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Design of Smart Site Supervision System Based on Multi-source Sensor Data

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Abstract. Under the background of the current Internet of Things (IoT) era, smart site projects have become the trend of modernization, information construction and growth of the construction industry. Sensor information fusion in the IoT is considered as a set of strategies and methods to realize complete, accurate, timely and effective comprehensive information processing. In this article, an improved multi-source sensor information fusion algorithm of the IoT is proposed. Based on the general information system, the high-attribute dimension data is cut into several relatively low-attribute dimension data by using the idea of division, and these relatively low-attribute dimension data are calculated, so as to ensure that the results obtained by segmentation calculation are the same as those obtained by direct calculation. The algorithm classifies the site supervision data, and the test results show that the classification precision is over 96% and the recall is over 90%. This model not only helps to ensure the authenticity and reliability of the information fusion results in the perception layer of the IoT, but also the data preprocessing method based on gross error can reduce the calculation amount of information fusion, reduce the demand for sensor node resources, and provide algorithm support for the design of the supervision system of the IoT in smart workplaces.

Keywords: Internet of Things; Sensing data; Data fusion; Smart construction site
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1 INTRODUCTION

With the acceleration of urbanization and the expansion of construction scale, the traditional project supervision methods of management and supervision institutions and construction companies are single, which leads to slow response and weak active control ability. Under the background of the current IoT era, the concept of smart site is refined accurately, and smart site projects have become the trend of modernization, information construction and growth of the construction industry. Data analysis in which the transmission sensor extracts meaningful information from the collected data.

Ahmad et al. [1] believe that a smart construction site supervision system based on multi-source sensor data from the Internet of Things is a system that utilizes aspects such as IoT technology for supervision. This system can collect various data on the construction site through various sensors, such as the operating status of construction equipment, the operation of construction personnel, environmental parameters such as noise and dust on the construction site, as well as data on the quality and safety of construction materials. The system can analyze and process the collected data, monitor the situation at the construction site in real time, and provide timely feedback to relevant personnel to identify problems and take measures to solve them. Chaganti et al. [2] need to consider the following aspects when designing a smart construction site supervision system based on multi-source sensor data from the Internet of Things. Selection and layout of sensors: The system needs to select multiple sensors, such as vibration sensors, noise sensors, temperature and humidity sensors, gas sensors, etc., and arrange them reasonably according to the situation of the construction site, in order to comprehensively collect data from the construction site. Hassan et al. [3] collected data from various sensors and processed and analyzed the data to monitor the situation at the construction site in real time. The collection and processing of data can adopt advanced technologies such as cloud computing technology and big data analysis technology to improve the speed and accuracy of data processing. Jiang et al. [4] analyzed the security and reliability of the system: the system needs to adopt technical means with high security and reliability to ensure data security and privacy protection. For example, encryption technology, data backup and recovery technology, and other technical means can be used to ensure the security and reliability of the system. In summary, the smart construction site supervision system based on multi-source sensor data of the Internet of Things is a comprehensive system that integrates multiple advanced technological means. It can achieve comprehensive monitoring and effective management of the construction site, improve the safety and efficiency of the construction site, and provide strong support for the smooth implementation of the construction site. Keene [5] determine the displacement and strain on a commodity graphics processing unit in a full field at high resolution and frame rate. The use of the basic theory and key technologies of information fusion is of great significance for promoting the growth of IoT technology and meeting people's actual needs. These nodes form a multi-hop self-organizing network integrating sensor technology, information processing technology and computing technology through wireless communication, so that the information of any environment or target within the network coverage can be monitored, perceived and collected in time, and then the collected and processed information can be transmitted to end users through multi-hop wireless communication. In this article, an improved multi-source sensor information fusion algorithm of the IoT is proposed. Based on the general information system, the high-attribute dimension data is cut into several relatively low-attribute dimension data by using the idea of division, which reduces the demand for sensor node resources and provides algorithm support for the design of the supervision system of the IoT in smart workplaces.

