Research on Smart City Platform Construction Technology for Digital Twins

Jianxiong Zhang
School of Computer Science and Engineering
Xi’an Technological University
Xi’an, China
E-mail: agonytriumph@163.com

Shiqian Wang
School of Computer Science & Engineering
Xi’an Technological University
Xi’an, China
E-mail: 1178208937@qq.com

Wuqi Gao
School of Computer Science & Engineering
Xi’an Technological University
Xi’an, China
E-mail: gaowuqi@126.com

***Abstract*—Urban digital twin is a key step to build a smart city, digital twin is an important application scenario for smart city platform, and the relationship between the two are both current research hotspots. In this paper, we will start from the demand of digital twin on smart city platform, study the architecture method and key technology of smart city platform, in this paper's platform construction method compared to the traditional construction method, reduces the difficulty of digital twin smart city construction, and also reduces the coupling degree between smart city platform modules, and use a smart city platform for engineering verification. Finally compared with the traditional smart platform construction techniques, the techniques in this paper are better than the traditional ones in terms of coupling, difficulty and cost. Through engineering verification and experimental results show that this paper on the digital twin-oriented smart city construction technology, the coupling degree of each module is the lowest, and in the development efficiency experiments, this paper by comparing with the traditional technology, the experimental development cycle compared to the traditional technology can be shortened by 61.7% of the development cycle, greatly reducing the development cost and improving the construction efficiency.**

Keywords-Digital Twin; Smart City; Engineering Verification

I. INTRODUCTION

As a leading technology in the construction of new smart cities, digital twin technology has become the core of building smart city platforms with its characteristics such as real-time monitoring and dynamic simulation. This paper aims to explore the key technologies and applications of digital twin technology in the construction of smart city platforms. Through IoT sensing, information modeling, ubiquitous network and other technologies, digital twin technology realizes real-virtual connection and mapping, providing the possibility of global spatio-temporal data fusion for urban operations. In this context, the paper will study the five-dimensional structural model of digital twins in detail, deeply analyze the basic principles of digital twin driving, and explore the application of the digital twin standard system framework. Through the research of the paper, it aims to provide technical support for the digital twin application of smart city platforms and promote the intelligent development of urban management, public services and other fields. Therefore, the construction of urban information models with digital twin technology as the core is the foundation of new smart cities, and provides a new idea for realizing three-dimensional visual monitoring of smart cities [1].

The digital twin technology in this article mainly focuses on three aspects: first, GIS data processing and unity 3D is used to realize three-

DOI: 10.2478/ijanmc-2024-0011

dimensional modeling of highways, green spaces, water systems, and real-life buildings in the urban environment; secondly, geographical information based on GIS (Geographical Information System) is used system) data to visually present a digital twin of the city that integrates sky, earth, and air, thereby providing spatio-temporal data services and other related application support for smart applications in various departments of the city, and assisting the construction of new infrastructure in the park; Finally, edge computing and terminal sensors and cloud computing are used to provide data support for the entire smart city platform [2]-[6].

II. DEFINITION OF DIGITAL TWIN

The concept of Digital Twins originated in the field of industrial manufacturing, and by combining with a new generation of information technology such as 5G communication, Internet of Things, cloud computing, big data, artificial intelligence, etc., it has realized the actual landing and transformation of Digital Twin theories in many industrial fields, and gradually extended to the application fields of smart city, smart transportation, smart water conservancy, etc. [3]. The digital twin is a digital model of existing or to-be physical entity objects, which perceives, diagnoses, and predicts the state of physical entity objects in real time through actual measurement, simulation, and data analysis, regulates the behavior of physical entity objects through optimization and instruction, and evolves itself through mutual learning among related digital models, while improving the decision-making of stakeholders during the life cycle of physical entity objects. The construction of digital twin smart cities will lead to disruptive innovations in city only management and services. The digital twin smart city is used in scenarios where buildings, roads, water systems, green spaces and other infrastructures in the city have corresponding virtual impacts in the digital world, where attribute information and dynamic change information are visible, trajectories can be traced, and statuses can be investigated; the virtual and real are synchronized to operate, and the scenarios are blended; the past can be traced, and early warnings for safety accidents and expectations of external development trends can be carried out; and the virtual services are realistic, and simulated decision-making can be simulated.

III. SMART CITY PLATFORM ARCHITECTURE

In 2023, the "First Edition of Digital Twin Industrial Software White Paper" was released. Many related digital twin manufacturers have also announced their own digital twin platform technology architecture. The divisions are basically similar, and they are basically divided into physical entities, virtual models, application services, and twin data.

