A Review of Beam Deformation Monitoring using Close Range Photogrammetry

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Abstract— Deformation checking is an important procedure for measuring the structural health of complete civil engineering structures. Most classical methods for measuring deformation or deflection taking place in structures need periodic access for the particular area being monitored properly. Like remote sensing techniques, photogrammetry does not need any connection with the objects of interest, and this can be a great benefit when it comes to the deformation monitoring of inaccessible structures or simply large structures. This paper shows a cost-effective setup of digital cameras used for photogrammetry for calculating deformation monitoring of structural materials. The setup was tested in two experiments, in which concrete beams were deformed at different loading conditions by a hydraulic actuator. The methodology necessary to measure the deflections or deformations consisted of:
(1) Image processing and extraction of co-ordinates.
(2) Measurement of deflection and comparison by terrestrial methods.

Key words: Deformation Monitoring, Remote Sensing, Photogrammetry, Civil Engineering, Digital Cameras, Remote Sensing, Hydraulic Actuator, Concrete Beam

I. INTRODUCTION

When mechanical stress is applied at any object or at any surface, the object or surface may result to different change in its shape and size, also known as deformations. This can also be termed as elongation, compression or distortion. Deformation monitoring is a method of performing precise measurements of the object or surface of interest at regular intervals in trying to detect changes that occur in structures. Structural building monitoring or monitoring the physical health of large and complex structures such as (bridges, mines, dams, tunnels, high-rise buildings etc.) is important so that severe damage or complete destruction of structure and the worst condition ie any casualties can be avoided as much as possible. This study is thus done to investigate the capacity for deformation monitoring of structural materials using photogrammetry. Classical deformation monitoring techniques can be divided into geotechnical measurements and geodetic-based surveys.

A. Direct Measurement

Direct measurements (also called contact measurements) are one in all the foremost simple approaches for getting data from the measured objects (Ansari, 2005). These mensuration strategies are ordinarily accustomed to measure the changes in stress of one purpose or little space (Li et al., 2009). The sensors are ordinarily buried within the target objects and these sensors are wired to a receiver, that is connected to a information (some systems use wireless transmission) so as to transfer the period deformation information for more analyses. Strain gauge and optical fibre gratings are the direct measurements which we are able to additionally say contact measurements done to check structural health monitoring of structures.

B. Geodetic Measurements

Geodetic measurements are adopted when we are measuring large objects and wide areas (Min, 2008) and this process is one of the most advantageous in terms of using these measurement methods for structural health monitoring. The apparatus used in this measurement or test method are mostly larger and heavier than the direct methods. Geodetic measurements are the most frequently used techniques in civil engineering because the required instruments are the most commonly used equipment in general construction and civil engineering (Karbhari and Ansari, 2009). Total stations, global navigation satellite systems (GNSS), Terrestrial Laser Scanning Systems etc. are the geodetic measurements which are used for structural health monitoring of civil engineering structures.

II. DIFFERENT METHODS USED IN PAST FOR DEFORMATION MONITORING

In terms of structural monitoring in civil engineering, selecting a proper measurement for a specific project relies on the professional judgment of the planning team (Connor and Faraji, 2012). In general civil engineering projects, the size of target objects can be as small as a single storey house or as large as a dam. According to the demands of required accuracy and the difference of target sizes, surveyors can choose the appropriate measurement method to meet the engineering requirements.

A. Strain Gauge

A strain gauge is a low-cost device used to measure the change in strain on an object when the object is placed under stress. The strain gauge can convert the mechanical force into an electrical signal (Yongdae et al., 2010). There are many types of strain gauges and each one has different operating principles and applications. Among them, resistance strain gauges are the most commonly used in structural monitoring applications.

B. Optical Fibre Gratings

In order to improve the issue of a small measuring range, whilst also wanting to retain the capability of real-time monitoring, strain gauges have gradually been replaced with optical fibre gratings in wide-area measurement applications (Choi et al., 2012). An optical fibre is a flexible, transparent fibre which is made of silica or plastic (Lee et al., 2009). Optical fibres are normally used to transmit light signals and audio signals between the two ends of the fibre. Due to the low impedance of the inner wall, signals travel along optical fibres with less loss.

C. Total Stations

total station can be used to perform three-dimensional coordinate measurements. Some of the latest models of total stations have been able to perform automated operation and can be remotely controlled. In general, surveyors need to choose stable locations to establish permanent observation points where they can still allow the operators to use a total station to observe the target objects. The operator regularly mounts the total station onto each observation point to measure the angle data from each target and to calculate the coordinates of targets using space intersection. By comparing the coordinate data of each target, which were measured in different periods, the deformation of the target structure can be obtained.

