

Experiments and engineering practice in the classroom teaching of sensor and detection technology

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ABSTRACT: Sensor and detection technology is a vital professional and technical course in electronic information majors. Teaching the application of the theory and the ability to innovate are important so as to realise the goal of producing excellent engineers. However, traditional teaching of sensor and detection technology adheres to the research teaching concept, with a bias towards theory, rather than the application of that theory. This causes many problems, but these were resolved at Heze University in China through a reformed course that implemented advanced teaching methods with an emphasis on experimental teaching and professional practice. This teaching model has inspired students to achieve fully their potential, as well as fostering their independent study. Hence, there has been a highly positive effect on the teaching of sensor and detection technology.

INTRODUCTION

In today's information age, sensors are key to gaining information. Sensors occupy a very important position in worldwide scientific and technological research and in industrial applications. Sensor and detection technology has become a substantive professional course in electronic information majors. These courses also play an important role in cultivating engineering and technical personnel, who master modern information technology [1].

Sensor and detection technology relates to many academic fields, and has the characteristic of strong theory closely connected to engineering practice [2]. New sensors are constantly emerging, with the application of them expanding and deepening. This creates new requirements for developing high quality innovative talent. Cultivating students' applied engineering, innovative and self-learning abilities has become an urgent task in reforming sensor and detection technology education. In recent years in China, the teaching of sensor and detection technology has adhered to the research teaching concept, with resultant beneficial reforms.

PROBLEMS IN TEACHING SENSOR AND DETECTION TECHNOLOGY

A survey of colleges and universities in China, offering courses on sensor and detection technology shows that the classroom teaching of sensor and detection technology is far from ideal. The main problems are as follows.

Difficult to Understand

The teaching material of early sensor and detection technology courses mostly focused on the theoretical analysis and design of sensors. This was suitable for an elite education of elite students. But, after the expansion of university enrolments leading to mass education, the courses needed to be more broadly available. Higher education generally is divided into two types, i.e. research and application. Students at application-oriented colleges are different from those in the research-oriented key universities. Their theoretical analysis and design knowledge is weak, so students find it difficult to understand the analysis and design of sensors. More importantly, the sensors that are taught about in applied colleges and universities deal with the detection of non-electric signals. Students often feel what they are learning cannot meet the needs of their future profession. As a result, they lack interest in learning and, in addition, teachers are often laborious in dealing with content. This first problem has been personally experienced by the author.

Difficult to Memorise

The teaching material of early sensor and detection technology generally was classified according to the sensor. Because there are many kinds of non-electric signals to potentially sense, there are many types of sensors. Sensors are independent and each kind of sensor can measure a variety of non-electric signals. But, each non-electric signal can be measured by a combination of sensors, arranged in a crisscross pattern. Therefore, students often feel the content of sensor and detection technology is too complex, without a simple pattern. Hence, it is difficult to memorise and master. This second problem has been personally experienced by the author.

Difficult to Apply

The objective of learning sensor and detection technology in application-oriented colleges and universities is not to design sensors, but rather to apply sensors to detect non-electric signals. However, when students finish the course, they know how sensors detect non-electric signals, but they do not know how to use sensors to detect non-electric signals. In fact, knowledge of sensors alone is not enough to know how to use them.

There are two problems to address; one is how to connect the front of the sensor to the measured object, and the second is how to connect the back-end of the sensor to the display instrument. Summing-up the two problems into one, the problem is how to construct a complete detection instrument using a sensor as the core. Obviously, the detection instrument provides the methods and tools for testing, and the sensor is only a part of the detection instrument. This third problem has been personally experienced by the author.

IMPROVEMENTS IN CLASSROOM TEACHING

To address existing problems in the classroom teaching of sensor and detection technology, the improvements below in classroom teaching have been implemented.

Use of Various Teaching Methods

Teaching by writing on the blackboard is limited by the small amount of information presented, while PowerPoint teaching does not synchronise with students' thinking [3]. Hence, teachers combine real demonstrations with writing on the blackboard and PowerPoint teaching. This is used to evoke the understanding of the structure, basic working principle and basic characteristics of the resistive sensor. For example, when the photoresistor is explained, the real light-controlling lamp is first demonstrated. Thus, the function of the photoresistor is grasped, and students' interest is stimulated. Meanwhile associated problems are raised.

