

Research Article

Joint Inspection of HD Video and Robot in Substation Based on OCR Technology

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The research on the joint inspection technology of HD video and robot in substation is of great significance in the operation and maintenance management of substation. The related research on multidimensional collaborative inspection technology of substation has attracted great attention. The substation monitoring system is designed to realize multidimensional collaborative inspection of HD video and inspection robot. OCR technology is used to improve the abnormal recognition system of inspection robot equipment. According to the collection of video information, DSP comprehensive information processing is carried out, and the detection information is analyzed by frequency domain filtering method through human-computer interaction interface. Meanwhile, the main component features of substation detection components are extracted by pattern recognition method, and the resolution model of similar features of video monitoring images is constructed. It plays an important role in the daily operation and maintenance of substation to construct the reliability visual tracking and identification model and optimize the multidimensional cooperative inspection system model.

1. Introduction

With the continuous development of power system automation technology, substation is responsible for voltage conversion, current aggregation, power distribution, and other functions in the power grid. It is an important node and is developing to the direction of unattended. The inspection of unattended substation plays an extremely important role in ensuring the normal work and safe operation of equipment in substation [1]. The traditional inspection method is carried out manually. It is necessary for the personnel on duty to regularly go to each substation to check the electrical equipment one by one with hand-held instruments to collect a large number of operating state data. With the increase in the scale and number of substations, the manual inspection work has gradually become complicated and cumbersome, which cannot guarantee the attendance rate and timeliness of the manual inspection. The contradiction between the number of substations and the number of substations on duty is increasingly prominent [2]. At the

same time, the quality of manual inspection has great randomness, which is related to various factors such as the responsibility, mental state, work experience, and business proficiency of the operators. Manual inspection has always been low efficiency, high labor intensity, scattered detection quality, and high management cost. Moreover, manual inspection has great safety risks in the alpine and cold regions or in the inclement climatic conditions, and there is a lack of other effective inspection means [3].

With the continuous development of image monitoring technology, robot technology, and computer technology, as well as the promotion of intelligent substation and unattended substation mode, the image monitoring system and robot are gradually replacing manual substation inspection. The image monitoring system is an indispensable part of unattended substation [4]. It can make the staff in the centralized station timely grasp the operation of the equipment of the substation under their jurisdiction and the safety situation of the station area. Substation inspection robot, as a mobile execution terminal of substation

equipment inspection, can carry a variety of instruments such as HD camera and infrared imager. It can check substation equipment one by one by automatic or remote control. It can also use image matching technology and OCR text recognition technology to obtain a variety of information that traditional relay protection equipment cannot obtain, such as outdoor primary electrical equipment appearance anomaly, temperature anomaly, and sound anomaly [5]. The ability of inspection robot in single and repeated inspection work of substation equipment is obviously more than that of manual. It not only greatly reduces the workload of electric workers but also improves the quality and efficiency of inspection work of substation equipment, effectively promoting the unattended process of substation equipment [6].

1.1. Research Status. In recent years, the video surveillance industry has developed rapidly in China. It mainly passes through several important periods: before 2005, mainly analog video surveillance; from 2005 to 2008, development into the digital surveillance era; and from 2009 to now, digital network monitoring, HD video, intelligent analysis, and other advanced technologies are introduced [7].

In recent years, domestic manufacturing industries have developed rapidly in the period of network digitization. A large number of enterprises, such as Hangzhou Haishi, Tiandiweiye, Shenzhen Tiyue, Nanjing Nanrui, Dahua, Dali, and Hanbang High-Tech, have developed their own terminal equipment technology. Moreover, the centralized platform system has become a new direction. The rapid development of domestic video enterprises has promoted the development of products and technologies in China's video surveillance industry towards IP and network [8]. Foreign video industry has always been ahead of domestic. The production of core camera components is mainly provided by large companies in the United States, Japan, and other countries. The main brands are SONY, Diorica, Philips, JVC, Samsung, Panasonic, Hitachi, Esculp of the United States, Bosch of Germany, Pelco, and so on [9]. The purpose of designing the video surveillance system is to control the substation inspection robot to complete the inspection task by providing information through the vision sensor. Its development is closely related to substation inspection robots [10]. Substation inspection robot is an important branch of special electric robot, which integrates environment perception, dynamic decision-making and planning, behavior control and execution, and other functions, and is used to detect and maintain the electrical equipment in the outdoor substation. By means of autonomous or remote control, it helps the maintenance personnel to complete the safety protection work of the substation system [11].

