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To cite this article: Yishu Zhou et al 2018 J. Phys.: Conf. Ser. 1061 012006

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Research on the Influence and Correction Algorithm of Illuminance Intensity of Photoelectronic Imaging Bridge Deflection Measurement Accuracy

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Abstract: As a non-contacted non-destructive testing equipment, the bridge deflection measurement instrument based on the principle of photo-electric imaging has the characteristics of high measurement precision, strong dynamic and static deflection observation ability and long observation range, and has a vast application prospect in the field of bridge structural health monitoring. The photoelectronic imaging bridge deflection instrument obtains the deflection measurement result based on the target image, and the image quality is an important influential factor of the measuring accuracy. Illuminance intensity is an important factor affecting the image quality, and will have an important influence on deflection measurement in different weather conditions and different time periods. This paper studies the effect of the different illuminance intensity conditions on the accuracy of the photoelectronic imaging bridge deflection instrument, then a correction method of deflection measurement accuracy based on illuminance intensity measurement is proposed, and the brightness balance correction to the experimental pictures is refined.

Keywords: Photoelectric Imaging, Illuminance Intensity, Brightness Balance Correction, Bridge Deflection

1. Introduction

Bridges are an important component of modern transportation systems, and load testing and health monitoring are essential for them. As one of the most important bridge structure parameters, beam deflection\cite{1,2} reflects directly the vertical rigidity of the bridge structure, and is closely related to the bearing capacity of a bridge and its ability of resisting dynamic load such as from earthquakes. The common measuring tools of deflection are theodolite, level, dialgauge, etc. but the limitations of manual measuring have greatly increased the difficulty of the site work. At the same time, some automatic deflection measurement methods\cite{3}, such as the method of total station, GPS observation method, inclinometer method and special deflection method (photoelectric bridge deflection instrument, laser deflection instrument, collimation laser projection type deflection monitoring system and microwave Interferometric Radar deformable measurement system), etc. are used in bridge deflection monitoring work. Among them, the photoelectric bridge deflection instrument is widely used in bridge deflection detection \cite{4}because of its relatively high observation accuracy and simple engineering operation.
2. **System Composition and Detection Principle of Photoelectric Bridge Deflection Instrument**

The diagram of the structure and principle of the photoelectric bridge deflection instrument[5] is shown in figure 1. It is mainly composed of three parts, which are the luminescent target, the photoelectric digital camera and the computer acquisition and processing system. The luminescent target is fixed on the point of measurement on the bridge body. The photoelectric digital camera is fixed in the stable mechanical device. The luminescent target is imaged on the photosensitive surface of the digital camera by the optical system of the camera. The computer collects the image of the luminescent target from the camera by the image acquisition card, and the exact location of the image point is determined by image processing recognition. Finally, the relationship between the object determines the location of the cursor target. When the bridge deflection is changed, the light target also produces the equivalent displacement with the bridge, thus the change of the deflection of the bridge is determined.

![Diagram](image)

(a) Schematic diagram of the structure of a photoelectric bridge deflection instrument

![Diagram](image)

(b) Schematic diagram of imaging theory

Figure 1. Schematic diagram of the structure and imaging of a photoelectric bridge deflection instrument system.

3. **Environmental factors affecting the accuracy of measurement**

When photoelectric bridge deflection instrument is working in outdoor environment, the work is affected by many factor. The huge impact of light, rain and fog, atmospheric disturbances and other environmental factors on the measurement system can not be ignored. As shown in figure 2, the intensity of light will lead to the reduction of the contrast between the luminescent target and the background light, and it will be impossible to take a target image with a clear outline; the presence of rain, fog, haze and other particles will cause a decline in the visibility of the surrounding environment, making it impossible for the camera to shoot a clear target image. Based the accuracy of the result of bridge deflection measurement based on image processing technology will inevitably be affected by the imaging environment. Among many factors, the illumination has a more serious effect on the accuracy of deflection measurement. Whether the brightness is too dark or too bright, it may result in the target image may not be able to capture the location information.

Therefor, this paper conducts a brightness test experiment focused on the influence of the light intensity on the brightness of the picture taken by the detector, and the picture’s brightness balance correction, which will is an important pretreatment process to improve the measurement accuracy.
4. Experimental Process and Result Analysis
The experiment is taken outside. In a wide open field, a fixed building is selected as reference, and the target is erected before the reference material to keep the lights on. In the experiment, HPQN-X photoelectric bridge deflection instrument is used for shooting, as shown in figure 3. The illuminance meter is used to detect the illuminance in real time. A total of 10 pictures of the building under different illuminance are taken, and as shown in figure 4, the brightness of these pictures is analyzed.

