Research on intelligent system of whole process supervision of building engineering construction

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Abstract: Aiming at the problems of low efficiency and lagging information in traditional construction supervision, this paper discusses the feasibility and implementation path of building an intelligent system of whole process supervision. Firstly, this paper analyzes the architecture design of intelligent supervision system, including micro-service architecture, key technology integration and standardization system construction. Then, the strategy of promoting by stages is put forward, from the deepening of digital infrastructure and intelligent application to comprehensive integration and ecological coordination, and the intelligent transformation of supervision work is gradually realized. In addition, the paper also discusses organizational and management changes, including organizational structure adjustment, talent team construction, management process reconstruction and performance appraisal innovation, in order to meet the needs of intelligent supervision. Finally, the paper analyzes the risks that may be faced in the implementation of intelligent supervision system, such as technology application risk, data security and ethical risk, organizational change risk, etc., and puts forward corresponding prevention and control strategies. The research results of this paper show that it is of great theoretical significance and practical value to build an intelligent supervision system for the whole process of construction projects, which can effectively improve supervision efficiency, ensure project quality and safety, and promote the digital transformation of the construction industry.

1. Introduction

As the core link to ensure the quality and safety of the project, construction project supervision has long been trapped in problems such as information lag, subjective decision-making and inefficient coordination. The traditional mode of relying on manual inspection and paper flow leads to delayed response to problems, different acceptance standards and poor cooperation among many parties, which seriously affects construction efficiency and cost control. With the maturity of technologies such as BIM, Internet of Things and AI, the construction industry is accelerating its digital transformation, which provides technical support for supervision upgrade: BIM realizes full-cycle data integration, Internet of Things realizes real-time monitoring of key parameters, and AI algorithm shows far more accuracy than manual in defect identification, which lays the foundation for building an efficient and intelligent supervision system. In this context, the National Construction Industry Development Plan in the 14th Five-Year Plan clearly puts forward the development goal of promoting intelligent construction, and emphasizes the construction of intelligent construction policies and industrial systems. As a key link, supervision needs to realize the intelligent transformation from experience-driven to data-driven. Promoting the deep integration of supervision mode and advanced technology is not only helpful to improve the fine and scientific level of project management, but also has strategic significance to build a new building industrialization system, and its systematic research and practice is urgent.

2. Intelligent system of whole process supervision of building engineering construction

2.1 Architecture design

Using microservice architecture, the system is divided into data acquisition layer, service layer,

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interface layer and access layer (Figure 1). This design supports modular deployment and flexible expansion, which is convenient for incremental development and functional iteration in different stages. Through API interface, the communication between all levels is realized to ensure the efficient and orderly transmission of data flow. Relying on cloud computing platform to provide flexible computing resources for large-scale data storage and complex model training; Edge computing nodes are deployed in the construction site, responsible for real-time data acquisition and preliminary processing, reducing network delay and improving response speed [1]. The combination of the two optimizes the load distribution, taking into account the global management and control and local real-time requirements. Multi-dimensional functional module integration includes core components such as project information management, quality monitoring, progress tracking, cost control and safety supervision. These modules interact with each other based on unified data standards, forming a closed-loop management link, and realizing full-cycle coverage from design submission to completion acceptance.

