Digital Twin Smart Campus Management System Based on IoT Technology Architecture

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Abstract: The concept of smart campuses has emerged from the wave of information technology and the Internet of Things, with its unique value increasingly highlighted in the field of education. After long-term technological advancements, such as innovations in sensor technology, widespread applications of cloud computing, and in-depth big data analysis, smart campus management has become a focal point of attention in the education sector. Smart campuses represent not only a conceptual innovation but also a profound transformation in the educational environment. The development of IoT technology has enhanced the role of sensor networks and environmental controllers in campuses, acting as the "nerve endings" of the campuses, maintaining real-time communication with the management center. This article introduces how to efficiently build an IoT-based campus management system using local software. It also explains how to utilize digital twin technology to develop virtual campus models for quick simulation and analysis of campus operational behavior. This approach provides support for management decisions and encourages educational innovation. With the advancement of the system and the implementation of digital twin technology, the future educational environment will become more intelligent, efficient, and humanized. Smart campuses will evolve into ideal places to nurture future societal elites.

Keywords: Internet of Things (IoT); Digital Twin; Smart Campus;

1. Digital Twin Technology Development Status

Digital Twin technology is a hot topic in the field of information technology today. It enables the simulation, analysis, and prediction of the behavior and performance of a physical entity or system by creating a virtual replica in a virtual environment.

Digital Twin technology has its early roots in NASA's Apollo program, initially used to simulate the working status of spacecraft [1]. It is defined as a digital representation of a specific physical entity or process with real-time data connections, providing an integrated view throughout its lifecycle and helping to optimize overall performance.

Digital Twin technology has been widely applied in various fields, including smart manufacturing, smart cities, healthcare, and environmental monitoring. In the field of smart manufacturing, Digital Twin is seen as an effective means to achieve the interaction and integration of the manufacturing information world and the physical world. In the construction of smart cities, Digital Twin technology is used to improve urban management and residents' lives, demonstrating the potential of IoT technology in enhancing urban operational efficiency and residents' quality of life.

Despite its enormous potential, Digital Twin technology also faces challenges in implementation, such as data accuracy, model complexity, and integration with existing systems. In the future, the development of Digital Twin technology will focus more on interoperability, standardization, and security. With the development of emerging technologies such as IoT, artificial intelligence, and big data analytics, Digital Twin will achieve higher levels of intelligence and automation.

Policies and standardization are important factors in promoting the development of Digital Twin technology. For example, in 2022, the IoT Blue Paper published by Huawei in conjunction with the China (Wuxi) Internet of Things Research Institute and other associations proposed new ideas for the construction of IoT sensing networks, which has played a significant guiding role in driving positive industrial development and industrial digital transformation [2].

2. Applications of the Internet of Things

The evolution of the Internet of Things (IoT) technology dates back to the early 1990s. During this period, the widespread adoption of the Internet and the rapid advancement of wireless communication technologies laid the groundwork for the emergence of the Internet of Things (IoT). In 1999, Kevin Ashton from the Massachusetts Institute of Technology (MIT) first introduced the concept of the Internet of Things, envisioning a future where objects could be remotely managed and tracked by attaching RFID tags, the size of a bean, to them and connecting them to the network [3].

The Internet of Things (IoT) involves integrating sensing devices, controllers, and other information-gathering components with networks to enable intelligent identification, location tracking, monitoring, and management of items. This domain not only encompasses traditional technologies such as RFID (Radio Frequency Identification), infrared sensing, Global Positioning System (GPS), and laser scanners but also continuously integrates cutting-edge technologies like wireless transmission and big data processing. By collecting data through these devices and transmitting it over the internet for processing by intelligent systems, the Internet of Things (IoT) enables smart interconnectivity and interaction among people and objects, as well as among objects themselves. The essence of IoT is to bridge the gap between the physical world and the digital network world through technological means, making human lifestyles and interactions with the environment more efficient and convenient.

2.1 Smart Homes

IoT technology enables various devices in the home, such as air conditioning, lighting, and security systems, to connect with each other and be controlled by intelligent systems, providing a more convenient, energy-efficient, and secure living environment.

2.2 Intelligent Transportation

By deploying sensing devices on urban roads, IoT technology can monitor traffic conditions in real-time, providing drivers with accurate route planning and assisting transportation managers in optimizing the allocation of traffic resources to reduce congestion.

