

EDAPPLETS: A WEB TOOL FOR TEACHING DATA STRUCTURES AND ALGORITHMIC TECHNIQUES

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Abstract: We present in this work the EDApplets tool, a Web-based application oriented to the teaching / learning of programming and algorithmics in engineering. Based on Java Applets technology, it provides the animation and visualization by traces of algorithms and data structures. The tool covers various aspects in teaching which may be directed to different kinds of learning styles: Active / thoughtful, methodical / intuitive, visual / oral, etc. Also, we present the methodological aspects that should be considered to put in place the tool in the classroom as a supplement to learning.

1 INTRODUCTION

The learning of topics related to the programming skills and algorithms presents perhaps one of the highest levels of difficulty in engineering studies. Students have always difficulties to assimilate abstract mathematical concepts, particularly when these include the dynamics of how the algorithms manipulate the data. Montgomery (Montgomery, 1998) states that these difficulties are maintained throughout each academic year. In his experience explores the dimensions of learning styles proposed by Soloman (Felder and Soloman) (processing, perception, understanding and representation) in the context of engineering, and concludes that the huge gap between learning styles of students and teaching styles, contributes to consolidate learning difficulties (Table 1).

Although there is no single definition and classification of learning styles (Felder and Soloman), all authors agree that there is no correct and incorrect styles and that it is customary for people to use the styles in a complementary manner (del Valle et. al). Thus, one of the greatest challenges in education in general and the teaching of programming in engineering in particular, is to be able to meet the particular needs of individuals. One way of approaching the individual students is through multimedia software on specific subjects (Alejandrino Gallego Rodríguez).

It is an objective of this work to present and disclose the tool EDApplets (EDApplets, 2003), an interactive tool oriented to the topics of data structures and algorithms. We designed this tool to reduce the gap created by the dichotomy between the styles of teaching and the styles of learning.

The idea of introducing such tools in the teaching materials is not new and are usually supported by the use of animations to illustrate the dynamic performance of the algorithms. Hundreds of animations have been developed and are scattered throughout the internet, in many cases as free software. Most of them have been designed under the assumption that the animation will work as an effective tool in the learning process. However, although the animations are always enthusiastically received, there is no empirical evidence demonstrating the effectiveness of the animations by themselves. Animations of algorithms should be thoroughly revised to take chances for further learning.

In our proposal, we start from a wider concept: the visualization of the algorithms by which they and its animations are introduced at different levels of abstraction in an integrated hypermedia environment. In EDApplets, each applet provides a step-by-step implementation of algorithms for inputs given by the students. It also shows the presentation of the traced code and its most representative elements (variables,

Table 1: Results observed by Montgomery on learning styles.

| Dimension | Learning | Education |
|----------------|---|--|
| Processing | 67% of students learn better in an active way | Most lessons are taught in a typically passive and reflexive way |
| Perception | 57% of students learn in an orderly way | Usually they are taught intuitively |
| Representation | 69% of students learn in a visual way | The lessons are usually oral |
| Understanding | 28% students learn in a holistic way | Rarely the teaching emphasizes an overview of the whole system |

data structures, etc ...), as well as the behavior of the algorithm using graphical animations. EDApplets has been conceived as a web application based on Java Applet technology and is publicly available at www.pcg.ull.es/edapplets.

Several level integration are supported:

- Integration of algorithms into a single environment versus to the huge dispersion of examples that had been developed in the last decade.
- Integration of interfaces in a way that minimizes the learning curve.
- Integration of various instructional elements (graphics and text) on a single piece of software, each component contains: executed code, input/output and an animation of the algorithm.

In recent years we have observed a rapid and widespread acceptance of the Web as a global medium to present and process information. This information is accessible in multiple formats (multimedia) and at acceptable speeds (hypermedia). The evolution of this environment has been due, among other factors, to the Java programming language developed by Sun Microsystems. In particular, Java Applets can be executed inside any web browser. The use of this technology to develop programs on the Web presents some advantages (Kamthan). These are the reasons that have motivated us to select this technology to develop our tool:

- Interoperability allows you to operate with a variety of formats (text, graphics, animations and sounds), with different languages (JavaScript, VRML, Flash), with other programs on server side and HTML/XML documents at client side.
- User interaction: applets with graphical user interfaces enhance the user interaction provided by plain HTML pages.
- Platforms independence and portability: Multi-platform versions of educational software are quite rare and often presents a huge dependence on the platform. Applets can be run on different architectures with just a compatible browser.