In order to adapt to development needs, a feasible smart site supervision system should be formulated in combination with the current situation. The construction industry is an important pillar industry of a city, so accelerating the construction of smart sites has also become an important part of the growth of smart cities, which reflect the main significance in the construction of smart cities. The technology of IoT has been applied in the industrial field to some extent, but in practical application, its problems such as huge quantity of nodes and high information redundancy are quite contradictory to the limited energy. It is need to introduce information fusion to promote the efficiency and reliability of information collection and save network energy. In this article, the design strategy of intelligent site supervision system based on IoT multi-source sensor data is studied from the algorithm level;

(1) Aiming at the high attribute dimension of the IoT, this article proposes an efficient feature fusion algorithm based on partition idea to eliminate redundant attribute feature data.

(2) In the absence of prior knowledge, the algorithm extracts rules that meet certain quality from a large quantity of IoT data information, that is, it finds some relationships between objective things.

(3) Based on the incomplete decision information system, the algorithm uses the idea of positive approximation to minimize the quantity of data objects participating in the calculation in each step without affecting the calculation results, thus improving the calculation efficiency.

2 RELATED WORK

Smart city has become the general trend of advanced countries in the world, which involves many supporters and technical levels, and one of the important infrastructures is the construction of smart sites. The initial IoT came into being and developed with the logistics industry as the target application background. Larrazabal et al. [6] elucidated the training computer-aided diagnostic artificial intelligence systems. Mohai et al [7]'s adaptive testing using new algorithms and a parameterized task library allows immediate evaluation of participants' reactions, thereby determining the level of difficulty of the next task. In this way, subsequent projects are adjusted to the estimated abilities of participants. The adaptive program enhances the diagnostic ability and sensitivity of the original test. By measuring target cognitive abilities and their limitations more accurately, a more accurate diagnosis can be obtained. Due to the rapid growth of sci & tech, the connotation of the IoT has been further deepened. As one of the core components of the sensing layer of the IoT, sensor network is mainly composed of many low-cost micro-sensor nodes deployed in the monitoring environment. Ramasamy et al. [8] proposed artificial intelligence IoT CPS algorithm is more effective in detecting diseases and falls in the elderly in terms of accuracy, accuracy, recall rate, and F-measurement. Ryselis et al. [9] analyzed the framework for creating foreground background masks in depth images. Soleimani et al. [10] transformed the input image into a depth image and removed some noise and missing values. Visualize the generated foreground background mask image to verify its quality. Use some feature extraction algorithms such as SIFT, SURF, HOG, etc. to extract feature expressions from the input image. V. Shajihan et al. [11] analyzed the three-dimensional reconstruction grid structure of images. It is usually composed of triangles, quadrangles or other simple convex polygon, which can simplify the rendering process. In 3D reconstruction, grids can be constructed based on different methods, such as polygon-based grids, voxel based grids, and grid based grids. Different methods have their own advantages and disadvantages, and appropriate methods should be selected based on specific application scenarios. Wei et al. [12] achieved intelligent real-time remote on-site detection of PCs and workers by using CVB technology. CVB technology is a remote monitoring technology based on vision and sound, which can capture on-site data in real-time through devices such as cameras and microphones, and transmit and process it through the network. Yaghoubi et al. [13] captured real-time on-site data by installing cameras, microphones, and other devices in PCs and workers' workplaces. Data preprocessing: Process the collected data to remove noise and missing values, and improve the reliability of the data. Yan et al. [14] used some feature extraction algorithms such as SIFT, SURF, HOG, etc. to extract feature expressions for PCs and workers from the data. Image reconstruction: Use depth image reconstruction algorithms such as HOG, SIFT, SURF, etc. to reconstruct the extracted features and generate foreground and background mask images.

The above security scheme either increases the quantity of interactions between nodes, or poses too high a challenge to the computing and storage resources of nodes. This article proposes an efficient feature fusion algorithm based on the idea of partition, which minimizes the quantity of data objects involved in the calculation in each step without affecting the calculation results, thus improving the efficiency of the supervision of the IoT in smart workplaces.

