Research on Long-distance Non-contact Surface Defect and Crack Detection System in Civil Engineering Structures

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Abstract: Cracks are the result of excessive internal stress released by concrete materials. Cracks reduce the peak stress of the section. Therefore, the deformation energy stored in the structure is lower than a certain limit. Reducing the internal deformation energy by cracking is the inherent characteristic of concrete materials. Many concrete structures will have different degrees and forms of cracks, which is a quite common phenomenon. Cracks have become a common disease of concrete structures, which has long been a technical problem for construction engineers. Traditional crack detection methods of concrete bridges can not meet the needs of modern bridge detection. Based on this, this paper presents a long-distance non-contact surface defect and crack detection system, which is an economical and effective new method for bridge disease detection. This paper analyses the working principle and workflow of the detection system.

1. Introduction
Bridge detection is not only the main means to understand the technical situation, but also the key to bridge evaluation. In order to ensure the accuracy of detection data, bridge detection often requires instrumental observation. When inspecting, the inspector must approach each part of the bridge to inspect its defect. After marking the condition of the disease, the inspectors can do all-round contact inspection. Among them, scaffolding and bridge inspection vehicle detection are commonly used in bridge contact inspection. However, the above methods need to set control points or use digital cameras with known interior and exterior orientation elements. The scale method also requires sticking the scale on the surface of the bridge. Because of the heavy workload on site, it is not suitable for the rapid detection of bridges. In this paper, a long-distance non-contact surface defect and crack detection method is proposed.

2. Principle of long-distance non-contact bridge detection technology
The basic principle of non-contact bridge detection technology is as follow. Image processing and stereo vision often involve four coordinate systems, including world coordinate system, camera coordinate system, image coordinate system and pixel coordinate system. As shown in Figure 1.
Figure 1: Image processing coordinate systems

\( O_w - X_wY_wZ_w \) is the world coordinate system, which describes camera location.

\( O_c - X_cY_cZ_c \) is the camera coordinate system, and the centre of light is the origin.

\( O - xy \) is the image coordinate system, and the center of light is the image center.

\( uν \) is the pixel coordinate system, the origin is the upper left corner of the image.

3. Detection coordinate control system

3.1 Acquisition system

The service object of this detection system is mainly the hard-to-reach building area and large and medium-sized civil building structures. Because of the long distance, it is difficult to adopt non-contact nondestructive testing. So the performance of imaging acquisition unit is very important. In this paper, a new design scheme of intelligent imaging acquisition system is presented. The design sketch is shown in Figure 2.

Figure 2: Sketch of intelligent imaging acquisition system

Note: 1. Long focal lens; 2. Patrol mirrors; 3. Laser rangefinders; 4. Charge coupled sensors; 5. CS jack; 6. Intelligent digital bidirectional stepping motor; 7. Fixed bracket; 8. Coarse quasi-focal helix; 9. Fine quasi-focal helix; 10. Cloud mounting plate; 12. Notebook computers; 13. Charge Coupled Sensor; 14. Industrial camera C transfer interface; 15. Data Acquisition Unit; 16. Could platform installation base; 18. Could Platform.

3.2 Four Unit Relations of the System

The crack detection system is mainly composed of four units, including imaging acquisition unit, three-dimensional coordinate control unit, image processing unit and general control unit. The basic relationship of collaborative work among units is shown in Figure 3.
3.3 System working mechanism and process

Under the cooperation of four units, the detection steps are summarized as follows. Firstly, the preparation of defect crack acquisition is shown in Figure 4. Secondly, getting the best defect image is shown in Figure 5. Thirdly, the 3D coordinate acquisition of fracture image is shown in Figure 6. Fourthly, the flow chart of image preprocessing is shown in Figure 7. Fifthly, the calculation of crack width is shown in Figure 8.

![Figure 4: Preparing Workflow Diagram for Detection System](image)

![Figure 5: Flow chart of fracture image acquisition](image)

![Figure 6: The 3D coordinate acquisition of fracture image](image)

![Figure 7: The flow chart of image preprocessing](image)
4. Crack image preprocessing
Crack image preprocessing is one of the key contents of this detection system. In the process of image acquisition, various kinds of noise often appear in the image, mainly because of distance, atmospheric disturbance, instrument noise and environmental impact. These noises bring great trouble to the calculation and analysis of crack width, so the original image cannot be directly applied in the calculation. Preprocessing of original fracture image is the basis of image processing and analysis. We need to highlight the useful features selectively and weaken the unnecessary features. That is to say, we need selective image enhancement to highlight the information of fracture characteristics and carry out effective calculation, processing and analysis.

The image preprocessing of crack width calculation is very rich. Generally, it includes image coding and classification, binary gray conversion, image smoothing and denoising, gray enhancement, crack edge sharpening and feature enhancement. It can be divided into two categories from the role of processing objects. First, frequency domain processing. We need to modify the transform coefficients or values of the image in the transform domain of the image, and then obtain the enhanced image by inverse transformation. Second, spatial domain processing. The image plane itself operates directly on the gray level of the image pixels in the spatial domain.

5. Conclusions
Through the long-distance non-contact surface defect and crack detection system, we can carry out non-contact inspection and identification of bridges. The detection system effectively fills in the blank that the inspectors can not contact the bridge inspection. The system ensures the safe operation of non-contact detection of bridges.

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