It is traditionally believed that the industrial Internet platform deployment architecture is divided into three levels: end, edge and cloud. If this architecture is applied to the construction of smart city digital twins, the production cost and implementation cycle will be very large. Regarding this problem, the architecture proposed in this article as shown in Figure 1, it is divided into three parts: the first part: the digital layer, which refers to converting the city into the corresponding digital model. This article proposes the construction of a converged digital body based on Unity 3D and Web platforms; the second part: the network layer, this article divides it into edge network and central network. The edge network performs field-level calculations on edge devices and finally aggregates the processed data to the central network, thereby reducing the pressure on the central network and improving the efficiency of network transmission; Section Three parts: Device layer, this article will be divided into soft gateway, hard gateway, and IoT devices[7][8].

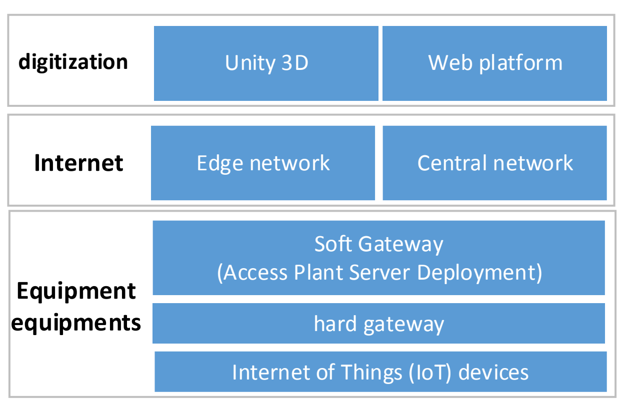

Figure 1. Platform Deployment Architecture Diagram

A. Mathematical layer analysis

The digitalization layer is subdivided into Unity 3D modeling and Web platform display integration, which improves the difficulty and efficiency of digitalization. In this paper, in order to verify the feasibility of the platform, a city's smart digital twin platform is used for verification, which is generally divided into three steps: ① Pruning and calibration of the city's GIS data to ensure that the GIS data and the real city scene correspond to each other, and the whole process is completed using QGIS software; ② The processed GIS data is imported into Unity 3D to make a real-life three-dimensional model of the target area; ③ Construct the Web platform, integrate the city digital model with the Web platform, and construct the three-dimensional display platform; Figure 2 shows the digital layer architecture diagram.

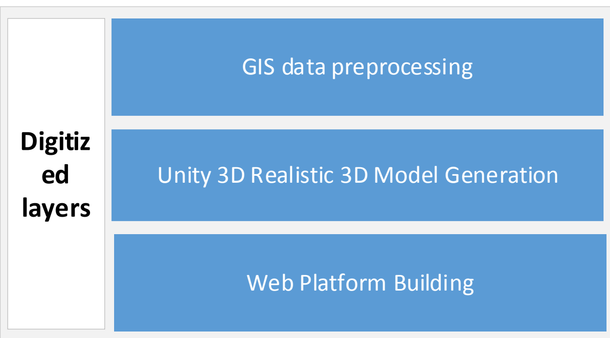

Figure 2. Mathematical Layer Architecture Diagram

B. Network Layer Analysis

For the five-dimensional model proposed in the Digital Twin 2023 whitepaper, which over-centralizes data, this model facilitates data management, but greatly increases the coupling of data and increases the intensity of central data processing. [9]

In this paper, we propose the edge network plus center network, as shown in Figure 3 the edge network is responsible for processing the data on the edge side and sending it to the IoT server through MQTT protocol, and the center network is responsible for the network service of the whole platform. The IoT server and the back-end server in Fig. 4 are in the same layer and they exchange information. This process will be explained in detail in this paper through engineering.

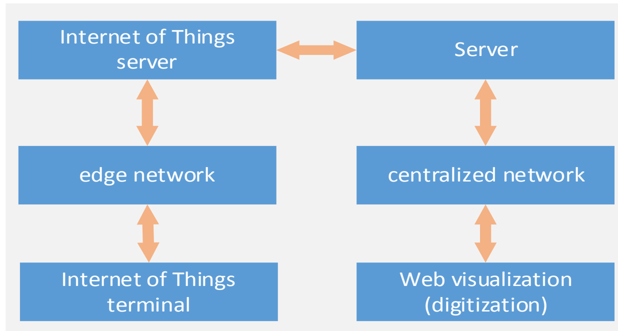

Figure 3. Network layer architecture diagram

C. Device level analysis

The device layer is subdivided into IoT devices, hard gateways, and soft gateways. IoT devices are considered to be at a level that does not have independent collection and communication capabilities. However, as Microcontroller Unit (MCU) technology becomes increasingly mature, more and more hardware is equipped with MCUs, and the time is divided into devices leaving the factory. It can be divided into front-mounted and rear-mounted. The rear-mounted MCU also needs to be installed with sensors or flow meters. It looks like a cheaper customized communication box. The existence of the rear-mounted MCU will weaken or cancel the hard gateway. Hard gateway is the most traditional end-side technology. It is generally believed that soft gateway can replace hard gateway in function and is more economical, because the difference between the two is that the deployment of the collection and forwarding program is changed from the box to the LAN server. However, in this article, hard gateways and soft gateways are used in parallel to ensure normal communication on different types of networks. Figure 4 shows the device layer network topology.

