Online Monitoring of Ship Block Construction Equipment Based on the Internet of Things and Public Cloud: Take the Intelligent Tire Frame as an Example

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Abstract

In view of the problems of insufficient data collection and processing capability of multi-source heterogeneous equipment, and low visibility of equipment status at the ship block construction site. A data collection method for ship block construction equipment based on wireless sensor network (WSN) technology and a data processing method based on edge computing were proposed. Based on the Browser/Server (B/S) architecture and the OneNET platform, an online monitoring system for ship block construction equipment was designed and developed, which realized the visual online monitoring and management of the ship block construction equipment status. Not only that, the feasibility and reliability of the monitoring system were verified by using the intelligent tire frame system as the application object. The research of this project can lay the foundation for the ship block construction equipment management and the ship block intelligent construction, and ultimately improve the quality and efficiency of ship block construction.

Keywords: Ship block construction, equipment monitoring, WSN, edge computing, Web.

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1. Introduction

In the context of Industry 4.0 and Made in China 2025, improving the level of digital construction is a current research hotspot in the shipbuilding industry. However, at present, China's ship manufacturing is still mainly labor-intensive. Problems such as lag in data collection, high processing difficulty, real-time monitoring and statistical difficulties are common. Therefore, it is the key goal of China's shipbuilding industry to promote digital shipbuilding and realize the intelligent transformation of key links [1]. A large number of construction equipment clusters, such as tire frames and welding machines, are necessary tooling equipment in the process of ship block construction, and their real-time operation status directly affects the efficiency and accuracy of block construction. Integrating equipment monitoring into the whole process of ship block construction can realize the barrier-free circulation of equipment status data, and facilitate timely adjustment and maintenance of equipment. It also provides data support for equipment fault diagnosis so as to arrange construction work more rationally and efficiently, and further improve the overall efficiency of ship assembly and construction.

The equipment periodic monitoring system is an early developed and widely used equipment monitoring system, which realizes the simultaneous management of multi-equipment through periodic itinerant monitoring and offline analysis. Liu et al. [2] proposed a strategy of using flying robots to find the best point of view for equipment inspection to obtain high-quality images to observe the status of equipment. Siddiqui et al. [3] proposed an automatic real-time electrical equipment detection and defect analysis system based on convolutional neural networks. This kind of system occupies a lot of manpower and material resources, and cannot understand the real-time operation states of the equipment. With the maturity of the Internet of Things (IoT) technology, the single-machine online monitoring system for equipment had been researched and applied in the industry. By using sensor technology, wireless data transmission and network technology, Zhan et al. [4] built a remote monitoring and fault diagnosis system for each single scattered machine in the cluster. Li et al. [5] analyzed the structure of a single-machine multimedia monitoring system based on PSTN, and developed a single-machine remote multimedia monitoring system by themselves. This kind of system cannot realize the information sharing between equipment and is not suitable for large-scale production applications. The continuous improvement of enterprise network construction promotes the development of decentralized data collection and centralized management, and the distributed remote online monitoring system of equipment emerges as the times require. Jia et al. [6] introduce a real-time monitoring system of substation high voltage equipment based on ZigBee and mobile communication technology, and propose a multi-hop routing algorithm based on opportunity routing to balance network energy. Chen et al. [7] combine RFID technology and wireless Internet to automatically collect equipment data configured in different layout workshops, and establish a set of equipment online monitoring system. This kind of system has gradually become the mainstream in the field of the equipment monitoring system. Researches on equipment monitoring systems at home and abroad are different, with different focuses. Its basic idea is mostly to rely on equipment status data back to solve the problem of centralized equipment supervision. However, the solutions to the problems of extracting structured information parameters from a large number of heterogeneous data, relieving the computing pressure of cloud servers, building reasonable system architecture and so on are not mature.

In recent years, with the rapid development of computer technology, IoT technology and so on, the demand for informatization and digitization of production and manufacturing is increasing. As the foundation of information development, various monitoring technologies, solutions, system architectures, platforms, etc. for manufacturing equipment, systems and construction machinery are constantly emerging [8-11]. The application of the IOT to the monitoring system is the inevitable result of the development of information and communication technology to a certain stage. The wireless sensor network as the perception terminal of the monitoring system is an important support for the IoT and also an inevitable way of information perception and transmission. Jian et al. [12] designed a campus three-dimensional monitoring system based on a wireless sensor network to realize campus information construction, which is of great significance to maintain campus security and campus management. Mancuso et al. [13] deployed wireless sensor network in the tomato greenhouse, and used RTD module to collect the environmental factors of the tomato in the greenhouse from realizing the microclimate monitoring in the greenhouse. Considering that battery capacity will limit the life of sensor nodes, Zhu et al. [14] investigated the joint utility maximization of wireless sensor networks combining energy collection and collaboration. In order to solve the problem of energy-saving data collection in the monitoring system, Li et al. [15] proposed a data collection scheme based on the key technology of WSN—noise reduction autoencoder. Research on wireless sensor networks in monitoring systems mostly focuses on data collection and building system architectures, lack of targeted node location algorithm research, and less research on data classification, analysis and statistics. Compared with wireless sensor networks, the research of edge computing in monitoring systems is relatively mature. Combined with target detection and tracking algorithms, Jha et al. [16] proposed a video surveillance system that can ensure the real-time performance of various edge computing environments by adaptively controlling the object detection and tracking cycle. Rajavel et al. [17] introduced a cloud-based object tracking and behavior recognition system, which uses edge computing to maximize the accuracy of fall behavior prediction. In order to overcome the mismatch between the low bandwidth of the sensor and the high transmission data volume in the rolling bearing condition monitoring system, Tritschler et al. [18] established a condition health monitoring system based on automatic edge computing. Navaneeth et al. [19] introduced a traffic monitoring system, which detects, tracks, and estimates vehicle speed in real-time through an embedded computer installed on an unmanned aircraft.

In summary, there are many researches on monitoring technology and system development at home and abroad, which lays a certain foundation for the digitalization and informatization development of production and manufacturing industry. However, ship block construction equipment has the distinguishing characteristics of a wide variety and a large number. The existing research generally focuses on single or a small number of terminal equipment for data integration methods, system architecture design, etc., and cannot meet the integrated monitoring needs of massive and diverse types of ship block construction equipment clusters. Based on this, this paper proposed a data integration method for ship block construction equipment based on edge calculation, and carried out the research of online monitoring system and key technology of ship block construction equipment, which realizes the visual online monitoring of all kinds of construction equipment running state and key parameters in ship block construction site, and provides theoretical and technical reference for improving the digital and intelligent level of ship block construction.

