DEVELOPMENT OF A WIND OBSERVATION SYSTEM UTILIZING PHOTOGRAMMETRY

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ABSTRACT

It is important in the study of wind to three-dimensionally determine on site where the wind is flowing near ground surface. The purpose of this study is to develop a system to measure data of wind flowing both horizontally and vertically utilizing stereo photogrammetry and single photogrammetry, and to establish a method for three-dimensional measurements on site where the wind is flowing near ground surface. This system uses two cigar-shaped kite balloons or some holding platforms on the ground to which is mounted a 35mm still camera, which stereophotographs or single photograph a third balloon released as a tracer, and three-dimensionally analyses the third balloon's path of particle. This time, we utilized a system in observing the paths of particle of wind flowing over a building, and confirmed the effectiveness of the system.

1. Introduction

Several systems to analyze three-dimensionally the data of wind stream flowing close enough over the surface of the ground utilizing photographs have now been under project with us (Toshio, K, 1994a), (Toshio, K, 1994b). The purpose of this study is to develop a system to measure data of wind flowing both horizontally and vertically utilizing stereo photogrammetry and single photogrammetry, and to establish a method for three-dimensional measurements on site where the wind is flowing near ground surface.

The wind observation system utilizing stereo photogrammetry uses two cigar-shaped kite balloons equipped with a 35mm still camera or four 35mm still cameras set on the ground, which stereophotograph a third balloon released as a tracer, thereby three-dimensionally analyzing the third balloon's path of particle. As the results of the experimental study on the campus of Chiba Institute of Technology paths of particles of wind flowing over buildings was successfully observed.

The wind observation system utilizing stereo photogrammetry uses a one 35mm still camera set on the ground, which photograph balloons released as a tracer, thereby three-dimensionally analyzing the balloon's path of particle. The paper first describes the fabrication of an analytical theory, followed by experiments carried out using the theory. The experiments consisted of a provision and utility experiment. The provision experiment consisted of a measurement of the three-dimensional position of a ping-pong ball suspended in a laboratory with a single photograph of the ping-pong ball being used. The utility experiments measured the paths of particles of wind flowing over buildings. The results of the experiments proved that the fabricated analytical theory was effective.

2. Observation System Utilizing Stereo Photogrammetry

This system uses two cigar-shaped kite balloons equipped with a 35mm still camera or four 35mm still cameras positioned on the ground, which stereophotographs a third balloon released as a tracer, and three-dimensionally analyses the third balloon's path of the particles.

2-1 Observation system utilizing aerial photographs

(1) Observation system

This system consists of flowing elements.
-Balloon: $7m^3$, $4.25m^3$, helium gas
-String: 1,000 meter
-Still camera:
35mm,wide angle, f=28mm(Olympus OM-1, Canon T70)
-Monitor camera: monitor and angle control
Horizontal 360 degrees
Vertical±90 degrees
-Time lag of two camera shutters is less than 0.04 sec.

-Total payload: 5.0kg, 3.0kg
-Analytical system:
Coordinate digitizer: Resolution 0.025mm(Mutoh BL)
Personal computer: NEC 9801
Fig.1 shows outline of this system.

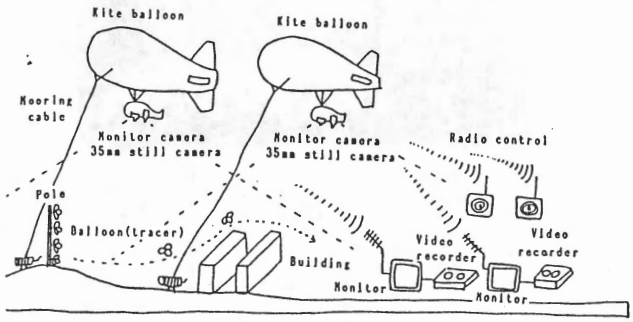


Fig.1 System Outline Utilizing Kite Balloons

(2) Observation of paths of particle of wind flowing over buildings

The observations were made with buildings in campus of Chiba Institute of Technology. Results of the test No.1 show Fig.2. From the charts of the paths of the particles obtained, it was found that it is possible to confirm the behaviors of wind, the velocity of which increases at the windward eaves of a building as the data observed on site. Accuracy of measurement was ± 18.5cm(horizontal direction) and ±24.34cm(vertical direction).

