GPS - PHOTOGRAMMETRIC - CG PLANE TABLE MAPPING AND CAD GLOBE

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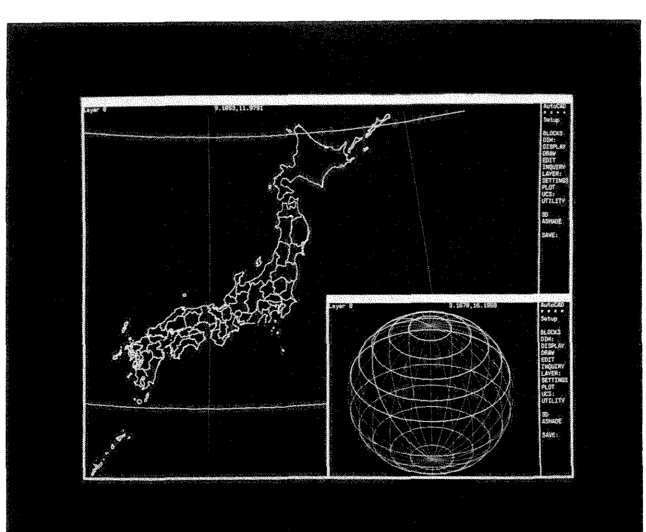
ABSTRACT

In 1990, PASCO and DAT/EM SYSTEMS INTERNATIONAL introduced the MAPCAD system for digital mapping. MAPCAD was originally developed to make Computer Aided Drafting (CAD) digitizers out of photogrammetric stereoplotters. Now the scope of MAPCAD has broadened to utilize surveying instruments as well as stereoplotters.
A variety of three-dimensional (3D) digitizers, including the GPS receiver, the total station surveying system, and the photogrammetric stereoplotter, are combined into the MAPCAD system for a full range of mapping abilities. During surveying, mapping symbols and related graphical features are acquired in the surveying field. Data is collected in real time directly into AutoCAD, a 3D CAD system running on a PC-based computer. The data is displayed graphically, and may be edited or further manipulated on site as well. These innovative components provide us a new surveying process for Digital mapping.

Photogrammetric procedures are the important link between small and large scale mapping. GPS surveying is applied to small scale mapping (1:50,000) in car navigation mode, and has been tested for ground control densification. In addition, the CG plane table surveying system was developed by PASCO and has been used successfully since 1990 for large scale mapping (1:500, 1:250). This ability to use such a wide range of scales in 3D digital mapping has led to new flexibility in globe-map combinations at different scales on the PC display.

Authors propose a new methodological concept, CAD GLOBE, which uses 3D CAD to furnish a full precision 3D coordinate system for visualizing the globe at any scale on a PC display. AutoCAD can also split the display for projected maps related to their global positions. This graphical combination can be linked with 3D Geographic Information Systems, such as GEO/SQL software in order to allow direct querying and graphical presentation of geographic subjects and SQL attributes.

KEYWORDS: MAPCAD, 3D CAD Digitizers, CG Plane Table Surveying System, AutoCAD, CAD Laser Printing, Specification for Digital Mapping, 3D GIS, CAD/SQL Combination



1. Purposes:

Japanese digital mapping specification was established in 1988.

PASCO introduced the DAT/EM 3D-driver of AutoCAD(DAT/EM Mapping System) for the WILD A7 analogue stereoplotter in late 1988.

For digital map productions for Japanese municipalities,PASCO has configured a total digital mapping system - MAPCAD - .

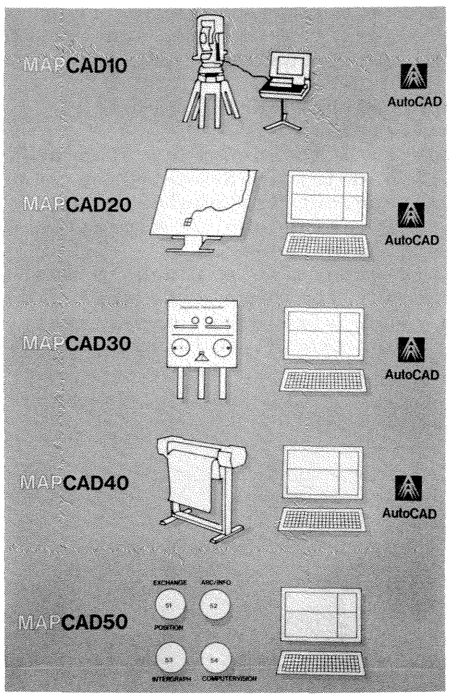


Photo 1.1 MAPCAD subsystems

MAPCAD has 5 subsystems for different procedures as follows:

