Research on Construction Risk Monitoring Method Based on Mobile Terminal

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Abstract. In building construction, due to the large number of staff and complex construction operation process, there will be a large number of unsafe factors, which will bring potential safety hazards to the construction project. Therefore, these factors affecting the construction safety must be monitored and managed to prevent the occurrence of safety accidents. In order to better ensure the safety of construction and avoid construction risks, a construction risk monitoring method based on mobile terminal is proposed. Combine mobile terminal technology to collect and identify construction characteristic data, build a construction risk management framework based on mobile terminal, build corresponding evaluation systems for different construction risks, optimize evaluation algorithms, and improve the construction risk monitoring system. Finally, it is confirmed by experiments. The construction risk monitoring method based on mobile terminal has high practicability in the process of practical application, and fully meets the actual requirements.

Keywords: Mobile terminal · Building construction · Risk monitoring · Evaluation system

1 Introduction

The establishment, analysis, research, design and plan of construction risk monitoring are based on the prediction of the future situation and on the normal and ideal technology, management and organization. These factors may affect the realization of the project objectives and the actual operation process of the project. The internal and external interference factors that cannot be determined in advance in these construction projects are called the risk of construction projects [1]. There are mainly the following five common safety accidents in construction, namely, falling from height, object strike, mechanical injury, electric shock and collapse. According to relevant survey data, the incidence of these five safety accidents accounts for more than 80% in construction. There are many reasons for the occurrence of these five safety accidents, mainly including the following points: first, the lack of construction ability of construction personnel leads to the occurrence of safety accidents, and the standardized operation is not carried out in accordance with the standard workflow. Secondly, inadequate safety protection measures are also

W. Fu and L. Yun (Eds.): ADHIP 2022, LNICST 469, pp. 557–570, 2023.
https://doi.org/10.1007/978-3-031-28867-8_41

one of the main factors causing safety accidents. The third is the management factor. The lack of awareness of safe production management and improper management of construction personnel are also one of the factors causing construction safety accidents. In the construction site, due to the lack of safe and reasonable supervision and management, it is very easy to cause construction safety accidents [2]. In the construction, the construction needs a variety of construction raw materials and a large number of construction equipment, which will affect the safety of construction operation. The work quality and construction ability level of construction personnel will have a direct impact on the construction quality.

In view of the above problems, relevant scholars have proposed some construction monitoring methods, such as building construction safety monitoring methods based on computer vision. This method first analyzes the application scope of computer vision technology in construction safety management, and summarizes the potential application of computer vision technology in the safety management of construction elements such as man-machine, material, method and environment by combing the provisions of the specifications, Two human related safety management, construction worker position safety management and occupational health and safety management, are selected as the main research contents. Aiming at the position safety management of construction workers, this paper analyzes the functional requirements of the position safety management system, summarizes the information needed to identify the position, trajectory and unsafe area of workers using computer vision technology, proposes the calculation method of the risk degree of workers' behavior in breaking into unsafe areas, and builds a recognition module based on the position and trajectory of workers. The unsafe area identification module and the danger degree calculation and warning module constitute an integrated computer vision construction worker position safety management system. In addition, some scholars have proposed a method of monitoring the construction process of prefabricated buildings based on feature extraction of point cloud models. They have completed the collection of point cloud data on the construction site by using a three-dimensional laser scanner, and obtained the point cloud data on the construction site of prefabricated buildings based on PCL platform, the point cloud data is preprocessed, and the prefabricated component segmentation, geometric feature extraction and measurement are completed Determine the site design elevation by 3D laser scanning technology; Simulate the assembly construction of prefabricated components and realize the monitoring of building construction. Although the above method can realize the monitoring of building construction, there is a problem of large risk error in the monitoring. Therefore, this paper proposes a method of building construction risk monitoring based on mobile terminals. The main research routes of this method are as follows:

(1) Collect and identify the characteristic data of building construction through mobile terminal technology.
(2) Build a construction risk management framework, build a corresponding evaluation system for different construction risks, and improve the construction risk monitoring system.
(3) The experimental results show that the proposed method is practical and fully meets the practical requirements.

