The Research for Open Source Hardware Used in Embedded Specialty

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Abstract. Embedded specialty students in higher vocational colleges often feel difficult to learn the professional courses because of the difficulty of course contents and high experimental complexity. The open source hardware applies modular hardware design and encapsulates complex software programming methods. It is easy to learn for students. This paper analyzes the characteristics and advantages of open source hardware, such as Arduino, Raspberry Pi and so on, and makes teaching practice from the teaching contents, the construction of embedded laboratory and the education of maker. The feasibility of using embedded hardware platform for embedded curriculum teaching is discussed.

Introduction

Since China has put forward the concept of "Internet+", the technology in “Internet+” accelerates the transformation and upgrades the traditional industries. Traditional manufacturing enterprises and Internet has been integrated deeply. The requirement for embedded system technicians is increasing rapidly, but the training for embedded professional technicians in higher vocational colleges is lagging behind to meet the requirement for embedded system technicians in the information 2.0 eras. The embedded system curriculum of higher vocational education belongs to interdisciplinary subjects such as computer, electronics, and automatic control and so on. The contents of the embedded system courses include the development of hardware, software and application program. The practical teaching of professional courses is complicated and hard to learn. Most experiments base on verification; it is difficult to meet the technical requirements of the hardware design technicians [1].

In order to improve the students’ technology quality in embedded system in higher vocational colleges to adapt to the intelligent transformation of traditional industries, it is necessary to update and optimize the interdisciplinary knowledge for embedded system courses, such as introducing new integrated chips, modular hardware design, increasing microelectronics, automatic control and computer, to improve the practicality of the courses. All of these are made the more difficult for curriculum teaching. The students who major in embedded system in higher vocational colleges have strong programming ability, but the knowledge of electronics and mechanics is relatively poor. The contradiction between them becomes the urgent problem to be solved in the training for embedded system students in higher vocational colleges.

With the development of open source software ideas, in recent years, open source hardware began to be attracted and used by embedded system development engineers, electronic enthusiasts and makers [2]. Arduino platform as the most typical open source hardware [3], not only provides a good integrated interactive development environment, but also develops functions using of its simple functions, so these can reduce the difficulty for the students to learn hardware knowledge. Using this platform, students do not need to master the microcontroller underlying hardware design and software coding. This platform can greatly meet today's hardware integration, requirements for modular design. In this paper, the advantages of open source hardware used in embedded system teaching and the feasibility of this reform are discussed.
The Problems of Embedded System Teaching

The difficulty of teaching contents. Embedded system specialty is generally launched in the computer department in vocational colleges. This specialty is the integration of computer, electronics, automatic control and other specialties. Students who major in this specialty not only need to learn computer, electrical circuit, automatic control and other professional knowledge, but also need to integrate these knowledges into the application. It is difficult to develop their professional skills and innovation ability when the vocational college students with weak foundation and lack of learning initiative face the relatively esoteric circuit and automatic control knowledge. At present, the embedded professional courses of higher vocational colleges include "C language program design", "embedded system design", "SCM and interface technology", "ARM architecture", "embedded Linux development" and so on. High vocational students in the limited time cannot master these partial difficult knowledges.

Limitation of teaching methods reform. Embedded specialty courses are mainly practice-based. The current teaching methods are based on a small amount of verification experiments for the theories of these courses. The hands-on assembly and debugging experiments for students are relatively less, so it is difficult to fully understand the learning knowledge and techniques. This traditional method of teaching has been unable to meet the requirements of higher vocational education.

In recent years, provincial, national skills competitions are carried out, this greatly promotes the improvement of embedded professional teaching methods. These contests can improve students' interests in their specialty learning and hands-on practices, and accelerate the upgrading of professional courses' contents. So this is the effective teaching method for the integration of theory and practice. But the role of competition still cannot keep up with the pace of development of the industry because the rapid development of intelligent hardware on embedded, so the higher requirements have been put forward on teaching methods.

The Advantages of Open Source Hardware

Introduction to open source hardware. Open Source Hardware concept derived from open source software licensing, the open source movement sponsor Bruce Perens in 1997 for the first time launched the "open source hardware certification program" [4]. Open source hardware is the design of computer and electronic hardware in the same way as open-source software. Circuit schematics, bill of materials, design and software development kit and other details will be published in free [4].