1) MAPCAD10 ; Total station Surveying
2) MAPCAD20 ; Map Digitizing
3) MAPCAD30 ; Stereoplotter Compilation
4) MAPCAD40 ; Automatic Graphic Output
5) MAPCAD50 ; Compatible File Output

In this paper we will present our plan to make tentative specifications for a new surveying process for digital mapping.

Our major mapping scales are for 1:500 ,1:2,500 and 1:25,000 topographical maps.

We have tried newly developed methods,such as GPS surveying,CAD compilation,CG plane table surveying and CAD Laser Printing.

The purpose of our study is as follows:

1) To configure new mapping procedures compared with current conventional digital mapping process.
2) To present guide lines of the tentative specifications for new digital mapping.
3) To examine key parts of those guide lines in some experimental projects.
4) To introduce new applications of 3D digital maps in the field of civil engineering design with DTM (Digital Terrain Modelling) techniques.
5) To combine the digital mapping process with 3D GIS,using new methodological concept known as CAD-GLOBE .

2. Subjects,Methodology and Substance

2.1 Research of guide lines for tentative specifications in digital mapping

2.1.1 Current standard procedures of digital mapping in Japan

1) Planning and Preparation
From the beginning until the present,the major purpose for digital mapping in Japan has been either digital data reservation for forthcoming urban planning system or automatic drafting output to previously produced by expert draftsmen. This step is now being restructured by 3D GIS systems.

2) Signalization
This step can be done with Ground Control Surveying by well trained surveyors,and may be reduced by GPS Surveying.

3) Aerial Photography
Precise large scale mapping has been modified with a FMC camera,and some simple GPS navigation systems were tested in surveying aircrafts.

4) Ground Control Surveying
Very recently, this step was reviewed and authorized by the governmental organizations,using a total station surveying system.Shortly this step will be changed and regulated by the official manuals for GPS Surveying.

5) Aerial Triangulation
This process was modernized by rigorous solutions in 1985,and restructured with PC programs. This should be modified and rationalized with GPS Surveying and CAD techniques.

6) Field Identification
This most important data acquisition process has been reorganized by new guiding principles.

7) Digital Compilation
There are 2 methods in this process in Japan.The most conventional way looks like analogue plotting on an attached drawing table or simple digital map data capturing contained in a stereomodel. MAPCAD has improved this so called plotting process with 3D CAD (AutoCAD) into compilation and editing procedures.

8) Map Data Editing
This step is done by three diffent methods as follows.
a)Digitizing plotted map
b)Offline Editing of captured map data
c)Refinement of compiled map data
Most of this process will be restructured using 3D CAD/GIS.

9) Supplementary Surveying
Plane table surveying,still in use now, has been a conventional method. PASCO has drastically changed this process by using the CG plane table surveying system which was created and developed in 1990.

10)Final Graphic Editing
This step is the most time consuming process for conventional digital mapping systems because erroneous data handling ,such as free editing without data, is

easily made using those systems,This is because their referential materials are not well applied by 3D CAD.

11)Data File Composition
This step was regarded as the final goal for standard digital mapping projects.The offical standard exchange file format was determined and published by the Japan Geographical Survey Institute in 1988.

12)Automatic Drafting
For the final output of digital products, mapping companies can produce automatically drafted maps using X-Y flatbed plotters utilizing scribing tools, ball point or ink pens.Color electrostatic plotters are used only for intermediate products. CAD laser plotting is the latest method from PASCO in this field.

Ground control Survey (&)

Signalization

Aerial Photography (%%)

Field Survey (%%)

Aerial Triangulation (&)

Photogrammetric Compilation of digital data (###)

Supplementary topographic survey (###)

Supplementary field survey and editing (###)

Compilation of digital data (###)

Editing digital geographic data (%%)

Editing/Updating standard files (%%)

Analyzing and adjusting the results (%%)

Creating administrative data files (%%)

Creating final digital drawings (%%)

Creating structured data files (%%)

Comments ;

: highly improved

%% : partly improved

& : to be modified ,shortly

,compared with conventional digital mapping

Figure 2.1 Current standard procedures in Japanese digital mapping

2.1.2 Remarkable innovations in respective procedures
Throughout the executions of digital mapping projects,PASCO has introduced and created new advanced methods.

