

MEASUREMENT OF SHRINKAGE IN CONCRETE SAMPLES BY USING DIGITAL PHOTOGRAMMETRIC METHODS

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ABSTRACT:

This paper shows the use of digital photogrammetry for measurement of shrinkage in concrete sample (4x4x22 cm) during the hydration process. A vision system consist of two digital video cameras was established to measure vertical displacement. The system was calibrated because of the cameras were designed for high accuracy measurement purposes. This was done by imaging a calibration object placed within the workplace. A least squares bundle adjustment determines the camera calibration parameters as well as the exterior orientation parameters of the cameras. Measurements were conducted at 2 epochs over 24 h. The estimated precision of the 3-D points positions is in the order of 0,1 mm, which is sufficient for this application. The resulting points can then be used for a deformation analysis.

1. INTRODUCTION

The measurement of objects such as deforming parts has often been realized using methods such as interferometry, Moiré techniques, theodolite measurement systems, or coordinate measurement machines. But various disadvantages (high prices, system have to rest stable during the whole campaign, measuring effort, influence of touching the object) lead to the demand of new techniques.

With the development of solid-state sensor imaging devices and powerful computer platforms, new image-processing-based solutions for a large number of 3-D measurement tasks have been successfully applied for many years. Compared with those techniques mentioned above, there are some obvious reasons, which make the use of digital photogrammetry more than just a useful alternative: Photogrammetry is non-contact, requires no manual reading of dials, yields three-dimensional measurements, and provides visual records of the testing. (Maas, 1994, Whiteman, 2002).

Concrete and cement paste show shrinkage and settlement during the hydration process. Although there are several measurement techniques to obtain the length variation of hardened concrete, we have serious problems on the determination of settlement in fresh state (Neville, 2000).

The paper reports on how to use digital close-range photogrammetric techniques for measurement of shrinkage and settlement of concrete sample in fresh and hardened state (Fig. 1) during the hydration process. Using digital photogrammetry, we were able to achieve a sufficient relative accuracy.

2. SYSTEM CONFIGURATION

2.1 Design

For the determination of an appropriate configuration and the calculation of the camera parameters, the following input was used:

- object size,
- principal distance and
- the size of the digital image. (Suthau, 2001)



Figure 1: Concrete sample

The system was arranged convergently at a distance of approximately 0.50 m from the concrete sample (Figure 2). Concrete specimens having the dimensions of 40x40x220 mm were used for the experimental study. Measurements were carried out on the specimen, which had not been demoulded, to obtain the fresh state behavior.



Figure 2: Camera configuration

2.2 Image data acquisition

For this experiment, we used Two Basler A302fs CCD cameras. The cameras were operated on a fast serial bus specified in IEEE 1394, allowing for fast transmission of digital signals from video cameras directly into the PC.

A CCD camera can be understood as a metric camera because of its solid CCD matrix. It is assumed that the lens is stably interconnected with the camera body and the focal length is fixed. (Suthau, 2000). The technical data of the camera are listed in Table 1.

Sensor Type	Sony ICX075AL/AK - 1/2 inch, HAD, interline transfer, progressive scan CCD
Pixels	782 (H) x 582 (V)
Pixel Size	8.3 (H) μm x 8.3 (V) μm
Video Output	8 bits per pixel, IEEE 1394 Compliant
Lens	focal length 16 mm

Table 1: Technical data of the camera

2.3 Calibration

Calibration and orientation of cameras and images are procedures of fundamental importance, in particular for all applications which rely on the extraction of precise 3-D geometric information from imagery where a calibration step is as prerequisite for accurate and reliable results. The calibration procedure is defined as the determination of geometric deviations of the physical reality from a geometrically ideal imaging system: the pinhole camera. Often, only the geometric modeling of the relation between objects and corresponding image features is considered, but a complete calibration procedure includes a more global analysis of lens system, sensor, and camera electronics

The fundamental mathematical model is the collinearity condition. It simply express that a point in object space, its corresponding points in the image plane and the centre of perspective lie on a straight line. The collinearity condition is expressed by:

$$\begin{bmatrix} x - x_p \\ y - y_p \\ 0 - c \end{bmatrix} = \lambda D \begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix} \quad (1)$$

where x, y = image coordinates of point
 c = camera constant
 x_p, y_p = image coordinates of principal point
 X_0, Y_0, Z_0 = coordinates of projection center
 X', Y', Z' = object coordinates of point coordinate system
 λ = scale factor between image and object vector
 D = orthogonal rotation matrix

The deviations of the physical reality from the ideal imaging geometry of the collinearity condition lead to systematic errors. These errors are compensated with correction terms for the image coordinates that are functions of a set of additional parameters. A set of these parameters consists of the parameters of interior orientation ($\Delta x_p, \Delta y_p, \Delta c$), a scale factor for the

uncertainty in pixel spacing (S_x), a shear factor (A) modelling a non-orthogonality of the image coordinate system, the parameters describing symmetrical radial lens distortion (K_1, K_2, K_3) and parameters of decentring lens distortion (P_1, P_2) (Remondio, 2002). The extended collinearity equations have the following form:

$$\begin{aligned} x - x_p &= -c \frac{U}{W} + \Delta x \\ y - y_p &= -c \frac{U}{W} + \Delta y \end{aligned} \quad (2)$$

where

$$\begin{aligned} \Delta x &= \Delta x_p - \frac{\bar{x}}{c} \Delta c - \bar{x} S_x + \bar{y} A + \bar{x} r^2 K_1 + \bar{x} r^4 K_2 + \bar{x} r^6 K_3 \\ &\quad + (r^2 + 2\bar{x}^2) P_1 + 2\bar{x} \bar{y} P_2 \\ \Delta y &= \Delta y_p - \frac{\bar{y}}{c} \Delta c - \bar{x} A + \bar{y} r^2 K_1 + \bar{y} r^4 K_2 + \bar{y} r^6 K_3 \\ &\quad + 2\bar{x} \bar{y} P_1 + (r^2 + 2\bar{y}^2) P_2 \end{aligned} \quad (3)$$

$$\text{with: } \bar{x} = x - x_p, \quad \bar{y} = y - y_p, \quad r = \sqrt{\bar{x}^2 + \bar{y}^2} \quad (4)$$