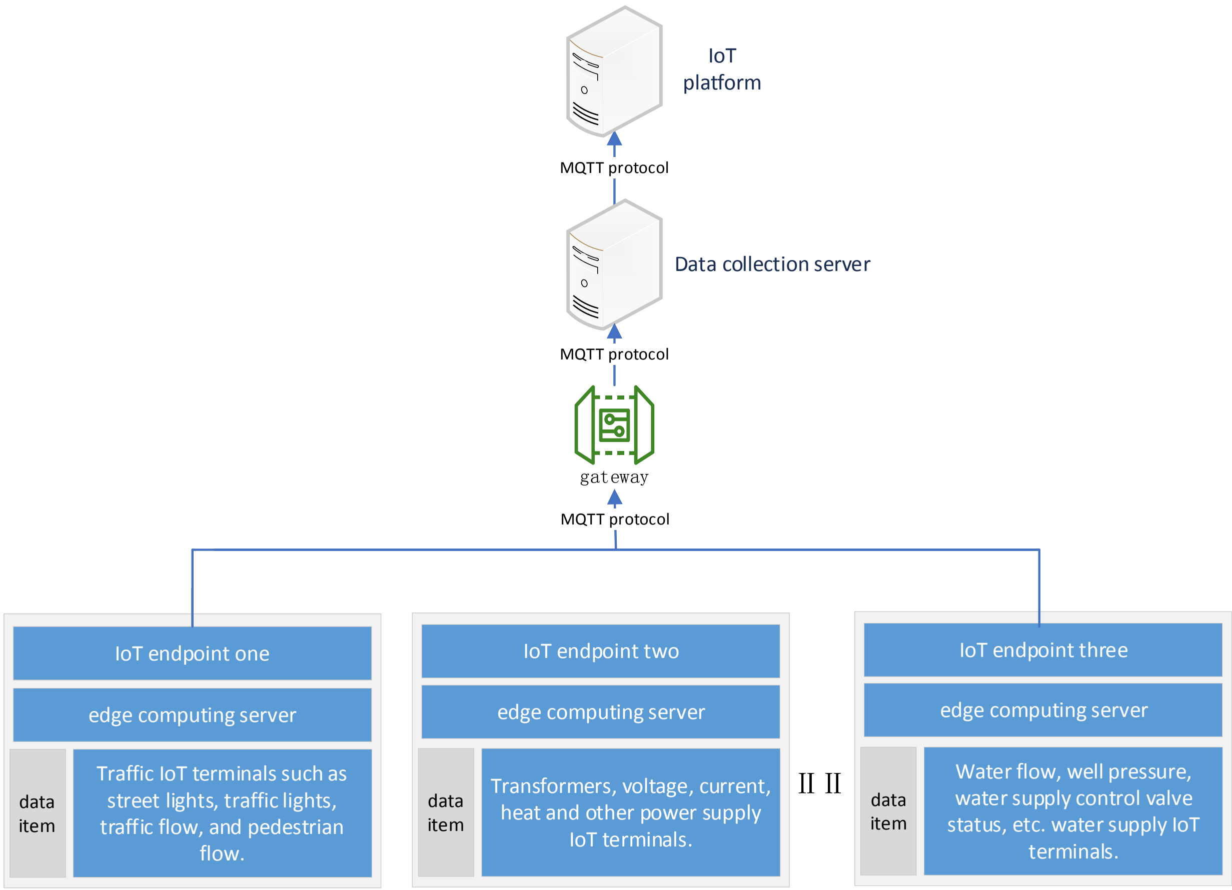

Figure 4. Device layer network topology diagram

IV. ENGINEERING VERIFICATION

As digital city construction continues to advance, local governments and urban district authorities are paying more and more attention to geographical information data. They are using geographical information, satellite remote sensing, smart terminals and other data to assist urban construction and planning, and governance [10]. The application of geographical information data can effectively solve the problems of poor information flow and lack of professional data support in urban construction in the new era. Through the sharing of resources in various fields, a new urban information system and service method can be formed to provide various services. Provide a basis for regional informatization and standardization construction work. This verification will be completed strictly in accordance with the above-mentioned smart city platform architecture for digital twins.

A. Engineering design

Currently, with its distributed system architecture, data sharing services, efficient computing load, independent client and other advantages, map display based on WebGIS technology has become the mainstream architecture model of GIS. The project adopts a B/S architecture and uses a traditional browser as the client to facilitate client access and data sharing. This project refers to the above-mentioned architecture and is also divided into a digital layer and a network layer. The device layer realizes loose coupling between modules, and each module can be used independently.

1) Digital layer. As shown in Figure 5 and Figure 6, QGIS performs pruning operations and verification on urban data, and the GIS data generates a three-dimensional real-life model in Unity 3D.