1)Planning and Preparation
The most significant change in this step is consideration of the GIS systems and their data utilization of digital mapping. Conventional digital mapping requires only automated drafting of the same graphical standard as in analogue mapping.

2)Ground Control Surveying and Signalization
Judging from the accuracy standard of signalized points,GPS surveying can easily overcome current triangulation and traversing,making use of kinematic and rapid static methods.
For this aspect we planned to test GPS measurements for base line analysis of a medium range size area (approximately 10 x 10 kms) in the Mt.Fuji project which is described later.

Photo 2.1 GPS base line measurement in the Mt.Fuji Project

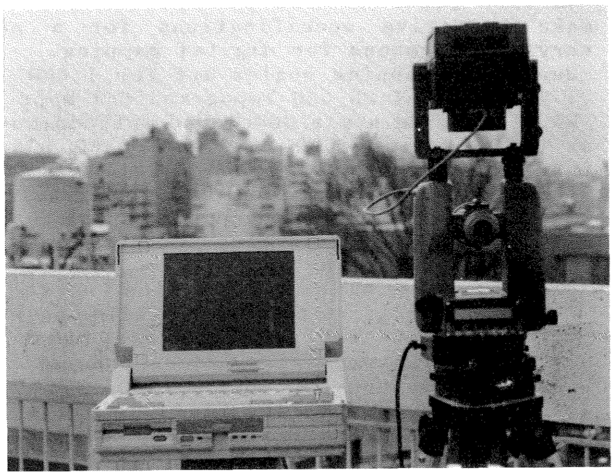


Photo 2.2 CG Plane Table Surveying System

Official Japanese surveying specifications for total station surveying has newly been established in 1992 by the Japan Geographical Survey Institute. This promotes traversing and network adjustments using total station surveying even, when using Notebook type PC's and telecommunications.
In this field we have done the combination of GPS antenna and total station on the basis of CG Plane Table Surveying System (Photo 2.2).

3)Digital Compilation
Different from the ordinary digital mapping systems in Japan, PASCO has been using 3 D CAD(AutoCAD) based digital compilation system for 4 years in production.

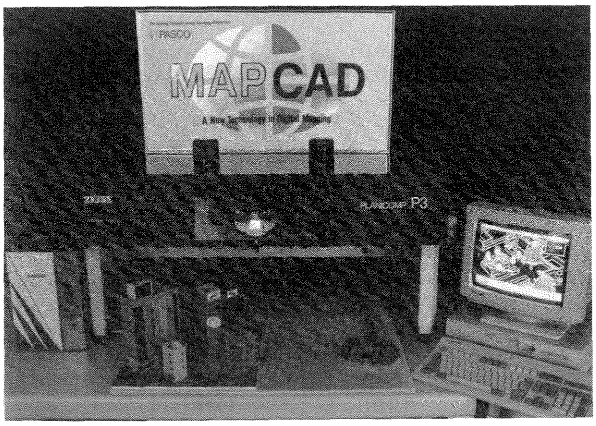


Photo 2.3 CAD based digital compilation

4)Field Supplementary Surveying
This procedure has been completely innovated by so called Computer Graphics Plane Table Surveying system(MAPCAD 11).

