Specialty-oriented "Computer Network" experiment design

Zhao Guang-yuan*

School of Automation, Xi'an University of Posts & Telecommunications, Chang'an West St. Chang'an District, Xi'an, Shaanxi, China

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Abstract

In this paper, the teaching usage feasibility of open-source electronics platform Arduino is discussed, with regard to the loosely combination status of "Computer Network" course experiments and measurement and control technology specialty. Then the improved solution of "Computer Network" course experiments is proposed and embedded server simulated industrial applications for experimental teaching is designed based on Arduino. Practice shows that the design cost is low and the development cycle is short due to the use of open source hardware. Moreover, the specialty-oriented characteristics can help students to enhance professional knowledge understanding, increase interest in learning and strengthen innovative practice atmosphere.

Keywords: Arduino, Computer network, Course experiment, Embedded sever, PBL

1 Introduction

With the development of science and technology, fusion of communication technology, computer technology and control technology has become the inevitable trend. Especially the Internet of things and its' vigorous development makes the necessity of the fusion more prominent. Therefore, it also has vital significance to offer "computer network" course for non-computer majors such as measurement and control technology, etc.

Limited to the students' knowledge structure of non-computer majors and school funds, the experiment setup of "computer network" mainly shows two directions on the premise of understanding promotion and cost reduction. One is through developing virtual experiment using sniffer tools, etc., to solve the problems of hardware experiment equipment deficiencies, reduce costs and enhance the students' understanding of knowledge; The second is through taking measures from different perspectives, to carry on the corresponding teaching reform activities, to improve the learning interest from a higher level, and to strengthen the students' ability of application.

There are practices that use open source software or simulate software to assist course instruction [1, 2]. Some virtual machine and protocol analysis tools are used such as Ubuntu Linux, Dynamips, GNS3, VirtualBox, PEMU, Wireshark, etc., also there are Omnet+ + and NS2 that are used for networking protocol simulation, virtual router Olive, Web server Apache, Tomcat, FTP server FileZillaServer, FTP client SmartFTP，Database system Mysql, Sqlite, Open source programming language Python, Ruby, etc.

More specifically, Ethereal software (Note: later renamed Wireshark) is used to trace and analysis actual network data packets for understanding and grasping the basic concepts of computer network [3]. Uses of Ethereal also save costs of expensive special network equipment; the network simulation software NS2 is used to simulate the network protocol, network topology and network performance, or develop computer network performance test project [4 - 7]. Packet network simulator Tracer is used to establish a simulation environment [8]. With the instructional need of computer network principles and protocols analysis, WinPCap is used to develop network protocol analysis experiment system [9]. Sniffer software is also used to design "computer network" course experiment [10].

To solve the problem of "computer network" abstract content, boring process of teaching and learning, and others such as computer network own fast updating, large amount of information, interdisciplinary characteristics and less class hours for non-computer majors, there is also instruction practice that is from more macro perspective [11, 12]. The practice got better teaching effect by means of optimizing course contents, reforming teaching method (using analogical teaching method, "bottom-up" and "top-down" combined teaching method, case teaching method, task driven teaching method, independent research method etc.), strengthening the experimental instruction, and reforming the examination form.

Using software to assist teaching and optimizing "computer network" content of non-computer majors can enhance the perception of network working processes to a great extent and increase interest in learning, active experimental atmosphere. It has vital significance in enhancing the instruction effect and improves the research ability of teachers and students.

But all these studies are generally carried out on non-computer major instead of specific major. Based on our teaching practice, we put forward instruction reform solutions which is combined with specific professional application, and designed "computer network" experiments using open-source electronics platform Arduino for measurement and control technology major.

The remainder of this paper is organized as follows. Section 2 attempts to analyze application feasibility of Arduino in teaching from three aspects. Section 3 describes the improvement of experimental scheme compared with the scheme used earlier. Section 4 describes the experimental design case, discusses in detail the hardware and software design of the Real Time Monitoring System for

* ***Corresponding author*** e-mail: zhaoguangyuan@xupt.edu.cn

Industrial Field Environment. Finally, section 5 concludes the paper.

2 Application feasibility analysis of Arduino in Teaching

Arduino is an open-source electronics platform based on easy-to-use hardware and software. It's intended for anyone making interactive projects [13]. It applies to designers, artists and fans of interactive project [14].

