TOPOGRAPHIC MAPPING METHOD USING SPOT IMAGERY

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ABSTRACT:

Since the SPOT-1 satellite was launched in 1986 SPOT images have been used for medium scale topographic mapping in various countries both in experimental level and production level. However, traditional photogrammetric techniques are not always applicable for SPOT image mapping, because there exist big differences between aerial photographs and SPOT images. In order to establish practical techniques for topographic mapping using SPOT images it is essential to standardize specification and procedure. In this regard, the Ministry of Construction of Japan and the Instituto Geografico Nacional of Peru have conducted a joint research from 1987 to 1990 aiming to develop and establish practical methods mainly applicable for medium scale mapping in developing countries.

As results of the four year study, draft of "Standard Procedure and Specification of Topographic Mapping using SPOT imagery" and "Manual for SPOT Image Interpretation" were obtained. Those documentations are expected to be used for overseas mapping and technology transfer programs in International Cooperation Aids of Japan.

KEY WORDS: SPOT, Mapping, Specification, Standard Procedure, Interpretation Manual.

1. INTRODUCTION

SPOT HRV sensor was designed to be able to obtain stereo pair images of the earth's surface and expected to be used for photogrammetric mapping. In order to realize stereo plotting of SPOT data, several softwares running on analytical plotters have been developed and introduced on market so far. Moreover, many topographic maps have been produced using SPOT images in many countries both as in experimental work and in practical work. Thus, mapping method using SPOT data is seemed to be established to some extent. However, topographic mapping is very comprehensive technology which is composed not only of stereo plotting but also of photo interpretation, field completion, compilation and reproduction. Therefore, the development of stereo plotting software is only a necessary condition but not a sufficient condition for the development of total method of mapping.

SPOT images are very different from aerial photographs not only in their geometrical property but also in their radiometric property. Observed wave bands are sifted to longer side including near infrared band and excluding blue band. The resolving power of SPOT images is officially stated as 10m for panchromatic mode and 20m for multi-spectral mode, which is getting worse according to weather and atmospheric condition. Those characteristics may affect image interpretation very strongly that there might need additional field completion work and might reduce economical advantage of SPOT image mapping. Therefore, it is indispensable for establishing practical method of topographic mapping using SPOT data, that we have to clarify plotting limitations of SPOT data and to make up new specifications of maps.

From this point of view, the Ministry of Construction and the Instituto Geografico Nacional of Peru have conducted a joint research from 1987 to 1990. The objectives of the research are those as follows.

(1) Development of method to get the best quality images for interpretation.
(2) Accuracy analysis of SPOT image plotting.
(3) Development of practical method to extract image control points.
(4) Analysis for plotting limits of SPOT imagery.
(5) Development of Practical method for field completion survey.
(6) Collecting examples of SPOT image interpretation.

As results of the four year study, the following two documents were formed.

(1) Standard Procedure and Specification of Topographic Mapping using SPOT imagery.
(2) Manual for SPOT Image Interpretation.

2. IMAGE ENHANCEMENT TECHNIQUE

2-1 Study flow

Gray levels of SPOT data are concentrated to lower level and contains detector noises. This make an image very flat and make interpretation difficult. Therefore, in prior of plotting, it is important to improve image quality by stretching image contrast and removing detector noises.

In order to determine appropriate pre-processing to produce good quality film outputs out of SPOT data, several density transformation functions were examined and evaluated.

2-2 Density Transformation Method

The following four types of density transformation functions were examined to SPOT data of Japan and Peru.

(1) Linear contrast stretch function
(2) Multi-zonal linear functions
(3) logarithmic function
(4) Histogram flattening function

Data distribution of Peru scene was rather normal but mostly below level 70. Simple linear function to stretch gray level range to full 256 levels gave very clear image. On the other hand, Japan data was irregular as bimodal distribution. Therefore, single linear function could not correct whole range of data. Different slope linear functions are necessary for each lumps of data. Then, dual linear contrast stretch function was adopted and gave good result.

It is supposed to give good result that original gray level is divided into a few zones according to data histogram and different linear functions are adopted to each zone.

3. PLOTTING ACCURACY

SPOT data is stated to be applicable for 1:50,000 scale topographic mapping. In accordance with the specification adopted in international cooperation project of Japan, planimetric error should not exceed 35m and altimetric error should not exceed 7m in class A mapping of the scale of 1:50,000. Since the pixel size of SPOT data is 10m, 35m planimetric accuracy is seemed to be accomplished in most cases. However, 7m altimetric accuracy might be rather hard to be achieved. Therefore, height measurement accuracy of SPOT stereo pair was examined.