2 Construction Risk Monitoring Method Based on Mobile Terminal

2.1 Construction Risk Management Framework Based on Mobile Terminal

2.1.1 Functional Framework of Safety Risk Management Module

Risk management is the top priority of the daily safety management of construction. The level of risk management directly determines the level of on-site safety production. However, mass casualties will always occur in the actual work, which may be due to the inaction of the safety management personnel on the construction site, or due to centralized resumption of work, rush time of some enterprises, rush for tasks, etc. In short, the main reason is that the construction safety risk management is not standardized, or the lack of a certain link of the management process [3]. Therefore, in order to ensure that the whole process of project construction safety and construction management is controllable and realize the systematization of risk management, the research of risk management module is a necessary choice for construction safety management. The security risk management module mainly includes four sub modules: risk source database, risk source upload, risk source audit and risk patrol. The functional framework of safety risk management module is shown in Fig. 1.

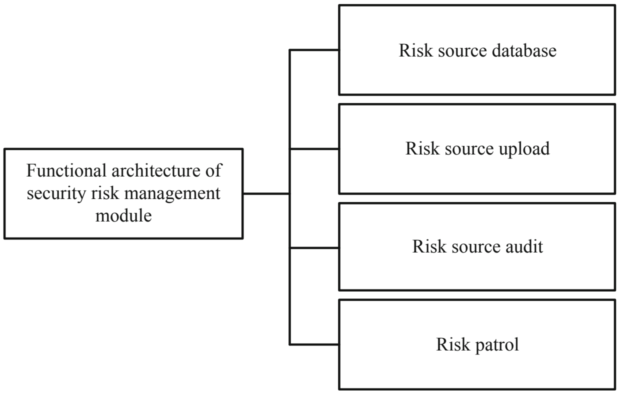

Fig. 1. Functional framework of safety risk management module

Construction risk collaborative management based on mobile terminal mainly refers to the cooperation of two or more different resources and management subjects to jointly complete the safety management of the construction site in the safety management of the construction site. Specifically, the safety collaborative management of construction engineering mainly includes the all-round coordination between different organizations, different departments, different application environments, people and people, people and machines, science and technology and tradition. On the basis of information technology, the safety collaborative management of construction site is to make full use of a variety of information technologies in the safety management of construction engineering, take the construction unit as the main body, and multiple organizations related to construction safety participate in the safety management and supervision of construction site, so as to ensure the smooth progress of construction engineering construction, and eliminate its unsafe factors to the greatest extent [4]. Under the condition of mobile terminal technology, the safety collaborative management level of construction site mainly includes three subsystems: safety training multimedia and assessment, construction site video monitoring, intelligent sensing and Internet of things technology monitoring, as shown in Fig. 2.