2. Demand Analysis of Equipment Online Monitoring System

In order to promote data communication and information fusion in the ship block construction production system, and ensure the accuracy and efficiency of block construction, it is necessary to conduct online monitoring of block construction equipment. The online monitoring system for ship block construction equipment designed and developed in this paper is the basis for real-time monitoring of the operating status of various construction equipment on site. Based on the analysis of the characteristics and process of ship block construction, the requirements for the equipment monitoring system are determined as follows:

(1) Requirement analysis of data collection. In the process of ship block construction, sensors are required to collect the pressure, temperature, displacement and other dynamic parameters of the block construction equipment. So as to provide a reference for the maintenance of the equipment. For example, the segmented outer plate will produce a certain deformation amount in the construction process. It is necessary to collect the pressure change of the tire frame in real-time, to realize the adaptive adjustment of the height of the tire frame and to reduce the deformation of the outer plate.

(2) Requirement analysis of data processing. As the number of terminal equipment accessed in the system continues to increase, the amount of data will grow exponentially and gradually reach the PB level or even the EB level. If a large number of equipment directly interact with the cloud server, the generation of massive data will increase the access pressure on network bandwidth and cloud server. In order to solve the above problems of data transmission and processing, it is necessary to provide services on the edge side to realize the low delay and high efficiency of data transmission.

(3) Requirement analysis of online monitoring system. The monitoring system needs to provide an interactive interface, which graphically displays various data in front of users in real-time through network applications. The system should also have a good framework for later function expansion and system integration. In addition, the performance requirements of the system include: the software has high portability, simple maintenance and low cost, easy system upgrade, good compatibility and good openness.

3. Overall Technical Framework of Equipment Online Monitoring System

Based on the equipment analysis of the online monitoring system for ship block construction equipment, the overall technical framework of the designed system is shown in **Fig. 1**:

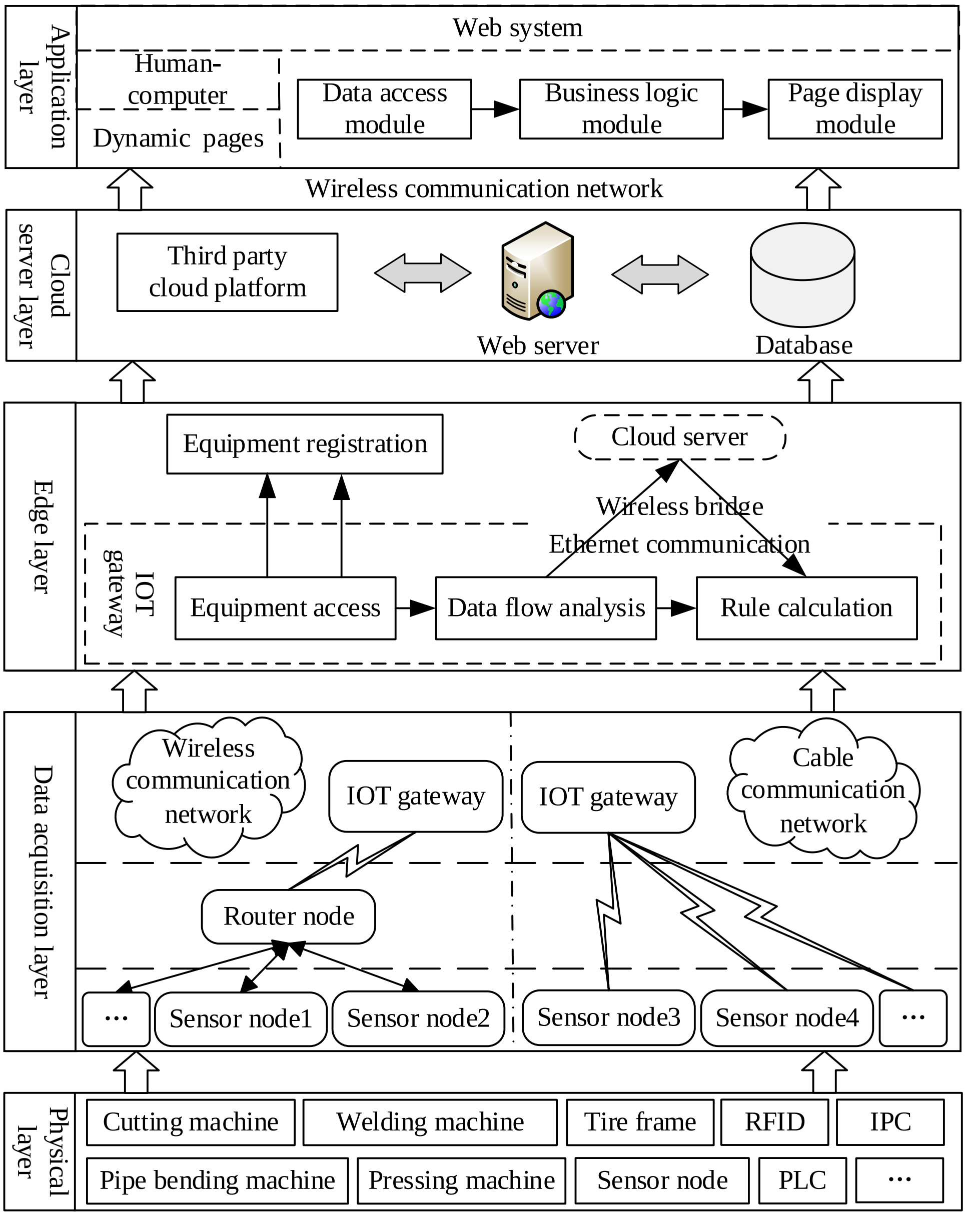

Fig. 1. Overall technical framework of equipment online monitoring system

(1) The physical layer is the manufacturing resource layer for ship block construction. It includes the construction equipment (such as tire frame, welding machine, cutting machine), control system (such as industrial control machine, PLC), network configuration environment, etc., which is the physical basis for realizing real-time data collection.