The first power inspection robot to be put into practical use was developed by Sawada et al. [1]. It used a wheeled mechanism to drive on high-voltage lines and to cross the obstacles of telephone poles through a hanging arm. The early research mainly focused on the design of the inspection robot body, and the control of the robot was limited to the field remote control and did not form a complete monitoring

system [12]. Inspired by transmission line inspection robots, Pinto et al. [2] designed a robot that moves on cables to inspect substation environments. The robot is equipped with an infrared camera to take infrared images and monitor the working temperature of on-site equipment in the substation. The operator can obtain the infrared image information captured by the robot through a video monitoring system based on graphical interface and give control instructions to the robot. The monitoring system can control the robot to carry out autonomous inspection. When the temperature abnormal instrument is found, the system will record the information and inform the operator [13]. The robot, designed and developed by the Tokyo Institute of Technology, uses two flexible arms to detect transmission lines by climbing power lines and switching routes between poles based on the previous cantilever robot. The robot is designed to prevent inspectors from climbing wires over dangerous areas to detect the state of the lines. It is an alternative tool, so the robot can only work in the state of remote control, and there is no complete background service program designed for recording inspection results [14]. Dymond et al. designed an unmanned helicopter to carry out inspection of high-voltage transmission lines. Their research focuses on the motion control and visual servo of the helicopter during the inspection process to ensure the reliability of the inspection system during the mission [15].

There are bottlenecks and breakthroughs in the domestic research on video surveillance and robot joint inspection. Wang et al. [5] extended the application of the unmanned helicopter to inspection of more electrical equipment. The systems mentioned above all use the remote control helicopter as the robot platform. The main content of the research is how the helicopter carries out line tracking according to the wire in the video picture and detects whether there is any abnormal problem in the line tracking [16]. Guo [6–8] and his colleagues used wheeled mobile robots as a platform to design a series of substation inspection robots that can be used on flat roads, named SmartGuard, and have been used in actual substations. The SmartGuard uses HD video and infrared cameras to detect unusual objects on the surface of the device and monitor its temperature. Because the reliability of the system can be guaranteed, the system is suitable for long-term continuous inspection of substation site. Moreover, SmartGuard also has a complete set of the graphic video surveillance system, which can display the running status of the robot, record the inspection results, and control the robot [17]. Park et al.'s Robot Company has developed a transformer substation inspection robot, which is waterproof, dust-proof, and crash-proof and can not only withstand high temperature but also cold. The robot is equipped with an infrared night vision light, which allows it to patrol at night [18]. Orsino, Science and Technology Co., Ltd., developed the intelligent inspection robot with visible light camera and thermal imaging device and adopted laser navigation and positioning method, video monitoring, tunnel environment monitoring and independent charging, and other functions; the robot is characterized by adopting modular design to monitor all aspects of substation equipment [19]. Osman and Kovačić developed an indoor rail

inspection robot for substation. The robot has the functions of background communication, navigation and positioning, motion control, power supply management, safety, and collision avoidance [20].

1.2. Content and Methods. Based on the current situation of substation video monitoring, this paper designs the high-definition video monitoring system. Image matching technology and OCR text recognition technology are used to improve the inspection robot so that the inspection robot can diagnose the abnormal appearance and temperature of substation equipment. The multidimensional collaborative inspection technology of substation based on robot video surveillance is studied to promote the construction of the substation remote inspection system based on “HD video+ robot,” so that the video system of substation and robot inspection system can be combined with each other, information can be connected, and joint intelligent strategy can be improved [21].

In this paper, the key technology research of the substation inspection robot is mainly reflected in three aspects: mobile walking, navigation and positioning, and equipment detection.

- (1) *Mobile Walking.* According to the different principles of moving and walking, inspection robots can be divided into three types: orbital robot, wheeled robot, and tracked robot. The navigation of the orbital mobile mechanism is stable and reliable, but it sacrifices the mobility of the inspection robot, and the construction of the orbital facilities is tedious. The wheeled inspection robot is the most commonly used type; it has the characteristics of flexibility and action efficiency. The tracked robot has a certain ability to cross obstacles and can enter the equipment area of the substation, which expands the working scope of the inspection robot [22].
- (2) *Navigation and Positioning.* The movement and navigation of the orbital inspection robot are completely dependent on the fixed track, so the situation is relatively simple. For wheeled and tracked inspection robots, the most commonly used navigation method is magnetic track navigation and assisted positioning by RFID tags. Image processing technology is used to realize robot navigation for preset guide rails and parking spots. With the development of research, the navigation and positioning of the inspection robot gradually develop from a single navigation mode to a combination of multiple navigation modes so as to achieve the complementary advantages of different navigation schemes [23].
- (3) *Equipment Detection.* The detection and diagnosis of substation equipment mainly depend on the infrared imager, HD camera, and pick-up sensors to measure and analyze the temperature, appearance, and noise of equipment, respectively. Infrared temperature measurement mainly relies on infrared images

returned by infrared thermal imaging to read the temperature value of the fixed point in the image to obtain the temperature of substation equipment. The abnormal appearance detection and instrument reading mainly use the image and template matching technology to compare and analyze, so as to identify the fault. Noise monitoring is mainly aimed at transformers. The method of “AR parameter model + Gaussian background model + frequency domain characteristic analysis” is adopted to construct a comprehensive model and then determine whether the transformer is in normal state [24].

2. Intelligent Video Surveillance Design

2.1. Image Monitoring System. The video monitoring system of substation is generally composed of substation, master station, and transmission channel. The general system structure is shown in Figure 1.

