

DETERMINATION OF DISPLACEMENTS IN LOAD TESTS WITH DIGITAL MULTIMEDIA PHOTOGRAMMETRY

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ABSTRACT:

This paper describes the use of multimedia photogrammetry for determine of deflection behavior of buried flexible pipe 312 mm diameter is placed in highly strengthened steel box under load. 20 mm thick transparent Plexiglas was used in front face of the box. An on-line configuration of three CCD cameras was established to measure targets subject to positional displacement. The entire measurement process was consist of five steps: calibration of camera system, acquisition of multi-image sets, establishment of corresponding points in the images, computation of their 3-D coordinates, acquisition of images after each load application and computation of 3-D coordinates. The algorithm proposed by Maas (1995) was used in order to solve problems of multimedia photogrammetry. For this algorithm is used, the XY plane of coordinate system should be chosen parallel with the plane interface air/glass. Sub-millimeter object point precision has been achieved in all three coordinate dimensions for each measurement epochs.

1. INTRODUCTION

The testing and monitoring of structures and structural components under different loading conditions are a standard engineering application. Geometrical measurements are performed for the examination of the behavior of test objects and for the verification of theories or mechanical models. This is often realized by static, quasi-static, or dynamic short and long time load experiments on test objects. In these tests, it is demanded to determine parameters and effects such as the changes in shape, load and strain which are commonly measured by LVDTs, extensometers and strain gauges. These devices provide on-line results with a high geometric precision and reliability. A general disadvantage of these techniques, however, is their point wise and only one-dimensional measurement capability. The techniques are generally not suited for tasks requiring a large number of measurement points distributed over an object surface or for complete surface measurements. In these cases, techniques of digital photogrammetry depict a valuable option for the design of powerful and flexible measurement tools (Maas, 2006; Hampel, 2003; Whiteman, 2002; Woodhose, 1999).

However, while the measurement of the absolute coordinates and the movement of signalized targets on an object can be solved by commercial software packages, non standard monitoring tasks or multimedia photogrammetry applications will often necessitate the development of customized software tools.

In this study, the photogrammetric system has been developed to measure the coordinates of signalized targets on structural components during static load tests and to solve problems of multimedia photogrammetry. Three experiments are carried out in order to demonstrate the functionality of the system. Vertical loads were applied with the increments of 10 kPa up to 140 kPa using air pressure membranes. Digital photogrammetric system has been used together with the classical measurement device

LVDT in load tests and the measurement results were compared with each other.

At first, the design of the photogrammetric measurement system is described. Then, the measurement process and the algorithm used to solve problems of multimedia photogrammetry are given. Finally, results of the measurement are summarized.

2. SYSTEM CALIBRATION

The three progressive scan CCD cameras (Basler a302fc) with a resolution of 780x582 pixels was used in developed system. The two cameras were fitted with 16 mm lenses, whereas the other camera had a minimum focal length of 12 mm and a maximum focal length of 70 mm. The CCD cameras were connected to the PC by the IEEE-1394 port (also called FireWire or i-link). Some features of the cameras can be controlled by software through the IEEE-1394 port.

The multiple camera system was oriented and calibrated by bundle calibration method and for these purposes a test field with white targets on a black background whose coordinates in space were known was used (Figure 1). The results of the calibration process are the exterior orientation of the cameras (position and rotations), parameters of the interior orientation of the cameras (camera constant, principle point), parameters for the radial and decentering distortion of the lenses and optic systems and two additional parameters modeling differential scaling and shearing effects. A thorough determination of these parameters modeling distortions and other effects is required to achieve high accuracy in the measurement (D'Appuzzo, 2003).

After the calibration and orientation of cameras was determined, before loads were applied, the signalized target points on object must have labeled in images. For this purpose, at first the images of test object was scanned for a specific template image and image coordinates of the recognized target images were

measured with sub pixel accuracy by using centroiding method. Then target points were matched using epipolar plane angle method which was proposed by Sabel (1999).

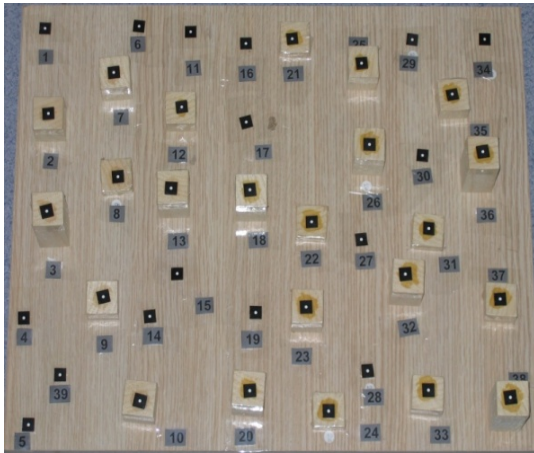


Figure 1. Test field

After these procedures were completed, the monitoring stage of signalized target points on test material under load can be begun. The entire process is composed of three steps.

- After Each load application, acquisition of the multi image sets of test material,
- the measurement of image coordinates of target images which was matched in previous steps,
- The computation of the 3-D coordinates of these points by forward ray intersection using the results of the calibration process

An algorithm similar to the method which proposed by Maas was used in order to remove the refraction effect. In loading tests, test field was placed as parallel to transparent Plexiglas which was used in front of the test box. The principles of algorithm are shown in Figure 2. If the point P (X, Y, Z) in object space is shifted to \underline{P} (X, Y, Z), the collinearity condition can be applied for P using the object coordinates of the shifted point \underline{P} .