The following discussion, which is from three aspects, analyses the feasibility of the introduction of Arduino in "computer network" course experiments.

2.1 ARDUINO, ITS OWN CHARACTERISTICS DETERMINE ITS APPLICATION CONVENIENCE IN "COMPUTER NETWORK" COURSE

Arduino has the following characteristics:

(1) It is cheap and easy to use. Compared with other micro controller, open source platform Arduino uses AVR series controller which has lower price than others. It can be easily connected with the electronic components, all kinds of sensors, and can be used to achieve system-level application quickly; it also can load program online with ISP mode under the support of bootloader.

(2) It has a good cross platform merit. The Arduino development environment can be run on Windows, Macintosh OSX, and Linux, while development environments with most other micro controller are only limited to Windows.

(3) It has a simple programming environment. The Arduino has an easy-to-use development environment built on Processing, and the Arduino programming language resembles C with a touch of C++. This not only can be easy to beginners, but also has strong scalability for advanced users.

(4) Hardware and software of Arduino are open source and support for extensions. It provides Eagle format PCB and SCH circuit diagram. Experienced users can extent or improve the circuit diagram according to the requirement; even relatively inexperienced users can also build a bread board circuit to deepen understanding; Arduino software is open source and can be extended through C++ library. For advanced users who want to understand the technical details can directly use the AVR-C programming language, or insert AVR-C code into Arduino program.

(5) It has various application forms. Arduino support a variety of interactive programs, such as Flash, Max/MSP, VVVV, Processing etc. it has strong performance, rich forms of expression.

In all these characteristics, low price is the most important factor that we introduce Arduino into teaching practice. In addition, good cross platform merit allows users to use in different platform; users can quickly be familiar with Arduino using simple its programming environment, and operate skillfully; open source hardware and software can enhance the students' consciousness of engineering, spur students to consider on the system level; rich application form is helpful to develop prototype system more rapidly for different applications.

More importantly, Arduino development environment includes network application library file (or class). For Ethernet application, for example, the Arduino not only developed the extended network related hardware modules, but also was supported with Ethernet library file and the corresponding routines. Users, who master only the basic knowledge of network application and understand the basic usage of library function, can carry out innovation design of network application.

In concrete teaching practice, we can take some measures such as preparing some introductory material, releasing material in advance for students' preview to help students to understand Arduino and develop application in a relatively short period of time.

2.2 ARDUINO IS HELPFUL TO PROMOTE UNDERSTANDING FROM MULTI-DIMENSION ASPECTS

There are several major factors can be helpful to promote understanding: information technology, effective teaching strategies and methods, meaningful teaching task or activities, effective organization of teaching task or activities, tools for students and teachers, group cooperation and discussion [15].Accordingly, we can construct teaching mode to promote understanding based on information technology using all these factors.

The process of making project is also a learning process for students. Compared with the teaching mode mentioned above, as a kind of information technology and a new form, Arduino is conducive to promoting the understanding of knowledge in general; secondly, Arduino makes the learning process become more meaningful activities. For example, with the help of Arduino, students can finish task more easily. So we can set the entire project, or establish their research practice project by students themselves and completed by the team, thus form project based learning. In this process, students are the main body and the initiative is in the students hands. Thus, Arduino supports teaching that promote the understanding from multi-dimension aspects, which has obvious effect in enhancing the understanding of knowledge, and improving innovative ability.

2.3 RICH TEACHING PRACTICE CASES OF ARDUINO CAN BE LEARNED

At present, application of Arduino in education mainly scattered in CAI (computer aided instruction) of different courses and their practice teaching. We can learn from their thought and application methods.

(1) Programming language teaching

In University of North Carolina at Asheville, Arduino was used in first and second programming courses for both majors and non-majors and was used to develop both artistic and engineering applications. They have found that the use of this small inexpensive platform in hands-on labs seems to excite students who can immediately recognize (or fantasize) many uses for these boards [16]. Purdum [17] introduces users to the C programming language, reinforcing each programming structure with a simple demonstration of how you can use C to control the Arduino family of microcontrollers and is written for those who have no prior experience with microcontrollers or programming but would like to experiment and learn both. This makes it

possible to learn C programming language based on the Arduino platform.

