

A Survey of Web Resources for Teaching Computer Architecture

William Yurcik
Illinois State University
wjyurci@ilstu.edu

Edward F. Gehringer
North Carolina State University
efg@ncsu.edu

Abstract

The use of Web resources is becoming a core part of teaching computer architecture. In this paper we identify five notable Web sites that specialize in teaching tools for computer architecture instructors and discuss the role they can play in facilitating learning. While these Web sites contain a wide range of valuable resources, there remain gaps in what is available online. Community support appears meager for making tools and resources available. We conclude that the computer-architecture community faces challenges both in the content of Web-based materials (accurate and appropriate information) and the process (making information known and available to academic community).

1.0 Introduction

Computer architecture is a difficult subject both to teach and learn for a plethora of reasons including—

- the dynamic nature of the subject, the lifecycle of current computer technology is arguably less than three years and decreasing rapidly
- the ever-expanding amount of relevant material, as new techniques are being developed continuously to build upon existing techniques
- the need for to understand disparate subjects, from electronic circuits to digital logic to assembly-language programming to system design, as well as higher level programming and discrete math and performance analysis and ...
- its lab component, requiring the design and execution of both hardware and software experiments, and
- increasingly higher levels of abstraction hiding more and more lower-level details.

Of course, computer architecture is not the only course facing these challenges, but it may be the one course that faces all of them simultaneously. One academic study of this situation found that even experienced computer architecture instructors found they are not confident or current in some topics considered core to the course [2]. Novice instructors and instructors teaching outside of their specialty area are in a worse situation.

Collectively, however, the computer architecture community possesses an impressive array of knowledge, experience, and tools for teaching the subject. In recent years, many of these resources have been migrating to the Web.

Finding the right resource for teaching a specific topic is problematic, so this paper seeks to provide an orientation to the current state-of-the-art in computer architecture education resources on the Web. The remainder of this paper is organized as follows: Section 2 describes in some depth the five major Web sites containing computer architecture educational resources. Sections 3 and 4 focus on the contrasting resource needs of new and experienced instructors in computer architecture. Section 5 attempts to identify gaps in what is available on the Web versus the needs of instructors and Section 6 seeks to understand why this gap exists. We close with a summary and conclusions.

2.0 Computer Architecture Education Web Sites

Reference 2 highlights the fractured state of computer architecture education, but there have been several attempts to address this problem via community effort. This section describes five significant computer-architecture education sites that contain valuable resources for the community. A survey of these Web sites also reveals unexpected insights into the current state of computer architecture education.

2.1 Computer Architecture and Assembly Language (CAALE)

<http://www.sosresearch.org/caale/>

An NSF-sponsored working group on "Distributed Expertise for Teaching Computer Organization" convened at the July 2000 Innovation and Technology in Computer Science Education (ITiCSE) conference in Helsinki Finland under the direction of Lillian (Boots) Cassel of Villanova University and Deepak Kumar of Bryn Mawr College. The two tangible products of this working group are the CAALE Web site and the seminal collaborative paper that identifies both current problems and potential future solutions for facilitating better computer-architecture education [2].

The goal of CAALE is to serve as a repository for Web-accessible resources identified by the working group, such as links to courses, people, textbooks, simulators, papers, organizations, relevant news items, career information, and conferences. Currently, CAALE is unevenly developed with many links containing no content. Work continues to populate the Web site.

CAALE makes its primary contribution with its comprehensive list and categorization of textbooks and simulators. Response to the CAALE simulator list especially has been immediate, continuous, and growing. It has facilitated data-mining of simulator resources, as presented in two recent papers [5,6]. Future plans include enhancing the interactivity of the Web site using XML integrated with database processing to enable queries to the Web site for information.

2.2 WWW Computer Architecture Page

<http://www.cs.wisc.edu/~arch/www/>

A long-time fixture in the computer architecture community has been the WWW Computer Architecture Page that is hosted at the University of Wisconsin-Madison (and mirrored in India and Japan). Though focused mainly on research, it contains downloadable versions of many simulators and compilers that could be used across a range of educational levels. The extensive content on the Web site include links to architecture projects, organizations, and tools such as simulators, compilers, benchmarks, and traces. It also has links to commercial

organizations, online publications, books, and newsgroups.

