PADRAS-PASCO Automobile DRAwing System-

Hiroyuki Hasegawa,Senior engineer of photogrammetry

Kohei Uesugi,Photogrammetrist

PASCO Corporation

Tokyo branch

2-13-5 Higashiyama Meguro-ku Tokyo

JAPAN

Commission No.2   Working group 6

Abstract

Photo-laboratory,portable analytical plotter and tolal station surveying-personal computer system are installed on a microbus as a continuous operation system.
This system is named PADRAS(PADRAS-PASCO Automobile DRAwing System)and applied,at first, in the field of archaeological (cultural properties) photogrammetry. This paper reports functions,accuracy level and potentialities of PADRAS in Industrial photogrammetry.

1.Preface

Standard aerial photogrammetry,as a tool of topographic mappig,has played an important role and given verious preconceptions.
It seems to be a complete image that photogrammetrists are using metric camera,plotters,aerial triangulation only for aerial photogrammetry.

Does any premises make engineers in other fields keep away from photogrammetry? We can point out fixed focal length,vertical photography and strip block formation as examples for such premises.
On the other hand, archaeologists have paid attention to the merits of photography,because of good positioning to the object and recordable characteristics.They have been pioneers in the field of cultural properties photogrammetry as well.
PASCO has completed a consitent system to summerize the whole requirement "on the spot-photogrammetry" in archaeological research.This system is called PADRAS(PASCO Archaeological DRAwing System).
By the way,Realtime photogrammetry or Video-grammetry have been so much highlighted as high-tech field of photogrammetry that we are pursuing on-line or real-time aspect of photogrammetry from different approach based on our experiences of PADRAS(PASCO Archaeological DRAwing System).
We now introduce an expanded general concept of automobile type of photogrammetry as PASCO Automobile DRAwing System(PADRAS).

2.System Construction

2-1.Prehistory of PADRAS

PASCO has made a lot of practices in most of the components in photogrammetry.

2-1-1.Non-metric camera

In Cultural properties photogrammetry, not specified cameraman takes different size of photos , like archaeological site, ruin and relic.
They simply require to use their photos for 3D measurement. there are quite number of researchs from this point of view (1).

2-1-2.Photo films

Archaeological objects include so many varieties,i.e.interior exhibits,outdoor excavated remains and artistic handicrafts and works that cameraman should select adequate type of films,like high-sensitibity,high-resolution and infrared/positive colours.
Sometimes developing exposed films is done on the spot using some modern types of film (Kodak Techpan etc.)for drawings.

2-1-3.Orientation methods

Corresponding to non-metric cameras,DLT(Direct Linear Transformation) orientation method is successfully introduced in some cases or other, since this method does not need any fiducial marks and focal length value.

2-1-4.Analytical plotters

Analytical plotter is a photogrammetric 3D measuring instrument (digitizer) to provide photogrammetric 3D model in an analytical way. As a 3D measuring tool,analytical plotter has an applicable range for medium or large structures.High precision (multi axis) 3D measuring instrument is applied for small size structure(<2m) and multi theodolite measuring system is still suffering from disadvantage of time consuming. Compareing with analogue plotter, portable analytical plotter has an advantage that person who measurs photogrammetric objects can simply follow the shape stereoscopically by measuring marks without any specific training in photogrammetric orientation.Nearly 10 types of portable analytical plotters have been developed in some countries.

2-1-5.Platforms

IN the field of cultural properties photogrammetry, several types of platforms which cover full range of photoscales and photoangles have been developed and used in practice. Mainly for low altitude photogrammetry, aircraft with FMC camera, helicopter, RC aircraft, air baloon and TV camera booms are handled on an ad hoc basis.

2-2.Directions of our development.

2-2-1.Topographic mapping

In our ordinary photogrammetric works we have been pursuing to higher precision mapping, especially in large scale mapping projects(2).
Apart from accuracy aspect,topographical mapping needs to get aerial triangulations,compilation using analytical plotter and personal computer based CAD system on the spot, especially in overseas projects.
Therefore we planed to introduce aerial triangulation programs and other components on a personal computer basis.
This direction couid be characterized as topographic mapping of a movable mode with consistent procedures,which differs from a stationary mode with indoor and seperated procedures.