(2) Robot teaching

In Slovak University of Technology in Bratislava, they used for many years the commercially available mobile robots for education, mainly in Mobile robotics, Embedded systems, Automotive control systems etc. To avoid the problem of original main controller, they designed a completely new controller board for the robot. The new robot platform offers many capabilities and the concept was proven on some robotic lessons [18].

(3) Electronics Course Teaching

Wilcher [19] pointed out that the book is for anyone interested in building cool Arduino electronic gadgets using simple prototyping techniques. Because it makes use of the Arduino plus discrete, integrated circuit components and breadboards, uses Multisim software for circuit simulation and design equations, and makes detailed principle interpretation before every chapter, it has great reference value in Electronics course teaching. This also indicates that introducing Arduino in Electronics course is possible.

(4)The design of embedded system

The major contention of introducing Arduino in teaching lies in the idea that students can access and use an open source community that is focused on getting things working as opposed to strictly looking at low-level technical aspects of embedded systems, And the presence of open source and reusable designs makes it difficult to identify what a student is doing. Jamieson [20] proposes a scheme that using the Arduino exposes students to sufficient complexity and challenges for an embedded system course.

The rule required that all external sources used (including fellow classmates) must be explicitly cited. And they consider one project a completely valid experience and submission even if a project uses a number of external sources and simply incorporates these sources together to form it; therefore there is little incentive to copy without citation. The students benefit from system integration, the code reading and understanding, as well as integration skills that are useful and play a major part in real-world engineering. The students have expressed high praise for the Arduino platform and their final projects are better and more creative compared with the previous years due to the availability of the Arduino kits.

(5) Curriculum design of Sensor course

SHI [21] discusses the curriculum design of Sensor course based on Arduino. The students begin system design using Arduino after learning the basic principle of the sensor. In this activity, the application design projects of various types of sensors were distributed to students at first, then students begin innovative application design when finished the basic sensor experiment.

Through introducing Arduino, students can carry out engineering design in second grade, and this greatly aroused the students' autonomous learning enthusiasm. As they use C language to develop and laid a solid foundation for the single-chip development and ARM learning, students' ability of innovative application have been well reflected in the graduation design in senior.

(6) Other teaching application

In addition to the aforementioned applications, there are also other applications such as robot teaching in primary school, physics experiment development in middle school.

The above applications in education indicate that Arduino has a wide adaptability, and takes a strong supporting role in some courses.

Based on the above analysis, Arduino is suitable for the design and development of "computer network" experiment, is conducive to promoting the understanding of knowledge, and can be helpful to develop experiments related with professional application. We regard that introducing Arduino in "computer network" experimental teaching of measurement and control technology major is feasible.

3 Improved experimental scheme

We focuses on the general application and basic concepts of computer network technology in "computer network" course considered with the actual teaching arrangements, deficiency of experimental hardware facilities and other related courses. The content is divided into five layers (physical layer, data link layer, network layer, transport layer, application layer). Table 1 shows all the experiments, which cover the five layers' network.

TABLE 1 The main content of the preliminary experiment

No.	Experimental Content	Goal
1	The use of some of the commonly used network command; Make Cable	familiar with Basic commands of network operation; Can make a network interface.
2	Using protocol analysis software Wireshark	Familiar with the functions of protocol analysis software, especially the filtering functions.
3	Network sharing application experiment; The data link layer (LAN) protocol analysis	Master 1 ~ 2 kinds of network sharing method(s); By comparison with the captured data, understand of LAN frame structure and the meaning of each field accurately.
4	Virtual LAN configuration; Analysis of network layer protocol	The realization of cross switch VLAN by Packet Tracer; By comparison with the captured data, accurately understand the structure and meaning of IP datagram.
5	Using some Web tools; Analysis of the transport layer protocol	Familiar with network speed test, online virus scan using Web tools; Through the observation of TCP and UDP data and comparative analysis, can accurately understand the section structure of TCP and UDP and their implications.
6	The establishment of FTP server; To set up and release a simple website	Understand the function of FTP server, and can build FTP server, can use FTP server to transfer file; Use basic HTML statements, and make static page; can release, access and test web site using IIS.

The early practice took advantage of the network analysis software to deepen understanding through part of the experimental protocol, which effectively overcomes the deficiencies of hardware experimental facility; added network application experiments to improve the network application ability and interest in learning. Although it has achieved a better result in practice, but still has not reflected specific application of measurement and control technology major.

