Teaching Reform and Practice of Sensor Course Based on Arduino+NI Multisim

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Abstract: The current state of sensor course instruction faces several challenges, including a lack of experimental facilities, limited practical training projects, an overemphasis on theory at the expense of hands-on experience, and a reliance on conventional teaching methods. These issues result in low student engagement, a lack of motivation and proactivity, and subpar teaching outcomes. To address these concerns, this study introduces an integrated approach that combines the open-source Arduino software-hardware platform and the NI Multisim virtual simulation platform. This approach optimizes teaching resources to foster student autonomy, as well as cultivate their engineering practice and innovation capabilities. The results of the teaching practice reform demonstrate an improvement in the effectiveness of the course, effectively empowering students to take on an active role in their learning, while also enhancing the guidance provided by teachers.

Keywords: Arduino; NI Multisim; Sensor Technology; Teaching Practice Reform

1. Introduction

Made in China 2025 represents the inaugural ten-year roadmap for China's pursuit of manufacturing excellence. Within this strategic framework, sensors emerge as a pivotal component of future intelligent factories. With the rapid advancement of artificial intelligence, sensors find extensive application across various domains, including industry, agriculture, commerce, transportation, medical diagnosis, military research, aerospace, modern office equipment, environmental monitoring, smart buildings, and household appliances. Consequently, the course *Sensor Technology and Applications* has evolved into a shared discipline among fields such as electrical automation technology, electromechanical integration technology, applied electronic technology, computer science, and intelligent building engineering. Aligned with the comprehensive development of vocational competencies, this course exemplifies the integration of theory and practical experience, fostering students' professional abilities and acumen in sensor recognition, detection, selection, design, development, and fabrication. It embodies a distinctive combination of theoretical foundation, practical relevance, and real-world applications. Proficiency in sensor detection techniques has become an indispensable skill and hallmark for engineering professionals in related fields.

2. Analysis of Teaching Challenges

Through research and analysis of Chinese and international literature[1-7], the course *Sensor Technology and Applications* exhibits prominent issues in the following three areas:

(1) Due to the overall reduction in teaching hours across different institutions, the course content tends to focus more on the fundamental theories of sensors within limited class hours. The teaching approach predominantly relies on outdated methods, such as PowerPoint presentations, with teachers delivering lectures while students passively listen. The disconnection between theoretical knowledge and the practical application of sensors used in industrial settings results in dull and unengaging classes, leading to poor teaching effectiveness.

(2) The lack of experimental conditions and limited laboratory equipment pose significant constraints on practical training projects. Even when practical training projects are offered, they primarily revolve around validating sensor principles, lacking comprehensive consideration of the reasonableness of the results. There is a scarcity of experiments related to practical applications of sensors, and

there is a significant dearth of design-oriented and comprehensive requirements, causing a detachment from engineering practices. Moreover, experimental reports often focus solely on the accumulation of observed phenomena, lacking theoretical analysis and critical reflection. The students' engagement in practical activities is incomplete and disconnected from theoretical instruction, impeding the construction of a cohesive and integrated knowledge structure.

(3) Currently, the practical teaching approach for the course *Sensor Technology and Applications* mainly revolves around signal acquisition using a limited number of sensors, such as the infrared temperature sensor MLX90614 and the optical frequency sensor TSL230. Although these experiments demonstrate the process of converting non-electrical quantities into electrical ones using different sensors, the narrow focus restricts students from actively linking theoretical knowledge to real-world applications. Such an approach lacks a comprehensive understanding of sensors and detection technologies, misaligning with the goal of nurturing applied talents. Given the practical and applied nature of sensor technology application, the integration of experimental teaching becomes a crucial element in course instruction.

3. Sensor Teaching Design Based on Arduino

Adhering to the vocational education philosophy guided by employment orientation, practical application, and skills development, the course aims to address the aforementioned issues by enhancing and expanding both theoretical and practical teaching effectiveness, as well as fostering increased student engagement and critical thinking. These are urgent matters demanding resolution to elevate the overall quality of instruction. This study explores two main aspects. First, it emphasizes theoretical instruction, utilizing the NI Multisim circuit simulation software to visually demonstrate the output results of sensor conversion circuits. This approach enables students to grasp the practical application of sensors in engineering settings[8,9]. Second, the exploration extends to experimental teaching, employing a novel open-source Arduino hardware and software platform[10,11].