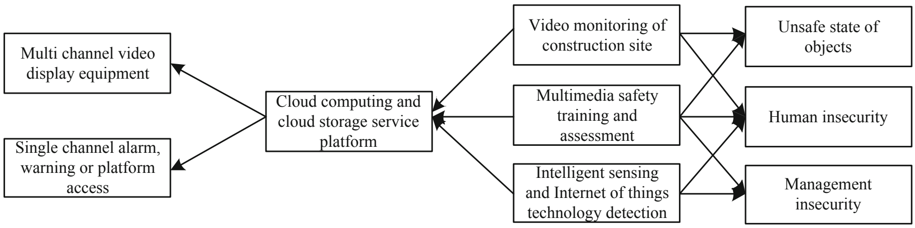

Fig. 2. Construction site safety system management framework

Under the condition of mobile terminal, in the construction of construction project safety management, it is necessary to comprehensively improve the safety awareness and safety problems of project construction personnel. According to the analysis of the causes leading to the safety problems of construction projects, in addition to the irresistible external factors, human is one of the most important factors. For example, the safety awareness of construction personnel and construction management personnel is insufficient, the construction operation must be carried out in strict accordance with relevant regulations during construction, and the safety measures are not set in place during construction. Based on this, in the construction of collaborative safety management system, must strengthen the safety training of relevant construction personnel. In the process of specific safety training, we can make full use of multimedia to visually display the potential safety hazards existing in the construction site and carry out early warning education. At the same time, on the basis of strengthening the training of relevant staff, it is also necessary to set up corresponding assessment mechanism to implement the safety responsibility at all levels [5]. Facing the problems of traditional construction methods, such as high energy consumption, serious waste of resources, large pollution emissions and insufficient labor force, the advantages of building friendly to the environment, high construction efficiency and large reduction of construction personnel are gradually emerging. At the same time, the performance of architecture in engineering quality is also better than that of traditional architecture.

2.1.2 Safety Monitoring and Early Warning Process

According to the theoretical research on the causes of risk accidents, the causes of safety accidents in engineering projects can be attributed to track crossing, that is, when there is overlap between dangerous sources such as human unsafe behavior, material unsafe state and unsafe environment, it is easy to cause safety accidents. Therefore, the fundamental goal of safety monitoring and early warning is to effectively find the hazard sources in the overlapping state or the upcoming track crossing events. All construction activities of the building take place in a fixed space. In order to facilitate safety monitoring, this space can be divided into several fixed size space unit cubes [6, 7]. In each space unit, various hazard information sources can be extracted and feature vectors can be constructed to reflect the safety risk of the space unit. There is a difference between the cell space feature vector with higher security risk and the cell space feature vector with lower security risk. The model constructed by this method has the following advantages: the model has learning ability, and the accuracy of the model continues to improve with the increase of training sample size; The model has good universality and can be applied to different engineering projects: it greatly reduces the system development cost and has better economy [8]. To sum up, the safety monitoring and early warning process based on space unit is shown in Fig. 3.

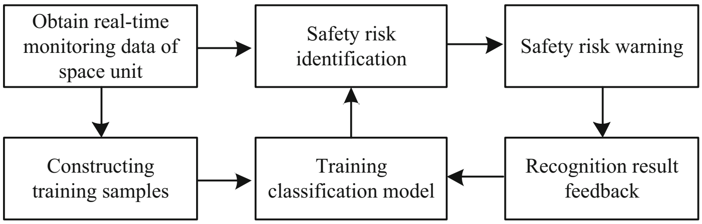

Fig. 3. Analysis, identification and early warning process of space unit construction

There are two key problems in constructing the safety monitoring and risk early warning model. The accurate feature vector is the basis for constructing the safety risk classification and prediction model of the space unit. Therefore, it is necessary to determine how to construct the feature vector of the space unit first, so as to fully describe the various safety States of the space unit. The feature vector classification model of spatial unit based on mobile terminal is established by using mobile terminal technology.

2.2 Construction Risk Evaluation Algorithm

In recent years, in order to facilitate the communication and coordination between the project participants and improve the management and control ability of the project management of the participating units, mobile terminal technology has been introduced into the building continuously. With the maturity of technology, mobile terminal technology has become an indispensable technology in the management and control process of construction projects [9, 10]. Figure 4 shows the mobile terminal construction risk monitoring and management system.

A large number of prefabricated components need to be used in building construction. Component stacking and storage may cause collapse and overturning accidents. See Table 1 for relevant hazard sources.

