Transmission corridor line safety monitoring method based on monocular vision

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Abstract—Aiming at the problem of low accuracy of traditional methods in transmission corridor line safety monitoring, a transmission corridor line safety monitoring method based on monocular vision is designed. First of all, this article defines the target object of the safety monitoring of the transmission corridor line. Then, based on the monocular vision measurement to obtain the internal parameters of the camera geometry, optical characteristics, etc., the position of the power transmission corridor line security surveillance camera is calibrated, the power transmission corridor line security monitoring graphics are displayed, and the security monitoring data of the transmission corridor line is used for perception and track. Finally, the safety monitoring and early warning of transmission corridor lines are realized. The experimental results show that the monitoring accuracy of the design method is significantly higher than that of the control group, which can solve the problem of low accuracy of transmission corridor line safety monitoring by traditional methods.

1. Introduction
Transmission corridor refers to the strip area under the line extending to both sides of the specified width along the side conductor of high-voltage overhead power line. In recent years, with the expansion of transmission line scale, line tripping accidents occur from time to time, including tripping accidents caused by transmission line corridor tree barrier and construction. A considerable part of the daily work of the transmission operation and maintenance team is the manual patrol of the line. As a large number of transmission lines are distributed in mountainous and forest areas, with lush trees and some towering trees under the line, the line trip will be caused when the trees are a specific distance from the conductor. At present, the main methods suitable for transmission corridor line safety monitoring are: video / image monitoring, infrared sensing, CO sensing and satellite remote sensing. Video / image monitoring, infrared sensing and CO: sensing technologies rely on point and distributed monitoring terminal devices to collect mountain fire characteristic information and transmit it to the remote monitoring center in real time. The monitoring center processes and analyzes the data of each measuring point, and issues monitoring results and alarm information to users. Operation experience shows that restricted by power supply and communication conditions, online monitoring terminal devices generally have the problems of poor operation stability and difficult maintenance. In addition, with the extension of transmission network, the construction cost of distributed monitoring terminal devices is extremely huge, which seriously affects the effectiveness of video / image monitoring, infrared sensing and CO: sensing in the practice of transmission line corridor monitoring. Monocular vision means that only one digital camera or video camera is used to take a single photo for
measurement. Because it only needs one vision sensor, this method has the advantages of simple structure and simple camera calibration. At the same time, it also avoids the shortcomings of small field of view and difficult stereo matching in stereo vision. Based on this, this paper applies monocular vision to the design of transmission corridor line safety monitoring method, which is committed to fundamentally improve the accuracy of transmission corridor line safety monitoring, and provide practical method support to ensure the safety of transmission corridor lines.

2. Monocular vision

The hardware of monocular vision measurement system includes laser rangefinder, industrial camera, computer, tripod and other equipment [1-2]. Industrial cameras are used to record line dancing online or offline, providing raw materials for analyzing dancing using monocular technology [3-4]. The laser rangefinder can measure the distance from the camera lens to each feature point, and measure the horizontal and vertical angles of the camera lens for data analysis and calculation [5-6]. The server and related software can be used to analyze and calculate the dancing video, obtain the relative displacement of the line feature points, and calculate the dancing feature parameters, as shown in Figure 1.

![Fig. 1 Monocular vision measurement system](image)

In Figure 1, the characteristic point is the sub spacer for transmission line. Monocular vision is based on digital image speckle correlation processing technology. It is a technology to recognize and track speckle patterns on images. In the process of line dancing, the whole dancing process is photographed by digital camera, and the camera shooting process can be understood as recording high-definition images [7]. In the studied and analyzed image, a coordinate system $(x_0, y_0)$ is established, and each pixel corresponds to a coordinate and an intensity $I(x_0, y_0)$. Similarly, a pixel in the original pattern also corresponds to a coordinate $(x_i, y_i)$ and an intensity $I(x_i, y_i)$. Then, the absolute difference of pixel intensity can be defined as:

$$\text{Diff}(x_0, y_0, x_i, y_i) = |I(x_0, y_0) - I(x_i, y_i)| \quad (1)$$

$$SAD(x, y) = \sum_{i=0}^{Trows} \sum_{j=0}^{Tcols} \text{Diff}(x + i, y + j, i, j) \quad (2)$$

In formula (2), $Trows$ and $Tcols$ represent the rows and columns of the original drawing. In the studied and analyzed image, the mathematical expression of searching the original pattern is:

$$P = \sum_{i=0}^{Trows} \sum_{j=0}^{Tcols} SAD(x, y)_{ij} \quad (3)$$
In formula (3), \( S_{\text{rows}} \) and \( S_{\text{cols}} \) represent the rows and columns of the studied and analyzed image. The minimum SAD value gives an evaluation value for the matching degree, and matches the image feature position through the evaluation value.