The substations are responsible for controlling the inspection robots to collect, encode, and transmit video information and alarm information. Some substations also have storage systems for local video storage [25]. The master station is responsible for receiving the image information and alarm information of the substation and displaying them on the large screen. It can also send control commands to the substation to control the PTZ and retrieve the video. The channel is an important part of the system. Most substations can transmit compressed images over a 2 Mbit/s channel. With the development of power communication, now some cities have used the transmission bandwidth of 4 Mbit/s or even plan a larger bandwidth for the transmission of substation video surveillance.

The distributed front-end and platform structure, centralized management, and control make the storage part of the network video surveillance system start to network. Networked storage enables flexible storage deployment and easy access. On the other hand, it is more convenient to build a video surveillance system that needs to realize large storage capacity. After different coding processing, HD video has different requirements according to different bit rates. The storage upper limit depends on the capacity of each substation. When the remaining capacity cannot meet the needs of the substation for video storage, the memory needs to be cleared. At present, high-definition video camera data can be compressed to about 2 Gbyte capacity per hour. However, because of the acquisition of high-definition video and the number of video cameras in the general surveillance system is dozens to hundreds of roads, this application will require more storage equipment and greater storage capacity. At present, according to relevant regulations, the retention time of video is usually one month. In this way, the storage capacity required for saving one video is

$$\frac{2 \text{ Gbyte}}{\text{h}} \times 24 \text{ h} \times 30 \times 1 = 1.44 \text{ Tbyte}. \quad (1)$$

Each video storage requires a net capacity of nearly 1.5 Tbyte. Generally, a substation has 9 video images, and a station needs at least 14 Tbyte storage capacity to store

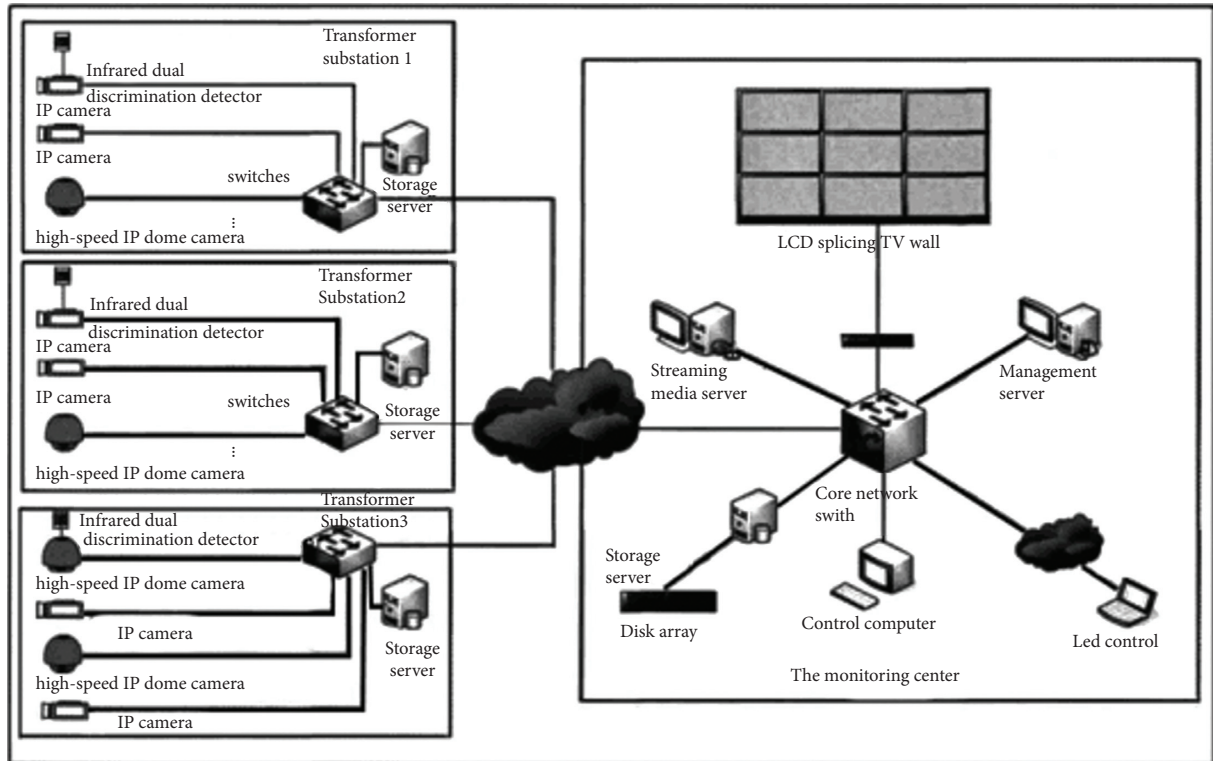


FIGURE 1: Intelligent HD image monitoring system.

monitoring data for 30 days. And now commonly used hard disk recorder has 8 SATA interfaces, currently can be used for monitoring of a large hard disk with 2 Tbyte storage space, so 8 blocks have 16 Tbyte storage space. Considering a 10% formatting loss, the available storage space is 14.4 Tbyte, which can meet the video storage needs of a substation. Considering that the video information of substation is mostly static information, the video recording method of motion detection can be adopted, which can greatly prolong the time of information storage.

