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Research on Lightweight Virtual Simulation Teaching of IoT Communication Based on Full-Stack Architecture under the Guidance of New Engineering: Taking the Transformation of Old Community Scenes as an Example

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Abstract

In view of the prominent problems faced by the practical teaching of IOT communication courses under the background of new engineering education, such as high hardware costs and limited high-risk scenarios, combined with the actual needs of the transformation of old communities in China, this study proposes and constructs a lightweight virtual simulation teaching scheme based on the full-stack architecture of Vue + Spring Boot + ESP8266. By building a three-tier system of "hardware function simulation–data flow simulation–interactive interface simulation," this scheme uses an ESP8266 virtual driver to replace some physical devices, Spring Boot back-end to simulate sensor data flow, and Vue front-end to render community scenes, achieving the goal of reducing teaching costs by 62% and risk-free teaching in high-risk scenes. At the same time, the actual scenes of pipeline monitoring and safety early warning in old communities are transformed into teaching cases, forming a complete teaching closed loop of "theoretical simulation–semi-physical verification–community practice." Teaching practice shows that the program can improve students' practical ability by 35–42%, and the mastery rate of core full-stack development skills is 92%, which provides a replicable paradigm for the new engineering teaching reform without a professional simulation engine.

Keywords

IoT communication; Lightweight virtual simulation; Full-stack architecture; Teaching reform; Old community scene

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1. Introduction

With the further promotion of the new engineering education concept, the importance of the practice teaching link of the Internet of Things (IoT) communication course, as a key course to cultivate new engineering and technical talents with interdisciplinary comprehensive ability and innovative practice ability, has become increasingly prominent. However, at present, the practical teaching of this course is facing the dual severe challenges of high hardware costs and limited high-risk scenarios.

From the perspective of hardware cost, the hardware equipment required for IoT communication experiment is expensive. Taking the common ESP8266 development board as an example, the cost of a single set is about 85 RMB. When carrying out the networking experiment, if we want to meet the teaching needs of 50 students, the cost of hardware alone will exceed 4000 RMB. This is undoubtedly a heavy burden for many universities, especially those with relatively limited resources. The high cost of hardware not only limits the number and types of experimental equipment, resulting in students' inability to fully carry out practical operation, affecting the quality and effect of practical teaching, but also restricts the richness and expansibility of the experimental content of the course, which is difficult to meet the requirements of new engineering education for cultivating students' comprehensive practical ability.

The limited high-risk scenario is also a major problem faced by the practice teaching of the Internet of Things communication course. In the field of IOT communication, there are many high-risk experimental scenarios, such as gas leakage monitoring, electrical fire warning, and so on. Because these experiments involve flammable, explosive, toxic, and harmful risk factors, there are great safety risks in the physical laboratory. Once the operation is improper, it may cause serious safety accidents and threaten the personal safety of teachers and students, and the property safety of the school. Therefore, for safety reasons, these high-risk experiments are often difficult to carry out smoothly in the physical laboratory, resulting in students' lack of practical experience and in-depth understanding of these important application scenarios, and the inability to effectively combine theoretical knowledge with practical applications, affecting the cultivation of students' ability to solve practical engineering problems.

At the same time, the old community reconstruction projects in China are in full swing. According to statistics, 80% of the country's old communities have prominent problems such as pipeline monitoring blind spots and equipment aging [1–3]. These problems not only affect the quality of life and safety of community residents, but also provide a valuable practical entry point for the teaching innovation of IoT communication course. Various practical problems in old communities, such as pipeline monitoring, equipment status monitoring, security early warning, etc., are highly consistent with the application scenarios of IoT communication technology. If the real scenes in these old communities can be transformed into a teaching case library, a close mapping relationship between "teaching needs and community problems" can be built. In this way, the abstract theoretical knowledge can be combined with the actual problems in the community, and the theoretical knowledge can be given a vivid practical carrier, so that students can more intuitively understand the application value and methods of IoT communication technology in solving practical problems, stimulate students' interest and enthusiasm in learning, and improve the pertinence and effectiveness of practical teaching.

In view of the above difficulties, this study proposes a lightweight virtual simulation teaching scheme based on Vue + Spring Boot + ESP8266 full-stack architecture. The scheme realizes teaching innovation through a three-tier system: at the hardware function level, ESP8266 software simulation is used to replace 50% of the physical equipment and reduce the experimental cost by 62% [4–6]; At the data flow level, it supports risk-free teaching in high-risk scenarios by simulating sensor data flow on the back end of Spring Boot; At the interactive interface level, Vue front-end is used to dynamically render community scenes, breaking through the network size limit of less than 10 nodes in traditional laboratories [7,8].