Figure 2. The environmental factors that affect the accuracy of measurement

Figure 3. Photoelectric bridge deflection instrument used in the experiment

Figure 4. 10 pictures under different illuminance intensity
Each picture is analyzed at 10×10 pixel, and the resulting luminance is shown in table 1:

| Picture | 1   | 2   | 3   | 4   | 5   |
|---------|-----|-----|-----|-----|-----|
| Luminance value | 0.1882 | 0.1647 | 0.1176 | 0.0980 | 0.0824 |

| Picture | 6   | 7   | 8   | 9   | 10  |
|---------|-----|-----|-----|-----|-----|
| Luminance value | 0.0627 | 0.0510 | 0.0353 | 0   | 0   |

Using the illuminometer for real-time measurement, the ambient illuminance intensity at the shooting time of the 10 photos are shown in table 2:

| Picture | 1   | 2   | 3   | 4   | 5   |
|---------|-----|-----|-----|-----|-----|
| Real time illumination/×10^4 Lux | 5.72 | 4.95 | 3.81 | 3.36 | 2.20 |

| Picture | 6   | 7   | 8   | 9   | 10  |
|---------|-----|-----|-----|-----|-----|
| Real time illumination/×10^4 Lux | 1.80 | 0.82 | 0.55 | 0.31 | 0.14 |

The analysis shows that with the decrease of ambient illuminance intensity, the brightness value of the picture gradually becomes smaller. When the illumination intensity drops to 0.3 × 10^4 Lux, the brightness value of the picture of the selected region is 0. Therefore, under the uniform illumination condition, with the decrease of the illumination intensity, the image quality of the picture drops; by contrasting the grayscale of the 10 pictures it can be known that when the target brightness is constant, the intensity of the background illumination decreases, and the contrast with the target brightness is enhanced, which will make the target prominent and easy to be captured by camera. Therefore, in the actual detection, the target and background light with strong contrast are more conducive to the accuracy of bridge deflection detection.

5. Luminance Balance Correction

On the basis of THE luminance analysis, this paper further improves the brightness balance of images by digital image processing technology[6], in the hope of achieving similar brightness by luminance equalization[7,8].

Dividing the image into several small blocks, the luminance information of each sub-block is calculated or estimated, and the brightness of each sub-block is adjusted so as to make the image’s brightness of the uneven illumination uniform. The difficulty of the brightness equalization algorithm lies in the extraction of brightness, the RGB color space does not give the brightness information of the color directly, but the calculation formula of L used when RGB is converted to HSL model.

\[
L = \frac{(\text{maxcolor} + \text{mincolor})}{2}
\]

Among them, maxcolor and mincolor represent the maximum and minimum value of R, G and B respectively in the picture.

From Equation 1, the brightness of the picture is related to the maximum and the minimum total
color component of the image, so the RGB three-channel sum can simulate the brightness information of the image. For the convenience of calculation, the image is converted into a grayscale image by rgb2gray conversion, the maximum brightness value in the grayscale image is selected as the standard value, the pixel brightness of all the images is adjusted according to the value, and the brightness of the image is adjusted to achieve the current best condition.

The algorithm principle is as follows:

the picture is converted to grayscale, the average brightness of each picture is calculated, assuming the picture is M × N pixel size, the grayscale is 0 to L, then the average brightness of the picture is

$$ L_{avg} = \frac{\sum_{i=0}^{M} \sum_{j=0}^{N} q(i, j)}{M \times N} $$ (2)

Where q(i, j) is the brightness value of the pixel point (i, j) in the image.

Taking the maximum brightness value as the standard brightness value, the ratio of the standard brightness to the brightness of each image is calculated

$$ k = \frac{L_s}{L_{avg}} $$ (3)

Where $L_{avg}$ is the average brightness of the Kth image.

Taking the ratio of the Equation 3 as the image brightness equalization coefficient, the brightness of each picture is adjusted so that all images are output to the same brightness range to achieve the brightness equalization.

The 8 pictures of Figure 4 are selected for brightness adjustment, and the balance effect is shown in Figure 5.

From Figure 4, it can be known that the brightness of the untreated picture changes with the illumination intensity, and Figure 5 is about the treatment of the picture through the brightness balance correction, which makes the picture under different illuminance reach the same brightness effect. The effect of background illumination on picture brightness is eliminated. Because the brightness values of the last two pictures in Figure 4 are too low, the brightness balance is invalid when the reference is not clear.

**Figure 5.** The result of the brightness equilibrium.

6. **Conclusion**

The paper analyzes the influence of illuminance intensity on the pictures taken by photoelectric bridge deflectometer, and the effect of light on the image quality is analyzed emphatically. The brightness balance of the pictures under the different illumination of the actual test is corrected. The experimental results show that illuminance intensity has a significant impact on the photoelectric imaging, and the
brightness balance can improve the image quality. The brightness equalization can be regarded as an important pretreatment step of the photoelectric bridge deflection instrument, thus further improving the deflection measurement precision.

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