On-line Authentic Instruction for Embedded Systems Applications and Processor Selection

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Abstract
The Internet has become an important professional and educational resource. We teach its use while introducing students to embedded systems. Embedded systems are important for our graduates because of the current growth in the field of pervasive computing as well as the billions of embedded computer chips currently used in a huge variety of products[1]. BYU has developed an embedded systems course with the goal of helping students become competent in implementing multiple types of embedded systems. As an introduction to these systems, it is desirable to present a broad perspective of the many different systems, applications, processor types, operating systems and development environments that are now available. It is also desirable to acquaint students with professional on-line documentation of varying quality.

This article describes an on-line introductory module that helps students develop an understanding of available microcontroller systems. This topic is well suited to web instruction for several reasons: 1) The web is the most current repository of information on processors. 2) The state-of-the-art in processors is highly dynamic. 3) The web techniques taught closely parallel the methods used by professionals to select components for a project.

In the module, students explore different types and capabilities of available processors and develop a sense of how each processor fits into the spectrum. The module uses authentic exercises and assessment methods to enhance the relevance of this experience. Students complete a series of exercises to enable them to: 1) Search on-line for available state-of-the-art systems. 2) Select a microcontroller given specifications. 3) Identify microcontroller or embedded applications. 4) Select a microcontroller for a given application. Students are encouraged to become familiar with embedded computer products from several different manufacturers.

Introduction
If students are to become successful technical professionals they need to be able to access and use

the technical data sources used by professionals in their field. Increasingly this means accessing technical data from the Internet using a browser. The Internet has become the standard source for professional documentation for technology designers. Data books, sales literature, user's manuals, white papers and application notes are all available on-line after a few minutes of searching the Internet. The information is more frequently updated and, since it costs the manufacturer or distributor very little in distribution costs, there is much more data available than when distribution was limited to printed publications. Computer-related technical disciplines are well suited to this type of data access as, in addition to the factors already cited, standards and products also change very rapidly and the on-line documentation distribution matches that rapidity of change.

The Internet and its related technologies have some inherent disadvantages compared to paper technical documents. Paper documentation is very easy to carry around, mark up and copy. In contrast to this, remote on-line documentation requires a working terminal and network connection; thus the documentation may not be available at the time and place it is needed. For example, it is not convenient to carry an Internet terminal into a working factory on a maintenance call, or if the network connection is malfunctioning or slow then the documentation may be inaccessible. Furthermore the availability of the remote documentation relies on the remote suppliers maintaining their site, a situation that could be affected by company policies, financial imperatives, bad luck or incompetence. The information user cannot control these factors. To protect long-term availability of technical information for support purposes, professional users need to create back-ups or know how to access long-term, on-line archives.

The Internet is also a source of shopping, news, entertainment and many other diversions and consequently most incoming students today are proficient in accessing on-line information, but not necessarily in a professional capacity. The plethora of information available could be, at the least, a distraction and can make it very difficult to find needed documentation.

A new problem with accessing technical information on-line is that of assuring the quality and validity of the information obtained. Many of the reliable external mechanisms used by professionals over many years, such as peer-review and editorial oversight, are rarely used with Internet data sources. Professionals and students need to develop new techniques to evaluate the quality of information obtained. This problem has been recognized[2,3] and the recommendations for ensuring quality include considerations of the source of the information, evaluation of the clarity and thoroughness of the writing and cross-referencing between information sources. Barger et al.[4], discussing a related problem for various information sources including web documents, state the following.

> "Whether case, problem, or inquiry-based learning, students must become familiar with gathering meaningful information and assessing, to some degree, the level of authority."

Although this question of authority or validity is a significant one, we do not discuss it in depth in

this report but are addressing it in on-going research for future publication. At present we encourage and expect the students to obtain their information from the websites of recognized system suppliers and support sources such as Microchip, Intel, Motorola, etc. Class discussions cover the need for evaluation of the reliability of the information obtained.

