Automated Distance Measurement of Ski Jump using Multi-Image

Kazuya NAKANO*, Hirofumi CHIKATSU**, Shunji MURAI ***

*AERO ASAHI CORPORATION
Minamidai 3-1-1,Kawagoe, Saitama, 350-1165, Japan

**Department of Civil Engineering, Tokyo Denki University
Isizaka,Hatoyama, Saitama, 350-0394, Japan

***Space Technology Application and Research Program
Asian Institute of Technology
P.O. Box 4 Klong Luang Pathumthani 12120, Thailand

Commission V, Working Group IC WG V/III

KEY WORDS: Image sequence, Video theodolite, Multi-image, Ski jump, Auto-tracking

ABSTRACT

The ski jump is scored by judges based on flight distance, style and performance. Generally, the flight distance has to be measured by many judges (distance measurers and recorder) according the FIS (Federation Internationale de Ski) rule.

From the view point of real-time automated distance measurement in ski jump and effective utilization of a motorized video theodolite, a simulated ski jump has been performed in a room by using a motorized video theodolite system and the effectiveness of this system demonstrated by the authors.

There are still,however,some issues which need to be resolved before this system may become operational.These problems include,necessity of increased speed for tracking and an image processing procedure under natural conditions.

This paper describes image processing procedures under natural conditions using mutli-image and an automated distance measurement method.

1. INTRODUCTION

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 Murai,1995). The effectiveness of this system for dynamic analysis of human motion has been indicated (Chikatsu and et al.,1996). This paper investigates utilization of a motorized video theodolite in ski jump as a new application domain of a video theodolite.

Generally, the flight distance has to be measured by many judges (distance measurers and recorder) according the FIS (Federation Internationale de Ski) rule. If a motorized video theodolite can be utilized, the flight distance can be measured in real-time because the rotation parameters and sequential images can be acquired in real-time while a ski jumper is flying on a parallel plane perpendicular to the camera.

The authors have indicated on the application of a video theodolite system to the ski jump(Chikatsu,Nakano and Murai, 1997). However, following issues need to be resolved before this system may become operational. These problems include, necessity of increased speed for auto-tracking and image processing procedure under natural conditions.

With this objective,a simulated ski jump was performed in a room using a motorized video theodolite and a wide angle camera.

2. VIDEO THEODOLITE SYSTEM

Figure 1 shows the motorized video theodolite used in this investigation. The current values of the rotation angles (zenith and horizontal) and distance are continuously superimposed on the image frames. A wide angle camera was mounted on the Video theodolite to acquire whole image of a jump course. CCD 1, the middle one in the Figure 1 is used for precise pointing the target through the monitor, and CCD 2, the lower one is used as a finder. The details for these camera and the components of the video theodolite system are shown in Table 1. Figure 2 shows the configuration of this system.

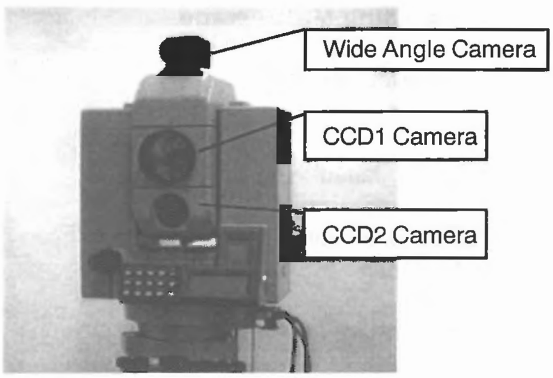

Figure1 Video theodolite

Table1 Conponents of video theodolite system

Theodolite	MET2NV (Sokkia, accuracy $\pm 2''$)	
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	OptiplexGXTM 5166 (DELL)	

3. CAMERA CALIBRATION

For the automated camera calibration for the CCD2 camera and the wide angle camera, control points should be automatically generated and its image coordinates also should be acquired. The automated calibration procedures developed in this paper are as follows:

1. Since changing a focal length of the CCD2 camera is responded as a numerical value from 0 to1023, camera calibrations were performed using different numerical values correspond to focal length in order to obtain the relationship between the focal length (f) and the numerical value. Regarding the wide angle camera, the nominal value is adopted as a approximate value since the focal length is fixed.
2. When the CCD1 is pointing to the center of control point under the condition that the distance is D from the center of the video theodolite to the control point, horizontal angle H_0 and vertical angle V_0 is regarded as the initial condition.
3. Position of control points on the monitor are previously arranged using the relationship between the effective picture elements (H/V: pixel) and sensing area (h/v: μ m).
4. Rotation angles (horizontal angle H_i and vertical angle V_i) of the video theodolite for each control point are then calculated using sensor coordinates and the focal length.
5. Following procedures, such as taking control points, extracting the center of control points and synthesizing control points on the monitor are performed while the video theodolite automatically is rotated according the calculated rotation angles.

Ground coordinates for these control points are calculated following equation.

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

Consequently, the automated camera calibration can be achieved. Figure 3 shows the control points synthesized using above procedures and it took about 120 seconds in total.

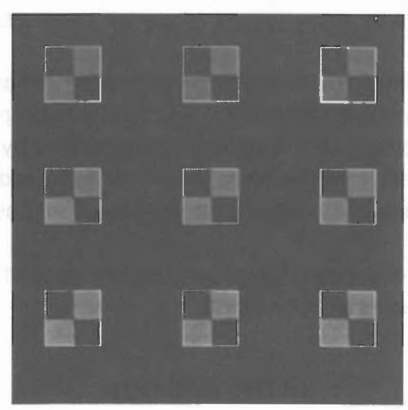

Figure3 Control points

4. SIMULATED SKI JUMP

It has been indicated in our former presentation(Chikatsu, Nakano and Murai, 1997) that the index for recognition of landing can be acquired using the normalized displacement of the head which is obtained by the following procedures (Figure 4):

