Applying Open Source Softwares Fritzing and Arduino to Course Design of Embedded Systems

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Abstract
The failure of education reform in Taiwan brings about the serious disorder of elementary technicians in Taiwan manufacturing industries in today. In this study, authors strongly emphasize the spirit of "learning by doing" to improve students' practical operating abilities. In the course design of embedded systems, open source softwares Fritzing and Arduino are chosen to teach our students the abilities of drawing the layout of breadboard wiring, the electronic circuit sketch and the PCB layout of a practical electrical circuit as well as the abilities of Arduino programming for electronic hardware. This sort of training can help students fully understand how to integrate hardware and software together. After running two-years teaching program on it, our students joining this elective course give us very positive feedback, that is, this novel lecturing way in conjunction with Arduino and Fritzing precedes better than our conventional lecturing way.

Keywords
Open Source Software; Open Source Hardware; Arduino; Fritzing; Embedded Systems

Motivation
In September 1994, Professor Yuan-Tseh Lee served as convener of education reform in Taiwan. Two years later, the committee of education reform completed the task of Total Consultative Report of Education Reform as a reference of education policy [1]. After a decade of education reform, the results end up miserable. Under the guiding policies of this education reform, many students in junior high schools choose the road to general high schools and then to universities, but not to vocational high school and then to colleges or universities of science and technology. Consequently, after this improper education reform in Taiwan, the ratio of student's number of vocational high school to that of general high school has a great change from 7:3 in the past to almost 3:7 today. This brings about the serious shortage of basic talents in manufacturing. The failure of the education reform in Taiwan starting from 1995 was admitted by many educational experts. One reason for this failure can be traced backwards to that the accreditation mechanism for universities leads to no apparent difference between universities of Science and Technology and general universities. Another reason for this failure is that students graduated from both private vocational schools and universities of Science and Technology have fewer opportunities of do-it-yourself practices. Before any possible and beneficial act may change in our education policy, the only thing we can do is to alter our lecturing way so that all graduates of the vocation-oriented Universities of Science and Technology can be trained more competitive, no matter how qualified they came in high schools.

It's well known that the major contribution of GDP in Taiwan comes from the manufacturing industries. The emerging and innovative industries still need lots of technicians and experts in chemical, civil, mechanical, electrical and electronic engineering. Otherwise, the overall Taiwanese manufacturing industries will be confronted with a series of developing bottlenecks due to shortage of basic talents. In December 2012, a reporter asked Cook, the CEO of Apple Inc., a question about an outsourcing labour controversy in the Mainland China, why Apple Inc. does not completely withdraw from the Mainland China? Cook admitted, "The wage is not the primary problem, what he is concerned with is the technology." He said the US educational system can not
cultivate sufficient technicians and experts satisfying the demand of modern manufacturing industries [2]. This speech apparently indicates technical skill in mass production is very important to manufacturing industries.

The survival of Taiwan's economic future lies in aggressive and innovative talents as Taiwan enterprises are seeking opportunities of developing new and creative products and services. What a pity! Many students recently attending private universities of science and technology possess low self-expectations in their studies and serious weakness in basic disciplines. This de facto can not be denied but can be altered. The high threshold of training them may make them retreat or give up before transforming themselves. Today, the cultivation over undergraduates in universities of science and technology must escape from the scripted lecturing way in the past for the sake of both moderately lifting students' curiosity and innovative ideas and providing more efficient fresh employees to Taiwan enterprises. Thus, what teachers can change is to keep up with their ability, to touch their curiosity and to make them gain a sense of achievement. Consequently, authors try to teach students the open source softwares Fritzing and Arduino in embedded systems for helping them fully understand the necessary integration between hardware and software for an electrical application.

Features of Arduino and Fritzing

Schank once said when there are “doing devices” available, it is easier to implement learning by doing. If you do something often enough, you get better at it --- simple and obvious. When people really care about what they are doing, they may even learn how to do their jobs better than anyone had hoped [3]. We firmly believe learning by doing is a good lecturing way and make our determination to prove it workable. Thus, Arduino and Fritzing are considered as lecturing tools for embedded system.

Arduino project started from 2004, the first release of Arduino Microcontroller Unit (MCU) board was UNO in 2005 [4]. Currently in Arduino's website you can see various official products, references, libraries, and their application examples. Supporting open source hardware, Arduino allows users to make a creative MCU, but he must follow the licenses under which the original board is made [5]. Hence users are easy to find other cheap Arduino compatible hardware for their projects around the world. More interestingly, from third-party vendors, users can discover many products for both input and output, and communication modules which are easily brought together with Arduino MCU.

It is worth noting that Fritzing is one of the best supportive open source software for Arduino. With the aid of Fritzing for an experimental circuit, users can easily do wiring connections among electrical components in an electrical breadboard, and accomplish its relative functional sketch for explanation and its PCB layout for later production. More importantly, users also can be inspired by many Arduino-based applications drawn by Fritzing in its official website [6]. Under the aid of Arduino and Fritzing for prototyping, users only need to concentrate their effort on how to make his native creativity possible.

Course Plan of Embedded Systems

Collocating Arduino programming with Fritzing in embedded systems, we intended to teach students 11 basic experiments and 2 advanced experiments. The brief description about them is listed below.

1. **LED flashing circuit**: Its first target is to learn the Fritzing functions for drawing the experimental circuit as shown in Figure 1. The second target is to familiarize the program style of an arduino code and to understand the usage of digitalWrite() for digital output.

2. **LED on/off by buttons**: Let’s keep on studing Fritzing function on circuit drawing as shown in Figure 1 and then use digitalRead() to pick up the external digital input and show the button’s status on the corresponding LED.

