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大島太市*

Experiences in using Orthophoto Maps in Japan

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Abstract

The orthophotograph technique has become popular in the world of photogrammetry in the past decade, but the idea behind this technique dates back a few decades.

In Japan, the modern system of orthophotograph by the on-line system was at first established by connecting the GZ-1 Orthoprojector with the A7 Autograph in 1969 and more and more considerations are being given to the use of the technique of orthoprojection as an aid in the preparation and revision of maps and charts.

The orthophoto Center organized with the cooperation of ten private companies was established in August of 1972 with two instruments sets consisting of GZ-1 and LG-1 and seven professional members. Each company uses Planigraph C8 or Autograph A7.

In forest survey projects, the Forest Agency of the Ministry of Agriculture and Forestry started to produce photomaps using the GZ-1 method in 1972 and since 1973 is going to do all the surveys by the mechanical method.

As a project of national large scale mapping series, the Geographical Survey Institute made tests to make photomaps at the scale of 1/10,000, 1/5,000 and 1/2,500 in 1972 and confirmed that the effect was better than the line-map.

This paper discusses the problems of solving the fundamental troubles in applying the orthophoto map techniques in the field of civil engineering projects.

1. Introduction

The orthophotograph technique has become popular in the world of photogrammetry in the past decade, but the idea behind this technique dates back a dew decades. In 1908, Sheimpflug made tests with zonal rectification. In 1929, O. Lacmann tried the first approach to rectify a photograph strip by strip. In 1933. R. Faber tested the differential rectification method in connection with a stereoscopic plotting instrument. But this orthophotograph technique was not realized in practice among the photogrammetrists as an important method until the development of the orthophotoscope by R. K. Bean in 1953 after World War II. This technique did not become really known and popular until this time. After that, alternatively

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new orthophotograph instruments were developed with new ideas, such as the GZ-1, the new orthoprojector by Prof. Gigas in 1964, the production of orthophotographs in connection with the conventional rectifier to a stereoplotter by Weibrecht in 1964 and orthophotography in connection with A8 stereoplotter by wild Co. in 1972.

In Japan, the modern system of orthophotograph by the on-line system was at first established by connecting the GZ-1 Orthoprojector with the A 7 Autograph in 1969 and more and more considerations are being given to the use of the technique of orthoprojection as an aid in the preparation and revision of maps and charts, although this fundamental concept is based on preliminary experiments done by the Geographical Survey Institute in 1967 using the prototype orthophoto instrumentations revising the Kelsh Plotter. The second Gz-1 Orthophotoprojector was used in 1971. At the end of 1971, the first Topocart-Orthophoto-Orograph was imported by a private company in Japan. They have all been used for preliminary tests to apply to practical works.

The Orthophoto Center organized with the cooperation of ten private companies was established in August of 1972 with two instruments sets consisting of GZ-1 and LG-1 and seven professional members. Each company uses a Planigraph C 8 or Autograph A 7. Therefore the off-line system of orthophotographs is now going on at the Center. At first this Center started to do practical work by studying and applying it to cadastral projects. This Center is now being operated actively not only cadastral surveys but also for other applicable fields of orthophoto work.

In forest survey projects, the Forest Agency of the Ministry of Agriculture and Forestry started to produce photomaps using the GZ-1 method in 1972 and since 1973 is going to do all the surveys by the mechanical method. The Geographical Survey Institute did the general research work and analysis of orthophotographs on the adaptability to the economy and the application to other fields.

As a project of the national large scale mapping series, the Geographical Survey Institute made tests to make photomaps at the scale of 1/10,000, 1/5,000 and 1/2,500 in 1972 and confirmed that the effect was better than the line-map. Fig. 1 shows the number of orthophotograph projectors imported into Japan in the past few years. Table 1 shows the orthophoto works in Japan from Jan. 1972 to Sept. 1973.