Based on the previous practice, we redesign the application layer experiment, in order to make the experiment to combine tightly with the professional application. The following is the specific scheme of application layer experiment.

3.1 PURPOSE AND SIGNIFICANCE OF THE EXPERIMENTS

(1) Through constructing embedded server with Adruino, simulating the industrial field monitoring, deepen the understanding of the practical application value of computer network technology in the field of industrial control.

(2) By writing Web program, to deepen understanding working principle of HTTP protocol.

3.2 EXPERIMENTAL CONTENT AND EQUIPMENT NEEDED

Choose a topic from Table 2, construct embedded server with the experimental material, revise and release it.

Required materials and equipment of the experiment:

(1) Experimental reference which was released on the network teaching platform;

(2) The embedded server hardware. Contains 10 sets of embedded server used for industrial field monitoring, and corresponding sensors.

(3) Network accessible computer.

TABLE 2 Design projects of embedded server based on Arduino

No.	Project Title	Project Content
1	Monitoring system for industrial equipment Operating condition	Using stepper motor to simulate industrial equipment and using Arduino to construct embedded server, gather and publish its working state data on real time.
2	Real time monitoring system for industrial field environment	Using Arduino to construct embedded server, gather and publish data of industrial field environment on real time.
3	Recording system for industrial equipment operation	Using DC motor to simulate industrial equipment and using Arduino to construct embedded server, gather and publish its working state data on real time.

3.3 THE EXPERIMENTAL METHOD AND PROCESS

(1) The overall deployment. The teacher organizes experiment content; Divides the class into several groups and each group has no more than 3 students;

(2) The implementation. Carry out each experiment according the steps described in the document. Each group can interchange experimental devices and carry out the corresponding design;

(3) The experimental examination and systematic summary. The teacher must carefully observe the experimental situation and answer questions in the experimental process. Finally, the teacher summarizes the experiment.

4 The experimental design case

As a case study, this section shows the hardware and software design separately of the real time monitoring system for industrial field environment in Table 2.

4.1 SYSTEM HARDWARE DESIGN

Hardware of the real time monitoring system for industrial field environment is shown in Figure1. The network card was designed with cascade mode and can be stacked in the Arduino board, and they constitute the embedded server together. Temperature and humidity sensor model is DHT11, which output temperature and humidity values with a single bus form. The embedded server collects and releases the industrial field environmental temperature and humidity data real-time and wait for client access continuously. System circuit is shown in Figure 2. Because the hardware uses the modular design method, students does not need to grasp the principle of hardware and can build system easily. This proves that it is suitable for lower grade students who have no background in hardware.

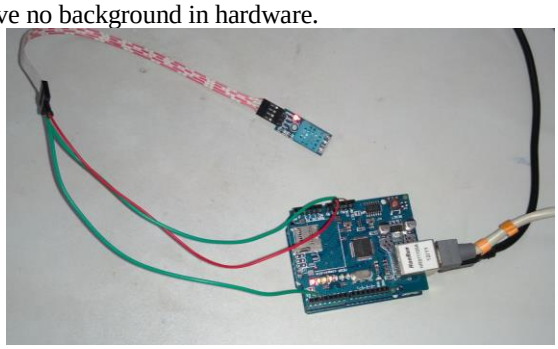

FIGURE 1 Hardware of the system

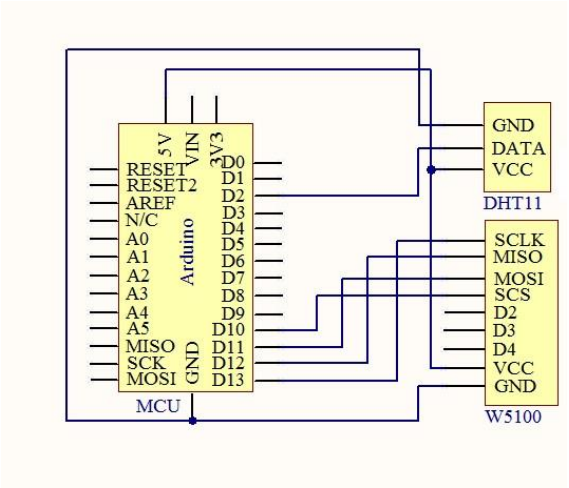

FIGURE 2 Circuit of the system

4.2 SYSTEM SOFTWARE DESIGN

The basic program flow is shown in Fig.3. Initialization of the system mainly includes the corresponding header file, definition of the server address and port, and start listens for client requests.

