



Construction Site Inspection System Based on Panoramic Image Cloud Processing Technology

Caihui Wu¹, Xiuyi Wang¹, Bin Chen¹, Xiaolu Deng^{1,1(✉)}, and Minghua Duan²

¹ China Construction Third Bureau Group South China Co., Ltd., Guangzhou 510000, China
466635938@qq.com

² Department of Urban Rail Transit and Information Engineering, Anhui Communications Vocational and Technical College, Hefei 230051, China

Abstract. With the acceleration of the pace of urban construction, the number and scale of construction projects are gradually expanding, so it is essential to reduce the frequency of accidents at the construction site. Therefore, this study proposes a construction site inspection system based on panoramic image cloud processing technology. First, the panoramic image data of the construction site is collected by the panoramic image technology, and the noise information in the panoramic image is removed after the denoising model is constructed based on the compressed sensing theory. Then, MSR algorithm with adaptive scale is applied to enhance the image information. Finally, select the inspection index of construction site, combine with the impact information processing results, evaluate the safety risk level of construction site, and realize the inspection of construction site. The experimental results show that the maximum SNR of the panoramic image of the construction site obtained by the system is 162 dB, and the inspection results of the construction site are consistent with the actual results, which proves that the inspection effect of the system is better.

Keywords: Construction Site · Panoramic Image Cloud Processing Technology · Construction Projects · Site Patrol Inspection · Construction Safety

1 Introduction

The construction industry is the basic industry of national economic and social development, and one of the important symbols to measure the industrialization level of a country and region. In the process of my country's economic system reform, the construction industry, as a pioneering field, provided practical development experience for other industries, and took the lead in bearing the various costs brought about by the system reform. At present, my country's construction industry is far ahead of other industries in terms of marketization with 7% of GDP. With the deepening of the market economy, the construction industry has played a huge role in promoting the rapid development of the economy [1]. However, in recent years, the global economic situation has been tense.

Therefore, the government has continuously adopted the policy of expanding the scale to stimulate domestic demand. Under this form, the scale of my country's construction industry has continued to expand, which has brought great hidden dangers to the safety of construction sites. At the same time, due to the difficulty of construction technology, many uncertain factors on site, and high mobility of operators, construction safety accidents continue to occur, which not only affects the development of the industry, but also poses a huge threat to personal life and property.

In addition to the characteristics of construction itself, the frequent occurrence of construction safety accidents in China is also related to the economic composition of enterprises. Due to the deepening of the economic system reform, the production and operation units in China have changed from the former state-owned and collective economic elements to the coexistence of state-owned, investment, joint-stock system and individual businesses. With the continuous increase of investment, the construction scale of the construction unit has been increasing, which has intensified the industry competition. On the other hand, the competition in the industry has made the society put forward new requirements on construction technology, employees' comprehensive ability, safety assurance system and on-site safety management. In particular, the use of new materials and processes developed by high-tech research and development can greatly shorten the construction period, but the increase in operation difficulty has brought new safety challenges to the construction site.

From 2011 to 2021, with the joint efforts of relevant government departments and construction enterprises, the overall number of construction safety accidents in construction projects has shown a downward trend, which shows that the safety production situation of construction projects in my country in recent years has not been affected by the government. With the joint efforts of relevant departments and construction units, the situation has improved, but the number of accidents in the country is still relatively large every year, which needs to be paid enough attention. Although the government's construction department has continuously increased the management of safety accidents, there are often many uncertain factors at the construction site, and the overall quality of construction workers in my country is generally low, which increases the difficulty of management, and makes construction accidents continue to continue. It has not only increased the cost of enterprises, but also hindered the stable development of the construction industry.

