

DLT BASED APPROACH FOR DEFORMATION MEASUREMENT

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ABSTRACT:

Non-metric consumer cameras have become more and more advanced in the recent years. Their capability to measure deformations has been tested and described in the paper. Two preliminary experiments were conducted. In the first preliminary experiment a test of image matching and geometric accuracy was conducted. Based on that test, second preliminary test was conducted in which we tested three non-metric cameras, and their suitability to measure 3D deformations, by using the direct linear transformation. Based on the outcome of these tests, close range photogrammetry was used to measure deformations of longitudinally stiffened plated girders in a bending-shear interaction experiment. In this final experiment three non-metric cameras Canon EOS 5 Mk II were used to calculate deformations, following a direct linear transformation.

1. INTRODUCTION

The paper presents the results of a research for university diploma thesis, at the University of Ljubljana, Faculty of Civil and Geodetic Engineering, where I am studying geodetic engineering. The thesis has been mentored by prof. dr. Mojca Kosmatin Fras.

Our colleagues from the Chair for metal structures are working on research of bending-shear interaction of longitudinally stiffened plated girders. They expressed a need for a method of measuring physical deformations of a metal structure with very high positional accuracy.

In the beginning, various methods were considered, from laser scanning, geodetic measurements with total stations, to photogrammetry. My job was to examine the capability of close range photogrammetry for the purpose.

Close range photogrammetry was considered because it offers accurate 3D positional information, simultaneous measuring of all points, and the data acquisition is almost instant. Further on, the whole process of data processing can be largely automated.

2. PRELIMINARY EXPERIMENTS

2.1 Image matching test

To assess the suitability of photogrammetry for the project, assessment of the measuring precision of the shifts of signalized points, when using a high-end non-metric consumer photo camera, was needed.

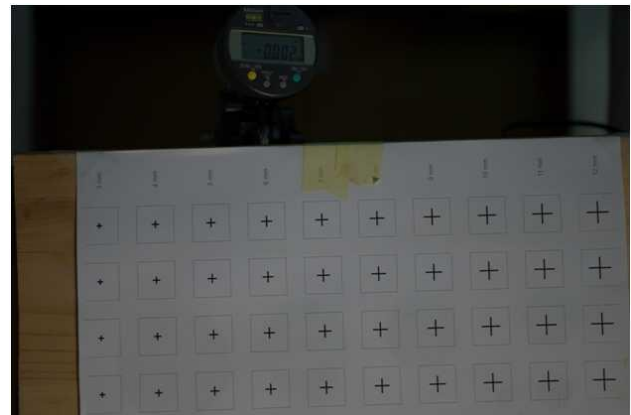


Figure 1. Sample photo from image matching test

A test experiment was conducted, in which sets of photos of a point field were made. Figure 1 shows sample photo from one of the photo sets. The point field was taped to a wooden board, which was moving in a vertical direction. Between the movements of the board, photos of the field were taken, and the shifts of wooden board were measured with a digimatic indicator, which can measure shifts of one point in single direction with an accuracy of 1 μm . Different lighting conditions, signalized point sizes, iso settings and camera distances of 60 cm and 1.5 m were tested.

To automate data processing, a Matlab program was developed. The photo coordinates were measured following an "adaptive least squares image matching" algorithm. Then the detection of the point's shifts followed. The shifts of the signalized points were then transformed from the image plane to the plane in which the board was laying, using a projective transformation. Assessment of the accuracy of the measured shifts based on the fact, that during the move the board did not deform, and that all signalized points were shifted by the same vector. Shifts of single points were compared against average shift of all points' shifts, and board movement measured by digimatic indicator.

The results showed that, along with lighting conditions, exposure settings, and overall picture quality, the size of the

point shift had a huge impact on the accuracy with which the shift was measured. It was expected that the accuracy of measured shifts will be around 0.1 pixels, but it turned out that average assessed accuracy of measured point shifts was as good as 0.06 pixels in case of shift sizes of around 11 pixel. In cases of shift sizes of 1 pixel average accuracy of estimated shifts was 0.04 pixels, and in cases where points were shifted for only 0.1 pixels, the estimated accuracy went up to less than 0.03 pixels. The results showed that high-end non-metric consumer camera could be used for deformation measuring.

