Curriculum of Embedded System for Software Colleges

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Abstract—**Embedded system has already been applied in numerous fields, such as the industry control system, information appliances, communication equipments, medical instruments, intelligence instruments and so on. As processors become more powerful, electronic products become more complex. Embedded system designers are able to include design features traditionally associated with personal computer (PC) including graphical user interfaces, TCP/IP networking, and database management. For introducing knowledge of embedded system to student of master of software engineering (MSE), the Software College at Tsinghua university and Beihang university had an opportunity to add technical electives for embedded system, the author received approval to teach embedded system design course. This paper describes the development and implementation of that course toward the goal of teaching students the hardware considerations, software considerations, and design processes involved in embedded system design. In the end, the teaching effect of course for embedded system design is analyzed.**

Keyword—**Embedded System; Embedded Software; Curriculum; Microprocessor; Real Time Operating System; Software Colleges**

I. INTRODUCTION

The embedded system has been widely used in numerous fields, such as the industry control system, information household appliances, the communication equipments, medical instruments and intelligence instruments and so on. For example, mobiles photos, PDA, MP3, portable equipments, intelligence telephones, set-top box.

The rapid proliferation of embedded systems requires an increasing number of engineers trained in microcontroller based systems, real-time concepts, hardware and software codesign, distributed processing, hardware-software integration, and system-level issues in embedded systems design[1],[2].

Since the portion of software in a system is getting larger and larger than hardware, software engineers with hardware background will serve as better managers than hardware engineers with software background[3]. Today's embedded system designer must have a mastery of high-level programming languages such as Java and C++ along with a clear understanding of the modern operating system (O/S).

To supply qualified embedded system engineers, a large number of university and technological academy in the seven seas offers an embedded design courses.

In [4], Sangiovanni-Vincentelli and Pinto present guiding principals for the embedded systems teaching and research agenda at the University of California at Berkeley. The principal goal is to bring closer together the fields of system theory and computer science. Pak describes how the Korean government has designed and driven the innovation of undergraduate curriculums to meet increasing industrial demand for quality IT experts in the computer-software field including embedded systems[5]. Muppaladescribes experience with designing and offering a senior undergraduate course on Embedded Systems Software in the Department of Computer Science at the Hong Kong University of Science and Technology. Course topics, hands-on laboratory experiences and course projects are presented in detail [6]. Grimheden and Törngren present embedded systemsusing a didactical approach together with some educational implications[7].

From course contents, the embedded system design is a synthetic course, which required high level on student's foundation about some related courses including Computer Discipline(such as Computer Architectures, Operating System, Program design and so on) and Electronics Discipline(such as Electronics Technique, Principle of Microprocessor and so on). In addition, the embedded system faces to application area, so the knowledge of application discipline is required at the same time so that training students to obtain the technical ability of embedded system product design. It is obvious that it's difficult for student to master the knowledge of computer, electronics and the application discipline at the same time.

In the paper, the curriculum of embedded system at software college of Tsinghua University and Beihang University is introduced. The objectives, design, and implementation of an embedded systems design course is outlined. Last, the teaching effect of course for embedded system design is analyzed.

II. CURRICULUM OF EMBEDDED SYSTEM DESIGN

The curriculum provision of embedded system course in the paper is designed for the course of Embedded System and Software Tools for graduate students at software college of Tsinghua University and the course of Embedded System Development for graduate students at software college of Beihang University. The property of the course is elective with 36 hours. The course faces to software engineering masters, so the target is placed in cultivating students' ability of understanding the theory knowledge and mastering the basic skills of embedded system design. Because of the

application characteristics of embedded system, the course specially emphasizes developing students' practice ability. According to this teaching target, we put forward teaching mode of 32 bits embedded microprocessors, Real Time Operating System and the engineering practice.

In the course of Embedded System and Software Tools and Embedded System Development we adapt the way of teaching and combined with experiments, and stands for on training students' practice ability. In the aspects of teaching content, 32 bits ARM embedded microprocessor and real time operating system µC/OS-II is used as main content and emphasizes on the course of the basic embedded concepts, design methods, the Architecture of ARM microprocessor, µC/OS-II real time operating system analysis, the porting µC/OS-II to ARM microprocessor, hardware design based on ARM and embedded software design based on the µC/OS-II[8],[9].