Regardless of disadvantages or advantages to the user, on-line documentation is growing at the expense of printed documentation. This trend is driven by the low cost of distribution of on-line documentation, discouraging manufacturers and distributors from using printed documentation. This dwindling of alternative options emphasizes the need for students to learn to effectively and professionally use Internet information sources.

Students in technical disciplines need to understand all these aspects of using on-line information sources for professional, technical applications. They need to develop skills to find, use and evaluate technical data on-line. Finding the data also means reformulating the technical problem into terms suitable for the medium. Evaluating the data includes checking the information found against the problem specifications, as well as considering data quality.

BYU teaches a course in embedded systems[5] that makes extensive use of on-line documentation. The course requires students to study and use a variety of different embedded system architectures so that they become proficient in embedded systems in general and can choose the most suitable embedded system for a given application, rather than automatically using the only one they have used before. Avila and Hinojosa describe another approach[6] to this need for generalization in teaching microprocessor courses. Notwithstanding some variations in approach compared to the BYU course they also promote active learning and a broad approach to the topic. Students in the BYU courses are required to use on-line documentation as the textbook for the course. One of the stated objectives of the course is to teach students to use the same types and sources of documentation that professionals rely on. In pursuit of this embedded systems class objective we have developed an on-line instructional module to help students develop the ability to define technical needs and find appropriate on-line resources. Although this module is targeted at a specific topic, the general skills and methodology proposed can be applied to other technical fields and other professional domains which make use of on-line documentation.

Intended Audience for the Instructional Module

The instructional module is targeted at senior students in an Information Technology program. The students will take the module near the beginning of the course in embedded systems; thus they are not expected to be familiar with the terminology and concepts of embedded systems. They are assumed to be generally familiar with web browsers and the Internet. They are also assumed to be familiar with digital electronics and to have some software experience. This module is intended to introduce them to the range and depth of products available in the embedded computer field. It is also intended to give them the skills necessary to be able to intelligently search the Internet so they can find further information for themselves. They will be expected to apply these skills later in the class and, we hope, in future professional applications.

The Instructional Module

The instructional module is set up as an on-line exercise, accessible using a standard browser. This is particularly useful as the instructional medium (web pages) matches the topic material and there is little disconnect between the two.

The module first introduces students to some important parameters and applications of embedded systems and microcontrollers. After completing this exercise, students should be familiar with the basic terminology of the embedded computer and microcontroller field. One early exercise helps them identify microcontrollers in many everyday products in their immediate environment. The module then coaches the students through a sample Internet search for a specific microcontroller to match given parameters. This exercise helps the students recognize typical manufacturers' technical publications and data books[7,8] and how to find desired information in these sources. Further exercises invite the students to find other systems given specific parameters. This is a direct application of the lesson just covered.

Finding microcontrollers useful for a specific, predefined purpose is valuable but not sufficient. Customers seldom, if ever, provide designers with a neat list of embedded system parameters they wish to use. More typically they will provide an application problem for which embedded systems are probably a suitable solution. If students are to become independent users of this material, they must also learn to translate embedded system application requirements into a set of parameters suitable for an Internet search. Thus the module teaches principles of identifying the important parameters given various applications. Finally students are given an application example from which they are required to identify the crucial microcontroller characteristics for themselves, and then to use on-line resources to find a suitable microcontroller.

The final assessment exercise is to compare their chosen microcontroller against an evaluation standard to see how suitable it is.

Pedagogical Features of the Module

Although this instructional module is new, the embedded systems course has been taught for a few years. Students have used on-line documentation in a manner similar to that described in this study without the benefit of a formal instructional module. Student response to the concept of using the same documentation that they will use in professional practice has always been positive. This module now formally teaches principles and practice of that instructional goal. Formative evaluation of the module by students has been positive, with surveys showing a significant increase in confidence and competency after completing the module. Feedback from that evaluation has been incorporated into the module and the module will be used with a full class of students this year.

