AC 2010-808: ADAPTING ASYNCHRONOUS COMPUTER-BASED INSTRUCTION TO INDIVIDUAL STUDENT LEARNING STYLES

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Abstract

This paper describes the approach and offers preliminary results for our guided on-demand adaptive learning (GOAL) project. GOAL provides asynchronous web-based instruction that detects preferred learning styles for each student and adapts the instruction to match the detected preference. It also provides a platform for research about learning and for evaluating instruction.

Introduction

Undergraduate engineering education must change to accommodate the accelerating dependence of society upon engineering and to harness the evolving strengths of our students. To be technologically literate, a student today needs greater breadth and depth of technical knowledge than previous generations of students. However, today's student cannot allocate more time to gain this greater knowledge. Further, the cadre of technical practitioners supporting our society must expand, become more diverse, and have greater access to technical knowledge.

Fortunately, many of the same advances that are compelling changes in undergraduate engineering education are also enabling these changes. Our understanding of the process of human learning has advanced significantly in recent years, and this improved understanding of teaching and learning tempts us to believe that we might be able to convey knowledge and understanding to students more efficiently. Any such efficiency improvements will help to address the challenge of increasing the depth and breadth of knowledge gained in a fixed interval of time. This project will expand our knowledge of the human process of learning by gathering and evaluating data to quantify certain aspects of the learning process. In addition, this work will address directly the increasing need to improve student access to technical knowledge.

This work is combining advances in technology with advances in understanding of human learning to teach engineering concepts more efficiently. Detailed data is being collected as the concepts are taught to attain new insight into the learning process. The central objective of this work is to show that this approach can improve the efficiency and availability of engineering instruction. This approach will automate and improve the delivery of facts and concepts, broaden access to this material, and create opportunities for the inclusion of additional material.

This project exploits results from research into the way people learn combined with technology providing instruction using established techniques for effective teaching. This work recognizes that different students learn in different ways, at different times and places, and at different rates. This project provides instructional guidance available on-demand at times and places convenient to each student. Our instruction is adaptive so that the student can proceed at his or her own pace using instructional techniques best suited to their own individual learning styles while their progress can be tracked and their instruction can be adjusted in response to their actions. We view this system as analogous to a patient and insightful tutor who is always available and who never tires of explaining and illustrating each concept.

We call this the Guided On-demand Adaptive Learning (GOAL) system. Instruction is coordinated using a computer-based learning management system that tracks the progress of each student and captures detailed data about each learning interaction. Each topic is carefully arranged into coherent modules, the modules are subdivided into molecular concepts, and the visual and verbal presentation for each of these concepts is scripted and produced. The initial demonstration material has been developed for standard web browsers augmented by standard free plug-ins, and the delivery mechanism could be extended in the future for student access through other interfaces such as web-enabled cell phones. Our vision is for efficient personalized instruction for everyone who needs it.

Eventually, the GOAL system will permit the addition of topics to a crowded curriculum with limited additional time demands. Access to instruction will be available at the convenience of the learner and in a form that is adapted to accommodate different learning styles. The future integration of existing classes into the GOAL format may permit more knowledge to be conveyed to a larger and more diverse set of learners efficiently.

The Adaptation Challenge

Students typically exhibit different levels of preparation, different learning styles, and different rates of learning. Some students may find material to be obvious while other students find the same material to be very challenging. Most students find their own learning experience to reside between these two extremes. While this range can be found to exist in many classes within a particular program at a particular school, the work described here is intended for a much broader range of students.

Live lectures to small classes can provide some adaptation to accommodate the average ability of the group of students, but even the best lecturers have difficulty reaching every student at the most appropriate presentation level for that student. Also, any teaching style is unlikely to align well with every learning style present in any classroom of more than a very few students. As class sizes get larger and other boundaries appear between the teacher and the students, teaching and accommodation become less practical.

Adaptation disappears entirely from the typical recorded lecture, scripted PowerPoint talk, streaming video presentation, or podcast. These presentation forms may allow the student to stop, pause, rewind, or fast-forward the presentation, but this is the full extent of control available to the student. The student cannot step aside to try a related activity. The student cannot ask to see the material repeated in a more abstract or more concrete manner. The student cannot ask that only the last concept be repeated unless the student understands the concept well enough to know how far to rewind the presentation. The student cannot ask where this particular concept fits within the broader topic being presented. In addition, most of these traditional presentations do not pay careful enough attention to the coordination of the visual and verbal learning channels used by the student. Finally, these existing presentations do not include the capability to track each student's interactions to permit the teacher to learn about the student's needs and learning style.

