

AC 2007-1996: AN INTERNATIONAL STUDY OF EMBEDDED SYSTEMS DESIGN IN THE COMPUTER SCIENCE AND ENGINEERING CURRICULUMS

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An International Study of Embedded Systems Design in the Computer Science & Engineering Curriculums

Abstract

In this paper, an international study is done to see how different institutions have integrated embedded system education into their computer science and computer engineering curriculums. Currently, there are six models that are used by institutions of higher education to integrate embedded systems education into their curriculum. The authors did this study to decide which model is the best choice for their students.

Embedded Systems Engineering

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 and operating 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 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}.

Background Information

Utah Valley State College (UVSC), located in Utah Valley, was founded in 1941. UVSC is a state college comprised of two interdependent divisions. The lower division embraces and preserves the philosophy and mission of a comprehensive community college, while the upper division consists of programs leading to baccalaureate degrees in areas of high community demand and interest³⁹. Currently, UVSC offers more than 40 baccalaureate degrees. UVSC is the fastest growing college in the Utah System of Higher Education with over 23,000 students attending. The Bachelor of Science in Computer Science was one of the first Bachelor of Science programs which was approved in 1992 and implemented in 1993³⁹.

In addition to the associate degrees, the Computing and Networking Sciences (CNS) department offers a Bachelor's Degree in Computer Science with five areas of specialization which include traditional Computer Science, Computer Engineering, Software Engineering, Database Engineering, and Computer Networking. The curriculum content for the Computer Science

degree is based on the 2001 ACM Curriculum Report. The CNS department has 14 full time faculties. The Computer Science degree at UVSC is accredited by ABET in 2002 and currently has 869 students.

The Bachelor of Science in the Computer Science program was one of the first Bachelor of Science programs implemented at UVSC in 1993. The program's goal has been to provide a quality program that meets accreditation standards while providing the students with a skill set that allows them to succeed in computing careers.

Introduction

It is predicted that majority 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 do not prepare the graduates with the required knowledge and skills to design embedded systems. The result is that the industry has difficulty finding sufficiently trained computer scientists and engineers⁶. In order to provide graduates with the system-level embedded systems design knowledge, it is crucial that the curriculums for computer science and engineering to be reviewed and enhanced.

Currently, there are five models for teaching embedded systems topics in universities and colleges:

1. Offering courses mostly on software (Real-Time Systems) in CS and SE undergraduate programs (e.g., at Florida State University, Vanderbilt University, Seoul National University ...).
2. Offering courses in CE and EE undergraduate programs which emphasizes the hardware aspects of embedded systems (e.g., University of Utah, Boston University, Carnegie Mellon University ...).
3. Graduate programs in Embedded Systems Design (e.g., University of Essex, Carnegie Mellon University ...).
4. Continuing education and training programs for the industry engineers (Nagoya University)
5. Offering a degree in Embedded Systems Engineering (e.g., Holon Academic Institute of Technology)

The first two models are traditionally used by most programs in CE and CS. The first model is software oriented and does not cover the course material for the integration of hardware and software components in the systems. The second is hardware oriented and does not cover the software development for the embedded systems. 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, the advanced courses are not available until the 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 have to train their unskilled engineers. Some universities, as a service to industry offer short classes on

the subject⁷. However, these classes are not systematic and the participants do not acquire wide knowledge in the area. The last method is to offer a degree in Embedded Systems Engineering (ESE). This option is the best choice for providing students with in-dept knowledge of embedded systems design.

Results of the Study

The motivation for this study was to decide how to integrate embedded systems design into our curriculum in the computer science department at Utah Valley State Collage. To make the decision, an international survey of computer engineering and computer science curriculums was done which is given in Table 1. The table includes the following:

- The name of the universities
- The country which they are located in
- Whether they have a computer science or computer engineering departments
- Whether the computer science department offers any embedded systems courses?
- Whether the computer engineering department offers any embedded systems courses?
- The last column gives comments on different universities programs

This study shows that only a small percentage of undergraduate programs in computer science/engineering programs are offering courses in embedded system design. Those that are offering courses are using the first two models which do not provide students with an in-dept expertise in embedded systems design. Most universities with engineering programs are offering graduate programs in embedded systems design which leaves a gap in training the undergraduate students. The best model for institutions of higher education with engineering programs is to adopt model number five and offer an undergraduate program in Embedded Systems Engineering. However, for colleges and universities like UVSC that does not have engineering programs, the last option is not feasible. The best option for colleges and universities like UVSC is to create a new track in their Computer Science department called Embedded Systems Engineering.

Concluding Remarks

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. In this paper, the authors have done an international study of the curriculums in other institutions of higher education to decide how to integrate embedded systems design in their curriculum in the computer science department. It appears from the study that the best solution for them is to add a new area of specialization in their computer science department called embedded systems engineering to provide their graduates with knowledge of designing tomorrow's complex embedded systems. The detail curriculum content of this new area of specialization in the Computer Science department is yet to be decided.

Table 1 - A Survey of Embedded Systems Courses in the Undergraduate CS/CE Programs in Different Countries

Universities	Country	Embedded Systems (ES) Courses in Computer Science Curriculum	Embedded Systems Courses in Computer Engineering Curriculum	Undergraduate Embedded Systems Programs	Comments
Holon Academic Institute of Technology ³⁸	Israel	N/A	N/A	Yes	Bachelor's degree in Embedded Systems Engineering
Heriot-Watt University ³⁴	Scotland	N/A	N/A	No	Masters in Embedded Systems
Florida State University ²⁶	USA	Yes	N/A	No	
Drexel University ²⁷	USA	No	No	No	
University of Essex ³⁵	United Kingdom			Yes-BS Computer Science (Embedded Systems and Robotics)	Masters in Embedded Systems & Robotics
Caltech University ³³	USA	No	N/A	No	
Vanderbilt University ¹⁵	USA	Yes	Yes	No	
Michigan Technological University ¹⁴	USA	No	N/A	No	
Princeton University ¹³	USA	No	N/A	No	EE – ELE 464 – Embedded Computing
Embry-Riddle Aeronautical University ¹⁶	USA	N/A	Yes	No	
Oregon State University ¹⁷	USA	No	No	No	
Ohio State	USA	No	No	No	

University ¹⁸					
North South University ²⁰	Bangladesh	No	Yes	No	
University of Utah ²⁸	USA	Yes	Yes	No	
Northwestern University ²³	USA	Yes	N/A	No	
University of Pennsylvania ³⁷	USA	No	No	No	
Isfahan University of Technology ²²	Iran	N/A	No	No	
University of Bradford ²⁴	England	Yes	N/A	No	
Balliol College ²⁹	England	No	No	No	
Seoul National University ³⁶	Korea	Yes	N/A	No	
Anglia Ruskin University ²⁵	England	No	N/A	No	
Boston University ⁸	USA	Yes	Yes	No	ENG SC 535
Brown University ⁹	USA	Yes	N/A	No	
ST. Bonaventure University ¹¹	USA	No	N/A	No	
Brigham Young University ¹⁹	USA	Yes	Yes	No	
Tokyo Institute of Technology ¹⁰	Japan	No	No	No	
Swarthmore College ¹²	USA	No	N/A	No	
Stanford University ³²	USA	Yes	N/A	No	
Carnegie Mellon University ³⁰	USA	N/A	Yes	No	Masters of Software Engineering , Real-Time Specializati

					on Track
Israel Institute of Technology ³¹	Israel	No	N/A	No	
Massachusetts Institute of Technology ²¹	USA	No	N/A	No	

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