Exploring Interface Options in Multimedia Educational Environments

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Introduction

Multimedia technology allows information to be organized and represented in a wide variety of ways. For a computer-based educational environment to be effective, the subject matter must be presented in a clear and comprehensible format. Many multimedia applications organize information based on its physical format, i.e., sound clips, still images, text, and so on. However it is also possible to organize information based on the learner's plan to use information. Such "cognitive media types", media organized around cognition rather than physical format, include definitions, examples, worked problems, and problem sets [Recker, Ram, Shikano, Li & Stasko 1995].

AlgoNet was an educational multimedia environment designed to test the effectiveness of these cognitive media types. Subjects using AlgoNet's cognitive media organization fared significantly better in a post-test than those using a traditional physical media organization [Recker et al. 1995]. While AlgoNet did show that cognitive media types helped students learn, how to best interface cognitive media types into a learning environment remained an open question. AlgoNet2 was created in order to explore some of the possible interface options for supporting cognitive multimedia. AlgoNet2 includes exactly the same domain information as AlgoNet, but with several new enhancements that allow users to navigate more easily and keep better track of their progress through the system.

In order to test AlgoNet2 in a real-life situation, we deployed the system in an introductory undergraduate computer science class at the Georgia Institute of Technology. The results of our study provide insights into the factors important in the design of a computer-based educational environment.

The AlgoNet2 System

The AlgoNet2 program is a prototype of an educational software package incorporating multimedia technology combined with features applying recent findings in cognitive science. AlgoNet2 is the second version of a computer learning environment that is being developed to explore possible interfaces for cognitive media learning environments. This version, as its predecessor, AlgoNet, teaches basic concepts in graph theory.

Figure 1 shows a typical AlgoNet screen. Domain information is presented in the large window in the upper left hand corner of the screen. To the right of the domain window is the *Topic Tree & History* window. This window provides information about the organization of the domain information, the user's current position within the system, and a graphical trace of pages the user has visited. In the lower left part of the screen are four cognitive media buttons that provide access to different kinds of cognitive media. In the box on the lower right, users can select from a list of questions to ask about the current topic. The bottom edge of the screen contains buttons for moving back to the last node visited, invoking the help system, and for exiting AlgoNet2.

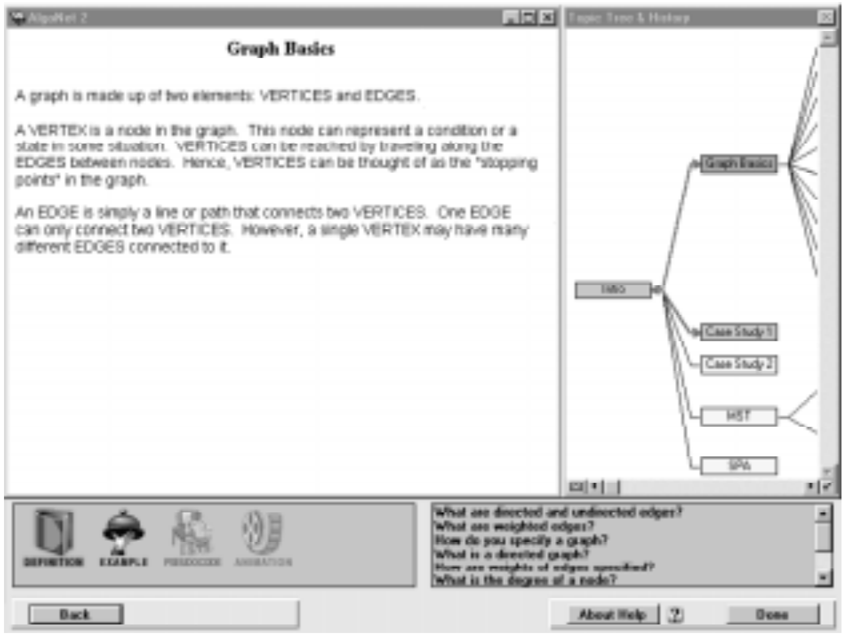

Figure 1: A Typical AlgoNet2 Screen.

Just as in AlgoNet, information presented in AlgoNet2 is divided into groups of pages. Each of these groups (or nodes) covers exactly one topic. Each page within a node belongs to one of four cognitive media types: *definitions*, *examples*, *pseudocode,* and *animations* (dynamic visualizations).