2.3 Smart Agriculture

The application of IoT technology in agriculture includes precise fertilization, intelligent irrigation, and crop monitoring. By collecting and analyzing planting environment data, agricultural production efficiency and product quality can be enhanced.

2.4 Smart Healthcare

The application of IoT technology in the healthcare field includes remote monitoring of patient health status, intelligent drug management, and personalized medical services, enhancing the quality and efficiency of medical services.

2.5 Smart Logistics

IoT technology enables real-time tracking and management of goods in the logistics process through RFID, sensor networks, etc., improving logistics efficiency, reducing costs, and increasing customer satisfaction.

3. Internet of Things and Smart Campuses

3.1 Smart Campuses

(1) The purpose of a smart campus

Constructing an intelligent campus system involves the utilization of modern information technologies such as the Internet of Things, cloud computing, big data analysis, and artificial intelligence to build a comprehensive digital, networked and intelligent educational environment. This kind of environment not only provides convenient and efficient teaching and learning resources for teachers and students, but also has great potential in energy saving and resource optimization. The intelligent campus gives priority to building an intelligent environment by implementing an information management mode, providing a platform-based service system and offering personalized educational content. It aims to improve the quality of education, simplify the processes of teaching and daily management, strengthen campus security and create a positive educational atmosphere through technical means.

(2) Developing environments

Operating System: Windows 11 x64
Java Development Kit: JDK 1.8
Web Server: Spring Boot Built-in Tomcat Server
Development Tool: IntelliJ IDEA
Development Framework: Spring Boot + Vue + EMQX
Database: MySQL 5.7
Browser: Google Chrome
Cloud Host for Project Release: Ubuntu 22.04 LTS Dual-core 2 GHz Processor 2 GB Memory
(3) Requirements Analysis and Modeling of Intelligent Campus

3.2 Requirements Analysis

User modeling of the intelligent campus management and development system is a key step to ensure that the system meets the diverse needs of users. This process not only involves providing customized experience for different user groups, but also includes role-driven functional design to tailor interaction interfaces and permission settings for various users such as teachers, students, and administrative staff. User modeling also pays attention to security and privacy protection, ensuring data security through refined permission management and meeting the requirements of privacy regulations.

In addition, user modeling guides the optimization configuration of resources through analyzing usage patterns to improve the utilization rate of resources. It also provides decision support for campus managers, helping them predict needs, identify service gaps through user behavior analysis and optimize service strategies accordingly. Good user modeling also lays a foundation for the scalability of the system, facilitating functional expansion or adjustment in the future according to the needs of campus development.

In summary, user modeling is crucial for building an efficient, secure and forward-looking Internet of Things-based intelligent campus system. It not only enhances user experience, but also provides data support for campus management and ensures the long-term applicability and sustainable development of the system.

3.3 System Management

In the intelligent campus system, department heads undertake various administrative duties. Their work is extensive and crucial, playing an irreplaceable role in maintaining the operation order of the campus and promoting the process of educational informatization. Here is a detailed introduction to the main duties and tasks of department heads as shown in Figure 1.

In addition, in the intelligent campus system, there are teacher module, student module, educational affairs module and online examination module.

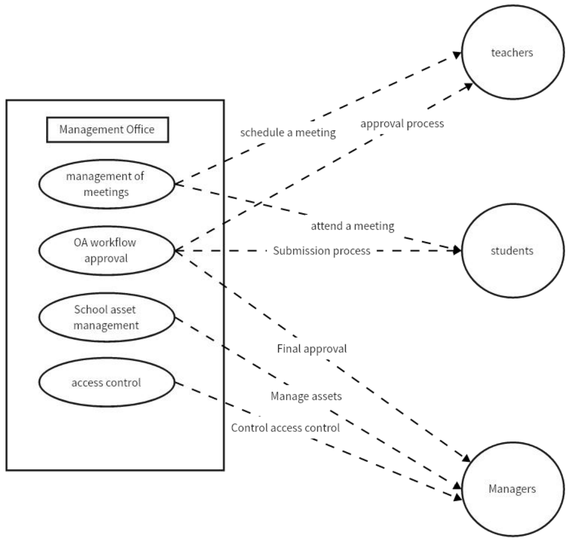

Figure 1. Office Management

3.4 Internet of Things Hardware Design Module

The Internet of Things hardware design module of the intelligent campus management system plays a crucial role as the core link of the campus intelligent construction. This module takes the ESP8266 Internet of Things camera module as the core and is supplemented by a temperature and humidity monitoring sensor, providing advanced technical support for campus security management and environmental quality monitoring.