Second, the basic structure, the main parameters, basic characteristics, methods of detecting and methods of selecting are discussed. Finally, the basic circuit of the light-controlling lamp shown in Figure 1 is analysed and designed [4]. This new method of teaching changes the abstract theoretical teaching into teaching that is more vivid and visual, and which greatly enhances the classroom effect.

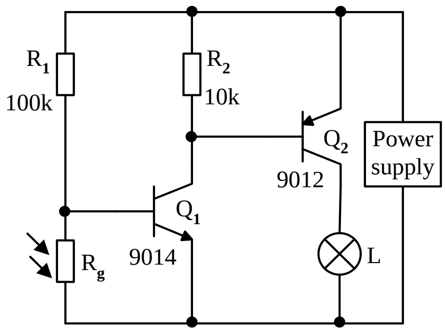

Figure 1: The basic circuit of a light-controlling lamp.

As well, full use is made of the excellent course management platform of Heze University. A network learning platform for sensor technology has been built and provides a rich multimedia teaching resource library of sensor technology. It also provides for teacher-student interaction, and is convenient for students' extracurricular autonomous learning.

Bring Experiments to Classroom Teaching

Sensor and detection technology is both a theoretical and practical course. Therefore, it should deal well with the relationship between classroom teaching and experiments. Grasping this important link between theory and experiment stimulates students' interest in learning. Students learn the basic knowledge of sensors; their manipulative abilities are cultivated; and their ability to analyse and solve problems can be greatly improved [5].

A few years of practice has shown it is feasible to carry out design and comprehensive experiments in the classroom while teaching theory [6][7]. The specific implementation process is shown in Figure 2.

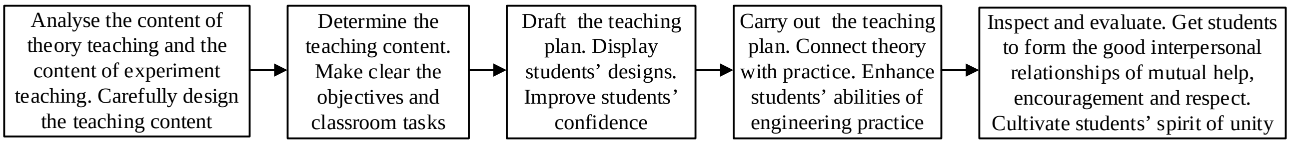

Figure 2: The implementation process for bringing experiments to the classroom.

Bring Engineering Practice to Classroom Teaching

The explanation of engineering practice in classroom teaching is conducive to the realisation of the organic combination of education and social requirements. In engineering practice, the connection of sensors and the design of conversion circuits are often used in practice.

Innovation and Practice in the Connection of Sensors

Sensors can be divided into analogue or digital, according to the characteristics of their output signals. Each sensor has four signal transmission wires, viz. red, blue, white and green. The traditional connection of sensor signal wires is shown in Figure 3 and Figure 4. The cross on the wire indicates that the wire is not used. Unused wires mean a waste of resources, but also when there is a breakdown, it is more difficult to investigate it [8].

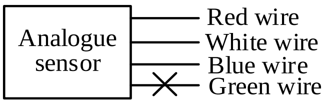

Figure 3: Traditional connection of analogue sensor.

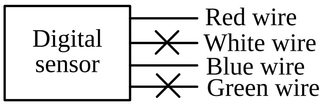

Figure 4: Traditional connection of digital sensor.

An innovative reform of the connection of sensors is as follows:

1. Two analogue sensors share a four-core signal transmission wire. The red and blue wires can be connected to the positive and negative poles with respect to power. In addition, the white and green wires can be used as the signal transmission wires of the two analogue sensors, as shown in Figure 5.

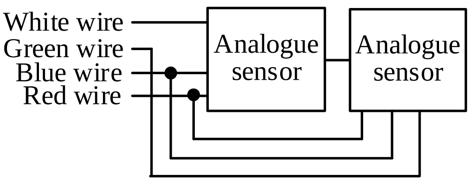

Figure 5: Innovative connection of analogue sensors.