Traditional college classes meet regularly at specific times, and this rigid "synchronous" class schedule is unlikely to align with the highly varied needs of the increasingly diverse student population. Many students may need to fit their studies within employment commitments and will therefore need to "attend" class in the evening, late at night, or early in the morning. Many students may be geographically dispersed so that the class must serve many different time zones. Some students may need to compress their studies so that they can complete the entire class in a few weeks of concentrated work while others may prefer to extend their studies across a time period longer than the typical college semester. These varied schedules suggest that classes should be available in an "asynchronous" on-demand basis.

While on-demand class access is desirable to accommodate different student schedules, it is also very helpful to address differences in student preparation and abilities. Students who find the material easy to learn should be able to move more quickly through the class while students who find the material more challenging can take more time. This delivery mechanism used in GOAL can permit each individual student to review selected topics as needed. Also, the GOAL delivery mechanism permits each individual student to view topic material presented for different learning styles. Some students may stay with one learning style, others may prefer different styles for different material, and some might need to be exposed to the same material in different ways to gain solid knowledge of the topic taught. Data is captured to record all of these paths of learning and enable researchers to learn more about how students learn.

Matching Teaching to Learning Styles

GOAL delivers on-demand distance learning in a manner designed to be analogous to an insightful tutor who is available at the convenience of the student. This virtual tutor presents material to the student at a rate that is controlled by the student using a style of instruction that is adapted to each student's learning style. The student can have the presentation of any concept repeated, and concepts are presented to the students in different ways. The topic modules are designed using the results of research from cognitive theory to enhance the learning process. Much progress has been made in recent years to understand how people learn, and results from that research is used to direct the design of the topic modules. While one objective of this work is to provide instruction that is both effective and efficient, another objective of this work is to collect data about student learning.

Different students learn differently, and significant mismatches between teaching and learning styles impede learning efficiency and effectiveness. Felder and Silverman[1] defined five dimensions of learning and teaching styles, and they subsequently reduced the number of dimensions to four for undergraduate students. This project uses all four of the remaining dimensions.

The dimension of learning and teaching removed by Felder and Silverman[1] is induction / deduction. They continue to believe that this is a valid dimension, but they removed it from their list because they subsequently decided that induction was clearly the superior teaching approach for undergraduates. In spite of this superiority, they claim that the most common method for college teaching uses the deductive approach, which starts from fundamental principles and works toward applications. In contrast, the inductive approach conveys facts and observations with the foundation principles inferred.

One of the four remaining dimensions represents learning and teaching style variation between active and reflective. Active instruction requires greater student participation and interaction while reflective instruction anticipates greater student introspection. This dimension is incorporated in our framework by providing parallel related paths through most segments of our learning modules. One path presents concepts in a manner similar to a proficient lecturer. Some student participation and interaction may be required to progress along this path, but the path focuses on concept explanation. This path should appeal more to the reflective learner, but it should also be of value to an active learner. The parallel more active path provides related activities to engage the learner through simulation, experimentation, and rich interactions. This path is expected to appeal more to the active learner, but it should also be of value to a reflective learner. The elements along both paths are always available to all students, but each student is allowed to establish a learning preference to influence the default flow through the module. For example, a reflective learner might prefer a default path flowing directly through the expository elements without the distraction of activities. While this learning mode bypasses most activities, the student has the option to divert to each activity as it becomes available. Also, the student can change the default path at any time. Similarly, an active learner might prefer to work through all of the activities while avoiding some of the purely expository material.

Another of the four remaining dimensions represents learning style variation between sequential and global. Most of undergraduate teaching is strictly sequential with concepts presented in a fixed order that builds later layers of knowledge upon the foundation prepared earlier. Global learners prefer to start with a broader view and then fill in the details as the need for those details becomes apparent. Global learners can be frustrated by sequential instruction to the point that they are unable to succeed in a sequential instruction framework. The sequential style provides progression in incremental steps while the global style endeavors to convey context and relevance so that the learner progresses in larger leaps. The GOAL project addresses this learning dimension by suggesting a preferred path through each learning module while also providing hierarchal knowledge maps and overviews accessible to all but directed to help the global learner. Proficiency is assessed at discrete points in the instruction regardless of the learning style, but the student enjoys significant flexibility in the path between these points.

A third of the four remaining dimensions represents learning style variation between concrete and abstract. Concrete instruction provides greater focus on data, facts, and solution approaches while abstract instruction offers more theory and heuristics. Wherever feasible, two expository presentations are provided to satisfy this learner preference. Each student can choose a default preference, but both forms are always available to all students. Having the two forms available provides further help for a student having difficulty understanding a concept.

The fourth remaining dimension of teaching and learning described by Felder and Silverman[1] represents differences between visual and verbal styles. The visual style includes diagrams, pictures, and demonstrations while the verbal style includes spoken and written words and sounds. Visual learners are reported to remember best material that they see while verbal learners remember best material that they hear or read. More recent work suggests that presenting the same material through both "channels" simultaneously enhances learning for both visual and verbal learners. This combined presentation approach is used in this project, so this dimension need not be considered separately.

