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ABSTRACT

This project enhances the transportation engineering curriculum by making teaching methods more efficient, realistic, flexible and engaging. This enhancement was accomplished by creating training materials that incorporate complex simulation models and real traffic control hardware. Training materials were structured so that individuals interact with the hardware and at the same time take advantage of life-like simulations of traffic operations provided by traffic simulation models.

To implement this type of training method, a hardware-in-the-loop-system (HILS) was used. A central part of HILS is NIATT’s recently developed controller interface device (CID). The CID is well suited to networks of 20 intersections or more. This project utilizes the NIATT CID to create a HILS that can be integrated into training materials thus enabling the consideration of simple to complex signal systems in transportation engineering curriculum.
INTRODUCTION

Current university curriculum in traffic signal control covers such topics as fixed time signal timing, signal coordination, and actuated signals. Frequently, tools used to convey this information are lectures and laboratories. There are, however, several areas in which this type of curriculum is limited and does not meet the needs of future and current transportation engineers. The root of this shortcoming is that the tools used in the curriculum, in almost all cases, are inadequate. One type of teaching tool is models. Due to time constraints, only the simplest models, such as HCS or Synchro, are used in most current curriculum. These models are unable to accurately model complex situations that frequently occur in practice such as cycle failures, queue spillback, pedestrian actuations, actuated signals, and coordinated signal control. This results in decreased student appreciation of such situations and reduced understanding of how they are addressed in engineering practice.

Another inherent problem with models used in transportation engineering curriculum is that the signal parameters that are output are not implemented in any actual traffic controller during the course or laboratory exercise. In fact, in many cases the signal timing plans cannot be implemented in a traffic controller without going through the effort of translating them from the model output format to the traffic controller input format. Giving students the opportunity to implement the signal-timing plan that they have created in an actual traffic controller introduces the student to two real-life situations. The first situation is the actual implementation of the signal-timing plans in the field and the second is that plans developed by using traffic signal models generally need to be modified or augmented to function correctly in a traffic controller.

This leads to the next shortcoming of models used in the current curriculum—the models do not accurately reflect actual traffic controller operations. Some specific examples of this are actuated intersections (in the case of simple deterministic models such as HCS), pedestrian actuations, signal preemption, and diamond interchange operations. This makes it more difficult to teach cause and effect relationships associated with different signal timing design
parameters such as extension intervals, maximum recall, minimum green, maximum green, and offsets.

While models are frequently used for university instruction, the most prevalent teaching tool is the lecture. In many instances, the lecture is not the most effective means for communicating signal control concepts, especially if lecturing is the sole means of communication. For example, the concept of gap-out and maximum gap may seem abstract unless presented in a way that the student can see how varying values of maximum gap affect the system. With lectures, it is also frequently a challenge to describe system failures and how these problems are exacerbated or remedied by different timing plans. One example is queue spillback at a diamond interchange. The challenge here is to demonstrate how standard timing plans prove inadequate and to show how implementing something like a Texas-three-phase signal timing plan can be used to remedy the problem.

Recently, hardware-in-the-loop simulation (HILS) recently made available to the transportation engineering profession. In general, traffic simulation models generate and track vehicles that operate based on a set of rules to ensure that they behave as realistically as possible. These models also govern the operation of signalized intersections through the implementation of algorithms for a coordinated actuated control system. Unfortunately, the controller parameters available in current traffic simulation models are limited to only the most common features provided in actual traffic control systems. This gap between simulation and reality can be addressed by substituting the simulation control systems with actual control systems, a process called hardware-in-the-loop simulation (HILS) [Engelbrecht, 2001; Bullock, 1998]. This process involves the physical replacement of simulated controllers with actual controllers, and it can help address the problems in current traffic engineering curriculum associated with models and teaching format.

The primary benefit of HILS is that it functions with an actual traffic controller, this is the hardware. This allows a great deal of flexibility to model complex situations such as diamond interchanges [Koonce, 1999] and signal preemption [Nelson, 1999]. Implementing HILS in a
course can help teach cause and effect relationships of signal timing concepts as simple as extension intervals and minimum green times to more complex ones such as signal phasing and signal coordination. Students would have the opportunity to deal with the realities of signal timing such as conversion from model outputs to controller inputs and the exercise of fine-tuning these inputs. Finally, HILS provides an efficient means for demonstration and student interaction with traffic signal systems. These demonstrations and opportunities for interaction would greatly increase student retention of traffic signal systems concepts.

Currently, HILS has been used for the evaluation of signal control systems by state departments of transportation and for experimental purposes in research but has been implemented in traffic engineering curriculum on a limited basis. One reason for its limited use in traffic engineering courses is that the HILS technology is not widely available. Another is that traffic engineering faculty are not convinced that it would improve course quality and as a result do not want to spend the resources required for HILS implementation. Recently, traffic control hardware vendors have started to offer HILS enabling technology at reasonable prices. However, the problem of HILS implementation in traffic engineering courses still needs to be addressed.

Traffic engineering curriculum needs to be improved to provide students and professionals the right combination of lecture, laboratory, and design experience. Current curriculum are structured in such a way that students and professionals get little opportunity to explore issues associated with signal control. This approach to education does not expose the undergraduate students to the myriad of exciting challenging issues that would encourage them to pursue careers in transportation engineering. Fortunately, HILS could be integrated into existing courses to improve student capability to interact with very realistic situations. In effect, this would allow students to explore issues currently covered in an existing course but to a greater, more engaging detail.
PROBLEM STATEMENT

Enhanced teaching methods are needed so that students will be able to retain more information, explore some challenging traffic control issues, and be encouraged to pursue careers in transportation engineering. This can be accomplished by developing teaching methods that are more efficient, flexible, realistic and engaging.