The ESP8266 module, as an energy-saving and powerful Wi-Fi communication unit, can seamlessly push the video stream to the campus data center in real time. Its built-in two-dimensional code scanning function greatly simplifies the data entry process within the campus and improves the efficiency of authentication.

The temperature and humidity monitoring system conducts meticulous real-time monitoring of environmental parameters through a sensor network deployed at various strategic positions in the campus, ensuring the suitability of the campus environment. These monitoring data not only ensure the comfort of the campus, but also provide data support for promoting energy conservation and emission reduction and equipment maintenance work.

At the data processing level, the Internet of Things hardware design module sends image and sensor data to the central database in real time through an efficient data transmission mechanism, providing a solid foundation for in-depth analysis and decision-making. The campus management team can obtain and supervise these key information remotely through an intuitive user interface, thus realizing the intelligence and remote operation of campus management.

In general, the Internet of Things hardware design module of the intelligent campus management system, with its innovative technology and thoughtful service, has given strong impetus to the intelligent management and environmental monitoring of the campus, and significantly improved the management efficiency and security level of the campus.

B. The Importance of the Internet of Things for Smart Campuses

The Internet of Things (IoT) technology plays a crucial role in the strategy of smart campuses. The deployment of numerous sensors and terminal devices enables schools to monitor and analyze various indicators in real-time, such as temperature, humidity, lighting intensity, and human traffic flow. The collection and in-depth analysis of this data can guide intelligent decision-making and refined management. For instance, smart energy management systems can adjust the operation of lighting and temperature control devices to maximize energy efficiency. In terms of security, the Internet of Things (IoT) can significantly enhance the intelligent response capabilities of campus monitoring systems, effectively preventing and responding to emergencies.

- Smart Classrooms: Smart classrooms achieve automated environmental adjustments and intelligent switching of teaching resources by integrating smart devices and environmental sensors.
- Campus Security Monitoring: Advanced cameras and sensing technologies are utilized to monitor campus safety in real-time. Biometric technologies, such as facial recognition, enhance access control measures.
- Energy Consumption Management: Smart meters are used to monitor the consumption of electricity and water resources, and data analysis helps optimize energy usage.
- Asset Tracking and Management: Technologies such as RFID are employed for electronic tag management of assets, achieving effective management to prevent loss and misuse.
- Environmental Quality Monitoring: Environmental sensing devices are used to monitor air quality and noise levels in educational or public spaces.
- Funding Costs and Daily Maintenance: Smart campuses require significant initial investments, and continuous maintenance and updates also demand substantial financial resources.
- Technical Standardization and Device Compatibility: With the rapid pace of technological advancements, ensuring seamless cooperation and compatibility among different systems has become an urgent issue that requires attention.
- It is anticipated that the future of smart campuses will be met with great expectation. It is hoped that through continuous technological innovation and practical application, existing problems will be resolved, and the educational sector will advance towards an increasingly intelligent and personalized future. On the path of integrating modernization and informatization in education, smart campuses will play an increasingly important role in driving progress.

4. China's Internet of Things Technology Development and Application Status

After the text has been edited, the paper is ready to be formatted according to the template. Duplicate the template file using the "Save As" command and name your paper according to the convention prescribed by the conference. In the newly created file, highlight all content and replace it with your prepared text. You are now ready to style your paper; use the dropdown window on the left of the MS Word Formatting toolbar.

A. Authors and Affiliations

The development of the Internet of Things (IoT) in China has progressed through multiple stages and achieved a series of independent development achievements. The concept of IoT in China originated around 2009, coinciding with the international emergence of IoT technology, which drew the attention of the Chinese scientific community and government departments to its potential. Initially, IoT in China focused primarily on theoretical research and technological exploration. As technology matured and market demand grew, IoT in China expanded rapidly. This phase saw not only the development of civilian applications such as smart homes and smart cities but also advancements in industrial, agricultural, logistics, and medical sectors, with smart manufacturing and industrial IoT gaining prominence. Bolstered by the development of new technologies like 5G, edge computing, big data, and artificial intelligence, China's IoT industry has entered a new phase characterized by innovation. The country has conducted extensive independent research and development in areas like chip design, communication protocols, and operating systems, thereby enhancing the autonomy and controllability of the IoT industry. For example, "HarmonyOS" is an operating system launched by Huawei specifically for IoT devices [4].

