FMC cameras,High Resolution films and very large scale Mapping

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Abstract
Very large scale mapping (1/250) was experimented on the basis of FMC camera,High resolution film and total station surveying.
The future attractive combination of precision photogrammetry and personal computer assisted terrestrial surveying was investigated from the point of view of accuracy, time effectiveness and total procedures control.

1.Preface

In the field of photogrammetry,nowadays,practices of aerial photography using FMC cameras are the state of the art techniques.Aerial films of high resolution quality have been developed in few countries as well.

As for photogrammetric large scale mapping, it is inevitable to utilize low altitude- large scale photography both with high resolution films and FMC cameras.

Fortunately,we have analytical plotters,which combine on-line aerial triangulation,digital compilation and total station surveying system to ensure the ultimate accuracy.

In this report we deal with accuracy-verification,which compares photogrammetric data with terrestrial data of mapped points.

Then we have added comparisons of several cases of aerial triangulation,to make sure of a feasibility for very large scale mapping from an accuracy point of view.

Finally we set up our practical guide lines for very large scale mapping.

2.Outlines of Study-Quest for modern combination of photogrammetric components

2-1.Working flow chart

To realize practical large scale mapping,we have investigated the whole procedures of accuracy-verification process as fig.1.
As shown at the right hand side column,we have improved the ordinary procedures into rather up-to date ones.
Following the steps, we will explain the contents in detail.