Compared with other developed countries, the incidence of construction accidents in China is still far higher than that in other developed countries, and the number of accidents and casualties has not been effectively contained. Therefore, people pay more and more attention to the safety inspection work in the construction process. It is an important goal and necessity of the construction safety management work, and one of the effective ways for construction enterprises to improve economic benefits, to effectively improve the inspection level of construction safety production, so as to minimize the occurrence of casualties in the construction process, It is also the premise and guarantee for the survival and continuous development of construction enterprises [2]. To sum up, the patrol operation on the construction site is the fundamental criterion to ensure the normal operation of the construction site, an important link to ensure the safety of life and property of on-site personnel, an important guarantee to ensure social stability

and establish a socialist harmonious society, and an important condition to ensure the healthy and rapid development of the construction industry. As the safety inspection of the construction site is not in place, it will inevitably cause huge losses to personnel, enterprises and society, and affect the stable development of economy and society.

At present, relevant scholars have proposed a series of construction site inspection schemes, such as the construction site inspection system based on computer vision, and the construction site inspection system based on deep learning. Based on traditional research, this research designs a building construction site inspection system based on panoramic image cloud processing technology. It is hoped that through the application of panoramic image cloud processing technology, the intensity and effect of building construction site inspection will be improved, and the construction personnel, building The safety of the project provides a more effective guarantee.

2 Design of Construction Site Inspection System

2.1 Analysis Module of Building Construction Characteristics

In order to improve the inspection effect of the construction site, the first step is to deeply explore the characteristics of the construction, so as to lay a solid foundation for obtaining the final inspection results.

According to the existing literature and the actual construction site, the integrated building construction features are as follows:

First, the production environment is limited due to fixed products. The construction products are fixed and cannot be moved. Therefore, operators need to work in the same place. In a limited space, simultaneous construction of multiple types of work often causes various potential safety hazards. At the same time, the use of mechanical equipment makes the working environment noisy and affects the construction of other operators;

Second, the open-air construction conditions are poor. Most building constructions are outdoor open-air operations, and a construction project often takes two or three years, or even longer. The operators start from the construction of the foundation, to the construction of the main structure beams, slabs, columns and walls of the building, and then to the facade of the building. All renovations need to be done in the open air. Coupled with the freezing rain and snow weather, such environmental conditions are very likely to cause safety accidents, adding a layer of difficulty to the work of construction workers;

Third, the staff mobility is strong. Since the construction products are fixed, all construction teams need to enter the site one after another, and then go to the next construction project after the construction is completed [3]. Therefore, they are not familiar with the construction environment, and they often need to reinstall or dismantle the construction equipment when entering the site and entering the next construction project. In the installation of these equipment, even if a small part is loose, it will lead to a major construction accident;

The fourth is the joint operation of multiple types of work. After most of the construction teams enter the construction site, the construction site faces another problem, that is, the joint operation of multiple types of work. Most of the construction workers

are from remote mountainous areas and have low education levels, so they do not pay attention to safe construction. Coupled with the large number of people, this negative safety awareness is even more deeply rooted. Some construction sites are undergoing facade decoration. There is often a phenomenon of construction on the same vertical line, which brings great hidden dangers to the site safety.

When organizing production activities, priority must be given to safety, and necessary safety measures must be taken throughout the production activities. Therefore, the principles of construction site safety management are as follows:

- (A) Implement the policy of “safety first, prevention first, and comprehensive management”, establish a supporting management system, intensify efforts to rectify safety management, and reduce the occurrence of general accidents;
- (B) According to the “Construction Law”, “Safety Production Law” and other laws and regulations, combined with the specific characteristics of the unit’s construction, and the relevant national regulations and standards to formulate a safety production management system;
- (C) The basic requirements and contents of the safety production management system must be included. Since different projects will have different situations, it is necessary to adjust and improve the system in combination with the actual situation and characteristics of the project to ensure the construction safety of the project;
- (D) It is targeted. The established management system should be applicable to all aspects of the project and can be used for reference by other projects, but it cannot mechanically copy the management measures of other projects without adjustment;
- (E) The principle of continuous improvement: when the construction unit manages according to the production management standards formulated by the unit, it should not only implement the work, but also constantly find problems and constantly improve the standard system [4].

