SEMI-AUTOMATIC DIGITAL PHOTOGRAMMETRIC SYSTEM ON PC

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ABSTRACT

Many studies have been made so far on the automatization of photogrammetric system through digital processing. Some systems based on workstation have been developed in recentyears and are now entering the stages of practical use, but there are still many problems left unsolved such as the difficulty of complete automatization and complexity of processing procedures.
In this study under such circumstances, we aimed at a simple system based on personal computer and developed the Personal Digital Photogrammetric System **"PyramidStereon"** employing "semi-automatic" processing which jointly uses human eyes and hands at the areas where the automatization is difficult. This paper will report the process of system development and verification results of test examples, and discusses the practical utility of the system.

1. Outline of past studies

The studies have already been made since 1960's on the automatization of photogrammetric system, especially on the compilation of DTM from stereo aerial photographs. In these studies, the automatic search (stereo matching) of corresponding points has been made mainly by "image correlation method" which compares the similarity of left and right images.

From 1960's to 1980's, the studies were made for the development of dedicated hardware called the Auto Correlator. The representative system of this development would be the Gestalt Photomapper (Hobrough, G.L., 1970). This was a system to identify the correlation among the photographic data of left and right photographs on the electric circuits, and was used as the basic method of image processing of later days.

In and after 1980's, the experimental systems were successively developed, which verify the processing result of image correlation method by workstations. The methods such as data input method, image display, rectification and stereo matching have been established through these development processes. Especially, the method to implement one dimensional search on epipolar line after the rectification was said to be effective for stereo matching, and multi-step searching methods using the image pyramid were employed to many system to shorten the processing time and prevent the mis-correlation. On the other hand, however, many problems were pointed out relating thereto such that there were difficulty in detection and matching of occulsion portions or deviation was observed comparing with existing mapping method because only the tree-top altitudes were obtained by matching. These problems were coped with and efforts were made to develop the system of practical utility by introducing the notion of so-called "man-machine interface," namely to use the help of human eyes and hands in stead of perfect automatization. There is EW: General Dynamics Experimental Workstation (General Dynamics, 1985) as a representative example of this type.

As the ISPRS Kyoto Conference held in July, 1988 as aturning point, many workstations were manufactured aiming at the practical use. The representative systems were DSP1: Digital Stereo Photogrammetric System (Kern Inc., 1988), HAI-750 (General Dynamics/Helava Assoc. Inc., 1990), DPW750 (Helava Assoc./Leica Inc., 1992), PHODIS (Carl Zeiss Inc., 1992) and PhotoScan (Intergraph Inc. 1992).

As stated in the above, the studies on the automatization of photogrammetric system have been made mainly around the image correlation method, and many kinds of systems, mainly the workstations, are sold on the market. As a merit of these systems, system development is relatively easy because the image correlation method is simple in terms of processing procedures and strong against noise, and therefore, it is possible to compile the data with high accuracy to a certain extent. Also, it is possible to efficiently generate high quality DTM by utilizing the techniques such as image pyramid, etc. Furthermore, the system with which operability is considered in its design is likely to be developed soon.

As the issues yet to be solved at present, the image correlation method hasa limitation in case of topography and objects with intensive relief and a difficulty in processing of aerial photograph of large scale. To cope with these problems, many methods have been tried to the stereo matching such as edge matching method and area matching method, but they are not completed yet as a practical system. Also, the system as a whole is still complex and highly prices as the development is made mainly on the workstations, and therefore, we can hardly say that they are easy-to-use processing systems.

2. Development of Semi-Automatic System Based on Personal Computer

Based on the recognition of the present state stated above, we developed the Personal Digital Photogrammetric System "PyramidStereon." This is a system activated on a personal computer which has shown dramatic advancement in terms of function; the system was developed for the purpose to establish a technique to easily compile DTM and digital orthoimage. We employed semi-automatic method to the portions which are difficult to automatize. Fig. 1 shows the hardware configuration, and Fig. 2 the software configuration.

