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A Three Dimensional Measurement System using Digital Still Camera and RTK-GPS

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ABSTRACT

The authors developed two topographic survey systems which could measure the three dimensional topography of earthwork in real-time to improve efficiency of construction. One is a survey system using real-time kinematic GPS (RTK-GPS) and we have applied this to the construction survey at more than a hundred sites. And another is a three-dimensional measurement system using digital still camera which computes the three-dimensional configuration of objects using stereoscopically photographed images taken from a aerial balloon and we have already implemented this system at several earthwork sites to estimate the volume of earthwork. However, there are some problems that arise when actually carrying out these operations using these technologies, such as mobility and limitations in the survey or photographic fields. To solve these problems we combined the RTK system and the three-dimensional measurement system using a remote control helicopter. The control points and major cross sections were measured by the RTK system in this operation and a remote-control helicopter was applied as a photographing platform in stead of a balloon. Comparing the operability of this combined system with other systems, we were able to complete on-site work in about one-third of the time compared to the RTK system only, and in about 1/2.5 of the time compared to the measurement system using a balloon.

1. INTRODUCTION

On-site measurement of earthworks under construction is usually carried out either by aerial photogrammetry or using multipurpose precision survey instruments such as total stations. Despite high survey accuracy attainable by use of those instruments, however, this approach involves considerable human intervention throughout the process from actual measurement to the processing and analysis of data obtained, thus making the process labor- and time-consuming. There are therefore many problems yet to be solved with the current measuring method, such as prohibitive costs, need for human intervention and insufficient accuracy and numerous attempts have been made to develop a practical three-dimensional measurement system.
To solve these problems the authors developed two topographic survey systems. One is a survey system using real-time kinematic GPS (RTK-GPS) and we have applied this to the construction survey at more than a hundred sites. And another is a three-dimensional measurement system using digital still camera which computes the three-dimensional configuration of objects using stereoscopically photographed images taken from a aerial balloon and have already implemented this system at several earthwork sites to estimate the volume of earthwork. However there are a number of problems in both system, such as mobility and limitation in the survey or photographic field. We thus combined both system and applied a remote control helicopter instead of aerial a balloon.

2. A NAVIGATION-TYPE SURVEY SYSTEM WITH RTK-GPS

2.1 System Configuration

The authors developed a GPS navigation-type surveying system using real-time kinematic GPS capability. Our system, as shown in Figure 1, consists of nine-channel, L1/L2, parallel-tracking GPS receiver equipment and a GPS antenna, at both the moving point (survey point) and the datum point (known coordinates), and a transmitter system. With previous kinematic methods, surveyors had to survey the datum point and the moving point at the same time, pool the surveyed data, and obtain the survey results after post-processing. With our new method, the

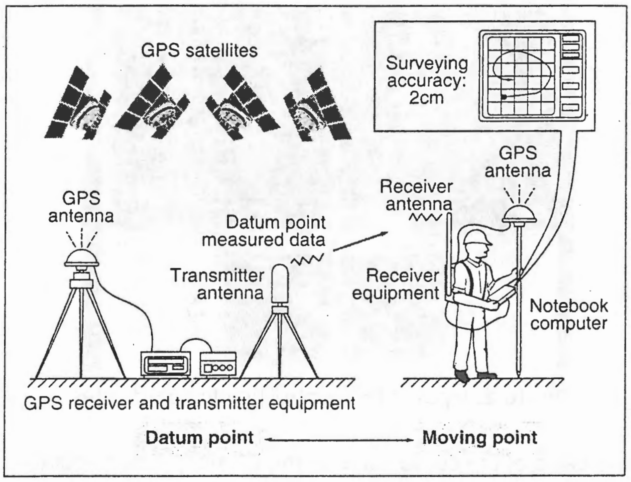

Figure 1. The GPS navigation-type surveying system

transmitter system sends the datum point data to the moving point; after post-processing the data, the system outputs the results in real time. We use a notebook computer with a display screen at the moving point.
The system is capable of the following function.

Coordinate conversion:
The system converts coordinates from the WGS-84 coordinates system (latitude, longitude, ellipsoidal height), which the receiver equipment output, to Tokyo datum and plane perpendicular system coordinates (X and Y coordinates, height).

Real-time display and recording survey results:
The system displays and records plane perpendicular system coordinates with millimeter accuracy every second. In addition, the system displays current position and route at any scale on the notebook computer mesh map (A mesh map is a white map with mesh; the mesh provides a scale and direction to the user, who can set the mesh intervals at any scale.)

