Techniques to Introduce Historical Computers into the Computer Science Curriculum

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Abstract: *Recent research has shown that students should be familiar with computer history. This paper examines three projects whose goals are to bring history of computers and technology into the computer science classroom in innovative and interesting ways – a video of the PDP-11/10, a virtual reality simulator of the ENIAC computer, and a videotaped interview with one of the principal designers of the ENIAC.*

Key words: *History of Computing, ENIAC, PDP-11, Virtual Reality Simulators.*

INTRODUCTION

Modern computers are significantly faster, smaller, and cheaper than those available just a few short years ago and it is important that computer science curricula keep pace with current developments in software and hardware design. However, it is also important that students have at least an introductory understanding of and appreciation for the technological developments which are the basis for today's technology.

In recent years many computer science curricula have included "history of computing" topics, and in fact the ACM Computer Curricula 2001 [5] includes significant history components. There are several reasons to include history in the computer science curriculum, including the following:

- Understanding and appreciating historical developments helps students place current technology and developments in their historical perspective, and can also help them predict future trends in technological development [1].
- Old computers were usually larger than today's computers and in some cases students can more easily visualize and understand computer science concepts on these old computers because it is easier to "see" abstract concepts (e.g., bits, bytes, busses, etc.) [3].
- Learning about the people who made significant contributions to computer science and technology can help students understand the political and social context and environment in which these developments were made; it can also help students understand and appreciate the "human" aspects of computer science.

The challenge to computer science faculty is how to introduce computer history into a course without it becoming merely "boring" historical facts and memorization. In this paper three projects of the author's are briefly described that attempt to bring history into the classroom in innovative and interesting ways: a video of the PDP-11/10 minicomputer, a virtual reality simulator of the ENIAC computer, and a video of Dr. Arthur Burks who was one of the principal designers of the ENIAC.

PDP-11/10 VIDEO

The PDP-11/10 was developed by Digital Equipment Corporation (DEC) and introduced in June 1972. It is one of the earliest members of the very successful PDP-11 family of minicomputers. The PDP-11/10 CPU implements the basic instruction set of the architecture, which consists of 59 instructions and twelve addressing modes. Memory space on the PDP-11/10 consists of a maximum of 64 KBytes, and memory is implemented with magnetic core. A front panel consisting of several lights and toggle switches is included with the system, allowing an operator to load and examine registers

and memory, reset the system, and control execution of a program (start, stop, and single-step).

DEC provided some software with the PDP-11/10. Specifically, the machine's paper tape software system included an editor, an assembler, several loaders, an online debugger, an I/O executive, and a math package. On disk systems DEC provided a simple disk operating system (DOS), a job-stream processing system (BATCH), and a time-sharing system (RSTS-11). BASIC and FORTRAN were also available.

The PDP-11/10 computer is physically large by today's standards, as shown in Figure 1. For example, the 48cm x 27cm x 58cm system unit weighs 50 kg and houses the power supply, CPU (implemented on two 21.5cm x 40cm printed circuit boards consisting of approximately 240 SSI chips), core memory (each 16KByte frame implemented on two 21.5cm x 40cm printed circuit boards and one 21.5cm x 40cm printed circuit board holding the actual core memory), and up to twelve peripheral cards. An entire computer system consists of one or more 59cm x 76cm x 183cm mounting cabinets holding the system unit and peripherals, weighs several hundred kilograms, and dissipates several thousand watts of power.

Figure 1. PDP-11/10 System

As a way of preserving our ability to demonstrate the PDP-11/10 to students, the author and a colleague made an instructional video with the help of two students who have taken the Computer Organization course and who also have had courses in television production [2]. The video runs for approximately fifteen minutes and focuses on the topic of developing programs on the PDP/11-10 and other similar computers.

We tried to make the video interesting to our audience in part by constructing a simple story line which unfolds during the video. We begin with a discussion between a modern-day computer science professor and his student during which the student complains about how time consuming it is to write and debug C++ programs. The professor tells the student that things used to be much more tedious in "the old days" and he offers to use a Holodeck Program to take the student on a trip to see an older computer. The pair enters the Holodeck and with the help of some special effects they find themselves in a 1970 era machine room complete with old line-printer art. In the machine room they encounter a programmer who is humorously dressed in 1970's clothing

and who is busily working to write a program on his brand-new PDP-11/10. During the ensuing dialog the professor-student pair asks the 1970's programmer a number of questions about how this machine works. As the questions are answered, the visitors learn how to toggle in the bootstrap loader using the switches on the front panel, and how to edit, assemble, save (on paper tape), and execute simple programs. Along the way points are made about a number of issues including the hardware configuration, the use of the octal number system, how bits, bytes, and files are represented on paper tape, the two-pass assembly process, etc. Whenever possible these points are related to concepts that are typically covered in the computer organization course. For example, the notions of bits, bytes, files, filenames, and directories on a paper-tape system are contrasted to their modern day counter parts.