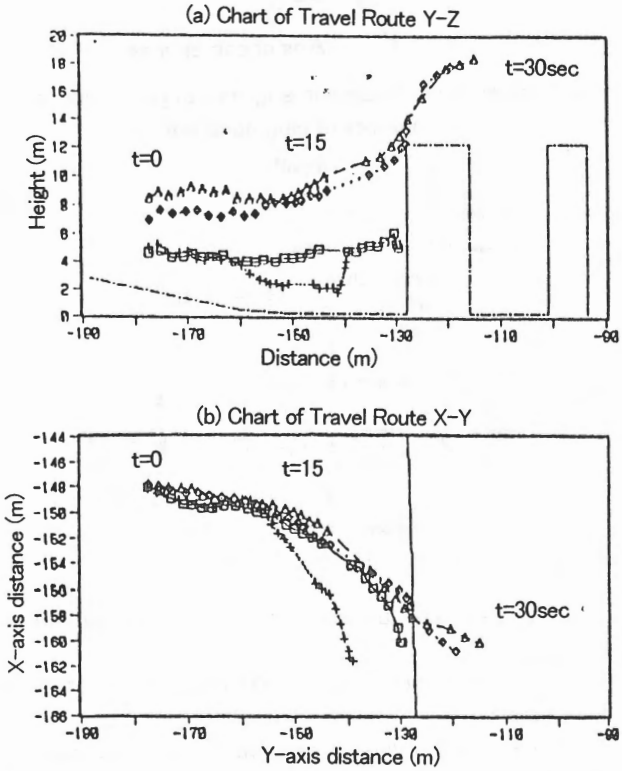


Fig.2 Paths of Particle Obtained from Experiment in Test 1

2-2 Observation system utilizing terrestrial photographs

In this paper, a description has been made with the adoption of a system developed for stereophotographing of balloons that have been released into air as tracers by manually positioning four 35mm still cameras by which simultaneous operations are made possible on the ground surrounding the observation area, instead of kite balloons. Fig.3 shows outline of this system.

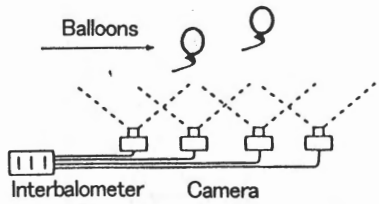


Fig.3 System Outline Utilizing terrestrial Photographs

3. Observation System Utilizing Single Photogrammetry

This system use a one 35mm still camera positioned on the ground, which photographs balloons released as a tracer, three-dimensionally analyzing the balloons' paths of the particles. Circle balloons of already known diameter were used as the tracers, the three-dimensional positions of balloons were measured utilizing balloons' diameter. The paper first describes the fabrication of an analytical theory, followed by experiments carried out using the theory. The experiments consisted of a provision and utility experiment. The provision experiment consisted of a measurement of the three-dimensional position of a ping-pong ball suspended in a laboratory with a single photograph of the ping-pong ball being used. The utility experiments measured the paths of particles of wind flowing over buildings and mountainous regions. The results of the experiments proved that the fabricated analytical theory was effective.

3-1 Three dimension measurement theory by single photogrammetry

When the radius of the ball is assumed to be b as shown in Fig.4, three dimension coordinates X_R, Y_R, and Z_R at center R of the ball can be obtained by the following equation.

$$Z_R = Z_O - Z_r$$

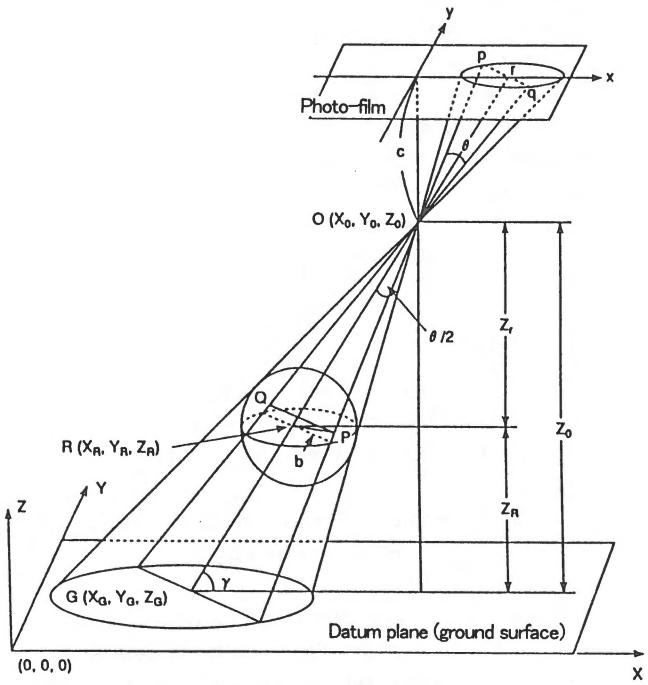
$$X_R = \frac{(Z_R - Z_O)(X_G - X_O)}{(Z_G - Z_O)} + X_O$$

$$Y_R = \frac{(Z_R - Z_O)(Y_G - Y_O)}{(Z_G - Z_O)} + Y_O$$

3-2 Provision experiment in room

(1) Experiment method

The experiment was done by the diameter's using an already-known ping-pong ball. Fig.5 shows the