2-2-2.Industrial photogrammetry

We are proceeding to next stage in close range photogrammetry.
As we have already mentioned,we have examined movable mode of photogrammetric procedures in the field of cultural properties photogrammetry and succeeded to realize most of it to a great extent.
In a similar way we applied our movable mode of photogrammetry in other fields of close-range photogrammetry,
we have found it feasible that our movable mode can be applicable at the real construction spot with full range from reference surveying, photography and processing to 3D photogrammetric measurement and data processing like computing strike and dip of geological layer(stratum) and volume.

2-3.PADRAS- total system of automobile analytical photogrammetry.

Parallel with actualizing the above mentioned requirements,PASCO has established a total system for aerial and close-range photogrammetry on the spot.
This system is quite competitive to the other measuring means on a on-line basis.
This system is embodied by a "Mobile photo laboratory and measuring-plotting room" which consists of 7 powerful outfits in a microbus,after traditional Japanese favorite,i.e.platforms,cameras,terrestrial surveying instruments, photo laboratory,portable analytical plotter,personal computer,XY-plotter for photogrammetric mapping.

Fig.1 shows the whole system carried on a microbus.

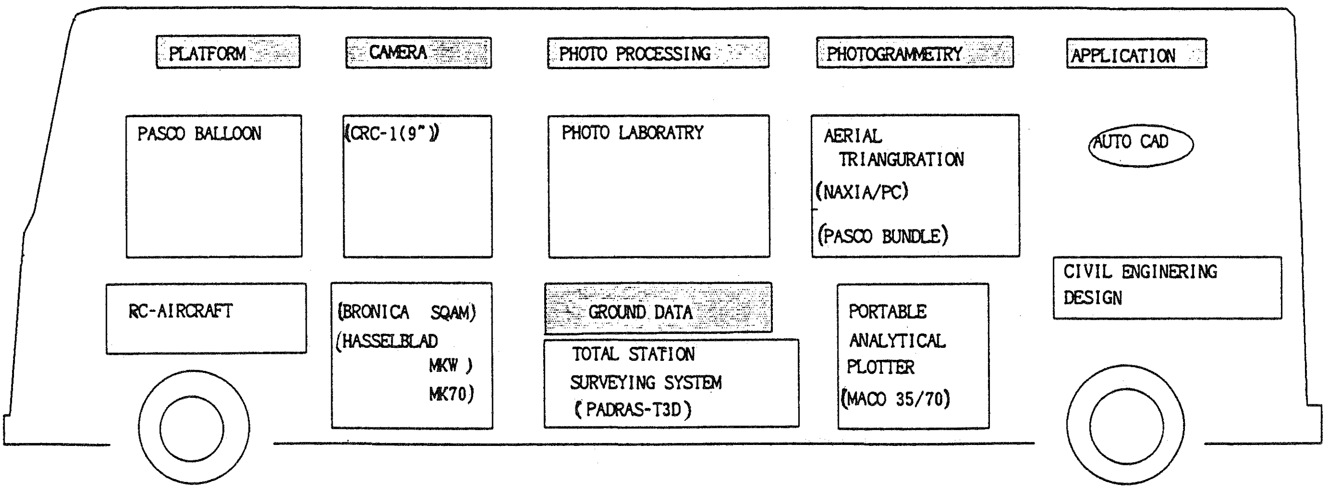


Fig.1 PADRAS CAR System-"Patent applied for".

At first this system has been completed as PADRAS(PASCO Archaelogical DRAwing System) for medium accuracy level. Then after improving orientation method,metric specification for camera and servo-encoder systems in analytical plotter,this system has evolved into PASCO Automobile DRAwing System(PADRAS) as higher precision and general measuringsystem in industrial photogrammetry.

3.System components

3-1.Quest of higher precision measurement.

Our movable mode of photogrammetry is established on a basis of portable analytical plotter ;MACO 35/70(ZENZA BRONICA MACO 35/70 in Japan).
It has a lot of advantages of analytical plotter as it is, comparing with the other large size-stationary analytical protters.

3-1-1.Comparator Stage Unit

Left and right stages are constructed symmetrically so as to maintain baiance and to make the system compact.
Material used for the moving parts (leadscrews) is SUS 440 which is processed (for hardness and anti-rust) so it will last long.

