Work in Progress - Enhancing Interactive Geometry Systems with Intelligent Tutoring Features

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Abstract – There are different approaches that drive the development and use of educational software, such as Interactive Geometry Systems – IGS and Intelligent Tutoring Systems – ITS. Considering their benefits to teachers and students, these systems may be used to complement each other. The ongoing development of ITS features in an existing IGS called iGeom is presented. First, the limitations of both approaches are listed, describing possible benefits of using them together. Then, the resulting component architecture of the conducted analysis and software design is outlined. The ITS paradigm chosen was Example-tracing Tutors. The current state of research is the tutoring features implementation and planning for testing in classrooms and in distance learning courses.

Index Terms – Computer Assisted Instruction, Electronic Learning, Intelligent Tutoring Systems.

INTRODUCTION

One of the main goals of educational software is to improve the learning and teaching processes. Interactive Geometry Systems – IGS [1] and Intelligent Tutoring Systems – ITS [2] are examples of educational software that has been widely used to support more effective learning.

Different approaches are adopted by IGS and ITS in order to help students with learning mathematical concepts. On the one hand, IGS are educational software that allow for free interaction with geometric objects [1]. Using an IGS, students can easily propose conjectures and test them. Thus, teachers can make a better use of constructivist approaches that facilitate learning through discovery and learning by doing [3]. iGeom is an IGS that presents additional features for authoring educational content, automatic checking of students answers [4] and integration with Learning Management Systems – LMS (such as Moodle) [5]. On the other hand, ITS use techniques from Artificial Intelligence to identify students’ knowledge, skills and misconceptions. With this information, an ITS can adapt the material to meet students needs and then propose new assignments or actions (e.g. personalized feedback) [2]. By doing so, the system reduces the time needed for a student to learn a concept, helps to motivate him or her and also support teachers by reducing their workload [6].

Considering the benefits of these two types of software, they may be used together to complement each other. This work aims to develop a system that presents both IGS and ITS features, as well as evaluating the contributions it could provide for teachers and students.

This paper briefly lists the main limitations of both IGS and ITS; then it reports the development of intelligent tutoring features in an existing IGS, iGeom. Finally, it finishes with conclusions and future work.

POSSIBLE BENEFITS OF AN APPROACH USING BOTH IGS AND ITS FEATURES

Besides offering many benefits for learning and teaching geometry such as making a faster “transition from empirical to abstract ways of conjecture and justification” [3], IGS have limitations regarding the capability of helping and guiding students. The list below shows specific situations of IGS use in classroom and in online courses that could benefit from the adoption of intelligent tutoring features:

- **Error handling**: when choosing or creating objects in a geometric construction, students can make manipulation mistakes that can spoil the solution [7], which could be prevented by a tutoring feature.

- **Mathematical anomalies**: a geometric construction can present unstable configurations that show mathematical anomalies. Teachers may have problems to answer to all students’ questions or even explore the anomaly to explain the concepts behind it [7].

- **Slow learning curve**: when a teacher or student starts using an IGS, he or she may use the system inappropriately (e.g. using the IGS just to show figures instead of interacting with them) and thereby not exploring the software main features [7]. In this case, intelligent tutors can help teachers and students to learn how to use the capabilities of an IGS.

- **Students “stuck” in difficult tasks**: if students cannot complete difficult tasks they can lose motivation [8], which often happens in distance education or during homework. Thus, a teacher may want the system to provide some support (e.g. hints) for students to successfully complete the task.

- **Poor feedback**: most of current IGS do not provide immediate feedback to students’ solutions in an assignment [4]. Intelligent tutors can offer personalized and meaningful guidance that help students to complete a task.

Similarly to IGS, ITS offer many advantages but, in general, they have interactivity limitations. Examples are [2] and [9], in which the student interacts with the system only by control and response types of interactivity [10].
“static” assignments tend to teach students procedural knowledge rather than concepts or logical reasoning, which contrasts with the interactivity of IGS, which have geometry-specific manipulate and co-construct interactivity types [10]. We believe that a domain-specific ITS with these types of interactivity could overcome the limitations and increase the benefits provided to both students and teachers.

**DEVELOPING ITS FEATURES IN iGeom**

*iGeom* is an IGS developed at the University of São Paulo that presents additional features in comparison with other systems [4]-[5]. To add intelligent tutoring features to assignments created in an IGS like *iGeom*, it is necessary to select an approach for developing ITS materials that does not require programming skills. Thus, any user without expert ITS knowledge (e.g. teachers and instructors) could develop tutoring content. The paradigm referred to as Example-Tracing Tutors – ETT has been developed for such a purpose [9].

The development started by assembling the original features of ETT with those of *iGeom*, when the functional requirements were listed. Then, an UML-based process was undertaken, allowing tutoring features to be defined decoupled from the system model. Regarding *iGeom*’s functionalities, the proposed features affect mainly three of them: the solving and authoring of assignments, and communication with LMS. This caused the *iGeom* ETT architecture to be based on three main components:

- **Tracing component**: this is the main component. It traces the user’s actions to compare the current solution state with the expected solution states. Each action is represented by a state in a graph [9]. By knowing where the student’s current state is in the expected state graph, the system can execute state specific help actions, defined during authoring. These help actions can be text messages, objects highlighting, geometric actions and animations and are triggered by the student’s interaction with the system interface or by a timer. To check whether the student’s solution is correct, *iGeom* can compare the current and expected states, and when not possible (in the case of unexpected solution states), it can use its automatic checking algorithm [4].

- **Authoring component**: this component adds ETT features to *iGeom*’s authoring functionalities [4]. While authoring an assignment, the author defines the initial state and the final state by solving it. Automatically, the authoring tutoring feature uses the tracing component to create (instead of comparing) solution states in the state graph. After the creation of a solution state, the author can set a list of help actions to it.

- **Communication component**: a component to manage the communication with LMS in which *iGeom* is embedded. In this case, the LMS must have specific communication features as well [5]. *iGeom* will be able to send information about unexpected students’ solution states and the tutoring actions used during the solution, so that they can be stored in the LMS database for further analysis. Also, the teacher may want to add help actions to these unexpected solution states during later assignment editing.

As compared to the original ETT features, this proposal adds new types of help actions and communication with LMS. Currently, the software design is complete and the implementation has already started.

**CONCLUSIONS AND FUTURE WORK**

A proposal to develop ITS features in an IGS called *iGeom* is presented, with the goal of improving the learning and teaching processes by extending guidance and interactivity limitations of current systems. These features will be integrated in *iGeom* as a component in its architecture.

In order to achieve our goals, future work includes finishing the implementation phase; write a guidebook for teachers to author assignments using it; and then test the system in classroom and in distance learning courses, looking for possible contributions to teachers’ work and students’ learning.

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**REFERENCES**