X_G: X coordinates on datum level of point G
Y_G: Y coordinates on datum level of point G
Z_G: Z coordinates on datum level of point G
X_0: X coordinates of center O projection
Y_0: Y coordinates of center O projection
Z_0: Z coordinates of center O projection
Z_f: Perpendicular distance of center O projection and center R of ball

Fig.4 Analytical theory of single photogrammetry

appearance of the experiment.
Three-dimension position of the ping-pong ball was measured by the method of intersection and resection with theodolites.
Fig.6 shows the appearance of taking a picture. The taking a picture distance is about 4m. Taking a picture was down at the position from Camera 1 to Camera 7.
29 control points were set up.

(2) Experiment result

From the result of the experiment, the standard deviation of the error in direction (X, Y) of the plane is ±0.16m and that of (Z) for the interior approach became ±0.328m.

3-3 Adjustment example

This technique was applied to the measurement of wind flowing around building. The experiment situation is shown in Fig.7.
The results for which this technique was used were compared by using a stereo photograph with the result of obtaining. And, the effectiveness of this technique was judged.
Fig.8 shows a part of the experiment result.
The standard deviation of the error was ±1.2m in (Z) for

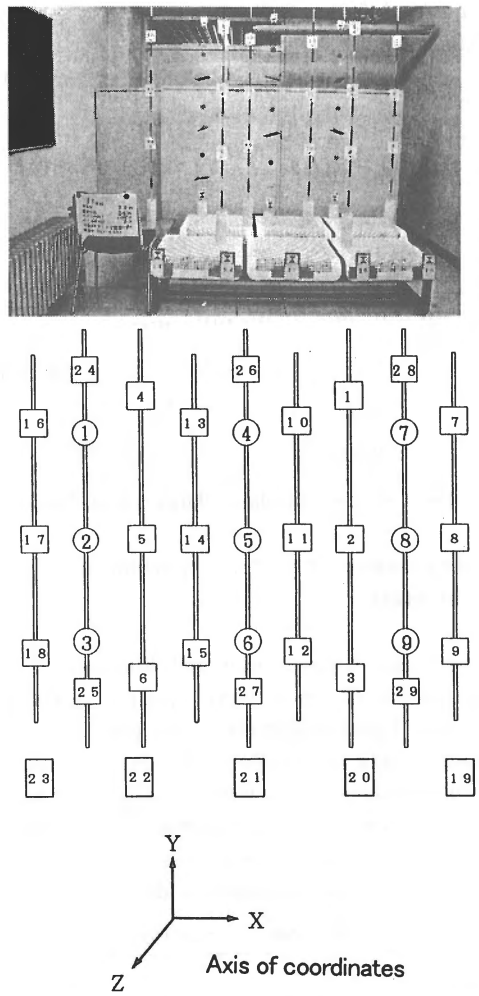


Fig.5 Appearance of experiment, control point number and number of ping pong ball

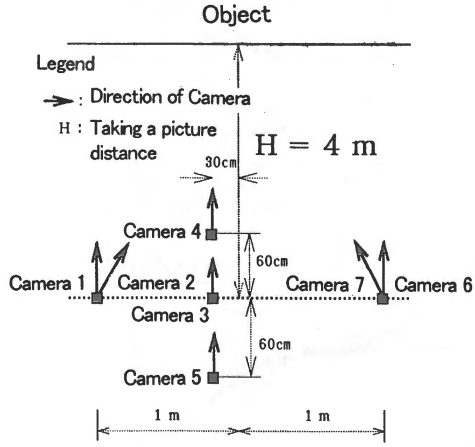


Fig.6 Taking a picture condition (Provision experiment)

the interior approach, and ±0.825m in direction (X, Y) of the plane.
Here, the result of the measurement was assumed to be the correct one by using the stereo photograph.