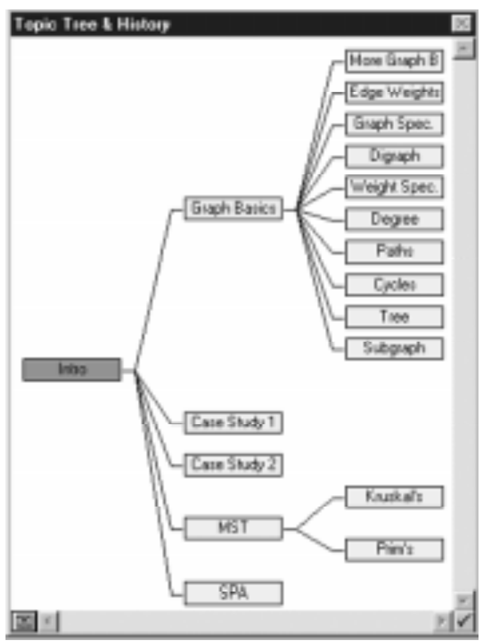

Figure 2: The Topic Tree and History Window.

To allow access to pages within the current node, we provide graphical buttons for the cognitive media types (Figure 1, lower left corner). The small images simplify the mental association between the button and content or type of domain information "behind" it. The current active view is highlighted. Buttons corresponding to cognitive media types unavailable in the current node are "ghosted" and drawn in light gray. The four graphical buttons remain on the screen at all times, unlike AlgoNet's buttons which were simple text boxes that changed from node to node.

AlgoNet2 allows for two different types of navigation between topics (nodes). One of these navigation styles was based on the idea that it would be very natural and familiar for a student to ask questions about the current topic. To avoid the rigors of natural language understanding, we instead presented a box with pre-formulated questions for each topic (Figure 1, lower right). When the user clicks on a question, a related topic containing the answer to this question is shown. The "back" button allows users to return to the previously visited node. It was hoped that the question-based format would encourage students to ask questions of both their peers and instructors as well as themselves. This question asking/answering behavior has been linked to learning goals [Chi, Bassok, Lewis, Reinmann & Glasser 1988; Chi & VanLehn 1991; Ng & Bereiter 1991; Ram 1991; Ram & Leake 1995; VanLehn & Chi 1992]. We intentionally omitted a "next page" function (contained in the original AlgoNet) that allows users to proceed through the system in some pre-formulated, linear fashion. By removing this feature we forced the users to choose their own paths through the system, hoping to encouraging active learning and reflection on learning goals and strategies.

Another new feature in AlgoNet2 was the *Topic Tree & History* window. This window provides a hierarchical, "bird's eye" view of the information in AlgoNet2. Each node is an instance or type of its parent, e.g., *cycles* and *paths* are two types of *graph basics*. We anticipated that adding this structure to the domain information would encourage students to incorporate a similar structure in their own mental models, facilitating the retention of the material.

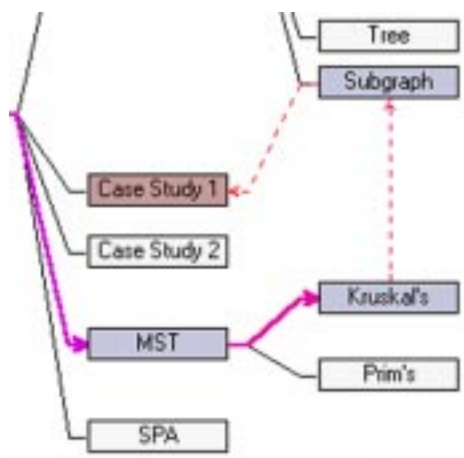

Figure 3. Topic tree links are shown as solid lines.
User generated jumps are represented as dotted lines.

In addition to the question-asking interface, a student can also move directly to any node by clicking the appropriate node on the topic tree. As the student navigates, the topic tree provides feedback, relating which nodes have been most recently visited as well as which nodes have yet to be visited. This additional information was intended to prevent the user from becoming lost in a tangle of pages and links, a common problem with hypermedia-based systems. The topic tree color codes the nodes. The current node is highlighted with a light red background. All previously visited nodes have a light blue background. Unvisited nodes are rendered light gray. A history of the last seven steps is provided by color-coding the links between nodes drawn using a "hot to cold" metaphor. The most recently used link is indicated by a bright red arrow, the next six most recently used links are colored various shades from orange to blue, blue being the least recently used link. Links used more than seven steps ago, or not at all, are represented as thin, black lines. In the topic tree, we distinguish between "regular" moves within the topic tree (solid lines) and random jumps to other parts of the system (dashed lines) (Figure 3). This color-coded path through the topic tree is provided in order to give context to the current node, helping to answer questions such as "Why did I come to this node in the first place?" "What information was I looking for?" and "What do I do with it when I have found it?"