In order to train students' ability of designing embedded software and hardware, the software and hardware development tools and environment is required. Therefore, mainstream embedded software and hardware development platform should be chosen in the course practice. We choose a embedded experiment platform UP-NETARM3000 made by Beijing Universal Pioneering Technology Co., LTD, which adopted the microprocessor of ARM7 architecture and can run both µC/OS-II and uCLinux operating system. In the aspects of experiment content, through the foundation experiments in the lesson students should realize development environment and basis of the embedded software and hardware, such as digital I/O, A/D, D/A, interface of memory, drive of touch screen, USB interface and so on.

Examination is another intractable problem in embedded system course. How to set a kind of suitable examination system, which can reflect a student's ability, is one of the problems that the teacher should pay attention to.

The examination of Embedded System and Software Tools and Embedded System Development adopt the method of written examination and final homework, which is half and half proportion. Written examination is mainly about the basic concept of microprocessor and real time operation system, interface of hardware and program design and analysis, which examine students' understanding basic concept and design method of embedded system. The final homework examines student's cooperation practice ability. Every R&D team is constituted by 2-3 students and hands over the item project design book in a month including the topic, target of design, distribute of the team labor, develop schedule, expecting results and so on. The final homework lasts for 3 months, and the ultimate demand is to hand over a design manual, design process software, source code and executable object file. The standard of perfection about the task mainly attends on quality of software design, document, technique difficulty, cooperation spirit and so on.

III. SETTINGS OF EMBEDDED SYSTEM EXPERIMENTS

The embedded system is application oriented, experiments is the most important content in the whole curriculum of embedded system. Consider most students had less experience of embedded system design before, a way of step by step is adopted for experiments of the curriculum. Experiments divide into three parts including basic knowledge, basic skills and integrated application. In basic knowledge part, students should learn development environment and process of software and hardware and learn to write simple embedded application program through two experiments (4 hours). In basic skills part, through four experiments (8 hours), students should learn embedded development methods of digital I/O, application of touch panel and multi-task programming. In integrated application part, students should complete the designing task of embedded software and hardware on the foundation of former experiments in order to foster student's independence or cooperation ability on completing the embedded project development.

A. Basic knowledge part

The teaching objectives of this part are to make students to understand the general development environment and process of embedded software and hardware, acquaint with the experiment development tools, acquire the operating method and usage of the experiment development tools, acquaint with the software programming environment, and prepare for latter experiments. Two experiments are arranged in this part:

1) Experiment one: Introduction of development environment of ARM microprocessor. This experiment introduces normal process of embedded development, then introduces installing and debugging of the software and hardware that uses in the development process. Though this experiment, students should understand and acquaint with embedded software and hardware platform.。

2) Experiment two: Development of basic embedded application program. This experiment introduces the basic development method of embedded application procedure through simple and basic program. Then, acquaint further with the development and debugging environment in the process of application program development. Through this experiment, students should understand the basic method and process of programming, and Establish good foundation for application program designing of the latter instances.

Through experiment one and two, students will acquaint with development environment and programming method, and can understand source code.

B. Basic skills part

The purposes of this part is to let students master the basic embedded program development, debug the program according to experimental guide, understand experiment source code and know how to modify the source code to realize other similar of function. This part arranges the following experiments:

1) Experiment three: Experiment of imitating traffic

signal. Students should know how to use the I/O interface of ARM microprocessor to control peripherals switches.

2) Experiment four: Experiment of imitating the electronic panel board experiment, namely application of the touch panel. Developing a electronic panel board on UP-NETARM300 platform to master the designing method on touch panel.

3) Experiment five: GUI design experiment. GUI can make embedded application procedure more friendly and easily to use. On UP-NETARM300 platform, students can develop embedded GUI and master the design method of embedded GUI.

4)Experiment six: Experiment of Multitasks and A/D conversion. Signal Sampling of Multi channels are imitated by Multitasks on the foundation of μC/OS-II operating system and monitor the multi channels signal according to the task priority.

The experiments in this part are carried out with best preparation and design. Requirements of experiments are put forwards before the lesson. Students are asked to prepare. In the experiment lesson, the contents are introduced and students are demanded to supplement the key source code.