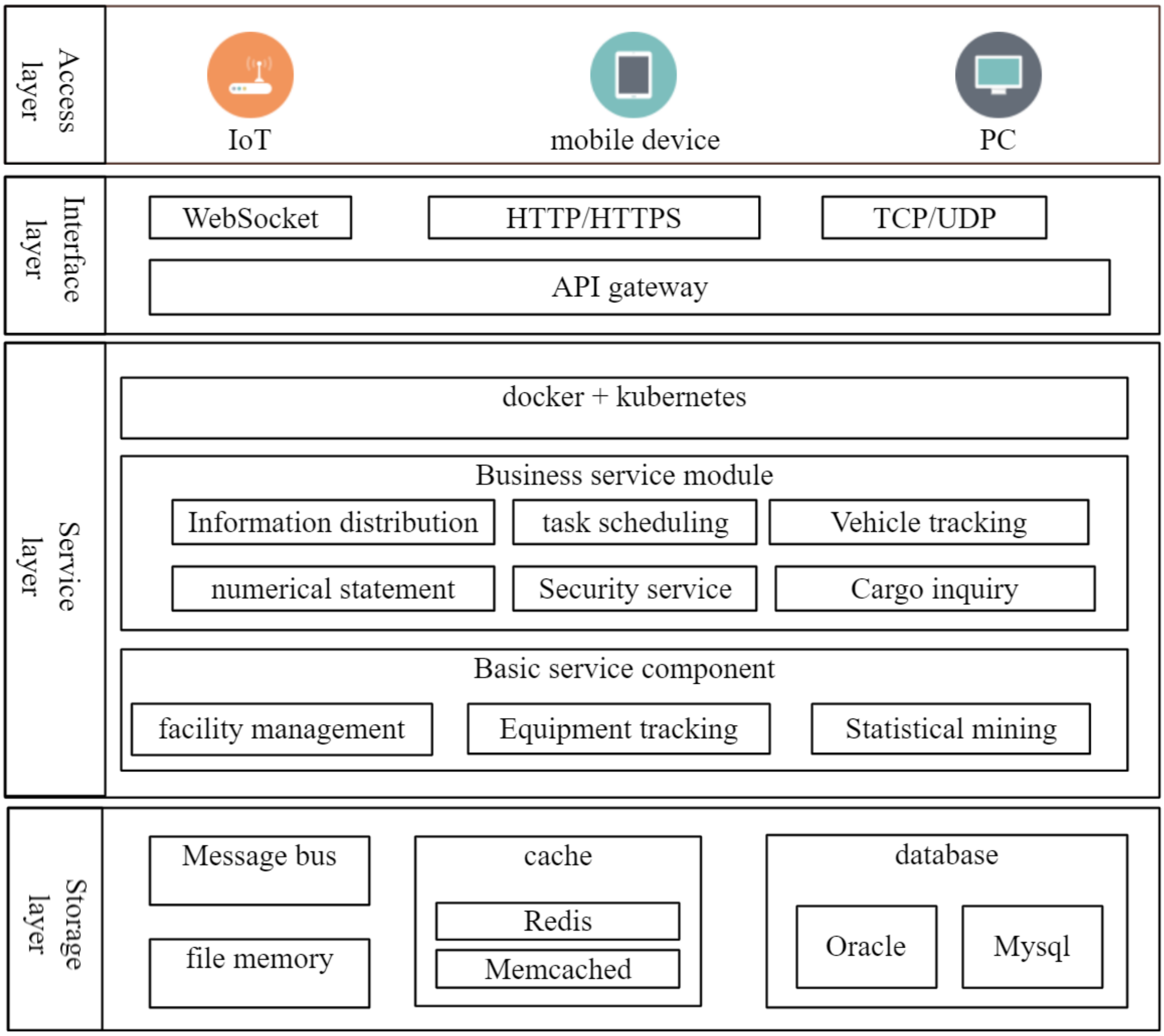

Figure 1 Hierarchical distributed architecture

2.2 Key technology integration

2.2.1 Internet of things and sensor network

By deploying various sensors and RFID tags, the environmental parameters, equipment status and personnel positioning information of the construction site are collected in real time [2]. Combined with the Internet of Things technology, automatic data uploading and remote monitoring are realized, which provides high-timeliness raw materials for subsequent analysis.

2.2.2 Big data and AI algorithm

Using machine learning model to mine historical engineering data and build a prediction model to identify potential risk points; Computer vision technology is applied to assist quality inspection and automatically identify cracks, leakage and other problems. In addition, natural language processing can be used to parse regulatory documents and assist compliance review.

2.2.3 Blockchain storage and traceability

Aiming at the key decision-making records, acceptance reports and other documents in the supervision process, blockchain technology is adopted to ensure their non-tampering and traceability. This technology strengthens the trust foundation of multi-party cooperation and simplifies the dispute resolution process.

2.2.4 Virtual reality/augmented reality training system

Develop an immersive simulation environment for supervisors to conduct emergency plan drills and complex process deduction. Such tools not only improve the training efficiency, but also verify the feasibility of the construction scheme in advance and reduce the actual trial and error cost.