2.2 Panoramic Image Denoising Processing Module

Based on the analysis results of the above building construction characteristics, the panoramic image technology is used to obtain the panoramic image data of the building construction site, which is used as the basis for the inspection of the construction site, and the inspection procedure of the construction site is simplified. Due to the numerous on-site factors, there is a lot of noise in the panoramic image, which affects the inspection effect of the construction site. Therefore, before applying the panoramic image, a denoising model is constructed based on the compressed sensing theory, and the panoramic image is denoised to improve the signal-to-noise ratio of the panoramic image.

The application of compressed sensing theory to digital image denoising is one of the research focuses in the field of image processing in recent years. The theory of compressed sensing makes full use of the advantage that the signal can be represented sparsely, and has achieved remarkable results in image denoising.

Panoramic image denoising under the framework of compressed sensing theory can be regarded as the process of restoring high-dimensional panoramic image signals from a low-dimensional panoramic image observation space, and this low-dimensional panoramic image observation space contains a large number of restored original panoramic image signals. Information [5]. In compressed sensing theory, panoramic

image signals can be sparsely represented on a sparse representation basis, while noise signals cannot be sparsely represented. Therefore, the noisy panoramic image signal can be expressed as the superposition of the sparsely representable panoramic image signal and the non-sparsely representable noise signal. The noise included, its flow chart is shown in Fig. 1.

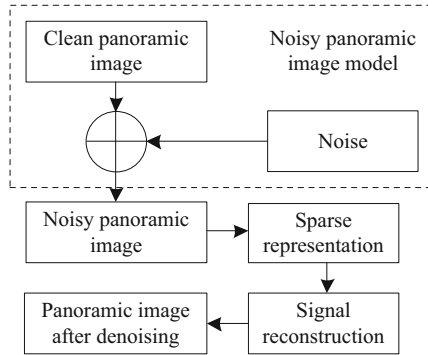


Fig. 1. Model diagram of panoramic image denoising based on compressed sensing

As shown in Fig. 1, the simplified mathematical model expression of the noisy panoramic image of the construction site is:

$$\beta = \alpha + \chi \tag{1}$$

In formula (1), β represents the noisy panoramic image of the building construction site; α represents the clean panoramic image of the building construction site; χ represents the noise collection.

The K-SVD algorithm is a dictionary learning algorithm based on singular value decomposition. It can construct an overcomplete dictionary B so that the given training signal can be sparsely decomposed on B . Its objective equation is:

$$\begin{aligned} \min_{A, \alpha} & \left\{ \|\beta - B\alpha\|^2 \right\} \\ \text{s.t. } & \forall i, \|\alpha_i\|_0 \leq \delta \end{aligned} \tag{2}$$

In formula (2), $B = [b_1, b_2, \dots, b_n]$ indicates that the dictionary is initialized too completely; β represents the given noisy panoramic image training signal of the construction site; α represents the matrix composed of sparse coefficients; α_i stands for column i of α ; δ represents the upper limit value of the number of non-zero elements contained in the sparse coefficient.

In the training process, the K-SVD algorithm can be divided into two steps: sparse coding and dictionary update, as follows:

① Sparse coding: fix the initial overcomplete dictionary B , use the OMP algorithm to solve the sparse coefficient matrix α for the target equation, and use the hard threshold as the iterative stop condition during the solution process;

② Dictionary update: During this process, the sparse coefficient matrix α remains unchanged, and each column of the overcomplete dictionary B is updated one by one. When the j column b_j of B is to be updated, the objective function of formula (2) can be transformed into the following formula:

$$\|\beta - B\alpha\|^2 = \left\| \beta - \sum_{k=1}^n b_k \alpha_k \right\|^2 = \left\| \left(\beta - \sum_{k \neq j}^n b_k \alpha_k \right) - b_j \alpha_j \right\|^2 \quad (3)$$