With the rapid development of FPGA, SoC design, and the promotion of well-known IT companies such as Google, Intel, Facebook and so on, the production cost of open source hardware is greatly reduced. Major enterprises have set up open source hardware platform projects, the representative open source hardware development platforms include: Arduino, Raspberry Pi from the Raspberry Foundation, BeagleBone from the Texas Instruments etc. Arduino has small size, low cost, ease of use and expansibility, active technology communities, a large number of sample projects and tutorials. It is the better entry-level platform tools for beginners to help them innovate their ideas. It is the most suitable for weak hardware-based vocational students.

Features and advantages of Arduino. Arduino is one of the most popular open source hardware development platforms for beginners in the idea of sharing open source licenses. It was jointly designed by Massimo Banzi and David Cuartielles in 2005 [5]. Arduino hardware includes Arduino official board, hardware drivers, sensor expansion board. Arduino IDE for software development use a similar Java, C language, and Scratch graphical development software can be used through the special interface, and further reduces the difficulty of embedded development.

Arduino using Atmel AVR microcontroller, although the processing function is relatively weak, but its advantages are more obvious, including:

Price cheap, the basic board price of Taobao online shopping are in 10 dollars. It is about 20-30 dollars coupled with commonly usual sensors, motors, diodes and resistors and other entry-level
development kits. It is very cheap and can be afforded for beginners and schools for experimental components investment.

**Easy learning**, Arduino as the easiest to use, entry-level open source hardware development platform, provides IDE development kit with the underlying hardware package, masking the microcontroller hardware programming details, so it greatly reduces the difficulty of learning. It is one of the best embedded platforms for high-vocational students as a beginner to learn.

**Expansibility**, Arduino provides a wealth of I/O interface. Through the expansion board and its I/O interface, it can be connected with keyboards, mouse, commonly sensors, motors, displays, Bluetooth, Wi-Fi and other modules to achieve functional expansion.

**Rich learning resources**, industrial ecosystem integrity. Arduino has many open source third-party extension function libraries with a rich tutorial and documentation. Beginners can get many learning and development documents in the communities for Arduino. In these communities, the developers can ask questions about Arduino, and they will get feedback timely, which will greatly stimulate the learning interests.

**Raspberry Pi features.** Raspberry Pi is developed by the British Raspberry Foundation based on ARM 11 architecture with USB, HDMI, Ethernet, SD card and other common interface, with pre-installed Linux operating system, supporting for Java, C, Python and other programming languages. Raspberry Pi is equivalent to a miniature low-cost computer, widely used in industrial control, robotics, smart home and other fields [6]. Although the price of Raspberry Pi is higher than Arduino, but much more powerful than Arduino, it can be seen as an upgraded version of the Arduino. Raspberry Pi has the following characteristics:

**Modular hardware architecture**, extended functions based on Raspberry Pi are only required to purchase finished modules, using the interfaces the modules can connect to the main board to work. These building block methods can greatly reduce the difficulty for students with weak electronic and hardware knowledge, so it is very suitable for embedded system design.

**Affordable price**, although Raspberry Pi in Taobao online price is about 30-40 dollars, it is more expensive than the Arduino, but it is cheap than other ARM 11 architecture development hardware board, coupled with the rich interfaces and powerful features, so that which has a high cost-effective, using Raspberry Pi can save a lot of teaching equipment costs.

**Sharing of resources**, numerous famous technical person and Raspberry Pi enthusiasts share their own design, resources selflessly in open source communities worldwide. The open resources can help students get technologies and ideas, furthermore this way can make them join the open resource teams, learn to share.

### Teaching Practice in Embedded Open Source Hardware

Through the above analysis of the advantages of Arduino and Raspberry Pi, these open source hardware platforms can be introduced teaching in embedded specialty. The teaching model establishment of open-source hardware based on professional courses will help students in the complex hardware design, reduce difficulty, and excite studying interests. This part will discuss the teaching practice based on Arduino and Raspberry Pi from the aspects of teaching contents, laboratory construction and the maker education.