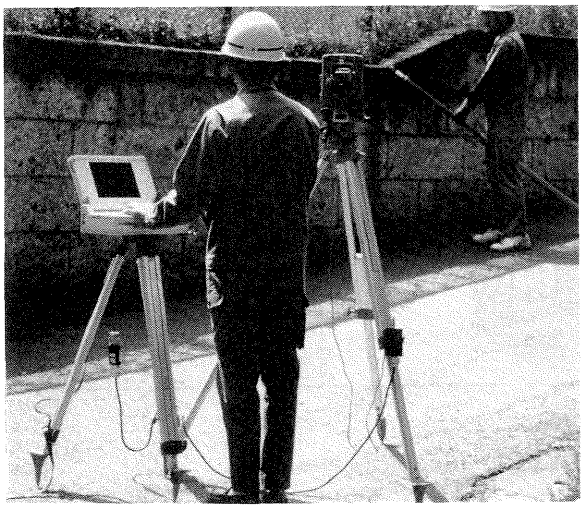


Photo 2.4 Field Supplemantary Surveying using CG Plane Table Surveying system

5)Map Data Editing, Drafting and Printing
Editing stations utilizing AutoCAD are networked to both stereo plotters and output devices.
Editing stations are also combined with GIS systems such as ARC/INFO for polygon formation and topological checking.
Drafting of intermediate graphical output is done on color electro-static plotters for quality control.
Raster - Vector overlays have been realized on the same color electro static plotter for output of GIS products.
Very recently we have succeeded in connecting large size laser plotters with our CAD(AutoCAD) system. Before this change in configuration, automatic scribing system needed 20-30 hours for each of four map printing sheets(base sheets). Even this previous change had shortened drafting time to one tenth required of manual mode. Our new laser plotting system reduced the time for the same process to 1-2 hours from data transfer to final handling, to dry a photo-processed film for printing.

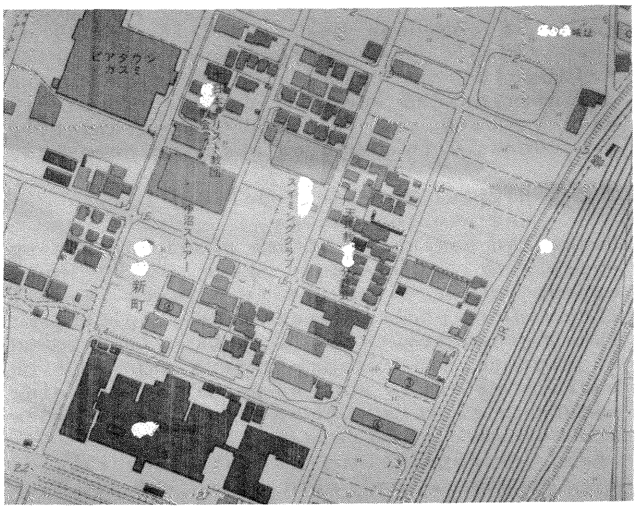


Photo 2.5 CAD based Scribing and Vector/Raster Overlay using color electro static plotter

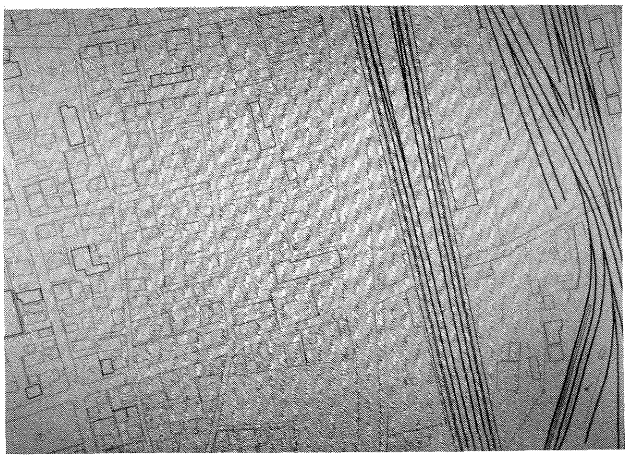


Photo 2.6 CAD based Laser Plotting

2.2 New applications of 3D digital maps

2.2.1 New mapping compilers with DTM(Digital Terrain Modelling)

New mapping compilers should be responsible not only for ordinary digital mapping of general topographical maps but also for specified purpose mapping in different fields.

Graphical features of digital mapping are freely processed within the environment of 3D CAD (AutoCAD) for the following applications.

1) Fundamental planning map or general purpose map
2) Structured data for GIS
3) Overlay or Superimposition of photomap on linemap
4) Basic graphical data for designing in civil and architectural engineering applications.

For most potential applications of digital mapping,we can afford digital data based on digital terrain modelling method,especially triangulated terrain modelling for precise terrain presentation and designing.

Photogrammetrists have played the major roles in analogue map production based on the classic procedures,such as aerial triangulation and photogrammetric orientation and compilation.3D CAD and GIS have reduced and replaced photogrammetric procedures with computer assisted commands.

2.2.2 Digital Terrain Modelling for Engineering Design

Since the beginning of map production using analytical plotters,we have tried many approaches in using DTM techniques in real time mode on photogrammetric stereoplotters.