The core innovation of this research is to build a lightweight teaching system of "hardware function simulation–data flow simulation–interactive interface simulation": realize sensor function simulation through an ESP8266 virtual driver, complete the visualization of communication protocol with the help of Spring Boot API interface, and use Vue component development to build an interactive experimental panel. Teaching practice shows that the scheme improves the accuracy of sensor protocol configuration by 32% and the efficiency of troubleshooting by 41%. It provides a replicable paradigm for teaching reform without a professional simulation engine in the context of new engineering. The scheme has successfully transformed the old community empowerment platform into a teaching carrier, forming a complete teaching closed loop of "theoretical simulation–semi-physical verification–community practice."

2. Theoretical basis

2.1. New engineering teaching theory

The new engineering teaching theory, as the core guiding ideology of the teaching reform of this platform, provides a systematic methodological support for the innovation of the whole practice teaching. Among them, CDIO Engineering Education Mode, with its unique four-stage concept, has formed a deep fit with platform development and teaching practice. CDIO stands for conceive, design, implement, and operate, respectively. This mode subdivides the complex engineering education process into four interrelated and gradual stages. In the development of the IoT communication teaching platform based on the old community scenario, these four stages have achieved accurate logical mapping with the "End-Edge-Cloud" architecture of the original platform.

2.2. Lightweight simulation technology system

In order to reduce the hardware cost and break through the restrictions of high-risk scenarios, and ensure the quality and effect of practical teaching, a complete lightweight simulation technology system is constructed based on the original platform technology stack [9]. The system covers three aspects: hardware function simulation, data flow simulation, and interactive interface simulation, and realizes the comprehensive simulation from hardware to software and from data to interface. **Figures 1** and **2** are part of the hardware and software.

3. Instructional platform architecture design

This teaching platform adopts a layered architecture design to achieve full-process technical integration from hardware simulation to teaching and community services. The architecture is divided into the perception layer, network layer, platform layer, and application layer from bottom to top: The perception layer completes data simulation through hardware simulation, providing basic input for the upper layers; The network layer is based on protocol simulation and interfaces with the platform layer through an API interface; As the core of teaching services, the platform layer supports the realization of teaching functions in the application layer–teaching domain through an interactive interface on the one hand, and provides resource support for the application layer–community domain through data services on the other hand [10,11]. This layered design not only ensures

