MatrixPro - A Tool for Demonstrating Data Structures and Algorithms Ex Tempore

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Abstract

Algorithm animation has been researched since early 1980's and many different visualization systems have been developed. However, most of them have remained as research prototypes and almost none have gained wide acceptance by teachers as classroom demonstration tools. One of the key reasons for this has been that preparing animations has been too laborious. In this paper, we demonstrate a new tool, MatrixPro, in which animations are generated in terms of visual algorithm simulation. The user can graphically invoke ready-made operations available in the library to simulate the working of real algorithms. Since the system understands the semantics of the operations, the teacher can ex tempore *demonstrate the execution of algorithms with different input sets, or work with "what-if" questions students ask in lectures. Such an approach lowers considerably the step for adopting algorithm visualization as a regular lecture tool.*

1. Introduction

A wide range of visualization systems has been developed to demonstrate various computer science core topics in the past decade. The major problem, for example, in teaching data structures and algorithms has been the difficulty of capturing the dynamic nature of the material. A proper tool for classroom demonstration would provide an ideal way to teach such concepts. The tool would support custom input data sets [1], provide multiple views of the same data structure possibly with different levels of abstraction [2], include execution history [3], and allow flexible execution control [6]. However, even though there exist many sophisticated tools to visualize and animate these topics, the systems do not support, in general, easy on-the-fly usage. The illustrative material is typically very laborious to create. Or, the material must be prepared beforehand – at least to some extent. Thus, very few systems support the demonstration *ex tempore*.

The new tool called MatrixPro applies *visual algorithm simulation* [4] to aid the development of illustrative material for a data structures and algorithms course. Visual algorithm simulation is a generalization of algorithm animation in the sense that it allows real interaction between the user and the underlying data structures in terms of GUI operations. In visual algorithm simulation the user made changes are delivered to the underlying data structures that are updated as well. Thus, there is always an actual implementation for each data structure involved in the simulation process and the corresponding visualization appears automatically on the screen after the structure has been changed by the algorithm or the user.

MatrixPro is based on the Matrix *algorithm simulation application framework* [5]. The framework provides the basic visualization and animation functionalities that are employed in this application.

2. System

MatrixPro is a tool for instructors to create algorithm animations in terms of algorithm simulation. The main view of the program consists of a menubar, toolbar, and the area of the visualizations as depicted in Figure 1.

The menubar and the toolbar share the main functionality incorporated into the GUI. Structures can be inserted and animation can be controlled through the menubar. The toolbar is an essential component that enables users to modify the created structures and animations.

The area of visualizations contains the *visual entities* that the user can interact with in terms of algorithm simulation. The simulation consists of *drag and drop operations* which can be carried out by picking up the *source* entity and moving it onto the *target* entity.

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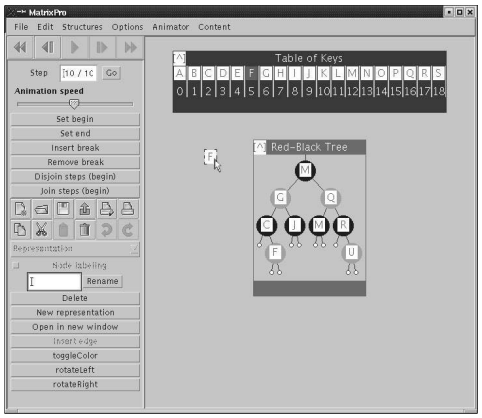

Figure 1. The MatrixPro main window. The user is currently dragging the key F to the Red-Black Tree.

2.1. Features

Ex tempore usage. One of the most important features is the ability to use the system on-the-fly basis. MatrixPro offers an easy way to create algorithm animations by either applying the automatic animation of the structures or by simulating an algorithm by hand.

The system aids the algorithm simulation process by making it easy to invoke operations for structures, such as rotations, also from the toolbar. Any method of the underlying structure can have a corresponding interface functionality (*e.g.*, push button) that appears both in the toolbar and in the pop-up menu of the structure.

In addition, the nodes in a structure can be automatically labeled, *i.e.*, a unique number appears beside each node. This is useful especially in a lecture situation as the instructor can ask questions concerning the view.

Customized animations. The system supports customization of animation in two ways. First, the user can build animations with custom input data sets by simply dragging elements from one structure, *e.g.*, an array to another structure. The second customization feature allows controlling the granularity of the visualized execution history, *i.e.*, how large steps are shown when browsing the animation sequence.

Storing and Retrieving Animations. Some instructors want to customize and save examples for later use. Thus, the *underlying data structures* can be saved and loaded as serialized Java objects. Moreover, the *animations* can be exported in Scalable Vector Graphics format and the structures as TeXdraw representation. Data structures can also be saved into and loaded from ASCII files.

Customizable user-interface. The user interface can be customized to fit the needs of various users as the initial set of toolbar objects can easily be modified. In addition, by modifying the configuration file, the contents of the menubar and pop-up menu can be changed.

Library. MatrixPro includes a library of data structures, which the user can operate on.

Exercises The simulation sequence generated by the user can be compared to a sequence generated by the actual algorithm. MatrixPro includes a set of such exercises with corresponding feedback on the solution.

3. Conclusions

In this paper, we have introduced a system, MatrixPro, which overcomes the preparation barrier by applying algorithm simulation and a simple user interface. The power of algorithm simulation is based on the following issues. First, data structures are presented and manipulated on a conceptual level, which gives the teacher an opportunity to concentrate on the key concepts and principles of the algorithm.

Second, algorithm simulation is a far more powerful interaction method than that allowed by simple drawing tools. In algorithm simulation, the system interprets the simulation operations in the appropriate context. One can perform either simple low level operations (such as assigning a new key value to a node), or higher level operations on abstract data types.

Because generation of examples remains a natural task for teachers, MatrixPro supports tuning the presentation output and dynamics in many ways.

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