2.3 Standardization system construction

The construction of standardization system is shown in Figure 2. Follow GB/T 12366—2009 "Guide to Comprehensive Standardization Work" and formulate a set of standards that are connected with each other around the principle of "optimal overall benefit". Focus on solving the interface specification problems in interdisciplinary collaboration, such as unified BIM model accuracy requirements, data exchange formats and coding rules. The work breakdown structure (WBS) is used to disassemble the project into manageable units step by step, and the mapping relationship with the specific clauses in the standard system is established. This method is helpful to accurately locate the execution deviation and support the dynamic adjustment of resource allocation. Establish a regular evaluation system of the standard system, and iteratively update the existing specifications according to the development of new technologies and application feedback [3]. For example, after introducing the measured data of smart wearable devices, the corresponding safety operation procedures are revised; Optimization of quality acceptance index threshold based on big data analysis results. Referring to mature standards at home and abroad, we will actively participate in international mutual recognition while promoting localization and adaptation. By establishing a cross-regional project database, we can accumulate the best practical experience under different geological conditions and climatic environments, and gradually form an open and shared knowledge map.

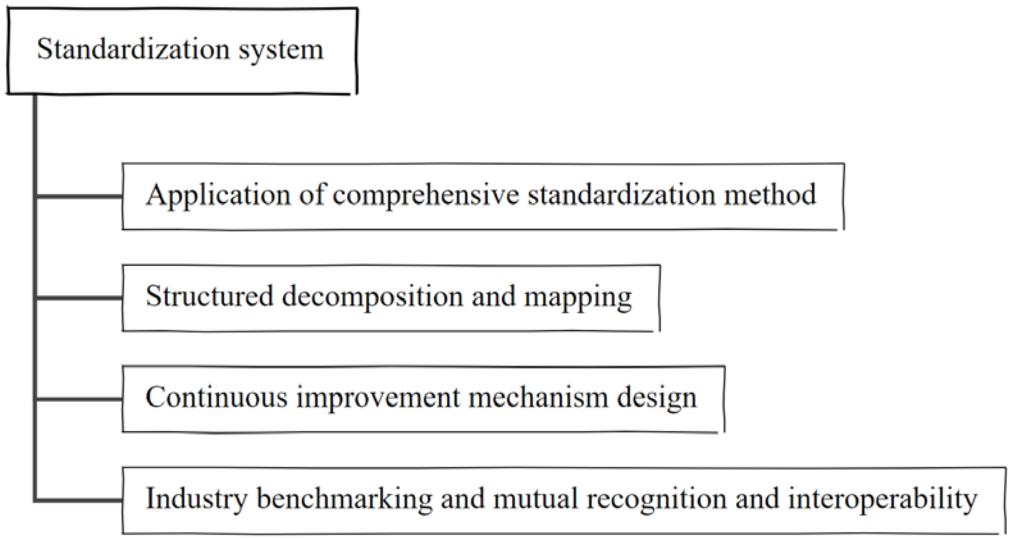

Figure 2 Construction of dynamic evolution standardization system

3. Implementation path of intelligent supervision system

3.1 Phased promotion strategy

3.1.1 Stage 1: Digital infrastructure and pilot application

In the initial stage, information infrastructure construction and pilot project exploration should be the core to lay the foundation for deep intelligent application. Enterprises need to build a technical platform to support multi-source data collection and fusion, including deploying hardware devices such as Internet of Things sensors, smart cameras, drones, and building software foundations such as BIM collaborative platforms and cloud computing centers [4]. In terms of data standardization, it is necessary to establish a unified data governance framework covering data collection, storage, exchange and analysis standards (Table 1).

