2014 Taste of Research Summer Scholarship Program

Never Stand Still | Faculty of Engineering

Deformation Monitoring by Digital Close Range Photogrammetry

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Research Theme: The Digital Future

Background

Digital Close Range Photogrammetry (DCRP) is a non-contact, precise, cost effective and visualization enabled imaging measurement technology.

DCRP is done by taking multiple convergent images within 300m from objects. This is to measure 3D coordinates of points of interest or surface point clouds on the objects. DCRP has been widely used in engineering fields such as Deformation Monitoring of Civil Structures *(Fig.1)* and Concrete beam characteristics testing *(Fig.2)*.

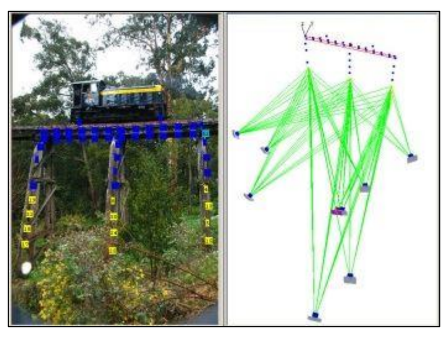

Fig.1: Bridge Deformation Monitoring

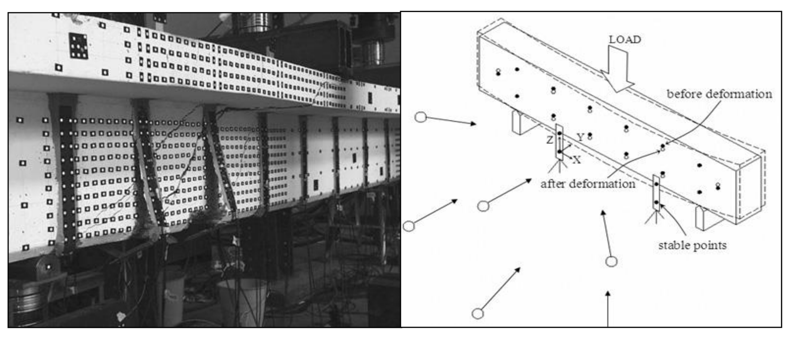

Fig.2: Concrete Testing

Aim

- Investigate the capability of DCRP on deformation monitoring of civil structures.
- Evaluate the deflection of a theoretical timber beam model with DCRP experiment.
- Compare DCRP results with conventional precise surveying method by using total stations in façade monitoring.

Camera Calibration

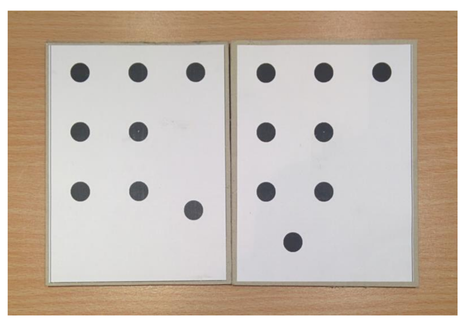

Fig.3: Coded Target Plates

DCRP software Australis and associated black and white coded targets *(Fig.3)* were used throughout the project.

Camera Calibration *(Fig.4)* is the process of finding the geometric parameters of the camera that took the images. These parameters include focal length, principal point and lens distortions. In order to achieve a higher accuracy cameras must be calibrated.

Fig.4: Field Camera Calibration

Deflection of a Timber Beam

Fig.5: Beam Deflection

A timber plate was placed on the edge of 2 wooden blocks. Point load was placed at the middle span. As load increased, the beam had a larger deflection. Coded targets were distributed over object. *(Fig. 5)*

Three calibrated Canon 450D DSLR cameras were used in this experiment. They were placed 2m away from the beam *(Fig.6)*. Tripods were adjusted into different heights to provide a larger image convergent angle.

