

AC 2008-1902: A COMPARISON OF EMBEDDED SYSTEMS EDUCATION IN THE UNITED STATES, EUROPEAN, AND FAR EASTERN COUNTRIES

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A Comparison of Embedded Systems Education in the United States, European, and Far Eastern Countries

Abstract

Worldwide, institutions of higher education share many of the same concerns with respect to embedded systems education. Some of these concerns involve curriculum design, offering proper courses, development of laboratories and appropriate experiences for the students. This paper will compare and contrast the embedded systems education in the United States, European, and Far Eastern countries.

Introduction

Embedded systems are electronic systems that contain a microprocessor or microcontroller, however, one doesn't think of them as a computer – the computer is hidden, or embedded. Embedded systems are ubiquitous. In the US, homes have an average of 30 to 40 microprocessors or microcontrollers each. Embedded System is one of the most dynamic, fast growing areas in industry. Embedded systems design addresses the challenges of hardware and software co-design.

The area of Embedded Systems Design has been gaining a tremendous growth in recent years. A major aspect of this growth has been the addition of networking technologies, operating systems, and database management systems to embedded systems. Embedded systems have application in many areas such as automotive/transportation, government/military, medical equipment, telecommunications, avionics/aeronautics, aerospace, electronics, office automation, data-communication, industrial automation, and consumer electronics¹. About 98% of all the 32-bit microprocessors currently in use worldwide are used in embedded systems². By the year 2010, it is forecasted that 90% of the overall program code developed will be for embedded computing systems³.

The design of embedded systems has been around for more than thirty years. However, the academic subject of embedded systems design is a relatively new subject. It is considered to be an interdisciplinary field combining areas such as computer science, electrical engineering, applied mathematics, and control theory.

The tremendous growth in embedded computing has given rise to a demand for engineers and computer scientists with experience in designing and implementing embedded systems. Embedded system design is currently not yet well represented in academic programs. Most computer engineering programs teach programming and design skills that are appropriate for a general-purpose computer operating under the control of a commercial operating system rather than for the more specialized embedded systems^{4,5}.

Embedded Systems Education Models

Currently, there are seven models for teaching embedded topics in universities and colleges worldwide:

1. Offering courses mostly on software (Real-Time Systems) in CS and SE undergraduate programs.
2. Offering courses in CE and EE undergraduate programs which emphasizes the hardware aspects of embedded systems.
3. Graduate programs in Embedded Systems Design
4. Designing an Embedded Systems Engineering track in computer science department
5. Continuing education and training programs for the industry engineers
6. Offering an undergraduate degree in Embedded Software Engineering
7. Offering an undergraduate degree in Embedded Systems Engineering

Embedded Systems Education in the United States

It is predicted that most of the future computing systems will be embedded systems and the importance of embedded systems will continue to grow rapidly. Current undergraduate computer science and computer engineering curriculums at most institutions of higher education in the US do not prepare the graduates with the required knowledge and skills to design embedded systems. The result is that industry has difficulty of finding sufficiently trained computer scientists and engineers⁶. In order to provide graduates with the system-level embedded design knowledge, it is crucial that the curriculums for computer science and engineering to be reviewed and enhanced.

Currently, Models 1 – 4 are used for teaching embedded systems topics in the US universities and colleges. The first two models are traditionally used by most programs in CE and CS. Because of the tremendous growth and need for embedded system trained professionals who are knowledgeable in hardware and software, the first two models are not adequate. Usually, the courses taught in the first two models are introductory level courses and the advanced courses are not available until graduate school, leaving a gap in training the undergraduate students. Since most of the undergraduate programs do not prepare students with enough skills on the embedded system design, companies are faced with a shortage of trained engineers⁶.

In a survey that was done by the authors⁷, more than twenty US Computer Science and Computer Engineering programs were examined to see how they have integrated embedded systems design into their curriculums'. This study showed that 8 Universities are using Model 1 in their computer science programs and are offering courses in embedded systems with a software emphasis. Six universities are using model 2 and offering courses in embedded systems design with a hardware emphasis. Several universities in the US are offering graduate programs in Embedded Systems Design such as San Jose State University and Monmouth University. Southern Adventist University has implemented a nontraditional approach by offering an embedded systems program track in their computer science program without the existence of a computer engineering program on their campus⁸. For colleges and universities that do not have engineering programs, the authors have designed a curriculum for an Embedded Systems

Engineering track in the Computer Science Department¹⁷. Currently, there are no universities in the US that offers an undergraduate program in Embedded Systems Engineering or Embedded Software Engineering.