(2) The data collection layer is a data collection module for online monitoring systems. Through a large number of sensor nodes arranged on the construction equipment, dynamic data (pressure, temperature, displacement, etc.) are centrally collected. These real-time data are the data basis for online monitoring.

(3) The edge layer is the core of the data processing and transmission of the entire online monitoring system. It connects the data collection layer through the communication network

and gathers the data to the IoT gateway. Relying on the edge computing ability and rule model of the IoT gateway, the edge layer processes and analyzes the data, reduces the pressure of the network bandwidth and cloud server computing, and improve the operation efficiency of the application.

(4) The cloud server layer mainly includes the third-party cloud platform, web server and database. Through the network communication technology, the equipment distributed in the ship block construction site is connected to the cloud in a unified and batch manner. It realizes the decentralized collection, centralized monitoring and unified management of various equipment data forwarded by the edge layer, remotes the equipment operation and maintenance business, and reduces the cost.

(5) The application layer is the remote online monitoring carrier of ship block construction equipment online monitoring system. It realizes human-computer interaction through a web system, which includes a data access module, business logic module and page display module. By designed dynamic web pages, authorized users can remotely view real-time and historical data of the construction equipment.

4. Key Technologies for Monitoring Ship Block Construction Equipment

4.1 Data Collection Method of Ship Block Construction Equipment Based on WSN Technology

4.1.1 Definition of the equipment data model

During the block construction equipment access system, model the equipment data, it is necessary to define the equipment data model. Based on the data collection function of the wireless sensor network, the equipment data model is designed. It describes the equipment attributes and interactive information, processes data, and resolves the analysis of massive heterogeneous data in a configurable form.

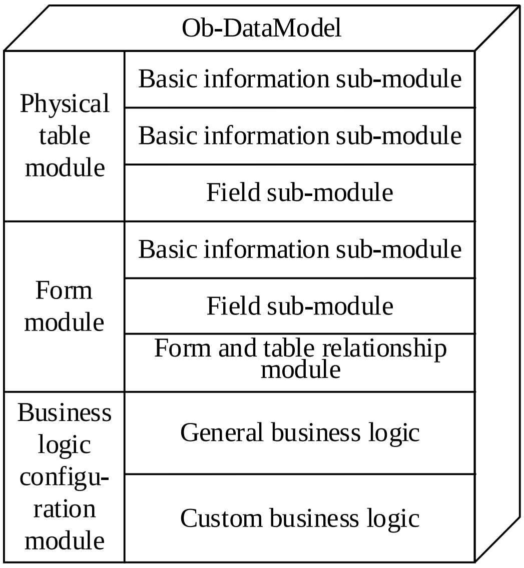

Fig. 2. Definition of the equipment object data model

The block construction equipment data is abstracted into a standard data structure, that is, the equipment data model (Eq-DataModel) [20]. The Eq-DataModel consists of multiple equipment object data models (Ob-DataModel), which can be described as Eq-DataModel = {Ob-DataModel1, Ob-DataModel2, …}. **Fig. 2** shows the Ob-DataModel, which consists of the Physical table module, Form module and Business logic configuration module. The Physical table module consists of Basic information sub-module, Field sub-module, and Master-slave relationship sub-module, which can be described as Physical table module = {Basic information sub-module, Field sub-module, Master-slave relationship sub-module}. The Form module consists of Basic information sub-module, Field sub-module, and Form and table relationship module, which can be described as Form module = {Basic information sub-module, Field sub-module, Form and table relationship module}. The Business logic configuration module consists of General business logic and Custom business logic, which can be described as Business logic configuration module = {General business logic, Custom business logic}.

4.1.2 Implementation method of the equipment data model

The construction equipment of the ship block construction site includes a welding robot, cutting machine, intelligent tire frame, and pipe bender, etc. The heterogeneous data collected by terminal equipment can be described by the Eq-DataModel, which can effectively improve the working efficiency. According to the definition of the above Eq-DataModel, the implementation method of the model is described, as shown in **Fig. 3**.

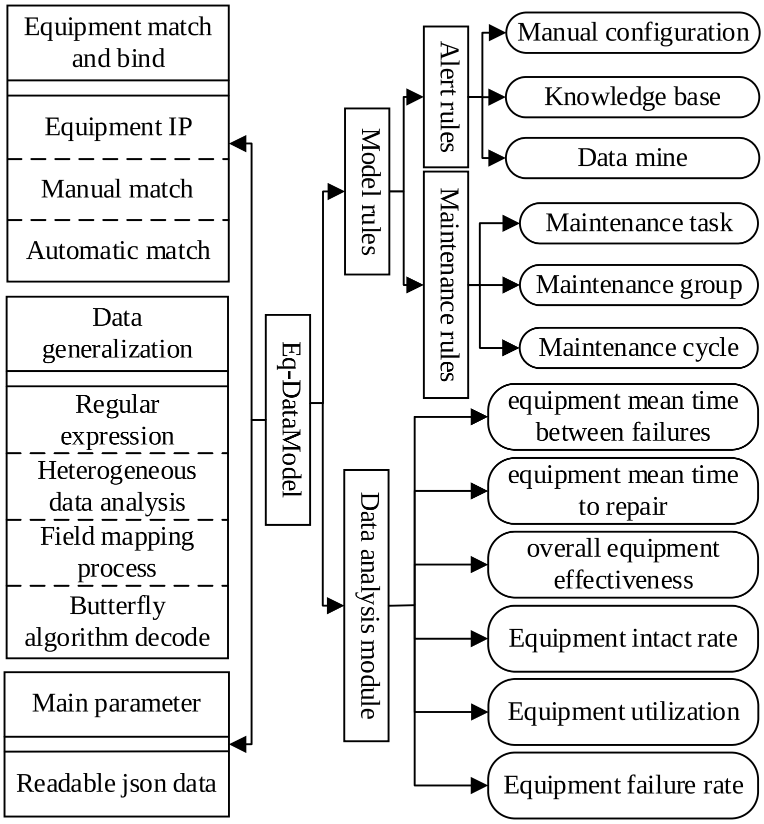

Fig. 3. The implementation method of the equipment data model

The block construction equipment is bound to the Eq-DataModel according to the method of automatic matching of data features or manual matching. Through a series of established rules or processes such as rule expression, heterogeneous data analysis and field mapping processing, the real-time data, attribute information and so on obtained by the model are generalized and parsed into readable JSON data with the same structure and format, which are stored as main parameters [21]. After the equipment binding is completed, the data flows normally. The operation and maintenance data is generated according to the built-in rules of the Eq-DataModel: (1) The alarm rules are designed to monitor equipment by means of manual configuration rules, empirical knowledge base and data mining methods. Using big data analysis technology to obtain normal parameters of the equipment during normal operation, compared with real-time data. If a large deviation occurs continuously in a certain period of time or important parameter threshold overflow, an alarm notification can be issued immediately. (2) Plan and create equipment maintenance tasks, group equipment maintenance, and define maintenance cycles. Meanwhile, the data analysis module carries on the combination analysis calculation to the equipment mean time between failures (MTBF), the equipment mean time to repair (MTTR), the overall equipment effectiveness (OEE) and so on, and outputs the statistical data.

