Research on Monitoring Device for Indicating External Damage Risk of Overhead line Based on Image Recognition technology with Binocular Vision Cameras

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***Abstract*—Utilizing the technology of image recognition, a design scheme of monitoring device of risks caused by external damages on overhead transmission lines was presented based on embedded DSP platform. Based on binocular stereo vision, the algorithm for detecting intrusions in the overhead transmission line corridor was investigated. Applying binocular cameras to obtain scenes of high-voltage overhead transmission lines, the functions calculating the distance between each conductor and intrusion and space coordinates were developed. The accuracy of the three-dimensional positions of the invasion objects obtained by binocular stereo vision algorithm was verified in the laboratory. The field availability of detecting external damages with binocular stereo vision algorithm was analyzed.**

Keywords—overhead transmission line; external damage; image recognition; binocular vision

I. INTRODUCTION

There is an increasingly demand for reliability of electric power supply facilities. The safety of power grid is threatened by external damages of overhead distribution lines. Kites, balloons or ribbons around the wires in the wet conditions lead to serious short-circuit faults and especially in the transmission route the improper lifting operation of overhead construction vehicles possibly causes earth faults. Substantial financial losses due to wide blackout and even casualties arise from these accidents. Immediate inspection and rapid actions for outer threatens are thus strongly practically required for the safe operation of power grid.

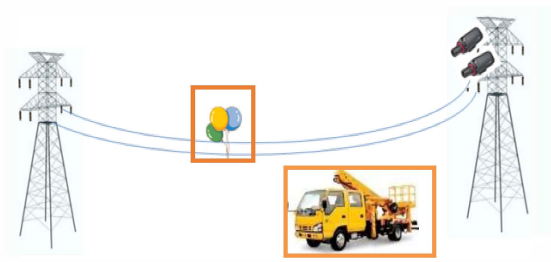


Fig. 1. Risk factors in transmission line corridor.

Traditionally, power-line inspection and maintenance tasks are performed by lineman [1]. With the inspection range of transmission lines growing and the geographical ambient being more complicated, problem of insufficient special lineman is more and more serious. For reducing labor, videos taken by cameras set up on the overhead lines are transported to control center. Monocular cameras are usually used to detect the risks with a loss of depth information [2]. Visual inspection is not effective and very subjective so that some risk factors could be neglected. Helicopter-assisted inspection is also becoming commonly used for power line inspection [3]. Although more effective than the foot patrol inspection, helicopter-assisted inspection is more expensive and is not able to implement continuous monitoring.

Using binocular cameras to obtain scenes of transmission lines is an effective method for reducing false positives and false negatives of a monocular vision system [4]. The theory of binocular parallax is applied. Binocular parallax is an essential basis for humans to obtain object depth information. Stereovision, as a main method to obtain depth information in computer vision, is widely used in the field of video surveillance. Reference [5] presented an online monitoring of insulator icing based on 3D image reconstruction utilizing the Stereovision. The coordinates of the insulator in 3D space are calculated by the parallax between two images after the calibration of cameras and its 3D model is then reconstructed. A method of binocular stereovision to identify driving environment of Autonomous Resource Prospecting Vehicle (ARPV) was adopted in [6]. An intelligent robot binocular vision system using image processing principle was developed and edge of the detection algorithms was clearly presented object contours[7]. Novel stereo segmentation and tracking techniques to handle multiple humans moving in groups in cluttered environments was proposed [8].

Real time monitoring of wires is of great significance. For increasing efficiency and accuracy, a monitoring system of risk factors on overhead transmission lines was presented based on embedded platform. Utilizing binocular stereo vision, space coordinates of the risk factor and the lines were calculated by the algorithm for detecting intrusions in the overhead transmission line route. For reducing misjudgment and improving work efficiency, automatic image recognition was applied to this system. Pressure of the communication channels and operating costs were reduced due to the embedded platform and wireless network.

II. SYSTEM DESIGN

Video system has been widely applied into the on-line monitoring of overhead lines, but the existing system now still have many problems, such as low accuracy and high costs. An optimized system was thus present.

A. *System Structure*

It is difficult to obtain an accurate estimation the spatial position of the object in the two-dimensional photo taken by a unique fixed single camera whether via manual or automatic recognition. For increasing accuracy, binocular cameras ware applied to this system based on stereo vision.

In the district of complex ambient, GPRS or 3G is used to transfer images. Due to the limited channel bandwidth, the quality of returned images is lower and not satisfying for artificial vision detection or automatic recognition. The cost of wireless channel is relatively expensive.