3 METHODOLOGY

IoT sensing devices collect analog signals of massive heterogeneous resources in the physical environment and convert them into processable data. The data obtained at this stage is a quantifiable and non-semantic original data. Associating and integrating the collected data with its metadata and other resource data, the data can be structured and ordered by object-oriented information modeling, and the consistent interpretation of the perceived objects, that is, information with certain semantics, can be obtained. According to the relevant knowledge rules, information can be learned. The knowledge modeling method of object-oriented graph can be used to integrate and fuse the related structured information and domain knowledge, and the information can be abstracted to form knowledge. Through the assessment and decision-making and other functional behaviors, it is finally transformed into control electrical signals, and the intelligent control of physical world objects is realized. The data transmission mechanism and processing flow of IoT in smart construction site are shown in Figure 1.

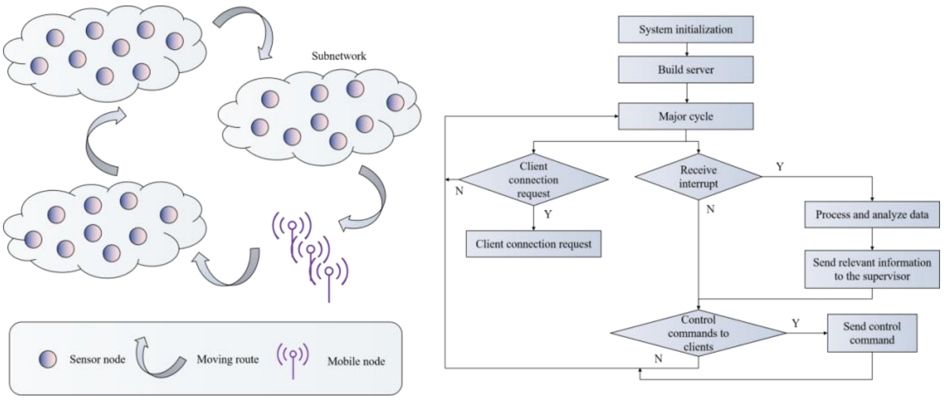

Figure 1: Communication mechanism and server program flow of IoT in smart worksite.

The problem of IoT sensor data processing in smart site supervision can be described by the following state space model:

$$\theta_k = f(\theta_{k-1}, v_k) \tag{1}$$

$$y_k = h(\theta_k, n_k) \tag{2}$$

$$E_T(i,j) = (E_{elec} + \varepsilon_{amp} d_{(i,j)}^2)B \tag{3}$$

The receiving power consumption of S_j receiving B bit data can be expressed as:

$$E_R(j) = E_{elec} + B \tag{4}$$

$$E_R(j) = E_{elec} + B \tag{5}$$

As one of the core components of the sensing layer of the IoT, the sensor network is mainly composed of many low-cost micro-sensing nodes arranged in the monitoring range, and a multi-hop self-organizing network is constructed among these nodes by wireless communication. So as to obtain a consistent description of the measured target object.

Let y_t be an observable variable in $k \times 1$ dimension including k construction risk variables. The measurement equation is defined as:

$$y_t = z_t \times a_t + d_t + \mu_t \quad t = 1,2,\ldots,T \tag{6}$$

Where T is the sample length, z_t is the $k \times m$ matrix, and d_t is the $k \times 1$ vector. μ_t stands for $k \times 1$ vector, which is a continuous uncorrelated perturbation term with a mean of 0 and a covariance matrix of H_t:

$$E(\mu_t) = 0, \quad \mathrm{var}(u_t) = H \tag{7}$$

$$a_t = T_t a_{t-1} + c_t + R_t \xi_t \quad t = 1,2,\ldots,T \tag{8}$$

Where T_t stands for $m \times m$ matrix, c_t stands for $m \times 1$ vector, and R_t stands for $m \times g$ matrix; ξ_t represents a random uncorrelated disturbance term with the mean value of $g \times 1$vector of 0 and covariance of Q_t:

$$E(\xi_t) = 0, \quad \mathrm{var}(\xi_t) = Q_t \tag{9}$$

Mining historical data, judging and analyzing construction risks in combination with hazard levels, preventing and responding to site risks in a targeted manner, and improving the supervision mode of construction sites.

