IOP Conf. Series: Earth and Environmental Science **100** (2017) 012152 doi:10.1088/1755-1315/100/1/012152

Image acquisition device of inspection robot based on adaptive rotation regulation of polarizer

Maoqi Dong, Xingguang Wang, Tao Liang, Guoqing Yang*, Chuangyou Zhang, Faqin Gao

Shandong Luneng Intelligence Technology Co., Ltd., Jinan, Shandong 250101,China

*Email: sdygq2004@163.com

Abstract. An image processing device of inspection robot with adaptive polarization adjustment is proposed, that the device includes the inspection robot body, the image collecting mechanism, the polarizer and the polarizer automatic actuating device. Where, the image acquisition mechanism is arranged at the front of the inspection robot body for collecting equipment image data in the substation. Polarizer is fixed on the automatic actuating device of polarizer, and installed in front of the image acquisition mechanism, and that the optical axis of the camera vertically goes through the polarizer and the polarizer rotates with the optical axis of the visible camera as the central axis. The simulation results show that the system solves the fuzzy problems of the equipment that are caused by glare, reflection of light and shadow, and the robot can observe details of the running status of electrical equipment. And the full coverage of the substation equipment inspection robot observation target is achieved, which ensures the safe operation of the substation equipment.

1. Introduction

Smart grid is the development direction of the future power grid, that is, there are a large number of new technologies in the electric power generation, transmission, power distribution, power consumption and other aspects of the application, and the automation, integration, centralization and intelligentization of power grid management will be realized[1]. Substation, a a power grid hub, must be regularly inspected to ensure safe operation, and it is very important to use robots to automatically detect the running state of substation equipment in unattended environment[2,3].

The change of outdoor light is one of the important factors that affect the detection of equipment[4]. In the robot inspection process, many factors restrict the patrol work such as the strong sunlight, the reflection of the equipment, the bright sky background, glare and so on. These unfavorable factors prevent the robot from accurately identifying the operation status of the substation equipment. As shown in Figure 1, the image of the device under strong light becomes very blurred when the brightness is increased. Thus it can be seen that the quality of the robot image acquisition is related to the results of the entire inspection mission.

In this paper, an image acquisition device for inspection robot equipment based on adaptive polarization adjustment is proposed. By setting a polarizer, the reflection of the scene is reduced to a minimum, and the harmful glare is reduced to the minimum or even disappeared. As a result, a clear device image is obtained.

2. Polarization of light

Light is a high frequency electromagnetic wave, which is formed by alternating vibrations of the electric field that is perpendicular to the direction of propagation and magnetic fields[5,6]. It is no essential difference with the radio wave except of the wavelength is shorter. The wave whose direction is perpendicular to the direction of propagation is called transverse wave, as shown in Figure 2.

Figure 1: Device image under bright light

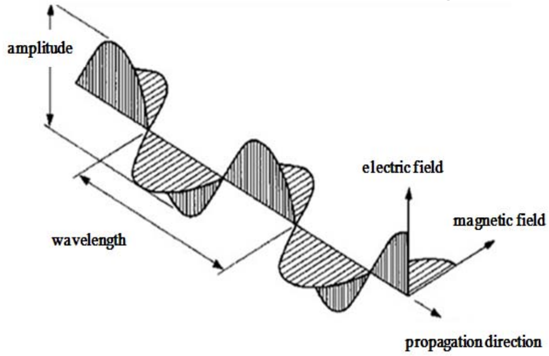

Figure 2: Transverse wave

The transverse wave has a characteristic that its vibration is polar. In a plane perpendicular to the direction of propagation, it can vibrate in either direction[7]. We usually take the direction of light electric field vibration as the direction of light wave vibration. If a beam of light is vibrating in the same direction, we call them polarized light, or strictly, call complete polarized light[8,9]. If the direction of a beam of light is directed in one direction and is doped with a small amount of polarized light in all directions, we call them partial polarized light. In general, natural light in all directions vibration is uniform distribution, which is called non-polarized light. When the non-polarized light irradiates the nonmetallic surface, the reflected light is partially polarized light[10,11]. The ratio of polarization is different due to the difference between the reflection angle and the incident angle.

Polarizer is a color filter. The excellent function of a polarizer is to pass through a light that is selectively vibrating in a certain direction. In color and black-and-white photography, it is often used to eliminate or reduce the strong reflection of nonmetal surfaces, in order to eliminate or reduce the spot[12]. For example, in scenery and scenery photography, it is often used to show the strong reflection of the object's texture, highlighting the scene behind the glass, pressure the sky and the performance of blue sky, white clouds and so on.

As shown in Figure 3, the polarized light K_i in any direction of incident light E_i (unpolarized light) can be decomposed into a E_{ip} portion parallel to the reflected plane (gray) and a E_{is} portion perpendicular to the reflected plane.