Evaluation

The AlgoNet2 system was evaluated in anticipation of fielding the system as a routine component of the introductory level computer science curriculum at Georgia Tech. Participants in the empirical studies were 148 students enrolled in a first-year introductory computer science course. The AlgoNet2 study was designed to take the place of one of the regular laboratory sessions in this course.

One goal of the empirical study was to determine the extent to which students could use the system as a stand-alone module for self-directed learning. As such, the subject material included in the AlgoNet2 system was not covered in classroom lectures. In addition, no formal instructions were given to the participants on the use of the system itself.

The laboratory sessions in this course are not normally designed to provide students with hands-on experience in computer problem-solving. In order to evaluate the system in as natural a setting as possible, the empirical studies were conducted within the context of a routine laboratory assignment and were directed by the students' normal laboratory instructors and teaching assistants. Our lab assignment asked students to solve a problem involving graph theory imbedded in a situation from the popular computer game Doom. By applying graph theory to a graph representing a part of one level of the game, students were able to "win" the game and solve the lab.

The students were given a lab assignment and were told only that AlgoNet2 would be of assistance in completing the assignment. In order to successfully complete the lab assignment, students needed to learn an appropriate graph algorithm and underlying concepts, (one of two "minimum spanning tree" algorithms) from among those presented in the system and then execute the algorithm. No attempt was made to explicitly direct students to specific graph concepts or definitions.

After completing the lab assignment, the students were directed to exit AlgoNet2 and complete a post-lab questionnaire. The questionnaire elicited personal information from each student (e.g., about their previous computer experience) and asked some general system evaluation questions. The questionnaire also included a section that contained questions designed to test the students' understanding of some basic graph concepts.

In addition to the lab assignment and the post-lab questionnaire, there were two other sources of data. The AlgoNet2 system automatically logged each participant's interactions with the system. We also videotaped four volunteers to help identify any system usage difficulties or other activities of interest.

Results

Navigation Method	Rationale	Average Uses per Student
Question-Asking Interface	Natural method of inquiry, encourages metacognition.	4.2
Topic Tree	Puts current node in context, shows overall layout of system, shows users where they've been.	22.6
Cognitive Media Icons	Provides consistent, easy access to the cognitive media types.	14.6

Table 1: Students used the topic tree far more often than the question-asking interface.

Recall that students had three different ways of navigating through the AlgoNet2. Table 4 recounts these methods and the rationale behind each one. The right hand column shows the average number of times each student used each type of navigation. Users used the topic tree far more than the question-asking interface even though the two provide essential the same functionality: the ability to move between different nodes in the system.

Overall, users showed a slight preference for examples and visualizations over pseudocodes and definitions. However there was no significant correlation between users' experience levels and their preference for one cognitive media type over another. Over two-thirds (68%) of the students responding said that they were satisfied with the AlgoNet2 system in the post-lab survey.

Students tended to view visualizations far longer than any other form of cognitive media type as measured by the amount of time spent with each media type (Figure 4). This tendency to dwell on visualizations was echoed in the original AlgoNet study [Recker et al. 1995].

Analysis of the numerical data produced several meaningful and statistically significant correlations. Students' time viewing the visualization was positively correlated with their performance on the lab assignment, ($r = .290$, $p < .01$). SAT-verbal scores were negatively correlated with time viewing the mostly textual definition and example pages, (r = .335, $p < .01$). SAT-verbal scores were also negatively correlated with use of the question-asking interface (r = -.211, $p < .05$). Number of uses of the topic tree interface was negatively correlated with the students' self-report of the difficulty of the lab (r = .192, $p < .1$). Post-lab quiz scores correlated positively with students' viewing times for definitions and examples (r = .323 and .215 respectively, both at $p < .05$).

Some correlations were conspicuously absent. Previous background, including major field, SAT scores, and previous computer science background had no significant bearing on students' performance on the lab or the post-lab quiz.