3.1 Reforming teaching with NI Multisim

Traditional teaching methods in sensor courses primarily rely on theoretical explanations to convey principles, analysis of sensor measurement circuits, and examples of sensor applications. To address these limitations, the use of NI Multisim, a Windows-based circuit simulation tool, is proposed for designing a sensor principles and applications curriculum that combines theory and practice, bridging the gap between virtual and real-world scenarios. With its interactive circuit schematic builder and intuitive graphical interface, NI Multisim offers abundant component resources, making the course easy to learn, comprehend, and visualize the concepts while providing a clear understanding of engineering applications.

For instance, the circuits for temperature and humidity sensors and thermocouples can be constructed on Multisim as depicted in Figures. 1 and 2. Students can swiftly create circuits, capture, simulate, and analyze them, comprehending the working principles. The visualization of measurements addresses students' difficulties with abstract measurement results, tedious PowerPoint presentations, and challenges in practical applications. This approach enables a deeper understanding and learning of sensor principles and applications. Additionally, Multisim allows for real-time observation and manipulation of model data parameters during the simulation process, facilitating a high degree of interactivity. As a simulation software, it avoids instrument damage and material consumption, significantly reducing research costs. The simulation results closely resemble actual experimental effects, providing valuable guidance for sensor electronic circuit design research and development.

3.2 Reforming Teaching with Arduino

Many educational institutions offer limited opportunities for hands-on training in sensor technology. Even when practical training projects are available, they often focus solely on verifying sensor principles, lacking experiments that incorporate real-world applications. Moreover, the construction of sensor training labs faces challenges such as the high cost of commercially available

experimental training equipment and the rapid obsolescence of such devices. Bulk procurement of experiment kits burdens school budgets, and the available equipment is often not conducive to expanding the range of experimental projects. To address these issues, teaching with sensor modules combined with Arduino development boards provides an effective solution. This approach enables students to rapidly engage in project development, thereby enhancing their learning interest and cultivating their practical skills.

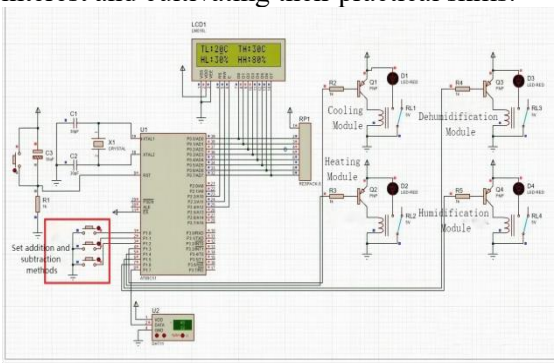

Figure 1. Construction of a Temperature and Humidity Sensor Module

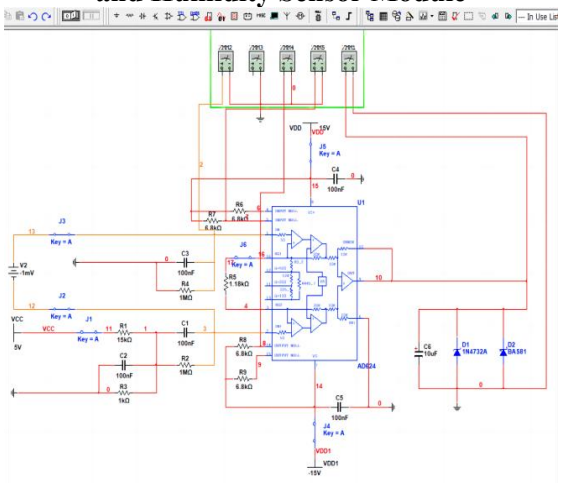

Figure 2. Construction of a Thermocouple Sensor Module

In sensor training, the primary hardware used is the Arduino Uno, which is a microcontroller board based on the ATmega328 core. The Arduino hardware offers a rich interface, including 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog inputs, a 16MHz ceramic resonator, USB interface, power jack, ICSP header, and a reset button, as depicted in Figure 3. Additionally, it supports SPI, I2C, and UART serial communication protocols, enabling physical hardware connections and enhancing students' hands-on skills, circuit application, design, and innovation abilities. This approach ensures that learning is effectively translated into practical use cases.

The Arduino development board comes with a pre-programmed boot loader, allowing for easy program downloading via a USB connection during usage. The strength of Arduino lies not only in its open-source software and hardware but also in its powerful system library provided to developers. The system library includes functions for serial communication, I/O pin manipulation, timers, ADC conversion, IIC communication, 1-Wire communication, SPI communication, interrupt handling, string manipulation, and wireless communication, among others. These library functions can be conveniently used during sensor application training by students, reducing the need for low-level driver code development and enabling a focus on the practical application of sensor technology.