4.1.3 Data collection and transmission based on wireless sensor network

To enable more efficient and coordinated operation between sensor nodes work, this paper proposes a WSN-based data collection and transmission network structure, as shown in **Fig. 4**. WSN technology is located in the core link, integrating the underlying data collection, data processing and data transmission. By arranging a large number of sensor nodes with specific functions on various construction equipment, and adopting self-organizing wireless communication mode, the data is aggregated to the IoT gateway.

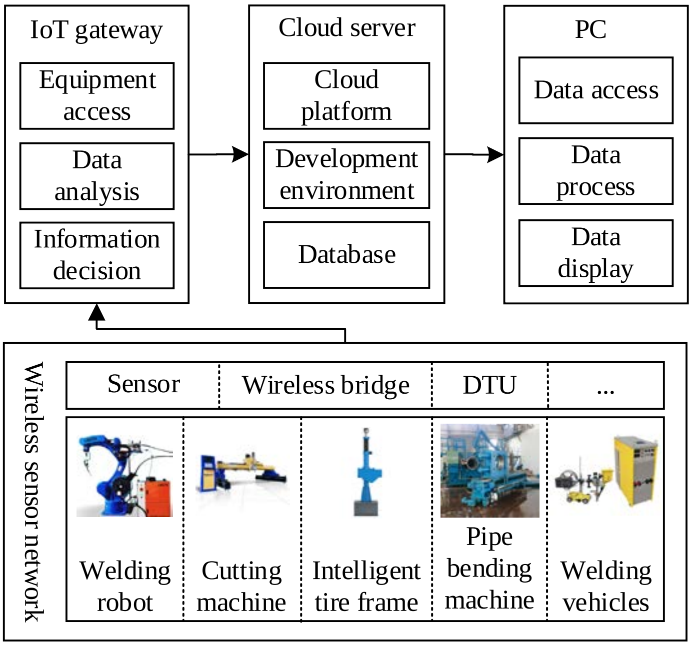

Fig. 4. Data collection and transmission network structure

Considering that the transmission distance of wireless sensor network is limited and the data collection of upper computer cannot be realized, short-range wireless communication technology needs to be coordinated and converted into long-range. The comparation of the advantages, disadvantages and application areas between the common short-range wireless communication technologies is shown in **Table 1**. Combined with the characteristics of equipment monitoring of ship block construction sites, ZigBee technology is selected as the wireless communication protocol for the online monitoring system of ship block construction equipment. Carrier Sense Multiple Access with Collision Avoidance (CSMA / CA) algorithm is used in the channel access of ZigBee wireless communication technology. The explicit ACK mechanism of the algorithm is very effective in dealing with data collision, which avoids the data transmission conflict between sensor nodes and ensures the reliability and durability of data.

Table 1. Comparison of short-range wireless communication technology

	ZigBee	**WiFi**	**Bluetooth**	**IrDA**	**UWB**	**RFID**
Working frequency	868/916MHz, 2.4GHz	2.4 GHz	2.4 GHz	820nm	3.1~10.6 GHz	5.8GHz
Transmission medium	Radio frequency	Radio frequency	Radio frequency	Infrared	Radio frequency	Radio frequency
Network node	255、65000	32	7	2	100	2
Transfer speed	20~250Kbps	>2Mbps	<1 Mbps	4~16Mbps	<1 Gbps	212Kbps
Transmission distance	10~100m	25~100m	10~100m	20cm~1.2m	10m	1m
Network scalability	Automatic expansion	None	None	None	None	None
Battery life	6 months to 3 years	1~7 days	1~7 days	——	——	1~7 days
Cost	Very low	Very high	High	Very low	Very high	Low

According to the actual production requirements of ship block construction, it is necessary to investigate and analyze the types of construction equipment such as tire frame, welding machines and the types of state data in the working process of the equipment, and design sensor nodes, including sensor module, processor module, wireless communication module and power supply module [22]. Through comprehensive analysis of the actual working environment of the production site, the sensor is selected according to sensitivity, accuracy, stability and other indicators. The mainstream ZigBee chip—CC2530 is used as a wireless communication microprocessor module which integrates processor module, wireless communication module. Taking into account the actual working environment of the ship block construction site, the sensor nodes are battery powered.

Location information is the basis of WSN technology application. In the actual application of ship block construction, it is necessary to determine the source position of the sensor node to grasp the events in the target area in time [23], and to ensure that the administrator understands the network coverage, balances the network load and improves the routing efficiency. The commonly used WSN positioning technology is measured from four indicators of positioning accuracy, beacon node density, node density, and energy consumption, and a positioning algorithm based on Received Signal Strength Indication (RSSI) ranging is selected.

The specific process of calculating unknown node coordinates is as follows: Wireless signal propagation generally obeys the probability distribution, and by simplifying the empirical probability model—Shadowing model, the RSSI-based ranging model is obtained as follows:

$$p_{RSSI} = \mathrm{A} - 10\mathrm{nlg}(d), \tag{1}$$

where *d* is the distance between the beacon node and the unknown node. According to the sensor node hardware and the block construction site environment, the empirical values A (the wireless signal strength RSSI value received by the receiving node when the wireless transmission and reception node at 1 m apart) and *n* (the path loss index determined by the environment) are determined. The RSSI value of sensor nodes at different heights and distances is measured, which is substituted into the ranging model and converted into distance *d*. The maximum likelihood estimation algorithm is used to calculate the unknown node coordinates according to the beacon node coordinates and the distance *d*, so as to realize the positioning of the sensor nodes. Considering that there may be interferences such as noise signals and obstacles at the ship block construction site, there is a certain error in the measured RSSI value, which further affects the estimated distance *d*. In order to improve the accuracy of the RSSI measurement value, the average value of RSSI is calculated as follows:

$$\overline{RSSI} = \frac{1}{n}\sum_{i=0}^{i=n} RSSI_i, \tag{2}$$

and the recursive algorithm of the averaging process uses the first-order IIR filter for data filtering, as follows:

$$RSSI_n = \alpha RSSI_n + (1 - \alpha) RSSI_{n-1}, \tag{3}$$

so as to reduce the measurement error of RSSI. Not only that, the error of the distance *d* is also corrected by the traditional least square method, and the distance correction model is established according to the site environment to obtain the corrected distance.

