

## Work in Progress: Development, Implementation and Evaluation of a Learning Object for Teaching Control Systems

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### Abstract

This paper reports on a work in progress in developing an interactive Control Systems learning object. The objective of the work is to enhance active learning and visualization, and to provide students with improved formative feedback and review of the learned concepts despite challenges of increased class sizes. The module is developed within a framework of the Co-operative Learning Object Exchange (CLOE), a collaborative project of several universities in Ontario, establishing an infrastructure for joint development of multimedia-rich, interactive learning resources. Since development of such resources is very time-consuming, one of the emerging trends in instructional technology is to focus on modular learning objects that can be shared among many users. Surveys of faculty confirm high interest in utilization of such objects. The module being developed by the authors consists of a series of interactive online tutorials. It is designed using Flash and streaming video technology and provides graphics, video, and animation to support the basic concepts. At any time the learner has access to several review quizzes, providing feedback on comprehension of the content. In-class testing of the beta version of the module is planned for Winter 2004, to be followed by a more systematic evaluation of the module's usability and observations of the interactions with the module by volunteers with different learning styles.

### I. Background

#### Learning Objects

Borrowing from the concept of object-oriented programming, learning objects can be simply defined as any computer-based instruction components that can be reused in multiple contexts<sup>1</sup>, and are generally understood to be deliverable over the Internet, allowing simultaneous access, collaboration and sharing of resources. Canadian Co-operative Learning Object Exchange (CLOE)<sup>2</sup> defines the learning object as “any digital entity designed to meet a specific learning outcome that can be reused to support learning”. In most existing online learning objects repositories, such as MERLOT<sup>3</sup>, WLH<sup>4</sup> and CLOE, the learning objects include some form of

interactivity, such as a Java applet requiring some user actions, or an online quiz providing instant scoring and feedback.

The concept of sharing digital resources is not new. At any given time hundreds of universities and colleges offer courses on similar topics and many publish their courseware online. Given the huge time investment required to create quality online materials, there is a lot of duplication of effort, and some institutions have begun to actively collaborate on sharing of such resources. Some of such courseware is available free online, MIT's OpenCourseWare<sup>5</sup> initiative being probably the most well-known example. OCW is advertised as a free and open educational resource for faculty, students, and self-learners around the world and boasts over 500 of its courses to be available online.

However, such attempts at sharing resources for whole courses, while having a broad appeal, have in fact limited practical usefulness. This is because of varying local requirements, depth of coverage, accreditation conditions, etc. Charles Reigeluth, a professor of education at Indiana University Bloomington and well-known instructional technology expert is quoted as suggesting that when teachers gain access to instructional materials, they break the materials down into their constituent parts<sup>1</sup>. They then reassemble these parts in ways that support their individual instructional goals. This explains the appeal and growing popularity of the learning objects repositories. If instructors have access to individual components of educational resources in the form of small, reusable chunks of instructional media, the decomposition step of the adoption process could be bypassed, increasing the speed and efficiency of instructional development for each potential educational user. Surveys regarding the use of digital instructional materials and online technologies support the idea of learning objects as the area of future growth. Learning objects are touted as the trend that will have the biggest impact on online learning in this decade, requiring a radical change in instructional design strategy, technical architectures, and delivery systems.

Sharing resources to save development time and cost is very appealing. A survey<sup>6</sup> of instructors using the MERLOT and WLH repositories showed that over 80% of respondents felt that providing online content is very time consuming. A Canadian survey on faculty perceptions regarding technology and student success, conducted annually among Canadian faculty since 1999 by McGraw Hill<sup>7</sup>, had similar findings. The two most frequently mentioned barriers to wider creation and use of digital resources were: knowing what is available (50%) and lack of development time (49%). Thus it is not surprising that in a recent survey<sup>8</sup> of decision-makers responsible for implementations of instructional technology, two thirds of respondents represented institutions interested in using learning objects in online learning.