2.2. Structural Design. The monitoring system itself has a very complex function not only to complete the basic hardware control but also to provide such advanced functions as automatic inspection and image recognition and not only to establish and manage the database but also to provide a good man-machine interface [26]. In addition, in the face of the complex working environment of the substation site, the monitoring software should also have a certain ability to handle exceptions. Even when there is no one in the situation, it can also deal with the emergency reasonably to ensure the safety of the inspection robot.

According to the difference of functions, the monitoring system can be divided into three levels which are shown in Figure 2:

(1) *Basic Layer.* This layer is mainly responsible for implementing the basic operations of all the hardware on the inspection robot so that the implementation of the upper-layer functions can be

separated from the tedious hardware call process. In addition, the monitoring system can still maintain the control of the inspection robot under the condition of poor network communication quality. All the functions of the robot control module are realized in this layer. When the program is implemented, the singleton mode is adopted to encapsulate the control module of each hardware, which is convenient for the upper layer to call the hardware interface, realize the low coupling between modules, and avoid the error of declaring two entities to the same hardware device in the system, which causes the conflict of resource access. In addition, this layer is responsible for managing the establishment and maintenance of connections between the monitoring system and the database. Since the base layer is responsible for managing the robot hardware, recording the historical running state of the device in the inspection log is also done here.

(2) *Functional Layer.* With rich and robust interface services provided by the base layer, this layer can easily organize high-level control functions. It is at this level that operational mode control is implemented.

(3) *Running Mode.* Automatic inspection is the core function of the whole monitoring system. Since this function is applicable to unmanned conditions, it not only requires frequent and orderly operation of each hardware device of the inspection robot but also

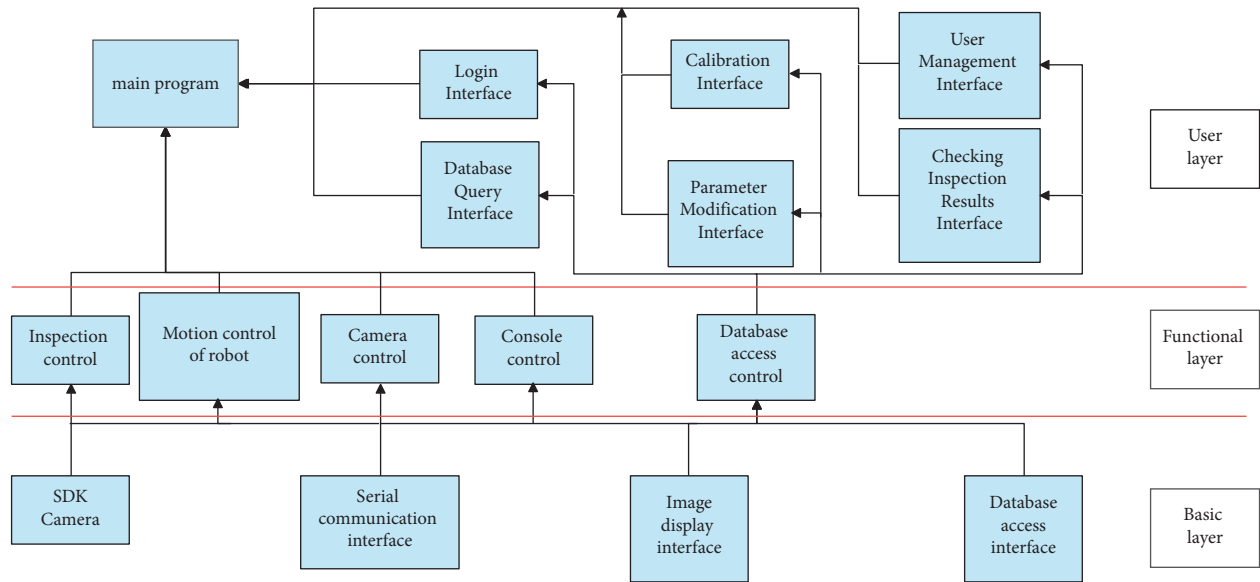


FIGURE 2: Monitoring system structure.

requires certain abnormal handling ability to deal with the complex working environment of the substation site and ensure the safety of the inspection robot itself.