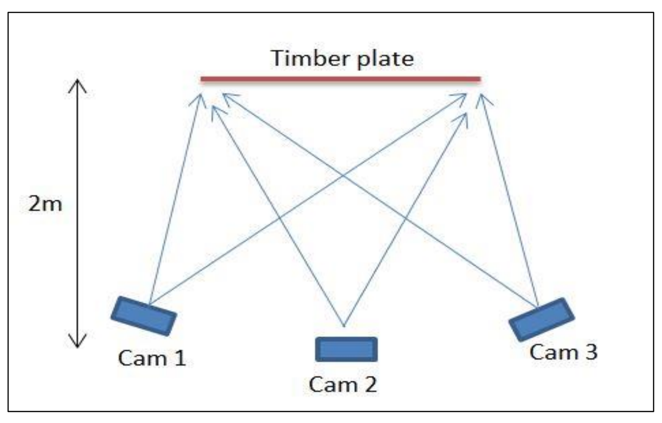

Fig.6: Camera Positioning (Plan)

Bending curvature theory was used to model the beam deflections.

$$\text{Curvature} = \frac{1}{R} = \frac{M}{EI} = -\frac{d^2v}{dx^2}$$

By integrating the expression twice,

$$v = \int\int \frac{M}{EI} dx$$

The beam was assumed to be simply supported. *(Fig.7)*

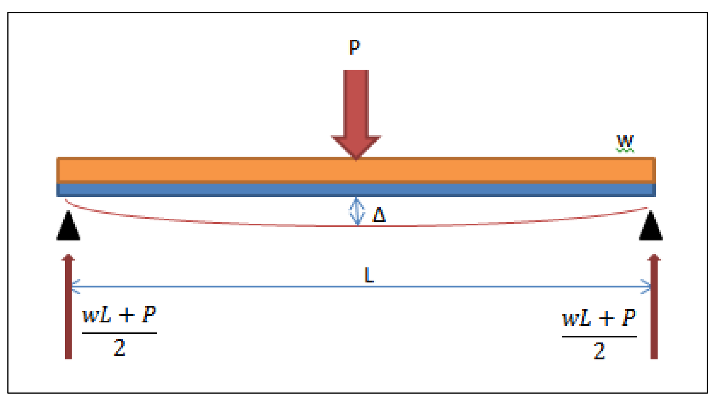

Fig.7: Deflection Modelling

Results and Discussion

DCRP measurement has achieved an accuracy of $\pm$0.08mm. The result also matches up with the prediction from the theoretical model *(Fig.8)*. Hence, DCRP can be utilized in a similar engineering condition such as modeling the defection of a structure member.