Table 1 Key tasks and outputs in the stage of digital infrastructure construction

Key areas	Primary mission	Technical output	Organizational output
Data acquisition	Deploy sensor networks, smart cameras and drones.	Multi-source heterogeneous data acquisition system	Data acquisition team and specification
Platform construction	Build BIM collaboration platform and cloud computing center	Project data center and digital signage	Platform operation and maintenance team
Standard setting	Formulate data exchange and interface standards	Data governance framework and protocol	Standardized workflow
Pilot application	Select typical project testing technical scheme.	Feasibility assessment report and optimization suggestions	Pilot project team

3.1.2 Stage 2: Intelligent application deepening and process reengineering

After the initial completion of the digital foundation, the focus turned to the deep application of AI and the reconstruction of supervision business process. At this stage, AI technology needs to be embedded in the core business scenarios of supervision, such as quality inspection, safety monitoring, schedule management and other key links. UAV inspection and AI quality inspection play an important role at this stage. Through the UAV equipped with high-definition camera and AI algorithm, the complex construction site can be fully covered and monitored at all times. The AI system can measure the spacing of steel bars with centimeter-level accuracy, intelligently identify the safety protection status of construction workers, and immediately call for warning when problems are found [5]. At the same time, it is necessary to digitally reconstruct the traditional supervision process and establish a working mode that matches the intelligent tools. The project management company can realize the "five-oriented" management mode of supervision work through the integration of "smart supervision" and "smart construction site": archiving management, standardizing operation, streamlining management and control, refining cost and maximizing benefit. This reconstruction not only optimizes the supervision efficiency, but also provides a practical sample for the digital transformation of the industry, and promotes the transformation from passive supervision to active management, from decentralized operation to system operation.

3.1.3 Stage 3: Comprehensive integration and ecological coordination

In the final stage, we are committed to realizing all-factor integration and industrial ecological coordination, and building a new paradigm of intelligent supervision in the digital twin environment. At this stage, it is necessary to integrate the scattered intelligent applications in the early stage into an organic whole to form a data-driven and automatic decision-making supervision ability. Platform ecological construction has become the core task at this stage, and it is necessary to establish an open intelligent supervision platform to support data exchange and business collaboration with all parties in the industrial chain. The ultimate goal is to form a self-evolving intelligent supervision ecosystem, which can automatically generate supervision instructions, notices of potential safety hazards, defect reports, etc., realize digital intelligent closed-loop management, promote the supervision industry to advance from "rule by man" to "digital wisdom" in an all-round way, and provide support for the landing of the national digital China strategy in the field of engineering construction.

3.2 Organization and management change

3.2.1 Organizational structure adjustment and talent team construction

Organizational structure adjustment is the primary challenge of intelligent transformation. Traditional supervision enterprises need to break the departmental wall divided by disciplines and establish an agile organization with project value flow as the core. Supervision should actively practice the "supervision engineer section responsibility system", break the traditional compartmentalization of "professional supervision", implement the "comprehensive supervision" mode, set up a supervision team according to the bid section, with the supervision engineer with strong professional ability as the team leader, implement the "one post with multiple responsibilities" system, and be responsible for the full-dimensional supervision of project quality, safety, environmental protection and progress in the section. This flat organizational structure reform has significantly improved the response speed and work efficiency.

In the transformation of talent team, it is necessary to pay attention to both the promotion of existing personnel and the introduction of new talents. The reconstruction of the training system is also crucial. The supervision consulting company can develop a "smart supervision" platform to realize the online education function, truly realize the online education of employees without geographical restrictions, save human and material resources and improve learning efficiency; At the same time, through technical means, the employee education test will be automatically marked to test the employee's learning achievements.

3.2.2 Reconstruction of management process and innovation of performance appraisal

The reconstruction of supervision process is the key link to realize intelligent value. It is necessary to redesign the workflow based on the digital platform to realize the standardization, process and automation of supervision business. The project management company can establish a project data collection and analysis system through the information supervision platform, strengthen the coordination and linkage of various disciplines, and promote the development of the project in the direction of management archiving, operation standardization, management and control process, cost refinement and maximum benefit [6]. In the aspect of optimizing the approval process, the project supervisor should strictly control the pilot List of Time Limit for Approval of Supervision Matters, and formulate the Work Instruction of Time Limit for Supervision Signing and Examination. The intelligent supervision system supports multi-department synchronous examination, and the opinions are summarized to form a unified examination sheet, so as to realize "at most one examination"; If the time limit is exceeded, it will be automatically reminded, and the early warning will be sent directly to the Digital Intelligence Supervision Enterprise Center, which greatly improves the examination and approval efficiency. The performance appraisal system needs to be innovated to meet the needs of intelligent management. Through data analysis and algorithm, employees are quantitatively evaluated to reduce the influence of human factors on the evaluation results; Project supervision can implement the dynamic integral assessment and star rating system, directly link the assessment results with the salary, and completely break the addiction of "doing more and doing less" in the supervision industry.