4. Conclusion

(1) It was experimentally confirmed that by using this system that the paths of the particles in both the horizontal

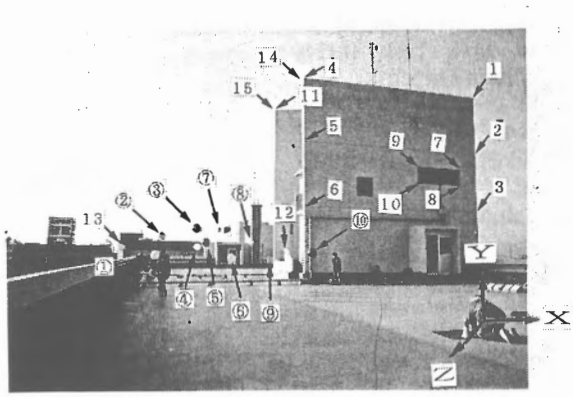
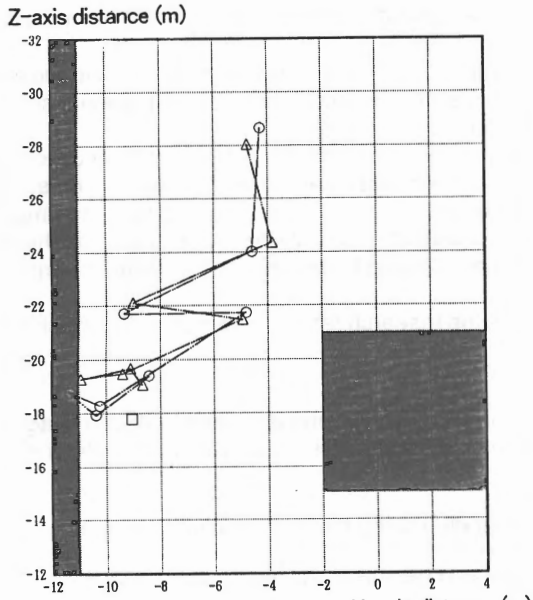
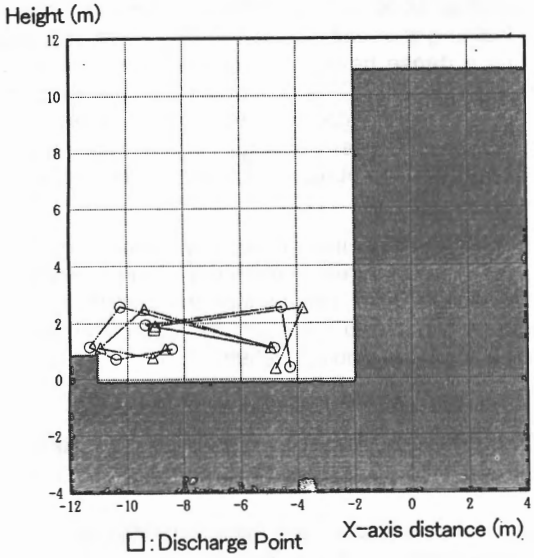


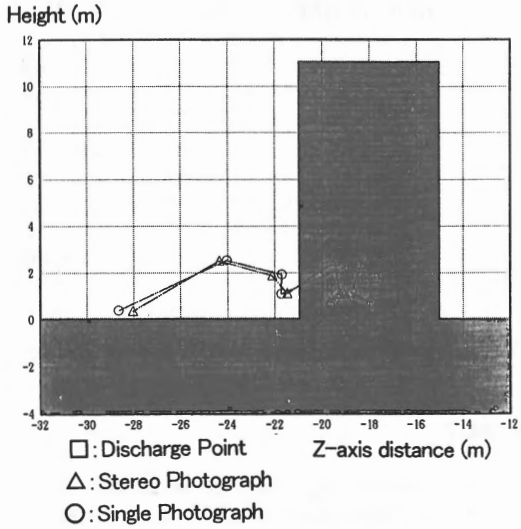
Fig.7 Experiment situation of wind flowing around building, control point number and number of balloon



(a) Chart of Travel Route X-Z



(b) Chart of Travel Route X-Y



(c) Chart of Travel Route Y-Z

Fig.8 Paths of Particle Obtained from Experiment

and vertical direction of the wind flowing could be observed on site simultaneously.

(2) A system to measure the data of wind flow utilizing photogrammetry could be achieved.

(3) This system can obtain both qualitative and quantity information of wind flowing on a three-dimensional basis.

(4) It could be confirmed that the system was suitable for fixed point observations at any altitude and that unskilled personnel could utilize the system simply and safely. As a result, the photographing of urban areas, etc. can be made, and the system is conceivably suitable for three-dimensionally observations of wind including wind flowing over buildings.

(5) Observation system utilizing aerial photographs is a useful method for measuring wind flowing over a wide area, on the other hand observation system utilizing terrestrial photograph is easy, simple, cheapened can be used in the case of strong winds.

(6) Observation system utilizing single photogrammetry has the following advantages compared with stereo photogrammetry.

-To follow a tracer is easy.

-Synchronization shutter of camera not necessary.

-Stereo matching not necessary.

-Device is simple.

(7) These systems offer results within acceptable accuracy in many cases.

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