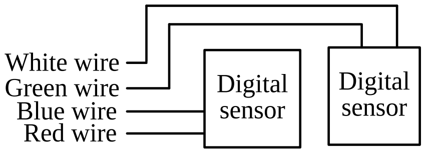

Figure 6: Innovative connection of digital sensors.

2. Two digital sensors share a four-core signal transmission wire. The red and blue wire can be the positive and negative poles respectively for the signals. In addition, the white and green wires can be used as the positive and negative pole respectively of the other signals, as shown in Figure 6.

3. An analogue and digital sensor share a four-core signal transmission wire. Using a three-way junction box, the positive pole of the analogue sensor power is connected to the positive pole of the digital sensor; the green wire is connected to the negative pole of the digital sensor and monitoring substation, as shown in Figure 7.

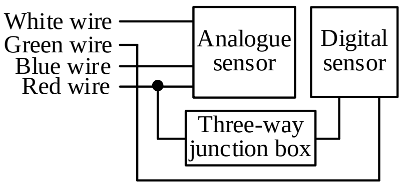

Figure 7: Innovative connection of analogue and digital sensors.

Through the analysis of an application, the connection of many sensors in a group can be determined from the theory.

Simulation and Design of Sensor Conversion Circuits

This sensor converts a measurement into a change of resistance, capacitance or other parameters and, thereby, realises the detection of non-electrical signals. However, the changes of these parameters are very small so they cannot be used directly. Conversion circuits are used to solve this problem. In the design of a conversion circuit, software simulation is used to set reasonable parameters for components [9]. In engineering practice, DC bridges and amplifying circuits are often used to realise the conversion circuit. The simulation conversion circuit of resistive sensors is shown in Figure 8; the simulation results are shown in Figure 9.

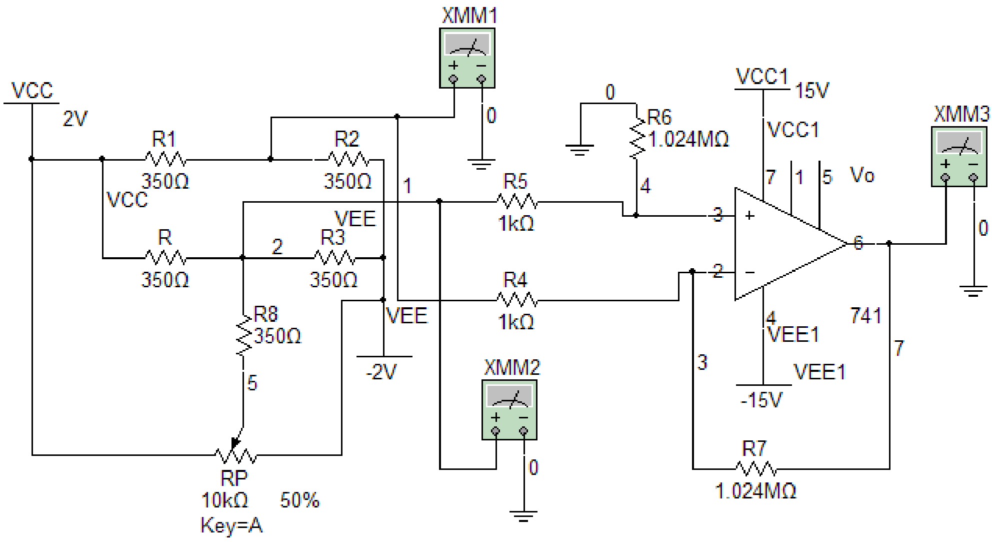

Figure 8: A typical conversion circuit of resistive sensors.