If there are quality problems in the construction practice of the proposed project, the system will stop the construction work in time and accurately locate the fault or quality problem, then the construction quality of the project will be guaranteed. Set the factor set U and the assessment grade set V for assessing construction projects:

$$U = \{u_1, u_2, \ldots, u_m\} \tag{10}$$

$$V = \{v_1, v_2, \ldots, v_m\} \tag{11}$$

Fuzzy assessment is carried out on each factor in U according to the grade index in the assessment set, and the assessment matrix is obtained:

$$R = (r_{ij})_{n \times m} \tag{12}$$

In which r_{ij} indicates the degree of u_i's membership in v_i. After determining the importance index of each factor, record it as:

$$A = \{a_1, a_2, \ldots, a_m\}, \quad \sum_{i=1}^{n} a_i = 1 \tag{13}$$

Synthesis:

$$\overline{B} = AR = (\overline{b}_1, \overline{b}_2, \ldots, \overline{b}_m) \tag{14}$$

After normalization, the following results are obtained:

$$B = \{b_1, b_2, \ldots, b_m\} \tag{15}$$

Therefore, the risk assessment level of the construction project can be determined.

4 RESULT ANALYSIS AND DISCUSSION

The cache technology is used to optimize the supervision information fusion algorithm, and the response speed and access speed of the system are improved through data cache. After the supervision information is collected, move the information data into the cache. Because the cache space is limited, the data can't be put into the cache space all the time, so the cache replacement algorithm is used to manage the cache and replace the cached data according to the priority. In this section, the performance of the sensor information fusion algorithm of the smart site supervision system is tested. The sample case of channel estimation is illustrated in Figure 2.

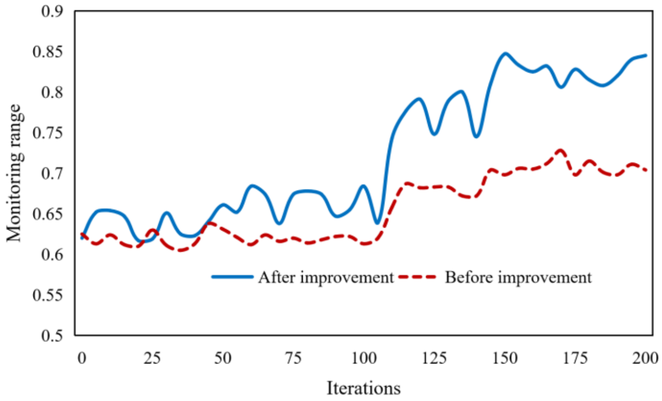

Figure 2: Channel estimation sample.

Tests show that this method is superior to the original method in estimating the monitoring range. The cache space is allocated to the supervisory data with high priority and inserted into the cache queue. When the supervisor accesses the system, the data object is searched in the cache first, and the cached supervisory information is transmitted wirelessly. If there is no data object in the cache, search the supervision data in the server again.

In order to adapt the needs of high reliability of collected data and high robustness of network application, the sensor nodes scattered in the sensing layer of the IoT are often highly dense, and the monitoring ranges of these nodes will overlap and their sensing data will be very close. If these data are sent directly without processing, it will not only waste the scarce resources in the network and shorten the network life cycle, but also make it impossible for the base station to obtain really useful information. In the complex underground environment and limited node resources, by introducing data compression and information fusion, the power consumption and communication traffic of nodes are reduced, and the reliability of information collection is improved. In the aspect of information collection and processing, the software filtering technology is used to do anti-noise processing on the collected data to minimize the deviation from the actual value, as shown in Figure 3.

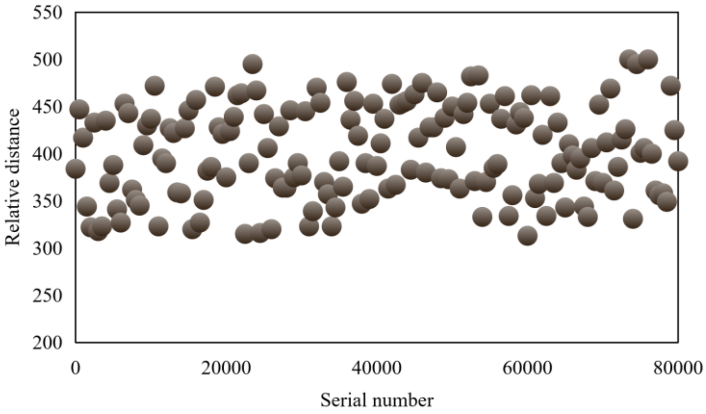

Figure 3: Data outlier removal processing.