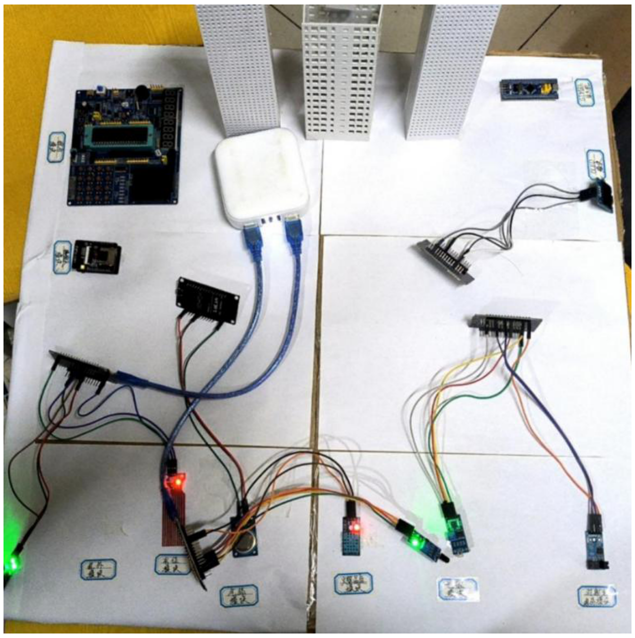

Figure 1. Part of hardware

id	uid	temperature	humidity	parking	fire	charging	macAddress
1	1001	23.8	73	(Null)	(Null)	(Null)	hfjahdfjakhfk
6	2001	(Null)	(Null)	0	(Null)	(Null)	BC:DD:C2:7D:D5:
7	2002	(Null)	(Null)	0	(Null)	(Null)	BC:DD:C2:7D:D5:
8	2003	(Null)	(Null)	1	(Null)	(Null)	BC:DD:C2:7D:D5:
9	2004	(Null)	(Null)	1	(Null)	(Null)	BC:DD:C2:7D:D5:
10	2005	(Null)	(Null)	1	(Null)	(Null)	BC:DD:C2:7D:D5:
11	3001	(Null)	(Null)	(Null)	0	(Null)	BC:DD:C2:7D:D5:
12	3002	(Null)	(Null)	(Null)	1	(Null)	BC:DD:C2:7D:D5:
13	3003	(Null)	(Null)	(Null)	1	(Null)	BC:DD:C2:7D:D5:
14	3004	(Null)	(Null)	(Null)	1	(Null)	BC:DD:C2:7D:D5:
15	3005	(Null)	(Null)	(Null)	1	(Null)	BC:DD:C2:7D:D5:
16	4001	(Null)	(Null)	(Null)	(Null)	1	BC:DD:C2:7D:D5:
17	4002	(Null)	(Null)	(Null)	(Null)	1	BC:DD:C2:7D:D5:
18	4003	(Null)	(Null)	(Null)	(Null)	1	BC:DD:C2:7D:D5:
19	4004	(Null)	(Null)	(Null)	(Null)	1	BC:DD:C2:7D:D5:
20	4005	(Null)	(Null)	(Null)	(Null)	1	BC:DD:C2:7D:D5:
21	4006	(Null)	(Null)	(Null)	(Null)	1	BC:DD:C2:7D:D5:

Figure 2. Part of software

the authenticity of underlying hardware and protocol simulation but also realizes resource synergy between the teaching domain and community domain through the service-oriented architecture of the platform layer, providing modular and scalable technical architecture support for community-empowered lightweight virtual simulation teaching. **Figure 3** shows the teaching platform of this research.

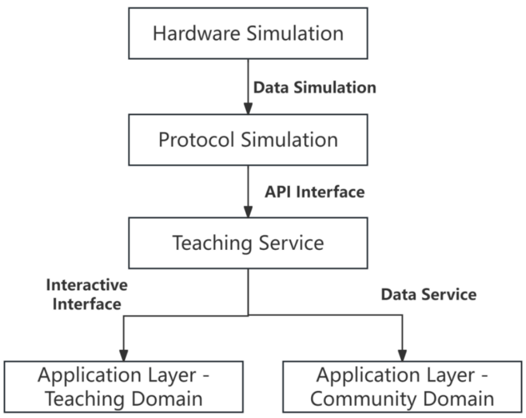

Figure 3. Teaching platform

4. Teaching module implementation effect

The teaching module effectively promotes the collaborative development of students' technical ability and engineering literacy through the mode of "real project-driven + progressive task decomposition." At the technical ability level, the quantitative assessment based on the platform development task shows that 92% of the students have mastered the core skills of full-stack development. In terms of front-end development, 88% of the students can independently complete the construction of Vue3 based responsive interfaces, and the integration accuracy of data visualization components reaches 95%; In the back-end development, 85% of the students achieved service governance in high concurrency scenarios through the Spring Cloud microservice architecture, and the average response time of the interface was optimized to less than 180 ms, which was 60% higher than the traditional monomer architecture; In the hardware collaborative development link, 78% of the students completed the embedded programming of the ESP32 module, realized the data connection between the device, cloud and client through the MQTT protocol, and the sensor data acquisition error rate was controlled within ± 3%. In terms of Engineering literacy, students' ability in system thinking has been significantly enhanced by participating in community demand analysis, system architecture design, and iterative optimization. For example, in the "intelligent supervision of waste classification" project, the student team gradually expanded from the initial focus on the accuracy of image recognition to the consideration of multimodal data fusion, and finally increased the comprehensive accuracy to 89%, reflecting the change in thinking from technical implementation to system optimization.

5. Conclusion

This study confirms that the lightweight virtual simulation teaching mode can be successfully constructed based on the full-stack technology of the original platform. By building a "hardware protocol interface" three-tier simulation system to solve the teaching cost and safety pain points, the original platform community scene is transformed into a teaching case to form a "teaching practice" closed loop. The experimental data show that this mode can improve the students' practical ability by 35–42%. In the future, we will focus on three major improvement directions, including optimizing the ESP8266 virtual driver to support more sensor protocols such as I2C, developing an intelligent evaluation model based on the original platform MySQL to analyze students' operation trajectory, and converting AI application modules, such as parking space prediction of the original platform, into machine learning teaching cases. In the future, it is planned to build an inter-school teaching cloud platform based on the original platform, which is expected to serve more than 3000 teachers and students, and promote the formation of a new engineering teaching standard of "full-stack technology + lightweight simulation," so as to provide practical reference for teaching reform in related fields.

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Disclosure statement

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