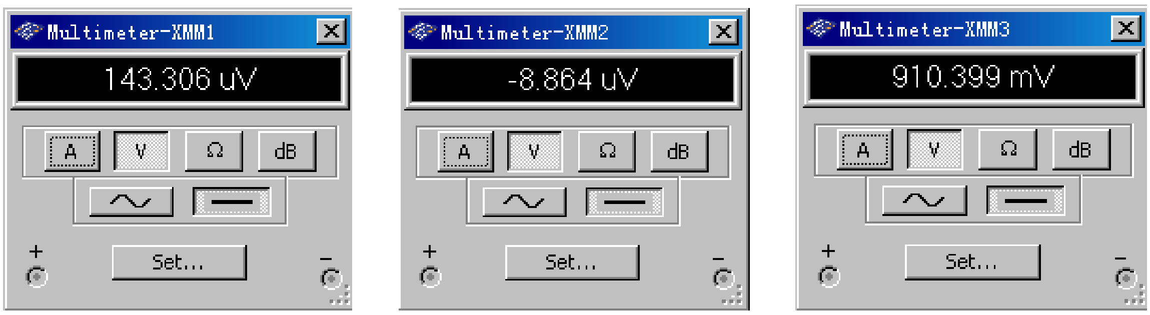

Figure 9: The simulation results of a typical conversion circuit.

A typical conversion circuit is made up of a Wheatstone bridge and an amplifier circuit, and a zeroing circuit. The output voltage V_o of the circuit is in accordance with the following formulae:

$$Vo = (\frac{R7 + R4}{R4})(\frac{R6}{R5 + R6})V_{i4} - \frac{R7}{R4}V_{i3} \quad (1)$$

Because,

$$\frac{R7}{R4} = \frac{R6}{R5} \quad (2)$$

$$V_{i4}\text{-}V_{i3} = \frac{V_i}{4} \bullet \frac{\Delta R}{R} = \frac{VCC - VEE}{4} \bullet \frac{\Delta R}{R} \quad (3)$$

So, the output voltage is found using the following formula:

$$Vo = \frac{R7}{R4} \bullet \frac{\Delta R}{R} \quad (4)$$

Simulation of a Wireless Sensor

The network simulation tool is OPNET. It uses a discrete event-driven simulation to analyse functions and performance of a model. It includes model design, simulation, data collection and data analysis. In OPNET Modeller, a finite state machine is used as the model and a protocol is established, called a LEACH protocol. The OPNET tool provides the process, node and network layer mechanisms. The data of each object are processed and simulated in the process layer. The objects of the process layer are interconnected to form equipment in the node layer. In the network layer, equipment is connected to the network and a plurality of network scenarios are simulated [10]. The process model is shown in Figure 10 and the node model is shown in Figure 11. In the simulation, each node sends a data packet of 100 bytes every 30 seconds and the length of cluster messages is 25 bytes. The simulation result is shown in Figure 12.

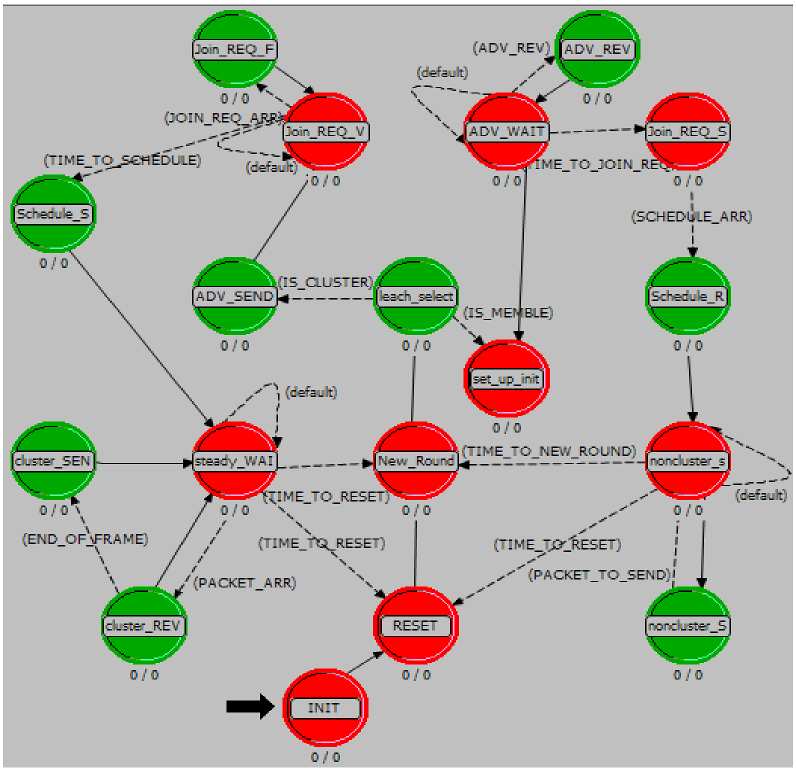

Figure 10: The process model.