- (4) The automatic/manual inspection switch is set in the inspection process to facilitate the operator to inspect the uncalibrated instruments during the robot inspection. Because of the good interface provided by the base layer, it can ensure that after the startup of the automata, the instructions can be executed accurately according to the steps to complete the inspection task. At the same time, considering that the inspection robot may encounter on the way of abnormal condition or hardware failure occurs because the robot itself make inspection task cannot continue, the automaton also increased the exception handling rings; after entering this state, the monitoring system will be suspended inspection tasks, depending on the abnormal situation, corresponding treatment measures. In addition to providing the function of operation mode control, the function layer is also responsible for the query, storage, and management of the monitoring system to each database.
- (5) *User Layer.* The user layer provides the final human-machine interface to the operator, is responsible for detecting whether the control requirements of the operator are reasonable, and calls the interface of the function layer to realize the control instructions of the operator. The user layer also needs to present the real-time working status of the inspection robot as well as the captured image and sound information to the operator. At the same time, operators need to manage the various databases and the large amount of inspection data generated by daily inspection. Database management functions are performed at this layer.

2.3. Inspect Recognition. The identification of abnormal equipment includes manual identification and automatic identification of inspection robot. Manual identification refers to that in the process of magnetic track navigation detecting the designated location, the pylon camera and infrared imager are put on the specific substation equipment to shoot the appearance image and temperature at the same time, and the image is uploaded to the monitoring software through the network for manual online analysis by the personnel on duty. At the same time, the inspection robot stores the photos taken during each inspection operation in the internal large-capacity hard disk of the inspection robot for offline analysis and historical data analysis by the staff on duty. The joint automatic inspection platform of robot and HD video can be used as “operation and maintenance assistant” and “inspection staff” of substation to replace manual inspection and improve the quality and efficiency of inspection. The substation inspection operating system is customized. Leading Internet technology is adopted to integrate HD video, inspection robot, AR, remote expert, object ID, and other modules, and various AI algorithms such as defect identification, environment interpretation and state analysis are configured to improve the accuracy of the algorithm by collecting a large number of structured pictures. Automatic identification means that the monitoring software uses the image recognition technology to identify appearance and temperature anomalies during inspection.

2.3.1. Abnormal Appearance Image Recognition. The standard template of appearance image of substation equipment is stored in the monitoring software. When the monitoring software receives the visible light image of the substation equipment uploaded by the inspection robot, it will immediately compare it with the standard template. When the difference between the two exceeds the allowable threshold, the monitoring software will immediately issue an alarm by popover.

Figure 3 shows the whole process of abnormal appearance image recognition. When the inspection robot detects the specified location and turns the cradle head to an accurate position, it will push the status string and image data to the monitoring end. When the monitoring software receives the status string, it first reads the current data frame from the video stream and then performs gray processing, template comparison, binarization, matching degree judgment, and other work. When the matching program of the two images is less than the set threshold, it is diagnosed as abnormal appearance. The stopping position of the inspection robot at each device is basically the same, and the swing angle of the cradle head is accurate, so this method is simple and effective.

2.3.2. Abnormal Temperature Recognition. The inspection robot uses infrared thermal imager to identify temperature. Infrared imager outputs its image data by USB video stream, and the image shows the maximum temperature of the temperature field in real time. In this paper, OCR text recognition technology is used to obtain the temperature value of the image frame.

The software of the monitoring end divides the video stream of the infrared imager into frame by frame images and then preprocesses the image frames of the infrared thermal imager and then converts the temperature indicator image in the image frames into digital characters through the OCR text recognition algorithm and obtains its digital values after screening. The identification process is shown in Figure 4.

- (1) *Pretreatment.* The program obtains the temperature image pixel on the image frame and carries out the noise reduction, grayscale, binarization, and tilt correction to the image. After binarization, the image is left with only two colors, black and white, one of which is the image background, and the other color is other objects. The binarization process helps the recognition model determine the location of the text area.
- (2) *Feature Extraction and Dimensionality Reduction.* The program obtains the temperature image pixel on the image frame and carries out the noise reduction, grayscale, binarization, and tilt correction to the image. After binarization, the image is left with only two colors, black and white, one of which is the image background and the other color is other objects. The binarization process helps the recognition model determine the location of the text area.
- (3) *Character Recognition.* The extracted text features are compared with the information in the resource base to determine the text.
- (4) *Post Optimization.* It is not possible to extract numbers from images with 100% accuracy. In order to improve the accuracy, this paper optimizes the recognized string according to the format rule of infrared thermal imager temperature display to eliminate the identification results with inconsistent format and improve the accuracy.

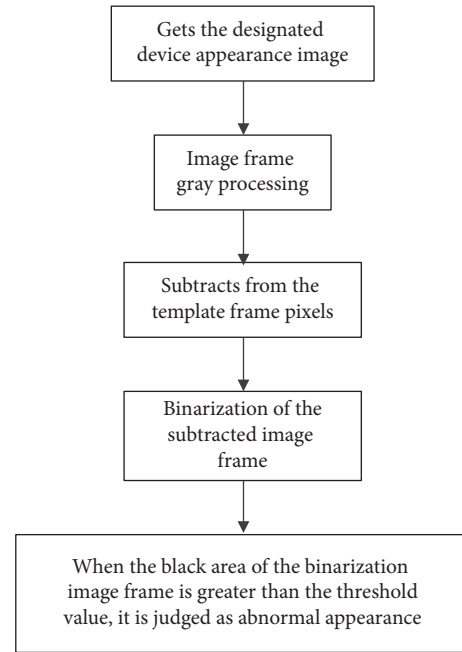


FIGURE 3: Abnormal appearance image recognition.