## Learning Objects Repositories and Scholarship of Teaching

Another important appeal of learning objects repositories is their potential to support the scholarship of teaching. While well-defined metrics exist for evaluation of research contributions through peer-assessed publications, successful grant applications, etc., the academic community seems to be at a loss when it comes to evaluating the scholarship of teaching. Most faculty members have no shared experience of teaching, and no experience of being a member of a community of practitioners. This affects the way teaching is evaluated, and compounds problems arising from the low priority assigned to teaching in hiring and promotion policies<sup>9</sup>. This is particularly true of engineering education<sup>10, 11</sup>. This may be partly to the fact that teaching is perhaps the most privatized of all the public professions, and thus evolved very slowly, compared to other professions<sup>9</sup>. Thus, faculty members interested in educational issues may feel isolated in their own departments. For them, a virtual community of practitioners sharing their experiences and learning from each other provides an answer. Popularity of initiatives to create such communities online, to mention just one such Canadian initiative, *facultydevelopment.ca*<sup>12</sup>, particularly aimed at helping younger teachers, attests to that. Online learning object repositories provide another way out of the isolation surrounding teaching. Submitted materials are peer-reviewed and rated, encouraging and ensuring quality of the resources, but at the same time providing an appealing possibility for an objective measure of educational excellence, comparable with journal publication metrics for research. In the survey<sup>6</sup> of MERLOT and WLH users, close to 50% of the contributors considered developing learning objects as a way for personal growth.

However, it is also important to realize that the promise of the radical change in the instructional design paradigm associated with the learning objects is still largely unrealized. Faculty surveys<sup>6, 7, 13</sup> still indicate that they overwhelmingly use online technology to provide a one-way information flow of mostly course management information and content. Web technology is still seen mainly as the broadcast medium, rather than an enabler of student engagement, collaboration and critical thinking. The McGraw-Hill survey<sup>7</sup>, with its large sample (n=1177) and demographic profile well matched with the data from the Association of Universities and Colleges of Canada (AUCC), provided a good snapshot of the faculty attitudes and practices vis-à-vis implementation of educational technology. Only approximately 10% (n=185) of respondents declared the use of learning objects, but of those, 14% did not know what the learning object was, and many considered web links (43%), lecture notes (22%) and assignments (19%) to be the learning objects. Only 1.5% respondents identified interactive components as the learning objects, and declared their use.

## Co-operative Learning Objects Exchange (CLOE)

CLOE<sup>2</sup> is a collaborative project of fifteen Ontario universities to create an innovative infrastructure for joint development of multimedia-rich learning resources, coordinated by, and located at, the University of Waterloo, Ontario, Canada. Each participating institution will

develop multimedia learning resources, will contribute them to the co-operative exchange and will use resources developed by the other institutions in return. The key innovation of CLOE is a concept of a virtual market economy that will encourage collaboration across institutions to pool ideas and co-ordinate development. The resources re-used the most will provide the most exchange credit for the institutions developing them. A key element to participation in the project is a commitment to utilize the learning object being developed, not just from the faculty at the local university where development work is taking place, but also from the collaborating faculty members at other institutions.

## II. Development of the Control Systems Module

The module being developed by the authors consists of a series of interactive online tutorials and is designed using Flash and streaming video technology, with the main module interface shown in Figure 1. The tutorials cover five areas of an introductory course in Process Control: Basic Concepts, Stability, Tracking, Disturbance Rejection and PID Control.