2.2 Deformation measurements test

Based on the results of the first preliminary test, a second preliminary test was conducted. The goal of which was to successfully measure 3D shifts of signalized points, by using direct linear transformation and non-metric cameras. Targets had been glued to an iron beam, which was being bent by a hydraulic jack, as shown in figure 2.

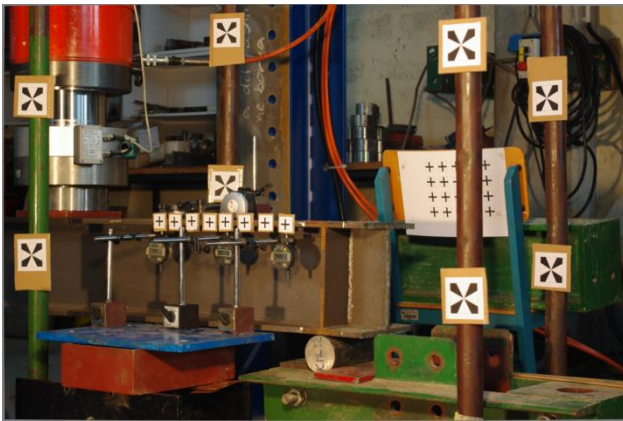


Figure 2. Deformation measurements test

There were 8 fixed points, placed around the beam. This time three mid-range, 10 mega-pixel consumer digital photo cameras were used. The distances between the cameras and the points were about 3 meters. Control measurements of the shifts of signalized points on the beam were measured by digimatic indicators. The fixed points' positions were measured with a Leica 2003 tachymeter. Prior to the test, photos of a test field were taken, which were later used to assess parameters of radial distortion of the cameras.

A Matlab program has been developed, to process sets of photos. First the 2D image shifts of signalized points, between successive photos in the sequence for each of the cameras, were measured. Then, using direct linear transformation, 3D shifts of the signalized points were calculated. The calculated 3D shifts were then compared to the control measurements. Results showed that accuracy of photogrammetrically assessed shifts was around 0.30 mm.

3. FINAL LABORATORY EXPERIMENTS

Based on the outcome of these preliminary tests, photogrammetry was used to measure the deformations of two longitudinally stiffened plated girders, which resulted from the girders being bent by a hydraulic jack. Two panels on each girder were measured. The total of four experiments was conducted. Deformations of one panel were measured in each experiment. The experiments followed a week apart of each

other. The panels were 1.5 and 1.8 m high, and 1.5 to 2.7 m long. This time three 21 mega-pixel Cannon EOS 5D Mk II cameras were used. The number of fixed points has been increased to 14, and there has been a total of more than 200 signalized points on each panel. To signalize points, crosses were printed on plastic foil stickers, which were then glued to the panels. Sets of photos from three different angles were made. To control the cameras a computer with software named "DSLR Remote Pro Multi Camera" was used. The layout of the experiment is shown in figure 3.

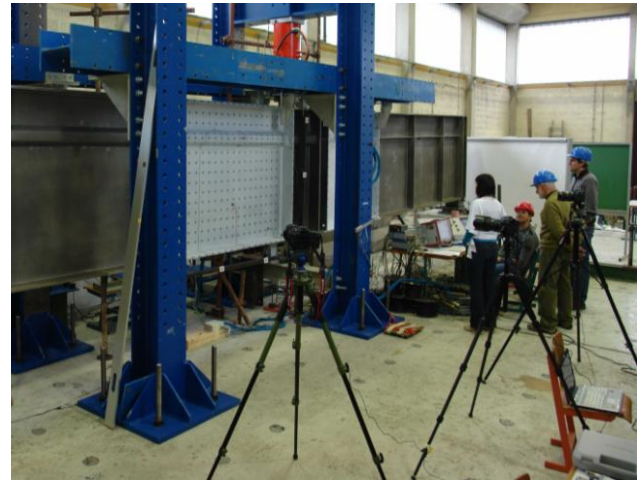


Figure 3. Experiment layout

One panel was deformed at a time. A force, going up to 2000 kN, was gradually applied to the panels in steps by a hydraulic jack. Photos from different angles were taken after each step. In the end the panel was again unloaded. Sample photo is shown in figure 4.