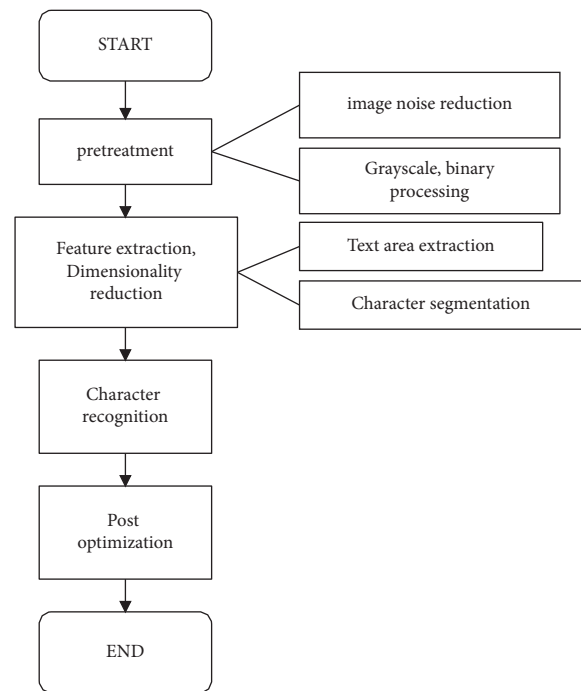


FIGURE 4: OCR text recognition algorithm.

3. Multidimensional Collaborative Inspection Technology

The traditional methods of multidimensional collaborative inspection of substation mainly include the multidimensional collaborative inspection method of substation based on machine vision feature analysis, the multidimensional collaborative inspection method of substation based on information degree feature extraction, and the

multidimensional collaborative inspection technology of substation based on intelligent PID control. However, the traditional method of multidimensional collaborative inspection of substation is not good intelligence, and video recognition level is not high. Therefore, the multidimensional collaborative inspection technology of substation based on robot and video surveillance is proposed. Does the inspection robot detect the low-pressure side or the high-pressure side? It depends on the actual situation. With the support of the original research data and literature, the problems existing in the above traditional methods are solved, and the multidimensional collaborative inspection of substation is realized.

3.1. Method 1: Feature Analysis Based on Machine Vision.

Firstly, the robot is used to collect video information intelligently. Then, DSP integrated information processing is carried out according to the collected results, and the man-machine interaction design of inspection information is realized through the man-machine interaction interface, and the data storage module and GUI man-machine interaction module are designed. The video information collection model of multidimensional collaborative inspection of substation is shown in Figure 5.

In the video information collection model shown in Figure 5, the video information frame segmentation model is constructed by using the method of single frame vector fusion. The edge blur information component Ω of video image acquisition is obtained:

$$\Omega = h_j(x), \quad j = 1, 2, \dots, p, \quad (2)$$

where $h_j(x)$ is the video information frame model and j is the frame number.

Based on the fuzzy rough set theory, the simulation scene model of substation inspection was built. Combined with the online video fusion method and robot recognition technology, the image tracking and information fusion processing of multidimensional collaborative inspection of substation were realized. The propagation distance and scattering coefficient distribution intensity of multidimensional collaborative inspection of substation were obtained:

$$a(t) = j \left(\frac{2\pi}{t} \ln b \right) - \Omega, \quad (3)$$

where t is the substation inspection time and $\ln b$ is the image tracking and information fusion function of substation inspection. According to the adaptive following parameter model of substation inspection, the scattering intensity information component α of substation inspection is obtained. Using the method of regular shape fusion and intelligent recognition, the reconstruction model of the point target of substation inspection is obtained as

$$W = a(t)\alpha \sum_{j=1} h_j(x). \quad (4)$$

According to the analysis above, the robot is used to realize intelligent collection of video information of

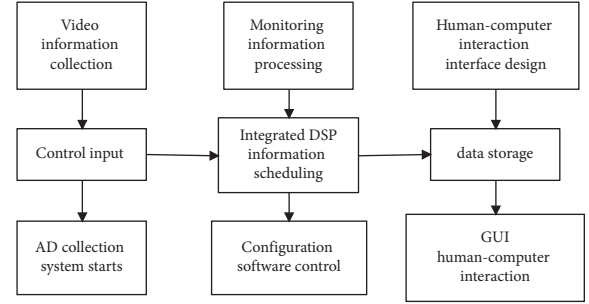


FIGURE 5: Video information collection model.

substation inspection, and information fusion and intelligent parameter identification are carried out on the collected video image information.