China places great importance on the construction of IoT standard systems. For instance, in 2017,

(Narrowband Internet of Things) national standard was introduced and jointly promoted by companies such as China Mobile and Huawei [5]. NB-IoT is a low-power wide-area network technology well-suited for various IoT applications. Major Chinese technology companies, including Alibaba (which launched an IoT platform through its subsidiary Ali Cloud), Huawei (which launched the OceanConnect IoT platform), and Tencent (which launched the Tencent IoT platform), have all developed their own IoT platforms. They provide related services and solutions to support a broad range of industry applications and enterprise-level IoT solutions, actively constructing their platforms and offering associated services to bolster extensive industrial applications and enterprise-level IoT solutions.

5. The Technological Architecture of the Smart Campus Management System, which is Based on China's Technological Innovation in Iot Software Development

This project adopts the FastBee open-source IoT platform, which is simple and easy to use, suitable for smart campuses, smart offices, smart communities, agricultural monitoring, water conservancy monitoring, industrial control, etc [6]. The system architecture is shown in Figure 2.

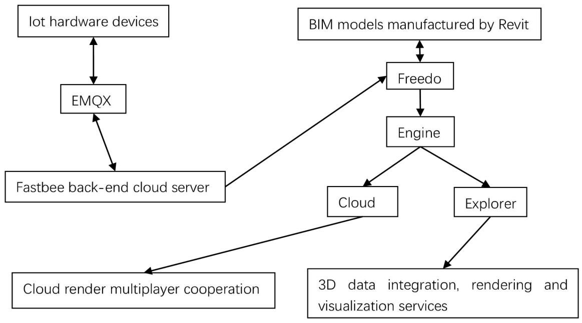

Figure 2. Architecture Logic Diagram

IoT hardware device access to the backend as Figure 3.

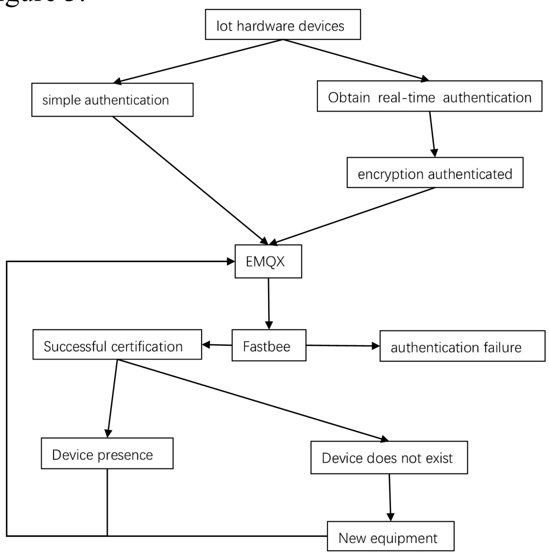

Figure 3. Hardware Device Access to the Backend

5.1 The System is Deployed Using the Spring Boot Architecture

Spring Boot is an open-source foundational framework for Java that simplifies the initial setup and development process of Spring applications [7]. It facilitates rapid startup and development of new Spring projects by providing default configurations. Its design principle of "convention over configuration" reduces the learning curve, allowing new users to quickly get started. It is designed to run with no or minimal Spring configuration. Spring Boot offers a multitude of starter dependencies, making project initialization very fast. Its auto-configuration features reduce the complexity of manual configuration for Spring and other frameworks. It does not require deployment to an external Servlet container, simplifying the application deployment process. Packaging into a single JAR file simplifies project execution and migration. It provides production-ready features such as health checks and metrics collection, making it easy to manage and monitor applications through the Spring Boot Actuator module.