Based on the sparse coding results of the noisy panoramic image of the building construction site, assuming the size of the panoramic image is $n \times n$, use a window with size $m \times m$ to slide on β for block sampling [6]. The optimization problem of formula (2) can be converted into an objective function:

$$\left\{ \tilde{\tau}_{ij}, \tilde{B}, \tilde{\alpha} \right\} = \arg \min \eta \|\alpha - \beta\|_2^2 + \sum_{ij} \lambda_{ij} \|\tau_{ij}\|_0 + \sum_{ij} \|B\tau_{ij} - K_{ij}\beta\|_2^2 \quad (4)$$

In formula (4), $\left\{ \tilde{\tau}_{ij}, \tilde{B}, \tilde{\alpha} \right\}$ represents the panoramic image information set after denoising processing; $\arg \min \eta \|\alpha - \beta\|_2^2$ represents the similarity between the noisy panoramic image and the clean panoramic image; $\sum_{ij} \lambda_{ij} \|\tau_{ij}\|_0$ represents the global sparsity limit; $\sum_{ij} \|B\tau_{ij} - K_{ij}\beta\|_2^2$ represents the noisy panoramic image and the reconstructed clean image. The total error between panoramic images; K_{ij} represents an auxiliary parameter matrix; $K_{ij}\beta$ represents an image from which β is extracted; τ_{ij} represents the sparse representation coefficient of the noisy panoramic image on the dictionary B ; η and λ_{ij} represent the penalty factor.

By solving the formula (4), the corresponding information of the clean panoramic image of the building construction site can be obtained, and the expression is:

$$\begin{cases} \tilde{\tau}_{ij} = \arg \min_{\tau_{ij}} \sum_{ij} \lambda_{ij} \|\tau_{ij}\|_0 + \sum_{ij} \|B\tau_{ij} - K_{ij}\beta\|_2^2 \\ \tilde{B} = \arg \min_B \sum_{ij} \lambda_{ij} \|\tau_{ij}\|_0 + \sum_{ij} \|B\tau_{ij} - K_{ij}\beta\|_2^2 \\ \tilde{\alpha} = \left(\eta I + \sum_{ij} K_{ij}^T K_{ij} \right)^{-1} \left(\eta \beta + \sum_{ij} K_{ij}^T B \tau_{ij} \right) \end{cases} \quad (5)$$

In Formula (5), $\tilde{\tau}_{ij}$, \tilde{B} and $\tilde{\alpha}$ respectively represent the sparse representation coefficient, dictionary and panoramic image of the construction site after noise removal; I represents the identity matrix [7].

The above process has completed the noise removal of the panoramic image, and output the panoramic image $\tilde{\alpha}$ of the construction site. However, there are still fuzzy areas, and accurate construction site information cannot be obtained. Therefore, the panoramic image is enhanced in the next section, as shown in the following section.

2.3 Panoramic Image Enhancement Processing Module

Based on the above-mentioned denoising result $\tilde{\alpha}$ of the panoramic image of the building construction site, the MSR algorithm of the adaptive scale is used to enhance the processing of the panoramic image of the building construction site, improve the overall quality of the panoramic image of the building construction site, and provide the basis for the final inspection results of the building construction site.

MSR algorithm is one of the Retinex algorithms with better fuzzy processing effect. However, in the process of use, the incident component estimation needs to be applied to the whole image, but it does not analyze the degradation degree of different parts of the image, resulting in the inability to effectively blur the details of different scales of the image;

Therefore, this study proposes an adaptive scale MSR panoramic image enhancement processing method, so that the filter can make corresponding changes according to the local information changes of the panoramic image. At the same time, the incident component is also adjusted to adapt to the relevant changes, highlighting the details of the panoramic image while suppressing the background.

