Application of Photogrammetric System for Monitoring Civil Engineering Structures

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Abstract— With the development of lot of construction techniques and different materials technology, the design of recent civil engineering has become so much advanced and difficult. Along with this we also need to focus on the improvement and effective monitoring of all the technologies in the structure because this is an essential part for the improvement in the performance of structural monitoring systems and for reduction in labour. Parallel to this, implementation costs have become important issue that all the experts and scientists are involved for solving. In this research paper application of cost effective and high accuracy photogrammetric system is studied and tested for monitoring civil engineering structures. This research paper includes the merits of photogrammetry for a cost effective and highly efficient accurate solution for structural health monitoring of large and complex structures. Therefore, this research paper introduces a real-time measuring system also called as VMS and this is based on digital photogrammetry. The calculated results of photogrammetric system are compared with those of traditional apparatus (dial gauge) and also theoretical calculations in various tests and then the accuracy of photogrammetric system is evaluated.

Key words: photogrammetric system, structural health monitoring, VMS, laser scanning systems, GNSS

I. INTRODUCTION

With the improvement of structural engineering, the design of modern buildings has become more and more complex. Considering civil structures as examples, due to the extensive use of composite materials, the strength of the structure is enhanced significantly which has led to increased sizes of modern structures. The widening of measuring areas (Baofeng and Gang, 2011) and the use of diverse building materials (Elaldi, 2005) have increased the difficulties associated with structural monitoring. In addition, because of the wider distribution of the population, artificial structures are no longer only located in densely populated areas. For example, dam constructions (Erfeng and Yongqiang, 2008) and large electric towers (e.g. large high-voltage pylons) (Ling et al., 2011) may be located in mountain areas or suburbs, but they also require long-term monitoring to ensure on-going structural safety.In terms of using conventional systems for structural monitoring, the following problems are usually encountered:

1) Costly and heavy equipment;
2) The susceptibility and performance of devices can easily be interfered with by environmental factors;
3) A system‘s ability to provide reliable measurements over a wide spatial area.

II. LITERATURE REVIEW

Structural monitoring has been deliberated to be a complex issue because the ideal measuring instrument varies according to the differences in test site conditions and also according to target objects (Sun et al., 2010). A review of some of the most frequently used measurements in modern civil engineering is presented in this research paper in the literature review.

A. Direct Measurements:

Direct measurements (also known as contact measurements) are one of the most straightforward approaches for obtaining information from the measured objects (Ansari, 2005). These measurement methods are normally used to measure the changes in stress of a single point or small area (Li et al., 2009). The sensors are normally buried in the target objects and these sensors are wired to a receiver, which is connected to a database (some systems use wireless transmission) in order to transfer the real-time deformation data for further analyses. Strain gauge and optical fibre gratings are some of the direct measurements are we can also say contact measurements done to study structural health monitoring.

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.

C. Close Range Photogrammetric Measurement:

Close-range photogrammetric techniques allow engineers using only a few imaging stations to perform non-contact measurements with wide-area coverage. Based on an understanding of these requirements and restrictions, a camera based, photogrammetric system is proposed in this research which is developed to meet a variety of structural monitoring demands in civil engineering. This chapter has outlined a number of structural monitoring techniques that are commonly used in modern civil engineering. The strengths and weaknesses of each measurement in structural monitoring aspects have been presented. Through the description of actual applications, the instrument configuration, experimental restrictions and achievable precision, etc. of each measurement were introduced.

Measurement	Strain	FBG	Total stations	GNSS	TLS	Close-range photogr

	gauge					ammetry
Range	S	M	S	S	M	M
Contact/ non contact	C	C	N	C	N	N
Ability of flexible structural monitoring	GOOD	GOOD	DIFFICULT	GOOD	DIFFICULT	GOOD
Instrument	LOW	MEDIUM	MEDIUM	HIGH	HIGH	MEDIUM

Table 1: Comparison of different measurement techniques for different characteristics.