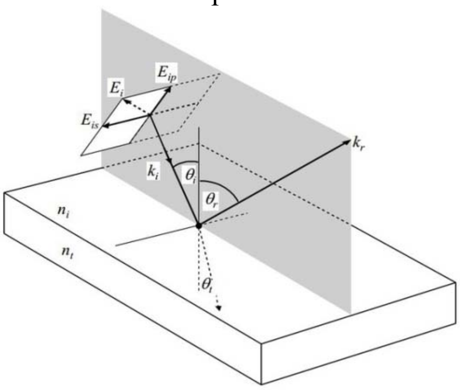

Figure 3: Reflectogram of light

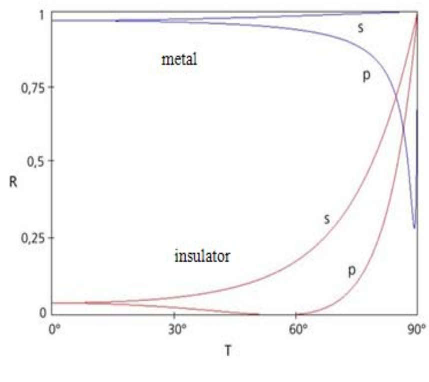

Figure 4: Object surface reflectivity

The relation between reflectivity and incident angle of metal and insulator is shown in Figure 4, where R is the reflectivity of light on object surface, and T is the incident angle of light. In the figure 4, the p-curve is a polarized light parallel to the reflecting surface of light (E_{ip} in Figure 3), and s is a polarized light (E_{is} in Figure 3) perpendicular to the reflecting surface of light. In the figure, only the light reflected by the insulator at about 50° to 60° is polarized light, since only the s part of the reflected light is left in this angle range. This angle is called Brewster's angle. The p part reflected from the insulator is very small, so you can get a satisfactory picture by only using the polarizer to filter out the s part. As for the metal, whether the s part or the p part is filtered, the other part of the light will still be reflected into the lens, so that no matter how the polarizer turns, the reflection of the metal will not be filtered out.

3. Automatic driving mechanism of polarizer

At the front of the visible light camera, the polarizing lens is fixed with an automatic rotating driving device of the polarizer, so that the angle of the polarizing lens can be adjusted according to the light requirement. As shown in Figure 5 and Figure 6, the automatic rotation drive of polarizer includes the following devices: fixing plate 1, fastening screw 11, rotating disk 2, polarizer 3, camera 8, support wheel 9, supporting axle 5, bearing 4, nut 10, motor gear 6, motor 13, reduction gear 7 and encoder 12. The mechanism employs two polarization angle reading modes.

(1) Servo closed-loop reading: Set the encoder to read the corner response of the rotary disk to the drive motor, The closed-loop control of motor, rotary disc, encoder and motor is realized. The polarization angle can be given by the encoder, and the resolution of the micro angle sensor is 0.088 degree (resolution can be set according to need).

(2) Pointer reading: The rotating disk has a reading pointer, and the fixing plate is set with a scale. When the rotary disk is rotating, the rotation angle can be read by the pointer. The minimum scale is 1 degree, and the pointer reading is generally only available as an auxiliary reading.

As mentioned above, the fixing plate has three jaws which are fixed in the outer of the lens frame of the camera by screws. The polarizer lens is fixed on the rotating disk, and the rotary disk has a pointer for indicating the scale on the fixing plate. Motor is installed in fixing plate which provides power for the whole device. Motor employs the motor gears, reduction gears and rotary discs to form the movement chain. The specific action relationship is: the motor power is transmitted to the rotary disk by the motor gear, reducer gear, and two stage decelerations of rotary disk gear ring, which realizes the rotation of the polarizer.

Fixing plate employs three support wheels to support rotary disc, which the three support wheels are made at an angle of 120 degree. Among them, the three point support makes the structure simple and the machining accuracy lower. Due to the installation position of the support wheel, the scale of the fixed disk cannot be continuous, so the method of increasing the scale on the opposite side of the supporting wheel is adopted to realize the continuity of the scale reading.