3-1-2.Encorder Unit

Rotary encoders are fixed to four axes (left X, left Y, right X and right Y) and the positioning resolution of the system is 0.15625 u m.

3-1-3.Optical Systems

For optical unit, comfortable viewing, size of floating mark, and magnification are important for precise measurement.
Here, in order to start with the "positive orientation" we have made the size of floating mark ϕ15 μm and the magnification range going from 8X to 40X with 10X eyepieces.
With this, we were able to minimize the effect of the viewing errors and were able to decide accurate orientation factors.

3-1-4.Glass-plate Calibration

We used a reseau plate which has 25 reseau marks on a 53mm x 53mm x 3mm plane glass. those 25 reseau marks are marked with vacuum evaporated chrome.
The distances between reseau marks are 12.5mm and those 25 reseau marks are positioned 5 marks in a row and in 5 rows.
Reseau marks were measured by using edge detection method using the LAMPAS MICRO which is a measuring equipment for the line width of IC (integrated circuit) and its accuracy is less than 0.5 um.

3-1-5.Glid Calibration Programs

3-1-5-1.Measurement

Measured 25 reseau marks on 53mm x 53mm x 3mm plane glass by setting it on MACO 35/70. We have measured 3 times per each reseau marks and have taken the average of 3 measurements as measured value.
However, when measuring same marks 3 times and if the differences of 3 measurements were more than 1.5μm, we have taken it as viewing error exists considerably and have remeasured them again.
In this case, instead of one more additional measurement, we have always measured 3 times.

3-1-5-2.Glass Plate

We used glass plate which we have mentioned in 3) Glass Plate Calibration above.

3-1-5-3.Computation

Based on measured values of reseau marks by MASCO35/70 and the measured values of the reseau marks by LAMPAS MICRO,we obtained 8 coefficients of quasi-affine transformation by the least square and have computed the standard deviations of residuals of each marks and have made this standard deviation as the stage accuracy.

3-1-5-4.Results of the Computation

As we have measured 3 systems, we have obtained following 6 results of computation shown in tab.1.

	1L	1R	2L	2R	3L	3R
X	0.963μm	1.177	0.885	1.116	0.867	1.115
Y	0.858	1.266	1.170	1.084	0.931	1.313

Tab.1 Grid calibration results

3-2.Free selection of orientation models

The central part of PADRAS system is a photogrammetric 3D measuring digitizer(portable analytical plotter) to show its ability on the spot in movable mode.
3D measuring methods,in other words photogrammetric orientation methods, in other large size-stationary analytical plotters are restricted within either 3 steps(inner,relative and absolute orientations)or 2 steps(inner and exterior orientations).
So far orientation parameters and driving parameters of analytical plotter measuring devices are concealed in a real time closed loop,which realizes central projection concept.
Recently,manufacturers tend to make users select arbitrary orientation method(3),(4).

On our portable analytical plotter MACO 35/70, some other orientation methods are being developed as shown fig. 2.