3.2. Method 2: Feature Extraction Based on Information Degree.

In the decomposition process of substation inspection image, the method of frequency domain filtering analysis is adopted to obtain the principal component characteristic value of substation inspection:

$$K = \beta W, \quad (5)$$

where β is the filtering coefficient in the frequency domain. The appropriate fusion rules are used to carry out collaborative filtering for the video surveillance image of the substation inspection. $X_{m,n}$ is the component of each pixel at the position of (m, n) , and the modal component of the substation inspection is obtained as follows:

$$X_{m,n} = \beta \text{med}(X_{m-1,n-1} + \dots + X_{m,n} + \dots + X_{m+1,n+1}). \quad (6)$$

In the process of iteration and screening, the video surveillance model of substation inspection is established, and the robot recognition technology is adopted in the $N \times M$ dimension space. The local maximum point distribution of substation inspection is obtained as

$$A(x) = \arg \max(M_{m,n}x + \lambda), \quad (7)$$

where λ is the number of robot recognition times and x is the video image information of substation inspection. Combined with the intelligent identification method, the feature matching set of substation inspection is obtained. The corresponding filter is used to filter the video monitoring signal, the principal component fusion model of substation inspection is established, and the characteristic quantity of principal component distribution is obtained as follows:

$$B = \frac{K}{A(x) + \ln b} \sum_{m=1} x_m \cdot \sum_{n=1} x_n. \quad (8)$$

After extracting the fuzzy identification feature quantity from the video image, the multidimensional cooperative control and image feature analysis of the inspection of substation are realized by combining the method of spatial region fusion filtering.

3.3. Method 3: Optimization of Multidimensional Collaborative Inspection

3.3.1. Construct Video Monitoring and Robot Automatic Control Model. In the process of substation inspection, the robot video tracking and information recognition technology, combined with the pattern recognition method, are used to extract the associated feature quantity in the video image, and the image pixel ambiguity generation sequence is obtained:

$$C = \Omega\{B_1, B_2, \dots, B_I\}, \quad (9)$$

where $1, 2, \dots, I$ are the angular point information of video surveillance. Combined with the multidimensional parameter identification technology, the autocorrelation characteristic quantity of multidimensional collaborative inspection of substation is obtained:

$$D = \frac{\varepsilon y}{\phi f(x)} - C, \quad (10)$$

where $f(x)$ is the frequency parameter of the filter bank of the multidimensional collaborative inspection of the substation; ϕ is the amplitude modulated to frequency modulated component; y is the video fusion parameter of the multidimensional collaborative inspection of the substation; and ε is the frequency spectrum information of the image.

The one-dimensional empirical wavelet generation algorithm is used to calculate the video surveillance image, and the iterative learning steps of the substation inspection video image fusion are obtained as follows:

$$D|h_j(x)| - \delta \leq 0, \quad (11)$$

where δ is the edge distribution threshold of the video surveillance image. Using the line filter and feature recognition method, the sub-band image of multidimensional collaborative inspection of substation is obtained as

$$G(x) = \delta \sum_{j=1}^p G_j(x), \quad (12)$$

where $G_j(x)$ is the sub-band image information frame model. According to the filtering results of multiple high-frequency sub-band images, the video monitoring and robot automatic control models are built to improve the automatic control ability of multidimensional collaborative inspection of substation.

3.3.2. Construct Reliability Visual Tracking Recognition Model. With the aid of robot vision, a reliable visual tracking and recognition model is constructed. The process component of the substation inspection is J . Combined with the multimode fusion identification method, the evolution characteristic quantity of the multidimensional collaborative inspection of the substation is obtained as follows:

$$Q(X) \frac{J_\beta X}{G(x)}, G(x) \neq 0. \quad (13)$$

The steady-state characteristic distribution set of substation inspection video surveillance is constructed, and the distribution pixel value of edge pixels is obtained. It should

consider how to compress the video data to a reasonable capacity. The similarity feature resolution model of the video surveillance images of substation inspection is constructed, and the three-dimensional visual reconstruction of substation inspection is realized by combining the pixel distribution matrix. The overall contour information of the two source images is

$$H(r) = \begin{cases} 1, & r \geq \frac{\pi}{2}, \\ Q(X) \ln\left(\frac{2r}{\pi}\right), & \frac{\pi}{4} < r < \frac{\pi}{2}, \\ 0, & r \leq \frac{\pi}{4}, \end{cases} \quad (14)$$

where θ is the similarity characteristic resolution value and ω is the reconstruction times. Set the grayscale pixel set. According to the fusion results of each component, the deep learning iterative formula is obtained:

$$P = s \sin \eta \cos \varphi, s = \frac{u}{2}, \quad (15)$$

where η is the edge brightness; φ is the sparse eigencomponent; s is the detail information of the source image; and u is the sub-band information. According to the above analysis, the reliability visual tracking and identification model is built to realize multidimensional collaborative inspection of substation.