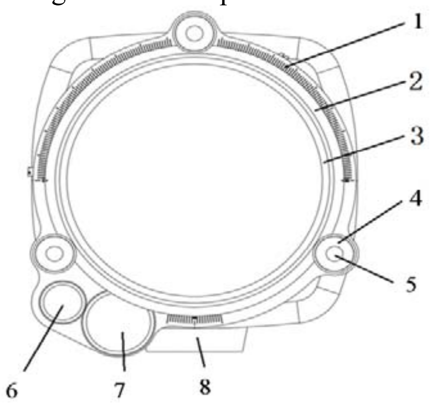

Figure 5: Schematic diagram of automatic driving device of polarizer

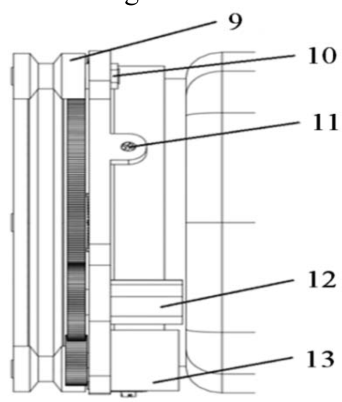

Figure 6: Side view of automatic driving device of polarizer

4. Simulation experiment

The simulation experiment is based on the substation inspection robot platform. After the polarizer is assembled according to Figure 5, and it is installed in the front of the robot camera. The robot inspection task is started in the station to test the advantages of the device system acquisition equipment. The system processing flow chart as shown in Figure 7.

The procedure for collecting images of each device in a substation is as follows:

Step1: Configure patrol robot. The background operator controls the robot to patrol the pre-set location of the next device, and set the appropriate PTZ rotation angle and camera focal length and other information to ensure that the appropriate size of the device displayed in the center of the image.

Step2: The judgment of polarizer is enabled. Check whether a polarizer is needed for device image acquisition or not, and if necessary, step 3 is performed, otherwise, step 7 is performed.

Step3: Polarizer is enabled. When the polarizer is enabled, the image acquired in step 1 is processed to extract the image feature.

Step4: Tilt angle calculation. According to the feature points of the device, the tilt angle of the glare polarization polar in the camera coordinate system is calculated.

Step5: Self-regulation of polarizer. The angle of inclination in Step 4 is converted to the rotation regulation angle of the polarizer, and sent to the polarizing mirror angle driving device to adjust the setting angle of the polarizer

Step6: The judgment of rotation. Check whether the polarizer angle rotation is in place or not, if in place, then began to collect the device image.

Step7: Save the parameters. The parameters of the image acquisition are saved, such as the camera focal length, PTZ angle, polarizer placement angle and so on.

Step8: The judgment of end conditional. If it is the last device, it will be over; otherwise, go back to step 1.

Figure 8 shows a flow chart of the steps in the device image acquisition process. The self-regulating process of the polarizer is shown in Figure 9, and the execution steps are as follows:

Step1: Calculate the input angle. The camera coordinate system of the robot image acquisition is used as the object of reference, and the Z axis is centered to rotate the polarizer counterclockwise. The calculated angle is used as an input to the polarizer automatic rotation driving device.

Step2: Polarizer is rotated by motor. The motor drives the lens to rotate the input angle in the specified direction, and the encoder records the rotation starting position.

Step3: Estimate of rotation situation. The encoder verifies whether the angle rotation is in place or not. If the rotation is in place, then step 4 is performed. If there is an error, the error value is taken as input, and step 2 is performed.

Step4:Start the acquisition device. Execute step 5 if you want to acquire the device image. Otherwise, the operation is finished and the completed signal is returned.

Step5: Collect device images.

Step6: Polarizer rotation angle is set to zero.

After the robot completes the acquisition of the device, zero setting command is sent to the polarizer, which will be taken as the input value of the next preset position.

Test data are from the actual substation, the test results before and after the automatic regulating system of polarizer are shown in Figure 10.

As can be seen from the figure, the equipment acquisition device in this paper makes the robot acquisition function enhanced, and the equipment image quality has been greatly improved.

Test results show that even in the rain and snow environment, the system device in the paper cannot get bright and clear equipment image, but the clarity of the device has also been improved, as shown in Figure 11.