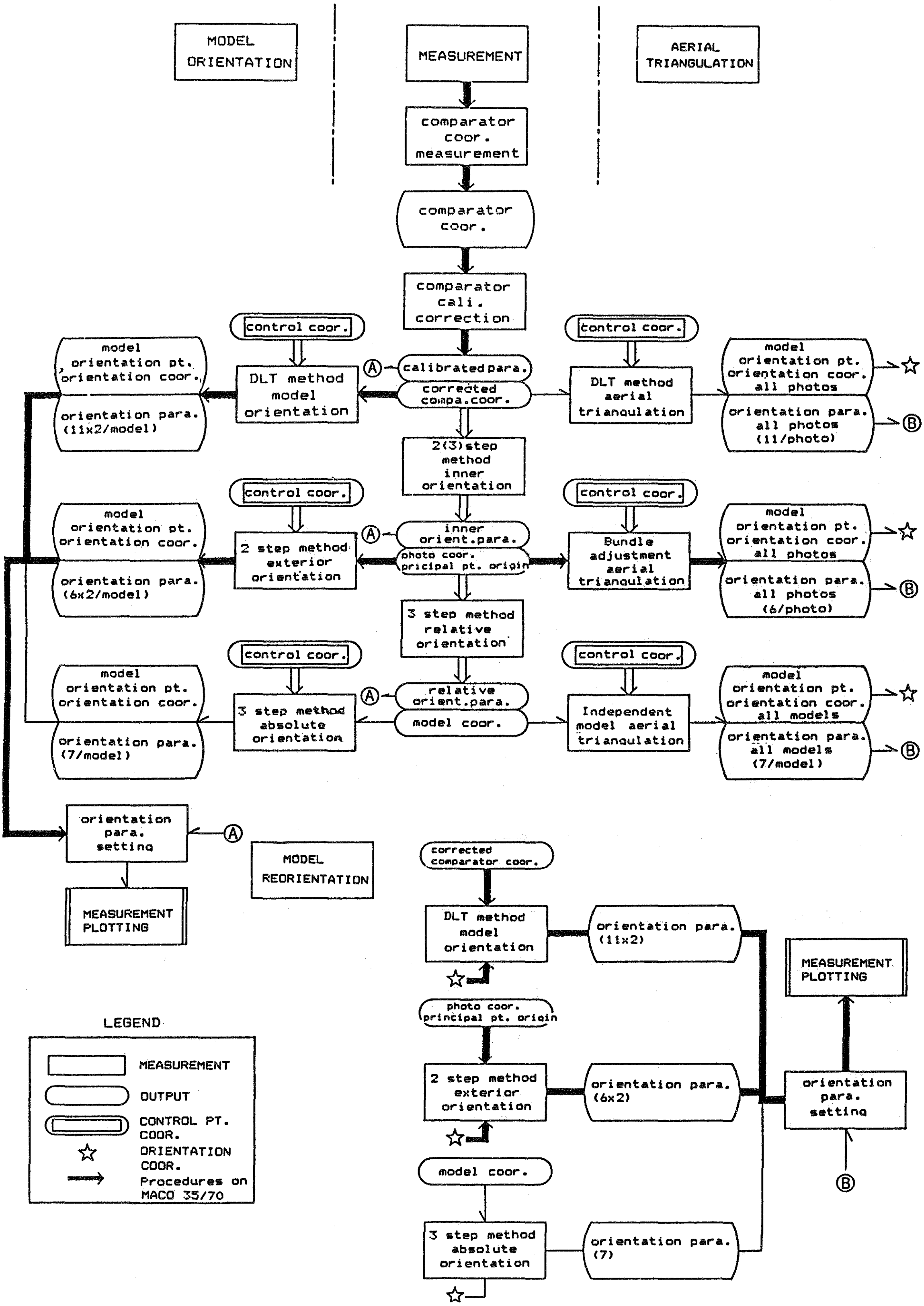


Fig.2 Orientation process

3-3.On the spot aerial trianqulation

For metric cameras,like Bronica SQAM or Hasselblad MK70,MKW, MACO 35/70is equipped with personal computer based bundle adjustment program(NAXIA/PC) for aerial trianqulation.
Up to now,photoqrammetric block with several handreds of photos has been adjusted by large computers in the office.
As compared with other programs, this NAXIA/PC progaram adopts sparse matrix alqorism to matrix calculation of normal equations.
This program has proved the efficiency of computing time even on a 16bit personal computer(5).
Fig.3 shows the flow-chart of NAXIA/PC program.