The WWW Computer Architecture Page makes its primary contribution with its comprehensive list of researchers, research groups, and conferences. This site is a one-stop virtual location for learning about the state of the art in computer architecture research, especially that emanating from educational institutions.

2.3 NETCARE

<http://punch.ecn.purdue.edu/Netcare/>

NETCARE (NETwork-computer for Computer Architecture Research and Education) is a Web-accessible distributed infrastructure of software tools and computing resources developed at Purdue University. It provides a common environment for testing, sharing, and evaluating tools for teaching and research in computer architecture and programming. It allows users to actually run tools in conventional Web browsers.

NETCARE was developed to address many of the hurdles mentioned in the introduction. Instructors need to obtain access to the hardware resources that meet their requirements, and then install it. They also need to support it, by disseminating documentation and answering questions, and develop educational content, such as tutorials and homework assignments. NETCARE performs all of these functions; small classes are able to use NETCARE facilities directly, while instructors of large classes can load the NETCARE software onto their own server.

Another important feature of NETCARE is its user interfaces. Research simulators often come with text-based interfaces. NETCARE wraps these in graphical interfaces that are tailored to the needs of novice users. This has the advantage of presenting a number of tools with similar interfaces, thus facilitating the task of learning to use them.

NETCARE currently provides 16 tools for computer architecture, including the uniprocessor simulators Daisy, DLX-View, Shade, SimpleScalar, MySimpleScalar, XSpim, and 68HC12 Simulator; the multiprocessor simulators HPAM Sim, RSIM, WWT2, and WWT2H, and cache simulators CacheSim5, CACTI, and DineroIV. Accounts may be

requested by filling out a form at the NETCARE home page.

2.4 Computer Architecture Course Database < <http://cd.csc.ncsu.edu>>

In addition to simulation projects, computer architecture courses include other homework problems and, of course, exams. These materials are also potentially reusable. The Computer Architecture Course Database currently contains about 1000 problems suitable for use on homework or tests, many with solutions. The goal of the project is to encourage instructors to share materials. When an instructor grants permission, material is downloaded from the Web and semiautomatically loaded into the database, where it can be located by keyword or fulltext search. Anyone with an account on the system is granted the right to reuse the material in his or her own classes, but not to republish it.

Because it has proved to be much easier to induce instructors to use the database than to get them to contribute material, an alternative means of finding material has been provided in the form of a search engine that searches computer architecture sites at educational institutions around the world. A single request can search both the database and the Web. While material retrieved from the Web may not be freely reused, it is possible to seek permission from the copyright holder (usually the instructor who established the site). Accounts may be requested by e-mail to efg@ncsu.edu.

2.5 SIGMicro <<http://www.acis.ufl.edu/~microWeb/>>

ACM SIGMicro, the Special Interest Group on Microarchitecture, launched a Web site in 2001. Called the Computer Microarchitecture Center, it contains an education section with a listing of microarchitecture courses and course Websites. It also has links to most of the other resources mentioned in this paper. An interesting section is the new Reviews area, which is intended to contain reviews of educational tools and documents. This area is awaiting its first entry. It also contains pointers to the proceedings of several past WCAEs.

3.0 Resources for New Instructors

New instructors, and experienced instructors teaching outside of their area of expertise, desire directed teaching resources focused on getting started and survival skills in the classroom such as—

- Web syllabi of similar courses at different universities
- identification of textbooks bundled with teaching aides (slides, test banks, software)
- homework, project, and test problems with solutions
- visual and intuitive simulations of computer architecture concepts to promote active learning
- contact information for other computer architecture instructors (support group)

Current Web sites can provide many of these resources efficiently if the new instructor knows where to look.

New instructors need to learn (1) “best practices” for teaching computer-architecture topics, and (2) the resources that are available for them to use and tailor to their own teaching environment. The first goal (best practices) could be addressed by cross-referencing resources so that it is possible to see which textbooks, simulators, etc. are used by which types of courses, and which ways of teaching particular topics have become the “consensus” approach of the discipline. The second goal (breadth of resources) can be addressed by encouraging the worldwide computer architecture to place innovative resources on the Web and make them available to anyone over the Internet.