The work has been structured as: section 2 describes the interface and the overall design of the tool, and some methodological approaches for its use. The website where the applets are published is presented in this section. Conclusions and future lines are presented in section 3.

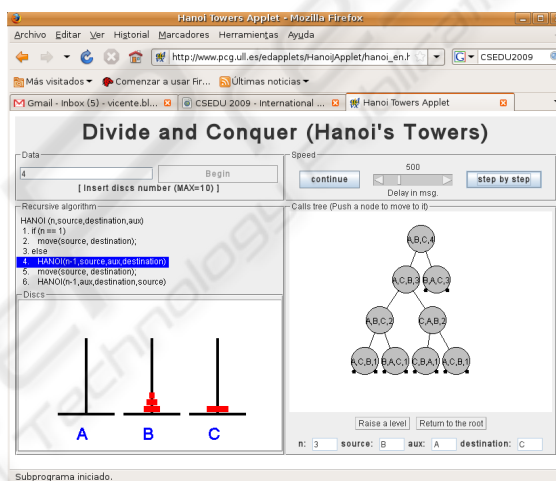


Figure 1: Applet example.

2 APPLETS DESIGN

In EDApplets all applets have a similar design of the interface. Each applet simulates the execution of an algorithm. The applet presents the code of the algorithm and the student introduces the input data for a simulation. The student interacts with the applet through the buttons that controls the speed of the execution. In every applet, there are five panels or work areas (see figure 2): the input data panel, the execution speed control panel, the code display, the animation and the output panel where variables are traced.

Next we describe the function of each panel:

- **Input Data Panel:** from this panel the student introduces the input values for the algorithm. The simulation begins after clicking at button 'Start'.

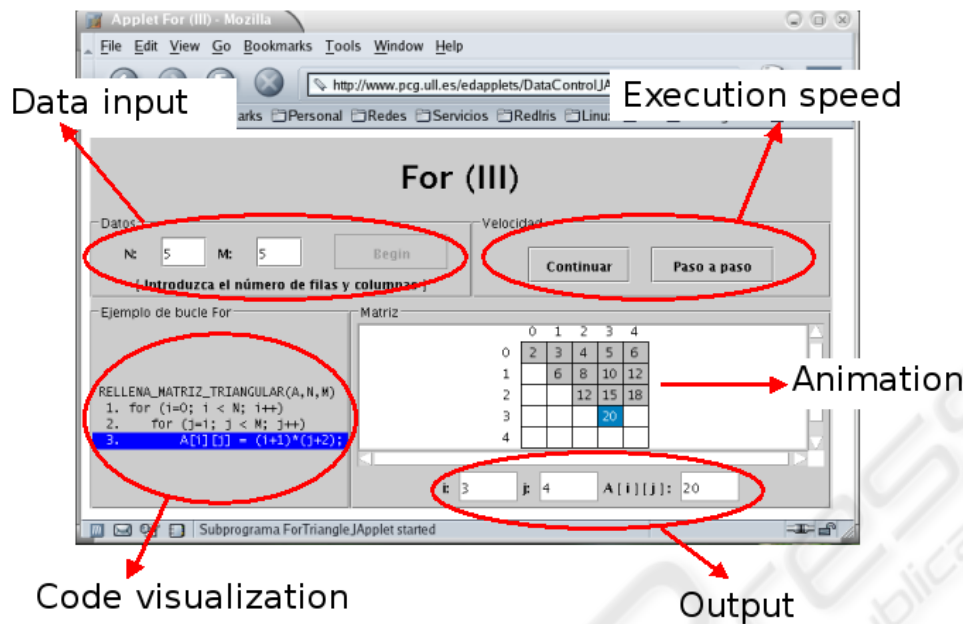


Figure 2: Applet illustrating a FOR iterative control sentence.