C. *Integrated application part*

The integrated application part is the open design project. Students are divided into many teams constituted by 2-3 people. They should apply the development knowledge and method of embedded software and hardware mastered in earlier lessons to complete the project. Two topics are provided:

1) Topic one: Design of electronic waiter system control based on LAN or wireless. In the near future, the attendants in the hotel may not exist any more, because the electronics waiter, equipments with LAN of wireless can connect to menu directly and ordering real time. This topic requests student's cooperation to complete electronics ordering system, which refers to TCP/IP network, touch panel, the LCD display and so on.

2) Topic two: The LCD control and application oriented to game GUI. It is a trend that game function will be integrated in the handset equipments. For this topic, requests Student are requested to complete an embedded game on the experiment platform, such as greedy snake, Tetris Elements and so on. Implement simple game, common graphs and cartoon effect through LCD control and graph programming.

Students can also choose the topics they interested in. The task, which is a complete opening practice, should complete dependently by students. Answering and instructing will be provided during the period. Cultivating students' independence or cooperation ability to complete embedded development item and training students' ability of designing embedded software and hardware.

IV. ANALYSIS OF CURRICULUM OF EMBEDDED SYSTEM

Adopting the curriculum of embedded system in this paper, author has taken on the teaching task of embedded system and software tools for the MSE of Software College of Tsinghua University in the fall of 2002, 2003, 2004, and taken on the teaching task of embedded systems development for the MSE of Software College of Beihang University in the spring of 2003, 2004 and the fall of 2004, 2005, also taken on the teaching task of embedded system and software tools for the undergraduate student (junior) of Software College of Tsinghua University in the fall of 2003, 2004 (The same curriculum as the MSE).

In general， the students show great interest to the embedded system course that combining the teaching with practice. And the learning passion is very high. The following is the analysis with the teaching thing of this curriculum for the undergraduate student and MSE of Software College of Tsinghua University in the fall of 2004.

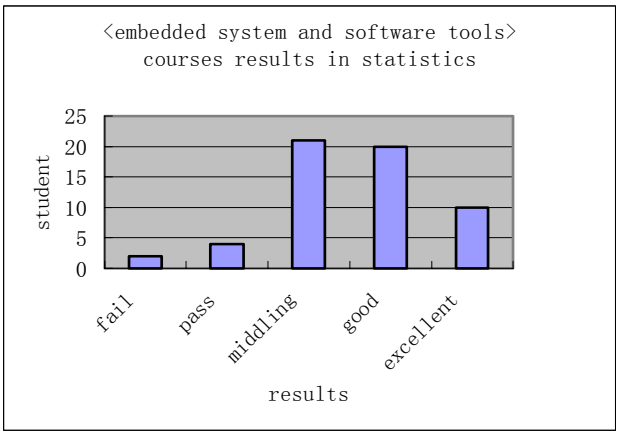


Fig.1. The result of MSE and graduate student

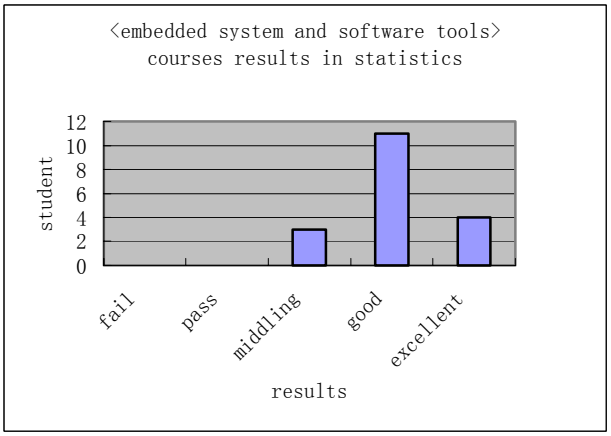


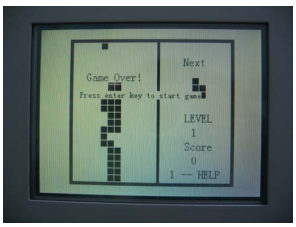
Fig.2. The result of undergraduate students

There are 18 undergraduate students taking embedded system and software tools as an elective course, and the number of MSE and graduate student is 57. The assessment of curriculum is in the form of final homework (60%) + examination (40%). The result of MSE is showed

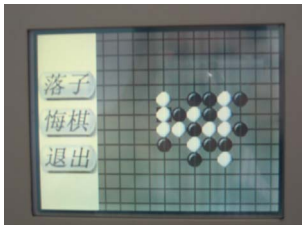
in Fig.1, there are 2 fail (under 60), 4 pass (from 60 to 69), 21 middling (from 70 to 79), 20 good (from 80 to 89), 10 excellent (from 90 to 100).