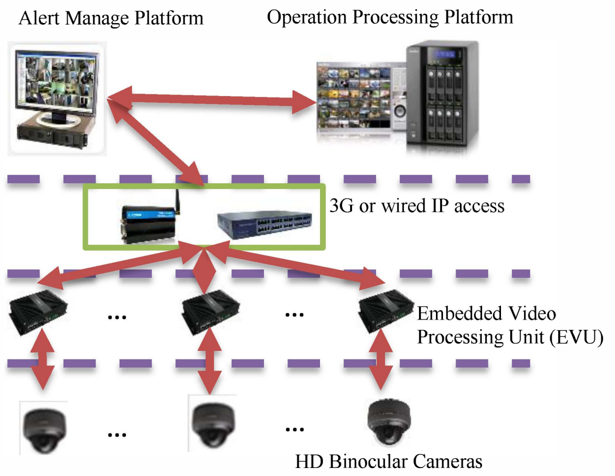


Fig. 2. System structure.

Therefore, function of automatic recognition should be implemented on tower. High quality images are returned only when system alarms and real time artificial callback is required. This will reduce the cost of wireless transmission without affecting the real-time detection. Reliability of the system and low power consumption are ensured.

An optimized system was designed based on binocular cameras and embedded platform. The monitoring system consists of four parts as shown in Fig. 1. Introduction of each part is as follows.

- HD binocular cameras. At the front end of the system, HD cameras transfer collected image data to the embedded image processing unit.
- Embedded video processing unit (EVU). EVU is an embedded device for intelligent recognition and analysis of the returned images.
- 3G or wired IP access. The front end communicate with alert manage platform and the client through the 3G or wired IP access.
- Alert manage platform. The alert manage platform debugging equipment is to set up parameters and query the operation status.
- Operation processing platform. The results of the transmission line state testing is uploaded to the operation processing platform regularly by EVU for display and management, etc.

B. *Embedded video processing unit (EVU)*

Main functions of EVU are to receive image data from HD cameras, analyze image data to examine the state of transmission facilities, report the state and image data of detected transmission facilities to alert manage platform and allow the client to set up and manage EVU.

Forlinx OK210 development board based on Samsung latest Cortex-A8 processor S5PV210 is applied in the EVU. Cortex-A8 is the first ARM application processor based on ARMv7 architecture, main frequency from 600MHz to 1GHz. Power dissipation of Cortex-A8 is lower than 300mW, but the performance is as high as 2000MIPS. Cortex-A8 has a rich internal resource and video processing capabilities, supporting DDR2 and multiple types of Flash NAND. Power VR SGX540 high performance graphics engines are integrated in S5PV210, to allow the 3-D graphics run smoothly, and play 1080P HD videos [9].

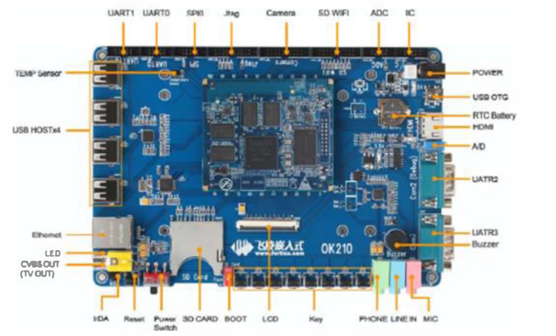


Fig. 3. Forlinx OK210.

III. LOCATING COORDINATE

A. *Invader recognition*

The foreground object is detected based on the background model of binocular camera image scenes that is established using the mixed Gauss model. Then SIFT (Scale-invariant feature transform) features of foreground object are extracted in each camera. And the corresponding relationship of foreground objects between the images of two cameras is thus established [10].

B. *Camera calibration*

The feature points are obtained based on the digital image. Then the pixel coordinates are transformed into the camera coordinates through the internal parameters matrix. In an ideal pinhole model camera, the objects in world space are projected onto the image plane as Fig.4 [11].

But in the actual case, the camera should be calibrated as the projection of the camera is not ideal. The projection relationship between the 2-D image and the 3-D object is determined by the intrinsic imaging geometric model of the camera. The parameters in this geometric model depend on the internal and external parameters of the camera.

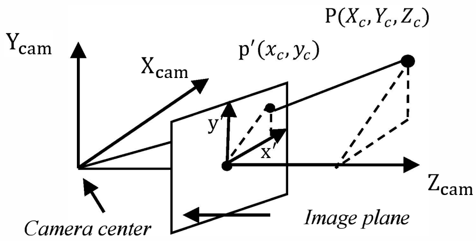


Fig. 4. Perspective projection geometry diagram

The plate calibration method [12] is often used to calibrate the camera. This method only needs the camera to take images of a plane calibration board in different angle of view. Assuming the calibration board is in the $Z = 0$ plane of the world coordinate system. The process of projection is described as (1).

$$s\begin{bmatrix}u\\v\\1\end{bmatrix} = K[r_1 \quad r_2 \quad r_3 \quad t]\begin{bmatrix}X\\Y\\0\\1\end{bmatrix} = K[r_1 \quad r_2 \quad t]\begin{bmatrix}X\\Y\\1\end{bmatrix} \quad (1)$$

where s is a scale factor, $[X, Y, 1]^T$ is a homogeneous coordinate on the template plane, $[u, v, 1]^T$ is the coordinate of the corresponding projected point in the image plane of that on the template plane, $[r_1, r_2, r_3]^T$ and t are respectively the rotation matrix and the plane matrix of the camera, and K is the intrinsic parameter matrix of the camera defined by (2).

$$K = \begin{bmatrix}\alpha_x & s & x_0\\0 & \alpha_y & y_0\\0 & 0 & 1\end{bmatrix} \quad (2)$$

Where $\alpha_x = fm_x$, $\alpha_y = fm_y$, and where m_x and m_y are respectively the number of pixels of X and Y axis in the image and f is camera focal length.