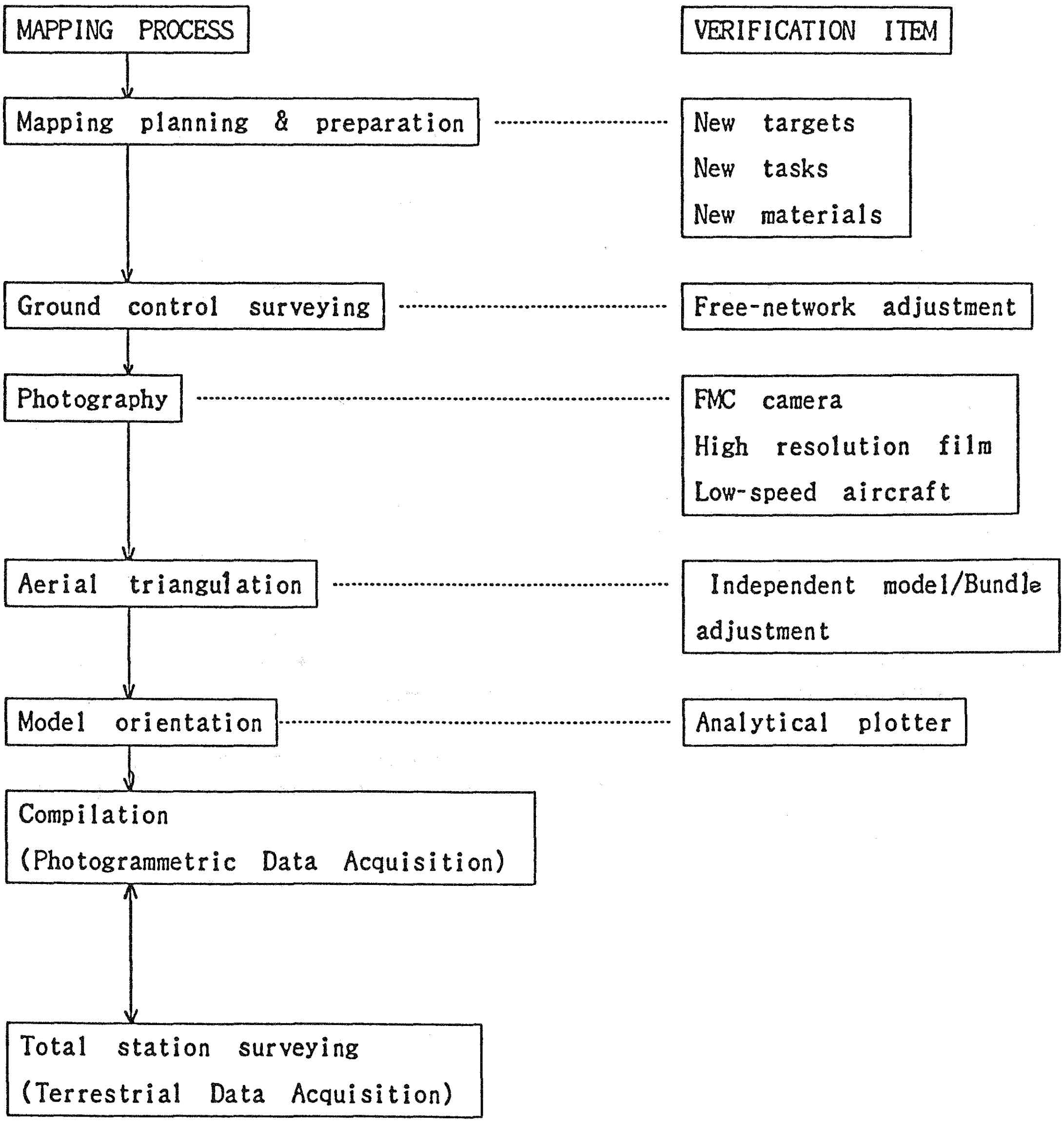

Fig.1 Accuracy-Verification Process

2-2.Planning and preparation

Our accuracy verification was concentrated on comparison between photogrammetric and terrestrial data.
In photogrammetric processes FMC camera,high resolution films and analytical plotter for digital compilation were used.In terrestrial processes free-network controls and total station surveying system were applied to supply precision ground control data.

During a practical project of 1/500 mapping for fundamental maps, We planned to take photos of scale of 1/2000 for 1/250 mapping.we estimated this kind of mapping to be performed in a dense urban area in the near future.

Films we considered as favorable were Kodak Technical Pan film,Agfa Gevaert Aviphoto-pan 200 and Kodak Plus-x.
We initially considered a systematic flight plan to ensure regular pattern of taken photos in an area of Fig.2.
One of the characteristics is the coincidence of principal points with map centers to get the common coverage of (ortho)photos and maps.

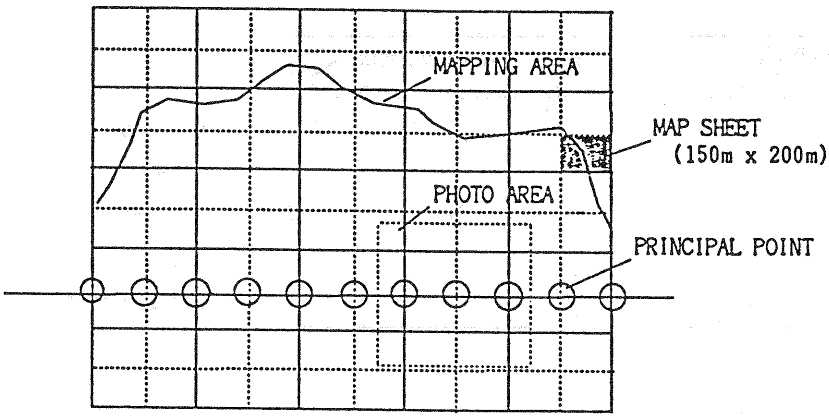

Fig.2 Flight planning

2-3.Free network ground controls

In Japan,even a national ground control has sometimes an error more than 20 cms.
We need accurate ground controls with smallest errors in large scale mapping.
1" theodolite has usually an obsavation accuracy of around 3" after the adjustment.
our EDM has an accuracy of 5 mm+- 2ppm.
The average observation distance was around 500ms through the mapped area,then we have got error ellipsoid of 2 cm (major axis) in the Free network solution.

Based on these ground control accuracies, we can get several kinds of accuracies in mapping procedures and consequently estimate the final error within 0.5 mms on the map (1/250),i.e.12.5 cm on the ground.

Ground control surveying	2~3 cm	
Aerial triangulation	1~2	(5~10 um)
Model compilation	4~8	(20~40 um)
Final drafting	7.5	(0.3 mm on the map)
Total amount	8.7~11.5 cm	

We hope to reduce the error of Final drafting by introducing digital mapping technique.

2-4.FMC camera

Forward Motion Compensation camera (LMK camera)we have is the earliest one in Japan.
FMC camera can compensate slip of the image position on the film surface caused by the exposure interval during the flight.
Fig.3 shows the schematic idea and calculating formula of the amount of Forward Motion.

