Application of the Digital Image Technology in the Visual Monitoring and Prediction of Shuttering Construction Safety

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Abstract. Construction safety has always been the first priority in construction process. The common safety problem is the instability of the template support. In order to solve this problem, the digital image measurement technology has been contrived to support real-time monitoring system which can be triggered if the deformation value exceed the specified range. Thus the economic loss could be reduced to the lowest level.

1. Introduction

In the construction project, safety issue has always been given priority over others. However, civil engineering safety incidents always take place in variety of forms. For instance, at around 10:10 am on March 13th, 2008, in the construction site of the holy gate of the ten stupa of Famen Temple, in Fufeng County of Shanxi Province the template support collapsed, because it could not withstand the weight of the building. This incident led to four workers were killed five were injured ,and the total economic loss was nearly 150 million. At 0:10 on May 8th, 2010, in the construction site of Guangzhou LIE DE sewage treatment plant a collapse of support plate occurred which caused more than 10 workers were buried on the spot, one killed and 9 injured. At 14:50,on September 27th 2012, in Qinyang City, Henan Province, an instantaneous collapse happened to an office building which under construction because of the instability of the high support template, and this resulted in 11 injuries On March 20th 2012, in the construction site of the East Bay Bridge number 2 of Luoyang to Songxian section, a project of motorway from Luoyang to Luanchuan in Henan Province, two workers who fell from the bridge in the process of pouring piers, died in the hospital. This incident was also caused by the template collapse.Such incidents are numerous. These above incidents indicate that template support instability collapse is one of the main reasons causing construction incidents in China Therefore, it is urgent to develop a new precaution method to avoid such incidents fundamentally.

2. Digital image technology

In 1964 in Jet Propulsion Laboratory of the United States thousands of moon photos send by the space probe Prowler 7 have been analyzed, marking the first successful application of image technology[1]. With the convenience of the digital image technology coupled with the development of computer processing and the technology imaging, the digital image technology has been widely used in various field especially in civil engineering construction[2], such as detecting weld defects and measuring excavation unloading deformation and detecting bridge deformation[3]. When analyse the

consolidated drained triaxial test results for reinforced soil, it can also help to investigate the influence of different confining pressures and reinforcement methods on the strength and deformation of reinforced soil, and the impact of geo-grid limit on the lateral deformation. Moreover the processing of the landslide of the slope can also be predicted by analyzing the image of the trailing edge of the slope.

Currently, the main reason for the collapse of the template support can be divided into three categories[4]:

- Material factors. This is mainly due to the substandard quality of steel pipe on the market. For instance, the specification of the steel pipe is Φ48 * 3.5mm, but the actual thickness of the majority on the market is 2.8-3.0mm, indicating their axial compression capacity has been reduced greatly before service, the erosion will further reduce the pipe wall thickness. Further, during transportation the bearing capacity could be impaired as the steel pipe bend due to all kinds of collisions.
- Construction factors. Most of the construction factors are related to the substandard professional demeanor of construction personnel as they lack pre-employment training, such as weak security awareness disturbed norms. During construction ,they may neglect standard and requires, and cut corners (e.g. lack of scissors and enlarge the space between sweeping pole and upright pole) All the above-mentioned factors could bring potential safety hazard of the template support. Moreover, in the process of removal the template holder it is fail to comply with the standardized procedure, such as removing the non-load bearing member before the load-bearing components and removing the bracket of template before the concrete meet the required strength is also the common reason causing safety hazard.
- Design factors. The main reason is that some construction companies lack safety awareness of the template support, and they layout the template support system only based on experience instead of professional computing. Moreover at design stage fail to take related factors into consideration, will lead to excessive space between two pipe or lack of necessary structures. In the course of template erection, the use of the fastener may cause the actual hinge node not coinside with the design node, which will lead to great discrepancy between the real situation with design.

In summary, the reasons for template support instability and collapse are varied. The traditional method was appointed a safety personnel to inspect shelve construction, but this approach entirely relies on personal experience, and it only works when large deflection happens the safety incidence has been unable to stop.[5] Therefore, there is an urgent need for a simple and effective means of monitoring instead of the traditional manual monitoring method in the shuttering construction process.