3.1 Examination

Three SPOT images of Mt. Fuji area were used as test images. The specifications of the images are as follows.

Column-Low	329-279
Observed date	Mar. 7, 1986 (Center)
	Mar. 8, 1986 (Left)
	Mar.17, 1986 (Right)
Off nadir angle	4.0 East (Center)
	24.1 West (Left)
	15.7 East (Right)
Mode	Panchromatic
Processed level	1A

SPOT image orientation and measurement was carried out by using PLANICOMP C-100 analytical plotter and the SPOT plotting software "BINGO". 32 GCPs were selected from 1:25,000 scale topographic maps for orientation of images.

At the two test sites of 3km by 3km of flat and mountainous area, DEM of every 100m were measured from oriented images and compared to DEM measured from aerial photographs. Furthermore, contour line of 40m interval was drawn at the scale of 1:50,000 and compared to 1:50,000 topographic map.

3.2 Height measurement accuracy

Orientation accuracy at the 32 GCPs was such that planimetric accuracy is 5m both in Center-Right pair and Left-Right pair, and altimetric accuracy were 5m and 4m in Center-Right and Left-Right respectively. Orientation accuracy is rather constantly good as decreasing number of control points. Required orientation accuracy is seemed to be achieved if there exist some ten control points.

Table 3-1 shows the result of DEM comparison. Root mean square of elevation errors were within 7m tolerance except the case of mountainous area of Center-Right pair, but quite close to 7m tolerance in other cases. From this result, it is hardly to say that 1:50,000 scale maps can constantly be produced out of SPOT images. 1:100,000 scale maps with 40m interval contour lines are supposed to suit to SPOT data mapping.

Table 3-1 Residuals at DEM points

area	pair	B/H	RMS	max.
plain	C-R	0.52	5.5m	-24.7m
plain	L-R	0.72	5.8m	22.4m
mountain	C-R	0.52	9.6m	62.7m
mountain	L-R	0.72	6.9m	31.1m

Figure 3-1 of the next page shows the contour lines drawn from the SPOT stereo pair, while figure 3-2 shows the 1:50,000 scale topographic map of the corresponding area. Through the visual inspection of two figures, it was convinced that principal terrain features as main ridges and valleys were correctly plotted as sufficient for 1:100,000 scale topographic maps.

4. CONTROL POINT EXTRACTION METHOD

In aerial photogrammetric mapping process, anti-photo signals were set at triangulation points before photographing. On the other hand, in the case of SPOT mapping, it is quite difficult to set anti-photo signals in advance of imaging. Therefore, it is necessary to develop practical method to extract ground control points out of given SPOT images.

GCP extraction is quite common technique in remote sensing. However, much higher accuracy of GCP coordinates is required in mapping than in remote sensing image registration.

Ground control points for mapping must have correct geodetic coordinates and should be clearly identified on an image. Since GPS got available, geodetic coordinates can easily be obtained any place in the world. The difficulty is that there can not always exist clearly identifiable and pointable ground object around where we need a GCP. Here, two

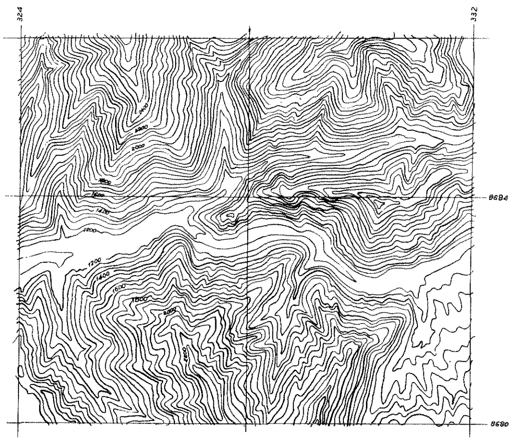

Figure 3-1 Contour lines drawn from SPOT data

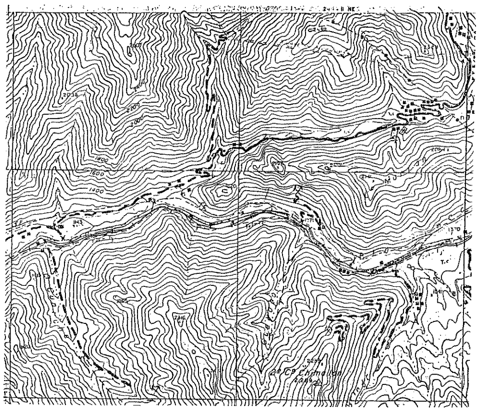

Figure 3-2 1:50,000 topographic map

methods to extract accurate GCPs out of SPOT images were proposed.