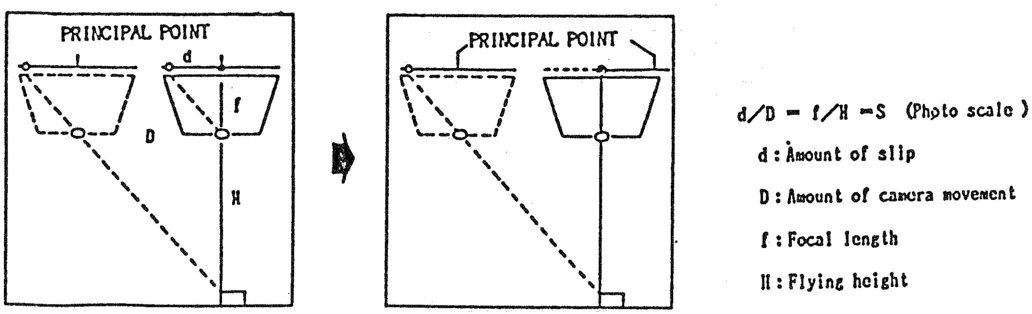

Fig.3 Schema of Forward Motion

For experiment,we estimate the amount of compensation as 160um under the condition of the flight as follows.

the amount of compensation = photoscale * shift of aircraft during exposure

shift of aircraft during exposure = Flying speed*shutter speed

where Flying speed = 200km/h;Photo scale = 1/2000;shutter speed = 1/175 sec.

Judging from the size of a floating mark,it is necessary to correct the amount of slip of the image position.

Since this function is most distinct to large scale photos,FMC cameras are respected as indispensabe component in photogrammetry in Japan.

2-5.High resolution films

There are various kinds of 35 mm and 6x6 films in the market,but photogrammetrist has been restricted within the medium level of resolution films in the field of aerial photogrammetry because of forward motion of aircraft during exposure.

Using FMC cameras,we can make use of high resolution and low sensitivity films in wider range of weather condition.
We can select slower shutter speed than usual and get more sharp image for photogrammetric compilation.
Even with medium resolution films,we can find a merit to use no shadow imagery in a cloudy weather.

All these things are the breakthrough of aerial photography in an image quality sense.
Fig.4 shows the comparison of various types of aerial films we have investigated during our experiment.

We still have some problems in photo-processing stage ,i.e.facilities,chemicals and experiences,to use high resolution films in Japan.

Designation	Manufacturer	Type	ASA	AFS	Resolution
Plus-x 2402	Kodak	Pan	250	100	50
Double-x 2405	Kodak	Pan	320	100	50
Panatomic-x 3400	Kodak	Pan	64	200	80
High Defi. 3414	Kodak	Pan	8	630	250
Aerocolor N 2445	Kodak	C N	100	80	40
Aerial C So-242	Kodak	C P	6	200	100
Aviphot Pan 200	Agfa-Gevaert	Pan	80	160	100
Aerial HS	Fuji	Pan	320	100	100

Fig.4 Aerial Films Used

2-6. Total station surveying system

For terrestrial ground control surveying, in other words ground coordinate acquisition, we have selected to use the total station surveying system, which is a system to acquire coordinates in 2 steps in one system. At the first step we measure angles and distance at a time using electro-tachymeter, then in either inside of the tachymeter or outside of it micro-processer compute the 3D coordinates of respective point.
Fig.5 shows the technical specification of our total station system.

TELESCOPE:		ANGLE MEASUREMENT SECTION:	
Length	169mm	Measuring method	Electronic absolute reading
Objective lens	40mm(EDM;55mm)	Least count	1″ (5cc)
Magnification	30x	Accuracy	1″ (standard deviation based on DIN 18723)
Image	Erect		
Field of view	1° 20′	Display unit	1″ (5cc)
Resolving power	3″		5″ (10cc) in tracking mode
Minimum focus distance	1.5m	Measuring time	0.4sec.
Illumination is provided on the reticle			0.2sec. in tracking mode
DISTANCE MEASURING SECTION:		Graduated circles	80mm φ (both horizontal and vertical), coded graduation
Accuracy	±(5mm+2ppm) m.s.e		
Measuring Time		AUTOMATIC VERTICAL INDEX:	
Single measurement and repeat measurement	4sec.	Leveling	Liquid compensator
		Working range	±5′
Tracking mode	0.6sec.	Setting Accuracy	1″
Least Count		LEVEL SENSITIVITY:	
Fine mode	1mm(0.005ft)	Plate level	20″ /2mm
Prism constant correction	-80to+20mm(by1mm)		

Fig.5 Technical specification of our total station surveying system

3.Methods of accuracy-verification

3-1.Former achievements and Present goal

During our previous experiments given below,we seek to find the present goal in confirming the point-accuracy of mapped points.

