Visualization on Learning Mathematics Concepts for Engineering Education*

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Abstract: - Visualization is now a widely used method in teaching practices. In particular, Java tutorials used as visualization and interactive tools introduce a very helpful support for the learning task, enhancing comprehension, engagement, memorization and satisfaction for the students. Furthermore, the interest and motivation among pupils is increased when the teacher uses those tools.
In this paper we present our experiences on the use of these tools and their advantages for learning mathematics, paying especial attention to which requirements these tools should accomplish.

Key-Words: - Visualization, e-learning, education, interactive learning, Java applets, mathematics teaching.

1 Introduction

During the last years, visualization software tools are becoming very popular within the education community, as the increasing number of publications in educational conferences and journals shows.

It is widely accepted that visualization enhances comprehension, engagement and satisfaction among students. Visualization technologies can be used to illustrate many mathematical concepts.

According to the conclusions of the working team "Improving the Educational Impact on Algorithm Visualization" [3], when a group of teachers were asked about the benefits they had experienced from using visualization, they got, among others, the following results: 90% declared that teaching experience was more enjoyable, 86% noticed an improved level of student participation, 83% had anecdotal evidence that the class was more exciting for students, 76% thought that visualization provided a powerful basis for discussing conceptual foundations of algorithm, and 52% got objective evidence of improved student learning. Our experience indicates that those results might be extrapolated to mathematics teachers.

In particular, it is often difficult to explain mathematical concepts and algorithmic procedures in the classroom. Even when the teacher is an artist using different coloured chalks and explaining around the picture in the blackboard or showing perfect slides presentations, the students get little more than static notes. In this sense, a good graphic interface environment would surely become helpful for a better understanding of those concepts or how the algorithms may be implemented.

We have been working in this field since many years, developing Interactive Java Tutorials both for being used by teachers on classroom lectures and students when learning by themselves. Those tutorials are available in our Department Web site [12 – 18].

In this paper we present our experiences on developing and using these tools in the teaching-learning process. We also analyze which are the main requirements these tools should accomplish to be useful for both teachers (coming from non computer areas) and first courses students, and present the advantages they provide for learning processes.

2 Features of a Visualization Tool

Graphical and dynamical visualizations are more appealing for learners than exercises or text books, but, if the students are not required to give some kind of answer or predict what is happening next, they might adopt a passive attitude that is not beneficial for their training. Many educators think

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that visual tools enhance their lectures and produce significant increase in student's comprehension, but such tools are of little effectiveness when students are not actively engaged in the learning process or teachers cannot present their own examples.

From other point of view, the applications cannot be platform dependent as they will stop working when new platform replace the one on which the application was developed.

A basic requirement a good visualization tool should meet is being friendly, interactive, attractive and intuitive [6, 9, 11]. Next, the characteristics we consider a visualization tutorial should fulfil are explained in detail:

- Easy to use: the students' effort should be directed to learn the concepts, not the tool. This can be applied to teachers' as well, when using the tutorial for enhancing their lectures.
- Intuitive and visual: a good graphic interface environment will be enormously helpful for a better understanding of maths.
- Interactive: allowing users to provide inputs when operating with the tool, or even better, interacting with the user, asking questions or expecting next solution, better than just showing it.
- Platform independent: reaching the widest possible audience by keeping the performance when the user updates the platform.
- For many teachers belonging to non computer areas, and/or first course students, the tool should need no installation or maintenance tasks.
- Clear and concise explanations of the theoretical concepts, better in hypertext format for an easier search.
- Nicely formatted appearance including mathematical expressions, interactive graphics and text explanations in a single document.
- Easy and clear presentation so that the student's attention is focused on the essential concepts instead of getting spread on minor ideas.
- Full time and place availability, to allow users' utilization when and where they need to.
- Light downloading weight in order to avoid overweight problems both for users and server.