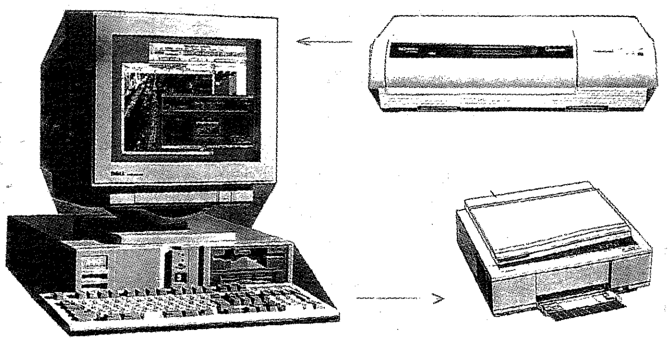
PyramidStereon		
Data processing	Image disp/edit	3-D mesh compilation
MS-Windows 3.1		
MS-DOS 6.2/V		

Fig. 2: Software configuration of "PyramidStereon"

The software composing of this system is activated by basic softwares of MS-DOS 6.2/V and MS-Windows 3.1. The majority of the software is occupied by "data processing group." In addition, photo-retouch software **PHOTOSHOP 2.5** made by Adobe Systems Inc. as an "Image display/editing group" and 3-D mesh compilation software **SURFER** made by Golden Software Inc. as a "3-D mesh compilation group" are used in combination. The processing procedures of this system is shown in the flow chart of Fig. 3.

Input by scanner
↓
Inner/Relative/Absolute orientation
↓
Rectification
↓
Compilation of image pyramid
↓
Stereo matching
↓
Edition and correction
↓
Re-organization of mesh
↓
Output as DTM
↓
Compilation of digital orthoimage

Fig. 3: Processing procedures of "PyramidStereon"



① IBM PC/AT compatible PC (Pentium 60MHz, Mem:32MB, Dsk:2.5GB)
② Crystal EYES PC by StereoGraphics Corp.
③ Genascan DT-S1030AI by Dainippon Screen Ltd.

Fig. 1: Hardware configuration of "PyramidStereon"

(1) Input by scanner

Aerial photograph is inputted by drum scanner as the image data to be proc-essed. It may be possible in the future to directly input the data through CCD camera, but it is practical at present to input it from a photograph. Input method is RGB full color input from a film or paper. Input resolution is in the range of 1 pixel = 0.005mm - 0.250mm.

(2) Orientation & Rectification

Since each kind of orientation method has been established in the field of aerial photogrammetry based on the precise geometric model as a preliminary processing, we used the orientation results of existing analytical stereo plotter (such as PLANICOMP) in this system. After the completion of orientation, we made rectification to eliminate vertical parallax. As a result of these processes, stereo view is obtained on the monitor, stereo matching is made efficiently, and matching accuracy is enhanced.

(3) Compilation of image pyramid

As a preliminary processing to enhance the processing efficiency of stereo matching, the image pyramid is made by sequentially reducing the rectified images to the size of 1/2. The image pyramid is made by the simple method to usethe average value of 2 x 2 pixels as one pixel of one rank higher hierarchy.

(4) Stereo matching

The stereo matching is started from the most coarse hierarchy of image pyramid, and matching points are converged by sequentially conveying the information to finer hierarchies. At each hierarchy, the square grid is placed on the left image, and matching point is found out on the right image by one dimensional search of image correlation method.

(5) Edition and correction

Many mis-matching and unmatching occur in stereo matching based only on the image correlation method. As a solution for practical use, therefore, we made it possible to have stereo view on the monitor by using the liquid crystal shutter glasses. Namely, edition and correction are made to the stereo matching result while visually confirming on the monitor. The data manipulation on the monitor is done by the software of image display/edition group.

(6) DTM and digital orthoimage

After the matching points are determined on left and right images, three dimensional information of each point is obtained from orientation factors and geometric principles. Next, the information is interpolated and made as DTM by re-organizing the meshes so that they form square grids against the ground coordinates. Interpolation is made by the software of 3-D mesh compilation group. Lastly, the digital orthoimage is compiled using rectified images and DTM.

4. Compilation of verification data

We used this system and compiled DTM and digital orthoimage from a pair of aerial stereo photographs. The scope of processing and the data used are as follows:

* Scope of processing: East part of Fukuyama City, Hiroshima Prefecture (2.2km x 1.4km)
* Data used: A pair of aerial color stereo photographs at the scale of 1:12500 (1987)
* Materials used: Topographic map, 1:2500 & 1:10000 (published in 1987)

(1) Data input and preliminary processings

We used positive photographic film for aerial color photograph, and inputted it at the resolution of 1 pixel = 0.050mm. Rectification was made by re-arranging the image data so that matching points of left and right images may align on one straight line basing on the orientation results of analytical stereo plotter. The data of 5 hierarchies were made as the image pyramid. One pixel of the coarsest hierarchy corresponds with 16 pixel x 16 pixel of the finest hierarchy.