After the sensor node is located and data collection is completed, data transmission through the network layer is required. The wireless sensor network based on ZigBee technology adopts a mesh network topology, and arranges sensor nodes which include terminal collection nodes and routing nodes on the block construction equipment. The network is built with the coordinator node, and the collected massive data is connected to the coordinator node through the sensor node. According to the Eq-DataModel, the coordinator node processes the data and transmits the terminal equipment information to the IoT gateway by TCP/UDP direct connection, and completes the convergence of the data to the IoT gateway.

4.2 Data Processing Method for Ship Block Construction Equipment Based on Edge Computing

In order to deal with the pressure of a large number of terminal equipment access on network bandwidth and cloud server computing, this paper processes the construction equipment data collected in the process of ship block construction through the important link of IoT architecture—IoT gateway and edge computing. The main functions include:

(1) Equipment Access: According to the interface and connection protocol used by the equipment to be accessed, the IoT gateway dynamically provides various types of access methods to realize equipment connection. After the terminal equipment is accessed, a large

amount of data is transmitted from the data collection layer. For the online monitoring system of ship block construction equipment, ZigBee is used between the data collection layer and the edge layer to form a local area network, including sensor node and coordinator node. The routers are selected as the wireless access point, that is, routing nodes, to reduce the difficulty of system development. After the coordinator node is powered on, it initializes its own processor module and wireless communication module, establishes and starts a new ZigBee network, monitors and responds to the network request sent by the sensor node, and waits for the sensor node to join. When the sensor node enters the network, the parent node with the strongest signal in the range, which includes the coordinator node, is selected to join the network. After success, a short network address will be obtained, and the data of the construction equipment will be collected, accepted and forwarded to the coordinator node in time. The IoT gateway is connected directly to the coordinator node through the serial port, receives data forwarded by the serial port and sends a control command to the coordinator node [24]. After the terminal equipment connection is completed, the data is transmitted by the message bus to complete the registration and management of the ship block construction equipment, and the equipment related parameters and status are written into the equipment management table.

(2) Data flow analysis: Data flow analysis is an important function of the IoT gateway. The IoT gateway needs to clean the large amount of data uploaded by the data collection layer, reduce the workload of the data process and upload it to the cloud server. Specifically to this system, there is information loss, random code and other instability in the working process of the sensor node. The median average filtering method is used to filter the data, and the missing values are deleted directly to simplify the data. The preliminary processed data signal still contains a lot of random noise interference that cannot be used directly for state analysis. The data must be cleaned to avoid the influence of the noise signal on the calculation results. The autocorrelation function has good noise reduction characteristics during the data signal processing. This paper uses autologous analysis to remove noise signals on the original signal [25]. The autocorrelation function $R_x(\tau)$ used to describe the degree of similarity between the original signal $x(t)$ and the time-shift signal $x(t+\tau)$ is:

$$R_x(\tau) = \lim_{T\to\infty} \frac{1}{T}\int_0^T x(t)x(t+\tau)dt. \tag{4}$$

The relationship between autocorrelation function and autocorrelation coefficient is:

$$\rho_x(\tau) = \frac{R_x(\tau)-\mu_x^2}{\sigma_x^2}. \tag{5}$$

When the time delay τ of the autocorrelation function is large enough, the autocorrelation function of noise signal tends to zero, $R_x\left(\infty\right) = \mu_x^2,\ \rho_x\left(\infty\right) \to 0$, that is, the signal $x(t)$ is independent of the signal $x(t+\tau)$. The actual frequency and amplitude information of the original signal is retained, and the accuracy of the data signal is guaranteed.

(3) Rule calculation: Based on the result of data flow analysis, the rules and models issued by the cloud server are used in the IoT gateway to further analyze the data, and the decision instruction are obtained to control the terminal equipment. This system adopts embedded rule engine as the tool of rule calculation, and its model is shown in **Fig. 5**.