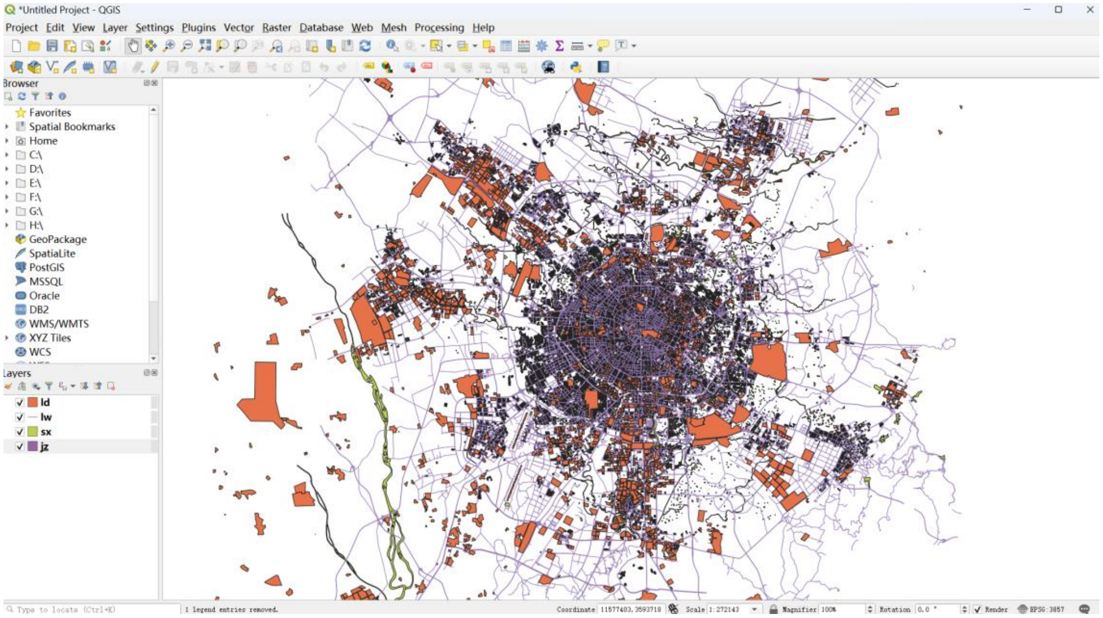

Figure 5. GIS data preprocessing diagram

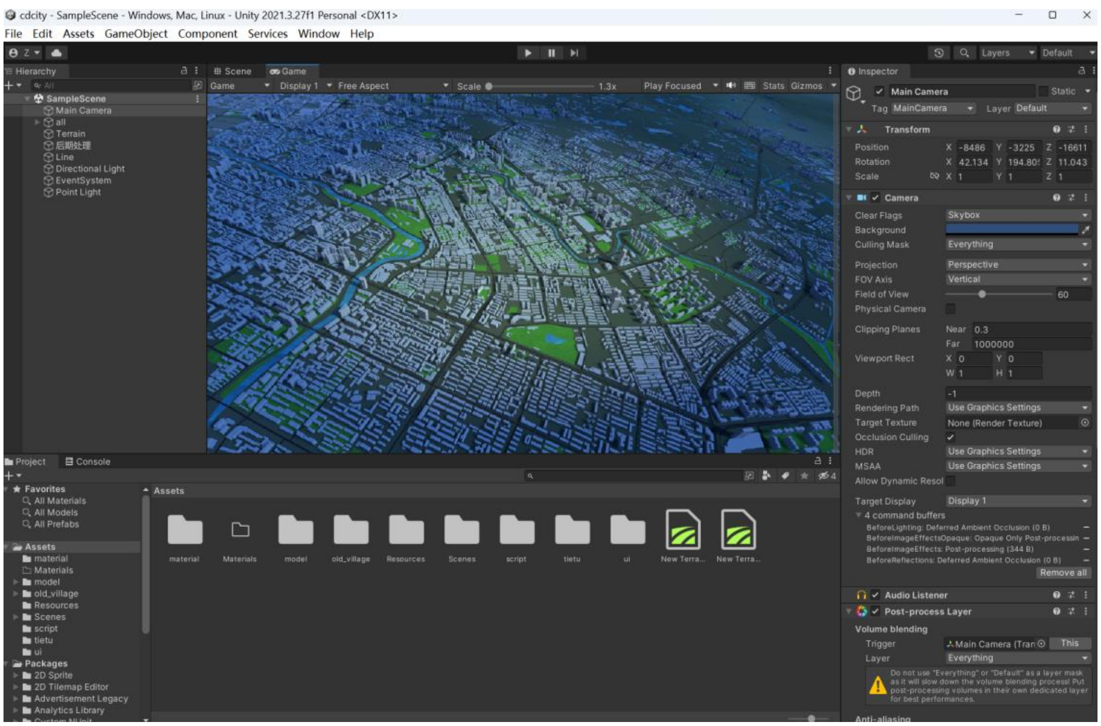

Figure 6. Unity 3D generates three-dimensional real-life imagesimages

2) The network layer. According to the framework of this article, is divided into edge network and central network. The edge network is responsible for the connection between IoT terminals and IoT servers, while the central network is responsible for connecting our back-end servers, which is responsible for our entire system. Intercommunication of data between various modules. Figure 7 is the visual interface of our IoT server, in which IoT terminals can be managed through this interface, such as deleting, adding, and modifying, and we can also observe the status of terminal devices in real time, such as data measured by sensors and relays. Switch, steering gear rotation angle, etc.