3 Interactive Java Tutorials for Learning Maths

Mathematical topics, such as Riemann integration or derivation, essentials in an Engineer background, have a visual dynamical essence difficult to be explained by static tools. Other mathematical concepts, such as Graphs and graph algorithms play an important role in Informatics Engineering education. A graph theory introduction is included as one of the main Discrete Mathematics chapters in our first course program. Because of that, we were stimulated for designing and developing tutorials containing several math topics [1, 8, 9, 12 – 18], whose purpose is to enhance the comprehension and learning of this matter to first year course students.

An important fact to be taken into account is that interactivity increases engagement. Due to all these reasons, tutorial tools in Java will surely play an important role in both teaching and learning processes.

3.1 Teachers' viewpoint

Visualization is a widely used method in teaching. Over the last years many instructors have shown their interest on integrating computer aid animations to support dynamic behaviour in their lectures [4, 5, 7]. However, although there are many good tools available in the network, this interest has not lead to a widespread use of them. In our perception, one of the main causes is that most tools have been designed for computer experts, and are difficult to install, maintain and use for many mathematics teachers. Because of this, Java applets are convenient and simple as they don't require any installation or maintenance.

Some mathematical concepts include dynamic structures difficult to show in static tools as blackboards or slides. Therefore, the feasibility of applying dynamic visual tools to represent those concepts shows an enormous potential for achieving high didactical goals.

As we could prove to ourselves, the ease of use and interactivity of our tools has simplified the teacher's task. In our experience, using these tools, lectures become easier and more efficient, and students' attention is more effectively captured and maintained. The pupils show more interest and participate more actively, both predicting the next step as well as asking for difficult points in the process.

3.2 Students' viewpoint

As mentioned above, interactive visual tools do enhance our lectures, but their best feature is the possibilities they show when used by the students themselves in the learning process. It has been verified that learners spend much more study time when visualization is involved. Furthermore, those who are actively engaged with the visualization

have consistently outperformed the other ones who passively viewed visualizations [2].

As shown in Deakin University (Australia) [10] students who used interactive tools learned 60% faster, and after 30 days the knowledge kept was from 25% to 50% higher than those who did not use them. So that, the increase of interest and engagement by the student, is one of the main benefits of this kind of tools.

3.3 Providing Final Term Projects

When teachers want to use didactical software they have to know its existence, find it, learn to use it, often they must install several other resources to make it work and most times it does not fit exactly their needs. All those problems discourage teachers from seeking and using didactical software.

The requirements listed in the previous section can easily be accomplished by developing our own tools with the aid of last course Computer Science students. In this way these students get a useful theme for their Final Term Project, review mathematical concepts from their first courses and implement them. Those students also feel proud of helping younger colleagues to learn mathematical concepts making them easier.

4 Conclusions and future work

Along the previous sections, we have described the didactical benefits of Java applets; however, there are some features we lack and are currently trying to add.

One of the Java applets' handicaps is that, due to security reasons, they are not allowed to write in the client's hard disk. It means that users cannot save their work for later review. The problem has been solved in some particular cases, but it is not completely satisfactory as it requires the user's permission and it disagrees with the conditions exposed above. We are considering the use of Java Web Start or signed applets to avoid this problem.

Another project is creating libraries for the applets where the teacher may store examples to present during the lectures and exercises for the students to practice.

We are also working on interactive applets implementing concepts from other fields of mathematics such as Karnaugh maps and Quine McCluskey's algorithm for simplification of Boolean functions, differentiation in two variables or Gauss method for solving linear equation systems.

According to our experience, the capital contributions of interactive tutorials for visualization and learning of mathematical concepts are:

- A change in the student's perception of mathematics.
- A change in the teachers' organization of lectures, providing them with adapted powerful tools.
- Enhancement of concepts and processes comprehension by the use of graphical visualizations as a way to facilitate theory's insight.
- Improvement of experimentation opportunities, increasing interactivity.
- Augment of students' understanding, engagement and satisfaction.

In our experience, the java interactive tutorials are very good aids for learning mathematics as they improve comprehension, engagement, memorization and satisfaction for the students, so as the interest and motivation among pupils when the teacher makes use of them.

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