When used in conjunction with Spring Cloud, Spring Boot is very convenient for building a microservices architecture. It supports microservices patterns such as service registration and discovery, configuration management, and message routing. You can choose the technology stack you need and integrate various technologies such as JPA, MongoDB, Redis, Elasticsearch, etc., by simply adding the relevant dependencies. It offers powerful customization capabilities, allowing you to extend the functionality of Spring Boot through configuration files and custom auto-configuration. Integrating Spring Security provides secure application development, supporting modern security protocols and measures such as OAuth2 and JWT.

Due to these benefits, Spring Boot serves as the framework for rapid development and deployment of Spring applications in this project. Whether it is the main body of the project or the microservices architecture that will be expanded in the future, Spring Boot provides effective solutions.

5.2 System Front-end Page Framework

Vue.js is a popular JavaScript framework for building user interfaces, particularly suited for single-page applications (SPAs) [8]. Known for its lightweight, simplicity, and flexibility, Vue.js has quickly gained widespread support from the developer community since its initial release. Along with Angular and React, it is considered one of the most popular frameworks in modern front-end development.

Vue.js uses a reactive data binding mechanism, where the view is automatically updated when the data in the model changes. By using reusable components, large applications can be constructed, with each component containing its own view and logic. Vue.js employs a virtual DOM to optimize the rendering process, comparing only the differences between two states and efficiently updating the DOM in batches. Vue provides a rich set of directives (such as v-bind, v-model, v-on, etc.) to simplify DOM manipulation. It also offers powerful development tools, such as vue-cli and Vue Devtools, which assist developers in quickly setting up projects and efficiently debugging. Vue presents a progressive framework pattern that ranges from the core library to full-stack solutions, allowing for the flexible selection of required features according to project needs. It can be seamlessly integrated into existing projects, and even used in a part of a page without the need to rewrite existing code.

Due to these advantages, Vue was chosen for the front-end page display of this project. From small modules to large back-end management system main applications, Vue can provide a clean, efficient, and reliable development experience for this project.

5.3 Backend Business Logic Framework of the System

The system utilizes the EMQX open-source IoT message broker server to receive and process messages sent by hardware devices to the server [9]. It is widely used in multiple IoT fields such as smart manufacturing, smart cities, the Internet of Vehicles, and smart homes. Capable of supporting tens of millions of concurrent connections and handling millions of message throughputs, it provides monitoring and alerting features, making it convenient for users to observe system status and respond to issues promptly. The project primarily adopts the MQTT (Message Queuing Telemetry Transport) protocol for transmission, which is the most mainstream protocol with good compatibility and can handle large-scale concurrent device connections [10]. As a message broker based on the publish/subscribe model, EMQX enables different IoT devices and services to exchange information through flexible topic subscriptions.

The project is built on Spring Boot and uses Fastbee, a rapid development open-source platform, integrating Spring Framework, MyBatis, Spring Security, Thymeleaf, Vue, and other popular open-source projects. It includes a built-in code generator that supports the generation of front-end and back-end code, reducing repetitive workload and avoiding basic errors. It allows for form design, list design, and other operations directly in the browser. The front-end uses modern technology stacks such as Vue and Element UI, while the back-end employs Spring Boot, Spring Security, MyBatis, etc. It integrates Spring Boot Admin for microservices monitoring, supporting server and application monitoring.

By using the Ruoyi framework, the development process can be greatly simplified, productivity can be increased, and development costs can be reduced, striving to create a one-stop solution from front-end to back-end, from framework to microservices [11]. For developers, it is an excellent choice for building the backend of this smart campus management system.

5.4 Functional Modules.

- Environmental Monitoring System: Real-time monitoring of environmental indicators such as air quality, temperature, and humidity within the campus, and improving environmental quality through intelligent regulation devices.
- Energy Management System: Monitors energy usage within the campus and optimizes energy distribution through data analysis to reduce waste.
- Security Monitoring System: Utilizes cameras and abnormal behavior detection algorithms to enhance campus safety, prevent and promptly handle security incidents.
- Resource Management System: Manages resources such as libraries, laboratories, and sports facilities, providing online reservation and usage inquiry services.
- Intelligent Navigation System: Provides navigation services within the campus for students and teachers, including route planning and facility inquiries.
- Intelligent Repair Reporting System: Allows students and teachers to report damages to campus facilities through the system, enabling management personnel to respond and handle issues in a timely manner.
- Student Information Management System: The student information management system is an integrated platform that includes multiple modules such as student file management, grade management, course scheduling, attendance tracking, and parent-teacher communication. The system achieves centralized storage, rapid inquiry, effective analysis, and secure protection of student information through digital means, thereby enhancing the school's management level and the quality of educational services.
- Teacher Information Management System: The teacher information management system aims to achieve centralized management of teacher information, supervision and evaluation of teaching activities, and support for teacher professional growth through digital means. By integrating various functional modules, the system provides convenient information management and services for school administrators, teachers themselves, and relevant educational management departments.
- Academic Affairs Information Management System: The academic affairs information management system aims to improve the efficiency and quality of academic management by achieving automation and informatization of academic activities through an integrated platform. The system will provide convenient services for teachers, students, and academic affairs management personnel, ensuring the smooth progress of teaching activities.

