

APPLICATION FOR CLOSE-RANGE PHOTOGRAMMETRY USING A CAMERA SYSTEM ATTACHED ON TRANSIT AND STEREO IMAGE SYSTEM (TOPCON PS-1000/PI-1000)

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ABSTRACT:

The measuring method called IMS(Industrial Measuring System),which consists of 2 sets of transits and a subtench bar,is capable for non-contact 3D measurements of objects with high accuracy using resection method,and it is widely applied for the industrial measurement and civil engineering measurement.

The developed camera system is an integrated system using a digital transit and metric camera.

This system is capable for determining camera position and angle(external orientation parameters),and obtaining the parameters of photographic condition and expected achievable accuracy in the depth measurement in advance without distributing control points on the object.

Applying this camera system together with a stereo image system (TOPCON PS-1000/PI-1000) in close-range photogrammetry,it is possible to improve the efficiency of taking pictures and measurement and to save man power.

Moreover, taking a CCD camera system to get digital data directory,it is expected to realize an on-line image processing system.

In this paper,outline of this camera system,achievable measuring accuracy obtained by the stereo image system and its process for plotting are described and efficiency to apply the system to the application is discussed.

KEY WORDS: IMS, close-range, orientation, stereoscopic, camera, resection, superimposition

1. INTRODUCTION

Close-range(terrestrial) photogrammetry is useful for non-contact 3D measurement method. Its measuring time, accuracy and operation, however, has not reached to the practical use and does not come into wide use. Also, this field has various measuring objects, so that the conditions of positions of control points, camera arrangement, etc. greatly affect the stability of measuring accuracy and stereoscopic observation. In the orientation processing, position and tilt of camera cannot be assumed like an aerial photograph and their approximate orientation elements are necessary. Such limitation requires technical knowledge on photogrammetry. To realize the easy measuring for nonprofessionals, elimination of absolute control points, establishment of simple orientation method, considering the camera arrangement and development of an easy operating digital plotter are required.

Therefore, as an orientation method for close-range photogrammetry, we tried a method which directly determines exterior orientation parameters when taking photographs, not obtaining parameters analytically from conventional orientation procedures, but by using IMS (Industrial Measuring System).

The IMS consists of transits and subtench bar, which obtains high accuracy of 3D positions (center of projection) of transits by collimating a several measuring points along the subtench bar and then the angles from the measuring network.

In this experiment, attach a metric camera onto the said telescope part and determine the relation of transit and camera at a target place measured with high accuracy in advance by single photogrammetry. Adopt this system to a measuring object, position the transits on the right and the left hand sides by using the IMS, read horizontal and vertical angles when taking stereo photographs and determine exterior orientation parameters.

Stereo image system consists of image scanner PS-1000 and stereo image workstation PI-1000.

PS-1000 converts stereo photographs into digital images by high resolution and the digital image data are stored on an optical disk. PI-1000 measures 3D objects by using the digital image information that is to be read from the optical disk. Like a close-range photograph, even on a photograph taken by convergence or oblique photography, stereo images without y-parallax are formed by digital rectification processing and simple stereoscopic measurement will be carried out on a polarized 3D display with a mouse. Moreover, interactive semi-automatic measurement by image correlation processing can be conducted. The measured data are defined as layers and are processed as drawing data such as line and circle commands and stored in a DXFTM*format file (i.e. drawing data exchange file) of AutoCADTM*. Since the drawing data can be superimposed on the stereo images as stereoscopic figures, confirmation of measurement results & editing and re-measurement processing can be conducted simultaneously. This function is especially useful to analyze the close-range photogrammetry which cannot limit depth and frequently needs plotting history.

* AutoCAD, DXF are U.S. registered trade marks of Autodesk, Inc.

2. STEREO IMAGE SYSTEM CONFIGURATION

Stereo image system is shown in Fig.1. This system has been developed to analyze 3D measurements of aerial photographs, close-range photographs, satellite images, and so on.

2.1. Image Scanner PS-1000

The image scanner, as shown in Fig. 2, consists of image scanner, personal computer, image monitor, optical disk driver and controller.