The specific steps of panoramic image enhancement processing of the construction site are as follows:

Step 1: Color space conversion

In the panoramic image of the color building construction site, there is a close relationship between the three components R , G , and B . In the past processing process, these three components will be processed separately, which requires a huge amount of calculation on the one hand., on the other hand, there is a gap in the color of the processed panoramic image [8]. In the HSI (hue, saturation, intensity) space, the following two components will be separated, namely the luminance component and the color component. In this paper, the R , G , and B spaces of the panoramic image are converted into the HSI space to ensure that the color space can be To maintain stability, the ratio of the R , G , and B components to the I component is retained here. The conversion of R , G , B components to I components is expressed as:

$$I = \frac{R + G + B}{3} \quad (6)$$

In order to make the color of the panoramic image of the construction site stable, it is necessary to compare the three color components and brightness components of the original construction site panoramic image in this process. The ratios are P_R , P_G , and P_B . To avoid errors in the process of zero division, when the brightness value of a panoramic image reaches 0, it is automatically set to I .

Step 2: Retinex processing of adaptive scale

In the Retinex algorithm, one of the core parameters is ν , which determines which details in the panoramic image need to be preserved and which need to be eliminated. In the multi-scale Retinex algorithm, various types of algorithm results need to be weighted to stabilize the dynamic range of panoramic images and achieve a compromise effect in terms of color consistency, which involves two issues: the definition of scale and the choose.

In general, there are three types of algorithm scale selection, namely, small scale, mesoscale and large scale. After a lot of experimental research, the corresponding conclusions are drawn. The relationship between the scale of Retinex algorithm and the actual processing results is shown as follows:

- a) If the algorithm scale is determined to be 1% to 5% of the size of the panoramic image, it will have a good effect in obtaining the edge details of the panoramic image, which can be used as a small scale;
- b) If the algorithm scale is determined to be 10% to 15% of the size of the panoramic image, it will have a good effect in obtaining the edge details and colors of the panoramic image, which can be used as a medium scale;
- c) If the algorithm scale is determined to be 30% to 50% of the size of the panoramic image, it will have a good effect in obtaining the balanced color of the panoramic image, which can be used as a large scale.

The panoramic image of the construction site is processed according to the above standards. It can be seen from the results that the smaller the selected scale, the more detailed the panoramic image can be, but it also has higher noise, but the noise also increases. The smoother the image, the more stable the color.

When selecting the scale, it is necessary to combine the size of the panoramic image. If a series of panoramic images have the same size, after determining the scale, the algorithm can perform good processing on all panoramic images of the series at the same time [9]. In specific practice, people often determine the scale according to their own needs. For example, if you want the panoramic image to express details more accurately, you can choose to add a small scale to meet the requirements, or adjust the weight of small-scale Retinex results to a larger value.

The scale selection function expression is:

$$v_{i,j} = \begin{cases} v_L & H_{\min} \leq \Phi_{i,j} \leq H_{\min} + H \\ v_M & H_{\min} + H < \Phi_{i,j} \leq H_{\min} + 2H \\ v_S & H_{\min} + 2H < \Phi_{i,j} \leq H_{\max} \end{cases} \quad (7)$$

In formula (7), $v_{i,j}$ represents the scale selection result; v_L , v_M and v_S represent large scale, medium scale and small scale respectively; H represents the variance of the area where each pixel of the panoramic image is located; H_{\min} and H_{\max} represent the minimum and maximum values corresponding to H . value; $\Phi_{i,j}$ represents the variance value corresponding to the panoramic image pixel (i, j) .

Step 3: Brightness image contrast blurring

This method can better compress the dynamic range and ensure the stability of color and brightness. However, through specific practice, we found that the panorama image obtained after processing with this algorithm will be more gray than the original panorama image, and even lead to white film in some cases, resulting in unsatisfactory visual effect. In order to make the panorama image more recognizable, The histogram equalization method is used to reprocess the blurred panoramic image. Due to the limited space, the processing results are not displayed.