5.5 Redis

Redis (Remote Dictionary Server) is an open-source, in-memory data structure storage system that can be used as a database, cache, and message broker. Redis is widely popular for its high performance, rich support for data structures, and atomic operations.

Most of the data in Redis is stored in memory, which means that data can be read and written very quickly, achieving millisecond or even microsecond data access. Redis can handle a large number of concurrent connections and requests, making it an ideal choice for high-traffic applications.

The benefits of choosing Redis include its excellent performance, flexible data structures, persistence mechanisms, replication and scaling capabilities, and a wide range of application scenarios. These features make Redis an ideal choice for building high-performance, scalable, and highly available systems. Whether used as a caching layer, message queue, or persistent database, Redis can provide stable and efficient services.

5.6 3D Model Rendering and Display

This project uses Revit to construct a BIM 3D architectural model. After the modeling is completed, the model is saved as an RVT format file. The model is then imported into Freedo Technology's Engine for processing, converting it into a "3dt" format file.

Freedo Technology (Beijing Freedo Technology Co., Ltd.) is an Internet company focused on providing three-dimensional full-domain data services. It is committed to offering digital transformation solutions for various industries through its innovative DTS (Digital Twin Scene) series of products. DTS is a data entity with characteristics of "full space, full elements, full process, multi-scale, and computable," aiming to build a "full-true world" that deeply integrates the physical and virtual worlds through digital twin technology.

Freedo Technology's 3DT (3D Twins Scenes Database) is a proprietary standard digital twin database created by Freedo Technology to cater to the characteristics and needs of digital twin scenarios. This database stores massive multi-source data from full space, full elements, full process, and multi-scale as 3DT digital twin databases through Engine, optimizing and accelerating data to enhance the user experience on the DTS high-rendering platform.

In Freedo Technology's DTS high-rendering platform, 3DT plays a crucial role. Through Engine, various data can be published as 3DT files, including terrain elevation data, oblique photography data, manual model data, BIM data, point cloud data, and vector data. These data are effectively managed and utilized in the 3DT database, providing users with a richer and more accurate digital twin experience.

After being converted into the 3dt format file, it is imported into AirCity Explorer, which offers highly realistic rendering effects and supports output at different precision levels from L1 to L5, meeting various levels of visualization needs. Built-in rich scene effects, such as weather changes and lighting effects, enhance the realism and immersion of the 3D scene. Users can simply import, manage, and display data without complex settings and programming knowledge. Explorer provides SDK and API interfaces, allowing developers to conduct secondary development and expand more functions and applications.

Additionally, Freedo Technology's Cloud service can be utilized. Freedo Technology's Cloud service is a cloud-based PaaS platform focused on providing cloud services related to digital twins. It offers users a powerful online environment for creating, managing, and analyzing digital twin scenarios. Users can build digital twin scenarios in the Cloud service for virtual simulation and analysis, supporting various applications such as smart cities and smart campuses. Leveraging the powerful computing capabilities of cloud computing, Cloud service can handle large-scale data analysis and complex scene rendering. It provides open API interfaces, allowing developers to connect external systems and services for broader application integration.

Overall, by converting BIM models to 3dt format through Freedo Technology's Engine and further processing with Freedo Technology's software, Explorer software primarily serves desktop users by providing three-dimensional data integration, rendering, and visualization services. In contrast, Cloud service is a cloud-based PaaS platform focused on the creation, management, and online collaboration of digital twin scenarios. Together, these two software solutions provide users with a complete solution from data integration to scene application, facilitating innovation and development in the field of digital twins.