The scanner converts a photograph into a digital image with high resolution without changing the information of the photograph position and moreover it has a high accurate comparator function. The photo film is placed on an XY stage sandwiched between two glass plates and is focused on an area CCD sensor, illuminated

2.2. Stereo Image Workstation PI-1000

2.2.1. Hardware

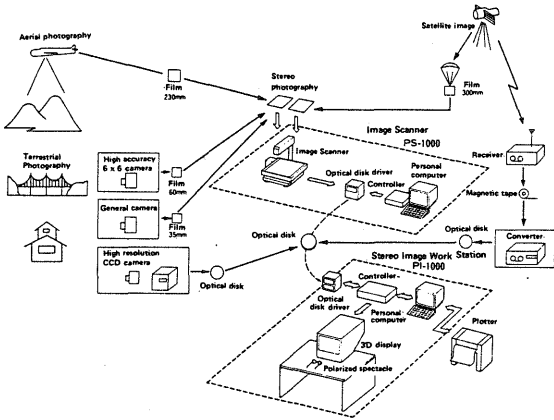


Fig.1 Stereo image system

partially by the transmitted light from a halogen light source. XY stage is controlled by D.C servo motors in the speed of 20mm/sec. Output format (A/D) of an area CCD sensor is converted in 8-bit binary data and stored on optical disk after being stored temporarily in a frame memory. Also, as index image data, a sampled image in user specified size can be formed at the same. Moreover, linear encoders of $1\mu\text{m}$ reading are provided along the XY stage and the film position can be measured with high accuracy by switching the optical system to high magnification (5X).

Specifications of Image Scanner PS-1000

- File size : Max. 240x240mm
- AreaCCD: Number of pixels : 780(H)x488(V)
- Area size : 8.97x6.58mm
- Pixel size : 11.5x13.5 μm
- Measurement magnification : 1x, 5x, (2x*)
- Accuracy of absolute position : $\pm 3\mu\text{m}$ (XY stage)
- Gray values : 8 bits

* indicates the scanner PS-1000S for 6X6 version and is used in this experiment.

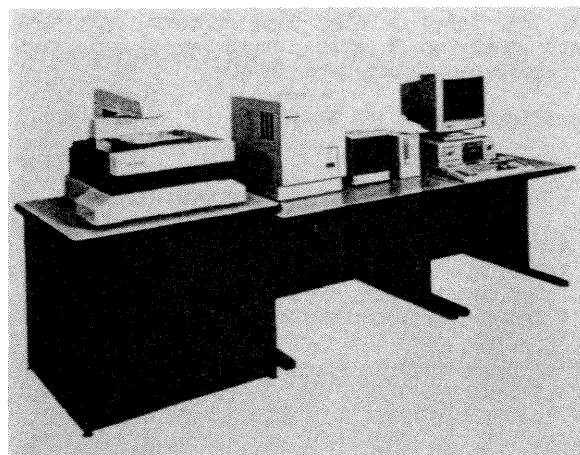


Fig.2 Image Scanner PS-1000

The stereo image workstation, as shown in Fig.3, consists of personal computer, 3D display monitor, optical disk drivers, image processing units, mouse for 3D measurement and polarized glasses.

The 3D display applies two color displays of high resolution and is attached orthogonal filters. Set a halfmirror for compounded images between the displays, so that the operator can observe the stereo images stereoscopically by wearing orthogonal polarized glasses.

The image processing unit consists of processor with functions of rotation, reduction, magnification of images on right and left, frame memory, memory for floating mark and drawing data, SCSI interface and so on.

The mouse has a 3D cursor, which has added Z direction (only for the floating mark on the right) control to the conventional functions of X and Y directions, for coordinate measurement and its menu operation.

