AUTO-TRACKING AND POSITIONING FOR MOVING OBJECT USING VIDEO THEODOLITE

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ABSTRACT

The authors have been concentrating on developing a auto-tracking and real-time positioning system using a motorized video theodolite. The most remarkable points of the video theodolite system are its ability to obtain the camera rotation parameters and to calculate a object position in real-time while tracking a moving object.
For the further application of the video theodolite system to a monitoring system or navigation system for robot, construction machine, traffic flow and human behavior, a test was performed using a radio-controlled car moved irregularly on the ground.
This paper describes auto-tracking and real-time positioning techniques using the motorized video theodolite system.

1. INTRODUCTION

Auto-tracking and real-time positioning for a moving object is particularly expected in a monitoring system or navigation system for robot, construction machine and ship. Bayer, et al.(1984) developed realtime positioning system using an electronic camera mounted on a motorized theodolite. However, a CCD camera or CMOS camera recorded in real time has been expected to become a useful tool in various digital photogrammetric fields.
The concept of a video theodolite using a CCD camera was first published in Huang and Harley (1989) for automated camera calibration. Test measurement was performed by Heck(1993) using the video theodolite LEICA TM3000V to get a position of a moving object.
The authors have been concentrating on developing a video theodolite system consisting of a CCD camera, a theodolite and a video recorder where the camera rotation parameters can be determined in real-time while recording a moving object. The current values of the rotation parameters are continuously superimposed on image frames and thus recorded as a part of the image data (Chikatsu and et al., 1994). The effectiveness of the video theodolite system for dynamic analysis of human motion has been demonstrated (Chikatsu and Murai,1995, Chikatsu and et al.,1996) and the application of the video theodolite system to the ski jump also has been demonstrated (Chikatsu and et al., 1997). For the further application of the video theodolite system to a monitoring system or navigation system for robot, construction machine,traffic flow and human behavior, a test was performed using a radio-controlled car in this paper.

2. VIDEO THEODOLITE SYSTEM

Figure 1 shows the motorized video theodolite (SOKKIA, MET2NV) used in this investigation. CCD 1, the upper one in the figure 1, is used for precise pointing to the target through the monitor, and CCD 2, the lower one, is used as a finder. In order to take wide scene, CCD 2 camera was mainly used in this paper.

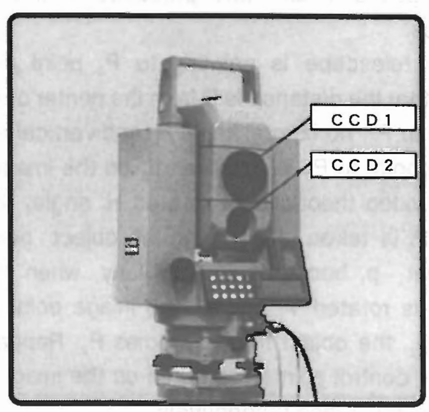


Figure 1 Mortorized video theodolite

The video theodolite system developed in this investigation, consisting of a CCD camera, a theodolite and a video recorder where the camera rotation parameters can be determined in real-time while recording a moving object.
The current values of the X and Y coordinates and velocity of a moving object are continuously superimposed on image frames and thus recorded as a part of the image data.
The detail of the CCD camera and the components of the video theodolite system are shown in table 1. Figure 2 shows the configuration of this system.

Table 1 Components of the video theodolite system

Theodolite	MET2NV (Sokkia, accuracy ±2″)	
CCD Camera	CCD 1	CCD 2
	CCB-GC5 (Sony, 510H×492V)	EVI-310 (Sony, 768H ×494V)
Lens	f=300 mm	f=5.9～47.2 mm
A/D Converter	MTAT-CL (microtecnica,15.734KHz)	
Video Recorder	PVM-1454Q (Sony)	
Monitor	HR-SC1000 (Victor)	
PC	Optiplex GXTM 5166 (DELL)	

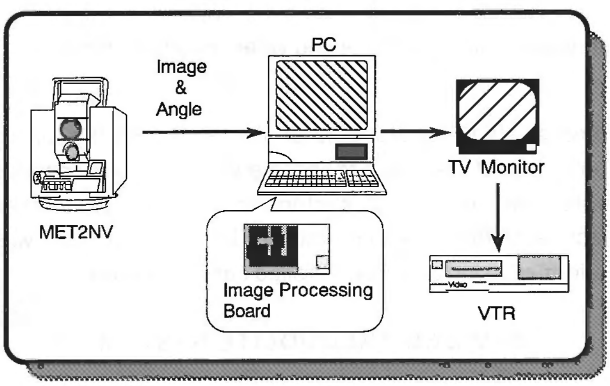


Figure 2 System configuration

3. CAMERA CALIBRATION

Bundle adjustment is applied for camera calibration using 9 control points which were produced in the following procedures:
When the telescope is pointing to P_0 point under the condition that the distance is D from the center of the video theodolite to P_0, horizontal angle H_0 and vertical angle V_0, the image point to P_0 is taken as p_0 on the image. Next, when the video theodolite is rotated H_1 angle, the image point to P_0 is taken as p_1, and the object position to image point p_1 becomes P_1. Similarly, when the video theodolite is rotated V_1 angle, the image point to P_0 is taken as p_2, the object to p_2 becomes P_2. Repeating this operation, control points are taken on the image and are produced in the space respectively.