Photogrammetrists in Japan have been asked to produce the current status maps and 3D terrain models as soon as possible following natural disasters,such as floods,land slides and volcanic eruptions.

Aero triangulations,3D data acquisition with contours and grid measurements were done successfully.However final presentation of the results have not yet been modernized for many years.Recently we combined data acquisition with DTM software on the same PC display in a success project following Mt.Unzen's eruption in 1991.

In this context, all the planimetric features situated in the down stream areas of lava flow were digitized in 3D format in MAPCAD environment.They were then combined with 25-meter contours manually drawn in MAPCAD environment.Lava flow area itself was covered by 50-meter square grid DTM generated from this contours by PC-AutoCAD based GWN-DTM software(Photo 2.3).In this study,we also have developed a MAPCAD/Volume module which has adopted a dedicated conversion approach to compute lava volumes directly from contours.Using the same data set,performance of this module has been evaluated against the conventional procedure of computing with prismoidal formula via TTM as followed by GWN-DTM software .It was found that volumes computed from different approaches were comparable to each other with the difference of only 0.5%.However it was noted that the computation time and required data storage were substantially less in the case of dedicated approach,i.e. in the order of 1:8 and 1:3 respectively for this particular study.

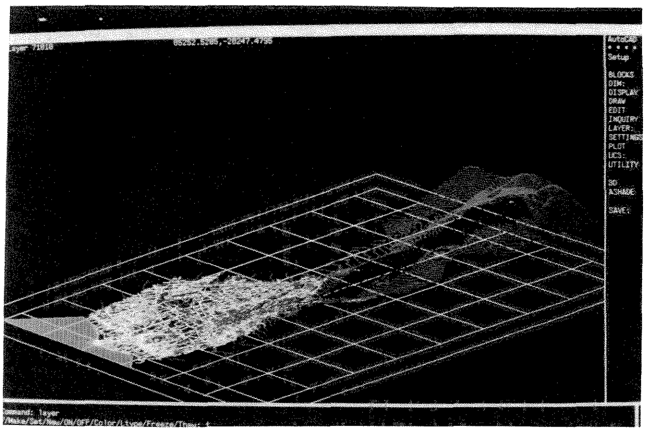


Photo 2.7 Terrain Modelling in Mt.Unzen Case Study

2.3 GPS Surveying,CAD GLOBE and Car navigaton Mapping

For many years we have been investigating the applications of GPS surveying in our digital mapping projects.Based on our experiences with 3D CAD,we have created globe ellipsoids within the AutoCAD environment ,and called this methodological concept CAD GLOBE.As further applications of new digital mapping technology,we are developing a combined system of CAD GLOBE with projected maps on the same display of the CAD system (Figure 2.2).

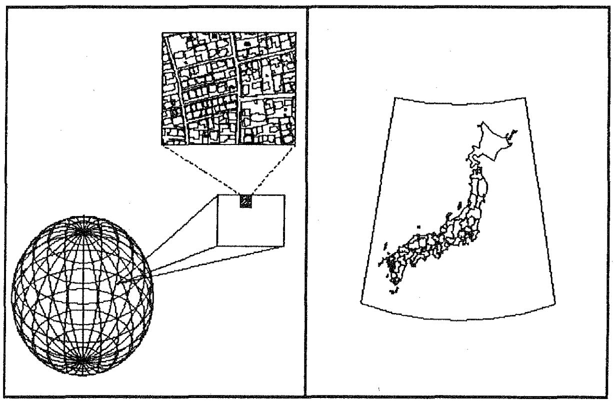


Figure 2.2 CAD GLOBE with Projected map

2.3.1 GPS surveyings in Mt.Fuji Project

This Project was organized by PASCO ,TOPCON,DAT/EM and ASHTECH in 1991.