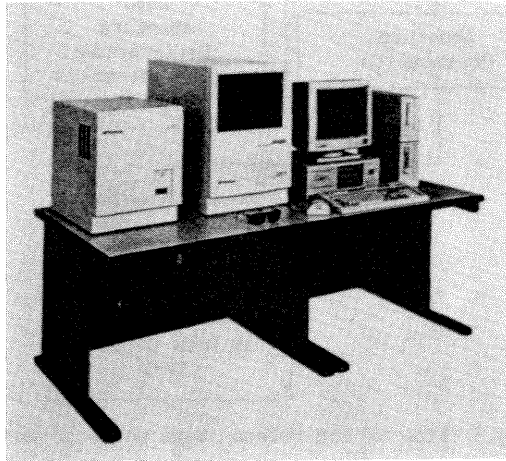


Fig.3 Stereo Image Workstation PI-1000

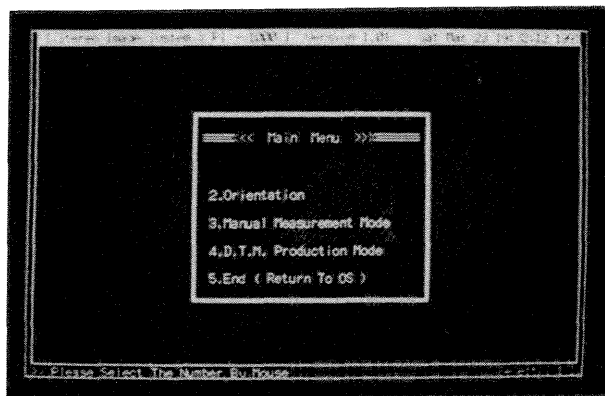


Fig.4 Main Menu on the PC Screen

2.2.2. Software

Measuring processing flow of the stereo image workstation is shown below:

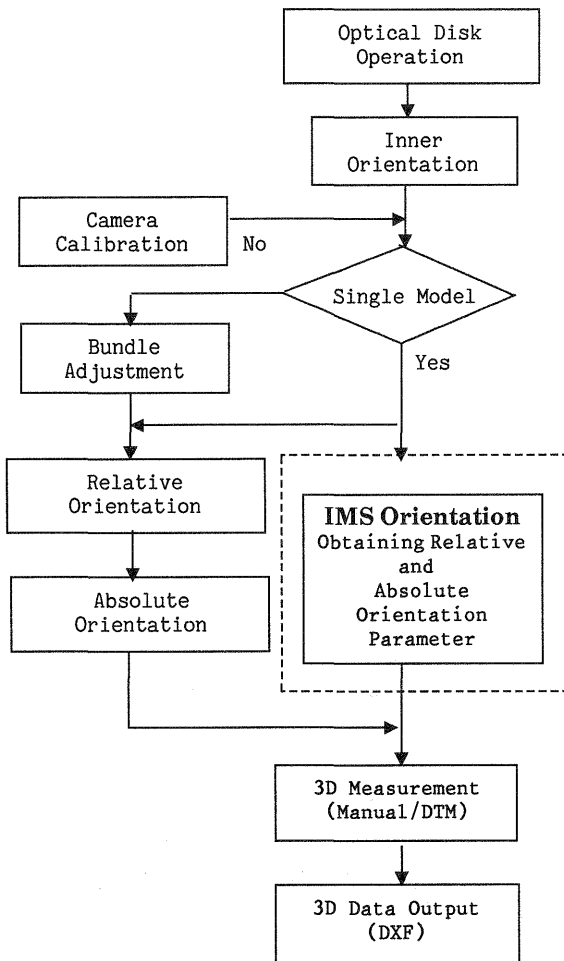


Fig.5 Flow of the Stereo Image Workstation

The orientation program consists of inner, relative and absolute orientation, camera calibration, bundle adjustment and IMS orientation (which we called and includes orientation of single photograph) conducted in this experiment.

A measurement processing unit is a single model in this system. Operator instructs a measurement point by observing the stereoscopic image on the 3D display. There are two measurement modes; one is manual measurement that measures interactively and the other is DTM measurement that allocates grid points of equal intervals in measuring area and conducts stereo matching with batch processing by a computer.

For measuring, by using the sampled image of whole photograph produced by the image scanner, read 3D display images on the right and the left in order from the optical disks. Then, display images stereoscopically after rectifying each image and measure the model coordinates with the mouse moving the floating marks. Images on the right and the left, therefore, have no y-parallax and the floating marks are to be always moving along the epipolar line. By using this way, the depth can be measured by simple operation, just coinciding the floating marks with a measuring point on the model.

The image correlation processing is absolute difference method and the combination of edge extraction by a laplacian operator of the images on the right and the left. Window size is 15 x 15 pixels, search size is approximately 90 pixels and a parameter can be changed according to a measuring object. Processing speed less than 0.5 seconds and can be processed in the interrupt mode according to the moving speed of the floating mark. Furthermore, this processing is used in the DTM measurement and its procedure is omitted but the semi-automated search processing for the corresponding point can be conducted.