D. Global Navigation Satellite Systems

In comparison to measurements made through the use of total stations, the data collection and data transmission processes of GNSS measurements are fully automatic. Therefore, GNSS measurements can be seen as a type of in-situ, automated system. The collected data can be remotely transferred back to the remote database and most of the receiving antennas are weather proof. Therefore, the GNSS measurement method can be used in those test sites that are in remote locations (Sariff et al., 2011).

E. Terrestrial Laser Scanning Systems

Terrestrial laser scanning technology is an efficient solution for a large range of monitoring projects. A 60 m (L) x 8 m (W) tunnel 3D model can be assembled from 11 aligned scans. The scanning process in each station can be completed within just thirty minutes (density acquisition at 100,000 points per second). The overall positional accuracy is 6 mm whilst the distance accuracy is less than 4 mm at distances up to 25 m (Fekete et al., 2010).

III. EXPERIMENT AND METHODOLOGY

In this experiment we had made a setup for calibration and deflection measurement. The photographs of these setup at different loading is taken and then it is processed to take out co-ordinates and then deflection is measured by counting the pixels. The process of taking out co-ordinates is shown in flowchart below:

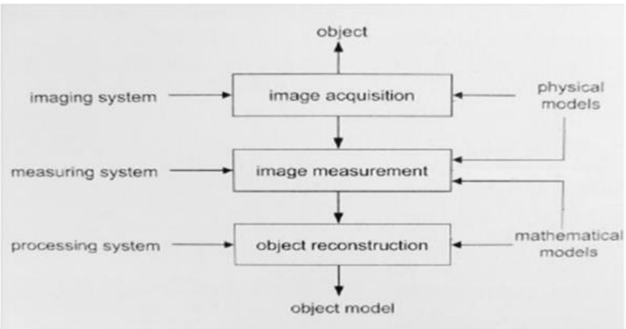

Fig. 1: Flowchart for Extraction of Co-Ordinates

A. Calibration

The objective of the geometric camera calibration procedure is to obtain the camera's internal features or interior orientation parameters (IOPs) and these include the principal point coordinates, the principal distance, and the lens distortion parameters. Calibration is done by making a setup of an iron net and a camera fixed at a tripod stand at the centre of the iron net at 1.5 m from net. The setup of the camera and iron net is shown in the fig (2) below.

Fig. 2: Setup of Calibration

In this calibration an iron net with size 5cm x 5cm and canon powershot A2300 HD camera is used. Calibration is done to find the least count or a scale on the x-axis and y-axis.

After the calibration the result calculated is:

On x axis- 1 pixel= .407876mm

On y axis- 1 pixel= .407112mm

This scale is used in the deflection measurement after calculating the difference in coordinates on each axis.

IV. MEASUREMENT OF DEFLECTION

The deflection measurement is done by using a beam which we have designed according to M-25mix and the dimensions are length=1800mm, breadth=150mm and thickness of 100mm.The setup of beam in the experiment is shown in the fig (3):

Fig. 3: Experimental Setup for Deflection Measurement

In the deflection measurement we also had set a dial gauge for getting the deflection manually. The setup of dial gauge is shown in the fig below:

Fig. 4: Setup of Dial Gauge

V. RESULT AND DISCUSSION

In the research paper we had to compare between the deflections of photogrammetry, dial gauge deflections and also theoretical deflection will be viewed. for now the graph between dial gauge and photogrammetry deflection is shown:

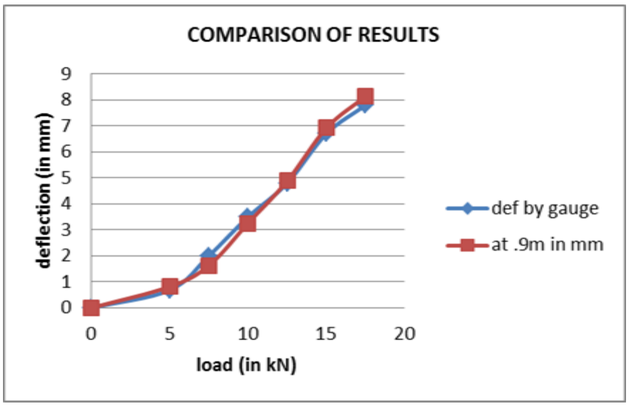

Fig. 5:

VI. CONCLUSIONS AND FUTURE SCOPE

This paper discovered the use of consumer grade cameras for deformation monitoring of building materials. The purpose of the two conducted investigations was to set up multiple camera on a metal frame in order to be able to identify deflections in concrete beams produced by a hydraulic actuator. After photogrammetric reconstruction has performed using manually collected image coordinates, it has been shown that sub-millimetre accuracy for the beam deflections could be achieved in object space. Future scope will include handling the data from the terrestrial laser scanning systems and reprocessing the image data by carrying out semi-automated surface reconstruction of the full plates and the visible beam surfaces. And the maximum focus will be given to get max accuracy with less cost and reduction in the labour.

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