(1)LMK -with FMC device-camera experiment

(2)Kodak Panatomic-x,Tech-pan,so-242 and so on experiment

(3)Total station PADRAS-T3D development

(4)Digital compilation,editing and Plotting using analytical plotter.

For the above mentioned goal,we have decided to investigate the accuracy of aerial triangulation and photogrammetric models as a basis of large scale mapping.

3-2.Verified items in aerial triangulation

(1)Effective size of block adjustment

For this purpose we treated large block aerial triangulation of 1400 models in a block.
Several kinds of case-study were done to find the best accuracy under the present practical conditions.

(2)Accuracy of small block aerial triangulation of large scale photos
In a similar way that we applied in a large block, we confirmed the present accuracy level of large scale photos.

3-3.Verified items in photogrammetric models

(1)Test field for large scale aerial photography
It was fortunate for us to use Free-network ground control survey data for the control points.

(2)Ultimate accuracy of minor controls in a photogrammetric model

(3)How accurate are the photogrammetric model-points in comparison with ground controls?

3-4.Accuracy standard for other mapping procedures

For further consideration we checked 2 other aspects in other mapping procedures.

(1)Accuracy of Photogrammetric minor controls for supplemental survey

(2)Efficiency of total station surveying system,as an alternative tool of plane surveying

4. Results of accuracy-verification

4-1. Accuracy level of mapped points

— Comparison between large and small block adjustments —

Unit in (m)

Block Adjustment	Case A1	Case A2	Case B3	Case B4	Case B5	Case B6	Case B7	Case C8	Case C9
Photo Scale	1/4000	1/4000	1/4000	1/4000	1/4000	1/4000	1/4000	1/2000	1/2000
NO.of Photos	1422	1422	214	214	214	214	214	28	28
Controls Distribution									
P.L	283	283	44	44	44	44	44	10	10
H	1621	1621	248	248	248	248	248	10	10
NO.of Controls									
P.L	283	81	44	21	11	14	32	10	5
H	1621	165	248	29	16	42	42	10	5
NO.of Checking Points									
P.L	0	262	0	23	33	30	12	0	5
H	0	1456	0	219	232	206	206	0	5
σ0.P.L		0.038		0.035	0.035	0.035	0.035	0.015	0.014
σ0.H		0.064		0.063	0.063	0.063	0.063	0.011	0.010
Residuals of Controls									
(R.S.M) P.L	0.05	0.06	0.04	0.04	0.04	0.04	0.04	0.006	0.008
H	0.04	0.02	0.04	0.03	0.02	0.03	0.03	0.014	0.005
Residuals of tie Points									
(R.S.M) P.L	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.012	0.009
H	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.010	0.005
Residuals of Checking									
Points (R.S.M) P.L		0.18		0.14	0.16	0.13	0.11		0.020
H		0.15		0.17	0.28	0.13	0.13		0.054
Residuals of Controls									
(Max) P.L	0.17	0.12	0.07	0.08	0.07	0.08	0.08	0.010	0.013
H	0.17	0.07	0.15	0.09	0.06	0.08	0.08	0.033	0.009
Residuals of tie Points									
(Max) P.L	0.18	0.17	0.17	0.16	0.15	0.15	0.17	0.022	0.018
H	0.18	0.23	0.13	0.13	0.13	0.13	0.13	0.013	0.009
Residuals of Checking									
Points (Max) P.L		0.51		0.27	0.27	0.29	0.23		0.027
H		0.92		0.59	0.73	0.50	0.50		0.099

Fig.6 Case study of large,medium and small block adjustment

4-2.Accuracy of detail survey(mapped points) using total station

Unit in (m)

	Electric Poles	Walls	Manholes	Traffic Sign	Road Corner	House	All Points
No.points	12	13	27	7	35	2	96
σx	0.038	0.036	0.031	0.032	0.038	0.028	0.034
σy	0.098	0.077	0.088	0.088	0.092	0.107	0.087
σxy	0.105	0.085	0.094	0.093	0.100	0.110	0.094
σz	0.064	0.118	0.073	0.060	0.078	0.125	0.079

Fig.7 Standard deviation of classified mapped points

According to 3.Methods of accuracy-verification we can derive some characteristics out of Fig.6 and Fig.7 respectively.