Measuring commands have functions of line, polyline, circle, arc, contour and layer (management for drawing information). The 3D data after the measurement is processed as stereoscopic drawing data and superimposed in color on the stereoscopic images. Editing commands have functions of deletion, insertion, copy, move, conjunction, orthogonal conjunction and so on. By using these commands, while observing the stereoscopic data after measuring, correction and editing can be carried out. The obtained 3D data are output in DXF file format. The DXF file interchanges the AutoCAD drawing data, supported by many CADs like IGES file format and can be applied to various kinds of application softwares because of the spread of the AutoCAD and simplification of operation for drawing information.

3. ORIENTATION EXPERIMENT USING IMS

3.1. IMS System MS-100

The IMS used in this experiment is TOPCON MS-100 and consists of two digital transits (1") & subnence bar (Measuring staff made of carbon fiber: Length 1.2m), personal computer and tripod with high accuracy.

To measure by this method, firstly set up two transits at proper positions and then the subnence bar at a position where enables precise aiming from each transits. After collimating 3 globe shaped measuring points on the both edges and the center of the subnence bar, transmit the obtained data (horizontal and vertical angles) to the computer via RS-232C and determine the positions for the transits with network analysis software by resection method.

The coordinate system of IMS is originated from the position of the transit on the left hand side and takes a base line between left and right hands on X axis, depth on Y axis and perpendicular direction on Z axis.

Specifications of IMS MS-100

- Measuring accuracy : \pm Less than 0.3mm
(Measuring distance: 10m)
- Measuring time : 30 sec./point approx.
- Memory capacity
for coordinates : 2,000 points approx.
- Connecting transits: 1-3 units

3.2. Setting Control point Targets

As an object for this experiment, control point targets on a wall in a room and the target area is 3m (L) x 3m (W) approximately. For the control point allocation and the target shape, see fig. 6. Total of 56 targets were set on the wall with the depths of 4 steps (wall surface, 12.5cm, 25cm and 50cm) being fixed on the wall by attaching aluminum bars onto the bolts on the wall surface.

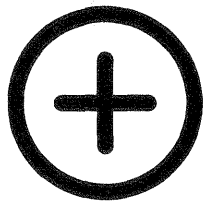


Fig.6 Control point Allocation and the Target Shape (Full size)

3.3. Metric Camera

PENTAX PAMS-645 was used for taking pictures. The camera is a terrestrial photogrammetric camera of fixed focus length and has four fiducial marks, vacuum system, etc. Interior orientation of the camera is calibrated and corrected photo coordinates based on the data sheet attached. In this experiment, the camera was used, attached to the telescope part of the transit for IMS by using an adaptor.

3.4. Determination of Exterior Orientation Parameters

Procedures to obtain exterior orientation parameters are shown as following order:

- (1) By using the IMS system, determine the positions of transits on the right and left hand sides and measure the control point target accurately.
- (2) At the measured control point targets, take a photograph almost vertical against the wall with the camera attached to the transit, give orientation of single photograph thorough positions of the transits and collimating angle as initial parameter and obtain the correcting values (ΔX , ΔY , ΔZ , $\Delta \omega$, $\Delta \phi$ and $\Delta \kappa$) of positions and tilts of transit and camera. Keep this relation between the transit and the camera after this.
- (3) Collimate a target around the center and take a stereo photograph.

- (4) Obtain the horizontal angles (ϕ) and the vertical angles (ω) of collimating direction of the transits by calculating three coordinates (as shown in fig. 7) of the transits on the right and the left hand sides and the target.
- (5) Determine the exterior orientation parameters from the correcting values and the actual measured values.
- (6) Divide the exterior orientation parameters into relative and absolute orientation parameters and converts them into the orientation parameters which are necessary to the stereo image workstation.

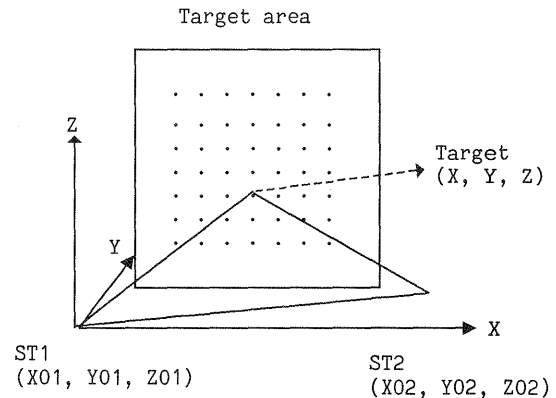


Fig.7 Orientation Processing by Using the IMS

3.5. Experiments Results

Results of 3D measurements by the conventional orientation procedures (case A) and the IMS orientation procedures (case B). are described below. Also, even in the conventional orientations, the camera positions and angles, obtained by the IMS, are used as approximate values.