Multimedia Design for Asynchronous Instruction

Human memory research has determined that knowledge is gained and retained in different ways such as auditory (verbal) and visual (pictures).[3] While printed text is received through the human visual system, the words presented are typically processed as verbal information. The mechanisms for knowledge transfer are different for these different learning "channels," and the learning process can be enhanced through complementary use of these separate channels. From this research, Meyer[2] describes three assumptions about human learning:

1. **There are two channels**. Human cognition occurs through two distinct channels: auditory (or verbal) and visual (or pictorial). The representation and manipulation of knowledge is different in each of these channels.

2. **Each channel has limited capacity**. Each of these distinct channels has limited capacity to manipulate and retain knowledge. Too many spoken words and other sounds at any one time can overload the auditory channel. Too many images presented together can overload the visual channel.

3. **Active processing provides learning**. People learn when they actively process information presented on either channel. The process of selecting and organizing information in the context of prior knowledge produces effective learning. This learning is likely to occur when corresponding information is presented through both auditory and visual channels at the same time.

Traditional instruction has emphasized verbal instruction either through lectures or through printed text representing words. Note that that the "verbal" channel is involved with reading printed words because people internally verbalize the words that are represented by the printed symbols. (Some people move their lips as they do this.) Books typically include static images to assist with learning, but verbal and pictorial channels integration in books is limited by the serial shifting between reading words and viewing static images. Good lecturers typically make use of a chalkboard or other imaging device to present images that complement the spoken words to assist with the learning process. The parallel combination of verbal and pictorial information by a lecturer can be very effective because both verbal and pictorial channels are used in tandem. Web technology supports this efficient multimedia instruction.

However, it is easy to get multimedia instruction wrong and to fall short of its instructional potential. One obvious example is provided by the common misuse of PowerPoint to provide instruction. Many lecturers use slides containing only lines of written text to represent each significant point. In this example, both the eyes and ears of the student are presented information in a "verbal" format so that only the verbal channel is used. As PowerPoint has become ubiquitous, most professionals have experienced such a presentation in which they either read ahead on the slide or ignored the slide and listened to the lecturer. Most find the value of the PowerPoint part of these typical presentations to be in the printed handout that provides the key points with space to write notes.

While PowerPoint does provide the capability to present images and simple animations, these features are not widely used because significantly more effort is required to prepare and produce relevant information directed to the visual channel than is required to record or write information directed to the verbal channel. The preparation of coordinated multimedia instructional material is extremely demanding, and the associated cost can only be justified if the resulting product will be both efficient and effective in conveying knowledge to many students. The research cited by Meyer[2] has suggested how to get multimedia instruction right, and the technology is available to capture and present good multimedia instruction.

Richard Mayer's survey paper[2] brings together a range of research on cognition and education to define eight principles for good instruction design. These principles form the foundation for the instructional delivery provided by this project. These principles extend the visual/verbal dimension of Felder and Silverman[1] with the recognition that visual and verbal are different channels that can be fruitfully used together. These principles are presented here fully credited to Mayer's work.

1. **Multimedia Principle**. Mayer[2] cites studies showing that learning is more effective when students are presented both narration through the auditory channel and carefully crafted images through the visual channel. Deeper understanding results from the connection of pictorial and verbal representations of the same concept. While Felder and Silverman[1] state that learners typically favor one mode or the other, Mayer suggests that all learners benefit from both modes if the modes are properly coordinated.

2. **Contiguity Principle**. Mayer[2] cites studies showing that learning is more effective when narration and images of a concept are presented at the same time. Simultaneous presentation through both channels places corresponding words and images in memory at the same time, and this supports the construction of mental connections that enhance learning. This contiguity of presentation is natural in multimedia, but is impractical in traditional printed books.

3. **Coherence Principle**. Mayer[2] cites studies showing that learning is more effective when extraneous sounds and images are excluded from the topic. This principle seems reasonable when presented in this way, but many multimedia presentations have included related but irrelevant material to increase learner interest. While the extra material might increase interest, the studies have shown that the extra material diverts attention away from the material to be learned.

4. **Modality Principle**. Mayer[2] cites studies showing that learning is more effective when the information in the two channels, auditory and visual, are kept separate. Thus, verbal information should be presented through the auditory channel while the visual channel should be used for images.

5. **Redundancy Principle**. Mayer[2] cites studies showing that learning is more effective when verbal information is presented only through the audio channel and is not presented for reading. Intuition might suggest that providing verbal information in both auditory and written form would permit the student to use the channel best aligned with the individual's learning style. However, cognitive theory indicates that the redundant printed text competes for the limited capacity of the visual channel and is therefore detrimental to learning.