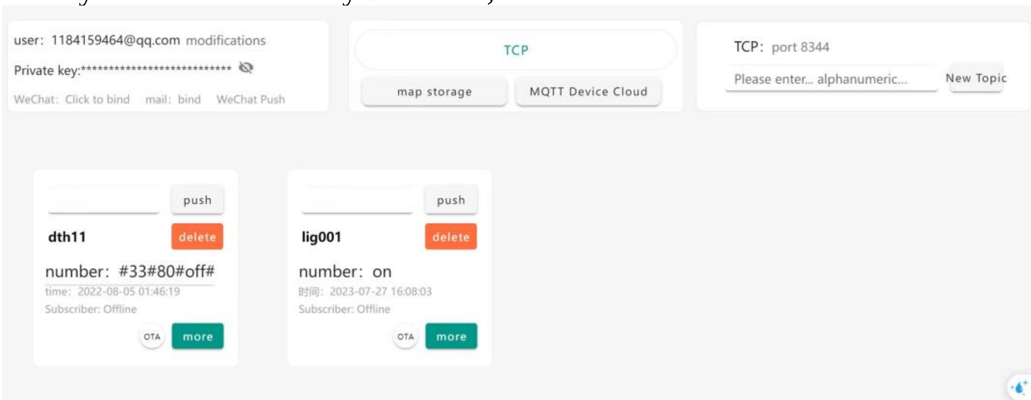

Figure 7. IoT server visual interface

3) Device layer. In this project we use the NodeMCU development board as the city's IoT terminal, in the project can be used to collect data and intelligent control of multiple NodeMCU development version, because the NodeCMU inherited the ESP8266 wifi module, it can be easily accessed to the local area network or the Internet, and you can pre-process the collected data on the board. It can also pre-process the collected data on the board and finally transmit it to the IoT cloud server through the edge network. The whole process of engineering device layer design and realization is strictly in accordance with the network topology diagram in Figure 5. As Figure 8 shows the NodeMCU pinout diagram.

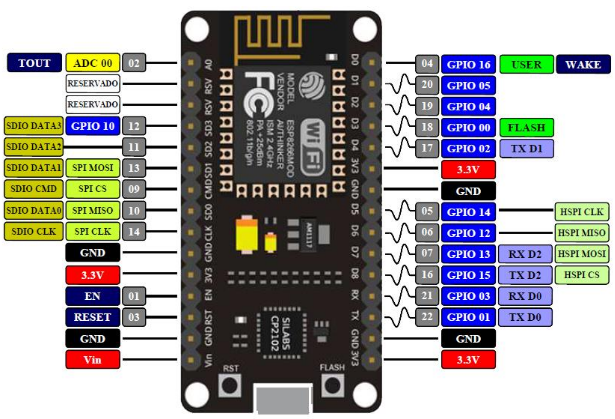

Figure 8. NodeMCU Development Board Pinout

B. Project summary

1) Overall project design. This project is based on the above-mentioned architectural design, and separates each module to reduce the coupling of the project. The entire model can be changed at will like building blocks, and the modules will not be affected. At the digitalization layer, we used GIS data preprocessing and imported it into Unity 3D to quickly obtain our three-dimensional real-life city, including models of the city's road network, water system, grassland, buildings, etc. By packaging it into a webGL file, we integrated the model into the web platform for easy display and can also be used across platforms and devices. At the network layer, the data collected by the IoT terminal will be pre-processed by the terminal's onboard MCU and sent back to the IoT server through the edge network. Finally, the back-end server can request data from the IoT server through API. The relevant data will be analyzed on the cloud computing platform and finally displayed on the web platform through API. At the equipment layer, the IoT terminals mainly collect various data of the city, and there is also a management platform that sends instructions to our IoT terminals to start and stop some equipment in the city. Through the above, our smart city can form a closed loop. This architecture also provides theoretical support for building loosely coupled smart cities, greatly reducing the production difficulty, cost and cycle. Figure 9 is the overall architecture diagram of this project.