This project utilizes Freedo Technology's ecosystem software to easily transform traditional BIM models into dynamic 3D scenes, not only simplifying the creation process of 3D scenes but also providing a wealth of customization options for the project, such as adjusting cloud density, thickness, and height, as well as creating water surface effects. Finally, additional elements such as environmental controllers, IoT hardware devices, and personnel demonstration models can be added to the project model as needed. Together, these elements constitute the 3D model rendering and display of this project.

6. Discussion

When undertaking the task of building an intelligent campus, although the basic framework of the project has been established, some challenges were encountered during the development process, and many aspects that need optimization were identified. The following is a profound reflection on the problems existing in the personal development process:

First of all, at the project initiation stage, the insight into user needs was not deep enough. This resulted in having to make multiple adjustments to some functions during the development cycle. Such rework not only slowed down the project progress but also increased unnecessary workload. Secondly, in the selection of the technology stack, excessive attention may have been paid to the cutting-edge nature of technology while ignoring the matching degree with one's own skill level. This reduced development efficiency to a certain extent and forced additional time to be invested in learning new technologies.

During the project promotion process, it was found that the control over the timeline was not strict enough, and the setting of key project nodes was not accurate enough, which further affected the overall development plan. At the same time, as the sole developer, there are limitations in the breadth of technology, which restricts the exertion of the project's potential performance. To solve this problem, it is necessary to continuously carry out technical learning and self-improvement.

In terms of software testing, it is realized that the testing process needs to be further strengthened to ensure more comprehensive test coverage, so as to discover and fix potential errors earlier. In addition, the automated continuous integration and continuous deployment (CI/CD) process has not been fully implemented, which limits the efficiency and quality of software delivery.

At the user experience level, excessive focus may have been placed on technical-level development, while insufficient consideration was given to the intuitiveness and convenience of user interaction, which may affect user satisfaction. Meanwhile, with the widespread application of Internet of Things devices, security has become an issue that cannot be ignored. More attention should be paid to data security and privacy protection during the development process.

In the early stage of the project, insufficient consideration was given to the maintainability and scalability of the system, which may bring difficulties to future system upgrades and maintenance. In addition, resource allocation needs to be more refined to ensure sufficient resource support at critical stages and avoid affecting the development progress due to insufficient resources.

Through reflecting on these challenges, valuable experience and lessons have been accumulated, which will guide better decision-making in future projects. In the future, more emphasis will be placed on deeply understanding user needs, reasonably selecting technology stacks, strictly managing project timelines, continuously improving personal technical capabilities, improving testing processes, strengthening CI/CD practices, focusing on user experience, enhancing security design, and rationally planning resource allocation. It is believed that through continuous learning and improvement, the development quality can be improved, and users can be provided with a more excellent product experience.

7. Conclusion

In the process of building the intelligent campus project, a profound realization was gained regarding the complexity and challenges inherent in modern software development. At the same time, the convenience and efficiency improvements brought about by technological innovation were also experienced firsthand. IntelliJ IDEA, with its excellent performance, served as the primary tool for project development, significantly enhancing the efficiency and accuracy of coding. The adoption of the Spring Boot architecture, characterized by its simplified configuration and robust functionality, laid a solid foundation for the rapid construction and future development of the project.

Through the utilization of the Ruoyi framework, efficient separation between the front-end and back-end was achieved. This not only boosted development efficiency but also reduced the development costs of system applications. The adoption of the Vue framework accelerated the front-end development process and markedly improved application performance. The selection of EMQX as the message middleware ensured the high efficiency and security of message transmission. The choice of the ESP8266 chip demonstrated the key role of Internet of Things technology in intelligent campus management. The stability of the development environment was evident in every aspect, from the operating system and database to the development tools and frameworks, all of which underwent careful consideration and configuration.

Credit is due to the efficient development tools provided by the Vue framework and IntelliJ IDEA. In the face of the continuous emergence of new technologies and frameworks, ongoing learning and practice became extremely crucial. Moreover, framework documentation and community support offered abundant learning materials and problem-solving approaches. The development of this project not only presented a valuable opportunity for learning and growth but also fostered great expectations for the application of Internet of Things and intelligent technologies in the field of education. Looking ahead to the future, there is a desire to apply these experiences and skills to a broader range of projects and make greater contributions to societal development.

Acknowledgments

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