4. Experiment and Discussion

In order to verify the application performance of the proposed method in realizing multidimensional collaborative inspection of substation, test and analysis were carried out, and the simulation test and algorithm design of multidimensional collaborative inspection of substation were carried out with Visual C++ and Matlab. The sampling time interval of video surveillance information of multidimensional collaborative inspection for substation is 0.45 s, the intensity of fusion background prior feature distribution is 25 dB, the frame length of robot visual information tracking is 800, the block matching size of multidimensional and cooperative inspection is 1212, the similarity coefficient is 0.34, and the gradient coefficient is 0.18. Several programming software can be used to analyze the advantages and disadvantages of this model. According to the above parameter setting, multidimensional collaborative inspection simulation of substation is realized. The environmental simulation of substation inspection is shown in Figure 6.

According to the sampling results in Figure 6, in order to prove the application effect of the proposed method, the output results of the three methods are compared. The three methods are text method (method 3), multidimensional collaborative inspection method of substation based on machine vision feature analysis (method 1), and multidimensional collaborative inspection method of substation based on information degree feature extraction (method 2). The output comparison diagram of multidimensional collaborative inspection of substation can be obtained (see Figure 7).

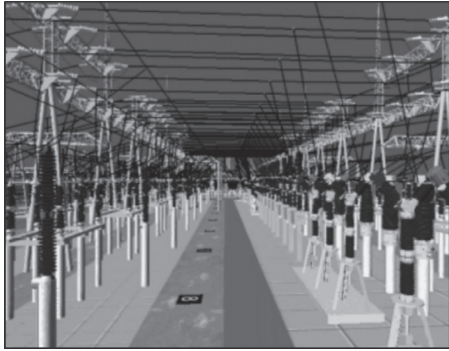


FIGURE 6: The environmental simulation of substation inspection.

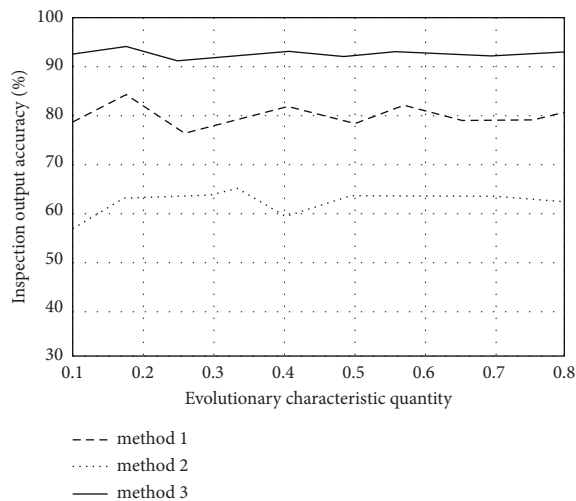


FIGURE 7: Result of multidimensional collaborative inspection of substation.

The analysis of Figure 7 shows that the output accuracy of inspection image of method 3 is more than 92%, which is higher than that of method 1 and method 2. With the aid of robot vision, the reliability visual tracking and recognition model is established, which effectively improves the ability of locating and tracking fault feature points. The reliability of multidimensional collaborative inspection for substation is better, and the ability of visual fault tracking and identification for substation is improved. Different methods are adopted to realize multidimensional collaborative inspection of substation, and the comparative results are shown in Table 1. It can be seen from Table 1 that method 3 achieves higher positioning accuracy and better inspection capability for multidimensional collaborative inspection of substation. Each part of the substation monitoring system is very important and irreplaceable, so it cannot be simplified at present.

5. Conclusion

Firstly, in the process of operation and maintenance management of substation, combining with online video surveillance technology, a high-definition intelligent monitoring system and related software are designed to

TABLE 1: Comparison of positioning accuracy of different methods.

The number of iterations	Positioning accuracy (%)		
	Method 1	Method 2	Method 3
10	81.4	81.1	92.4
20	83.6	82.4	93.8
30	84.6	85.7	96.8
40	91.4	86.5	99.8

realize intelligent inspection of substation and improve the operation and maintenance management ability of substation. A multidimensional collaborative inspection technology based on robot and video surveillance is proposed. DSP integrated information processing is carried out according to the video information collection results, and the man-machine interaction design of inspection information is realized through the man-machine interaction interface. The characteristic components of the principal components of substation inspection can be obtained by using the frequency domain filtering analysis method. Combined with the pattern recognition method, the relevant feature quantity of video images is extracted, the similarity feature resolution model of video surveillance images is constructed, and the reliability visual tracking recognition model is constructed to realize the multidimensional collaborative inspection.

Then, in order to verify the application performance of the proposed method in realizing multidimensional collaborative inspection of substations, the proposed method is compared with other two commonly used methods for test and analysis. According to the test results, the accuracy of the inspection image output of this method is higher than that of the other two methods.

The results show that the method proposed in this paper is more reliable and practical and can realize multidimensional collaborative inspection of substation. It plays an important role in the daily operation and maintenance of substation. In the next stage, the substation will implement the dual-track parallel joint automatic inspection and manual inspection, accelerate the functions of automatic information collection, remote automatic inspection, efficient processing of massive data, and intelligent push of abnormal information of construction equipment, ensure that automatic inspection can replace manual inspection basically, and have the conditions for popularization and application in the field of substation operation and maintenance.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest with respect to the research, authorship, and/or publication of this article.

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