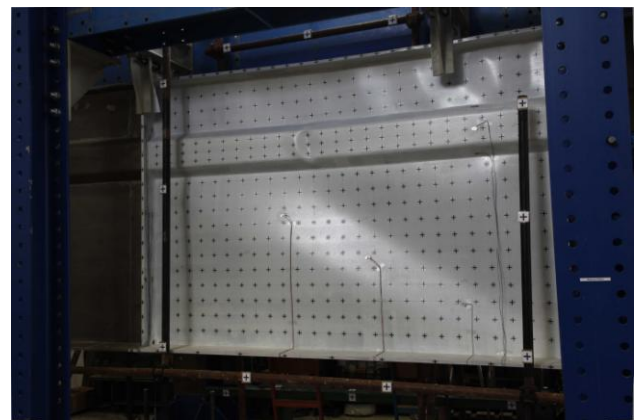


Figure 4. Sample photo

2d shifts of the signalized points in image sequences were observed. Based on these 2d shifts, out-of-plane deformations of panels were calculated in Matlab, using the direct linear transformation. In cases where signalized points in set of photos from one of the angles could not be seen, due to the points being overlapped by the frame, which was holding fixed points in place, shifts were calculated based on photos from photo sets from the other two angles.

4. RESULTS AND ANALYSIS

To represent the results, out-of-plane deformations were plotted. Figure 5 show the deformation of the panel portrayed in figure 4.

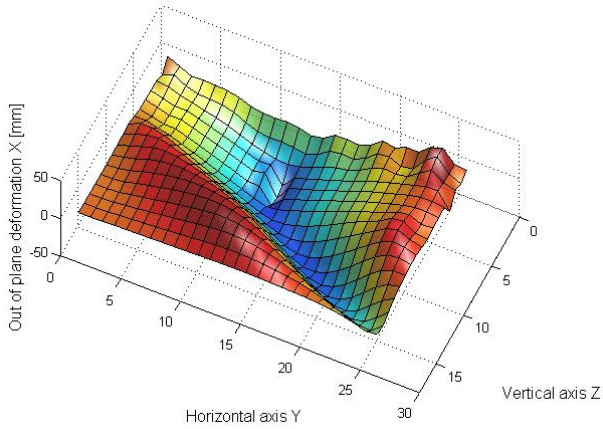


Figure 5. Plot of deformations

The results were compared against control measurements. For each of the panels tested, out-of-plane deformations on three locations, where the biggest deformations were expected, were measured by inductive gauges, connected by strings to the back of the panel. Photogrammetrically measured deformations were compared against control measurements. Figure 6 portrays the comparison of the photogrammetric and inductive measurements for one of the points.

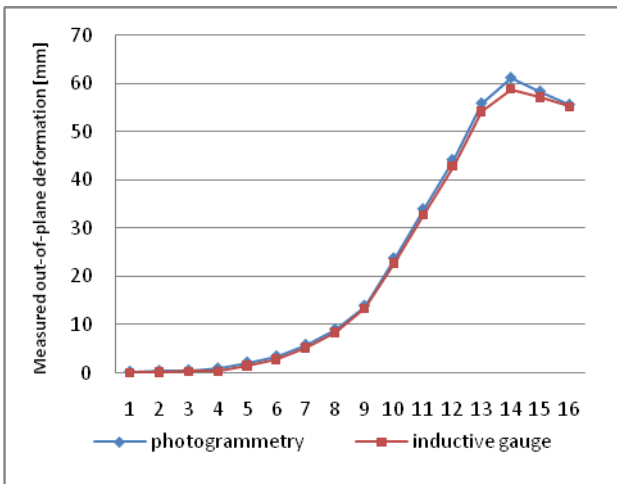


Figure 6. Comparison between photogrammetric and inductive measurements of one point

The comparison showed that smaller deformations could be measured more accurately. Based on this comparison accuracies of the deformations measurements were assessed to be between 0.5 mm and 1.0 mm, on average 0.7 mm.

5. CONCLUSION

The tests were successful. Although higher accuracy than the one achieved, was expected, results are still considered to be good, and will be used in our colleague's doctoral research on bending-shear interaction. The tests showed that non-metric cameras can be used for deformation measurements. However, we believe there is still room for improvement. Accuracy of photogrammetric deformation measurements could be greatly increased, if photogrammetric measurements would be fitted onto control measurements. To achieve that, more of the control measurements would be needed.

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