(1)For large block case B4 is a standard application of Japanese surveying regulations.Residuals of checking points display some apparent errors included in some parts of blocks,but RMS values appear to be much accurate than usual. Case B6 shows that increasing the number of height controls compensate or improve the accuracy even in the case of decreasing the number of planimetric controls. Consequently we are satisfied with the number of controls of large block(>1000 models) for large scale mapping(1/500).

(2)Case c9 shows that we can get the accuracy of 2~5cm(RMS) at a present stage in the case of large scale photos.

(3)Overall accuracy of mapped points enable us to get the accuracy of less than 10 cm at compilation stage using analytical plotter.

(4)We have not yet succeeded to confirm the ultimaaate photogrammetric accuracy,because we are still short of ground control accuracy of 1 cm.

(5)Simultaneously with checking surveying using total station system, we have realized the efficiency of total station systeeem for detail survey to some extent.

5.verification

5-1.Targets of very large scale mapping

Our present targets are the 3 following items.

1) To satisfy A-1 class accuracy standard in Japanese cadaster surveying regulations.

2) To apply this method for cadaster ground controls in a dense urban area.

3) To produce basic(aerial photogrammetric)maps for civil engineering design.

From these points of view,our results are very close to the satisfactory level.

5-2.Tasks of very large scale mapping

We need further improvements on matters mentioned below.

To acquire a stable platform,like a airship camera station.

Fig.8 shows a plan of airship-borne camera.

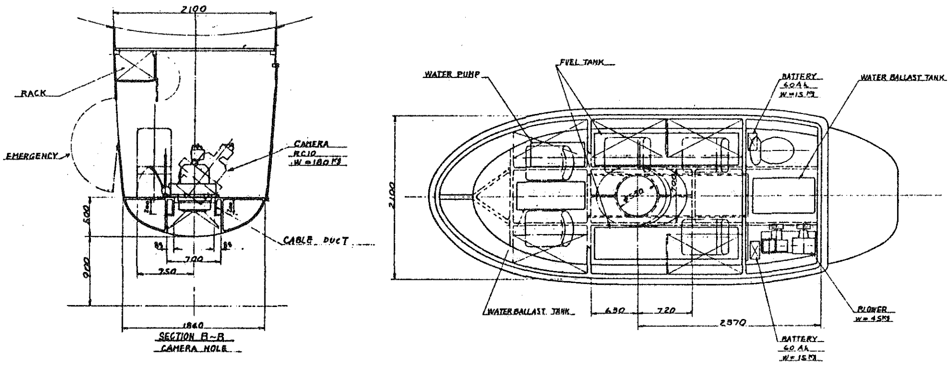

Fig. 8 Airship-borne camera

To get more precise ground controls, such as either free network ground controls or simultaneous adjustment controls of aerial and terrestrial surveying data

To get economical spatial ground controls and resection technique using total station survey

Fig.9 shows the schematic idea.

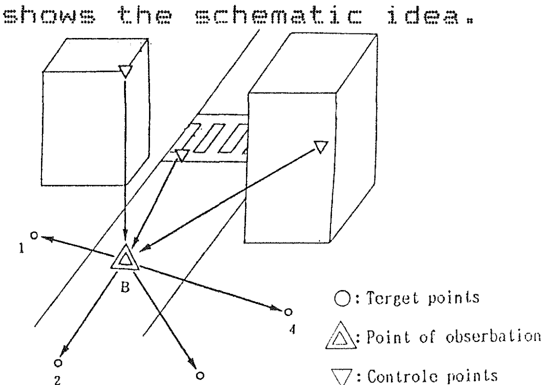

Fig.9 Spatial controls and resection

To innovate the whole procedure,using lap-top personal-computer plane surveying system with CAD display.

5-3.Provisional technical specifications

Here we propose a provisional technical specification as Fig.10.