The video has been distributed to over one hundred academic institutions and is used regularly in Computer Organization classes at several universities including DePauw University and The Ohio State University. The video is typically shown to the class midway through the course after basic concepts such as machine language, assembly language, loaders, memory organization, etc. have been covered. A short discussion session follows the video where concepts presented in the video are emphasized.

83 students over several terms at Ohio State and DePauw were surveyed about the effectiveness of the video, and the results suggest that the video has a positive impact on the learning process. Students were asked to indicate their level of agreement (i.e., strongly agree, agree somewhat, neutral, disagree somewhat, or strongly disagree) with several statements. The statements and results are:

- The video was interesting (73.5% agreed or strongly agreed)
- Watching the video was useful because it helped me to understand the history of computers better (72.3% agreed or strongly agreed)
- Watching the video was useful because it helped me understand one or more concepts that we have discussed in class this semester (56.6% agreed or strongly agreed)
- Watching the video was a waste of time (71.1% disagreed or strongly disagreed)

These results indicate that a significant majority of students found the video interesting and helped them understand the history of computers better. A slight majority of students also found the video helpful in understanding course concepts. Students were surveyed about which course concepts were understood better by watching the video, and these data are currently being analyzed.

The video and other resources are available for free on the web at:

`http://acad.depauw.edu/~dharms/pdp11`

VIRTUAL REALITY SIMULATOR OF THE ENIAC

The ENIAC (Electronic Numerical Integrator and Calculator) was designed and built between 1943 and 1946 at the Moore School of Electrical Engineering at the University of Pennsylvania. It was 2.5 meters high, 1 meter deep, 24 meters long, and occupied a 12 x 18 meter room. It weighed 27 metric tons, consumed 140 kilowatts of power, and contained over 18,000 vacuum tubes. Although it was physically impressive it only had the capacity to store twenty 10-digit decimal numbers. A photograph of the ENIAC is shown in Figure 2.

The ENIAC was designed to calculate artillery shell trajectories for the US Army but could in fact solve a variety of differential equations. Programming the ENIAC was accomplished by setting knobs and switches appropriately and connecting cables between

various components of the machine. Reprogramming the ENIAC often took several days. Although the ENIAC was very different from today's computers, it is the ancestor of practically every modern computer.

In 2001 the author began a project to develop a virtual reality simulator of the ENIAC [4]. Users of the simulator don a head mounted display and are presented with a stereoscopic image of the ENIAC room in 1946. Users can navigate around the room, and interaction with the ENIAC (e.g., turning knobs, setting switches, and moving cables) is accomplished with hand and finger motions using a dataglove.

The functioning of the ENIAC units is fully implemented so users can watch the ENIAC calculate (i.e., see the lights flash) at roughly the same speed at which the ENIAC operated. The ENIAC could be placed in "single-step" mode, and this is also implemented in the simulator.

At present the accumulators, master programmer, and high speed multiplier units have been implemented, permitting relatively interesting programs to be developed on the simulator. A screen shot of the simulator is shown in Figure 3.

The simulator is presently being developed and is not at the point where students can easily use it. However, in the near future the author intends to introduce an exercise in the Computer Organization course where students will study the ENIAC and use the simulator to do some simple programming on the machine.