Step 4: Restore color

In order to restore the color of the panoramic image, the ratio value can be calculated by combining the color component of the original panoramic image with the luminance

component. The ratio value is the R' , G' , and B' component values of the new panoramic image, and the expression is:

$$\begin{cases} R' = P_R \times I' \\ G' = P_G \times I' \\ B' = P_B \times I' \end{cases} \quad (8)$$

In Formula (8), I' represents the brightness component of the panoramic image after histogram equalization.

The above process has completed the enhancement processing of the panoramic image of the construction site, highlighted the details of the panoramic image, and prepared for the subsequent inspection results.

2.4 Acquisition Module of Inspection Results of Building Construction Site

Based on the above-mentioned enhanced and processed panoramic images of the construction site, the inspection indicators of the construction site are selected to evaluate the safety risk level of the construction site, and based on this, the inspection operation of the construction site is realized.

The construction site inspection indicators need to be selected from multiple angles and levels to accurately and practically assess the level of site safety risks. Therefore, the construction site inspection indicators are selected according to the principles of scientificity, comprehensiveness, feasibility, comparability and pertinence, as shown in Table 1.

Based on the indicators shown in Table 1, the procedures for obtaining the inspection results of the construction site are formulated as follows:

Step 1: Determine factor set X and evaluation set Z

The factor set of the evaluation object is a set of all influencing factors. For the evaluation of the safety risk level of the construction site, the factor set represents the set of various indicators of the evaluation, which is marked as $X = \{X_{11}, X_{12}, \dots, X_{ij}, \dots, X_{nm}\}$. The value range of n is 1–5, and the value range of m is 1–4.

Evaluators will have different results when they score different factors, and the collection of these results is called the evaluation set. In the evaluation set $Z = \{Z_1, Z_2, \dots, Z_q\}$, Z_j represents each evaluation result. In this paper, the safety risk situation of the construction site is divided into five levels, namely, low safety risk Z_1 , low safety risk Z_2 , general safety risk Z_3 , high safety risk Z_4 , and high safety risk Z_5 , namely $Z = \{Z_1, Z_2, Z_3, Z_4, Z_5\}$.

Step 2: Establish the fuzzy relation matrix

The fuzzy relation matrix represents the fuzzy relation from X to Z , which is marked as $A F = (f_{ij})_{n \times m}$. f_{ij} indicates the degree of membership of factor X_{ij} . As it involves the rating of various indicators of the safety risk level of the construction site, and some indicators cannot be measured quantitatively, in order to reflect the actual situation of the indicators more objectively, language values are used for evaluation. The initial score of each index is 100 points. The final score of each index is determined by inviting experts to give a score. Set 90–100 points as low security risk, 85–90 points as low security risk,

Table 1. Construction site inspection index table

First-level indicator	Code	Secondary indicators	Code
Human factor	X1	Security awareness at the operational level	X11
		Security awareness of management	X12
		Security Awareness of Leadership	X13
Material factor	X2	Personal protection	X21
		On-site protection	X22
		Safety sign	X23
		Equipment	X24
Scheme and technical factors	X3	Scaffolding Construction Technology	X31
		Machinery and equipment construction technology	X32
Institutional factors	X4	Safety Production Responsibility System	X41
		Security check	X42
		Safety Education and Training	X43
		Accident prevention	X44
Environmental factor	X5	Natural environment	X51
		Working environment	X52
		Surroundings	X53

65–85 points as general security risk, 50–65 points as high security risk, and less than 50 points as high security risk.

Step 3: Determine the evaluation weight D

The weight reflects the importance of each factor in the safety management of the construction unit. The corresponding weights d_{ij} are assigned to each factor X_{ij} , while satisfying $\sum d_{ij} = 1$, these weights form a weight set D (the weight results obtained by the network analysis hierarchy process).