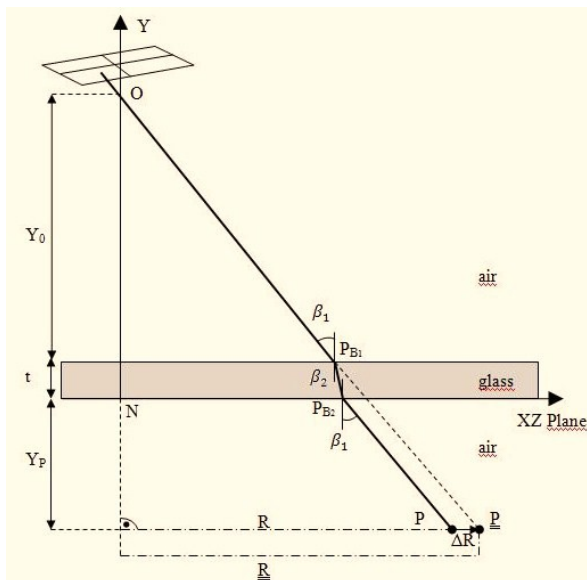


Figure 2. Radial shift for compensation

Only a radial shift by ΔR parallel to the XY plane has to be computed for each point relative to the nadir point of each camera (Maas, 1995).

From figure 2 can be derived:

$$Y_0 \tan \beta_1 + t \cdot \tan \beta_2 + Y_p \tan \beta_1 = R \quad (1)$$

$$(Y_0 + t + Y_p) \tan \beta_1 = \underline{R} \quad (2)$$

With Snell's Law

$$n_1 \sin \beta_1 = n_2 \sin \beta_2 \quad (3)$$

the system describing the multimedia geometry is complete. Equations (1), (2) and (3) can only be solved iteratively due to the trigonometric functions. If P is chosen as a first approximation for P and

$$R_{(0)} = \sqrt{(X_p - X_0)^2 + (Z_p - Z_0)^2} \quad (4)$$

the angle of incidence in the medium n1 in the first iteration becomes

$$\beta_1 = \tan^{-1} \left(\frac{R_{(0)}}{Y_0 + t + Y_p} \right) \quad (5)$$

The angle of incidence in the plexiglas media according to Snell's Law and the correction for $R_{(0)}$ are computed by using following equations.

$$\beta_2 = \sin^{-1} \left(\frac{n_1}{n_2} \sin \beta_1 \right) \quad (6)$$

$$\Delta R = \frac{t \sin (\beta_1 - \beta_2)}{\cos \beta_1 \cos \beta_2} \quad (7)$$

$$\underline{R} = R_{(0)} + \Delta R \quad (8)$$

The equations (5)-(9) are used iteratively until the difference between consecutive ΔR values are equal or smaller than the predefined threshold value (0.001 mm). And finally the coordinates of the radially shifted point is computed.

$$\underline{X}_p = X_0 + (X_p - X_0) \underline{R} / R \quad (9)$$

$$\underline{Z}_p = Z_0 + (Z_p - Z_0) \underline{R} / R \quad (10)$$

The collinearity condition for cameras C_j can then be used with the radially shifted point P_j (X, Y, Z) instead of P (X, Y, Z) (Maas, 1995).

3. APPLICATION

Test box in which was placed buried flexible pipe 312mm diameter had a dimensions of 700 mm length x 500mm width and 700 mm in height. 20 mm thick transparent Plexiglas was used in front of the box in order to make photogrammetric measurements (Figure 3). An air pressure membrane was used to applying vertical loads.



Figure 3. The test box

At the experiments, an LVDT was placed in the approximate perpendicular directions and measurements were made under gradual load and these values are saved as text files on the pc hard disc.

After each load application, photogrammetric measurements were obtained using the developed system with user interaction. In load experiments which were used three CCD cameras, the average camera-to-object distance for the outer two cameras was 90 cm (imaging scale of 1:50), whereas that for the centre camera was 80 cm (1:55 scale). Circular targets on test material were 6-7 pixels within the imagery. The measurements were carried out at 10-14 epochs at load experiments which continue up to 140-100 kPa with the increments of 10 kPa.

4. RESULTS

In summary, the use of multimedia photogrammetry for determine of deflection behavior of buried flexible pipe has been successfully demonstrated. Sub-millimeter object point precision was achieved in all three coordinate dimensions. The RMS value of image coordinate residuals ranged from 0.06 pixels to 0.2 pixels.

The readings of measurement obtained from LVDT which was placed in the approximate perpendicular direction were compared with measurement results obtained by using photogrammetric system. Figure 4 is shown comparison of measurement results achieved for first load test. Similar graphics were obtained for other tests.

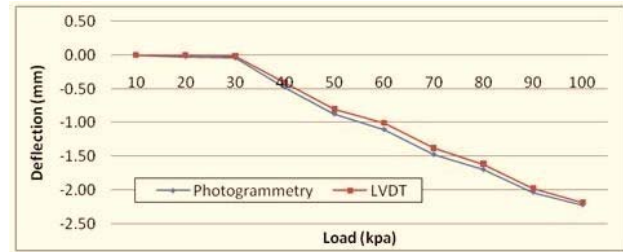


Figure 4. Comparison of measurement results

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