Navigation to coordinate point:
If the surveyor input the coordinate of a desired set-up point (X and Y coordinates, height) in advance, the system displays the position of this point and its present position on the mesh map, and shows the orientation and distance to the set-up point.

2.2 Topographical Surveying with the System

In construction work, there are two kinds of surveying methods. One is to make points on site for constructing structure, for example, surveying the coordinates of set-up points. The other is topographical surveying, which provides the topographical information of the work area, X and Y coordinates, and elevation of each measured point. We use these data to estimate the cut and embankment of earthwork. Using this estimation, we design and schedule the earthwork. Mesh lattice point elevation surveying, cross-profile surveying, and plane table surveying are all topographical surveying methods, and the system proved adept at all three.

Mesh lattice point elevation surveying:
When surveyors conduct earth leveling using the mesh method for work such as housing site formation, they survey mesh lattice point elevations. With the system, the surveyors could move to the lattice points while looking at the screen. They do not have to perform lattice point surveying or other kinds of survey work beforehand, and they could survey lattice point elevation directly.

Cross-profile surveying:
In this kind of surveying, such as for road construction work, surveyors form the cross profile by establishing the cross section at right angles to the center line and surveying the distance and elevation from the center line. With our system, after the operator input the center line alignment, the vertical scale of the computer screen can be set for the measurement of the appropriate cross-profile line. Accordingly, by simply moving the GPS antenna along this longitudinal line, the users could survey automatically and continuously (at one second intervals) the three-dimensional coordinates of the cross-profile line topography and form the cross profile.

Plane table surveying:
In this, the reverse of cross-profile surveying, one surveyor moves the GPS antenna along the boundary line of the topography and automatically surveyed the plane condition of the topography. For example, the user moves the GPS antenna along the line of the boundary of golf course tees, fairways, and greens. The surveyed route is displayed on the computer screen in real time, and a plane map can be drawn using the surveyed data.

2.3 Evaluation of the Accuracy and the Efficiency

Accuracy of the System:
As the result of comparison with EDM, the accuracy of this system became 1 cm in horizontal and 2cm in vertical and this is enough for the earthwork surveying.

Efficiency of the System:
We have been using the real-time kinematic GPS system on more than 150 construction projects, including the formation of housing sites and golf course. The results show that the surveying is conducted about 70-90 percent faster than with the usual methods. In addition, the creation of soil calculations, cross-profile map, and plane maps can be done almost automatically using the three-dimensional topography coordinate data recorded in the notebook computer. As a result, we can achieve 3 to 10 times saving in time and money in surveying operations

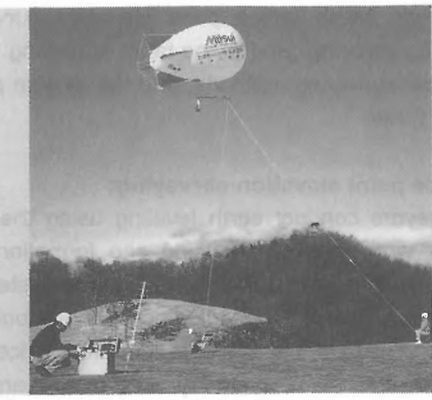

Photo 1. Taking Photographs from a balloon

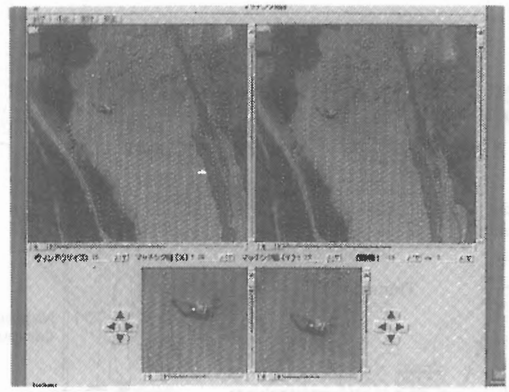

Photo 2. Input of the control points coordinates

alone, and several percent reduction of time and cost of whole construction projects.

2.5 Problem with the System

The measurement precision and the reliability are high because the operator has the antenna of GPS and measures on the just points. It is possible to measure by installing an antenna in the vehicle in the place with flat shape. However, there is seldom such place, the most of measurement must be done in the place which is wealthy in the heave. As the problem of this system, the following points are given.

1) The measurement in the steep slope and so on is dangerous.

2) Depending on the landform, the measurement sometimes becomes impossible because the GPS receiver cannot catch the sufficient number of GPS satellites or the radio signal which is broadcasting revision data cannot be received.