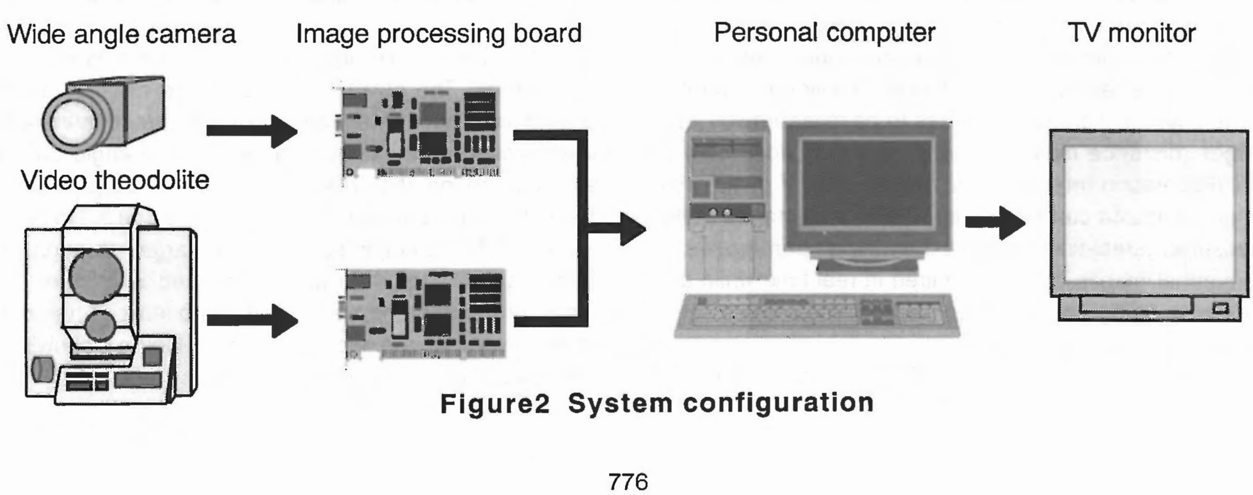

Figure2 System configuration

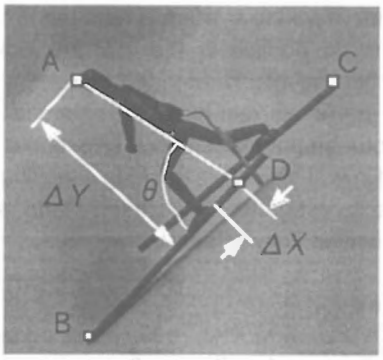

Figure4 Displacement of the head

+ feature points such as the head (A), the top (B) and the tail(C) of the skis are extracted.
+ foot position (D) is calculated as a ratio 4 to 6 of skis.
+ these feature points are then superimposed in real-time.
+ body angle (∠ADB) is calculated using the top of the skis, foot and the head position.
+ distance between the head and the foot is calculated.
+ normalized displacement of the head (ΔX, ΔY) against the foot is calculated using the angle and the distance.

For the operationalization of the video theodolite system to the ski jump, necessity of increased speed for tracking and an image processing procedure under natural conditions need to be resolve. With this objective, a simulated ski jump was performed in a room by using a 2.0m length, 1.0m height and about 27° slope course (Figure 5) and an automated tracking procedure was improved in this paper. An improved tracking procedure consist of two steps. Firstly, a background image is previously taken by the wide angle camera and automated tracking is performed using differential image because the video theodolite does not rotate while a ski jumper is tracked by the wide angle camera.

Figure5 Test field for the ski jump

The detail procedures in the first step are as follows:

+ camera calibration for each camera is performed by the automated calibration procedure.
+ make the video theodolite rotate until the CCD2 camera will be able to take the edge of the take-off table, and compute the 2D coordinates for the edge point using the CCD2 camera because the calibration parameters are known.
+ make the video theodolite re-rotate until the CCD2 camera will be able to take nearby landing area, and take the background image by the wide angle camera.
+ in order to speed up image processing procedure, a window is cut out so that a ski jumper can be included and pixels in the window are thinned out alternately.
+ ski jumper is extracted using differential image for the window and the 2D coordinates for area gravity of ski jumper are computed using calibration results.
+ changing value of the window is calculated using difference in the area gravity of the ski jumper of a front image and a moved image.
+ repeat the differential image processing for every sequential image.

As for further additional results of this procedure, a background image can be refreshed according the changing of background such as meteorological changing. Furthermore, as a next step, when the 2D coordinates computed by the wide angle camera come nearby landing area, camera is changed from the wide angle camera to the CCD2 camera for recognition of the landing style and automated distance measurement. The detail procedures in the second step are as follows:

+ the corner coordinates of the window for the wide angle camera are then transformed into the coordinates for the CCD2 camera using the calibration results.
+ pixels in the window are thinned out alternately.
+ changing value of the window is calculated using difference in the area gravity of a front image and a moved image.
+ area gravity of a ski jumper is calculated via binarization and labeling procedure, and rotation speed of the video theodolite is then controlled so that the area gravity becomes the center of the monitor.
+ from the view of speed up, the window size is changed to become minimum size using the feature points in the front image.
+ repeat the image processing procedure for every sequential image.

Due to the relatively slow data (rotation parameters) acquisition, the rotation parameters for the landing image alone are acquired into the computer, and the 2D coordinates for landing point are calculated using calibration results. As a results, the flight distance is obtained using 2D coordinates for start point and landing point.

These procedures are shown in Figure 6 and the tracking speed is rapidly progressed such as 15 images can be acquired per second in the case of the wide angle camera and 10 images in the case of CCD2 camera.

Ideally, 300mm/sec. is required as a flying speed in the simulation because the actual speed for ski jumper is about 80Km/sec. However, the simulated ski jump was performed at 200mm/sec. due to the ability of hardware.