2. Examples of Experiences using Orthophotomaps

2-1 Cadastral Surveys

The cadastral survey in Japan is carried out by the Economic planning Agency on the basis of the National Land Survey Law. The principal purpose of the law is to clarify the natural characteristics of the country by cadastral surveys including establishment of control points for cadastral surveys, land classification surveys and water resources surveys. The cadastral survey consists of two aspects – investigation and survey – and the survey is broadly classified into ground survey and aerial photography survey. In Japan, as the area requiring survey is inevitably extended not only to the agricultural area but also to the mountainous regions and furthermore what was demanded was to survey a wider area in a short time. The orthophoto method has come into the limelight as one of the means to cope with this situation.

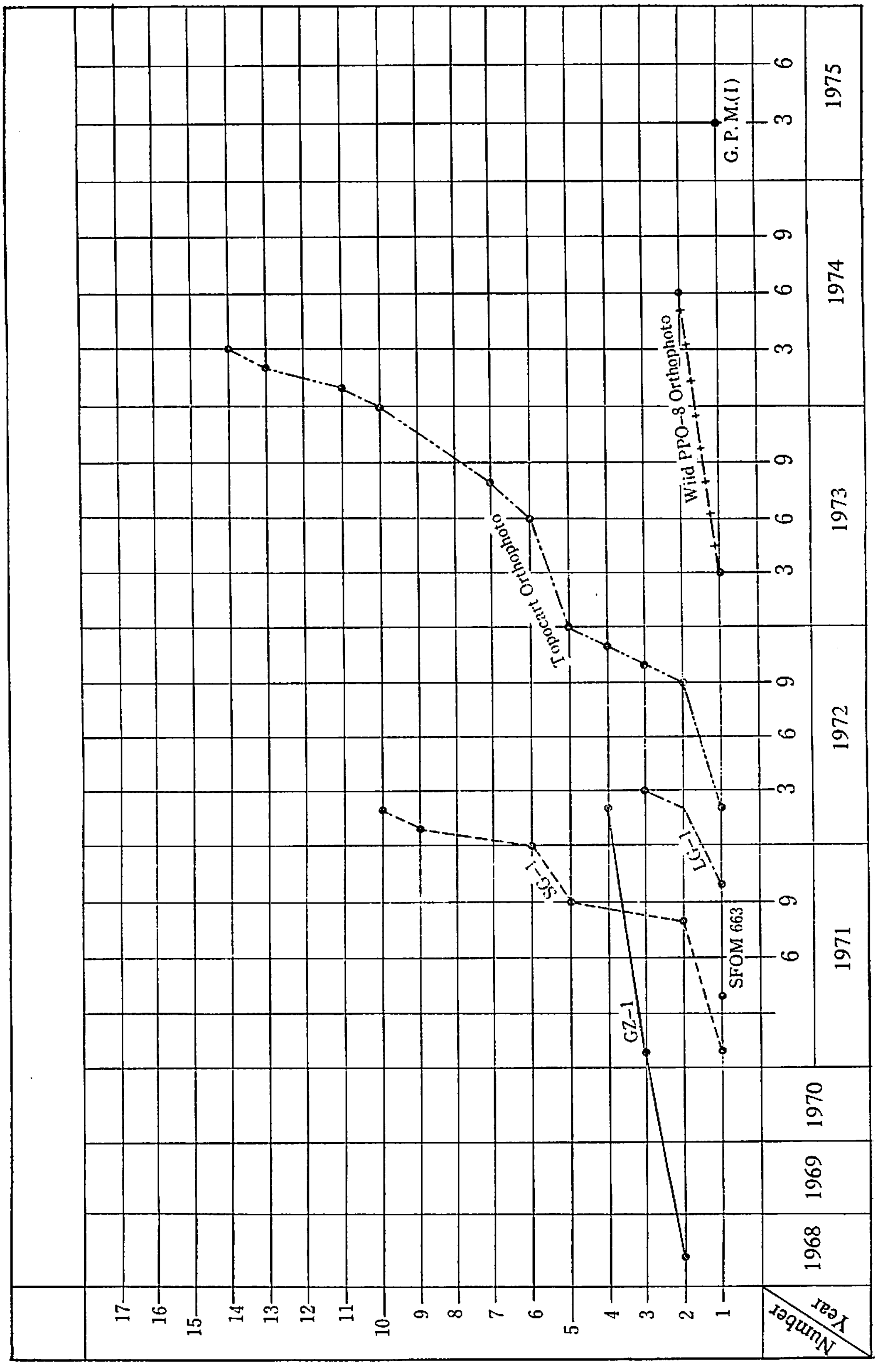

Fig. 1 Orthophoto Equipment in Japan from 1968 to 1975

The Japanese Government selected a model district in 1971 and organized the Consulting Committee, consisting of specialists from various fields to conduct repeated experiments and to check and evaluate the surveys fairly. As a result, though there were various problems caused by in sufficient experience, the Government could obtain satisfactory results which can be applied to the mountainous districts which require less accuracy than the residential and agricultural districts. This research project was done by the cooperation members of ten private companies belonging to the Orthophoto Center.

In 1972, orthophoto work for cadastral surveys were done to cover the area of about 600 km^2, 912 km^2 in 1973 and plans are to increase the area covered by about 30 o/o in 1974 compared to the preceeding year. A special noticable point is that these works are now managed by the cooperative effort of ten private companies.

Outline of process of making cadastral maps by the orthophoto method is as follows:

(1) Increase in the number of control points.

Density: one control point per 1 km^2 (by ground survey)

(2) Installation of signals at the existing control points and additional establishment of control points. (including orientation points)

(3) Selection of aerial survey supplementary control points. (This is a supplementary control point with which the geodetic coordinates can be obtained in the aerial photography survey and is necessary for the processing, maintenance and administration of cadastral map making and the density is one point per 4–2 hectare) and establishment of stone monuments at the site.