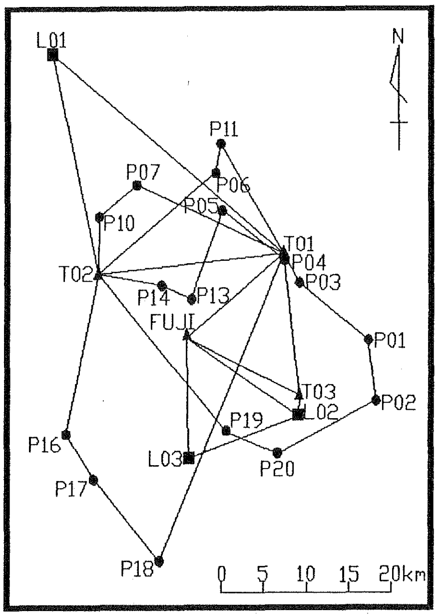


Figure 2.3 Ground Control Network in the Mt.Fuji Project

The purpose of this project were as follows:
1)Initially we intended to obtain precise ground controls for SPOT imagery model orientation in the mountainous districts.
2)Confirmation of medium range distance measurements for mountainous areas
3)Checking our realtime GPS mapping system in car navigation mode.

For this real time GPS mapping system,we combined ASHTECH RANGER receiver with AutoCAD using the DAT/EM 3D driver on a Notebook type PC.(Photo 2.8)

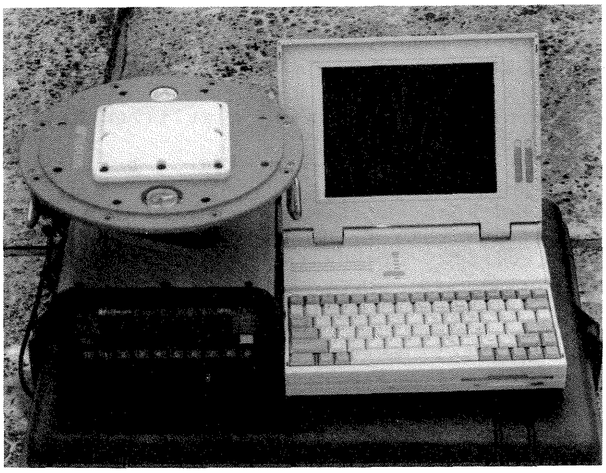


Photo 2.8 Real time GPS mapping system

Before this project J.Yates completed a successful survey expedition to Mt.McKinley,Alaska in 1989, where he measured the summit elevation using GPS.

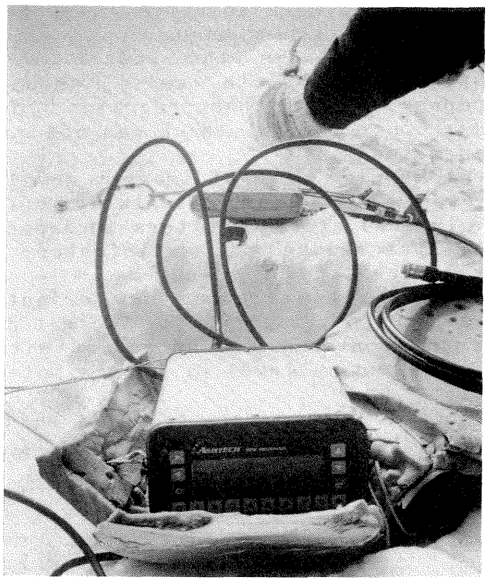


Photo 2.9 GPS surveying at the summit of Mt.Mckinley

Some technical Data in the Mt.Fuji Project are described as follows:

Observation Period:	1991.7.14 ~ 7.25
Participants:	PASCO,TOPCON and DAT/EM
Equipments:	ASHTECH MXII 7 sets
Ground controls:	(H) 3 ;(V) 3
Observed points:	22 points
Base line analysis:	GPPS Software
Network Adjustment:	FILLNET Software

Project area is shown on the figure ( ) with the position of Mt.Fuji.
We used ASHTECH's GPPS software for base line analysis for 5 sessions and confirmed the repeatability of distance measurements in the differential method.
Figure 2.4 shows the results of repeatability of this project.

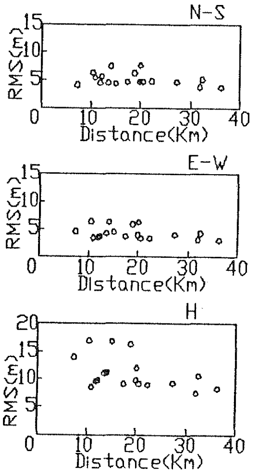


Figure 2.4 Repeatability test in base line measurement

Our base lines were adjusted in 3D network by ASHTECH's Fillnet program

Figure 2.5 shows the result of this adjustment, along with small amount of discrepancies in thecoordinates of the Mt.Fuji Control Point, which was not used in the adjustment.