Step 4: Fuzzy operation

The evaluation result of fuzzy comprehensive evaluation can be obtained by fuzzy operation between fuzzy matrix F and weight set D . If the fuzzy comprehensive evaluation set is set to C , then:

$$C = D \times F = (d_{11}, d_{12}, \dots, d_{nm}) \cdot \begin{bmatrix} f_{11} & f_{12} & \dots & f_{1m} \\ f_{21} & f_{22} & \dots & f_{2m} \\ \vdots & \vdots & f_{ij} & \vdots \\ f_{n1} & f_{n2} & \dots & f_{nm} \end{bmatrix} \tag{9}$$

According to the calculation result of formula (9), the inspection result of the construction site is determined, and the determination rule is as follows:

$$\left\{ \begin{array}{ll} C \in [0, 0.50) & \text{High security risk} \\ C \in [0.50, 0.65) & \text{High security risk} \\ C \in [0.65, 0.85) & \text{General security risk} \\ C \in [0.85, 0.90) & \text{Low security risk} \\ C \in [0.90, 1] & \text{Low security risk} \end{array} \right. \quad (10)$$

Through the above process, the determination of the safety risk of the construction site is completed, the operation of the construction site inspection system is realized, and an effective guarantee is provided for the safe construction of the construction project.

3 Experiment and Result Analysis

3.1 Experiment Preparation Stage

A construction project is selected as the experimental object, which is composed of 7#, 8#, 9#, 10#, 11# buildings, podium and underground garage. The total building area is 117095 square meters, of which 7#, 8#, 10# buildings are 33 floors above the ground and 1 floor below the ground; Building 9# is one floor underground, 27 floors above the ground and 22 floors locally; Building 11# has one underground floor, 33 floors above the ground and 24 floors locally, and all underground garages have one underground floor. The construction area of the main building is 98.945 million square meters, and the construction area of the garage and basement is 18.15 million square meters. The design grade of building engineering belongs to large high-rise building, and the fire resistance rating is Grade I. The seismic fortification intensity is Grade VIII, and the structure type is cast-in-place reinforced concrete shear wall structure.

Through on-the-spot investigation on the construction site of this project, and according to the construction site inspection index system established above, the construction site inspection index of the experimental object is evaluated. According to the actual situation of on-site safety management of the project, based on the scoring standards in each standardized scoring table, a review team composed of 5 experts will score the results of the standardized safety management of the project. After counting the scores of each standardized scoring table, the weight value of the construction site inspection index is determined, as shown in Table 2.

The above process has completed the determination of the weight value of the construction site inspection index, providing convenience for the smooth implementation of subsequent experiments.

3.2 Analysis of Experimental Results

In order to display the application performance of the design system more clearly, the signal-to-noise ratio of the panoramic image of the construction site and the inspection results of the construction site are selected as the evaluation indicators.

Table 2. The weight table of the construction site inspection index weights

Secondary indicators	Code	Weight value
Security awareness at the operational level	X11	0.090
Security awareness of management	X12	0.101
Security awareness of leadership	X13	0.095
Personal protection	X21	0.042
On-site protection	X22	0.041
Safety sign	X23	0.021
Equipment	X24	0.030
Scaffolding construction technology	X31	0.078
Machinery and equipment construction technology	X32	0.060
Safety production responsibility System	X41	0.083
Security check	X42	0.057
Safety education and training	X43	0.079
Accident prevention	X44	0.062
Natural environment	X51	0.022
Working environment	X52	0.058
Surroundings	X53	0.081

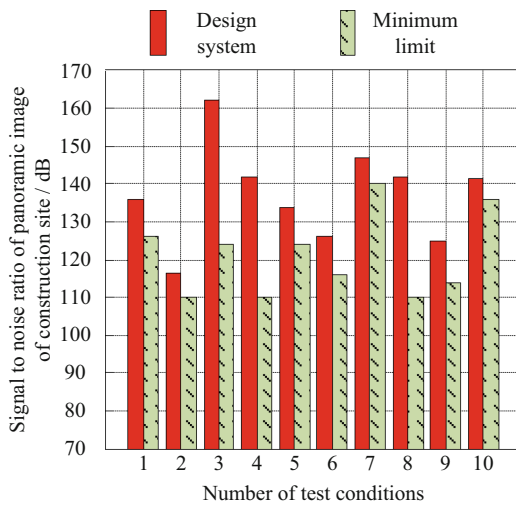


Fig. 2. The data map of the signal-to-noise ratio of the panoramic image of the building construction site

The signal-to-noise ratio data of the panoramic image of the building construction site is shown in Fig. 2.