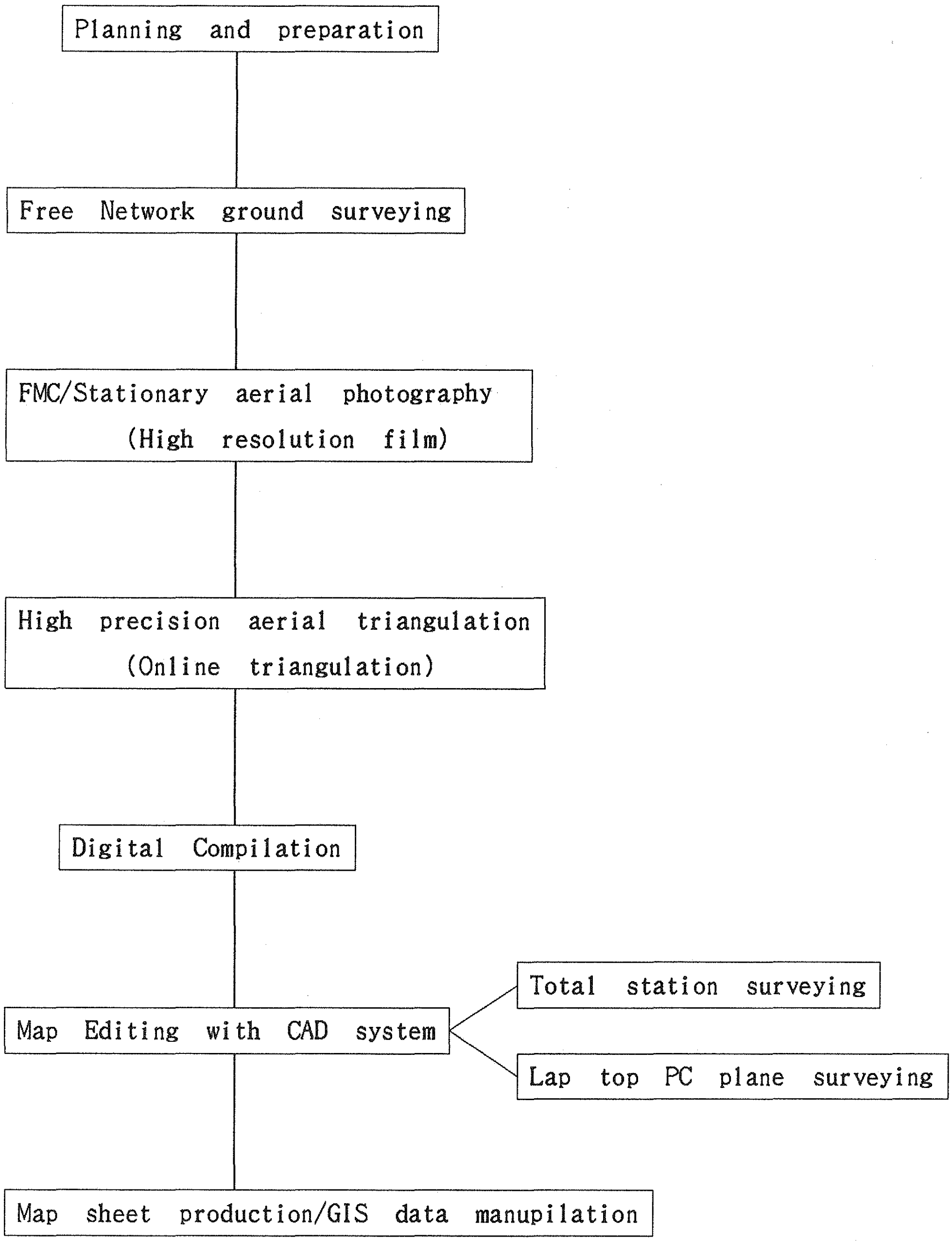

Fig.10. Provisional Working Flowchart

6.Conclusions

As far as accuracy is concerned,we have almost succeeded to get satisfactory results using 1/2000 photo aerial triangulation.
Some provisional approaches,like high resolution films, total station surveying, are becoming more popular to photogrammetrists as well.
Data requirements from geographical information system will accelerate cadaster survey in dense urban area.
Our photogrammetric efforts will contribute to control key process as a breakthrough for very large scale mapping (1/250).

References

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