Work in Progress – Putting a Course in Context

Alan Clements
School of Computing, University of Teesside,
Middlesbrough TS1 3BA, UK. a.clements@tees.ac.uk

***Abstract* – An undergraduate course can be characterized by its breadth and its depth. *Breadth* is a measure of the range of topics covered and *depth* is a measure of the rigor with which they are taught. To provide students with the tools necessary to help them find employment, undergraduate courses in computer science concentrate on depth at the expense of breadth. Consequently, students often lack a historical perspective on their own subject and do not know how it developed. All too frequently students are not even aware of alternative approaches to computer-based problem solving. Nowhere is this truer than in computer architecture education. This work in progress describes the construction of a website that provides a background for computer architecture courses by putting material in a historic and social context and by introducing alternative computing mechanisms such as neural networks, analog computers and quantum computers.**

Index Terms – Computer architecture education, computer ethics, computer history, neural networks, supporting material, web-based teaching.

LIMITATIONS TO COMPUTER SCIENCE EDUCATION

The ACM/CS CC2001 model computing curriculum specifies courses in all the areas regarded as forming the core of modern degree programs in computer science. A wealth of material has been created to support computer science education, ranging from text books to web-based teaching material. There is no shortage of Internet-based material covering computer science courses from programming to AI.

This work in progress is concerned with one component of the computer science curriculum; that is, *computer architecture*. The ACM/CS CC2001 curriculum for computer architecture includes: digital logic, machine-level data representation, machine-level architecture, memory systems architecture, and interfacing. The website under construction *complements* existing courses in computer architecture. Although it will contain conventional teaching material for the sake of completeness, its primary goal is not to provide a course on computer architecture that simply follows the appropriate ACM/CS CC2001 curriculum.

Computer architecture is often taught in a vacuum with little reference to the wider world of computing. Teachers attempt to supply the missing perspective and context, but the pressure to cover the examinable syllabus in a few weeks makes it difficult to stray far from the core curriculum. The website under construction creates a context for computer architecture by covering its history, relating it to other computing paradigms, and introducing professional issues; for example, a computer designer is as likely to be found in the courtroom defending patents as in the laboratory.

TOPICS COVERED BY THE WEBSITE

History

I am not a historian. I was stung into writing a section on computer history by an article by Kaila Katz [1] who argued that the average perfunctory history of computing in a Computer Architecture text book was misleading at best. Many classic textbooks provide a brief overview of computer history, often so cursory that the basic facts are terribly distorted and the student is left with a misleading impression of the development of the very tool they are studying. In fact, the computer has had a remarkably long history that stretches back to the ancient Greeks.

Students need to appreciate how the computer developed in order for them to understand the forces shaping their industry.

Alternative paradigms

Remarkably, some computer science graduates think that the von Neumann stored computer is the only computing machine, indeed, the only computer mechanism possible. The digital computer is everywhere; it is pervasive and ubiquitous. However, just because the stored program digital computer is so widely used today, it does not mean that it is best suited to solving every problem or that it will still be the only computing machine 40 years after today's students have graduated. The website under construction introduces students to other forms of computation, for example;

- analog computers
- neural networks
- quantum computers
- DNA-based computers.

Students should be aware that not all future computing machines will look like high-speed Pentium processors.

Another reason for introducing students to non-Von Neumann architectures is to help overcome some of their misconceptions. For example, some of my students do not appreciate the fundamental differences between human memory and conventional random access digital memory. In particular, they do not always understand that human memory behaves as if it were *content addressable*, whereas RAM is accessed via the address of the required element.

Professional issues

My students understand that a microprocessor design team may include engineers, programmers, and computer scientists. They are less aware that the lawyer may be as important a member of the group as the computer architect.

Computer architecture texts frequently cover all aspects of computer design but neglect the legal world. There have been several patent infringement cases between computer manufacturers, involving patents dealing with bus protocols, motherboard chipsets, and even interrupt processing. One means of delaying a competitor's progress is to file a patent infringement suit against them and then tie their chief designers up in the courtroom.

ORGANIZATION OF THE WEBSITE UNDER CONSTRUCTION

The website under construction is designed as a resource that students and their teachers can access. The website is divided into five sections: history, ethics, paradigms, resources and architecture. The first three sections cover the type of breadth-before-depth background described above and the last two sections will provide resources and a sample course (taken from my own teaching material). The resources section will contain articles, computer simulators and PowerPoint presentations.

History

The section on history puts computing in a better historical context than some textbooks. It should, at least, dispel the average student's notion that computing began in about 1998 when the PC fell out of a time-warp complete with Windows.

Books typically mention a few great names in the history of computing and leave out many of the forces that shaped computing and many of the enabling technologies, such as the development of the telegraph.

The website material on the history of computer architecture emphasizes the growth of intellectual ideas such as the concept of *conditional behavior*. It also attempts to wean students off the notion that the computer was invented at one point in time.

Ethics

I will be honest and admit that I had never really thought about ethics until I became involved with curriculum development. The CS accreditation for my own school requires a course in ethics. I politely asked my Department Chair where exactly the course was and he said "we integrate ethical considerations into all our courses and don't need anything specific". Mmmmm…

The section on ethics looks at a range of issues ranging from safety-critical systems to intellectual property rights. We focus on professional responsibilities and provide codes of conduct from professional bodies.

We also introduce the idea of safety critical systems and discuss some classic engineering disasters such as aircraft crashes that could well be called "computer-aided tragedies", where lapses in software and hardware design have led to deaths.

Paradigms

This section of the web site looks at alternatives to the von Neumann machine. Twenty years ago universities taught courses in analog computing, once used to solve many numeric problems. Today, scientists are investigating the use of quantum computers as a means of factoring polynomials in cryptography.

We begin with the analog computers that preceded digital computers in the early years of the 20th century. Analog computer technology provided much of the technology needed to develop digital computers.

The next alternative computing paradigm is the neural network. We include it partially because it is far easier to understand than the quantum computer and partially because it is already used in several practical applications where it offers advantages over digital computers.

We also discuss quantum and biological computers. Although quantum and biological computing are not yet in widespread use, introducing these systems helps students appreciate that there is more than one way of performing certain classes of computation and that some of the alternative approaches have advantages over sequential program-driven digital machines.

CONCLUSIONS

The goal of this project is to bring breadth to the conventional computer architecture course's depth. Few professors have the time to cover the details of computer history, issues of computer ethics, and alternative computing models to von Neumann machines. The proposed website under development helps give students a more complete picture of their chosen field than that presented in conventional courses driven by the need to cover as much hard computing as possible in a scant one or two semesters.

ACKNOWLEDGMENT

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REFERENCES

[1] Katz, Kaila, "Historical Content in Computer Science Texts: A Concern", *IEEE Annals of the History of Computing, Vol. 19, No. 1 1997, pp. 16-19*