(4) Setting of signals for the aerial survey supplementary control point and the boundary corner points, etc.

(5) The scale of photographs thus taken is 2.5–3.0 times the required cadastal map scale. Overlap is 60–80 o/o, side lap is 30–60 o/o and care has been taken to use only the center part of photographs.

(6) Confirmation of signal points on the photographs (Photographs have been magnified approx. 4 times) – the objects to be confirmed are; all signal points such as control points, aerial survey supplementary control points, boundary corner points, etc.

(7) Computation of geodetic coordinates such as the aerial survey supplementary control points, major boundary corner points, etc. by aerial triangulation.

(8) To make a recording board of profile scanning by a combination of the first order stereoscopic plotting instrument and SG-1. (Recording system)

(9) To make Orthophoto negatives by the combination of the slope correction system (Glass-fiber optical ring) GZ-1 (Orthophoto Projector) and LG-1 (Reading system)

(10) Confirmation of the boundary corner points and the indication and delineation of parcel border lines and sheet lines – by red or reddish colours – on the orthophoto printed on aluminum foil copy paper.

(11) Confirmation and additional indications of boundary corner points, etc. by field survey at site, etc.

(12) Accurately indicate the cadastral items on the polyester mat base by transferring these items from the orthophoto and adding required marginal designs, thus completing the cadastral map copies. (These steps mentioned above are the outline for producing cadastral maps by the orthophoto method. Success or failure of this method depends upon the settling condition of

signals at the numerous parcel border points.

2-2 Forest surveys

The forest Agency of the Ministry of agriculture and forestry, in cooperation with the Gegraphical Survey Institute, has taken aerial photographs of mountainous areas in Japan that principally correspond with forest areas. The forest Agency has a project to take photographs of about 190,000 km^2 of Japan. The scale of the photographs is mainly 1/20,000. Since 1972, the Agency has done the work of the orthophoto project, for example, 3 districts in 1972, 5 districts in 1973 and 6 districts in 1974. Orthophotos of 1/5,000 in scale with contours of 20 m are produced from the aerial photos of 1/20,000 in scale.

The following effective ways to use the orthophotos at the present stage are considered.