Figure 3. Arduino Uno Control Board

Using the color recognition sensor as an example, depicted in Figure 4, the TCS3472 device provides digital readings for red, green, blue (RGB), and clear light sensing values. This is made possible by the integration of an IR-blocking filter on the chip, strategically positioned to minimize the impact of infrared light in the incident spectrum, thus ensuring accurate color measurements. With its high sensitivity, wide dynamic range, and IR-blocking filter, the TCS3472 proves to be an ideal color sensing solution, well-suited for diverse lighting conditions and material attenuation scenarios[12]. Introducing the Arduino development board into the teaching of the *Sensor Technology and Applications* course allows for flexible adjustments to the practical training content by adding or removing peripheral modules as required. This ensures a better alignment between equipment selection and teaching materials.

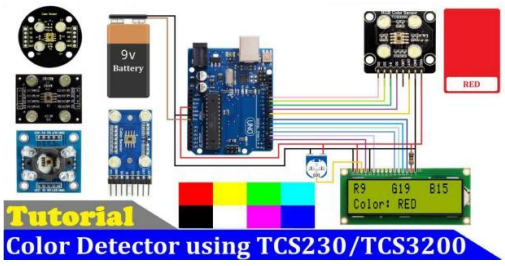

Figure 4. Schematic Diagram of a Color Recognition Sensor

4. Conclusion

Based on current feedback from educational practices, the integration of sensor modules with Arduino development boards has enabled students to rapidly engage in project development, thereby enhancing their learning enthusiasm and practical skills. Additionally, the use of NI Multisim circuit simulation software has facilitated the creation of a teaching design that combines theoretical and practical aspects, providing a more industry-relevant approach to training projects. This method not only nurtures and hones students' innovative abilities but also encourages them to unleash their imaginative potential, enabling a more intuitive presentation of course material and ultimately achieving an enjoyable and effective teaching outcome.

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References

[1] Zheng Chunjiao, Zhao Yueling. Exploration and Practice of Composite Teaching Mode for Sensor and Detection Technology Course. Journal of Liaoning Institute of Technology (Social Science Edition), 2019 (2): 114-117.

[2] Jiang Shujie. Design and Reflection on Experimental Teaching of Sensor Application Technology. Education Science Forum, 2019 (21): 70-72.

[3] Cao Liangzu. On the Teaching Reform for Sensor Theory and Engineering Application Comprehensive Experiment. Jingdezhen Comprehensive College Journal, 2016 (6): 93-95.

[4] Xie Haifen, Mou Haichuan, Luo Duanbin, et al. Application of Task Driven Teaching Method in the Course of "Modern Sensor Technology and Application" Teaching. Education and Teaching Forum, 2016 (52): 181-182.

[5] Han Baoru, Zhang Chunxia. Research on Practical Training Teaching of Sensor Technology and Application Course in Higher Vocational Education. 2021 (2013-6): 67-69.

[6] Yang Chen, Zhou Yue, Huo Haibo, et al. Current Situation and Reform Practice of Teaching Sensor and Modern Detection Technology Course in Electrical Specialty. China Modern Educational Equipment, 2019, (07): 48-51.

[7] Xiao Huirong. Teaching Reform and Practice of Sensor Principle Course Based on the Idea of Innovation and Entrepreneurship Education. Journal of Nanchang Hangkong University (Natural Sciences), 2020, 34 (01): 116-120.

[8] Zhou Yiyong, Fang Jianping, Bu Yanhan, et al. Simulation modeling of fluxgate sensor based on SIMULINK. Automation & Instrumentation, 2022 (12): 240-245.

[9] Zhou Bo, Chen Xiuyan, Wu Di, et al. Application of Multisim in Sensor Experimental Teaching. Journal of Shenyang Normal University (Natural Science Edition), 2023, 41 (04): 336-340.

[10] Sun Linjuan, Jia Yuehui. Teaching reform of Arduino programming design based on project-based teaching. Laboratory Science, 2019, 22 (04): 153-155.

[11] Nieh H M, Chen H Y. An Arduino-Based Experimental Setup for Teaching Light Color Mixing, Light Intensity Detection, and Ambient Temperature Sensing. The Physics Teacher, 2023, 61 (2):133-137.

[12] Yu Xiaowen. Development of an Automatic Color Difference Titration System Based on Color Sensor. Jiangsu: Jiangsu University, 2021.