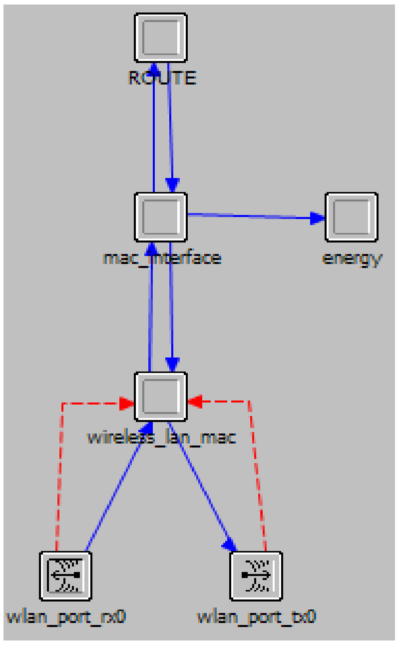

Figure 11: The node model.

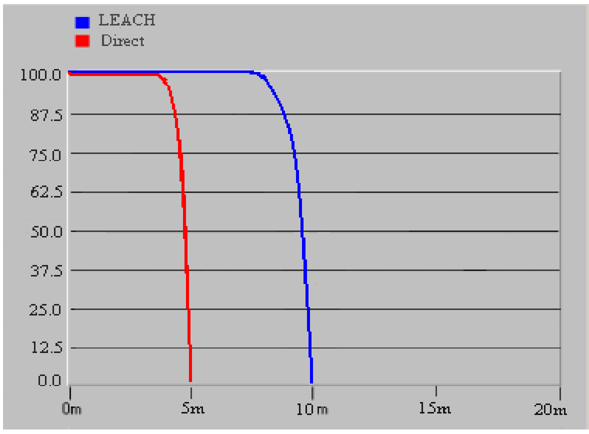

Figure 12: The simulation result.

In Figure 12, the horizontal axis is the time axis, and the vertical axis represents the number of live nodes. From the simulation result, the LEACH protocol can effectively reduce the energy consumption of nodes.

EFFECT OF THE NEW TEACHING METHODS

The new teaching methods have allowed students to grasp the overall concept of sensor technology. They develop an understanding of the construction and design of non-electric sensor detection systems. Students' engineering application, design and creative-thinking abilities have been significantly improved. At the same time, the reform of the classroom teaching of sensor and detection technology promotes the development of extracurricular and professional activities and knowledge, sometimes referred to as the *second classroom*. More details of the effects of the new teaching methods at Heze University are below.

Enhance Students' Learning by Practice

Surveys of students highlight the strong link between learning and practice. Students come to understand analogue and digital sensor technology, and the principles of microcomputers. Their professional knowledge has been increased and their ability to use that knowledge improved.

Improve Students’ Innovative and Practical Abilities

The combination of classroom teaching with typical cases and engineering practice has greatly improved students’ ability to innovate and their knowledge of engineering practice. Students have published several academic papers and have gained patents for inventions. Practical training also greatly enhances students’ teamwork and innovation, and improves their competitiveness in the job market.

Promote the Development of the *Second Classroom*

At the end of the course, students can apply the knowledge learned to extracurricular activities and to the *second classroom* of the professional world. Students can design an overall system, and solve practical problems guided by theory. This provides a solid foundation for students in their future work in related areas.

CONCLUSIONS

A new teaching mode was developed for teaching sensor and detection technology at Heze University. The reform was based on student feedback, experience within the University, and professional training objectives. The reformed course breaks down the boundaries between theory, experiment and training. Flexible application of various teaching methods stimulates the students’ interest and improves the efficiency of the classroom teaching. Through the organic combination of experiment, engineering practice and classroom teaching, students master the working principles and construction of sensors and of circuits of sensors.

The new teaching mode focuses on engineering practice. Its purpose is to produce application-qualified talent by application-oriented teaching highlighting the students’ professional practice and practical ability. Hence, students should be able to seamlessly integrate into a professional career after university.

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