Digital mapping of SPOT imagery model have been tested by existing orientation software on analytical stereo plotters in Japan, but has not yet reached the satisfactory level for existing mapping standards.

Since we will introduce new orientation method for SPOT imagery, a sufficient number of ground controls are necessary within a certain accuracy level of approximately +- 1 meter.

This accuracy level was tested by base line analysis and 3D adjustment of base lines as described in figure 2.4 and 2.5.

POINT	LAT.(sec.)	LON.(sec.)	ELEV.(m)	STD. ERRORS (m)
L01	35 36 55.80454	138 32 7.87995	257.981	0.046 0.048 0.000
L02	35 16 38.02798	138 52 59.74742	541.624	0.009 0.013 0.000
L03	35 13 51.46541	138 43 30.52623	533.314	0.034 0.036 0.000
P01	35 20 49.85490	138 58 0.24295	411.382	0.030 0.033 0.052
P02	35 17 10.20539	138 58 56.17204	716.582	0.034 0.037 0.052
P03	35 24 17.32186	138 52 43.39717	983.374	0.012 0.016 0.040
P04	35 25 34.02474	138 51 26.73331	984.044	0.009 0.013 0.038
P05	35 29 1.77787	138 46 21.70950	867.617	0.014 0.015 0.038
P06	35 30 35.29684	138 46 8.11622	843.116	0.032 0.034 0.051
P07	35 29 49.04228	138 40 4.00099	901.426	0.018 0.020 0.033
P10	35 27 33.68026	138 36 12.62706	901.777	0.019 0.022 0.035
P11	35 32 18.94003	138 46 34.46194	906.831	0.033 0.035 0.055
P13	35 23 29.25174	138 44 4.76827	2292.328	0.015 0.018 0.030
P14	35 24 11.81569	138 41 49.36370	1738.657	0.012 0.014 0.029
P16	35 14 50.76068	138 34 55.41172	270.108	0.050 0.052 0.075
P17	35 13 3.80332	138 36 30.76616	116.157	0.050 0.051 0.075
P18	35 07 54.94364	138 42 0.51172	6.280	0.058 0.059 0.081
P19	35 15 32.08415	138 46 36.69309	935.270	0.035 0.037 0.047
P20	35 15 8.03296	138 50 45.66833	628.349	0.034 0.036 0.045
T01	35 25 53.32000	138 51 33.75600	1102.364	0.000 0.000 0.038
T02	35 24 43.60200	138 37 5.09900	1029.841	0.000 0.000 0.033
T03	35 17 27.41200	138 53 12.78600	561.409	0.000 0.000 0.014
FUJI	35 21 26.55234	138 43 49.76873	3776.631	0.032 0.033 0.033
	35 21 26.540	138 43 49.772	3775.630	

Figure 2.5 Results of Network Adjustment by Fillnet Program

Judging from this result, ground control for small scale mapping of the scale 1:50,000 can be obtained by this type of GPS surveying.

GPS observations in Car navigation mode were then tested for small scale mapping (1:50,000) in the same area.

Mapping symbols and graphical features are displayed in real time mode by our GPS mapping system, which is not yet named.

Plotted positions are compared with the existing topographical map in 1:25,000 as shown in figure 2.6.

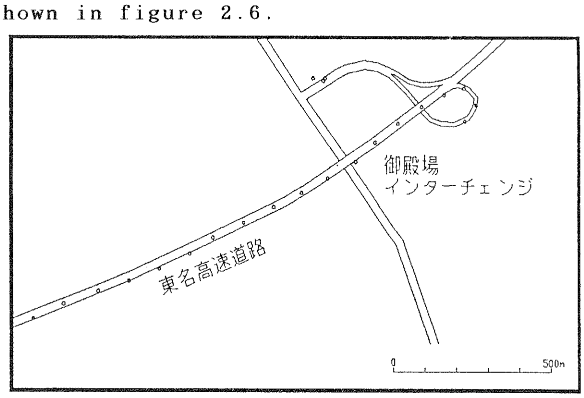


Figure 2.6 GPS Observation in Car navigation

Considering the generalization of existing map, the positions of the antennas are within the tolerance of mapping standard.

For further application of this project, we intend to develop the following functions.

a) 3D GPS Network Adjustment.
b) Graphical display of the results of network adjustment on CAD software.
c) Ground Control Densification or distribution by effective GPS surveying method, such as Rapid Static and Kinematic.