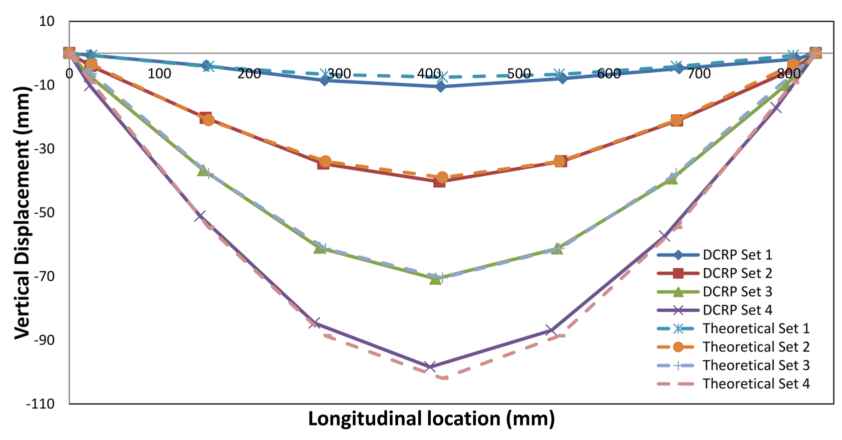

Fig.8: Theoretical Model and DCRP Results

Deformation of a Car Park Facade

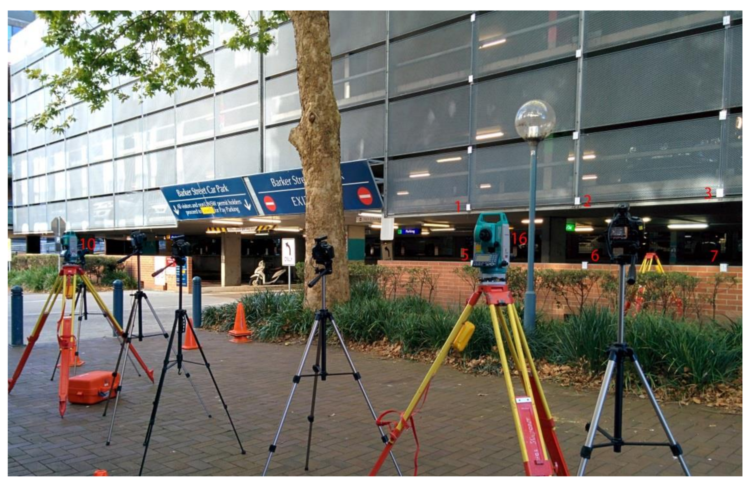

Fig.9: Camera and Total Station Setup

Coded targets were placed on the façade. Cameras were setup 10m away from the targets *(Fig.9)*. Measurement was taken in 2 epochs. One was in the early morning when the car park was nearly empty. Another one was taken in the afternoon when the car park was almost full.

Three approaches were used to take convergent multiple images of the facade

- Multiple 450D cameras (5 cameras taking 5 images simultaneously)
- Single 450D camera (20 images)
- Single 700D camera (20 images)

Each set of images was processed in Australis, Fig.10 is the point rays from multiple cameras.