Using these data to train the designed smart site supervision system, we can get better network weights, and then substitute the obtained network weights into the smart site supervision system to become a model for site construction risk assessment and prediction.

Introducing information fusion into the sensing layer of the IoT can reduce the traffic between nodes, reduce transmission congestion and information transmission delay, and then avoid the collision of sending packets, which can improve the efficiency of information collection system. Compare the output data of the smart site supervision system with the real risk data, as shown in Table 1 and Figure 4.

Sample set	*Prediction value*	*Actual value*
40	0.765	0.857
80	0.796	0.878
120	0.742	0.714
160	0.801	0.883
200	0.779	0.871
240	0.795	0.807
280	0.828	0.92
320	0.771	0.785
360	0.779	0.861
400	0.765	0.857

Table 1: Machine learning results.

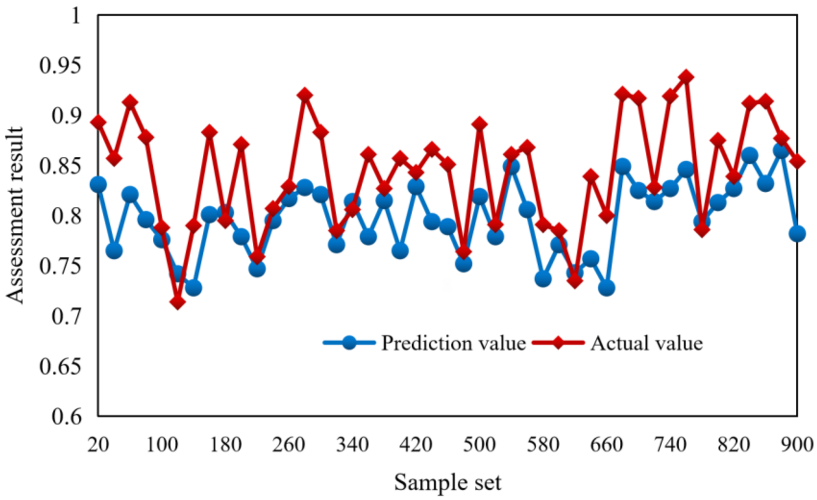

Figure 4: Machine learning results.

It is not difficult to see from Table 1 and Figure 4 that the learning result of this algorithm is convergent, which can approximate the original data well, and has a basis for predicting the construction risk of the site. The modeling stage of traditional quantitative prediction method does not have the ability of learning data samples and pattern recognition, and its modeling process is an abstract stage of original data, which is completed in numerical calculation. Through the training of the smart site supervision model, the high fitting of the relationship between system variables is realized, which is beneficial to the analysis of the related influence between system variables, so as to find the regularity of the relationship between system variables.

In general, the object of information fusion operation is application layer information, so it is very need to know the semantics of application data during fusion operation. According to different fusion levels, if the fusion operation is carried out at the application layer, there is no semantic interval, and the application data can participate in the fusion operation immediately. Figure 5 shows the recall of this algorithm. The classification precision of this algorithm is shown in Figure 6.

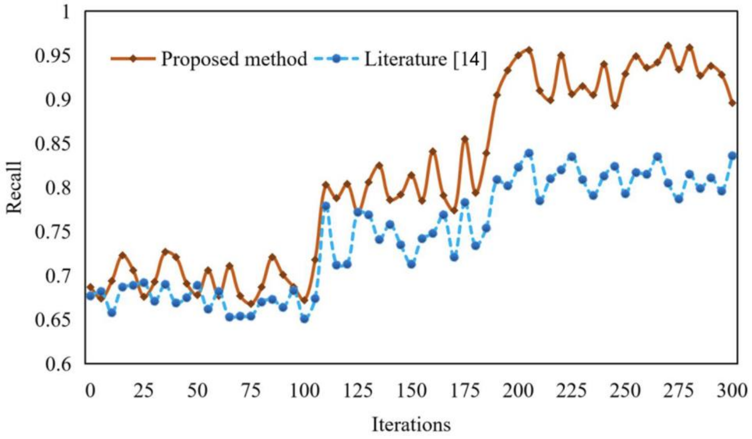

Figure 5: Recall of the algorithm.