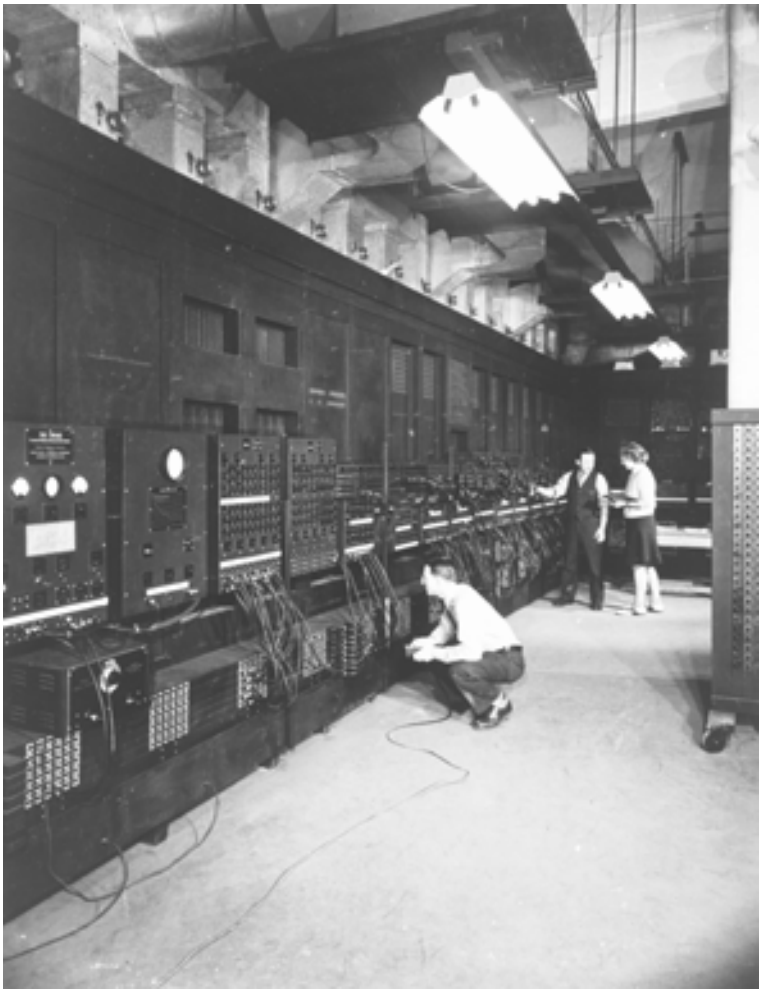

Figure 2. The ENIAC in 1946

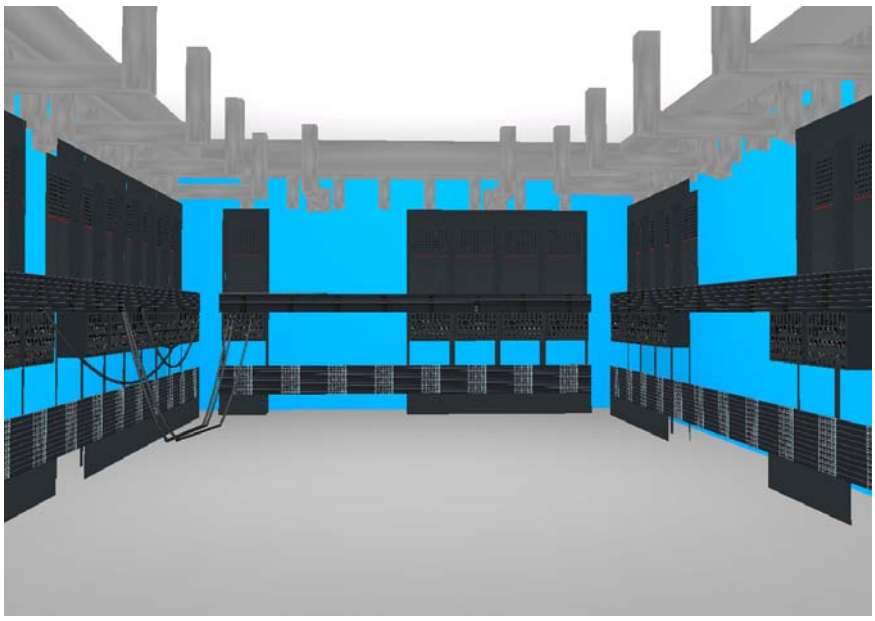

Figure 3. A Virtual Reality Simulator of the ENIAC

VIDEOTAPED INTERVIEW WITH AN ENIAC DEVELOPER

Dr. Arthur W. Burks, who earned his undergraduate degree from DePauw University in 1936, was a senior member of the ENIAC design team and designed several significant portions of the ENIAC, including the master programmer unit. In Scott McCartney's 1999 book, "ENIAC: The Triumphs and Tragedies of the World's First Computer," [6] Dr. Burks is referred to as the number 3 man on the project, behind John Mauchly and J. Presper Eckert. (In Figure 2, Dr. Burks is shown in 1946 crouching in front of the ENIAC.) After working on the ENIAC, Dr. Burks went to Princeton University, and then to the University of Michigan in Ann Arbor where he helped found portions of what is now the Electrical Engineering and Computer Science department.