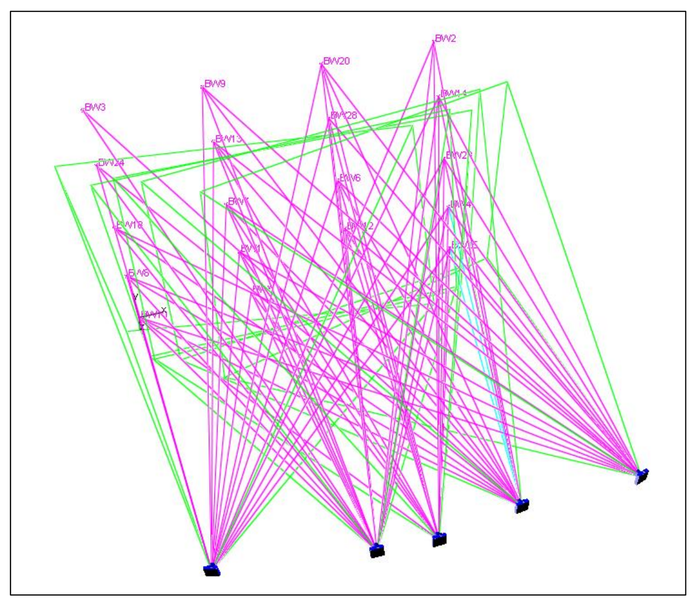

Fig.10: Point Ray of Each Camera in 3D View

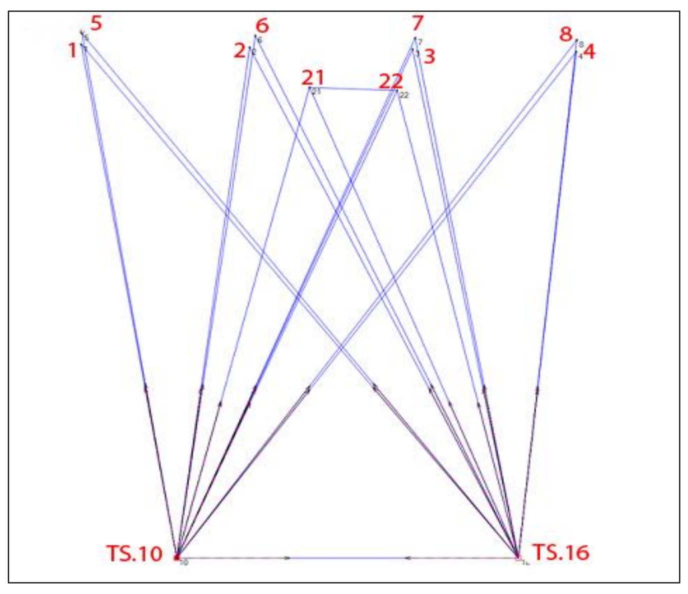

Fig.11: Site Plan by Fixit

Total station method is well known as a precise surveying technique. In this experiment, two SOKKIA530 total stations and a high precision scale bar were used to survey the same target points. Point coordinates were solved by Least Square method using Fixit software. Fig.11 is the total station observation network.

Results and Discussions

The Accuracies of DCRP and Total Station measurement results are listed in Table 1.

	Single 450D	Single 700D	Multiple 450D	Total Station
Accuracy (Standard Error in mm)	±0.16	±0.16	±0.54	±0.32

Table 1: Accuracy of Different Approaches

- Accuracy achieved by the above 4 methods are at sub millimetre level.
- 20 photos were taken with single camera 450D or 700D, while the multi-camera approach which took 5 photos for each measurement. Result shows that the single camera measurement with more photos achieved higher accuracy.
- Higher resolution images normally lead to higher accuracy. Camera 700D has a larger resolution then 450D. Higher accuracy was expected with 700D. In this experiment, it did not follow this expectation. The reason could be that the resolution difference between the cameras is not significant.

In this experiment, we are only interested in vertical direction displacements of the bottom edge of the facade. Results are plotted in Fig.12

- The displacement directions measured by different methods are the same.
- The single 450D, single 700D and total station results are very close while the multi-camera results have small disagreement at point 3 and point 4. This could be due to its less accurate measurement than the other approaches.

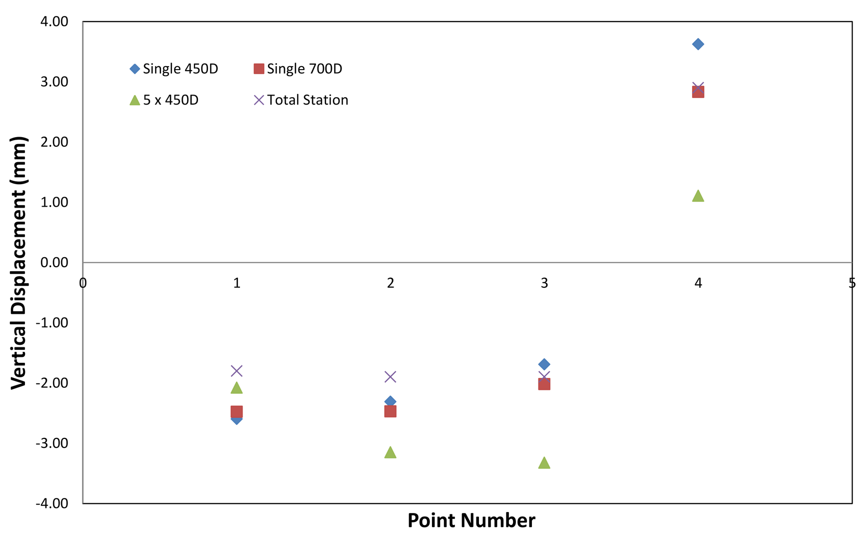

Fig.12: Vertical Deformation of Different Point of Different Approach

Conclusion

Digital Close Range Photogrammetry is a very precise measuring technique with its non-contact advantage. It is capable and applicable in engineering deformation monitoring projects.

The timber beam deflection results agree with its theoretical model. The accuracy achieved by DCRP in façade monitoring project is similar or better than the precise surveying measurements by total station. We also found that a better accuracy can be achieved as the number of photos increased.

Future Work

To achieve a high accuracy measurement individual coded targets are required to attach to the object. As computer image matching technology progresses automated DCRP without coded targets could achieve precise measurement in the near future.