3. Transmission corridor line safety monitoring method based on monocular vision

3.1. Defining the target object of transmission corridor line safety monitoring

For the real-time monitoring of the conductor temperature of the transmission line, the current carrying capacity calculation technology and the dynamic capacity increase model of the transmission line are used to determine the maximum transmission capacity under the operation conditions of the line, make full use of the objective invisible capacity of the line and improve the utilization rate of the line [8-9]. For transmission line galloping monitoring, a suitable number of sensors are installed on the transmission line conductor to form a data acquisition network. Through the acceleration and displacement data of the sensors, the information is sent to the tower monitoring extension and transmitted to the monitoring center through long-distance data. Generate the displacement change curve of a monitoring point of the transmission line and the line galloping displacement change diagram of the line within the whole monitoring range to determine the line galloping condition. The transmission line environmental monitoring device detects the meteorology of the transmission line corridor, including the temperature, humidity, wind direction and other data of the monitoring points, uses the meteorological early warning model to warn the icing disaster, and also provides meteorological monitoring data support to other monitoring subsystems.

3.2. Calibration of transmission corridor line safety monitoring camera position based on monocular vision

Taking the above contents as the target object of transmission corridor line safety monitoring, the position of transmission corridor line safety monitoring camera is calibrated based on monocular vision, so as to realize the measurement in transmission corridor line safety monitoring. Camera calibration is to obtain the internal parameters such as geometric and optical characteristics of the camera, as well as the external parameters such as the position and direction of the camera in the geodetic coordinate system. The actual displacement can be obtained by calibrating the measured data.

Vertical displacement calibration coefficient \( K \) at any point in space, i.e.:

\[
K = \frac{b \times D}{f} \times \cos \alpha \quad (4)
\]

In formula (4), \( K \) is the calibration coefficient of vertical displacement of a measured point; \( b \) is the hardware parameter and the pixel size of CCD; \( D \) is the distance from the monocular vision camera to the measuring surface; \( f \) is the focal length of the lens; \( \alpha \) is the elevation of the monocular camera. In the formula, \( D \) can be expressed as:

\[
D = d \times \cos \beta - \frac{f}{1000} \quad (5)
\]

In formula (5), \( d \) is the distance from the measured point to the camera; \( \beta \) is the included angle between the measured point and the optical axis of the camera. Through the above formula, it can be deduced that the calibration coefficient of vertical displacement measured by transmission corridor line safety monitoring camera is \( K(x, y) \), so there is formula (6).

\[
K(x, y) = \frac{b \times (d \times \cos \sqrt{(x-x_c)^2 + (y-y_c)^2} - \frac{f}{1000}}{f} \times \cos \alpha \quad (6)
\]

In the above calculation, only \( d \) and \( \alpha \), that is, the distance from the camera to the measured point and the elevation angle of the camera are unknown. It can be measured on site by laser
rangefinder. Based on this, the position of transmission corridor line safety monitoring camera is calibrated.

3.3. Graphic display of transmission corridor line safety monitoring
After calibrating the position of transmission corridor line safety monitoring camera based on monocular vision, the on-line monitoring system sends the collected signal through the sensor to the central controller through the data acquisition card, and the MCU effectively calculates the environmental variables such as temperature, humidity, rainfall and vibration received by the sensor in unit time. On the one hand, the central controller can follow the communication protocol, It is transmitted to the remote monitoring center through GPRS / CDMA / 3G. On the one hand, the effective data is also stored in the unjustly lost high-capacity flash memory. Based on the transmission line survey data, the measured data and evaluation results during the operation of the monitoring system, the transmission line and electrical equipment are displayed on the geographical background according to their actual geographical location. The graphic display of transmission corridor line safety monitoring can intuitively monitor the icing status of conductors through intuitive image monitoring and analysis technology. General cameras are installed on the line tower PTZ and are directly exposed to the external environment. Therefore, under extremely bad weather conditions, the image device itself may be covered by ice and snow. On the one hand, it is easy to make the equipment unable to use normally, on the other hand, it is also easy to affect the capture of line image.

3.4. Transmission corridor line safety monitoring data sensing and tracking
According to the graphic display results of transmission corridor line safety monitoring, combined with the distribution law of transmission lines in the monitoring area, the environment of transmission line corridor and the operation of transmission line corridor, video decompression technology, intelligent sensing technology, wireless communication technology and solar power supply technology can be used in mountain fire prone areas transmission line towers in mountain fire prone areas are equipped with mountain fire prevention monitoring and early warning terminal equipment, so as to achieve good monitoring of key areas of mountain fire monitoring in transmission line corridors and real-time monitoring. The power source of this equipment is solar energy, and data transmission and video transmission are realized through China Unicom / Telecom 4G + WiFi. In the absence of early warning information, the monitoring and early warning terminal equipment will regularly transmit the Meteorological Video and data monitored by the meteorological sensor to the background of the system. If the flame sensor, smoke sensor and temperature sensor in the equipment detect abnormal phenomena in the monitored area, it will automatically start the video recording function of the Omni-directional monitoring camera. At the same time, the fire risk early warning information is sent to the system background. In this way, the line management personnel can carry out corresponding management work in combination with the warning information and information transmitted by the equipment.