(2) Stereo matching and edition/correction of matching results

We made stereo matching based on image correlation method using the image pyramid. The matching results were stereo-displayed on the monitor each time when the processing of one hierarchy was completed, and correction was made to the mis-matching. The matching points were placed so that their interval should be 5m on ground at final step. Fig. 4 shows a part of matching result at the third step.

(3) Compilation of DTM and digital orthoimage

After obtaining three dimensional coordinates from the matching results of the last step, we made DTM by re-sampling them as to form square grids at the interval of 5m on the ground. We also compiled the digital orthoimage from the rectified images and DTM. Fig. 5 is the DTM expressed by contour lines, and Fig. 6 is the digital orthoimage of the same area. In addition, we made DTM using theanalytical stereo plotter by the same specification for verify the accuracy, etc. However, the measurements obtained

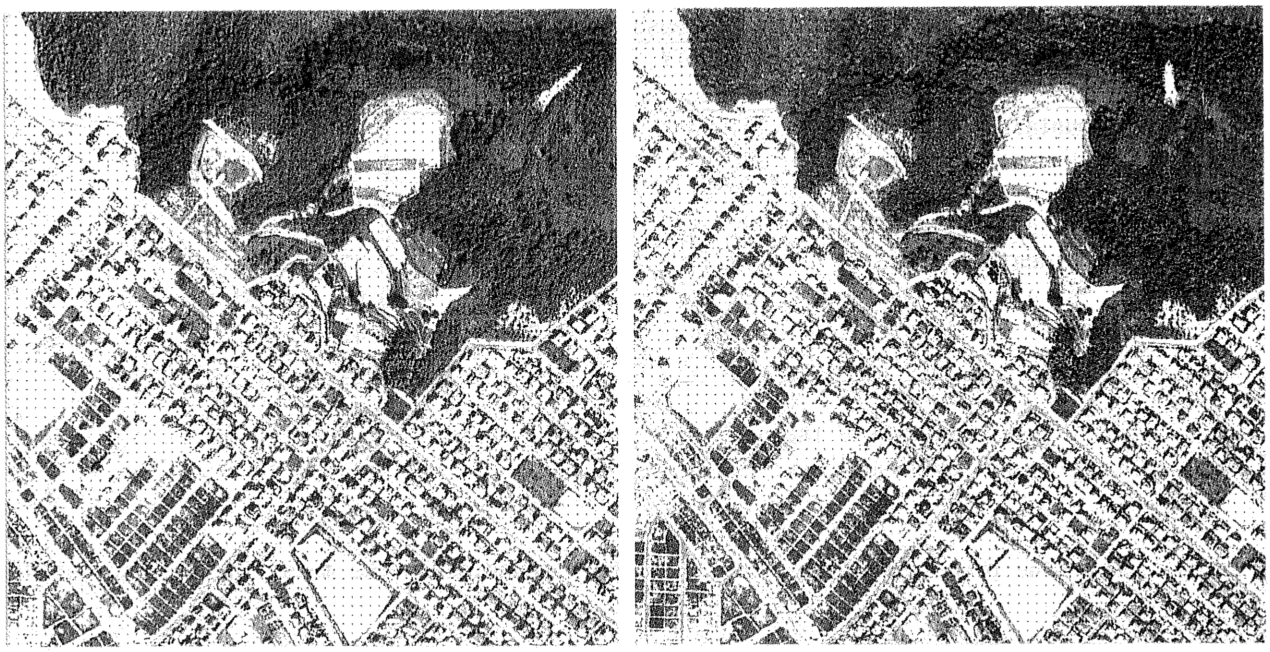


Fig.4: Results of stereo matching by image pyramid (part)