The discriminant matrix is the relative importance relationship between the child attributes under the same parent attribute. A series of importance relationships are compared in the same matrix to obtain the importance contribution of the child attribute

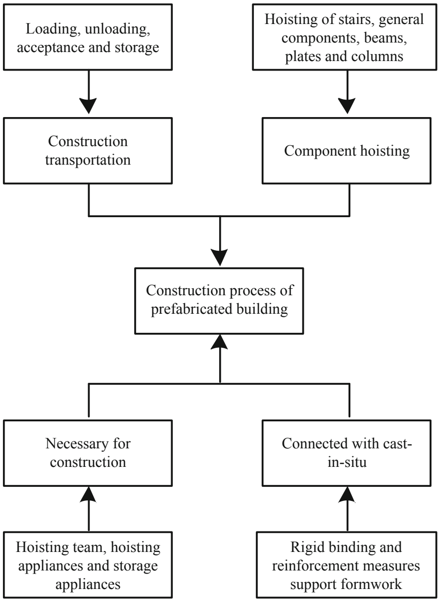

Fig. 4. Mobile terminal construction risk monitoring and management system

Table 1. Hazards in components and storage

Number	Hazard source	Occurrence link
A	The number of stacking layers exceeds the specified load pressure	Stack
B	Improper stacking form of components	Storage
C	Insufficient stacking stiffness and bearing capacity	Storage
D	No reinforcement measures are taken when components are stacked	Stack
E	Triangular channel steel support is not placed symmetrically	Stack
F	Component stacking without base plate	Stack
G	The stacking area of components is not within the effective range	Construction preparation
H	The ground of component stacking area is not hardened	Construction preparation

to the parent attribute. Using the discriminant matrix, the relative weight relationship between different levels and parent-child level attributes is gradually realized, and finally integrated into the absolute weight of each level element in the complete system. The specific operation of establishing the discrimination matrix is to establish the discrimination matrix table according to the hierarchical relationship of the index system, and then judge the relative importance of elements according to the important scale table. The discrimination matrix is shown in Table 2.

Table 2. Discrimination matrix

Target layer	S1	S2	S3
S1	1	Q12	Q13
S2	Q11	1	Q13
S3	Q21	Q22	1

The method of using discriminant matrix to solve the index weight method is mainly divided into two steps: the first step is to calculate the relative weight of the elements of a single decision matrix to the W-level elements, and the second step is to calculate the absolute weight of the elements of each layer combined with the hierarchical relationship and relative weight. Calculate relative weights. First normalize the discrimination matrix in columns:

$$w_{ij} = \frac{1}{\sum_{i=1}^{n} w_i}, \ (i = 1, 2, \cdots, n, \ j = 1, 2, \cdots, n) \tag{1}$$

Further, sum the discrimination matrix row by row:

$$w_k = \sum_{j=1}^{n} w_{ij} - n \tag{2}$$

Then, the column direction w_k is normalized to obtain the weight $\lambda_{\max}$ of the risk factor, which is the relative weight of each element. Calculate the discriminant matrix and bring $\lambda_{\max}$ into the formula for testing, and only if the ratio of CI to RI is less than 0.1 can be satisfied:

$$CI = \frac{(\lambda_{\max} - w_k)}{n - 1}, \ (n = 1, 2, \cdots) \tag{3}$$

By referring to the definition of physics, it is judged that the dispersion state of each risk index is recorded as $\left(r_{ij}\right)_{m \times n}$, so as to evaluate the scheme. Due to its objectivity, accuracy and recognition are high. The calculation process is as follows: the construction matrix A contains m evaluation indicators and n objects, namely:

$$A = w_k \left(r_{ij}\right)_{m \times n} - 1 \tag{4}$$

Since the dimension difference of each indicator $f_{t'}$ is relatively large, in order to eliminate its influence, it is necessary to normalize the data:

$$b_y = A \frac{r_{iy}}{r_{\max} - r_{\min}} \tag{5}$$

$$e_i = -\frac{1}{\ln n}\sum_{t=1}^{n} A\left(b_y - \ln f_{t'}\right) \tag{6}$$

Calculate the indicator weight according to the above steps, and the entropy value of the i indicator under (m, n):

$$w_{ej} = \frac{1 - e_1}{m - \sum_{i=1}^{m} e_i} \tag{7}$$

During construction, due to the large quality of prefabricated components on the construction site, it is common for multiple cranes to operate at the same time, which may easily lead to hoisting accidents such as falling, impact, and overturning. See Table 3 for related hazards.

