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Application and Practice of Intelligent Control System in Microcontroller Experiment Courses

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Abstract: The microcontroller course, as a core course for majors such as electronics and communication, is an essential foundation for cultivating professional theoretical knowledge and practical skills in undergraduate students. With the rapid development of intelligent technology, intelligent control systems have found extensive applications. This paper proposes the introduction of intelligent control systems into the microcontroller laboratory course, exploring the advantages of using intelligent control systems in microcontroller programming instruction, hardware design, and software development. Through specific teaching practice cases, the practical applications of microcontrollers in robot control, sensor data acquisition and processing, and wireless communication are discussed. Research indicates that integrating intelligent control systems into microcontroller laboratory teaching not only enhances students' innovation levels but also stimulates their interest in scientific exploration, demonstrating significant practical teaching effects and interdisciplinary promotion value.

1. Introduction

With the rapid advancement of intelligent information technology, robotics and intelligent control systems related applications have gradually permeated various aspects of production and daily life, including restaurant service robots, industrial robots, assistive medical robots, and agricultural cooperative robots. The employment market in the field of intelligent control increasingly demands higher standards for microcontroller education.

Microcontroller courses[1,2] are characterized by their strong engineering and practical focus, with the primary teaching goal being to train students to independently achieve hardware design and software development, and to program and apply microcontrollers according to specific application scenarios. Through the microcontroller course, students develop a solid theoretical foundation, strong hands-on abilities, and comprehensive innovative skills[3]. These evolving requirements place higher demands on the teaching of microcontroller courses in universities.

The core of intelligent control technology lies in the design and implementation of its control systems, with microcontrollers playing a crucial role as key components. The STM32 microcontroller, known for its high performance, low power consumption, and rich peripheral interfaces, has become a central component in various control systems. However, traditional microcontroller education tends to emphasize theoretical knowledge[4,5], lacking practical operation and application components, making it difficult to meet the current employment market's demands for students' innovation and practical skills. Traditional microcontroller courses often lack depth, leaving most students at a beginner level even after completing the course. They typically do not master the development methods required for designing systems with microcontrollers and significantly lack the ability to analyze and design complex projects.

As an ideal choice for intelligent control systems, teaching control systems programming based on STM32 holds significant theoretical and practical value. Researching the application and practice of intelligent control systems in microcontroller laboratory courses can enhance students' mastery of microcontroller theory, develop their programming skills and innovative abilities, and stimulate their creative thinking and teamwork spirit.

2. Technical Features and Advantages of the STM32 Microcontroller

The STM32 microcontroller boasts technical advantages such as high performance, low power consumption, rich interface resources, and ample development resources. It has a wide range of applications and promising development prospects in embedded systems, the Internet of Things, and intelligent robotics.

In terms of performance, the STM32 microcontroller utilizes the ARM Cortex-M core, offering high processing capabilities. With a clock frequency range from tens to hundreds of MHz, it can quickly respond to and handle complex data computations, making it well-suited for the diverse and complex tasks required by modern intelligent robot control systems.

Regarding external interface resources, the STM32 boasts a wide variety of peripheral interfaces, including GPIO, UART, SPI, and I2C. These abundant interfaces offer ample connectivity options for a diverse range of sensors.

For development resources, the STM32 microcontroller offers a wealth of software libraries (such as HAL and LL libraries, RTOS support, and middleware) and development tools (such as STM32CubeMX, STM32CubeIDE, Keil MDK, and IAR Embedded Workbench). These resources support various programming languages and development environments, facilitating practical teaching and the development of various innovative projects. This enables students to quickly get started and implement complex control systems.

In terms of system power consumption, the STM32 microcontroller offers various low-power modes, such as sleep, stop, and standby modes. Additionally, the STM32 features a flexible power management mechanism that balances optimal performance with power consumption. These technical advantages provide a solid foundation for innovative applications across a range of projects.

This paper will delve into the application and practice of the STM32 microcontroller in intelligent control systems programming education. Through specific case analyses and the implementation of teaching reforms, it will verify its effectiveness in enhancing students' practical abilities and innovative awareness. The findings of this research not only contribute to improving current teaching methods for microcontroller courses but also provide a comprehensive theoretical and practical reference for teaching reforms and innovative approaches in other related courses.

3. Implementation Method of Intelligent Control Systems Case Study

3.1. Project-based Teaching Design

The control system serves as the "brain" of the robot, directing and coordinating its various parts to achieve the desired functions. Integrating STM32 microcontroller instruction with the control system will significantly enhance the effectiveness of practical teaching and the interdisciplinary value of the curriculum. Typically, the control system consists of two components: hardware and software. The hardware includes the microcontroller, sensors, and actuators, while the software comprises control algorithms and program code. In course instruction, effectively combining the STM32 microcontroller with control system programming enhances students' practical and hands-on skills. Additionally, real projects and experimental operations further elevate the cultivation of application-oriented talent.