3) The measurement in the construction site while construction machine's being operating is dangerous.

3. A THREE-DIMENSIONAL MEASUREMENT SYSTEM USING DIGITAL STILL CAMERA

3.1 System Configuration

The authors have also developed a three-dimensional measurement system using digital still camera by introducing close-range remote sensing technology to survey topography on the construction sites.

The measurement process is shown below.

1) Take stereophotographs of the target area using a digital still camera from a aerial balloon (see Photo 1).

2) Input the image data thus obtained into a general purpose computer (EWS) by way of memory cards.

3) Display the input stereoscopic images on a CRT where the operator choose several sets of coordinates to be used as control points (see Photo 2).

4) Carry out orientation, matching and other processing on the basis of the coordinates of the control points to obtain data on three-dimensional geometry.

3.2 Evaluation of the Accuracy and the Efficiency

Accuracy of the System:

When taking photographs by the digital still camera of 1,600,000 picture elements, the coordinate precision is about 1/2500 of the photography range. For example, in case taking 100m all sides photographs, the coordinate precision becomes 4cm. The calculation error with area and volume is about 2% comparing with the conventional methods. The precision and reliability of this system are worse than the RTK system and so on but enough for the measurement of earthwork .

Efficiency of the System:

This system makes it possible to measure the dangerous area as it isn't possible to measure by the RTK system. Without entering such dangerous area, the object can be measured by remote control photographing and computer analysis. Use of a camera capable of recording digital images eliminates the need of analog-to-digital conversion, thereby solving the problems of image quality and special hardware requirements. It is therefore possible to process the measurement data in real-time.

3.3 Problem with the System

The problem of this system is shown below.

1) Actually, a lot of time must be spent on the preparation before raising the balloon and taking photographs.

2) The operators control the balloon having the ropes which stretch from the balloon on the ground . Therefore, it is not total remote work actually, and the measurement becomes impossible in the place where the operators cannot enter. When becoming photography from the slant, the precision of the analysis becomes worse.

3) When the wind velocity becomes more than 8 m/s, the control of the balloon gets difficult and it isn't possible to do work.

Photo 3. Photographing from Radio control helicopter

Photo 4. The experiment area

4. THE COMBINED SYSTEM WITH REMOTE CONTROL HELICOPTER

4.1 Features of the System

By adopting a radio control helicopter with combining the RTK-GPS system and the three-dimensional measuring system, we developed a system with the safe and high mobility. In the system we are using RTK-GPS for the measurement of the control points and the main cross sections.

The advantage of implementing a remote control helicopter instead of a balloon is as follows.

1)Without entering the target area, the photography can be done.

2)We are able to complete the field operation faster by the remote control helicopter than the case to use a balloon.

3)Because it is possible to fly to the about 15 m/s wind velocity, a remote control helicopter isn't influenced by the weather than raising a balloon.

4)The photograph can be taken while hovering.

5)The helicopter maintains a high photography altitude and can move a wide area at high speed, so the measurement of wide area can be implemented at short time.

As the limit of the application, because the photography in doing more than 300 m of advanced is difficult, it is necessary to analyze, dividing into more than one in the block in the measurement of the wide area. Photography precision is influenced by the condition of the weather such as the wind and rain.

4.2 The Operability Verification Experiment

We compared the work time of the methods shown below for the topographic measurement at the earthwork area of about 10ha (see Photo 4). The area was so steep at the cutting slopes that it was very difficult to survey on the ground.

Table 1. The comparison of work time

Operation methods	Work time (hour)
The RTK system only	15
Photographing from a balloon	12
Photographing from a remote control helicopter	5

1) Cross-section survey with the RTK system only.

2) Taking stereo photographs from a balloon and the control points survey by the RTK system.

3) Taking stereo photographs from a remote control helicopter and the control points survey by the RTK system.

The comparison of the work time is shown at Table 1. We were able to complete on-site work with a remote control helicopter in about one-third of the time compared to the RTK system only, and in about 1/2.5 of the time compared to the measurement system using a balloon.

5. CONCLUSION

By adopting a radio control helicopter with combining the RTK-GPS system and the three-dimensional measuring system using digital still camera, we developed a system with the safe and high mobility. It is essential for the construction manager to obtain the correct information about construction progress as early as possible and to feedback to the construction process. The earthwork volume which has been done or left is one of the most important information for the construction manager. In the sense, we continue to develop the system to provide such information efficiently and apply these system to actual construction project.

References:

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