A step calibration target plate is employed that provides a three-dimensional target field, as shown in Figure 3. The calibration object was taken at a distance of approximately 50 cm and at the principal distance of 16 mm from the CCD camera from 8 different directions and positions.



Figure 3: Calibration object

The software package PICTRAN which produced by Technet GmbH is used. A set of 4 additional parameters was used to compensate systematic errors. This package enables us to determine calibration parameters for more than one camera simultaneously.

The parameters of the interior orientation of the cameras and the exterior orientation for each camera were determined with a least squares bundle adjustment. Table 2 lists the estimated camera calibration parameters and their standard deviations for one of the two cameras. Similar results were obtained for the other camera.

In order to test the absolute accuracy of the configuration, we calculated the coordinates of the calibration points as new points. The achieved accuracy of the 3D measurement is 0,1 mm in X- and Y-direction and 0,15 mm in Z.

Camera 1	value	σ
Focal Length (mm)	16.006119	0.0093
Principal Point x	0.001229	0.0046
Principal Point y	0.000508	0.0016
A1	-0.469369D-03	0.1807D-03
A2	0.324284D-05	0.2350D-04
Scale	-0.559509D-04	0.5976D-04
Shear	-0.118859D-03	0.5949D-04

Table 2: Results of camera calibration for camera 1

3. RESULTS

As a result we get the difference of coordinate's value between the beginning and the end of period. Fig 4, 5 illustrate the surfaces of the specimens for either 0 hour of 24 hour measurements. It is clearly seen from the surfaces that there is a significant settlement on concrete specimen. Colorized scales are also given in Fig 4 and Fig 5. The results show unsatisfactory random behaviors in x and y directions. A downward movement was determined for the z- coordinates. The maximum value of z-coordinate movement is 0.739 mm while the minimum value is 0.16 mm and the average is 0.42 mm.

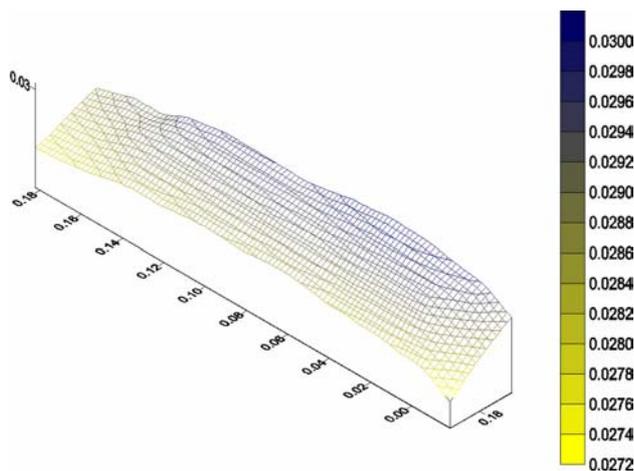


Figure 4: The surface of concrete specimen (Just after casting)

Settlement of the concrete in early ages (before the setting) is an expected phenomenon. Volume of the hydration products is lower than the total volume of the reactive materials before hydration. This phenomenon, which is called chemical shrinkage, causes volume reduction on concrete. This volume reduction is occurred as settlement in fresh concrete (Aitcin, 1998). Air voids could also cause the settlement by leaving from the paste in this state.

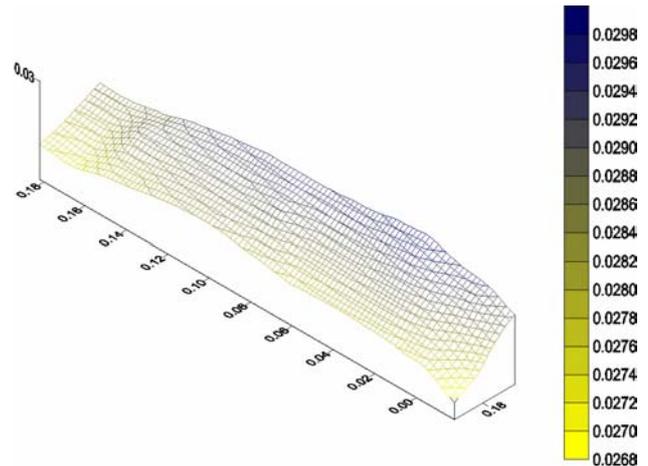


Figure 5: The surface of concrete specimen (1 day later)

4. CONCLUSIONS

This paper presented a stereo vision system designed for activities of inspection. The system was divided into three stages: stereo image acquisition, preprocessing, and reconstruction.

The precision of this system could be improved by a higher camera resolution. The precision and the reliability may be improved by adding more cameras to the system. A surveying of other objects is possible. The size of the object plays no role, but must be considered regarding the resolution and the accuracy however. Satisfactory settlement values were obtained from this study. Effect of the thickness of the specimens on the z-coordinate variation could be studied in further studies.

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