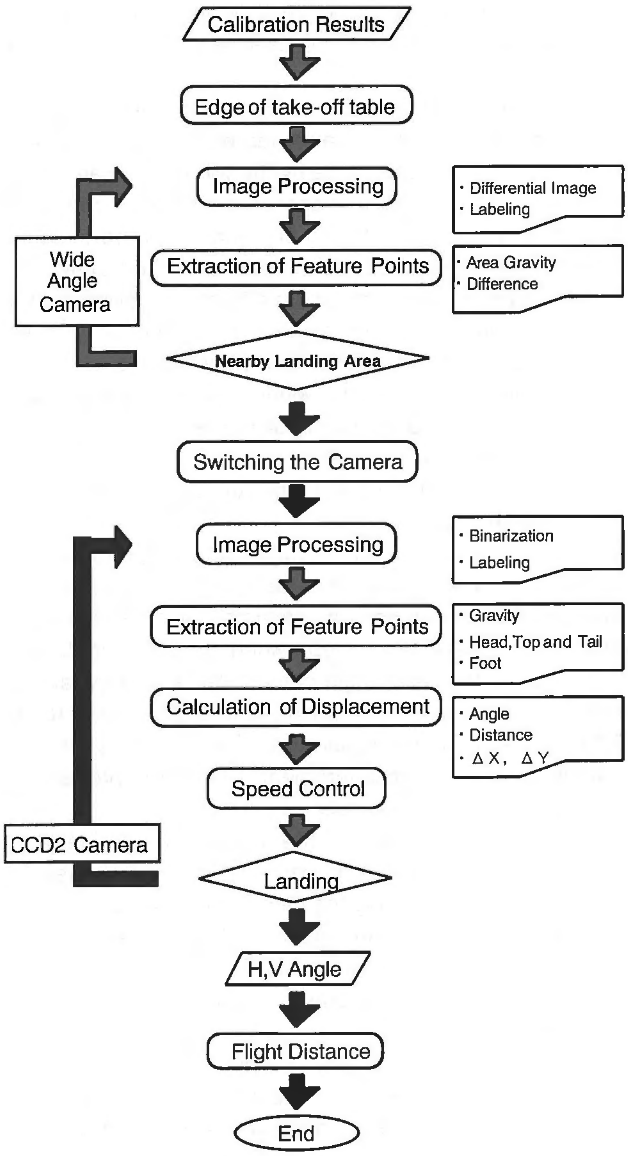

Figure6 Image processing procedures

5. CONCLUSIONS AND FURTHER WORK

Two issues on real-time automated distance measurement of the ski jump have been described in this paper. One was an image processing procedure under natural conditions. It has been shown that the ski jumper can be effectively extracted using differential image taken by the wide angle camera.

With regard to second issue, necessity of increased speed for auto-tracking has been progressed so that 15 images can be acquired per second in the case of the wide angle camera and 10 images in the case of CCD2 camera.

Real-time auto-tracking system is required in the real-time photogrammetric domain in the feature. However, it is concluded that the motorized video theodolite system is a useful tool in various real-time photogrammetric domains since the rotation parameters and sequential images can be acquired in real-time while tracking a moving object.

Finally, this investigation have been made as a part of master's thesis of Tokyo Denki University.

References

1. H. CHIKATSU, S.MURAI,1995. Application of a Video Theodolite System for Sports Dynamics, International Archives of Photogrammetry and Remote Sensing, Vol.30-5W1, pp.110-115.

2. H.CHIKATSU and et al.,1996. Dynamic Analysis of Human Motion using Sequential Images of Video Theodolite, International Archives of Photogrammetry and Remote Sensing, Vol.XXXI, Part B5, pp.82-87.

3. H.CHIKATSU, K.NAKANO, S.MURAI, 1997.
On Automated Distance Measurement of Ski Jump using a Video Theodolite, Optical 3-D Measurement Techniques IV, pp.383-390.