The instruction is authentic. Students are using the same techniques and the same resources as professionals in the field. The problems assigned and case-studies discussed are also chosen to

mirror real problems.

The module is offered on-line. This is particularly appropriate since the subject of the module is on-line information access. Thus the instructional medium and the instructional material are closely matched. In addition this on-line instruction enjoys other well-known benefits such as being remotely available and allowing the students to work asynchronously.

A simple but logical selection methodology is proposed which enables students to identify important parameters of the equipment they need, starting from the proposed application. This enables them to design and execute an Internet search that will find suitable items for their design needs.

The specific application domain for this module is the selection of microcontrollers to be used in applications. There is often a significant gap between the customer's description of the application and the specifications of the microcontroller. In teaching embedded systems over several years one of the authors has noted that students have difficulty in starting with an application and then drawing up appropriate microcontroller specifications. In order to bridge this gap the authors have developed a simple methodology to assist in breaking down an application into the necessary key features. Once these features are identified the necessary embedded systems can be sought using the Internet.

The key features of applications which are necessary to identify microcontroller specifications can be found by analyzing the application. These features include the following:

- The number of digital inputs to the CPU for the application. The types, voltages and signaling characteristics of these inputs.
- The number of analog inputs to the CPU for the application. The type of the signals (frequency, voltage, current or other).
- The number of digital outputs required from the CPU. Their types and characteristics.
- The number of analog outputs required from the CPU. Their types and characteristics.
- Other communication needs of the application such as Ethernet, serial, USB, Firewire, or X10?
- The user-interface. (Is it likely to require a display and/or keyboard?)
- Estimates of the type and difficulty of the processing capability required of the CPU. Whether the application needs significant mathematical capability, large word sizes or high speed.
- Estimates of the required program and data size.
- The power constraints of the application, in particular if the application is mobile and will therefore require battery power. Also cooling requirements of the unit.

Other parameters could be added to this list but analyzing the application in these terms helps to isolate necessary specifications of the microcontroller to be chosen. In the instructional module

we present the analysis approach but only explore a small subset of these parameters.

Conclusion

There is a vast quantity of information available on-line. It is essential that students develop the skills to use this resource both efficiently and effectively as technical professionals. This module helps develop skills for students to do so, specifically for the purpose of microcontroller selection, although many of the skills learned can be applied more generally. We propose both to use the current module in teaching and to extend it to address the problems of information validity and quality mentioned earlier.

Bibliography

1. Cahners In-stat Group, *1999 MCU Unit Vendor Market Shares* Report Number: ML00-06MS August 2000 http://www.instat.com/abstracts/ds/2000/ml0006ms_abs.htm

2. David A. Waite, *Internet Information Sources – Quantity vs. Quality* Annual Quality Congress Transactions, 1998, p344-348. Proceedings of the 1998 ASQ's 52nd Annual Quality Congress.

3. Honora F. Nerz, Suzanne T. Weiner, *Information Competencies: A Stategic Approach,* ASEE Annual Conference 2001. Session 2241.

4. Marilyn Barger, Renata Engel, Richard Gilbert, Mark Maughmer and Bonnie Osif, *The Role of the Lecturer in the New Learning Strategies* Proceedings, ASEE Annual Conference 2001. Session 2457

5. C. Richard G. Helps, *Teaching Embedded Systems From Eight Bits to Operating Systems and Networks* Proceedings, ASEE Annual Conference 2002 (Montreal). Session 3647

6. Alfonso Avila and Juan Manuel Hinojosa, *Integrating active and cooperative learning strategies to a re-designed Microprocessor based system design course* Proceedings, ASEE Annual Conference 1998. Session 2532

7. Motorola Corp. *MC68EZ328 Integrated Processor User's Manual,* Motorola, 1998 http://e-www.motorola.com/brdata/PDFDB/docs/MC68EZ328UM.pdf

8. Microchip Corp. *Microchip PICmicro 18C MCU Family Reference Manual,* Microchip 2000. www.microchip.com/

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