After coordinates of all feature points of the calibration board are detected, using corresponding relationship between 3-D coordinates of the feature points in the world coordinate system and the image coordinates homogeneous transformation, matrix H is calculated: $H_i = K[r_1 \quad r_2 \quad t]$. Camera internal and external parameters are thus obtained by H_i of multiple perspectives.

C. 3-D Reconstruction

Note that the coordinate system of left camera is the world coordinate system. After the invader coordinates in the images of both cameras are obtained, using camera projection matrix obtained by camera calibration, the 3-D position $x = (x, y, z)$, is restored. The 3-D graphics of the invader are thus obtained.

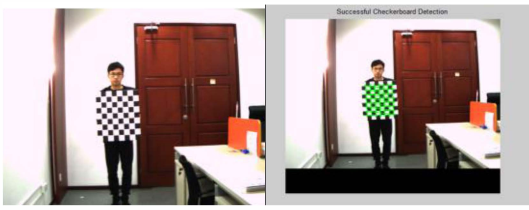
D. Laboratory Experiments

A laboratory experiment was performed. A $8 * 9$ calibration board, 5 million pixel binocular cameras was applied in this experiment. The code to obtain the 3-D coordinates of the target information was programmed in MATLAB.

(a) Front view (b) Top view

Fig. 5. Binocular cameras

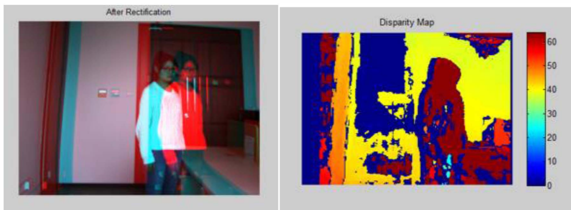
Two same cameras are planted on the binocular bracket to capture the images of the calibration board in five angles. Five images of each camera are processed in the calibration. Fig.6 (a) showed the image of the board in first angle in the left camera. Fig.6 (b) showed the successful checkerboard detection to obtain the parameter matrix of the camera in MATLAB.



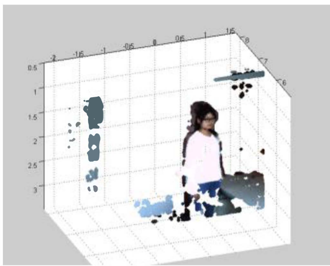
(a) Left 1 (b) Successful checkerboard detection

Fig. 6. Plate calibration

After calibration, two images of the target were processed to reconstruct 3-D model. The coordinates of the object is showed on the image.



(a) Rectification (b) Disparity map



(c) 3-D reconstruction

Fig. 7. Experiment Result.

After two images are rectified through the matrix of cameras, the disparity map of the images is obtained. The algorithm automatically recognizes the target in the image by depth information. Fig.7 (a) is the rectification of left and right image. Fig.7 (b) is the disparity map of the image to display the depth and gray of objects in the image. 3-D reconstruction and coordinates of the target is showed in Fig.7 (c).

IV. FIELD EXPERIMENT

After the experiment in the laboratory has been completed, the theory was testified. But the measurement distance of this program in MATLAB is limited, so it is not practical to detect the object from a long distance. And the sensitiveness to colors leads to misjudgment easily. OpenCV and Linux embedded platform were thus applied to improve the sensitivity and accuracy of the program and allow it to be more suitable for monitoring environment of transmission lines.

A. *Overhead line Stimulation Experiment*

Some wires and risk factors are set up to stimulate the corridor of transmission lines. The area marked by the blue line is a warning area and by the red lines is an alarm area as in Fig. Risk factors are marked and the positions are displayed on the monitor screen as in Fig.8.

(a) Marked areas (b) Invader position

Fig. 8. Perspective projection geometry diagram.

B. *Vehicle inspection Experiment*

Drive the vehicle with the vehicle monitoring device along the high voltage transmission line and take the image of the transmission line along the line. The lines and the building as a risk factor were detected and the distance of them were displayed on monitor screen as Fig.9.

Fig.9 eal time monitoring on a vehicle.

C. *Transmission line tower Experiment*

The monitoring device was set up on the transmission line tower to verify the stability and effectiveness of the system in practical working environment. The world coordinates of the objects are obtained. The height of the objects are thus calculated and displayed on the screen. The height of the car is 1.80m as in Fig.10 (b), and the height of the person is 1.68m as in Fig.10 (c). The evaluation error of the system is 0.10m.

(a) Tower (b) Height of the car (c) Height of the person

Fig.10 ransmission line tower Experiment.

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