With the advent of HILS, new approaches to teaching can be explored and developed. However, little has been accomplished in the way of exploring and implementing HILS in transportation engineering curriculum. The purpose of this project is to develop undergraduate, graduate, and continuing education training materials that draw upon HILS to enhance the transportation engineering curriculum.

RESEARCH APPROACH

The target audience for the training materials was both undergraduate and graduate students, though the materials developed could be used to train entry-level engineers as well. Training material was created to meet the needs of the target audiences by varying the complexity of the topic being discussed, as well as the degree of instructor involvement. The introductory training material contains more problems that have unique solutions with fewer variables. More open-ended problems are introduced as the level of competency increases.

HILS was incorporated into this new training material by requiring that the trainees interact with the traffic controller to implement changes ranging from small to complex. Small changes were as simple as modifying green time for a particular phase and complex changes were as involved as the development and implementation of completely new signal timing plans. Furthermore, HILS increased the student and trainee interaction with real traffic control hardware and real life scenarios. The training material was structured so that this interaction improved learning and teaching efficiency by prompting interaction as each concept is introduced.
A controller interface device (CID) is required for each intersection and controller that is included in the HILS. The CIDs used in this research were those developed by researchers at the National Institute for Advanced Transportation Technology (NIATT). The laboratory environment contains seven workstations where two students work together to master the subject of traffic signal timing.

As the training materials were developed, feedback was solicited from traffic engineers at the Idaho Transportation Department, faculty members at the University of Idaho, members of the NIATT peer review panel, and training session participants. All training modules were beta-tested by students whose background is representative of the target audience. This feedback was then used to enhance the training materials to better meet the objectives of this research and the needs of the target audiences.

**TRAINING MODULES**

Four training modules were created as part of this project:

1. Basic signal timing
2. Actuated signals
3. Coordinated signals
4. HILS or hardware-in-the-loop simulation

These modules can be accessed on-line at http://www.its.uidaho.edu/niattproject.

In all modules, background information necessary to understand and complete the exercises can be easily accessed within the website. Because frequent use is made of traffic simulation software and traffic signal optimization packages, tutorials on their application to the exercises were created and are also available on the website. The tutorials are as follows:

1. Creating CORSIM input files
2. Using CORSIM
3. Viewing CORSIM output
4. Observing the simulation animation using TRAFVU
5. Using SYNCHRO to model isolated intersections
6. Viewing animations of SYNCHRO simulations
7. Using SYNCHRO to optimize coordinated systems

While these tutorials do not go into great detail regarding their specific topics, they do present the level of information necessary for individuals to complete and understand their exercises. Because the tutorials and the rest of the training material are available from the same website, individuals can easily access the information that they need if they do not remember how to perform a particular task.

Beta testing of the training material was performed either by students in a lab required for an undergraduate course or as part of students’ research internships. In both cases, students performing the beta testing were new to the subject of traffic signal timing and thus representative of the target audience for these training materials.

One of the primary problems noted by the beta testers was the difficulty of navigating the training material website. More specifically, students found it cumbersome when they had to go through multiple web pages to access the information that they needed. In response to this, improvements were made to the navigations options by creating the following links, which are available on all pages:

1. Home
2. Basic signal timing
3. Actuated signals
4. Coordinated signals
5. HILS
6. References
7. Tools

When the cursor passes over these links, outlines comprised of additional links that can be selected are displayed. The link for References was added to clarify the supporting documents for some of the material used in the training modules and tutorials. Tools was
added as a link to provide easy access to information that individuals frequently use and may not remember, so that they can complete their training exercises more efficiently.

The basic structure of the training modules is to include first a discussion of the background material and then to introduce case studies that get progressively more complex. In the Basic Signal Timing training module, for example, once the user has studied the background material, he or she can begin the case studies. Case Study One introduces HILS and traffic controller programming and then walks the user through the process of calculating an improved two phase signal timing plan and HILS for the same intersection. Case studies Two and Three have different travel patterns and require different signal timing plans. Case Study Four uses overlapping protected left turns. An additional case study discusses capacity at signalized intersections and the final case study involves a design project for an isolated intersection in Moscow, Idaho.

The other two traffic signal timing training modules operate the same way—introducing the individual to the topic of the module through the background and then starting with a simple case study. Though these modules do not include design problems, they could be added easily within the framework of the existing training modules.
CONCLUSION

This project resulted in a suite of training modules and supporting tutorials that provide an interactive medium whereby individuals unfamiliar with traffic signal timing can be introduced to the primary topics in traffic signal timing. These training materials are focused around a set of case studies that use hardware-in-the-loop simulation (HILS) to help students internalize the concepts of traffic signal timing. Furthermore, sufficient supporting information is provided with the training modules so that individuals have all of the information necessary to complete the case studies. Finally, navigation of the website is such that its various links can be accessed with minimal effort, making the learning process enjoyable and more efficient.

The structure developed for the training material and the electronic medium that was used allows future additions and improvements to be made with minimal effort. In addition, the training material can be accessed from the web, allowing other organizations to easily incorporate it into their educational programs.
REFERENCES