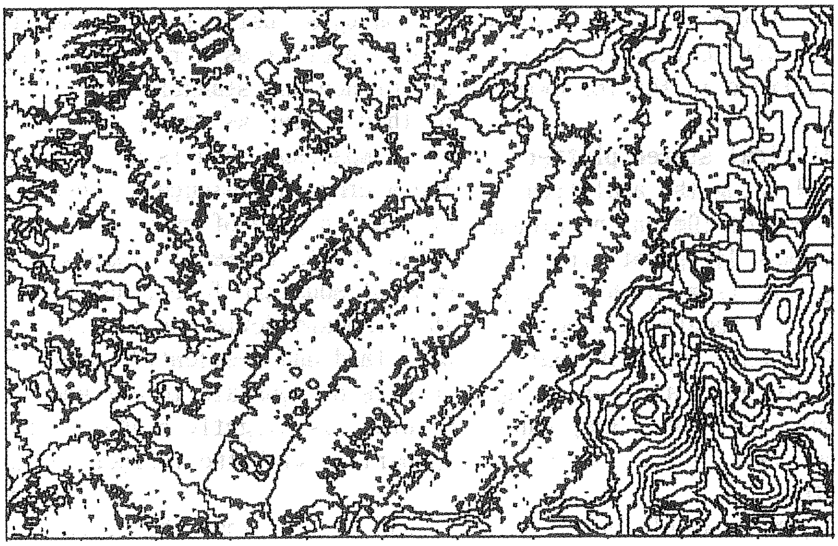


Fig.5: Contour line expression of DTM

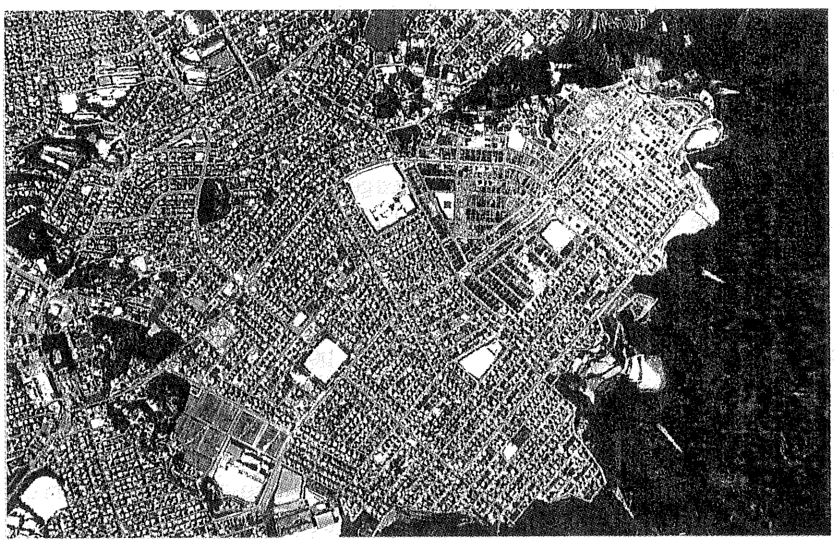


Fig.6: Digital orthoimage of the same area as Fig. 5

Table 1: Comparison of measuring accuracy of DTM

AREA	LANDUSE	MEASURING POINT	AVERAGE DTM PyramidStereon	AVERAGE DTM A. P.	DIFFERENCE of AVERAGES	STANDARD DEVIATION
A	**Mountain**	Tree-top	151.88 m	152.82 m	- 0.94 m	2.47 m
B	Forest	Portion	100.97	103.40	- 2.43	5.75
C	**Bare**	Land	78.61	78.72	- 0.11	1.42
D	Land	Surface	87.48	87.65	- 0.17	0.83
E	**Residential**	Land	78.44	78.91	- 0.47	2.02
F	Area	Surface	87.81	87.77	+ 0.04	1.80
G	**Hill**	Tree-top	31.48	31.95	- 0.47	2.00
H	Area	Portion	44.93	46.36	- 1.43	3.60

by analytical stereo plotter were the altitude of top surface of land cover such as tree-top and roof-top.

5. Discussion on the processing time

The length of processing time is one of the important factors to determine the practical utility of this system. Focusing on the compilation of DTM, we compared our system with the conventional method using the analytical stereo plotter. The results are outlined in the following.

(1) In case of the analytical stereo plotter

We acquired the DTM using the analytical stereo plotter at the mesh of 10m on the ground. Number of acquired mesh was 441 points from east to west and 141 points from north to south, and 31,161 meshes in total. Length of time necessaryfor measurement was 6 days. The data acquired by analytical stereo plotter are aligned in square mesh format, therefore, they can be used directly as the DTM.