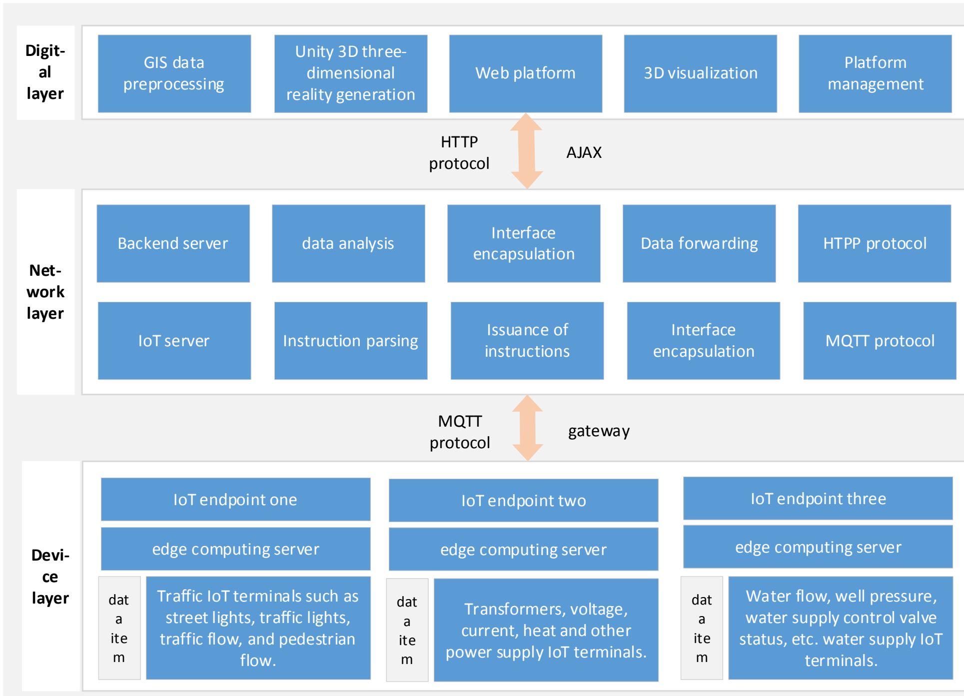

Figure 9. General Architecture Diagram of a Smart City

Figure 10 is a web platform interface diagram that integrates a three-dimensional city model. The model behind the interface can be operated with the mouse. For example, the day and night of the entire city will be dynamically displayed on the platform. When night comes, the model behind the platform will also be displayed. After entering the night state, the command that it is night will be sent to our terminal equipment, and the terminal equipment will control the public lights in the entire city to be on.

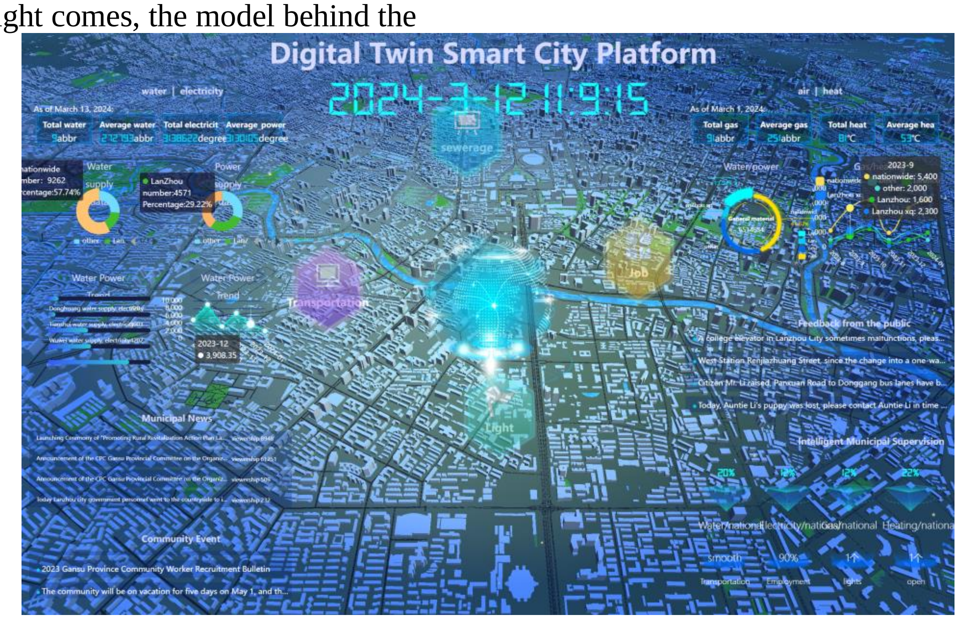

Figure 10. Digital twin platform for a smart city

2) Validation results. We have verified the above architecture through projects. As shown in Table 1, the coupling degree of each module, whether it works independently, and whether it is cross-platform have been verified through the above project.