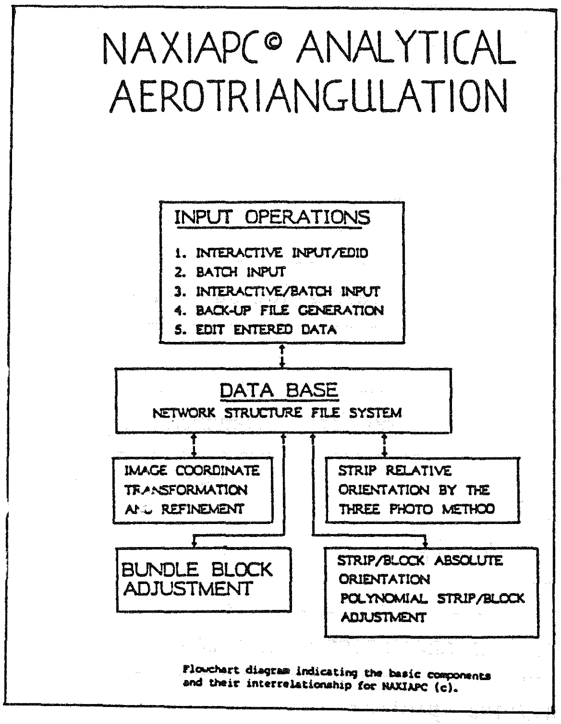


Fig.3 Flow-chart of NAXIA/PC program

3-4.Consistency of compiling,editing and plotting

3-4-1.Selection of personal computer CAD

On a portable analytical plotter,mapped(digitized) data should be displayed on either a computer graphic display or a XY-plotter as a monitoring shape.
We call this step of mapping as a compiling stage in the whole process of digital mapping,Digital Terrain Measuring and Civil engineering design.
For this purpose we investigated a popular and established personal computer CAD system in CG market.
We have selected AutoCAD as favorable for the time being(6).

3-4-2. Data compatibility

Using AutoCAD system, we are constructing compatibility with DXF file of AutoCAD system to other main photogrammetric plotters and CG systems.
Also AutoCAD system has its own wide range of applications in some related fields like civil engineering and architecture.

4. Results

4-1. Provisional automobile method specification

Fig.4 shows our provisional working flow-chart of PADRAS. Recently we have added aerial triangulation program(NAXIA/PC) to the central part of MACO 35/70 analytical plotter.

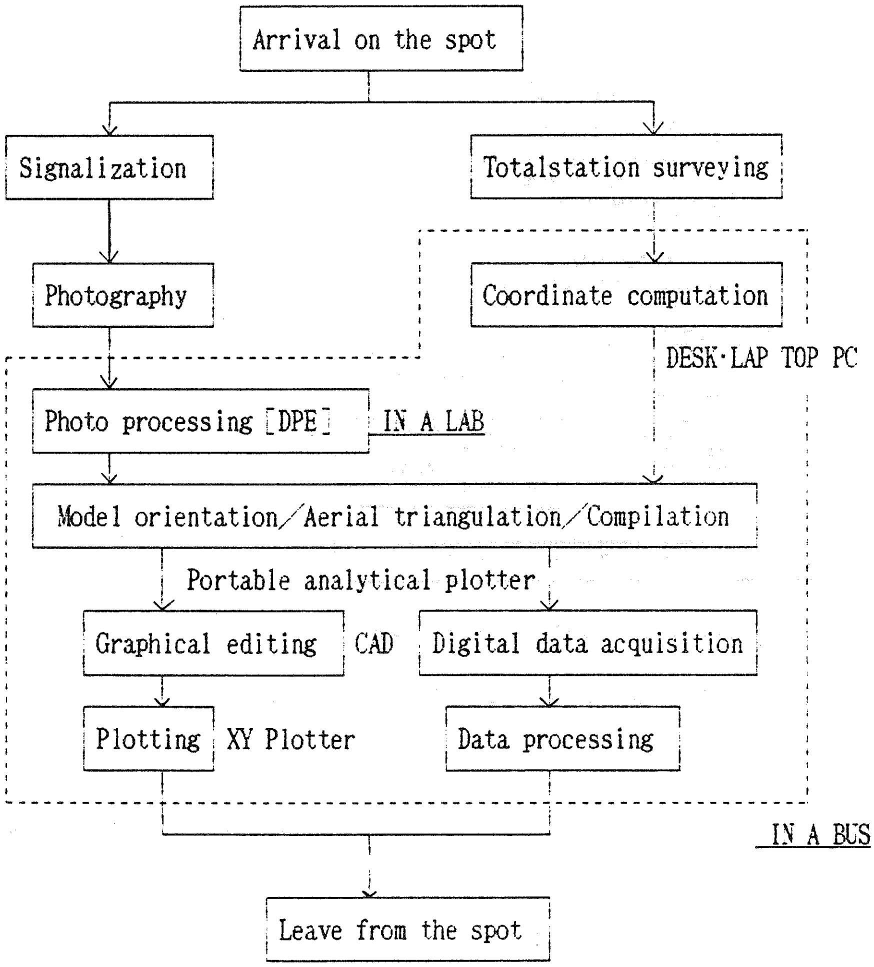


Fig.4 Automobile method flow-chart

4-2.Practicality(Processing speed) of PC- aerial triangulation program

Fig.5 shows processing time(forming and solving reduced normal equation) on our PC(IBM PC/AT) using NAXIA/PC program.

