will be integrated in the school curriculum. The domain chosen has been geometry which has been admittedly considered difficult for students to understand [Senk 1983]. Therefore, we believe that software can provide a lot of help in improving the students' intuition and skills in the domain.

One very important feature of the tool to be developed will be an environment where teachers and students will have the facility to draw geometric figures which will be able to show motion like [Geometer's Sketchpad 1989]. The tool will also incorporate intelligence by using techniques from Intelligent Tutoring Systems [Wenger 1987] that have been proved successful. ITSs have not been used a lot in classrooms although there have been quite a lot of successful evaluations of ITSs [e.g. Mark & Greer 1991] and reports on the successful use in classrooms of ITSs such as ANGLE (A New Geometry Learning Environment) [Koedinger & Anderson 1993].

Teachers are going to be able to use this tool to prepare the presentation of the lesson that they plan to teach and exercises. Students are going to be able to use this tool to read lessons prepared by the teacher, answer questions, draw solutions to exercises and experiment with drawings. The various ways that a teacher and/or a student is going to be able to use the software will be represented as different modes of function:

- *Authoring mode*: In this mode the teacher will be able to prepare the presentation of a lesson and create new exercises in the context of the theory presented.
- *Lecturing mode*: All students in class are going to see in their screen the file that the teacher will have created in order to present a new lesson. In this case, the teacher will be in charge of the operation of the tool, which is going to work in the local network of the class.
- *Experimentation mode*: In this mode the students or the teacher will be able to experiment with drawings, motion and graphical representations. The teacher may need to do this in order to select the best way to present a lesson and the student may need to do this in order to gain better understanding and intuition of geometric proofs. The user interface in this mode will give the user two choices:
  a) Toolbar and menus, such as those used in the authoring mode.
  b) Communication in simple natural language sentences, such as "Draw a circle with centre O(x,y) and radius R".

The facility of natural language processing will give the student the opportunity to practice and improve his/her skill of giving accurate and complete geometric descriptions.

- *Solving exercises mode*: Students are going to solve exercises using the facility of constructing geometry graphics. The educational software is also going to allow communication with a word processor.
- *Answering multiple choice questions*: Students are going to answer multiple choice questions which will help them consolidate their knowledge and assist the teacher in evaluating the students' performance. The students' performance in these questions is going to be saved in a file each time they are in this mode.

- *Recognition of geometric entities*: In this mode the student is going to answer questions concerning the recognition of geometric entities that will be shown on the screen. For example, if a "rectangle" figure is shown on the screen, the student will be asked the question: "What is this figure". The answer to the question will be in natural language. The system will recognise answers such as: "I think that it is a square", or "I don't know", or "It is probably a rectangle". In this mode, there is going to be a diagnostic component which will perform error diagnosis on the student's answer. If the student's answer is not correct the system will try to find out what the misconception of the student has been and give an explanation to the student.

  The diagnostic component will be based on previous research [Virvou 1992] in error diagnosis which explored the utility of a formal theory of Human Plausible Reasoning [Collins & Michalski 1989] in the context of an Intelligent Help System for novice users of operating systems. This research showed that Human Plausible Reasoning could be a helpful tool when employed for error diagnosis. The Human Plausible Reasoning theory was originally constructed to provide a formal model of the reasoning that people use to reach some conclusions about questions for which they do not know the immediate answer. Starting from a question asked to a person, the theory tries to model the inferences made, based on similarities, dissimilarities, generalisations and specialisations that people often use to make plausible guesses. These guesses may be correct as well as incorrect. For the purposes of error diagnosis we exploit the fact that the human plausible reasoning that a student may have used may have led him/her to make an error. The diagnostic component will make use of domain knowledge represented in "isa" and "ispart" hierarchies. An example of an "isa" hierarchy is illustrated in [Fig. 1]. This "isa" hierarchy represents generalisation/specialisation relations among different quadrilaterals. For example, a parallelogram is a special case of a trapezoid, therefore it may inherit some properties from trapezoids. If a student gives an erroneous answer to the question asked then the system will try to locate the student's answer in the hierarchy where the correct answer belongs.

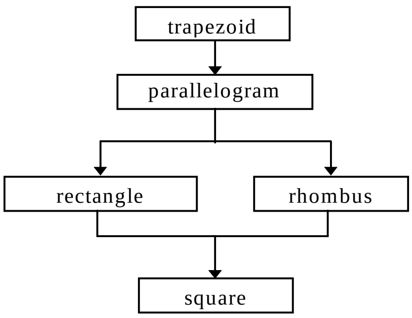

Figure 1: An isa-hierarchy concerning quadrilaterals

Assuming that the figure shown in the screen is a rhombus, an example of interaction between the system and a student could be the following:
System: What is this figure, Chris?
Student: I am not sure.
System: Make an effort…
Student: It is not a trapezoid
System: You are right. Can you tell me what it is?
Student: It is a parallelogram
System: What you say is not wrong. The quadrilateral that you see is a special case of a parallelogram. Can you find what it is?
Student: Is it a rectangle?
System: No Chris, it is not a rectangle. It is a rhombus. I think you should study the definitions of quadrilaterals.

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