2.3.2 CAD GLOBE and map projections

Starting from 3D CAD presentation and 3D digitizers, we have made a series of experiences towards CAD GLOBE.

The oldest existing terrestrial globe was made by Martin Beheim in Germany in 1492. This image of the globe prevailed in the world and impressed Columbus to find the gold country, ZIPANGU, during that era.

Using 3D CAD we can define the global ellipsoid and introduce a transformation from geographical coordinate system to geocentric coordinate system using direct parameters and graphic language, AutoLISP.

AutoCAD has a powerful support for the computational digits which can display the globe itself with "ZOOM" command immediately at any scale.

We have also applied SQL based RDBMS software in the field of archaeological photogrammetry and mapping.

From these backgrounds we started to construct a 3D graphical presentation - CAD GLOBE - with SQL based Database system.

This configuration presents us with a more advanced GIS system which ensures us direct connection between 3D CAD and SQL Database systems (CAD/SQL Combination).

2.4 3D GIS system based on CAD and SQL (RDBMS) systems

We applied digital map data for 3D digital mapping (AutoCAD) and data retrieval system (R:BASE) separately in the initial stage.

After experimenting with some preliminary systems in indirect mode connections, we selected CAD/SQL Facilities Management systems like GEO/SQL and Spatial Analyst.

These 3D GIS systems are utilized in the following projects.

1) Central governmental buildings' Facilities Management
2) 1/500 Road facilities management mapping
3) 1/2,500 City Planning Mapping
4) University Campus facilities management

These systems have utilized special data bases which are structurally topologic as well as intenally tile-indexed, thus making the digital mapping data suitable for further data analysis.

3. Results of our study

3.1 Guide_lines of tentative specifications for new digital mapping

1) Based on the above-mentioned experiments ,studies and experiences,our working flowchart for new digital mapping procedures shown in figure ( ).

Some procedures are quite different from existing systems for map production in Japan.This process is quite productive, proven in real mapping projects but not well known by majority of photogrammetrists in Japan.Acceptance of this process in digital mapping requires a new educational system for the new type of engineers who are specialized in CAD and in GIS as well.

2) Trials for tentative specifications for new digital mapping in Japan

Industrial background or infrastructure for surveying and mapping industry in Japan has been threatened with the change of paradigm in mapping and map-utilization.

The current surveying regulations were established in 1986 with major changes in photogrammetry,(i.e. aerial triangulation and analytical plotter).Its revival cycle is usually about 10 years.Nevertheless so many changes have taken places in the field of surveying and mapping, technical development requires new standards for production and cost modelling.

3.2 DTM-based digital-map-data utilizations

Throughout our experimental projects of DTM technology, we have proved its efficiency in 3D data terrain modelling as a whole.Attached to this function,we proceeded into civil engineering designs using DTM fundamentals.

3.3 New combined system of CAD GLOBE with projected maps on a CAD display

Many 3D CAD systems enable us to use multiple windows in real time presentation of graphical features both on CAD GLOBE and on projected maps.

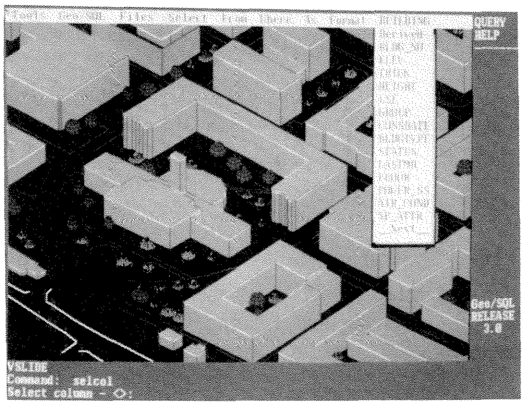


Photo 2.10 University Campus Facilities Mapping (GEO/SQL)

4. Conclusions,Summary and Considerations

Most state-of-the-art technologies related to digital mapping and surveying have changed the standard procedures of map production.

New guide lines for updated specifications can be described with CAD,GPS and GIS based techniques.

DTM techniques would be the foundations of civil engineering design related to topographical aspects.

CAD GLOBE and its projected maps on the same graphical display can be combined with SQL Database systems for GIS and Facilities Management projects.

Acknowledgements

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