(2) In case of our system

We compiled DTM so that the mesh of 5m is formed on the ground. Number of acquired mesh was 441 pints from east to west and 281 points from north to south, namely 123,921 meshes in total. As for the time length necessary for processing, 2 hours were used from the input by scanner until the re-organization of meshes as DTM, but meanwhile, 10 hours were used for the correction works by stereo view on the monitor.

As stated in the above, this system realized the drastic reduction of processing time comparing with the conventional method. The time necessary for the correction by stereo view on the monitor is considered to vary according to the condition of land use at object area, but it should be possible to reduce the number of visual verification points by thoroughly implementing correction at the earlier steps of image pyramid. As a result, DTM can be made in a relatively short time even when the size of mesh is smaller.

6. Discussion on the measuring accuracy of DTM

We verified the accuracy of DTM compiled by the above mentioned manner by extracted minute areas having the same land use among the verification data, using the DTM made by analytical stereo plotter as a reference, and using the difference and standard deviation of DTM made by this system as indices.
The comparison results are shown in Table 1.
The average difference betweentwo DTM's is 50cm or less in case of bare land and residential areas (C-F), while it expands to maximum 2m in case of mountain forest and hill areas (A,B,G,H). The standard deviation is within 2m in case of bare land and residential areas, but is 2 - 6m in case of mountain forest and hill areas. The accuracy is slightly higher in bare land in the comparison with the residential area.

It can be said that the stereo matching is made most favorably and therefore the accuracy of DTM is higher in bare land comparing with the areas of other land use. Residential areas has shown comparatively good result, but the accuracy is considered to have been deteriorated to some extent because there are occulsions at the edge parts of buildings. Also, in case of mountain forest and hill areas, the measuring point is the tree-top portion which has intensive up and down relief, therefore, the value of altitude fluctuate largely accordingto the selected position of matching points. Readers may notice that the values measured by this system is generally lower than those measured by analytical stereo plotter. This is considered to be due to the systematic error resulting from the difference of measuring method and peculiarity of measuring personnel.

7. Summary and problems to be solved in the future

The Personal Digital Photometric System "PyramidStereon" developed by us isa simple system activated only by the personal computer and its peripheral devices. As is evident from the compilation of DTM in comparison with conventional method, we could drastically reduce the processing time, and in terms of measuring accuracy, we were successful in minimizing the mis-matching by employing semi-automatic method, namely the visual confirmation. Based on these findings, we consider that this system can be put to the practical use at the fieldswhere prompt and efficient acquisition of DTM is necessitated. Especially, the use of GIS is advocated in recent years, and therefore, the demand for DTM is considered to increase as the important basic information.
As for the practical use of this system, we consider it to be important to discuss this system from the following viewpoints.

(1) The system to supplement stereo plotter
From the viewpoint to supplement the conventional method of map construction, this system shall be positioned as the system to efficiently compile the DTM which is regarded important as the basic information for GIS in recent years. Also, if the digital orthoimage is recognized more highly as a map, this system will be regarded as a new function that stereo plotters do not have.
(2) Application of ground survey
Although photogrammetric principles and methods have already been used for the ground survey, there is a problem in orientation works, etc. because the main subjects of stereo plotter are aerial photographs. If the functions necessary for ground survey are added to the orientation processing function of this system, this system will exhibit the higher simplicity in use and be used in various fields of survey.
(3) Application to the construction of image database and topography database of CAD & CG
As an application of structure design and scenic analysis, this system can be used for the construction of each kind of database of CAD and CG. In this case, the accuracy and efficiency of data acquisition can be adjusted freely according to the use purpose of database because aerial photographs or ground photographs may be selected as necessary as the input media.

Currently, we are continuously attempting to improve the system, taking up the following matters as the main issues.

* To clearly identify the unmatching points and skeptical portions (-->improvement of efficiency of visual confirmation)
* To identify the kinds of land use from the correlation property (-->improvement of measuring accuracy)
* Reinforcement and replenishment of orientation function (-->application to other than the aerial photographs)
* Compatibility with the digital mapping technologies (-->application to map drawing)

We will add discussions to the system from various viewpoints in the future, too.

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