Work In Progress - Integrate Embedded Systems into CS Curriculum with Labs-in-a-Box Courseware

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Abstract – Embedded systems are widely used everywhere and play especially important roles in smart green computing application nowadays. The rapid growth of embedded systems results in a shortage of professionals for embedded software development. How to meet this urgent need is a challenge. To support embedded system education, we have developed a portable and reusable embedded software labware with hands-on labs in a relatively inexpensive box. The developed labware especially targets on schools that face budget deficiencies for embedded lab equipments and lack dedicated instructors whose expertise is in the embedded system area. The portable and inexpensive real hands-on labs and the modular and flexible design of this work provide a “ready-to-adopt” courseware for these schools.

Index Terms – Embedded systems, labware, Lab in a box

INTRODUCTION

The rapid growth of embedded system applications has increased demand for experienced professionals in this area. It is forecasted that 90% of the overall program code developed will be for embedded computing systems in the next decade [1]. There is a shortage of professionals having such specialized skills. Despite this high need, current undergraduate computer science and engineering curriculums at most institutes of high education do not prepare the graduates with the required knowledge and skills to design embedded systems [2].

Many schools have realized this urgency and they either develop new dedicated embedded system degree programs or add new courses in the curriculum to meet the challenge. Because hands-on laboratory is required for all embedded courses, many schools have made great efforts to enhance the hands-on labs for embedded systems education and some of these works have been supported by the NSF CCLI program [3-4]. Despite these efforts, most existing embedded systems laboratories require significant investment in resources and are difficult to be integrated into the courses in CS curriculum. On the other side, many core CS courses such as computer organization and software engineering lack the laboratories to improve student learning. Motivated by the above deficiencies, we are developing a labware that can be used for embedded systems education in multiple courses in CS curriculum. The developed labware especially targets on small colleges or universities that have limited financial and instructor resources.

PORTABLE HANDS-ON LABS IN A BOX

In the developed labware, all hands-on labs are developed and implemented using a portable, supercharged 8051 MCU based C8051F005DK development kit from Silicon Laboratories Inc. The development kit comes with necessary I/O, serial ports, and a basic RTOS, and can be reused many times without using a solder. It costs at an average textbook price. Figure 1 shows a sample lab of a single digit 7-segment LED which incremented once per second using this development kit.

Figure 1 Palm Sized C8051F005DK kit

The kit comes with the Integrated Keil C51 IDE which provides students with excellent hand-on opportunities to work with real-world embedded system projects instead of simulations only. Figure 2 shows a screen shot of cross-compilation, debugging, and testing sample on PC/Laptop before deployment to a target embedded system.

MODULAR LABWARE

To facilitate the courseware to be easily integrated by different related courses in CS curriculum, we adopt a modular design in our work. The developed courseware and projects are modular and have multiple learning levels. This modular design gives instructors the flexibility to adopt the full course or to integrate selected modules based on their needs.
specific needs. We are also developing a series of labs associated with the modules that can be used for computer organization, operating systems, software engineering, and capstone courses with the same development kit. Each module includes lecture notes, PPTs, review questions, hands-on laboratory practices, and assignments. All learning materials and lab manual videos are available online. The goal is support students to get both hands-on experience of embedded system and theoretical fundamentals using the embedded systems labs in a box.

Below are some sample modules that we are currently developing:

1. Computer organization labs: CPU and Memory of Microcontrollers, Interrupt, Peripherals of embedded systems, Serial communication, and Embedded programming.
2. Operating systems projects: Scheduling, Multi-tasking, Tiny Operating Systems, and RTOS.

The hardware resource needed to teach these modules is minimized due to the portable labs associated with the lab materials. We have used these lab modules in an elective course of “Embedded Systems Analysis and Design” and required capstone course. We plan to use these lab modules in computer organization and operating systems in the next year.

All course materials organized according to the teaching modules with labware are made available online so that it is also suitable to be carried out for online course delivery. The real hands-on labs are guided by step-by-step Flash tutorials. Supported by these multimedia outline lab guidelines, students can conduct the labs anywhere and at anytime using the portable tiny microcontroller development kit. They can run labs, do assignments, complete projects without restriction from the class and lab schedule and lab space requirement. The developed kit is accompanied with a dedicated textbook by the Springer. This “learning by doing” pedagogy will promote students’ life-time long learning skills. It will allow students not only practice pre-designed hands-on labs, but also have opportunity to design and invent their own smart embedded devices by themselves. The teaching modules emphasize both the software and hardware aspects of embedded systems. They allow students not only get benefits from experience in software engineering activities such as software requirements analysis, modeling, design, development, testing, and integrating the well packed products with the supported hardware devices but also get electronic engineering discipline experience.

EVALUATION

The student feedback from the two class implementations was very positive. Most students enjoyed what they learned with this new labware. Especially, students like the hands-on portable labs. Many of these CS students did not have opportunity to explore a microcontroller by C or assembly language. After the courses, they understood better the fundamental concepts of CPU, memory, I/O, interrupt, and operating system. Also, students were excited with their creativity opportunity by working on the embedded projects with the portable kits.

CONCLUSION

This paper presents a new pedagogical teaching and learning model for improving student learning in embedded system design and preparing students for tomorrow’s embedded system workforce. The proposed labware can also be integrated into other CS core courses to provide students with hand-on learning experience.

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REFERENCES


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