Ground coordinates for these control points are calculated with the following equation:

$$\begin{aligned} X_i &= -D\cos V_0 \sin(H_i - H_0) \\ Y_i &= D\left\{\cos V_i \sin V_0 - \sin V_i \cos V_0 \cos(H_i - H_0)\right\} \quad \cdots(1) \\ Z_i &= D\left\{\sin V_i \sin V_0 + \cos V_i \cos V_0 \cos(H_i - H_0)\right\} \end{aligned}$$

The unknown parameters for the orientation image are as follows: exterior orientation parameters { ω_0, ϕ_0, κ_0 (rotation parameters), X_0, Y_0, Z_0(camera positions)} and interior orientation parameters { f, x_0, y_0 (principal points), a_1, a_2(scale factor), p_1(lens distortion)}.

4. EXPERIMENT

Figure3 shows the test site and the rectangular target in this figure corresponds to the above P_0 point. Similarly, Figure 4 shows a moving object (Radio-controlled car) used in this test.

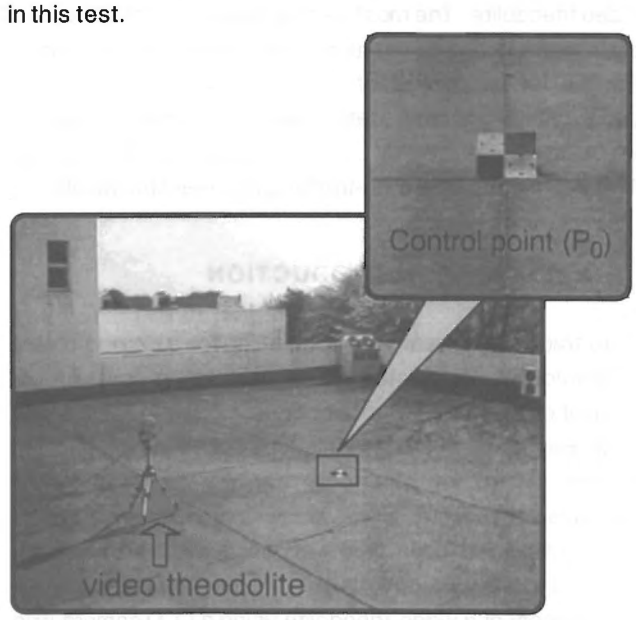


Figure 3 Test site and rectangular target


Figure 4 Radio-controlled car

The relatively slow 4 images acquired per second is perhaps due to the ability of image processing board or MET2NV. Test for auto tracking and real-time positioning was performed while moving the radio-controlled car so that a locus may become "S".

The detail procedures for the test are as follows:

+ Window is previously cut out and color information for the car is extracted.

+ Area gravity for the car are extracted using binarization and labeling procedure.

+ Two dimensional ground coordinates for the area gravity can be calculated using the calibration parameters. Since the unknown rotation parameters, ω and ϕ for sequential images can be obtained as the sum of changing vertical and horizontal values resulting in ω_0 and ϕ_0 for the orientation image respectively and parameters other than ω and ϕ are considered as the same values as the calibration results for the orientation image.

+ Due to the discord between the center of the theodolite and the lens of the CCD camera, exposure position for each sequential image has to be corrected to respond to the rotation of the video theodolite.

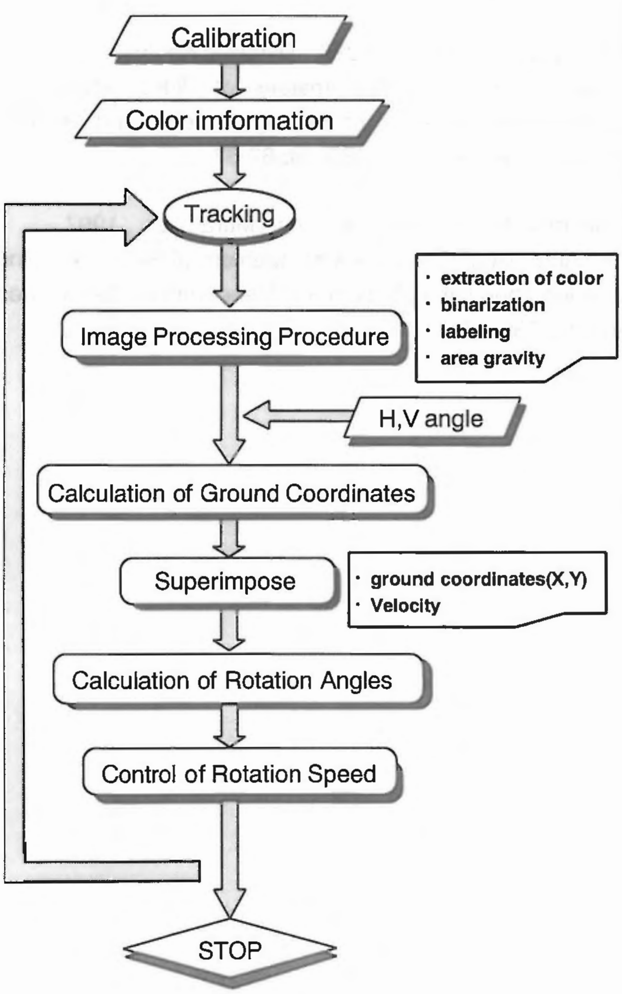


Figure 5 Tracking Procedures

+ Velocity for the car can be calculated using the differences in the moved distance and time interval of a front image and a moved image.