- Speed Control Panel:** There are two buttons, 'Continue' button and 'Step by step' button. These buttons allow you to toggle between a continuous execution of the code and a step by step execution. In the step by step execution mode is necessary to press the button 'Step by step' every time you want to simulate a new sentence of the algorithm. For continuous execution mode, when the algorithm requires it, a scroll bar was introduced in the applet that can increase or decrease the simulation speed (Figure 1).
- Display Code Panel:** This panel presents the code of the algorithm to be simulated. All codes in EDApplets appear in the form of pseudocode and follow C programming style. Every line of code is tagged with numbers for easy referencing. During the simulation process the running line of code is shaded. For each sentence, the animation panel shows the animation corresponding to the shaded line. At the same time, the new data values assigned to variables are shown on the output panel.
- Animation Panel:** Presents the graphical display of the algorithm simulation. When needed, the applet splits the panel in as many panels as necessary to obtain a suitable display (Figure 1), thus increasing the capacity of animation.
- Output Panel:** It shows the values of variables being traced on the algorithm. The value shown represents the content of these variables before it

is executed on the shaded line of code.

Figure 2 shows a sample of execution for the Applet For (III). The applet simulates the fills of values to an upper triangular matrix. The code uses two nested loops with upper limits N and M . The input values are the limits of the loops, and the animation shows the data accessed in every moment and their values.

With this design, we try to provide support for active and intuitive students which can be taught through animation and graphical elements. On the other hand, we can not neglect the skills of the methodical and thoughtful students through the use of reasoning about the code or on the trace for its implementation. The kind of integration allows for a global view of objectives when necessary.

The design followed in EDApplets is sufficiently simple to allow students to begin to make use of applets without too much effort. However, just as an animation on its own could not contribute effectively in the learning process, step by step execution of an algorithm and the visualization of its trace might not be instructive if used in isolation. We propose that each applet should be accompanied by a text description that could be included within the applet, or in a separate report. This textual information can be given in the form of a tutorial, putting the student in the context of the problem to be solved. In addition to this introduction, another medium, not so obvious but very important, is an "applet question paper", which must be completed by the student. The question paper can be simply answered using the applet, or reasoning

from it. The question paper could assist instructors in integrating the resources of the applet in the lessons, asking the student to answer it as part of the lab work.

Once the design and overall structure of applets have been completed, we implemented various algorithmic techniques and examples of use for data structures using this design. Special emphasis is placed to achieve that the student can follow the technique in a visual way. At the same time, the student can also follow the pseudocode of the technique implemented.

Applets are developed and grouped with the algorithmic techniques and data structure implemented. We have designed a simple Web portal in which these Applets are available for use by students. We separate applets for *Control Structures*, *Data Structures* and *Algorithmics techniques*.

As an example for these techniques, Figure 1 presents the execution for a typical *Divide and Conquer* algorithm: the *Hanoi towers* problem. This applet shows the recursive call tree and the function parameters specified in each function execution. Student get all the information in a visual way which eases the understanding for this recursive technique.

3 CONCLUSIONS AND FUTURE

We have developed a multimedia tool which acts a supplement in the teaching/learning tasks for programming skills and algorithm understanding in engineering. It is a web application that was developed using Java Applets technology. We start from an integrated and coherent design that enriches classical animation of algorithms with the possibility of carrying out executions and step by step traces on the code. The design provides a teaching / learning active, visual, methodological and sequenced, without releasing elements that contribute to an instruction reflective, verbal, intuitive and comprehensive as needed. With this approximation we try to narrow the gap that usually exists between teaching styles and learning styles generally shown by the students.

The tool has been used successfully for three academic years, in cooperation with virtual teaching projects in Computer Science. We carried out a study of the tool usage in the last academic year and we found that we also have accesses from students of other universities, mostly from Spanish-speaking countries. Now we are in the process of internationalization of the tool, to extend it to other communities. The experience gained in developing these tools in teaching encourages us to continue working on this line. We have the need to add new examples of the use of the structures and algorithmic techniques, which

would help the student a better understanding of these mechanisms. Many of these techniques are better treated as far as more examples are proposed. We are considering the open implementation of the applets, and also to integrate the tool in an open educational content management system, so that users/developers can, dynamically, provide new applets.

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