The result of undergraduate students is showed in Fig.2, there are 3 middling (from 70 to 79), 11 good (from 80 to 89), 4 excellent (from 90 to 100). The result of undergraduate students is better than the result of MSE on the surface. Because the students of MSE are coming from different specialty and other university, and the basic is less difference.

In final homework, most students choose the development of embedded game, and some of them did pretty well. Fig.3 are some final homework of this curriculum, there are Tetris Elements, Gobang and electronic waiter system. Students make a concerted effort, a rational division of labor, some responsible for the overall structure, some for algorithms, some for achieving interface. The time using for the final homework for most students are 20-30 hours, and some are more than this.



a) Tetris Elements



b) Gobang

c) Electronic waiter system

Fig.3 The final homework completed by students

Most students show great interest to the embedded curriculum that combining the teaching with practice, after finishing whole development of embedded software (the final homework), they fill the achievement that not getting form the previous courses. As a curriculum, the student's feeling of achievement is very important. Because it can stimulate the new interest on embedded system, and working in an embedded system to continue research in the subsequent study and work. The following is some feedback of students:

- "After completing of an interesting game design independently, the feeling of proud is hard to say. Just because the practice of former time, we can have the ability to finish the final homework. We gain great through the experiment."
- "Though we meet some difficulties and questions, we deeply realize the pleasure of developing embedded program under μC/OS-II. When our Tetris Elements run successful, the feeling is so exciting! We believe that through continued learning in the future, we will further enhance the embedded system development capabilities and into an embedded system's development holy house!"
- "Through a semester of study and practice, we have possessed the initial development of knowledge in this major operation, and have further understanding on the programming methods combining of software and hardware after final homework."
- "While large operation is only integrated of the old small experiments, but we encountered many difficulties when achieving it. A small knowledge point can let us using dozens of minutes even few hours to resolve it. A small bug can let us check and recheck the code. Once we didn't stop programming until 4 o'clock in the morning. But the pleasure and the achievement is hard to say."
- "After completing the major operations, we understand the broad framework of an embedded programming, and know a lot of details. After all, we have done it. Overall, the final homework spent a lot of time and energy, while the harvest is great. It can be said that the embedded programming curriculum was very successful."
- "The development of greedy snake is the first development for an whole embedded application. Through this comprehensive development process, we gained new understanding on the development of embedded."
- "Finally compelled to mention, in this region, we have succeeded combine the software development actually with the professional theories that we have learned. Data structure class is a major computer science professional foundation courses. We have learned lots of complex data structures on this course, but rarely find its practical applications. When we developed snake game, we used the thinking of list and static list. And we also saw some classic theory in the actual development of the role. This has become a tremendous driving force for the learning of professional theories."

Students have made some valuable recommendations for this course. They think that the embedded system is a new course, and has strong background application, which is required for the college education courses. They also think the experiments are very good, because it apply the chance for the students to contact with the embedded development. But they also feel the presence that the relationship between the learning process in the course of theoretical knowledge and experiment is not close enough. They advise to introduce the embedded equipment used for this course and the application program interface of the equipment. Some students suggested that the focus on the teaching should be the knowledge closely related with practice, in particular the design of an embedded operating system and examples, such as μC/OS-II, this theme can be

used three or more hours to explain. These recommendations will further improve our curriculum and teaching practice to provide useful reference content.

V. Conclusion

In the IEEE Computer Society/ACM Task Force on Computing Curriculum, embedded system has been listed as one of the key curriculums[10]. In addition, electronic engineering, software, automation, and other disciplines will also give a course of embedded system, the research and practice on the embedded system of various disciplines will be a long-term process. This paper combine the embedded system teaching application of Software College of Tsinghua University and Software College of Beihang University, introduced the embedded systems curriculum and courses for examination methods, the effects of teaching and curriculum analysis. We hope that these contents can provide reference and information for other universities to create the embedded system curriculum.

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