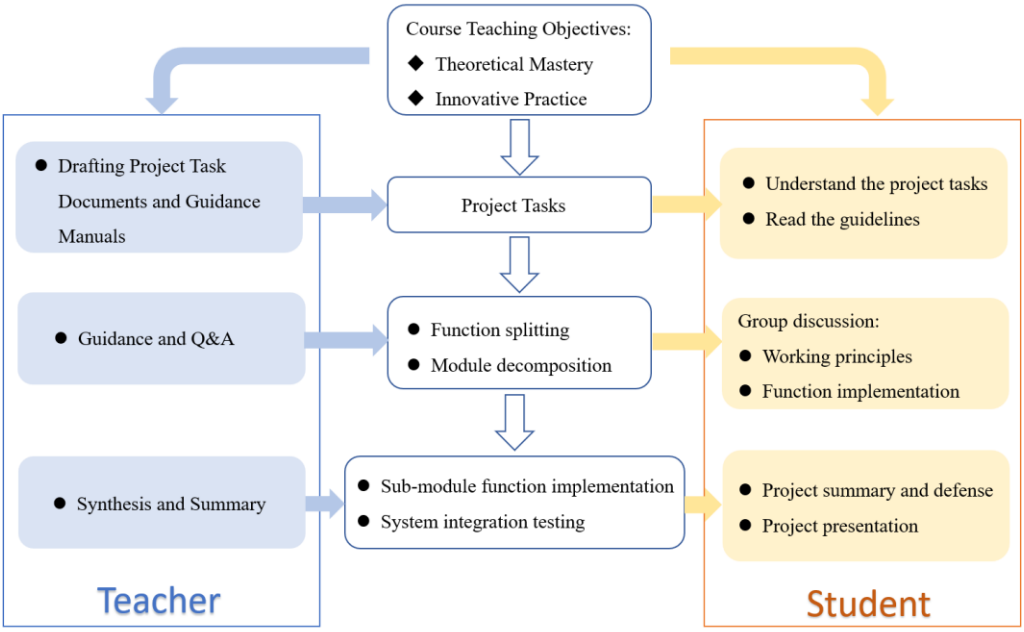

Figure 1: Course project execution flowchart.

Figure 1 illustrates the implementation flowchart for project-based teaching. In this approach, the teacher sets clear objectives, and students complete specific tasks based on project requirements within a given timeframe and budget. Throughout the teaching process, the teacher breaks down the course objectives into individual functional modules, emphasizing practical applications and providing specialized training in vocational skills. This method enhances the course's autonomy, practicality, and engaging nature. In project-based teaching, the teacher's primary responsibilities are project design and instructional guidance. Students gain mastery of the entire project development process through self-study, group discussions, teacher Q&A sessions, group experiments, and project integration.

3.2. Project Teaching List

Each project in the list involves knowledge from multiple disciplines, including electronic engineering, computer science, and control theory. By integrating and applying this knowledge, students can develop innovative thinking and enhance their problem-solving skills.

Figure 2 shows the Practical project list of curriculum reform. The course provides students with multiple project options, acknowledges their individual differences, and encourages them to extend functionalities and pursue independent innovation. Through project-based teaching reform, the previously fragmented teaching knowledge points are organically integrated into a systematic project, resulting in a well-structured consolidation of the knowledge system. During the project execution process, teachers guide students through group division, project analysis, information retrieval, task design, project implementation, and project evaluation. This approach not only deepens students' understanding of the course knowledge system but also fosters their initiative, comprehensively enhancing their capacity for independent innovation.