4.0 Resources for Experienced Instructors

After teaching a course for a few semesters, an instructor is likely to have a repertoire of lectures. The main challenges at this point are developing new homework assignments, labs, and exams. For homework assignments and exam questions, the Computer Architecture Course Database can be very helpful. It contains many questions on the Hennessy/Patterson texts, and microarchitecture in general, with caches

being the most widely covered topic. However, more contributions are being sought, as detailed in Section 6.

For lab projects, experienced instructors might consider the simulators available through NETCARE and CAAL. WCAE has published several papers related to simulators. Eight of these are still available on the Web. Two of these are targeted at the DLX architecture used in Hennessy and Patterson's *Computer Architecture: A Quantitative Approach* [7]; Dan Hyde's VHDL approach [8] and the DLX-view [9] simulator. Two of them use the MIPS architecture, a SimpleScalar enhancement from Manjikian [10] and MipsIt from Brorsson [11]. One targets Patt & Patel's LC-2 architecture [12]. The others are RSIM, a simulator for ILP-based shared memory multiprocessors and uniprocessors [13], SATSim, a superscalar architecture trace simulator using interactive animation [14], and esim, a design language simpler than VHDL, implemented in Tcl, in which students can build and simulate digital modules [15].

Experienced instructors also face the challenge of remaining current in the field. While some teaching resources lend themselves as a base upon which to build the future, many new tools will need to be developed from scratch. This makes tool development environments for experienced instructors an important area of investment.

5.0 What is Missing?

While the Web sites we have identified contain invaluable educational content, there are still critical voids that need to be addressed. The most glaring omissions include:

- a teaching computer architecture virtual support group
- implementation experience with the new ACM/ABET Computing Criteria 2001 for computer architecture-related courses
- a pooling of teaching resources, with Web sites being one forum but not necessarily the only forum

While progress has been made, it must be accelerated. Novice educators must be guided to

teaching resources and experienced educators can become disconnected from current mainstream teaching resources. In both instances Websites can provide a glue to maintain healthy teaching relationships and professional growth in the field.

6.0 The Tragedy of the Commons

In his classic 1968 paper, "Tragedy of the Commons" [4], Garrett Hardin illustrates that an open resource owned collectively and shared by all (a "commons") will be exploited by free-riders until depletion. Without the property rights of ownership, there is little or no incentive to contribute to care of the commons.

We apply this metaphor to Web site content for teaching computer architecture - there are few incentives beyond altruism to share teaching resources. Most instructors do not contribute and yet gain from the hard work of a select few. There is a need to either increase incentives to share resources or make it easier to do so.

In our work on the Computer Architecture Course Database, we found that only 29 of 73 instructors contacted agreed to contribute their materials in electronic format to our database [3]. Those who declined to contribute were asked why. We heard from about a dozen of them. Their concerns were divided about equally into two categories.

- 1) *Copyright concerns.* Some instructors could not contribute because their materials had borrowed heavily from copyrighted works, such as textbooks, making their course materials "derivative works." Others were writing textbooks and wanted to include their course materials, but feared that making their material available in advance would compromise the market for their books.
- 2) *Diffidence.* Many other instructors were concerned that their materials were not polished enough, either because they were teaching a course for the first time, or because they had not been able to devote enough attention to it. This concern has also been noted by Cassel [1]. Her advice is, "Get over it!" Only by access to shared materials can

we eliminate this perception of inadequacy.

To give instructors an incentive to contribute, a feature is currently being added to the Computer Architecture Course Database to track how often specific items have been downloaded. A high reuse count will indicate a problem or lecture that other instructors find quite useful. This would be one of the few quantitative measures of teaching contributions (beyond student course evaluations), and could help buttress cases for tenure and promotion.

7.0 Summary

This paper reviews several computer-architecture education Web sites found valuable to both novice and experienced instructors. The goal is to provide instructors both a general educational introduction to the broad field of computer architecture as well as detailed resources for more in-depth inquiry. While valuable resources do exist, making them known and available to educators has been problematic. In addition, the field is a moving target such that new ideas and technology are being continually introduced making collective sharing of appropriate resource materials a difficult task. There is hope, however, in that the five developing Web sites noted in this paper represent a diversity of accessible teaching resources in both depth and breadth and may be complemented by additional Web sites in the future.

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