An Innovative Multi-headed Camera Network: A Displacement-Relay Videometrics Method in Unstable Areas

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1 Introduction

The subsidence of ground beds occurs frequently in large construction projects such as bridges, dams, high buildings and railways, which may cause damage and sometimes create disasters. Especially along with the establishment and the development of the high-speed railway, tiny subsidence and deformation of the railway beds will result in the decline in the service quality and safety. Therefore, automatic and long-duration subsidence surveillance is becoming increasingly important.

Conventional subsidence measuring instruments such as laser range finders, theodolite, and total stations, among others, have been used to gather subsidence information. However, these methods are limited by being time consuming to set up, low efficiency, and requiring large workloads. Moreover, all of them are inappropriate for long-term measurement. Space geodetic techniques, particularly the Global Positioning System (GPS) and differential SAR interferometry (DInSAR) have been widely used in monitoring ground deformations associated with earthquakes, volcanoes and land subsidence [1, 2]. But the measurement accuracy of space geodetic techniques in the vertical direction is insufficient for engineering applications, besides, they can’t work in tunnels because of no signals.

Videometrics methods are effective for the deformation measurement for large structure[3-5]. However, conventional videometrics instruments cannot meet the demand for the subsidence surveillance of long railroad beds, etc, because it is usually not practical to find stable positions to install the measurement instruments, mainly formed by cameras. Unstable positions may cause measurement errors or total measurement failure of long-term surveillance.

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In [6], we presented a displacement-relay videometrics method for subsidence surveillance using double-headed camera (DHC) networks. In this paper, we extend the idea to multi-headed camera (MHC) network and the corresponding displacement-relay videometrics method, which can precisely measure the vertical subsidence of unstable areas of interests.

2 Principles

Generally, we can fix the camera on stable areas so that it can shoot its target and directly measures the subsidence of targets. However, in most cases, the areas that the camera fixed on is unstable, which will cause measurement errors and the traditional measuring method is unfeasible. So there is need to put forward a new measuring method or design an instrument which can works in unstable areas. To solve this problem, we bring forward an innovative MHC network which is comprised of MHCs. A MHC is the basic cell of multi-headed camera network and it comprises a variable number of cameras which are held together rigidly, as show in Fig. 1. Where, (a) is an ordinary single-headed camera (SHD), (b) depicts a double-headed camera(DHC) which shoot in opposite directions, (c) and (d) are triple-headed cameras (THCs) which comprising three cameras and shoot in three different directions, and (e) depicts a DHC fixing with markers.

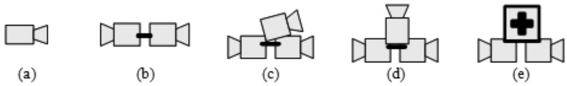

Fig. 1 Variable multi-headed cameras (MHCs)

As cameras are held together rigidly, there are some constraints that we can use to compute the deformation of target areas. A single MHC cannot be used to measure the subsidence of the targets and we design a MHC network to solve this problem. A MHC network is consisted of a number of MHCs and markers and it can be different basing on measuring circumstances and requirements. Besides, A MHC network displacement-relay videometrics system should also contain image processing systems, data transferring system and data processing terminal. Fig. 2 shows one kind of MHC network displacement-relay videometrics system (a DHC network). Fig. 3 shows an example of MHC network.

During working time, each measuring station cooperates with each other. First, each MHC cell shoots at the same time with the same frequency; Secondly, images are transferred to image processing system by data transferring system, then extracting the coordinates of markers and transferring the extracted results to data processing system; Finally, we can get the subsidence of each target area through data processing system. The measuring principle of a DHC network displacement-relay videometrics has been described in [6].

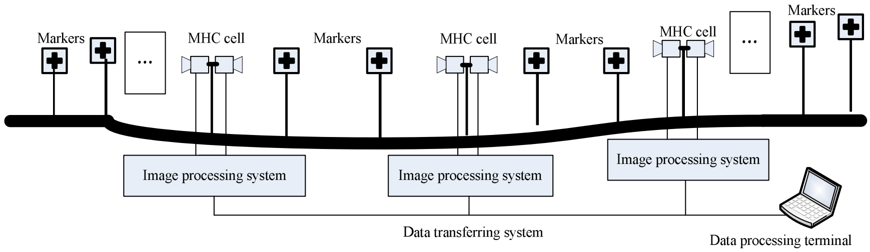

Fig. 2 A DHC network displacement-relay videometrics system

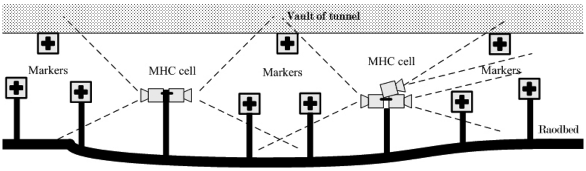

Fig. 3 An example of MHC network

3 Experiments

We evaluate the proposed measuring method experimentally using DHC network. The DHCs and markers are distributed along a line so that the cameras can shoot the neighborhood four markers. The layout of experiment is illustrated in Fig. 4. In order to get the reference values of subsidence and pitch angle, we take advantage of the controllable electrical elevating table and tilt table to simulate the subsidence and tilting of roadbeds and change the values by using computer in which we can program to control the equipments.

Fig. 4 Layout of the experimental subsidence measurement system

To implement the experiment, first of all, we dispose the measuring system like Fig. 4 and insure that each camera can shoot the corresponding markers. Calibrate distances and the magnification factors of each camera and their shooting markers and then, locate and record the coordinates of markers. Furthermore, control the electoral elevating table and tilt table to make part of markers and DHCs having a certain extent of subsidence and/or tilting. Locate and record each marker's new coordinates currently, and calculate the variables of each marker on the corresponding images. Finally, solve the measuring equations to obtain the subsidence and/or tilting of markers and DHCs.

In the experiments, the standard deviation of subsidence errors was 0.17 mm, which indicated that our measuring system could obtain the subsidence of each point precisely, though the subsidence and tilts happened where the cameras were fixed.

4 Conclusions

In this paper, we propose two innovative concepts, "multi-headed camera network" and "displacement-relay videometrics" , and design the multi-headed camera network displacement-relay videometrics system which can concurrently give the subsidence of the points to be measured and the positions in which the cameras are fixed. The method and its measurement system are thus capable of automatically measuring the subsidence of railroad beds in unstable locations over long durations. Furthermore, the method has the broad prospect of being adopted to undertake automatic, long-term and continuous measurement in engineering projects such as bridges, dams, and the ground beds of tall buildings.

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