Embedded Systems Education in the European Countries

European countries have developed a scientific community called ARTIST. “The strategic objective of the ARTIST Network of Excellence is to strengthen European research in Embedded Systems Design, and promote the emergence of this new multi-disciplinary area⁹.” The ambition of this organization is to compete on the same level as equivalent centers in the US (Berkeley, Stanford, MIT, and Carnegie Mellon), for both the production and transfer of knowledge and competencies, and for the impact on industrial innovation⁹. A guideline for a graduate curriculum on embedded software and systems has been developed in the ARTIST and ARTIST2 projects¹⁰.

Currently, models 1 – 3 are used for teaching embedded systems topics in European countries universities and colleges. University of Bradford in England is using the first model to integrate embedded systems knowledge into their computer science curriculum⁷. Tallinn Technical University in Estonia is offering embedded systems courses in their Computer and Systems Engineering program (Model 2). There are many institutions of higher education in Europe that are offering a graduate program in Embedded Systems Engineering. The Delft University of Technology in Netherlands and ALaRI University of Lugano in Italy are offering a Master of Science degree in Embedded Systems Design.

Embedded Systems Education in the Far Eastern Countries

In the Far Eastern Countries, the first six models are used for teaching embedded systems topics in universities and colleges. In Japan and many other countries in this region, computer science programs use model one to integrate embedded systems design concepts into their program. Electronics Engineering or Electrical Engineering programs use model two to integrate embedded knowledge into their programs. Students are graduating from these programs without acquiring enough skills on embedded systems design. In October 2004, Nagoya University has started an extension program on embedded software, called NEXCESS¹¹. This university, as a service to industry, offers short classes on the subject¹¹. Generally, these types of classes are not systematic and the participants may not acquire wide knowledge in the area. Several universities in this region offer graduate programs in Embedded Software Engineering. For example, BeiHang University in China is offering a graduate program in Embedded Software Engineering¹². Some universities are using model 5 and offering an Embedded Systems Design Track in Computer Science department in Seoul National University in Korea. Some of the Far Eastern countries curriculum of higher education is designed by their government¹³. For example, Korean Government has designed an undergraduate curriculum for the computer-software field. Their computer-software field is divided into five specialization areas. One of these areas is Embedded System Software. There are 19 universities that have implemented the Embedded Systems Software track¹⁴.

Summary and Concluding Remarks

In this paper the authors did a study of different models that are used by different institutions of higher education to prepare their graduates for the Embedded Systems Design. Currently, there are seven models that are used by universities and colleges throughout the world. It was found that institutions of higher education in the US use five of those models to prepare their students. The European countries use three models and Far Eastern countries use six models to prepare their students.

Embedded industries in many countries especially in the Far Eastern countries have been a booming industry in the last few years. These industries are facing a big shortage of manpower of quality to satisfy their needs. There is a 'skill mismatch' phenomenon, where maturity levels of skill of graduates from institutions of higher education is lagging far behind the required level in the spot industrial sectors. There is a big demand to significantly increase the quality and quantity of graduates specializing in embedded systems design. The colleges and universities are not preparing their students with sufficient embedded systems design knowledge that is required in industry nowadays⁶. The tremendous growth in the area of embedded systems requires the academic institutions to update their education in the area of embedded system design. Otherwise, it will become very difficult to design tomorrow's complex embedded systems. The process of updating the curriculums requires a close interaction with industry to provide the right focus. This study showed that institutions of higher education in the Far Eastern countries are closely working with industry in order to provide quality graduates.

The authors feel that the best solution for preparing qualified manpower is to offer an undergraduate degree in either Embedded Systems Engineering or Embedded Software Engineering. Right now, an undergraduate degree in Embedded Software Engineering has been implemented in several universities in Taiwan. Also, an undergraduate degree in Embedded Systems Engineering has been implemented in Canada¹⁵ and Israel¹⁶. This study shows that majority of the countries worldwide are aware of the skill mismatch phenomena and are moving toward solving this problem. Some are moving faster than the others.

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