After system initialization, the program will loop to read sensor data, and listen for client access. The server will establish connection and release parameters when client access it, and close connection when the client received all the data. Then the program will continue to cycle the process.

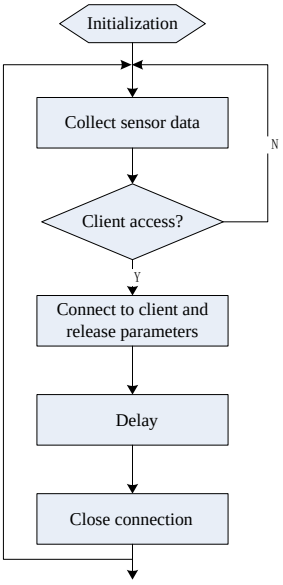

FIGURE 3 Program flow chart

The main code corresponding with Figure 3 is shown in Figure 4.

```
…… //definite parameters,
//start the embedded web server
void setup() {
  Ethernet.begin(mac, ip);
  server.begin();
 }
//loop
void loop() {
  int chk = DHT11.read(DHT11PIN);//data collection
  EthernetClient client = server.available();//listen to
client
  if (client) {
      ……
    client.println("<html>");
    client.println("<meta http-equiv=\"refresh\"
content=\"5\">");
    client.println("<head><title>Real Time Monitoring
System for Industrial Field
Environment</title></head>");
    client.println("<body>");
    ……
    client.println(DHT11.temperature);//output the
temperature value
    …… //output other parameters
    client.println("</body>");
   client.println("</html>");
   }
delay(1);// delay before close connection, client
receive data at this time
client.stop(); // close connection with client
 }
```

FIGURE 4 The main code corresponding with the program flow chart

The software uses OOP (Object Oriented Programming) method; sensor and the Web server are regarded as object. In this program they are named as DHT11 and server respectively. It is very easy to operate on them. For example, we can call begin() method of the server object to start the Web server; and get temperature value through calling temperature method of the DHT11 object.

Compared with website construction, the system program is more conducive to deepen understanding of client-server interaction process.

Figure 5 shows the web interface accessed from a client browser.

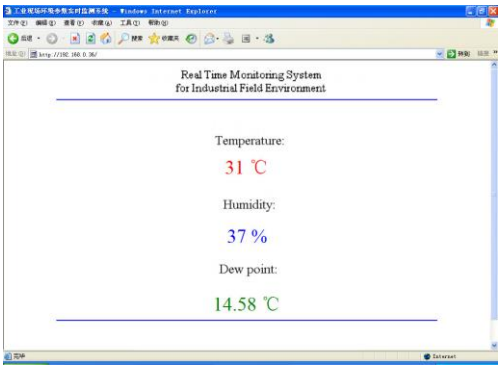

FIGURE 5 The web interface accessed from client

5 Conclusion

In order to solve loosely combination problem of "Computer Network" course experiments and measurement and control technology specialty, we designed embedded web server with Arduino, and applied successfully to the design of course experiments. From our practice, we can conclude that:

(1) Students learning interest are aroused due to the combination of course experiments and professional application. The students not only can write Web page personally in the existing prototype system, but also can further change the parameters of monitoring sensor, so that experiments are very vivid and this mobilize the enthusiasm of learning greatly.

(2) Our further practice shows that students continue to benefit from projects realized with Arduino that are useful for improving the ability of innovation and providing self education opportunities. For example, began from this experiment, some of the students participated in the "National Challenge Cup" contest and many other disciplines contests, took charge of a number of "National College Students Innovation Training Projects".

In the subsequent teaching practice, we will develop WLAN, Bluetooth, GPRS and other different projects with Arduino to support "Computer Network" course teaching and enrich the content of experiment, and further promote the combination of experiments and professional application.

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Authors

Guangyuan Zhao, 1975, Shanxi province, China

Current position, grades: associate professor
University studies: wireless sensor networks
Scientific interest: computer vision
Publications: 10
Experience: Received his B.S. degree in Industrial Automation from Northeastern University of China in 1998,and M.S. degree in Computer Technology from Shaanxi Normal University of China in 2007.His research interests include object tracking, object detection in ITS.