Strips	Photos	Images	Unknowns	Time	Average
3	26	512	738	2^m38^s	6"/ph
4	45	913	1 272	13^m39^s	18"
5	67	1 375	1 872	35^m32^s	31"
5	146	3 190	4 338	1^h57^m	48"
10	213	4 565	6 144	5^h18^m	89"

Fig.5 Processing time on IBM PC/AT

4-3.Results of orientating,compiling,editing and plotting models

Fig.6 shows 2 representative examples of oriented models using MACO 35/70 orientation programs(DLT,inner/exterior).

Photographic condition

camera	HASSELBLAD MK70	distance	1.3~1.8m		
film	KODAK PANATOMIC-X	shutter speed	1/2	F	16
focal distance	64.19mm	control frame	0.5mx0.5mx0.5m		

Orientation accuracy

unit in (m)

Orientation method	DLT		2 step	
Control residual X	σ	0.35mm	σ	0.27mm
	MAX	0.73mm	MAX	-0.58mm
Control residual Y	σ	0.31mm	σ	0.38mm
	MAX	0.71mm	MAX	1.07mm
Control residual Z	σ	0.33mm	σ	2.26mm
	MAX	-0.96mm	MAX	-7.61mm
Analitycal plotter	MACO 35/70		MACO 35/70	
3D control frame was measured by 0.5"theodolite. Each point has an accuracy of 0.1mm.				

Fig.6-1 Orientation results(3D control frame;Tinker-toy model)

Photographic condition

camera	Bronica SQAM	distance	400m		
film	KODAK PLUS-X	shetter speed	1/500	f	5.6
focal dist.	41.52mm	photo scale	1/10,000		

Orientation accuracy

unit in (m)

Orientation method		2 step (25fiducials)	3 step
Cntrols redidual	x	σ 0.145 MAX -0.276	σ 0.31 MAX -0.44
	y	0.122 -0.185	-0.33
	z	0.623 0.859	1.56 -1.64
Check point discrepancy	x	σ 0.168 MAX -0.395	σ 0.42 MAX -0.74
	y	0.225 0.380	0.40 0.72
	z	0.445 0.890	1.11 1.51
Analytical plotter		MACO 35/70	
Controls were measured on 1/2000 aerial photo, triangulated by PAT-M, using DSR-11.			

Fig.6-2 Orientation results(Aerial photogrammetry)

Fig.7 shows oriented photos,compiled,edited and plotted model.(Nippon-maru;Japanese memorial sailing boat)