[Parameters]

- Camera arrangement: Convergence photography
- Focus length of camera : $f=44.979(\text{mm})$
- Length for camera and object: $H=3(\text{m})$
- Base-line length for cameras: $B=1.5\text{m}$

Assuming coordinate measuring accuracy of the stereo image system (resolution) : $\sigma_p=7(\mu\text{m})$, measuring accuracy of coordinates in 3D measurement can be obtained by the following formulas:

[Theoretical value of plane coordinates]

$$\sigma_x = \sigma_y = \frac{H}{f} \cdot \sigma_p \approx 0.467(\text{mm})$$

[Theoretical value of depth coordinate]

$$\sigma_z = \frac{H}{f} \cdot \frac{H}{B} \cdot \sigma_p \approx 0.934(\text{mm})$$

[Measured Results]

	Measurement Error RMS (mm)		
	X	Y	Z
Case A	0.531	0.389	0.987
Case B	0.711	0.706	0.996

3.6. Example of 3D Measurement (Superimposition)

By using IMS orientation, example of 3D plotting of our office is as shown below:

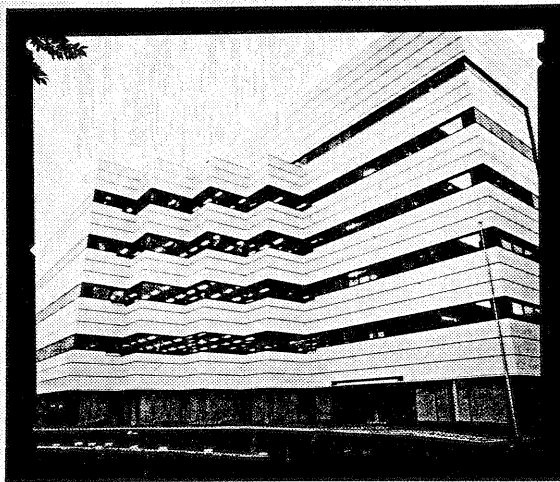


Fig.8 Photograph on the Left Used in the Measurement

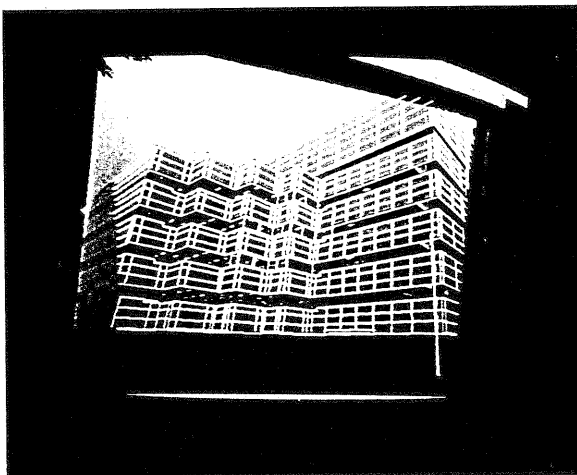


Fig.9 Example of the Measured Data, superimposed on the left Image by Using the Line Command

4. CONCLUSION

Our concepts on the configuration of a practical system for close-range photogrammetry are described below:

- ① Easy operating devices for photography and orientation processing
- ② Automatic measuring system based on the extraction of features (edge) on the object
- ③ Development of on-line plotting by using the 3D CAD system wire frame models
- ④ Direct image input by using high resolution CCD camera

Our experimented orientation by the IMS was processed to obtain orientation angles by collimating a specified reference point by using transits. Originally this orientation, however, is a method of determining exterior orientation parameters just observing the angle of collimating direction directly and its purpose is to establish a most fundamental problem ① in close-range photogrammetry.

In this experiment, many observation discrepancy were seen owing to the target sizes which were big, but the measuring accuracy was almost reached to the theoretical values that allows us to say this method is near the practical level. Furthermore, algorithm to obtain the exterior orientation parameters has been confirmed.

For the future, after finding methods of improving the adapter's stability and its calibration, we plan to establish a configuration that is more accurate and simple measurement for a base line of cameras than the IMS (for example, a high accurate total station) and develop a high resolution CCD camera system.

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