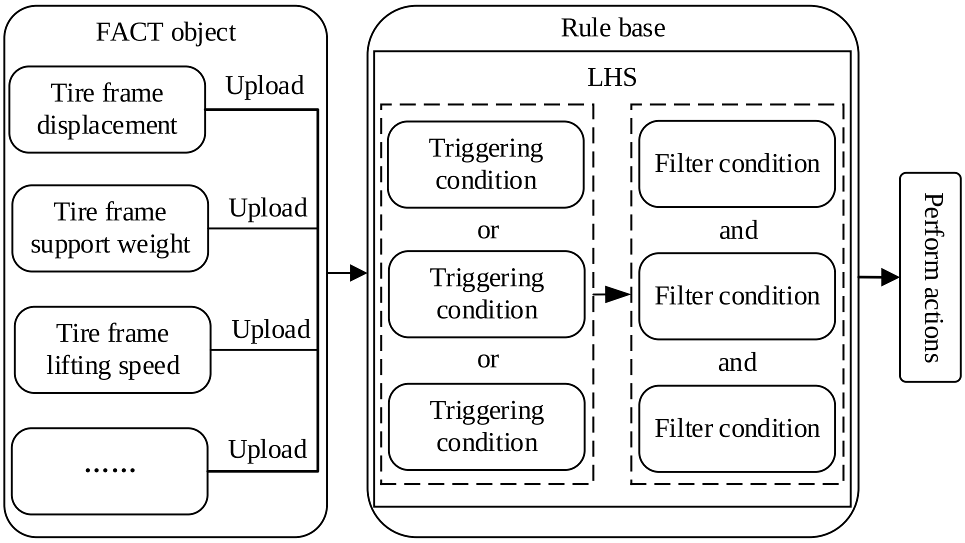

Fig. 5. The rule engine model

For the online monitoring system of ship block equipment, the FACT object is the construction equipment data collected by the sensor node. After uploading the data to the user predefined rule base, when the data meets any trigger condition of LHS (Left Hand Side), it will enter the filter condition to judge again. If satisfied, the corresponding execution program will be activated to generate decision instructions and execute actions. However, when the number of rules in the rule base is large, it is crucial to quickly judge and match rules. The Rete algorithm is a fast forward rule matching algorithm, which uses time redundancy and structural similarity to improve system matching efficiency by building rete network. In this paper, the Rete algorithm is selected to dynamically construct the network to achieve rapid rule matching [26], and the schematic diagram of the rete network is shown in **Fig. 6**. The matching process of the Rete algorithm is mainly divided into the following steps: 1)Upload all Fact objects to the RootNode of the rete network. 2) After the Fact object enters the rete network from RootNode, it immediately enters the ObjectTypeNode, which provides the ability to filter objects by object type. 3) The Fact object reaches the Alpha network after filtering, selects its first node for matching, which sets at the time of network construction, recursively traverses all the child nodes of AlphaNode, and obtains a set called AlphaMemory that meets each mode in the rule. 4) Add AlphaMemory to BetaNode. If BetaNode is not a Terminal node, it detects whether there is a Fact that meets the conditions in another input object set. If satisfied, join will be performed to obtain BetaMemory, and enter the next BetaNode to repeat the execution 4). If the BetaNode is a Terminal node, it means that the rule matches all the conditions, and an agenda is generated. 5) After matching the full rule, execute in order of priority.

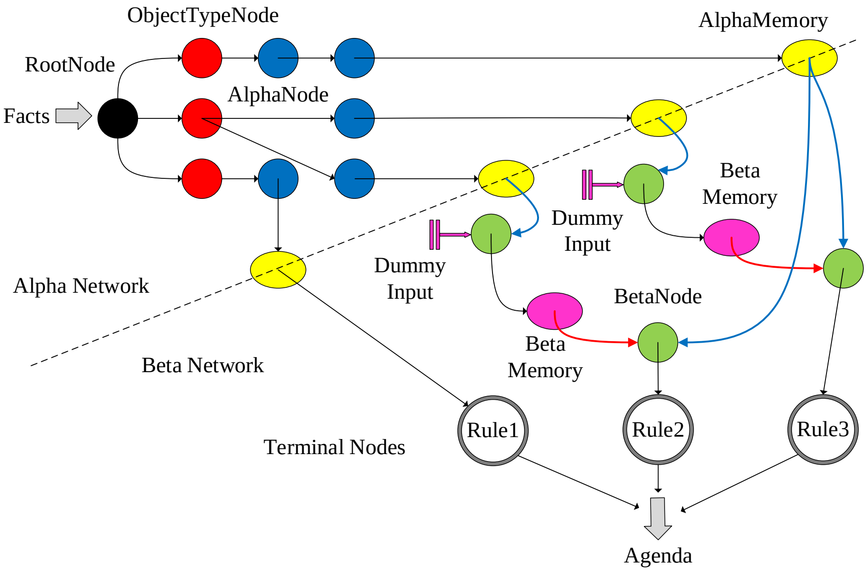

Fig. 6. The rete network

4.3 Online Monitoring System for Ship Block Equipment Based on Public Cloud and B/S Architecture

Compared to the C/S architecture, the B/S architecture has advantages such as simple maintenance and strong scalability. Therefore, this paper selects the B/S architecture to design and develop an online monitoring system for ship block construction equipment. The Web client and the Web server receive and forward data using the HTTP protocol, and encrypt user data with the cookie. The Web server and the Web application communicate by the Servlet interface. The Java programs in the Web application interact with the database server through the JDBC interface. The web-side data structure of the online monitoring system of ship block construction equipment based on B/S architecture is shown in **Fig. 7**.

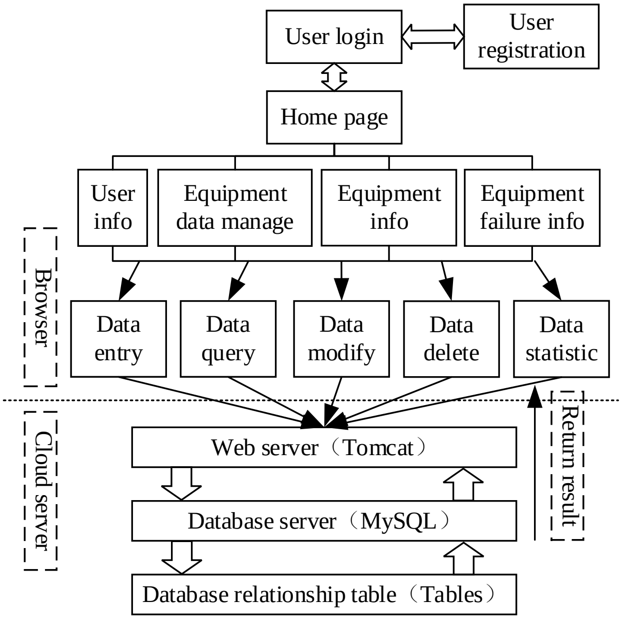

Fig. 7. The web-side data structure of the system based on B/S architecture

Cloud computing has gradually replaced traditional data processing methods. The cloud server provides computing services over the Internet, allowing users to access shared computing sources with minimal administrative work. In this paper, the cloud server platform of the ship block construction equipment monitoring system is designed based on the public cloud, and its basic architecture is shown in **Fig. 8** below.