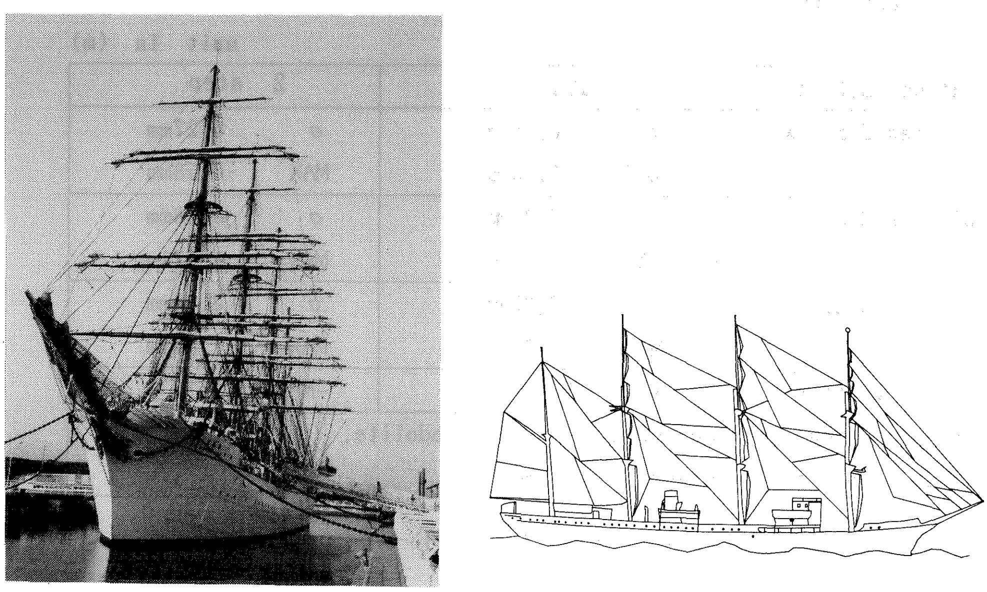
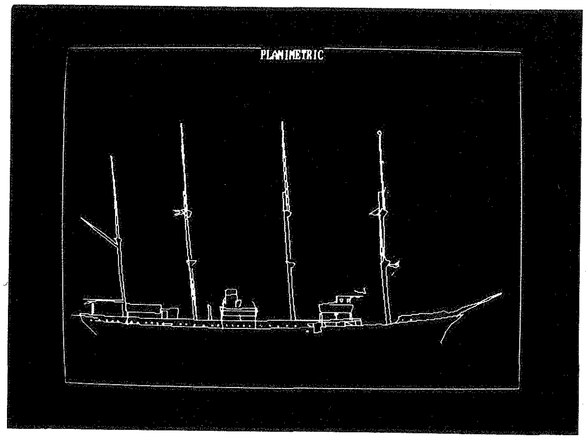


Fig.7-1 Oriented and plotted model(Nippon-maru)



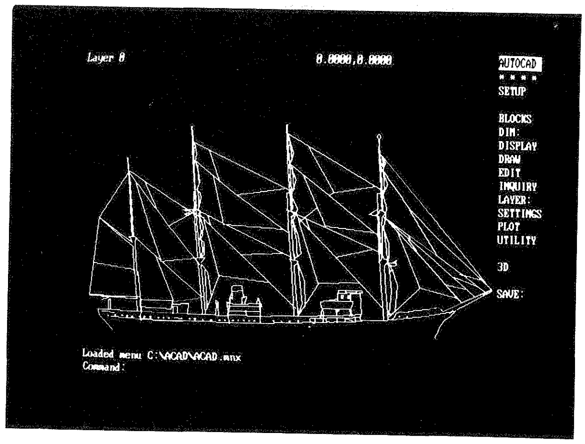


Fig.7-2 Compiled and edited model(Nippon-maru)

5.Verification

We are going to verify the whole developing process from some points of view according to our fundamental criterion, that is to what extent have we reached to our goal in establishing movable mode(automobile method).

5-1.targets of our technical specification

Judging from our provisional specification, we make it a first task to train photogrammetrists or researcher in other fields to manage our total system.

5-2.Practical aerial triangulation on the spot

We need some support from GPS surveying in some overseas area.
We are still suffering from rather long processing time in industrialized countries where we can utilize other large computer based aerial triangulation programs in the office.

5-3.Multi-purpose orientation programs

We are not satisfied with our present orientation programs because of needs for other applied photogrammetry.
We need orientation program for mirror photogrammetry,base-lines orientation and ship-borne analytical plotter measuring marine animals etc.

5-4.Civil engineering design on the spot

For process control in civil engineering works,our system has paths to civil engineering design in some ways or other, based on coordinate geometry and popular personal computer CAD system.

6.Conclusions

We have succeeded to some extent to actualize automobile method in photogrammetry by introducing portable analytical plotter.

6-1.New combinations of automobile measuring system

Consequently,for topographic mapping of wide area,we propose to introduce GPS surveying system plus total station surveying system added to our present PADRAS.
For industrial photogrammetry,we may introduce economical 2D digitizer instead of portable analytical plotter to a certain level of application.

6-2.Video-grammetry vs photogrammetry

Video-grammetry,in other words real time photogrammetry is an ultimate mode of automobile method in photogrammetry and will produce(create) a Video analytical plotter in the near future as the gap in resolution between photo particle and video pixel would be reclaimed.
For the time being our PADRAS will play a roll as a transitional style of real time photogrammetry.

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