AC 2007-765: CIRCUITS LEARNED BY EXAMPLE ONLINE (CLEO)

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Abstract

Project CLEO (Circuits Learned by Example Online) offers a comprehensive web-based repository of solved circuit analysis example problems delivered as narrated video clips. The videos are created by drawing and writing on a computer-hosted digitizing tablet while a screen capture program captures video frames and audio of the content expert's commentary. The result is a carefully scripted and edited hand-drawn animation that appears as a close-up of a piece of paper with writing and drawings appearing as if "by magic." Results from research in teaching and learning motivate the pedagogical style of the commentary, which emphasizes expert explanations of the rationale behind the multi-step solution process. Since beginning students often experience difficulty knowing how to conceptualize the big-picture solution process, watching and listening to the visual solution unfold (redrawing and simplifying circuits, highlighting points of interest, writing equations) helps students to learn available options and strategies at each juncture of the multi-step problem, and to become familiar with common conceptual pitfalls and how to avoid them. The video format accommodates various styles and rates of student learning since students can interact with the material by pausing, replaying, and skipping to points of interest as needed. The audio commentary – by far the most valuable aspect of the video – is available in English, Chinese, and closed-captioned text.

Introduction

"Please do more examples in class" is an oft-repeated request of engineering students taking sophomore-level circuit analysis courses. Instructors try to strike a balanced presentation of general theories, facts, problem-solving strategies, and illustrative examples, but it seems that students always want more examples. Students spend most of their out-of-class time preparing solutions to homework sets, so they express a desire for many specific examples. While some students may simply be seeking templates for pattern matching, the fact remains that learning by example is a powerful and effective way for anyone to begin mastery of a new knowledge domain[1]. Observing an expert solve problems in a particular knowledge domain constitutes an early stage in the apprenticeship style of learning[2] in which a learner begins by observing, then tries the activity with frequent feedback from the expert, then continues with decreasing feedback as the learner becomes more like the expert. Outside of class, students find additional examples in print resources such as textbooks and study guides such as Schaum's Outline series, online tools such as MIT's OpenCourseWare[3], and archived online lectures. Online lectures are frequently accessible only to enrolled students, but some schools provide complete archived lectures free of charge, for example, the EECS 40 circuit analysis course at UC Berkeley[4]. However, students have limited time to devote to any particular class, and searching through hours of archived lectures for the single needed example relevant to the problem at hand is not feasible. A single "one-stop shopping" web-based repository of worked examples accompanied by expert explanation would be a valuable resource.

We have developed Project CLEO (Circuits Learned by Example Online) as a comprehensive web-based repository of solved circuit analysis example problems delivered as narrated video clips. The materials are intended to augment any standard one- or two-semester sophomore-level course in circuit analysis. The videos are created by drawing and writing on a computer-hosted digitizing tablet while a screen capture program captures video frames and audio of the content expert's commentary. Results from research in teaching and learning motivate the pedagogical style of the audio commentary, which emphasizes expert explanations of the rationale behind the multi-step solution process, and also explains common misconceptions and pitfalls. The examples available at CLEO can be worked by the student before watching the expert video as a test of their own mastery, or the videos can be watched first for instruction in a new topic. The video format accommodates various styles and rates of student learning since students can interact with the material by pausing, replaying, and skipping to points of interest. The audio narration is available in English, Mandarin Chinese, and closed-captioned text to ensure that non-native English speakers and hearing-impaired individuals have full access to the learning materials.

In this paper we review previous work in remote delivery of educational video for circuit analysis courses, and the apprentice-style pedagogical model upon which CLEO is based. At this time the project is a work in progress, and we present our results so far.

Remote Delivery of Video-Based Learning Materials – A Brief History

Remote delivery of video-based educational materials dates back to the MPATI (Midwest Program and Airborne Television Instruction) project during the early 1960s[5]. Sputnik's launch in 1957 initiated a massive increase in federal funding for science and math education. A shortage of qualified high school science and math teachers was overcome by placing television sets in schools, and a DC-6 airplane filled with television broadcast studio equipment flew around the state, transmitting educational videos to schools who would tune in at the proper time of day. This "one expert to many learners" model is precisely what the Internet today makes possible for a world-wide audience.

Beginning in 1961 William Hayt, Jr., created over 50 instructional videos for circuits classes[6]. Closed-circuit circuit television by microwave link was used to deliver a two-semester course sequence to a branch campus in Indianapolis, which is now Indiana University - Purdue University at Indianapolis (IUPUI).

In 1985 National Technological University (NTU) pioneered satellite transmission of live and taped lectures of courses intended to serve practicing engineers working in industry[7]. A two-camera approach was used to record the lecture, with one camera facing the instructor and another suspended from the ceiling over the instructor's writing pad to show writing, diagrams, and equations. The instructor's head-shot would often be placed as an inset into the primary view of the writing pad. The "JustAsk" web-based resource under development by Wiley Publishers[8] uses a similar approach, in which an overhead camera captures the instructor's writing and drawing.