The shuttering construction instability incident is devastating and usually occurs by sudden. The main method currently used to prevent this incidents is to strengthen the management work during design and construction stage where no reliable monitoring equipment has been adopted. In this paper, a real-time template support deformation monitoring system has been developed based on the digital photography and image analysis technology[6], and the corresponding processing procedure has also been developed with the platform of MATLAB. The practicality of this real-time monitoring system has been verified using the template support instability test .Moreover, the influencing factors of image measurement results have been discussed, such as structural elements, threshold segmentation, and color image threshold segmentation. The method to real - time monitoring the target objects and to make comparisons have been provided, and an advanced automatic warning system has been developed based on the characteristics of the deformation of template support.

3. Experiment and image processing

There are two conditions when the template support loses its stability. One is that the support tilts and the overall template support slides, because the top of the support received a horizontal force. The other is that the template support deforms and collapses due to the overburden weight. The simulation experiments were conducted to simulate the incidents with these two conditions, and the proposed real-time monitoring system was adopted to prove that this system can predict the incident, make a

warning, and then prevent the incident.

3.1 Experiment

The test procedure is as follows:

(1) Measure the distance (e.g. 150 cm in this study) between the camera (800-megapixel) and the object, then fix the camera and take pictures.

(2)Place the steel pipe vertically, mark the bottom line of it, and then take a photo again (figure 1).

(3)To simulate the collapse of the steel pipe caused by horizontal force, maintain the bottom of the steel pipe position unchanged, make the upper part slightly tilt, and then take pictures, as shown in figure 2.

Figure 1. Steel pipe vertical case photos

Figure 2. Inclined Steel pipe

(4)To simulate the deformation of the steel pipe caused by excessive vertical load, bend the middle part of the steel pipe, then place the pipe in the initial position while ensure the top and bottom of the pipe on the same vertical line, and then take a pictures, as shown in figure 3.

Figure 3. Bended steel pipe

Through the comparison between the photos taken in step (3-4) with the initial photo taken in step (2), the changes in the process of steel pipe instability can be known.

3.2 image processing

The procedure to analyze the photos using MATLAB is illustrated in figure 4. Firstly a certain threshold was set, then the digital image measurement technology was used to process the binary image, and then the actual displacement of the steel pipe can be obtained[7].

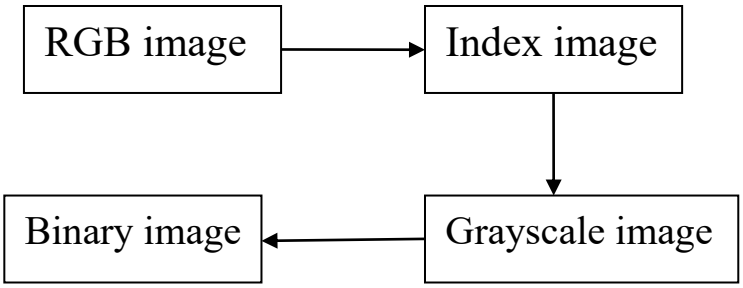

Figure 4. Image processing flow

4. The results of digital image measurement experiment

Figure 5 and figure 6 were obtained by superimposing the binary picture of figure 1 and figure 2, figure 1 and figure 3 respectively. These pictures were processed using the software developed with MATLAB, and then using a series of formulas the actual deformation data of the steel pipe were obtained[8].

Figure 5. Superimposed picture of vertical and inclined steel pipe

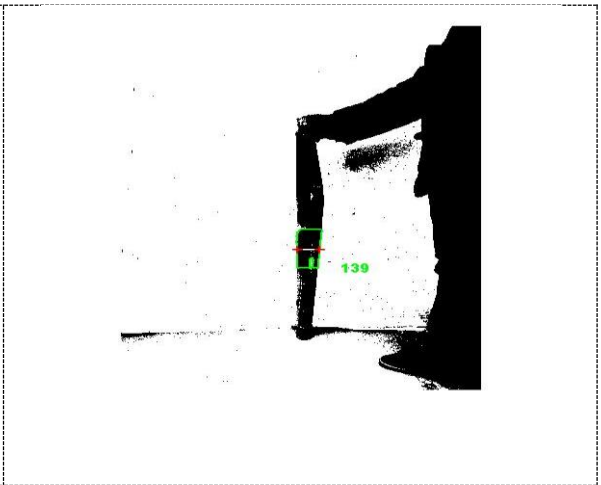

Figure 6. Superimposed picture of vertical and bended steel pipe

The horizontal displacement of the template support in figure 5 can be obtained through equation (1)