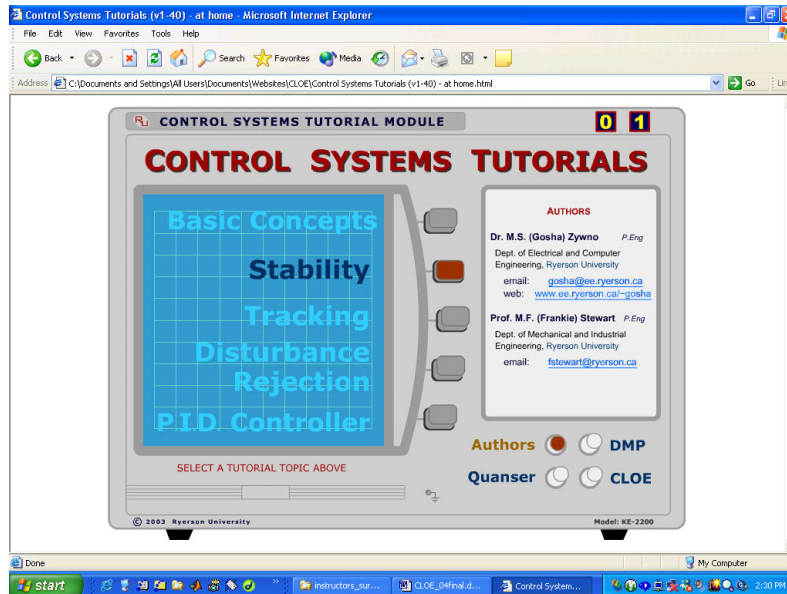


Figure 1: Main Interface of the Control Systems Tutorial Module

The goal for the module is to increase student engagement and support of active learning, issues of continuing relevance in face of increasing enrollments in undergraduate programs in Canada. When implemented in the classroom practice, it will further enhance innovative teaching/learning strategies already in place in undergraduate courses in Controls in Electrical Engineering at Ryerson<sup>14, 15</sup> and at Memorial University, and will also support an introduction of similar strategies into a Control systems course in Mechanical Engineering at Ryerson.

Each tutorial consists of a mix of text and graphics, interactive animations and streaming video.

The module is intended as a “Smart Tutor”, providing interactive introduction to Control Systems. It allows the student to cover various topics at his/her own pace; to activate animations and view videos of actual control systems in operation. As well, each section of the module is accompanied by a self-scoring quiz to test the student comprehension of the reviewed concepts. A screen capture of an animated example of introductory concepts of self-regulation and disturbance rejection in a car cruise control is shown in Figure 2.

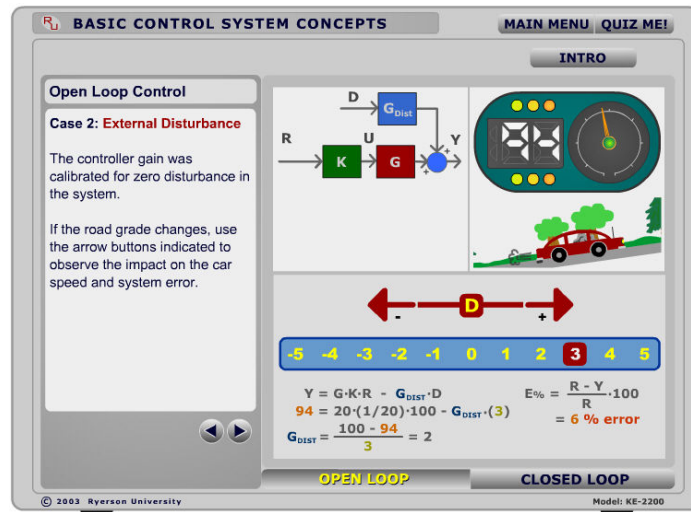


Figure 2: Screen capture of an Animation Example

The project received support input from an industrial partner, Quanser, Inc.<sup>17</sup>, a company specializing in innovations geared towards engineering education, and whose facilities were used in shooting video segments that illustrate practical behaviours of a variety of control systems. Figure 3 shows one of several experiments videotaped for the module. In this experiment, a helicopter simulator is following a pre-set trajectory when it is subjected to a disturbance in a form of a push on its nose, which may represent a real-life condition of an unexpected wind shear. The video then illustrates how the controller is able to handle the disturbance. Other experiments included regulation of the liquid level in interconnected tanks, with a valve opening between them acting as disturbance and an inverted pendulum, a control system educators' favourite, as it represents an open-loop unstable system, challenging to control and at the same time representing very real control challenges present at rocket launches. Several examples of servomotor control under different configurations of the standard three-mode controller (Proportional + Integral + Derivative), a “work-horse” of industrial control systems, were also explored in detail. To relate the real-life system responses better to theory learned in class, video was synchronized with recorded computer displays of the servo tracking the input command, as shown in Figure 4.