TABLE I. COUPLING, INDEPENDENT WORKING, CROSS-PLATFORM VERIFICATION TABLE

module	*Coupling*	*working independently*	*cross-platform*
Unity 3D	Low coupling	Yes	Yes
Web platform	Low coupling	Yes	Yes
IoT terminal	Low coupling	Yes	Yes
backend server	Low coupling	Yes	Yes

There are many software designed in this project because it has gone through many processes, such as: GIS data preprocessing, GIS data reality model generation, 3D reality model generation, Web platform construction, data interaction, C# script writing, IoT terminal programming, and hardware simulation design. Wait for multiple processes. Table 2 will list the software designed in the above process and its functions.

TABLE II. SOFTWARE USED IN ENGINEERING AND ITS FUNCTIONS

software	*effect*
Visual Studio Code	Develop web platform and server and write corresponding code.
QGIS	Preprocess GIS data, such as data pruning.
Unity 3D	Generate 3D reality models.
Visual Studio 2022	Write C# scripts for dynamic interaction in Unity 3D.
Arduino IDE	Hardware program writing and burning.
Postman	Data interaction API interface test.

For the platform in this paper to build the feasibility of technology and development cycle, in this paper will be used and the traditional technology compared to develop the same effect in time and coupling to do further experiments, respectively, using the two architectures to build a complete digital twin case study, to see the actual completion of the time (the smallest unit of time for the hour) and coupling degree. For the traditional architecture in the number of chemical layer is used completely unity for development, the network layer uses a central network to build, and unity to build the model to do interaction, for the device layer, the use of serial communication or the use of bluetooth, etc., direct or indirect communication methods. Finally, according to the actual experimental comparison, the construction efficiency is improved by about 61.7%. Specific data as Table III.

TABLE III. COMPARISON OF ARCHITECTURE DEVELOPMENT CYCLE TIMES AND THEIR COUPLING DATA TABLE

Construction Methods	*traditionally constructed*	*this paper constructs*
digitalization layer	24h(high coupling)	18h(Low coupling)
network layer	48h(high coupling)	40h(Low coupling)
device layer	10h(high coupling)	8h(Low coupling)

V. CONCLUSIONS

Through engineering verification, this architecture is feasible and loosely coupled in actual applications. Each module of the architecture can be organized in any way, and each module can run independently. For example, if the real-life model built by our Unity 3D is not integrated into The web platform can also run and communicate with normal data. If you need to access other services later, such as AI functions, you only need to connect the interface to the back-end server at the network layer. A digital twin cannot yet reach the stage of shared intelligence. Multiple digital twins can be constructed, and they can share wisdom and evolve together.

The above project demonstration video has been uploaded to open source platforms and self-media platforms, and has also received suggestions and discussions from digital twin researchers and enthusiasts, as well as very strong interest in this architecture. At present, a rough estimate of the number of people interested in this project and architecture has There are about 20,000 people, of which graduate students and doctoral students can account for about 50%, and the rest are related workers and undergraduate students. Since the original project is relatively large from design to model, the total size is about 2GB, and it has not yet been open sourced on Github. Later, I simplified the interface and rebuilt a simplified version of this project based on the architecture of this article. It is currently open source. Because it is still relatively large, readers need to use the git lft tool when downloading this open source project to download large files from GitHub document. Open source URL: https://github.com/zjxWeb/digitalTwins-short.

The architecture of this article is still in its infancy, and there is still a long way to go to achieve the goal of digital twin co-intelligence. In the future, more new technologies should be added, the architecture should be kept low-coupled, and a universal digital twin should be built. Twin architecture. Figure 10 is a preliminary idea for further improvement of the architecture. Engineering verification has not yet been carried out. However, this architectural idea is also constructed in strict compliance with the architecture of this article. It only adds and deletes modules based on the loose coupling of this article's architecture. , achieve rapid construction.