As shown in Fig. 2, the SNR values of the panoramic image of the construction site obtained by applying the system in this paper are all greater than the given minimum limit, and the maximum value reaches 162dB.

The inspection results of the construction site obtained through the experiment are shown in Table 3.

Table 3. Result of inspection on construction site

Number of test conditions	Construction site safety risk level	
	This article system	Actual results
1	Generally	Generally
2	High	High
3	Low	Low
4	Lower	Lower
5	High	High
6	Higher	Higher
7	High	High
8	Low	Low
9	Low	Low
10	Lower	Lower

As shown in Table 3, under different experimental conditions, the inspection results of the construction site obtained by applying the system in this paper are consistent with the actual results.

The above experimental results show that the signal-to-noise ratio of the panoramic image of the construction site obtained by the application of the design system is greater than the given minimum limit value, and the inspection results of the construction site are consistent with the actual results, which fully proves the effectiveness and feasibility of the design system.

4 Conclusion

The introduction of panoramic image cloud processing technology to propose a new design and research of building construction site patrol system can effectively increase the signal to noise ratio of building construction site panoramic image, improve the accuracy of building construction site patrol results, provide more effective system support for building construction site patrol, and also provide some reference for related research.

However, the real-time performance of the system in this paper still needs to be improved. Therefore, in the future research, the system in this paper will be further optimized in terms of reducing the data transmission time.

References

1. Li, Z.Y., Zhang, D.S., Du, Y.B.: An intelligent safety inspection system based on AR technology. *J. Beijing Univ. Chem. Technol. (Nat. Sci. Ed.)* **49**(05), 59–66 (2022)
2. Hashiguchi, N., Kodama, K., Lim, Y., et al.: Practical judgment of workload based on physical activity, work conditions, and worker's age in construction site. *Sensors* **20**(13), 3786 (2020)
3. Chen, W., Ouyang, Y., Mo, M.: Site construction of Eu²⁺ and sensitized luminescence of Eu³⁺ in LaF₃: Eu nanophosphor. *J. Am. Ceram. Soc.* **105**(4), 2646–2654 (2022)
4. Liu, S., Liu, D., Muhammad, K., et al.: Effective template update mechanism in visual tracking with background clutter. *Neurocomputing* **458**, 615–625 (2021)
5. Sukamani, D., Wang, J., Kusi, M.: Impact of Safety worker behaviour on safety performance in construction firm of Nepal; a moderated mediation model. *Eng. Lett.* **28**(4), 1271–1286 (2020)
6. Martinez, J.G., Gheisari, M., Alarcón, L.F.: UAV integration in current construction safety planning and monitoring processes: case study of a high-rise building construction project in Chile. *J. Manag. Eng.* **36**(3), 1–15 (2020)
7. Liu, S., Wang, S., Liu, X., et al.: De Albuquerque, human memory update strategy: a multi-layer template update mechanism for remote visual monitoring. *IEEE Trans. Multimedia* **23**, 2188–2198 (2021)
8. Bridi, M.E., Formoso, C.T., Saurin, T.A.: A systems thinking based method for assessing safety management best practices in construction. *Saf. Sci.* **141**(2), 105345 (2021)
9. Mou, P., Du, J., Chen, M., et al.: Construction engineering management information system application in safety management of construction engineering. *Guangzhou Arch.* **49**(02), 52–56 (2021)
10. Sukamani, D.: SEM model for investigating factor of an accident affecting safety performance in construction sites in Nepal. *Eng. Lett.* **28**(3), 783–795 (2020)