3.3 Risk control mechanism

3.3.1 Technology application risk and prevention and control strategy

Technology maturity risk is the primary challenge for intelligent supervision. The applicability of many intelligent technologies in practical engineering environment has not been fully verified, and there may be problems such as insufficient identification accuracy and poor environmental adaptability. In view of this risk, it is necessary to establish a technical verification mechanism. At the same time, we should keep the traditional supervision methods as backup, form a transition scheme of "man-machine cooperation", encrypt the inspection frequency in high-risk areas, and use video monitoring to track it in real time; For conventional areas, the inspection process is optimized to liberate manpower to key links. The risk of system integration can not be ignored. Intelligent supervision system needs to be integrated with many existing systems, and there may be problems such as incompatible interfaces and inconsistent data formats. In order to reduce the risk of technology application, it is necessary to establish a continuous technology evaluation mechanism.

3.3.2 Data security and ethical risk control

With the rapid increase in the amount of data collected and processed by intelligent supervision systems, data security risks are becoming increasingly prominent. The multi-source heterogeneous data at the construction site contains a large amount of sensitive information, and once leaked, it may cause serious consequences. Engineering supervision can adopt advanced blockchain certification solutions - based on the key level of violation identification results, video clips, sensor data, and acceptance images can be segmented into dynamic fragments ranging from 8kb to 32kb; Generate unique weight coefficients for each data fragment and dynamically select encryption algorithms based on chaotic mapping algorithm. The higher the weight, the stronger the encryption strength; Using the Merkel Patricia tree structure, the encrypted fragments are associated with the entry records to calculate a dual layer hash value, generating a globally unique fingerprint across data sources.

The ethical risk of privacy protection also needs to be highly valued. Workers' behavior data collected by intelligent monitoring system may involve personal privacy issues, so it is necessary to balance regulatory needs and privacy protection. The patent of supervision information management emphasizes the control of access rights to data, and realizes the secure sharing and restricted access of data through blockchain technology. This scheme not only ensures the availability of data needed for supervision, but also protects personal privacy from infringement.

In addition, it is necessary to establish a framework of data ethics and clarify the ethical boundaries of data collection, storage and use. In the process of implementing "Digital Intelligence Command Module", the supervisor needs to build a mechanism of "Digital Intelligence+Integrity", set up a QR code of integrity in the first line of construction, and push the information reported by the public to the command module in real time to realize the linkage between social supervision and site.

3.3.3 Risk prevention and control of organizational change

Organizational resistance in the process of intelligent supervision transformation can not be ignored. Traditional supervisors may have resistance to new technology, or they may feel anxious because of the pressure of skill updating. In view of this risk, it is necessary to formulate a comprehensive change management plan, including strengthening communication, training support and gradual promotion.

The risk of capacity fault is another important consideration. The traditional supervision team may lack digital skills and intelligent management ability, which will greatly reduce the application effect of new technologies. In view of this risk, the supervisor needs to implement a comprehensive talent transformation plan, on the one hand, strengthen the training of existing personnel, on the other hand, introduce new forces with BIM operation ability and AI tool operation ability. Finally, we need to pay attention to compliance risks. The application of intelligent supervision system needs to meet the requirements of relevant laws and standards. For example, the new version of "Construction Engineering Supervision Code" in 2025 puts forward clear requirements for the whole process supervision.

4. Conclusion

The intelligent supervision system of the whole process of building engineering construction constructed in this study not only improves the refined and scientific level of engineering management, but also provides strong support for the implementation of the national digital China strategy in the field of engineering construction, which has important theoretical value and practical significance. In the future, with the continuous progress of technology and the continuous improvement of the standard system, the system is expected to be further optimized and contribute to the high-quality development of the construction industry.

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