Table 3. Hazardous sources in component hoisting

Number	Hazard source	Occurrence link
A	Unreasonable setting of lifting points	Hoisting process
B	Improper selection of hoisting equipment	Construction preparation
C	Long term overload operation of equipment	Hoisting process
D	Operation error of hoisting operators	Hoisting process
E	Cross interference of tower crane parallel operation	Hoisting process
F	The construction personnel are in the blind area of the tower crane driver's vision	Setup script
G	Worker position conflicts with lifting route	Hoisting process
H	Construction workers did not wear safety belts	Setup script
I	Heavy snow, fog, heavy rain and other bad weather	Hoisting process

The source of danger in Table 3 occurs in the hoisting process. Because the reserved steel bars are pulled out during the hoisting process or the location of the hoisting point is unreasonably selected, it is easy to cause overturning accidents. If there is a danger source A, it is easy to cause overturning accidents. In addition, in the construction site of group tower operation, when multiple tower cranes operate in parallel, it is easy to generate C danger source, which leads to tower crane collision accidents. In addition, when installing prefabricated components, D hazard source may cause a high-altitude fall accident; E hazard source will cause construction difficulties such as reduced visibility at the construction site and prefabricated components swaying with the wind, which can easily lead to accidents.

2.3 Realization of Construction Risk Monitoring Based on Mobile Terminal Technology

Based on the real-time monitoring and early warning mechanism of construction safety, the real-time monitoring and early warning model of building construction safety is constructed by using real-time monitoring data collection and safety risk classification and identification model, as shown in Fig. 5.

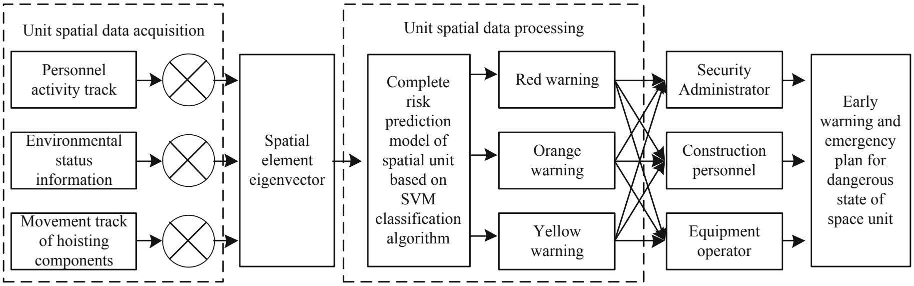

Fig. 5. Model for real-time monitoring and early warning of space unit safety

Construction risk factors involve people, materials, machines, etc., and have a high degree of dispersion. In order to ensure the accuracy of the analysis results of construction risk factors, this paper has studied a large number of relevant domestic and foreign literature, and fully combined with expert interview records (Appendix B), divide these 20 risk factors into five categories according to their essential attributes: personnel, materials, machinery, technology, and management. Finally, the risk evaluation index system of the building construction stage is obtained, as shown in Fig. 6.