3.5. Realizing the safety monitoring and early warning of transmission corridor lines
After completing the sensing and tracking of transmission corridor line safety monitoring data, this paper realizes transmission corridor line safety monitoring through early warning function. The application support layer was composed of data service bus module, workflow management module, GIS module and system platform management module. Through internal connection, each monitoring module is organically connected to realize information and data sharing, including intelligent transmission line monitoring information management, monitoring data information analysis, transmission line condition diagnosis, system management and so on. In order to ensure the safety of transmission corridor line monitoring, a complete security guarantee must be provided. The intelligent transmission line monitoring system is directly connected with the public network, which needs to ensure the system security at the software level. Generally, the network threats to the monitoring system include data theft, network congestion, virus attack, etc.
On this basis, comprehensively analyze the monitoring data, including on-line data and off-line data, basic data of electrical equipment, judge the critical conditions of equipment fault of the line, and timely notify the line maintenance personnel to operate and eliminate the fault on the premise that the line may have fault. When a series of extreme natural disaster conditions such as rain, snow and sand are detected, the meteorological system in the monitoring system analyzes the early warning information of the time, place and scope of the disaster, and timely notifies the line operation unit to formulate a disaster early warning scheme to reduce the disaster caused by the disaster. The establishment of a complete disaster early warning system shall include four aspects: early warning and warning mechanism in advance of disasters, emergency rescue mechanism in the process of disasters, post disaster evaluation mechanism and emergency material allocation mechanism. In the process of line disasters, the emergency command center can regulate and control monitoring images, data and other information for emergency command and rescue.

4. Case analysis

4.1. Experimental preparation
This paper designs the following example analysis. The experimental object selects a transmission corridor. The experimental content is to monitor the line safety of the corridor. The safety monitoring information of the transmission line corridor is shown in Table 1.

Table 1. Safety monitoring information of transmission line corridor

| Sat. transit time | longitude | latitude | Line name          | Voltage level | distance/m |
|------------------|-----------|----------|--------------------|---------------|------------|
| 2020-8-10 19:20  | 109.562   | 024.547  | Sand retaining line| 220           | 672        |
|                  |           |          | Sand climate line  | 220           | 489        |

In combination with table 1, it is the safety monitoring information of transmission line corridor. On this basis, firstly, the transmission line corridor safety is monitored through the design method in this paper, and the monitoring precision is measured by MATLAB software, which is recorded as the experimental group. Then, the transmission line corridor safety is monitored by traditional methods, and the monitoring accuracy is also measured by MATLAB software, which is recorded as the control group. The comparison index selected in the example analysis in this paper is the monitoring accuracy. The higher the monitoring accuracy data, the higher the monitoring accuracy of this method in practical application.

4.2. Experimental results and analysis
The experimental results are summarized as shown in Table 2 below.

Table 2. Comparison of experimental results

| Monitoring times (times) | Monitoring precision rate (%) | Monitoring accuracy (%) | Monitoring precision rate (%) | Monitoring accuracy (%) |
|-------------------------|-------------------------------|-------------------------|-------------------------------|-------------------------|
| 1                       | 36.35                         | 91.0                    | 14.64                         | 62.5                    |
| 2                       | 34.54                         | 91.4                    | 12.34                         | 63.5                    |
| 3                       | 35.67                         | 91.2                    | 13.28                         | 62.6                    |
| 4                       | 36.95                         | 91.0                    | 14.56                         | 62.7                    |
| 5                       | 38.05                         | 90.9                    | 15.52                         | 62.8                    |
| 6                       | 38.04                         | 90.9                    | 15.90                         | 62.3                    |
| 7                       | 39.71                         | 91.0                    | 17.80                         | 64.5                    |
| 8                       | 38.04                         | 90.8                    | 16.57                         | 62.4                    |
| 9                       | 39.25                         | 90.7                    | 15.55                         | 62.3                    |
| 10                      | 39.76                         | 91.1                    | 18.04                         | 61.8                    |
It can be seen from table 1 that under the same monitoring time, the monitoring accuracy of the design method in this paper is significantly higher than that of the control group, and the monitoring accuracy is higher, which shows that it has more practical popularization value.

5. Conclusion
After the application of the transmission corridor line safety monitoring method based on monocular vision designed in this paper, the information can be transmitted to the early warning system at the first time of the potential safety hazards of the transmission corridor line, and the maintenance personnel can formulate the rescue plan through the on-site monitoring video, so as to improve the mountain fire rescue and early warning effect and reduce the mountain fire loss. At the same time, the satellite remote sensing function in the system can monitor the overall monitoring area, but can not achieve real-time monitoring, which will make it difficult to monitor and prevent the safety of transmission corridor lines. Therefore, in the future construction of smart transmission lines, the state perception, monitoring and early warning, analysis, diagnosis, evaluation and prediction of transmission lines should be realized to provide strong support for dynamic capacity increase, disaster prevention and reduction.

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