Today transmitting lectures live or from pre-recorded archives over the Internet is a mainstay of distance education. Producing and transmitting live content has become very easy and cost effective in recent years with the emergence of screen capture software tools such as

TechSmith's Camtasia Studio and Macromedia Captivate, making it feasible for an individual faculty member to produce all of the needed materials with little or no support from other university staff. At the receiving end, most students have high-speed Internet access on and off campus, and standard video software such as Microsoft MediaPlayer, Apple QuickTime, and Shockwave Flash require no specialized hardware. In addition to capturing a complete lecture, other types of web-delivered visual aids abound for circuit analysis. Interactive tools such as "6.002x Circuits Tutor"[9] and "Electric Circuit Study Applets"[10] present a circuit and problem statement to the student, who in turn solves the problem and submits the numerical answer. The interactive module grades the problem and provides feedback. The CyberProf project[11] which evolved into the Mallard web-based tool[12] are also well-known as automatic graders for circuit problems.

Other interactive modules available at repositories such as NEEDS[13] and MERLOT[14] illustrate or animate a particular concept, with the student interacting with the simulation to develop a more intuitive feel for the concept.

Pedagogical Model for CLEO

The report *How People Learn: Bridging Research and Practice*[15] summarizes three key principles learned from research on teaching and learning: (1) The student's initial understanding of and preconceptions about the new knowledge domain must be recognized, (2) mastery of a subject requires that a deep knowledge of facts be organized into a broad conceptual framework, and (3) students need encouragement to define their own learning goals and self-assess. Based on these principles, the report recommends that teachers acknowledge the pre-existing knowledgebase of the student (correcting any misconceptions as needed), provide a firm base of factual knowledge, and offer many examples to show how a given concept can be applied to a variety of problems.

The apprenticeship model[2] is another relevant learning principle, consisting of a four-step process in which the learner first observes an expert modeling an activity, then receives advice and examples, then tries the activity under supervision of the expert, then continues the activity with less and less supervision until the learner has also become an expert.

Worked examples are clearly an important part of learning any new subject. In the initial stages of learning a new domain, research studies have demonstrated that asking students to study correctly worked examples is more effective than solving problems[17]. Self-monitoring skills can be developed by asking students to identify the flaw in incorrectly worked examples[18]. A deeper understanding can be achieved when students are asked to explain both why correct solutions are correct, and why incorrect solutions are incorrect[19].

The principles described above guide the design of Project CLEO. The structure of the CLEO website allows students to either try the problem first (self-assessment) or go straight to the expert's solution to the problem. The expert solution is based on over fifteen years of collective experience teaching circuits to sophomore engineering majors, so common misconceptions that the students bring into the class are pointed out and explained. The expert also discusses the available options at each juncture of the multi-step solution, and explains the rationale for selecting a way to accomplish the next step.

Progress to Date

During Summer 2006 the Project CLEO's website front-end and database back-end were developed, as were 150 new problems to cover the first semester of a standard linear circuits course. Nilsson and Riedel[20] and other widely-adopted textbooks were used to design the topic coverage, including introductory topics in circuit variables and elements, simple resistive circuits, analysis techniques (nodal, mesh, Thevenin equivalents, source transformations), and operational amplifiers. The second-semester content – sinusoidal steady state, phasors and power, frequency-domain techniques such as Laplace and Fourier transforms, filters, and two-port networks – will be developed during Summer 2007, bringing the total problem count to 300 to provide an average of four worked examples per class day of instruction for a 15-week semester. The website provides a variety of search mechanisms to find problems of interest. In addition, an instructor may organize selected problems into a "playlist" to make it easy for students to find relevant problems for each day of class.

In order to broaden the accessibility of the materials, the audio language can be selected as either English or Chinese. We plan to add Spanish audio in the future. Moreover, captioning can be selected so that hearing-impaired students can read the commentary.

The assessment and evaluation component of the project will study correlations between website usage patterns, demographic information (major, gender, and ethnicity), and academic performance (end-of-term course grades). In order to maintain confidentiality, students receive an account number from their instructor, and only the instructor knows the student name associated with the account number. When a student uses the CLEO system for the first time, they read an informed consent statement and indicate that they agree to participate in the study.

We are presently working with faculty at [our home institution] as well as at five other universities that represent a mixture of public and private institutions as well as large and small institutions. Student usage information is now being collected, and we plan to expand the number of participating universities during the next academic year.

Conclusions

Project CLEO offers a new resource for students taking engineering circuit analysis courses. The videos are structured around the apprentice-style pedagogical model, which emphasizes explanations by a content expert, and explains *why* the multi-step problem is solved in a particular way. The video materials are delivered by a website that facilitates searching for worked problems that are similar to the problems that have been assigned as homework.

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