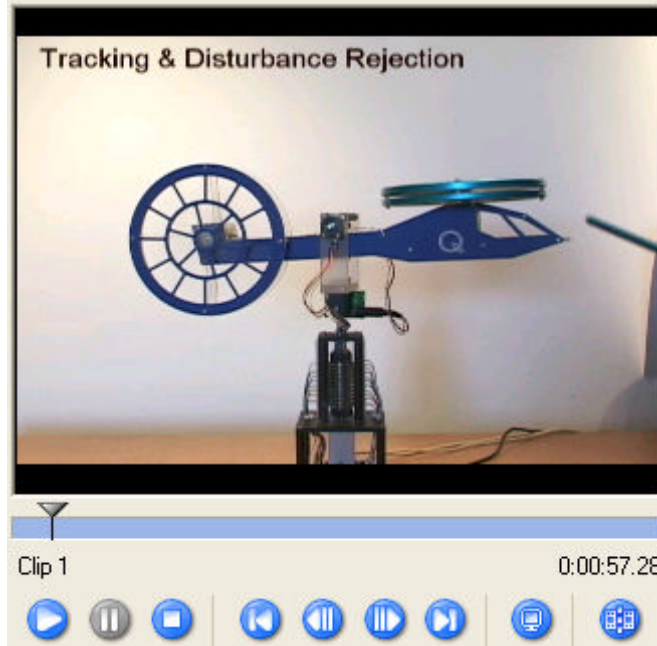


Figure 3: Screen capture of a Streaming Video Example

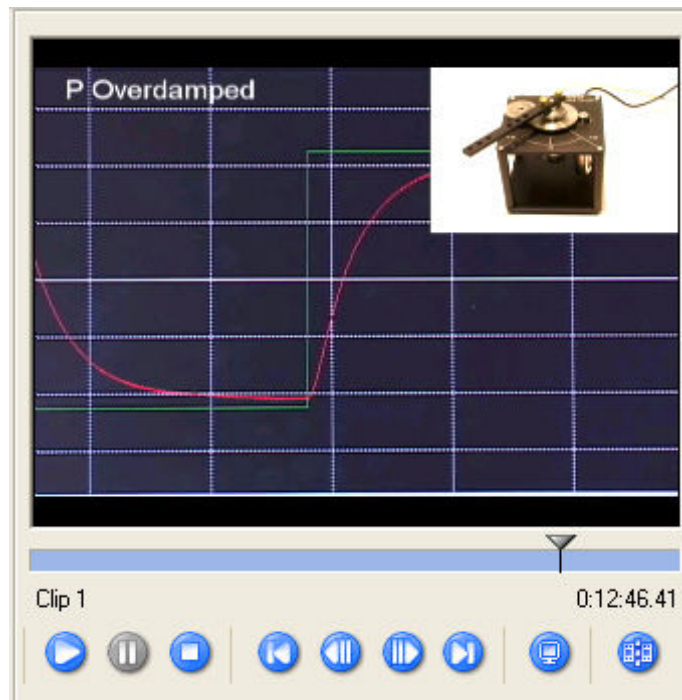


Figure 4: Screen capture of a Streaming Video Example with Signal Tracking

This feature allows a more specific discussion of the system performance, i.e. overshoot, speed

and errors. The system responses can also be related to Matlab simulations performed in the course on models of the videotaped systems.

Self-scoring quizzes follow each of the five tutorials, testing learner's comprehension of the content, but can also be accessed at any time from any point in the module. Answering quiz questions provides formative feedback for the learner regarding whether the answer was right or wrong, and why. The project represents an example of an interdisciplinary, team approach to developing and testing courseware. The authors teach in the departments of Electrical and Mechanical Engineering, respectively, and have been working on the project in cooperation with the Digital Media Projects Office<sup>16</sup> at Ryerson. Beta version of the module, expected to be available by the end of January 2004, will be tested in-class by three instructors teaching different Control Systems courses at Ryerson, as well as by one instructor at the Memorial University of Newfoundland. The instructors will provide feedback on how the module fit into their instructional design, on its content, on the module quizzes and on student reactions. Student survey on the module usability is also planned.

### III. Further Work

Once the beta-testing of the module is complete, a more systematic evaluation of the module is also planned, using a Talk-Aloud Protocol observations of several student volunteers to be recruited for the project. The volunteers will interact with the module, and will be also asked to complete a learning style questionnaire, and a pre- and post-test quiz. The learning style model to be utilized in the proposed follow-up evaluation is the Felder Learning Styles Model<sup>18, 19</sup>, with its corresponding psychometric instrument, the Felder-Soloman Index of Learning Styles questionnaire<sup>20</sup>. The first author has recently completed a large study of the relationship between learning styles described by the Felder Model and learning outcomes in a technology-rich environment<sup>14, 15</sup>, including a contribution to the validation of the ILS<sup>21</sup>. In that study, due to its logistics, no direct observations of the users interacting with courseware were possible, so using this particular model will constitute a natural follow-up to the previously completed work. Feedback from the students and faculty utilizing the tutorials, as well as the results of the more systematic evaluations of the learning object will be reported at the future ASEE conferences.

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