III. EXPERIMENT & METHODOLOGY:

A. Calibration:

In this, first of all calibration is done so that we may get a scale on the x-axis and y-axis. Calibration was done in order to get a relationship between pixels and the metric units. We had made a setup by installing a camera at the centre and a iron net which has size of 5cm x 5cm. In terms of the implementation of the field calibration, the camera calibration parameters were obtained based on a precise and sufficient number of object space control points. The camera was installed at 1.5 m in forward direction from centre. The camera used for all this photogrammetry is CANON powershot A2300 HD. After the photograph has been taken the photograph was viewed in paintshop pro software in order to get the co-ordinates. The technical specifications of the camera used is as follows:

Technical Specifications of the camera used:

Focal length (equiv.)	F2.8–6.9
Maximum aperture	4608 x 3456
Max resolution	
Other resolutions	4608 x 2592, 3264 x 2448, 1600 x 1200, 640 x 480
Image ratio w:h	4:3, 16:9
Effective pixels	16 megapixels
Sensor size	1/2.3" (6.17 x 4.55 mm)

The setup of calibration ie. installed iron net and camera is shown in fig (1).

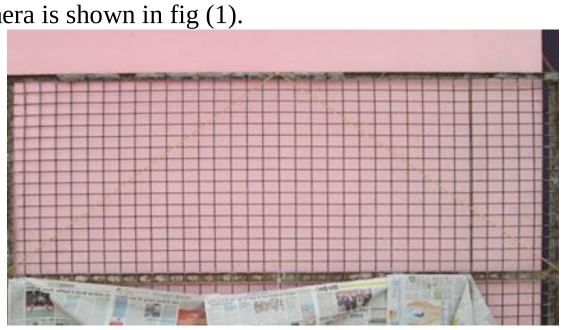

Fig. 2: Frame used for caliberation

After calibration and doing the calculation by using the coordinates at several points we got the scale as follows: On x-axis- 1pixel= .896mm and on y axis- 1 pixel=.878mm.

With the help of co-ordinates the scale calculated is shown below in the table[2].

BLOCK	corner x				corner y				X1	X2	Y1	Y	X[a	Y[avg]	X[a	Y[a	SCALE	SCALE
	a	b	c	d	a	b	c	d										
A	439	485	485	438	1653	1653	1697	1697	46	47	44	44	46.5	44	50	50	0.88	0.88
B	1009	1054	1054	1009	1652	1652	1694	1693	45	45	42	41	45	41.5	50	50	0.9	0.83
C	1551	1594	1594	1551	1652	1651	1694	1695	43	43	42	44	43	43	50	50	0.86	0.86
D	435	481	480	435	1874	1874	1917	1917	46	45	43	43	45.5	43	50	50	0.91	0.86
E	1009	1053	1054	1008	1872	1872	1916	1917	44	46	44	45	45	44.5	50	50	0.9	0.89
F	1554	1598	1598	1554	1874	1874	1919	1919	44	44	45	45	44	45	50	50	0.88	0.9
G	431	478	477	430	2098	2098	2142	2141	47	47	44	43	47	43.5	50	50	0.94	0.87
H	1009	1055	1055	1009	2097	2097	2143	2142	46	46	46	45	46	45.5	50	50	0.92	0.91
I	1558	1601	1602	1558	2102	2102	2147	2147	43	44	45	45	43.5	45	50	50	0.87	0.9
																	0.896	0.878

Table 2: Calculation of scale on x and y-axis

B. Deflection Measurement:

For deflection measurement first of all a beam was designed with the dimensions as follows: length- 1800mm, breadth- 150mm, thickness- 100 mm. and the design mix used was M-25. This beam was kept for curing for 28 days. This beam was kept on compressive testing machine for measurement of deflections. In the test first of all a hydraulic loading was applied at different intervals. Several photographs were taken at different loads. Photographs were processed to take out co-ordinates by paint shop pro by dviding it into grids and several other factors were considered. Also MATLAB software was used for the image acquisition process and image processing.