$$Z1=0.00033*1500*（168-89）=39.15mm \quad (1)$$

The deformation of the template in the test of figure 6 is

$$Z2=0.00033*1500*（139-89）=24.75mm \quad (2)$$

The image processing results above are in accordance with the on-site manual measurement results. Therefore, a warning system shown in figure 7 was further developed in this study. That is, a timed camera is used to take the picture of the bracket column regularly, and the initial image is set as a

reference. when a new photographic image is stored, the computer will process this image and contrast it with the initial reference image, at same time monitor the displacement of the template support automatically, and then display the value. If the value exceeds the specified range, the computer will make an early warning.

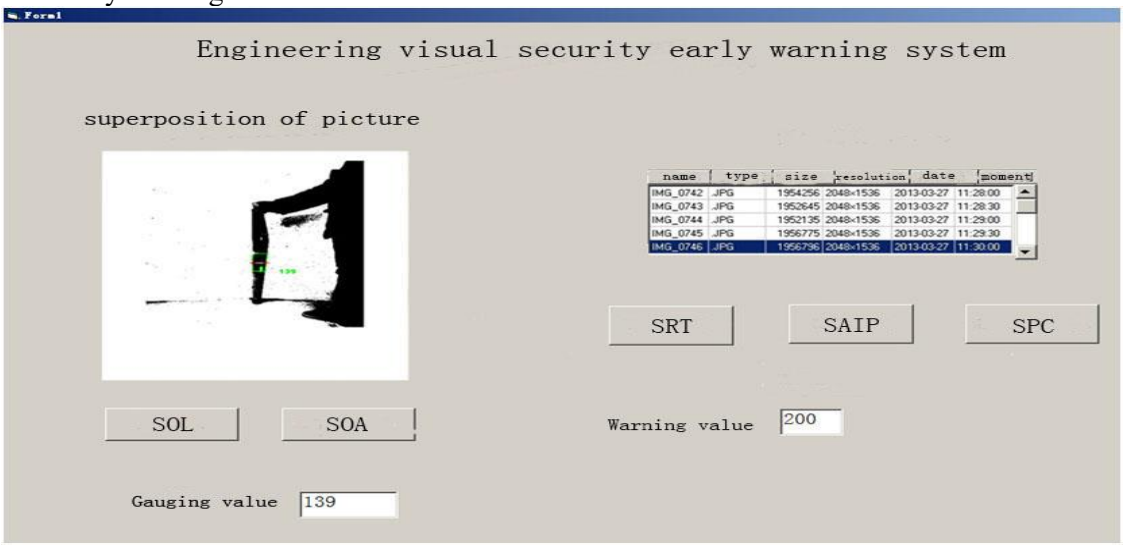

Figure 7. Engineering visual security early warning system work interface

5. Conclusion

The simulation test results reveal that it is feasible to use digital image technology to predict the instability of the template support deformation, and the test results are reliable and accurate. Therefore digital image processing technique can be used for real-time monitoring of the template holder, and processing the image automatically The processing results can be transmitted through the network to appropriate certain computer program, and then afterward the computer will choose whether to issue a warning. based on the results. This is a smart, automatic, simple, fast and practical engineering warning method. Using the early warning system, it is possible to prevent the construction incidents caused by instability of the template support. In addition, it is worthy to note that when the proposed monitoring system is applied in the practical project, two problems are required more attentions: (1) In case of the dead end of the camera, it is important to set up two cameras in the opposite positions. (2) To avoid overloading information, monitoring priorities should be set to the most important brackets.

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