In the 1960's Dr. Burks arranged with the US Army to have four ENIAC units permanently loaned to the University of Michigan for display. The ENIAC units on display include two accumulators, one unit from the high-speed multiplier, and one unit from the master programmer. The display itself is 2.5 meters high, 2.5 meters wide, and 1 meter deep.

In May 2003 the author interviewed Dr. Burks in Ann Arbor, Michigan, and videotaped him describing the development and operation of the ENIAC; Dr. Burks was also videotaped "programming" the ENIAC components on display at the University of Michigan. Figure 4 shows Dr. Burks describing the ENIAC components. The author has approximately 3 hours of videotape that he is currently editing into several short segments. When these are completed they will be used in the Computer Organization class to help students understand the design and function of one of the world's earliest electronic computers.

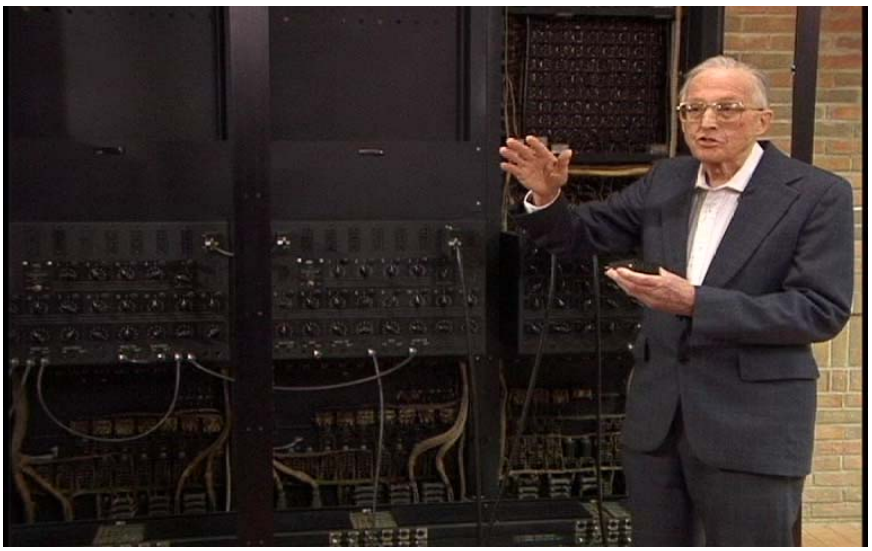

Figure 4. Dr. Arthur Burks with the ENIAC

CONCLUSIONS AND FUTURE WORK

It is important to introduce history of computers and technology into the computer science curriculum in a manner that is both historically accurate and interesting to the student. In this paper three projects have been described – a video of the PDP-11/10, a virtual reality simulator of the ENIAC, and a video interview with a developer of the ENIAC. At the current time only one of these projects (the PDP-11 video) is developed enough to be used in class; data indicates that students do benefit from the video. When the remaining projects are completed they too will be incorporated into coursework and their effectiveness evaluated.

Also, the author acknowledges that these projects all center around the historical development of US computers. Future work will include projects involving the development of computers in other countries.

REFERENCES

[1] Kurzweil, R. (2000) *The Age of Spiritual Machines: When Computers Exceed Human Intelligence*. New York, USA, Penguin Group.

[2] Berque, D., Harms, D. (2001) Using a PDP-11/10 to teach content and history in computer organization courses. *Proceedings of the thirty-second SIGCSE technical symposium on Computer Science Education*, Charlotte, North Carolina, USA, 209-213.

[3] Harms, D., Berque, D. (2001) Smaller and Faster is not Always Better: Using Old Hardware to Teach Computer Science Students, *Journal of the Association for History and Computing*, Vol. IV, No. 3 (November 2001). <http://mcel.pacificu.edu/JAHC/JAHCiv3/ARTICLES/harms/harms.html>

[4] Harms, D. (2004) Poster Session: A virtual reality simulator of the ENIAC. *Proceedings of the thirty-second SIGCSE technical symposium on Computer Science Education*, Leeds, England, 239.

[5] The Joint Task Force on Computing Curricula (2001), Computing Curricula 2001, *Journal on Educational Resources in Computing (JERIC)*, v.1 n.3es, Fall 2001.

[6] McCartney, S. (1999) *ENIAC: The Triumphs and Tragedies of the World's First Computer*, Walker Publishing Company.

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