6. **Personalization Principle**. Mayer[2] cites studies showing that learning is more effective when the narration is presented in a conversational style rather than an expository style. Conversational style is typically used by good lecturers and by tutors in one-to-one instruction.

7. **Interactivity Principle**. Mayer[2] cites studies showing that learning is more effective when students have some control over the presentation rate. Each topic can be divided into modules and concepts so that the student controls when to proceed from one concept to the next. Further, modules may include points at which instruction stops until the student allows it to continue. Allowing the student to control the pace helps to avoid cognitive overload.

8. **Signaling Principle**. Mayer[2] cites studies that have shown that learning is more effective when key concepts are "signaled" in the narration. This signaling might be accomplished by specifically identifying the key concepts through the organization of the narrative, by using voice intonation to emphasize key words, or by using some other audible cue to signal a key concept. Good lecturers commonly use these techniques, and this research shows that their value extends to multimedia presentations.

Organization and Implementation

The instructional framework for this project is composed of a hierarchy of instructional elements:

1. **Class —** A typical course of study is composed of multiple classes. A class defined here contains content approximately equivalent to a typical single-semester undergraduate college class.

2. **Topic —** Each class is composed of multiple topics. A topic contains about the same material as might be contained within several lectures of the typical college class. Thus, a typical class should be expected to include between about ten and twenty topics.

3. **Module —** Each topic is composed of one or more modules. A module contains a coherent grouping of concepts and assessments as appropriate to cover the topic.

4. **Concept —** The finest granularity constitutes the building blocks from which modules will be assembled. Students can exert control to jump forward or back through concepts. When a tutor interacts with a student, it is common for the student to ask for a concept to be repeated. Similarly a student may want to repeat a module with the option to skip over concepts that were understood the first time. Concepts and concept streams are available for different learning styles.

Two demonstration topics have been prepared for delivery over the web so that students interact with the server-based tutor through a standard web browser with a free plug-in to support Adobe® Flash®[4]. This demonstration project provides two sets of modules covering topics that are core parts of a digital logic design class. The modules are served with all interactions recorded. Each topic is available on-demand to be taken at the convenience of each student.

Learning about Learning

As students progress through GOAL-based instruction, their paths are recorded to support learning about learning. Data collected during a student lesson naturally includes outcome-based measures to assess individual learning. However, the path image contains many hints as to how each individual student acquires mastery of material when a variety of options is available. Does a student proceed methodically in a sequential manner, adding new material on a foundation of basics? Does the student instead sample a little of each topic, adding more details and understanding in a spiral process, revisiting each topic multiple times? If there is a set of learning activities available, does a student choose none, some, or all of them? Are the activities performed in tandem with the material or after seeing a large sequence of presentations? Does a student tend to choose the more abstract presentation or the more concrete or both? If both, which first? Does either tendency correlate with the use of learning activities? There is a very large set of such questions we can investigate using the data gathered by GOAL.

This project includes development of initial analysis techniques to examine each path using characteristics that are associated with the learning dimensions, metrics associated with the number of times a module is visited, the frequency and duration of learning style changes, and the effectiveness of each module as measured by content knowledge. What is more exciting than the possibility of watching and measuring learning in situ is the ability to correlate and compare these measurements with other factors, including demographic characteristics, academic characteristics such as academic year and major, and self-selected preferred learning style[5]. GOAL provides the potential to measure the characteristics of a learner and perhaps even to predict the most effective way to present a particular type of material to a particular student. Findings may be applicable to a broader set of situations such as classroom teaching.

Evaluation

The central objective of this project is to provide proof of concept that this approach to teaching and learning will improve efficiency and availability of instruction to match different student abilities, schedules, and learning styles. The primary premises are that:

1. Distance learning using the GOAL approach can be as good as traditional classroom learning. This addresses the effectiveness of this approach.

2. Adapting the presentation of material to the students' preferred learning style will enhance the student learning experience. This will manifest in student satisfaction, interest, and continued motivation.

3. The ability to record and analyze students' paths through the topic presentations will provide a mechanism for collecting new, rich data on student learning in terms of needs and style. This will also allow for the improvement of instruction provided by this delivery system, and will provide new in-formation on learning.

Therefore, the evaluation of this project ascertains the ways in which this new delivery system provides effective, efficient instruction for diverse learners. The project evaluation uses a mixed method design, using both quantitative approaches (tests, instruments, percentages, etc.)

and qualitative approaches (focus groups, questionnaires, observations, interviews, etc.) The evaluation also includes both formative and summative evaluation components.

Status

The first prototype topics will be subject to student trials during the Spring semester of 2010. Data collected from these trials will be used to refine the framework and the delivery. Also, initial analysis will be performed on the data collected.

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