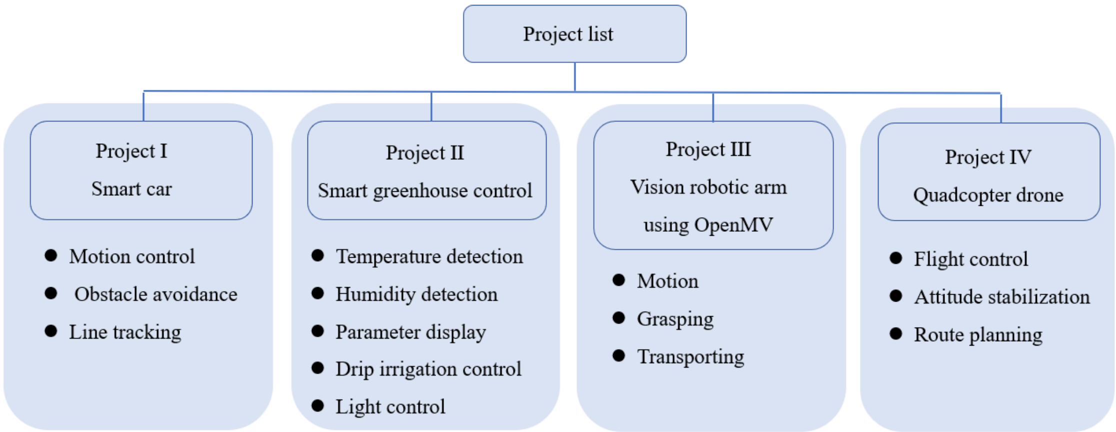

Figure 2: Practical project list of curriculum reform.

Introducing smart control system projects into STM32 microcontroller teaching holds significant theoretical research importance and practical application value. By researching and reforming the teaching of STM32 microcontrollers within robotic control systems, we can provide rich educational resources and practical opportunities. This approach also aims to cultivate students' programming skills, innovative abilities, and professional qualities. As robotic technology continues to develop and expand, the research and reform of STM32 microcontroller teaching in robot programming will further contribute to technological advancement and educational innovation.

3.3. Reform of the Diversified Evaluation System

This course aims to cultivate innovative abilities by optimizing teaching content and fostering a spirit of innovation. In the evaluation system, the emphasis on exam scores will be reduced, with a greater focus on comprehensive, ongoing assessment. The introduction of a diversified evaluation system in the microcontroller course aims to comprehensively assess students’ knowledge acquisition, skill application, and innovation capabilities through multi-dimensional and multi-method evaluations, thereby enhancing teaching quality and students' overall competence.

The course employs a combination of continuous assessment and summative assessment, and focuses on evaluating students' abilities in knowledge acquisition, practical skills, project development, and innovative thinking. The project-based experiments (P) account for 50% of the total course grade, regular assignments (R) contribute 10%, and the final summative assessment (F) constitutes 40%. The details are as follows:

$$\text{The total score} = \mathrm{P}\times 50\% + \mathrm{R}\times 10\% + F\times 40\% \quad (1)$$

The project-based experiment score consists of five components: basic functionality score (40%), innovation and extension score (15%), student self-assessment (5%), group peer evaluation (10%), and project defense teacher evaluation (30%), as shown in Figure 3.

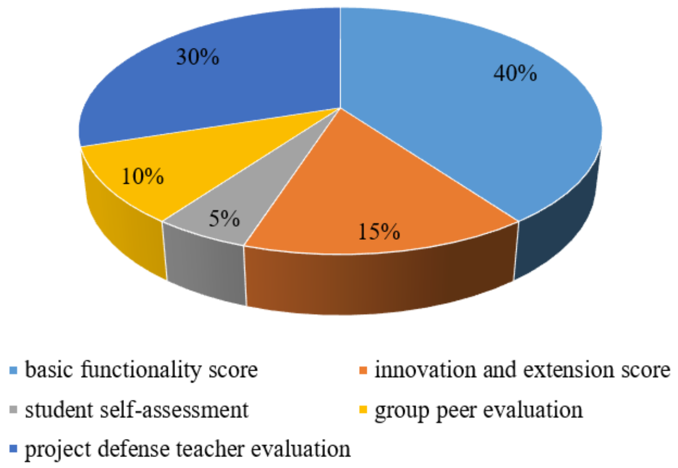

Figure 3: Components of the project-based experiment score.

The evaluation system proposed in this paper comprehensively assesses students' learning from multiple dimensions, including knowledge acquisition, skill application, innovation capabilities, and teamwork. It emphasizes performance throughout the learning process. By using formative assessment, it can promptly identify and address issues in students' learning, recognize and encourage their progress and efforts, and enhance their confidence and motivation. Additionally, this mechanism reduces the limitations and subjectivity of a single evaluation method, thereby improving the fairness and objectivity of the course evaluation results.

4. Conclusions

To comprehensively enhance the cultivation of students' innovation abilities in the microcontroller laboratory course, this paper proposes integrating a smart control system into the microcontroller lab curriculum. Specifically, it suggests incorporating project-based teaching into microcontroller programming, hardware design, and software development processes. This approach updates teaching concepts, enriches classroom content with multiple project cases, and sparks students' interest in scientific exploration. Additionally, the project includes a diversified evaluation system that employs multi-dimensional and multi-method assessments to thoroughly evaluate students' knowledge acquisition, skill application, and innovation capabilities. This enhances teaching quality and improves students' overall competence. In summary, the teaching reform concepts presented in this paper promote students' comprehensive development and elevate the quality of education and teaching.

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