+ The current ground coordinates (X,Y) and velocity for the car are continuously superimposed on the image frames.

+ Rotation angles (vertical and horizontal) of the video theodolite are calculate using the ground coordinate of a front image and a moved image.

+Rotation speed of the video theodolite are then controlled so that the area gravity becomes the center of the monitor using the moved distance.

These procedures are shown in Figure 5.

Figure 6 shows a monitor image while tracking the car. The left-hand number superimposed in the upper left corner shows the ground coordinates for the area gravity of the car (X= - 4.226m). The number just to the right is the Y coordinates (Y= - 1.545m) and the velocity (0.651 m/s).

Figure 6 Monitor Image

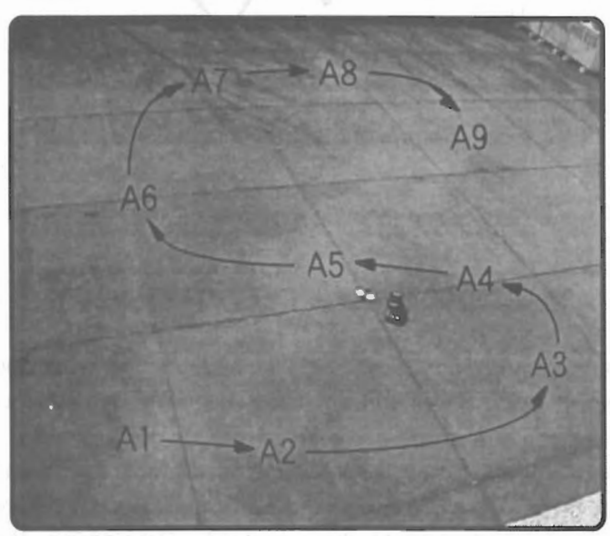
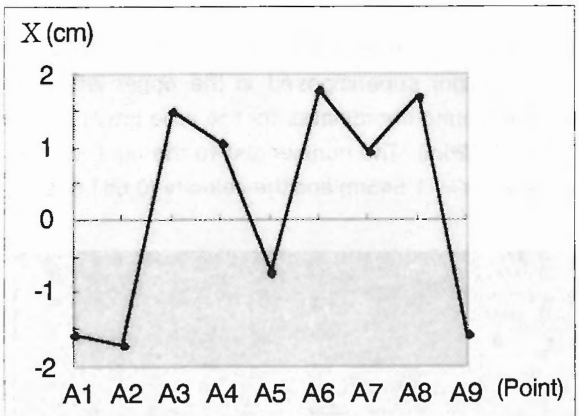


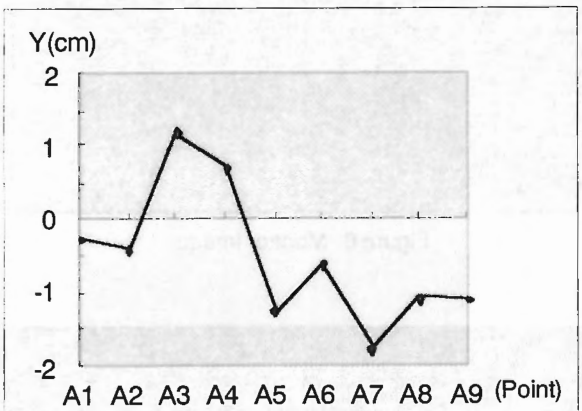
Figure 7 Locus of the radio controlled car

In order to evaluate the accuracy, the sheet reflector was fitted on the car, and the X,Y coordinates at 9 points illustrated in Figure 7 were measured using total station.

Figure 8 shows the X,Y errors for the area gravity. 2-3cm errors can be found due to the height difference between the area gravity and the sheet reflector fitted on the car for the measurement using total station.
Considering the above, it is concluded that the application of the video theodolite system for a moving object is a useful method.



(a) X errors of the ground coordinate



(b) Y errors of the ground coordinate

Figure 8 X,Y errors

5. CONCLUSIONS AND FURTHER WORK

Auto-tracking and positioning procedures for a moving object using the motorized video theodolite system has been demonstrated.
Although, necessity of increased speed for tracking and image processing procedure under natural conditions are issues which should be resolved. Considering the construction machine such as bulldozer moving around slowly, it is concluded that the motorized video theodolite system is a useful tool in construction site and may become a useful tool in various real-time photogrammetric fields since the rotation parameters and sequential images can be acquired in real-time while tracking a moving object.

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