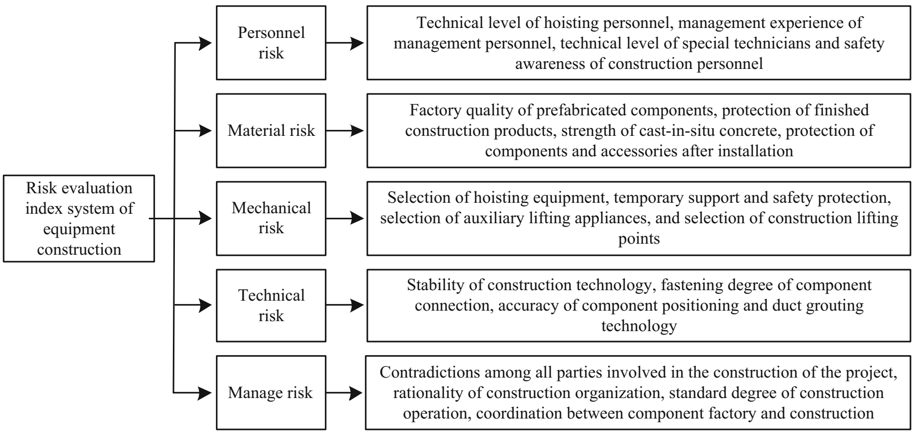

Fig. 6. Final risk factor confirmation chart

The real-time monitoring space unit feature vector is used as the input variable of the space unit security risk classification model, and the output result is the risk identification result. Movement trajectories of workers and hoisting equipment can be monitored through GPS data combined with RFID technology. The risk identification results include: red warning, orange warning, yellow warning and no security risk. Depending on the type of risk warning, different response measures should be taken at the construction site. For the red warning, emergency intervention measures should be taken immediately. The uncertainty associated with construction projects, especially the construction of high-rise buildings, is increasingly complex, the variety and number of risks affecting construction safety are increasing, and the severity of the consequences of these risks is gradually increasing. Therefore, many researchers have begun to pay attention to the study of risk management, and project managers have also begun to pay attention to risk management in the construction process. The research on safety risk management of high-rise buildings is to combine safety management methods with risk management methods to manage the whole process of safety risks in the construction of high-rise buildings.

In order to further improve the effectiveness of safety management, the safety management system needs to be comprehensively adjusted to optimize project management centered on safety technology management and the actual construction needs of high-rise buildings. The optimization of the safety management system needs to be combined with the overall coordination of skyscraper construction project management, supervision and management methods and application of the management system, in order to achieve an overall improvement in the effectiveness of safety management.

3 Analysis of Results

The sample is described by the characteristics of the construction project, and the risk data is estimated based on the previous engineering experience. By reading a large number of documents and consulting professional relevant personnel, the construction area, structure type, number of floors, exterior wall decoration, interior wall decoration, foundation type, storey height, door and window type, and assembly rate are selected as the indicators affecting the construction cost estimation. The above data is quantified according to the complexity of the process. The larger the quantification value, the more complex the process and the greater the potential risk. The specific content is shown in Table 4.

Table 4. Data quantification

Quantized value	2	4	6	8	10
Structure type	Concrete frame	Concrete frame cast-in-situ shear wall	Concrete shear wall	——	——

(*continued*)

Table 4. (*continued*)

Quantized value	2	4	6	8	10
Foundation type	Independent foundation	Strip foundation	Raft foundation	Pile raft foundation	Box foundation
Exterior wall decoration	Face brick	Imitation stone brick	Common coating	Lacquer	——
Interior wall decoration	Cement mortar	Mixed mortar	Latex paint	Coating	——
Assembly area	——	——	By actual data (percentage)	——	——
Number of layers	——	—	According to actual data	——	——

The sample data of 35 completed construction projects were selected, and the MAYLAB2014 software was used for relevant programming. The first 30 sample data were selected as training samples, and the last 5 sample data were used as testing samples. According to the data quantification table and the sample data of the building, the data quantification processing is performed on the training samples and the testing samples. The processing results are shown in Table 5:

Table 5. Quantification of training data

Category	Input vector									Output vector
Serial number	C1	C2	C3	C4	C5	C6	C7	C8	C9	0 (yuan/m^3)
A	14.83	3	1	7	1	2.9	2	3	55	1765
B	16.8	2	1	8	2	2.9	3	3	55	1925.6
C	23.15	3	1	13	3	3	1	3	55	2192.6
D	16.95	2	1	7	3	3	2	1	55	1741.6
E	26.92	1	2	10	3	2.8	3	1	55	2182
F	28.36	1	2	21	3	2.7	3	1	55	2512
G	27.65	3	3	8	4	2.9	2	3	65	2295.6
H	31.3	2	2	13	3	2.9	3	2	75	2689.5

Identify the main influencing factors that affect project risk. Through the calculation, it is concluded that the ability of relevant personnel, the risk of capital supply, the unreasonable division of rights, responsibilities and interests, and the mistakes in production allocation decision-making are the main influencing factors. We should focus on it and take measures to reduce the corresponding risks. Table 6 shows the calculation results of the risk factor of unsafe factors.