(1) Condenced forest areas covered with planted forests lower than height of 600 meters and surrounded by city areas.

(2) Natural forest area higher than 600 meters.

2-3 Civil engineering surveys

The orthophotographs were used at first for planning of super-highways in 1964. At this time the super-highway connecting Nagoya and Osaka was already under construction and the highway connecting Tokyo and Nagoya extending about 400 km had just started but the project length of the land development projects at that time covered 3,000 kg out of the complete project length of 7,600 kg. The important problem at this stage was to complete the topographical map of 1/5,000 scale of preliminary designing quickly and economically.

Orthophotographs were used extensively during the year from 1966 to 1971. The reason why orthophotos were used only for limited projects after 1971 are as follows.

(1) National large scale maps such as 1/5,000 and 1/2,500 were produced by the Geographical Survey Inst. and country Government which can also use for civil engineering projects.

(2) Orthophoto maps of 1/5,000 in scale were used for road constraction design but the contour line of 10 meters was not adequate for detailed design work.

(3) Road engineers were not familiar with use of orthophotos and they did not have good leaders among them at that time. It was necessary to train them in the effective use of orthophotos.

3. Accuracy

3-1 Carl Zeiss Orthoprojector

The result gained by the experiments of the cadastral survey done by the Japanese Government are as follows:

(1) The discrepancy error of orthophotos compared with geodetic triangulation coodinates.

Table 2

	photo scale	orthophoto scale	number of test points	mean square error
A district	1/7,000	1/2,500	184	M = ± 56.2 cm (mountainous)
B district	1/10,000	1/2,500	85	M = ± 54.0 cm (mountainous)
C district	1/6,000	1/1,000	167	M = ± 27.3 cm (hilly)

(2) Error caused by difference of slit width

Table 3

slit width	1/1,000 (hilly)	1/2,500 (mountainous)
2 mm	18.2 cm	38.0 cm
4 mm	20.6 cm	47.1 cm
6 mm	21.7 cm	64.6 cm

3-2 Topocart-orthophoto-orograph

(1) Grid test of Topocart instrument

Result of accuracy of the 25 grid points measured by mono comparator is as follows:

Mean coordinate error $\Delta Y = \pm 9\ \mu m$

$\Delta Y = \pm 8\ \mu m$

Mean height error ± 0.12 mm

(2) The grid plate is placed in horizontally and is printed 2 times as large as the original photo-size by scanning with an 8 mm slit. The results checked by precise coordinatemeter are as follows:

Scale error of grid length in a diagonal 1 : 1.0004

Mean coordinate errors of 35 grid points $\Delta X = \pm 0.05$ mm

$\Delta Y = \pm 0.12$ mm

(3) The geodetic coordinates of control points for 25 models which consist of 42 points for each model were determined by triangulation. 3 or 4 points on orthophotos were used for orientation and coordinates of other control points which were measured by precise comparator were used for checking the orthophoto error, that is, the coordinate values of results of triangulation and the readings of the comparator were compared and are shown at table 4.

Table 4

photo scale	model scale	orthophoto scale	land use class.	slope	mean error	max. value of discre.	class of point	width of slit
1/2200	1/1250	1/500	field	flat	14 cm	38 cm	clear	8 mm
1/5000	1/3200	1/2000	paddy	flat	41 cm	95 cm	clear	16 mm
1/6200	1/3200	1/2000	paddy forest	steep	62 cm	128 cm	clear	4 mm
1/12000	1/8000	1/4000	villege forest	normal	110 cm	207 cm	pricked	4 mm
1/22000	1/12500	1/5000	forest	Height 350 m	130 cm	298 cm	clear	4 mm
1/22000	1/12500	1/5000	cultivated forest	Height 350 m	84 cm	211 cm	pricked	4 mm

4. On the efficiency and saving of time and cost of the orthophoto method

(1) Expenditure making orthophoto

The Commission of Study Group of orthophoto checked the result of cost of test areas and compared the photogrammetric method and orthophoto method.

