AC 2007-1900: EMBEDDED SYSTEMS ENGINEERING AREA OF SPECIALIZATION IN THE COMPUTER SCIENCE DEPARTMENT

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Embedded Systems Engineering Area of Specialization in the Computer Science Department

Abstract

In our computer science department, there are five areas of specialization: computer science, software engineering, networking, database engineering, and computer engineering. In our curriculum, the students matriculate into the Computing and Networking Sciences (CNS) department after completing the requirements of 30 credit hours of core courses common to all computer science students. The students continue taking core courses until the first semester of their junior year, when they begin taking their electives from different specialization areas.

In this paper, the authors are proposing a new area of specialization in their computer science department called Embedded Systems Engineering. The paper elaborates the detail content of the curriculum requirement for this track.

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 electronics[1]. About 98% of all the 32-bit microprocessors currently in use worldwide are used in embedded systems[2]. By the year 2010, it is forecasted that 90% of the overall program code developed will be for embedded computing systems[3].

The remarkable 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 more specialized embedded systems [4, 5].

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 industry has difficulty finding sufficiently trained computer scientists and engineers[6]. 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 subject[7]. However, these classes are not systematic, and the participants do not acquire wide knowledge in the area. The last and best method is to offer a degree in Embedded Systems Engineering (ESE). However, due to the limited resources at most universities and avoiding inflation of programs, the authors propose a new track in the computer science department called Embedded Systems Engineering. This model is most appropriate for colleges and universities that do not have engineering programs.

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 interest[8]. 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 1993[8].

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.

Curriculum for Embedded Systems Engineering Area of Specialization

In order to graduate with a Computer Science degree at UVSC, students must complete 123 semester hours of course work. The current curriculum consists of 30 hours of General Education and 10 hours of science requirements that must be taken by all the different areas of specialization.

Computer science core requirements consist of 28 hours. These core requirements, which are taken by all the areas of specialty, are given below:

- CNS 1400 Object-Oriented Programming I
- CNS 1410 Object-Oriented Programming II
- CNS 2810 Assembly Language & Computer Architecture
- CNS 3050 Computer Ethics
- CNS 2420 Object-Oriented Data Structures
- CNS 2600 Fundamentals of Data Communications
- CNS 301R Invited Speakers Series
- CNS 3060 Operating Systems Theory
- CNS 3240 Introduction to Computational Theory
- CNS 3690 Advanced Topics in Data Communications

The following courses will only be required for the Embedded Systems Engineering area of specialty:

- CNS 4380 Adv/High-performance Computer Architecture
- EENG 4890 Senior Design Project
- EENG 2750 Circuit Theory
- EENG 2740 Digital Design I
- EENG 3740 Digital Design II
- EENG 3750 Engineering Analysis
- EENG 3770 Signals & Systems
- EENG 2730 Introduction to Embedded Systems
- EENG 3730 Embedded System Design

- EENG 4750 Digital Signal Processing
- EENG 4730 Advanced Embedded Systems Design

Embedded Systems Engineering students must take a minimum of 3 credits from the following:

- EENG 4760 Semiconductor Devices
- CNS 3400 Software Engineering
- CNS 3520 Database Theory
- CNS 3670 Network Programming
- CNS 4470 Artificial Intelligence
- CNS 4510 Operating Systems Design

To summarize, the students in the Embedded Systems Engineering area of specialization take 30 hours of general education, 10 hours of Science, 17 hours of Math, 40 hours of computer science, 33 hours of engineering requirements, and 3 hours of electives. The purpose of this area of specialty is to provide students with an in-depth expertise in embedded systems. This is intended to meet the big demand from the industry for engineers and computer scientists possessing the knowledge and skill needed for work on all aspects of embedded systems. The students will learn both the fundamental knowledge and the most recent developments in the field. They will also gain experience in practical applications and the hardware/software co-design of embedded systems technology.

Introduction to Embedded Systems (EENG 2730)

The goal of this course is to introduce the fundamental concepts of hardware and software needed for the design of embedded systems. This course is oriented toward the engineering principles and techniques of applying microcontrollers in various embedded systems. The course places strong emphasis on hands-on experience with topics, including six labs and a design project. The students will use 68HC12 Evaluation Boards (16 bit microcontroller) to do their labs. Students become exposed to the 68HC12 instruction set, and learn how to use a cross assembler and simulator to develop code in assembly to control the basic hardware. In addition, students will add additional hardware elements to their boards, and will develop the firmware to control this new hardware. A typical design project involves designing and developing a controller for a small mobile robot.

Embedded Systems Design (EENG 3730)

This course is an introductory course on real-time systems design and implementation. Students learn basic design and implementation issues in real-time systems. Topics covered include hard and soft real-time systems, distributed real and embedded systems, commonly used approaches to real-time scheduling, clock driven scheduling, priority-driven scheduling of periodic tasks, resources and resource access control, priorities, event triggered and time triggered models of real-time, safety critical systems, intertask communication and synchronization, and real-time operating systems. A typical project in this course is writing a real-time operating system for a mobile robot.

Advanced Embedded Systems Design (EENG 4730)

The objective of this course is to provide the practical and theoretical skill needed to understand the design process of embedded systems. Topics covered include the embedded system design process, hardware and software system design and analysis techniques, embedded communication architectures and multiprocessing, and system design methodologies and techniques to assure reliability. This course is also to review and discuss new advancements in embedded systems and software. We will also include special topics which provide flexibility in the curriculum by allowing advanced embedded systems concepts to be introduced on a regular as-needed basis. Such topics would include, but not limited to, embedded network systems and low power system design.

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 the industry to provide the right focus. The authors are proposing a new area of specialization in the computer science department called embedded systems engineering to provide the graduates who are ready to design tomorrow's complex embedded systems.

References:

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