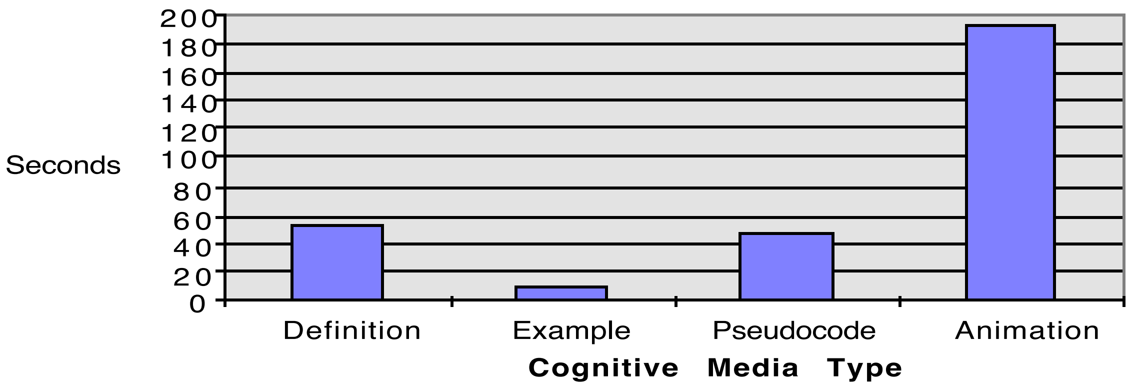

Figure 4. Relative viewing times for cognitive media types. Students spent more than three times as much time viewing visualizations as any other media type.

Discussion

Student reports of the difficulty of the lab were negatively correlated with their usage of the topic tree. Students using the topic tree more often found the lab to be easier overall. While this result is purely correlational, we are hopeful that we can demonstrate that our experimental interface does in fact increase ease-of-use.

The question-asking interface and the topic tree both provide the same function: the ability to move from one node to the next. However, the students used the topic tree far more than the question-asking interface. One reason for this difference might be that the topic tree allowed instant access to any node in the entire system while the question-asking interface only allows one-hop moves along the topic tree. The students' preference for the topic tree may be pure convenience. Alternately, the larger, more graphical topic tree may draw the students' attention. Finally, the topic tree may actually be a more comprehensible interface. Additional research is needed to explore these possibilities.

The negative correlation between SAT-verbal scores and time viewing definitions (which tend to be composed of plain-English definitions of concepts) can be explained in the following way: highly verbal students viewed the same number of definitions and examples, but needed less time to absorb the same amount of content as less-verbal students. This suggests that students with different abilities use cognitive media types differently.

One of the clearest messages in the log data is that "glitzy" multimedia, i.e., fancy animations, is not an atheoretical luxury. Multimedia is capable of capturing and holding the subject's attention far better than any other media type we studied. There was only one visualization in the entire system, but users spent far more time at this page than of any other category of page. This finding is confirmed by the post-lab questionnaire as well. When asked what the system lacked, students often requested more multimedia support. Students' suggestions ranged from, "More animations for algorithms," to "Add kewl (sic) sounds."

When queried on their learning strategies, very few students could give a clear answer, if any at all. Of the students responding to the question, the most common strategies cited were "wander randomly," and "read everything." Students also reported frustration with this type of instruction, citing a lack of "direction" and "what to do next information." This clearly demonstrates that our question-asking protocol was not enough to encourage students to effectively guide their own thinking process and suggests that there is a need for the effective teaching of learning strategies.

While students were unable to identify their learning strategies, experimenters circulating through the labs did notice a consistent learning strategy. Many students tended to scan all of the content information quickly, then begin solving the lab. As they worked on their lab, students often returned to the AlgoNet2 system, suggesting that they were actively hunting for information they needed. This suggests that students do use learning strategies, but may not be aware of them.

Future Work

Our pilot study of AlgoNet2 produced large amounts of data. Our next step will be to continue the analysis of the data and report any additional trends discovered. When all the data have been analyzed, we will begin work on AlgoNet3, a third version of the AlgoNet system which will include more cognitive media types such as problem sets and worked problems as well as more multimedia and interactive components. The next system will also be applied to domains outside of graph theory.

Future versions of AlgoNet can be useful in three distinct ways. First, they can be deployed in actual classrooms as instructional tools. Second, we can continue to study students' interaction with the systems in order to refine the learning environments and develop design guidelines as we have done in this paper. Finally, future systems can help us explore the learning itself, revealing students' strategies and understandings of their own learning processes.

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