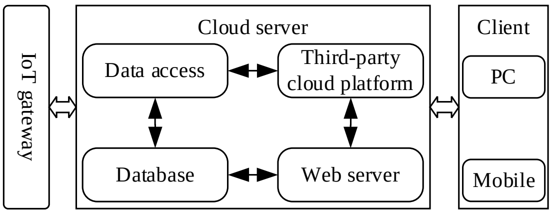

Fig. 8. Basic architecture of cloud server platform

In response to the ship block construction equipment online monitoring system, according to the characteristics and needs of the data management cloud server platform, the corresponding functional modules are divided into [27]: user data management module, equipment data operation module, system management module. Each module should be completed by the cooperation of multiple components and interfaces. Its operating mechanism is shown in **Fig. 9**. After entering the online monitoring system, users can manage different functions through different web pages of each function module. At the same time, the web page will provide users with a human-computer interface for data interaction with the cloud server platform: 1) The web page uses AJAX components and HTTP protocols to send JSON data to predefined URL on the Servlet side. The data is parsed through the built-in plugins of the Spring framework, filtered through the packet filter and handed over to the business logic layer in the form of GET/POST. 2) The business logic layer provides the corresponding interface for the Servlet to access the predefined processing methods (user information operation method, storage data management method, etc.), calls the public cloud storage device by API and builds the Hibernate framework to save, update and delete the local database resources, that is, data persistence operation. 3) In response to this system, the cloud server platform has a JS script on the web page, which can realize the dynamic display of the construction equipment data.

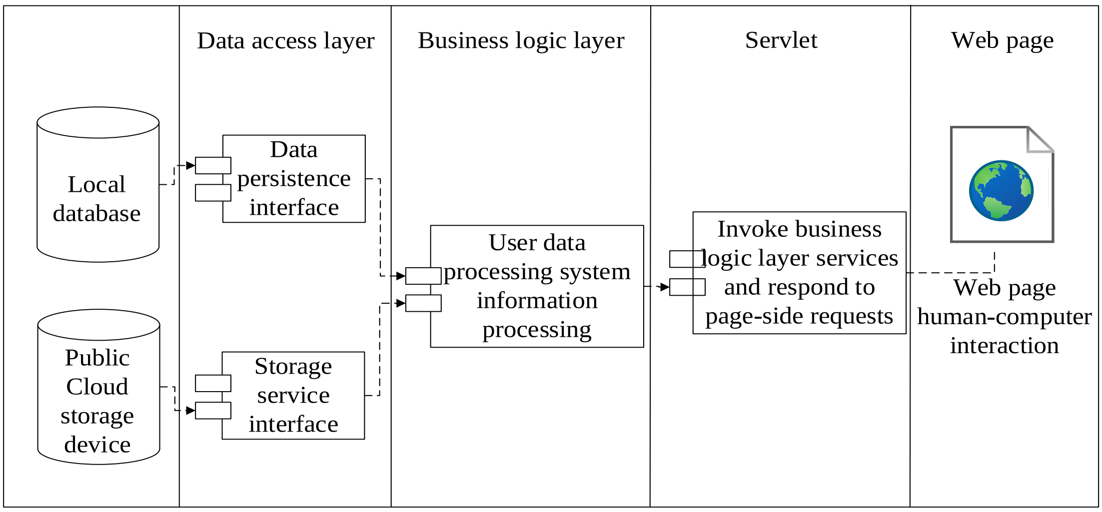

Fig. 9. The operating mechanism of the functional modules of the data management system based on the public cloud

5. Example Application

As necessary tooling equipment of the ship block construction process, the tire frame has not fully realized the digital transformation, making it impossible for ship enterprises to effectively maintain, expand and monitor them. Based on the intelligent tire frame system [28], this paper verifies the online monitoring system of ship block construction equipment, as shown in **Fig. 10**.

(1) Intelligent tire frame data collection: According to the construction data (pressure, temperature, displacement, etc.) involved in the block construction process of intelligent tire frame support, we choose WELLS's WSL-3 type spoke pull pressure sensor, QOQIO's IRTT151-113 type infrared temperature sensor, MILONT's pull rope displacement sensor, etc. The processor module and the wireless communication module are integrated on the CC2530 chip produced by TI. The power supply module uses the filter capacitor to filter the battery voltage, and supplies the power directly. After the sensor node is designed, based on the RSSI ranging positioning algorithm, the coordinates of unknown nodes are calculated to realize the positioning of the sensor nodes. According to the actual arrangement of the intelligent tire frame, the distance d between partial unknown nodes and the beacon node is calculated, as shown in **Table 2**. Then, according to the distance d and the coordinates of the beacon node, the partial unknown node location data obtained by the maximum likelihood estimation algorithm is shown in **Table 3**. The sensor nodes access the collected data to the Eq-DataModel for processing, and converge to the IoT gateway through TCP direct connection. Some data can also be displayed directly through the digital tube, and all components are arranged on a small circuit board.

Table 2. The distance d between unknown nodes and the beacon node

Beacon node	**Unknown node**					
	X1			X2		
	Actual distance/m	Calculated distance/m	Error/%	Actual distance/m	Calculated distance/m	Error/%
N1	5.01	5.33	6.4	3.20	3.05	4.7
N2	8.26	7.66	7.3	6.88	7.35	6.8
N3	12.06	11.23	6.9	15.36	16.42	6.9
N4	18.13	16.81	7.3	20.30	22.11	8.9

Table 3. The unknown node location data

Unknown node	**Actual coordinate**	**Positioning coordinate**	**Positioning error/m**
X1	(2,4)	(2.2, 5.1)	1.12
X2	(1,5)	(1.3, 4.4)	0.67

(2) Data preprocessing: The intelligent tire frame remote monitoring system selects Eclipse embedded development platform as the hardware platform of the IoT gateway, and carries the basic embedded operating system Windows Embedded Compact developed by Microsoft, that is, Windows CE. Windows CE kernel version is 7.0, which integrates LPC3250 serial driver, PCMCIA driver, file system, GWES (graphics, windows and event subsystems) and so on, and forms a complete embedded Windows CE system. By using edge computing technology, the access of intelligent tire frame and the data flow analysis of intelligent tire frame are realized, and the intelligent tire frame operation action is generated. Take the pressure on the intelligent tire frame as an example: 1) According to the connection protocol and interface of the intelligent tire frame, the IoT gateway provides the corresponding access mode to connect the intelligent tire frame. 2) Storing the read intelligent tire frame pressure data in the local database in the specified data format. 3) Checking if the pressure value is missing, and when there is a sample of absence, the sample is discarded directly. 4) Filtering the median value of the collected pressure data every five minutes to optimize the data. 5) Removing the noise signal in the preliminary processed pressure signal by autocorrelation analysis. 6) Uploading the pressure data to a predefined rule base, comparing it with the preset pressure threshold, and activating the corresponding execution program. 7) Generating decision instruction to control the adaptive adjustment height of the intelligent tire frame.