Fig. 3: deflection measurement photography

After the setup is done and photographs are taken VMS technique is used in the photogrammetry for co-ordinate calculation and deflection measurement. The process is shown in the fig (4):

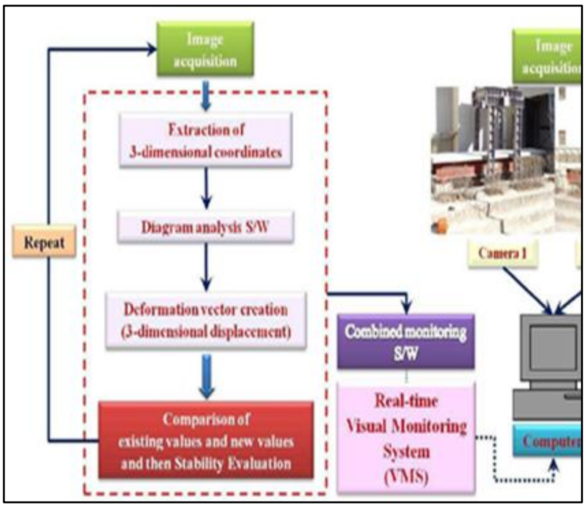

Fig. 4: process of co-ordinate extraction and deflection measureme

IV. CALCULATIONS

The deflection calculated by dial gauge and by photogrammetry are shown in the table

load in Kn	DEFLECTION AT CENTRE BY GAUGE at .9m	DELECTION BY PHOTOGRAMMETRY IN PIXELS at .9m	IN mm at .9m
0	0	0	0
5	0.68	2	0.814224
7.5	2	4	1.628448
10	3.5	8	3.256896
12.5	4.8	12	4.885344
15	6.7	17	6.920904
17.5	7.8	20	8.14224

Table 3: Calculation of deflection

V. COMPARISON B/W PHOTOGRAMMETRIC SYSTEM AND CONVENTIONAL MEASUREMENTS:

To confirm the accuracy and the applicability of Photogrammetrric deflection values and dial gauge deflection values are compared by plotting a graph for similar experiment. And it is seen that the developed photpgrammetric system can accurately measure an overall deformation of the test member. It is concluded that the developed photogrammetric system has the high accuracy of 90% and the applicability of deformation measurement for the several structures. A graph is plotted for the comparison of the systems. The graph is shown below:

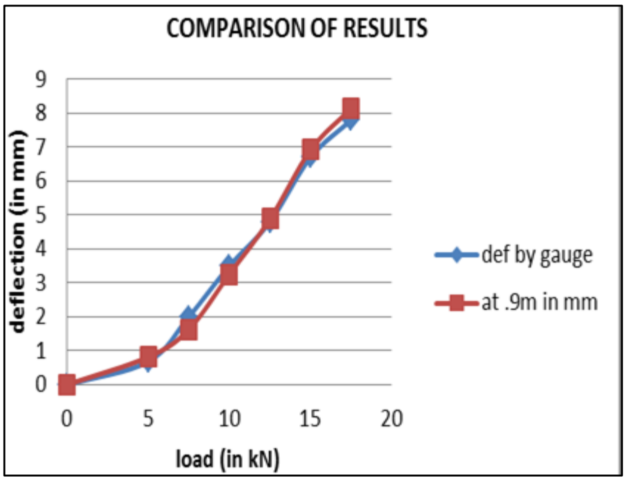

Fig. 5:

VI. CONCLUSION

This chapter introduces research cases related to photogrammetry and a real-time measuring system (called as visual monitoring system, VMS) which is based on digital photogrammetry. It confirms the applicability of digital photogrammetry in civil engineering structures and cultural assets. Digital photogrammetry is applied in various fields and it is developed rapidly with development of image processing technique and image acquisition apparatus. Therefore, if digital photogrammetry is applied continuously in civil engineering structures, micro measuring instruments, and cultural assets, it is a very useful tool as disaster prevention monitoring system due to the quantitative digital image. However, image acquisition apparatus should be improved in high precision. Techniques of camera capacity should be developed to decrease an error rate of image acquisition apparatus. With high techniques, real-time monitoring system will be used more widely in various fields.

VII. FUTURE SCOPE

Photogrammetric monitoring system is capable of long-term structural monitoring applications. With the development of hardware speciation, the system can still be improved in some specific aspects to satisfy more requirements for different measurement schemes. In this research paper a cost effective and efficient system or model is made. In future we can work more on the efficiency so that structural health monitoring can be done easily with reduction in labour and high efficiency. image acquisition apparatus should be improved in high precision. Techniques of camera capacity should be developed to decrease an error rate of image acquisition apparatus. With high techniques, real-time monitoring system will be used more widely in various fields.

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