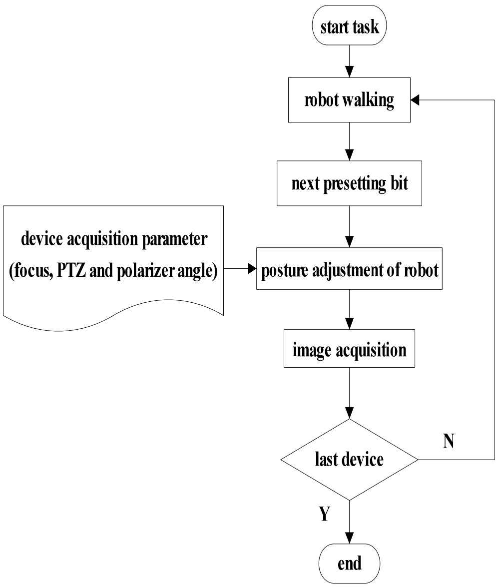

Figure 7: The system processing flow chart

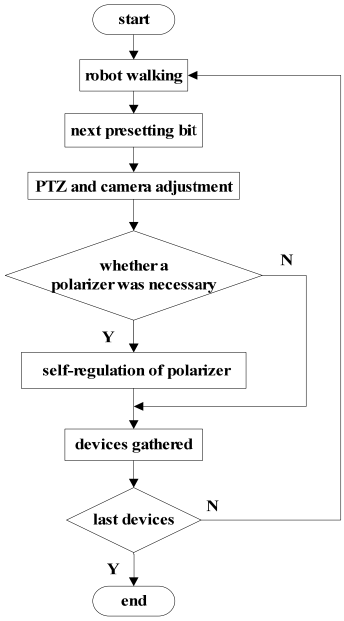

Figure 8: Flow chart of equipment image acquisition

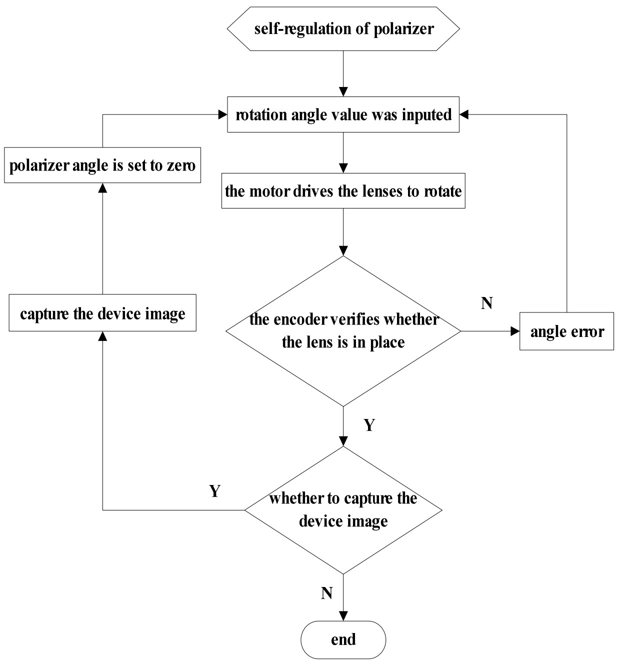

Figure 9: Flow chart of automatic rotation regulation of polarizer

(a) unused (b) used (c) unused (d) used

Figure 10: Comparison of test results

(a) unused (b) used

Figure 11: Comparison of test results in the rain and snow environment

5. Conclusion

The simulation experiment the working record of the robot in the substation shows that the clarity of the image is greatly optimized by polarizer automatic rotation regulation of inspection robot for image acquisition system in this paper. According to the inspection records of a 500KV substation in Jiangsu, the error of equipment identification caused by glare, reflection and shadow interference has been improved in all aspects. Moreover, the robot can observe the details of the operation of power equipment, which realizes the full coverage observation of substation equipment by the inspection robot, and ensure the safe operation of substation equipment. According to the different position of the equipment, the device system can be adaptive rotation regulation, which reflects a highly intelligent and automatic operation of the inspection robot, cuts down on operation cost, and the successful implementation of the system promotes the unattended process of substation.

References

[1] Zuo M, Zeng G P and Tu X Y 2011 *Acta Electronica Sinica* Research on visual navigation of untended substation patrol robot 39(10) pp 2464-2465

[2] Lu S Y, Qian Q L and Zhang B, et al 2006 *Automation of Electric Power Systems* Development of a mobile robot for substation equipment inspection 30(13) pp 94-95

[3] Yang X D, Huang Y Z and Li J G, et al 2015 *Shandong Electric Power* Research status review of robots applied in substations for equipment inspection 42(1) pp 30-33

[4] Sha H. 2010 *Southeast University* Research of object detection and multi-target tracking based on background modeling pp 1-10

[5] Zhou L, Liu L H and Li J M 2006 *Control & Automation* The finite element computing research of optical fiber sensors on vibration measurement for thin structures 22(31) pp 228-229

[6] Wang P X, Wang K and Han L B, et al 2015 *Physics Experimentation* Improvement of the polarization optics experiment system 35(6) pp19-22

[7] Wei J X and Wang C Y 2003 *Oil Geophysical Prospecting* Study of S-wave test and measurement technique in laboratory 38(6) pp 630-635

[8] Chen J B, Guan G X and Li L L 2014 *Navigation and Control* Polarization navigation 13(1):57-63.

[9] Zhang Z G, Mao L and Cheng T, et al 2013 *Journal of Infrared and Millimeter Waves* A technology for eliminating stray light in optical readout of FPA 32(4) pp 331-336

[10] Cronin T W and Marshall J 2011 *Philosophical Transactions of the Royal Society of London* Patterns and properties of polarized light in air and water 366 (1565) p 619

[11] Zhang T R, Sun M J and Li L J 2014 *International Conference on Multisensor Fusion & Information Integration for Intelligent Systems* Analysis on ghost image contrast using linearly polarized light pp 1-7

[12] Chu J K, Chen W J and Wang H Q, et al 2011 *Optics and Precision Engineering* Mobile robot navigation tests with polarization sensors 19(10) pp 2419-2425.