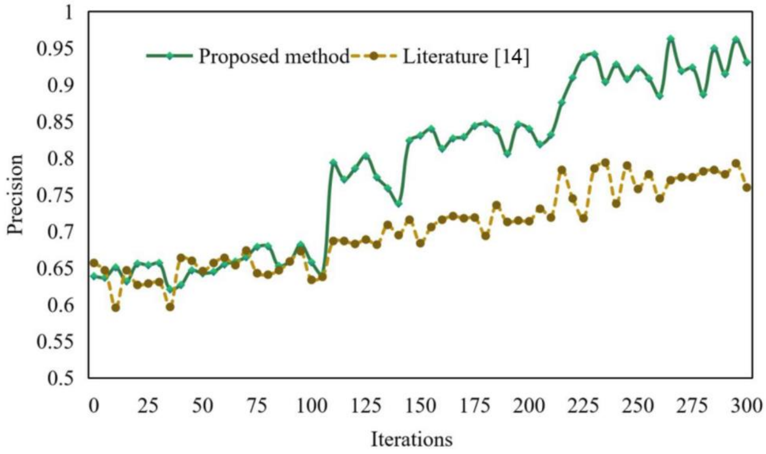

Figure 6: Classification precision of the algorithm.

As can be seen from Figure 5 and Figure 6, compared with the literature 14 method, the sensor information fusion algorithm in this study has obvious advantages in classification precision and recall. The algorithm classifies the site supervision data, and its classification precision is over 96%, and the recall is over 90%. Based on the analysis of historical data with certain conclusions, this model finds out some characteristics, and then makes some predictions for future conclusions according to these characteristics.

Smart site supervision system provides a reliable data source for the platform, which is composed of site IoT sensors and wireless network nodes, with the help of flexible site wireless communication system network structure scheme. In practical application, the monitoring speed of construction risk is an important index. Generally speaking, in practical application, the shorter the time required for construction risk monitoring, the better the real-time performance of this method. After processing, the construction risk monitoring data obtained from the test are shown in Table 2.

Experimental condition number	*Processing time of this algorithm /s*	*Processing time /s of literature [14]*
01	4.45	6.79
02	3.36	6.12
03	4.51	6.48
04	5.25	5.27
05	5.24	6.55
06	4.75	6.56
07	4.75	6.77
08	3.31	5.29
09	4.27	7.68
10	3.78	6.25

Table 2: Processing time of construction risk monitoring data.

Compared with the control method, the processing time of construction risk monitoring data obtained by this algorithm is shorter, which shows that the processing of multi-source sensor information fusion in the IoT in this study has higher real-time performance.

The relative error of measurement results is:

$$\delta_n = \frac{\overline{X}_n - X_0}{X_0} \times 100\% \tag{16}$$

Where δ_n is the relative error of construction risk monitoring; $\overline{X}_n$ is the average value of construction risk monitoring; X_0 is the standard value of construction risk monitoring.

In this study, it is planned to organically integrate wireless and wireless methods, and implement the whole network laying in the construction site, so as to achieve comprehensive coverage of the construction site, improve the transmission efficiency of the system to a certain extent, and reduce the relative error of measurement. The results show that this method can effectively improve the measurement precision of construction risk. The relative errors of construction risk monitoring are shown in Table 3 and Figure 7.

Experimental condition number	*Relative error of this algorithm*	*Relative error of that method in reference [14]*
01	2.25	3.27
02	2.55	2.99
03	1.64	2.99
04	1.11	2.94
05	1.98	2.36

06	0.95	1.83
07	0.66	1.95
08	0.98	2.65
09	1.21	2.10
10	1.24	1.98

Table 3: Relative error of construction risk monitoring.