Table 5

scale	photogrammetric method	orthophoto method
1/1,000	100	70
1/2,500	100	85
1/5,000	100	90

The orthophoto technique was useful for saving the working labor in the field does not require editing and inking.

Total working days for both methods, photogrammetry and orthophoto were compared. The results are as follow:

Table 6

scale	area	total working days	
		photogrammetry	orthophoto
1/1,000	10 km^2	1045 persons	352 persons
1/2,500	10 km^2	241 persons	141 persons
1/5,000	30 km^2	216 persons	122 persons

The required working time for orthophotos are shown at table 7.

Table 7

district	topographic condition	land use	orientation time (min.)	slit width (mm)	scanning time (min.)	magnifying power
a	flat	field	65	8	155	4.5
b	flat	paddy	60	8	160	2.5
b	flat	paddy	60	16	90	2.5
c	terrace	plowed land and forest	70	4	360	3.1
d	suburbs	mixing	75	4	340	3.0
d	suburbs	mixing	75	8	180	3.0
e	slope	forest	70	4	270	4.2
f	complicated slope	forest	80	4	480	4.2

The example shows the man-power requiring for completing of one map sheet by the orthophoto technique compared by photogrammetry at table 8. Test area is 60 km^2 and scale is 1/5,000.

Table 8

	topographic map	orthophoto map
planning	10 persons	7 persons
control pt. surveying	12	12
field checking	80	10
aerial triangulation	12	12
plotting	150	34
rectification	—	33
editing	68	16
auxiliary survey	35	—
inking	140	30
copying	—	19
total	507	173

5. Consideration and Conclusion

From the points mentioned above, the orthophoto technique has many advantage points compared to line map for saving time and provides various information in the form of images which can be selected by users. The photomaps will be further developed in the future. In many countries in the world, it will be produced at various scales depending on its purpose because at present the photomap is most promising in serving as a reliable base for planning purposes as a product that is rapidly available and relatively inexpensive.

In other areas the photomap will supplement existing line maps or fill up gaps in the range of scales. Orthophotos will aid revising existing maps more rapidly and in greater detail.

A great advantage of orthophotos is obtained when the property boundaries from cadastral maps are to be transferred. Because of the large number of visible details in an orthophoto, transfer of such boundary lines is much easier and more accurate than transfer to a line map, thus a reduction in signalized boundary markers is possible. The orthophoto with its wealth of information allows the extraction of all important details for civil engineering studies and design without additional costs in the preparation.

Besides the characteristic points of the orthophoto mentioned above, we have more problems to solve in order to develop this technique into a more advanced method as a tool for modern surveys. Just as stated before, the actual record of the orthophoto method indicates that the districts surveyed by this method are still small, but from the information obtained by actual survey operation, we wish to mention a few points.

(1) Since the topographic conditions of Japan are complicated and very steep, some part of the images on the photographs are sometimes blurred and erased.

(2) As long as one orthophoto sheets is covered by one model, mosaic work is necessary. If the mosaic work is done on film, the connecting lines appear on the orthophoto. These are of no value from the commercial point of view. Therefore mosaic work with printing paper is now popularly used.
(3) In scanning work in the forest areas by the orthophoto projector, scanning speed and the position of targets are very important especially as long as the target on the tree is nôt placed around the vertical point, adjustment is necessary afterwards.
(4) The orthophoto shows various type of informations. But if the engineer uses the orthophoto for actual work, he must select pertinent information that he desires. This is a problem area. Because he is not familiar with works of orthophoto.

In some countries, the so-called "controlled photomosaics" were somewhat disappointing when used for planning purposes because it was not realized that the mosaics lacked the geometrical properties of conventional line maps. But as the photomaps are superior at this points, we will find the more wide applications in the field of photogrammetry.

Furthermore, orthophotos will also serve as a basis for digitizing and subsequently storing of various topographic features represented. They will lead to further development in the field of automatic mapping permitting line maps to be produced more rapidly and economically than at present.

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