3. **4 X 4 keypad scanning circuit**: Firstly, we draw 4 X 4 keypad as an eight-port connector due to the absence of this component in Fritzing. Another target is to read the status of 4 X 4 keypad by multiplexing the scan lines via the alternate functions between digitalWrite() and digitalRead().

4. **Four-digit seven-segment display**: Herein four-digit BCD number (data) is feeding to the common nodes of four-digit seven-segment display and the timing of turn-on or turn-off for each digit is controlled by the
corresponding four-digit driving signal. Similar to the previous experiment, the display function is achieved by accurately multiplexing over driving signals under the demand of vision persistence.

5. **5 × 7 LED matrix array display**: Jointly bringing the row-based scanning and the column-based data feeding together, the running of multiplexing program will present numeric patterns from 0 to 9 iteratively on 5 × 7 LED matrix array.

6. **DC motor driving**: This experiment focuses on the determination of rotational direction of a DC motor by settling a set of digital control signals over two pairs of motor driving circuit.

7. **Step motor driving**: Three driving ways (single phase, two phases and half stepping methods, respectively) for a step motor are introduced.

8. **Alarm signals and music signals playing**: Any sound and music signals are made up of various frequencies waveform. Students can make his composition (tones and beats) about one special alarming signal or a song and then play it in speaker module by digitalWrite() instruction.

9. **LCM display**: To show a message on LCM display, students first understand the commands of LCM. Next, they follow the necessary handshaking procedure to do programming about LCM initialization and the message delivery to LCM.

10. **Voltage measure across a electronic device**: Arduino-based controller can acquire an external analog signal by the instruction analogRead() over a specific pin for analog input, for instance, the midst pin of a working variable resistor and/or the test pin over a light-controlled circuit by a photoresistor.

11. **PWM controlled LED brightness**: To light a LED at varying brightness or to drive a motor at various speeds, user can impose an instruction analogWrite() over specific pins (e.g. 3, 5, 6 in UNO) for analog output. In this experiment, three different PWM signals are applied to red, green, and blue LEDs so that students can create an atmosphere of colourful LED lamp.

![FIGURE 1. CIRCUIT FOR LED FLASHING CIRCUIT AND LED ON/OFF BY BUTTONS](image)

### Advanced Experiments

**Alarm and Clock System**

Almost all computer systems have their internal embedded clock systems that can be used to reflect the present time and the working duration ever passed. Timer module is itself independent of other modules in a computer system. In Figure 2, the execution of clock program in the Arduino UNO board can fetch the present time from DS3231 through SPI interface and then send the clock message to LCM display.

**Solar Tracing System**

Green energy instead of petroleum has been proposing to solve the scarcity of energy. Solar energy is one of useful
and regenerative green energy. To effectively make use of the solar energy, the working solar platform with many pieces of photocells at best must face to the incident solar ray. Since the solar trail along the earth can be computed by astronomical formula, our solar tracing system is implemented based on the information of altitude, longitude, latitude and time. Once tilt angle and azimuth angle are determined by computation, two step motors for driving the working solar platform shown in Figure 2 will be tuned hour after hour from dawn till dusk in accordance with yielding more electrical energy from solar energy.

![Advanced Application Circuit](image)

**FIGURE 2. ADVANCED APPLICATION CIRCUIT**

**TABLE 1. THE NUMBER OF THE RESPONSE TO A QUESTION**

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**Feedback Analysis on Curriculum Design**

For evaluating the efficiency on this course design of embedded systems, an investigation of questionnaire was conducted for juniors and seniors whose numbers were 45 and 25 students in 2013 and 2014, respectively. They ever studied 8051 C programming but didn’t familiarised computer-aided circuit design (CACD). The questions are given below.

1. What is your experience about 8051 chip? (a) have ever used C programming for 8051 chip, (b) have ever taken similar courses, (c) self-learning, (d) heard only, (e) never heard.
2. What is your experience about CACD? (a) have ever used CACD tool to do circuit layout, (b) have studied CACD course, (c) self-learning, (d) heard only, (t) never heard.
3. What is your comment about the introduction of Fritzing in this course?
4. Do you believe Arduino programming is easy?
5. Do you think that embedded system can help you integrate hardware and software together?
6. Do you think that embedded system can help you do a creative project?
7. Do you think that Arduino programming is easier than conventional C programming for 8051 chip?

The responses to questions (3)-(7) are the same and the response list is (a) most agreeable, (b) more agreeable, (c) acceptable, (d) more disagreeable, (e) most disagreeable.

8. The difficulty of experiments is (a) easier, (b) easy, (c) ordinary, (d) difficult, (e) very difficult.

As shown in Table 1, many students have ever studied C programming for 8051 chip and nearly 4/7 of students didn’t ever study CAD. They affirmed that Arduino in conjunction with Fritzing is helpful in easy programming than conventional 8051 C programming, and these ordinary experiments we designed can help them do innovate a creative project.

Conclusions

Observing the miserable fact that insufficient practice over basic experiments in vocational high schools had been happened in Taiwan, authors taught undergraduates how to utilize Fritzing to draw the deployment of components in electrical breadboard, the functional sketch of electronic circuit and its PCB layout of an experiment. It is well known that the logic concept and C programming skill are very important for studying embedded systems, but our undergraduates are too weak in 8051 C programming, for instance, lack of capturing the meaning of byte manipulation and inability in simplifying the Boolean function comprised from the complex combination from logical and relational functions. For help them understand the integration of hardware and software in these experiments in embedded systems, authors introduce C-like Arduino language to do bit manipulation over a signal line. As a result, undergraduates can make sense over digital inputs/outputs as well as analog inputs and outputs. The response of the investigation of questionnaire for this course design from 70 juniors and seniors is positive. That is, this lecturing way of learning by doing can effectively and strongly enforce our students’ ability on doing the integration between hardware and software.

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REFERENCES


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