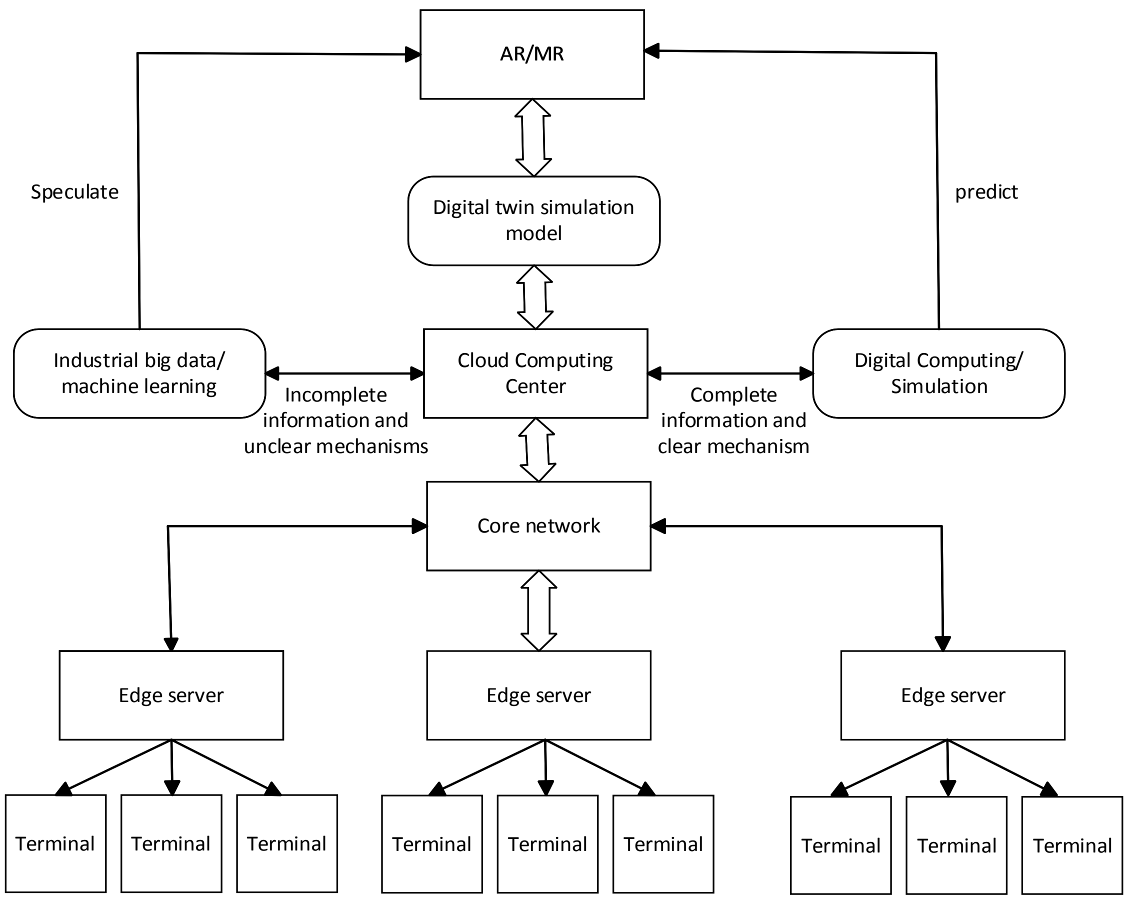

Figure 11. Architecture upgrade flow chart

For Figure 11, the entire display and interaction part has been upgraded during the process. With the rapid development of augmented display technologies such as AR and MR, there is an increasing trend that AR/MR glasses may become an integral part of our daily life, work, and study. A second screen will greatly facilitate all aspects of our lives. At the same time, this flow chart will judge the data in the cloud computing center. When our data has incomplete information and unclear mechanisms, we need to make inferences through industrial big data and machine learning. Finally, the inference results will be transmitted to our display end. It is AR/MR; similarly, when the data in cloud computing has complete information and clear mechanisms, it is necessary to predict future data through digital calculation and simulation, and finally the prediction results are transmitted to our display, which is AR/MR; later The latter has higher accuracy than the former because we make predictions based on complete information and clear mechanisms.

REFERENCES

[1] Wang Yujie, Shi Kaimin, Lou Shujian. Research on comprehensive design and application of digital twin Sanmenxia Water Conservancy Project [J]. Water Conservancy Informatization, 2022, 2022(06):1-6+14.

[2] Xu Yuanxiao, Lou Huan, Chen Shu. Practice of digital twin technology in smart parks [J]. Communications and Information Technology, 2023 (06):41-44.

[3] Wang Hao. Visualization of underwater acoustic information processing platform based on digital twin technology [J]. Electroacoustic Technology, 2022, 46(05):25-28.

[4] Shi Yingna. Research on geographical information data processing methods in digital city construction [J]. Technological Innovation and Productivity, 2022, 2022(11):71-73+77.

[5] Tang Dandan. Design of map data organization model based on improved usability of GIS map vectorization results [J]. Intelligent Buildings and Smart Cities, 2024 (01):36-38.DOI:10.13655/j.cnki.ibci.2024.01.009.

[6] Han Wenlong. Research and development of management system for housing construction on randomly occupied farmland based on WebGIS [D]. 2023. DOI:10.26976/d.cnki.gchau. 2022. 001402.

[7] Wang Jinghong, Chen Yu, Hu Jianqiang. Partial offloading analysis based on reinforcement learning in mobile edge networks [J]. Journal of Minnan Normal University (Natural Science Edition), 2023, 36(04):62-72.DOI:10.16007/j.cnki.issn2095-7122.2023.04.006.

[8] Yuan Qiufeng. Intelligent desk lamp design based on NodeMCU and WxBit [J]. Journal of Ningde Normal University (Natural Science Edition) [10], 2023, 35(04):382-386.DOI:10.15911/j.cnki.35-1311/n.2023.04.012.

[9] Tao Fei. Digital Twin Industrial Software White Paper [R]. 2023.

[10] Zhang Lunyan. Research on industrial Internet platform construction technology for digital twins [J]. Intelligent Manufacturing, 2022.