**Use the hardware platform to learn the programming language.** Embedded specialty basic courses include "C language programming", "SCM and interface technology" and so on. The traditional teaching method is to explain the basic grammar and operation, flow control, array and string of C language according to the knowledge point. The MCS-51 is the basic course of the embedded specialty including the components of SCM, interface technology, serial communication, AD conversion and so on. Students can only learn basic programming knowledge, cannot be associated with the actual application of embedded engineering, so it is easy to lose interest in learning.

C language teaching introduce Arduino platform, put the C language knowledge points into the Arduino experiments. The students learn basic syntax of C language in Arduino experiments. Through the design of SCM experiments explain the basic operations of the C language, process
control, and programming methods [7]. This can help students understand the C language knowledge points, and promote students to understand these in engineering applications. So, students achieve a sense of accomplishment quickly as soon as possible, improve learning interests and enhance development experiences. Some experiments as shown in Figure 1.

![Diagram](image)

Figure 1. The Relationship of C Language and Arduino Experiments.

From the Figure 1, Arduino open source hardware platform can be used in C language teaching, the experiments can effectively integrate the programming language with engineering applications, so this can increase the interest and motivation of vocational students.

Arduino has the ability to deal with a variety of sensor data, collect data, and it can be used in process control, sent data to another platform and so on.

Traditional embedded Linux development teaching is generally based on ARM9 S3C2410 development board, because this board is typical to run Linux OS. Linux transplantation including kernel configuration, cross compilation, driver programming and application programming are teaching based on ARM 9 development board, these teaching contents can help students understand the Linux system. But this knowledge is complex for high vocational students to learn, and is difficult for teacher to teach. Raspberry Pi with Linux OS can run Java language applications and Java class libraries, Python language applications to operate GPIO, serial communication, LCD screen and other hardware. The hardware drivers are included in the Linux OS of Raspberry Pi. Some functions can quickly achieve using these drives. Compare with development process "Linux driver -> C programming language -> cross compiler" for the traditional S3C2410 development board, development efficiency of Raspberry Pi is greatly improved, students can easy master and implement the embedded Linux development.

For example, TCP/IP communication function can be achieved in a few lines of code using Raspberry Pi recommended Python language; this is not need simulator and cross compiler [8]. The development process than S3C2410 is simple and efficient, so it is suitable for vocational education. Furthermore, Python has libraries to support the robot, robot arm and other intelligent functions; it is easy to expand to smart home, intelligent robot and intelligent Wearable equipment and other items.

**Constructing the Maker Education Model Based on Open Source Hardware.** Now "Maker" is giving the meaning of innovative people who realize their creative ideas using the network, open source hardware, 3D printing and other novel technologies [9]. The innovations, integration, practice and sharing of Makers influence the students in higher vocational colleges. The students can creatively make the novel ideas into realization by the open source hardware. The traditional teaching idea and teaching mode are changing quietly. [10].

How to cultivate students' innovative ability has become a challenge for higher vocational education. The “Maker” innovative education mode will be a research in vocational colleges [11]. The Arduino, Raspberry Pi as the typical open source hardware, 3D printer and other technologies support to build innovation studios for teachers and students. These studios attract different professional background, different grades of students to join in for vocational and technological innovation and collaboration. Students make various prototype applications for demonstration using Arduino, Raspberry Pi and other open-source hardware developments. This can enhance students’
project prototype delivery abilities, training interactive to help students get a sense of accomplishment as soon as possible, the development experience, learning motivation, sharing and collaboration.

Summary

Arduino, Raspberry Pi these two open-source hardware platforms can be introduced teaching in "C language", "SCM and interface technology", "embedded Linux development" and other embedded system courses based on the analysis of the existing teaching problems. This paper puts forward the idea of reforming teaching practice based on open source hardware. Arduino, Raspberry Pi and other open source hardware make the embedded system curriculum become lively and interesting, enhance the students' motivation to learn, improve the students’ hands-on practical abilities. Students take the initiative to participate in project design and various types of competitions.

In the follow-up work, we will continue to accumulate the teaching experiences of open-source hardware platforms such as Arduino and Raspberry Pi, and gradually update the teaching contents of "ARM architecture" and "embedded system design". We will do some work for creativity education in students training.

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References