Table 6. Calculation results of the risk factor of unsafe factors

Sort	Unsafe factors	Risk coefficient
A	Unreasonable division of rights, responsibilities and interests	1.322
B	Production allocation decision error	0.789
C	Risk of capital supply	0.628
D	Ability of relevant personnel	0.487

Taking concrete structure as an example, the application advantages of building risk monitoring are analyzed, as shown in Table 7.

Table 7. Application advantages of building risk monitoring

Primary coverage	Fabricated concrete structure	Cast in situ concrete structure
Construction progress	Production and construction are separated, and both are carried out at the same time. The construction efficiency is greatly improved, one floor in 3–4 days, and the labor demand is reduced by 50%	The construction efficiency is low and the speed is slow. It takes 6–7 days for one floor, and requires a lot of manual cooperation
Construction quality	The large-scale assembly line production in the factory greatly reduces the quality problems. At the same time, the construction accuracy control is high and the project quality is greatly improved	The error and precision control are low, the spatial size deformation is large, the inspection batches are uneven, and the quality is difficult to guarantee
Resource utilization	Based on meeting the requirements of skill emission reduction and environment-friendly advocated by the state	Large water consumption, large power consumption, serious material loss and large amount of construction waste abandoned in construction
Environmental protection	Due to the special construction process of prefabricated buildings, prefabricated components are not processed on site, avoiding all kinds of pollution caused by concrete pouring on the construction site	The construction site has high dust and noise, and a lot of waste water and garbage, which not only wastes resources, but also needs human treatment

To verify the construction risk monitoring error, the building construction safety monitoring method based on computer vision and the prefabricated building construction process monitoring method based on point cloud model feature extraction are compared with the methods in this paper. The results are shown in Fig. 7.

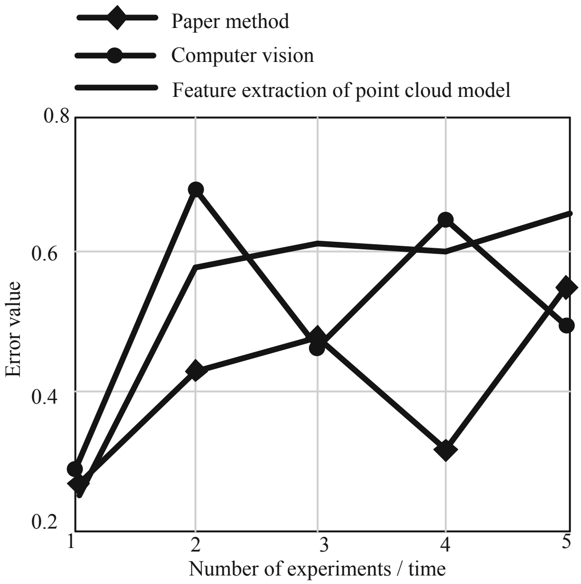

Fig. 7. Risk monitoring error

It can be seen from the results in Fig. 7 that the construction risk monitoring method for mobile terminals constructed in this paper has an error within 5%, so the estimation accuracy is relatively high. Once the sample data and the trained network are obtained, the estimation process is very simple, which saves the tedious work of applying the quota to calculate the engineering volume, which can greatly improve the monitoring and management speed.

4 Concluding Remarks

In construction site construction, safety production management is an important part of construction management. In specific construction management, safety management belongs to a systematic and comprehensive management process. Based on information technology, construction projects must fully combine the current status of safety production management, take effective measures, actively build an information collaborative management system, and comprehensively strengthen the safety management level of construction projects.

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