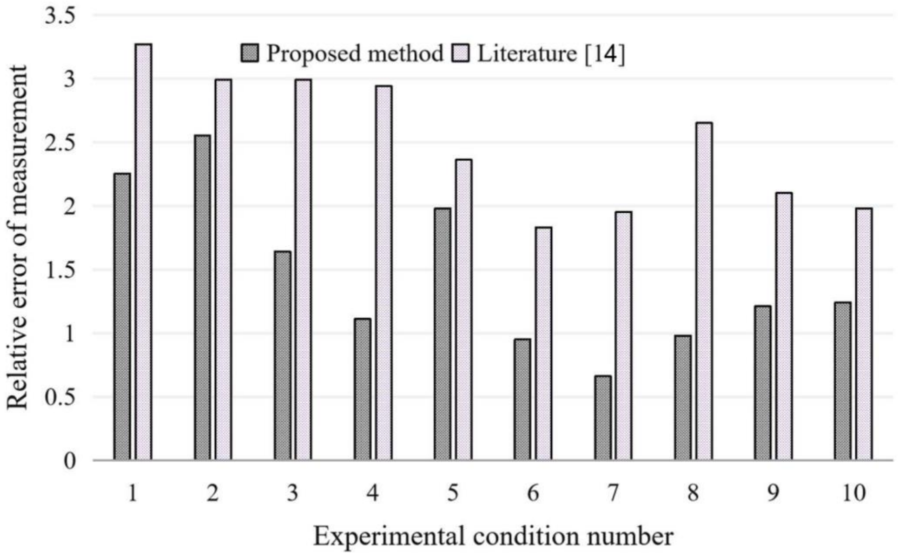

Figure 7: Relative error of construction risk monitoring.

As can be seen from Table 3 and Figure 7, the relative error of the construction risk monitoring results obtained by this algorithm is smaller than that of the control method. In the actual deployment of the smart site supervision platform, the service-oriented technical architecture analysis and design method is used to decompose business applications into various services, and encapsulate services into various components according to integration, abstraction and compliance. Leading iterative design principles can complete project analysis, design and development.

The comprehensive test results show that, compared with the control method, the data processing time of construction risk monitoring is shorter and the relative error of construction risk monitoring is smaller. Moreover, the classification precision and recall of this algorithm are significantly better than the traditional algorithm. This fully affirms that the information fusion algorithm in this article has a better monitoring effect on construction risks, and also verifies the feasibility and effectiveness of the smart site supervision system. Based on the incomplete decision information system, the algorithm uses the positive approximation idea to minimize the quantity of data objects participating in the calculation in each step without affecting the calculation results, thus improving the calculation efficiency.

5 CONCLUSION

Smart construction site is an intelligent system with on-site comprehensive management and control functions, which is mainly based on technologies such as big data and IoT. Smart site is the use of IT, cloud computing and other technologies to develop engineering site supervision functions, collect and transmit site data, and provide information push and transaction reminder for on-site operators. In this article, an improved multi-source sensor information fusion algorithm of the IoT is proposed. Based on the general information system, the high-attribute dimension data is cut into several relatively low-attribute dimension data by using the idea of division, which reduces the demand for sensor node resources and provides algorithm support for the design of the supervision system of the IoT in smart workplaces. The comprehensive test results show that, compared with the control method, the data processing time of construction risk monitoring is shorter and the relative error of construction risk monitoring is smaller. Moreover, the classification precision and recall of this algorithm are significantly better than the traditional algorithm. This fully affirms that the information fusion algorithm in this article has a better monitoring effect on construction risks, and also verifies the feasibility and effectiveness of the smart site supervision system.

According to the current construction situation, the intelligent site supervision system based on IoT technology does ensure the quality of site management to a certain extent. In the future development, in order to solve all kinds of bottlenecks and problems in construction projects and realize the comprehensive innovation of IT in construction industry, technicians must combine the needs of site management and explore the deep integration of AI frontier technology and traditional construction project management for a long time.

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