(3) Visual display of the monitoring platform: The intelligent tire frame remote monitoring platform is designed based on the B/S architecture, and the open platform OneNET of China Mobile Internet of things is selected as the third-party cloud platform. The IoT gateway communicates with the OneNET platform through TCP/IP protocol and the Socket port to complete data receiving and forwarding. This platform uses web-based programming to form a Java Web technology stack in Java language. In addition, it uses JDK + Eclipse development tools and MVC ideas to build a Spring system framework, and is deployed on Tomcat servers. According to the Eq-DataModel, a MySQL database is created to receive the intelligent tire frame data collected by the sensor node, and the data is analyzed, stored and visualized. The intelligent tire frame remote monitoring platform includes five functional modules: equipment management module, operation monitoring module, alarm management module, energy efficiency management module and user management module. Users can understand the specific attributes and working status of the intelligent tire frame through this platform, and use the rich chart plugin to query the real-time data and historical data of the intelligent tire frame. When an intelligent tire frame fails, users can go to the alarm management page to view specific information. The platform also provides a common user management interface in which users can register or modify the information as needed.

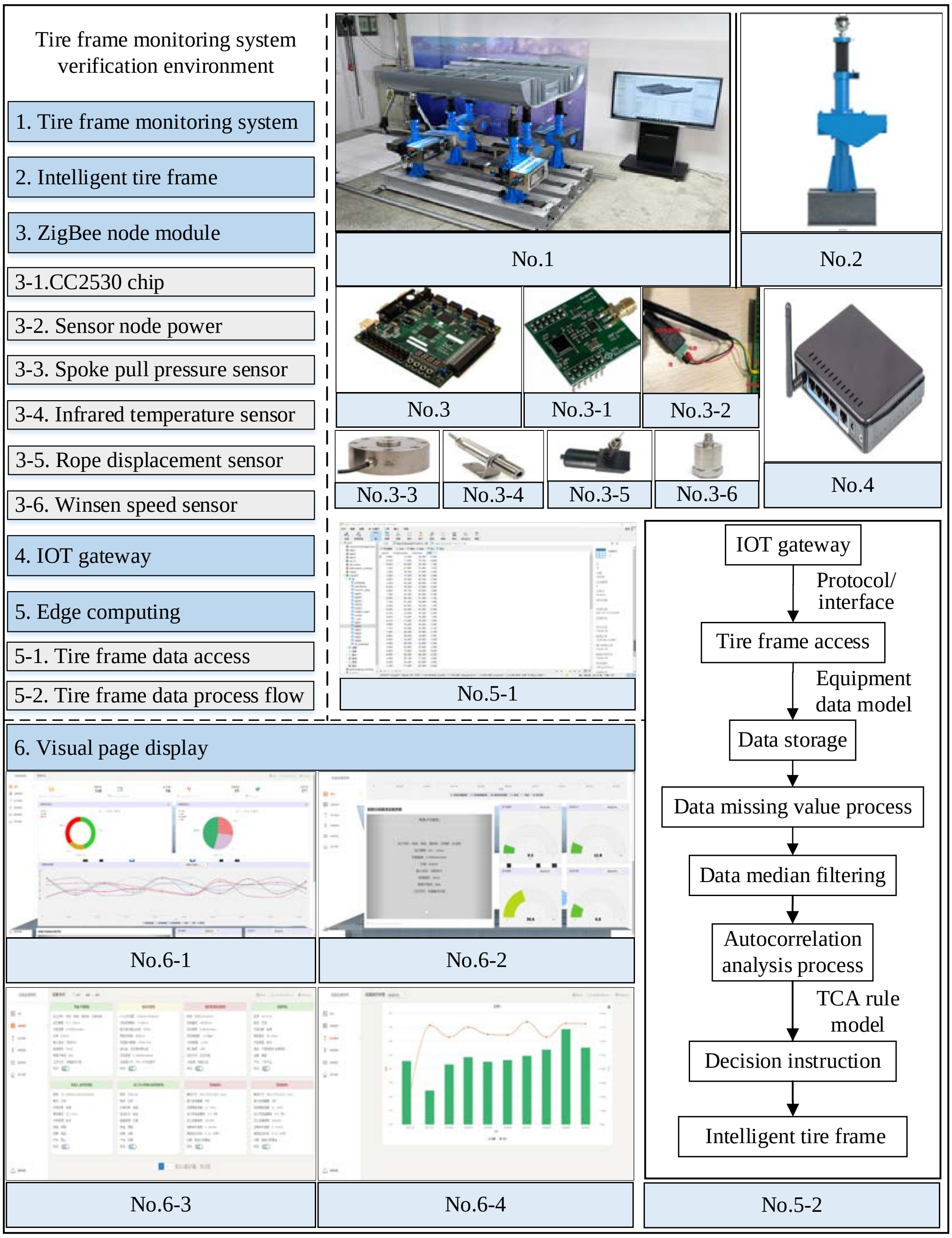

Fig. 10. Verification environment of the online monitoring system for ship block construction equipment based on intelligent tire frame

6 Conclusion

In response to problems such as insufficient processing capacity of equipment data and online visualization monitoring, the online monitoring system of ship block construction equipment based on IoT and public clouds is proposed. The wireless sensor network is established to collect the equipment data. Based on the RSSI ranging positioning algorithm, the unknown node coordinates are calculated. Through the design of the Eq-DataModel, the data analysis is completed and sent to the IoT gateway via the ZigBee transmission module. The edge computing technology is introduced, the protocol conversion ability of the IOT gateway is used to access the equipment, the autocorrelation analysis of the original data signal is carried out to remove the interference noise, and the decision instruction is obtained by establishing the rule model. Based on the B/S architecture and a ONENET platform, the equipment visualized online monitoring platform is designed, and the Hibernate framework completes the data persistence of local resources, realizing real-time monitoring assessment of equipment operating conditions.

The establishment of the online monitoring system of ship block construction based on the IoT and public clouds is an effective means of implementing equipment status data without barrier circulation. It is convenient to adjust and maintain equipment in time to provide data support for equipment troubleshooting to make more reasonable and efficient arrangements. It also improves the quality, efficiency and intelligence level of ship block construction, and promotes the overall development of the shipping industry.

This article is only validated for the intelligent tire frame, and the other equipment will be studied in the later period. The data fusion algorithm will be introduced to fuse the data to better prevent equipment failure and improve the reliability of the system in practical applications.

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