4.1 <u>Line matching method</u>

In order to extract a GCP in the area where no clearly pointable object as intersection of roads is exist, we tried to develop method to utilize linear object instead of point object as a GCP, because linear features can be found much easier than point object.

In visual image interpretation, we can identify each linear features as roads, railways or streams by looking their unique patterns as number of curves, curve shapes, etc.. Those patterns tell us line to line correspondence between SPOT image and real ground. However, they can not tell point to point correspondence which is essential for the use as a GCP.

The method proposed here is to get point to point correspondence from line to line correspondence using line matching analysis. The process and algorithm of the line matching method is as follows.

(1) Measurement of a line feature

Characteristic part of a line is to be measured at a set of points both on an image and on the ground as shown in figure 4-1 and 4-2.

(2) Line matching

Two lines are to be matched by introducing two parameters for adjustment of x and y shift.

(3) Adoption as a GCP

The center of the measured points is adopted as a GCP on the ground. And the corresponding image point is to be calculated with the x and y shift obtained by the line matching.

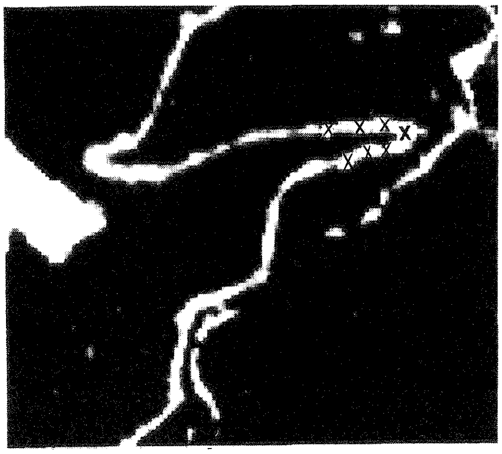

Figure 4-1 Line feature on SPOT image

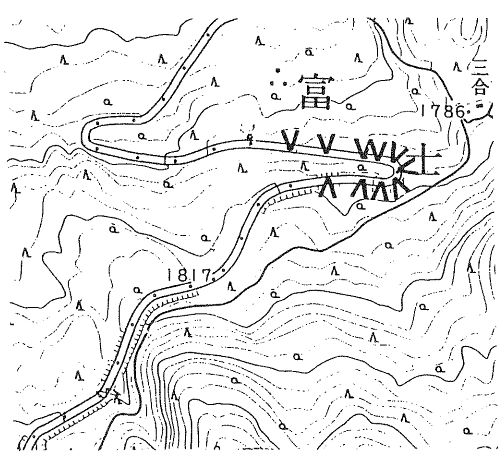

Figure 4-2 Line feature on a map

4.2 Muti-point matching method

In order to extract a GCP in the area where many pointable objects are exist but no single object satisfies necessary accuracy, we tried to develop a method to lift up the accuracy of a GCP by using multiple points and getting an average of them. The process and algorithm of the multi-point matching method are as follows.

(1) Measurement of non-accurate GCPs

Some ten points in a local window are measured both on an image and on the ground, whichever the accuracy of each point is good or not.

(2) Average matching of points

Correspondence between image coordinates and geodetic coordinates is given by least square adjustment using those points in the window.

(3) Screening of points

Among the points in the window, those points which residuals exceed certain tolerance are to be omitted. Then average matching is repeatedly executed excluding the omitted points.

(4) Adoption as a GCP

The center of the points included in the final matching calculation is adopted as a GCP.

5. PLOTTING LIMIT ESTIMATION

The resolving power of panchromatic SPOT image is stated as 10m on the ground, however, it is not exactly mean that every objects larger than 10m can be plotted and those smaller than 10m can not be plotted. Practically, narrow street may sometimes clearly be seen, while large buildings may sometimes be difficult to be identified. Therefore, it was inspected whether ground objects expressed on a topographic maps were able to be identified on SPOT images.

5.1 Study flow

Two SPOT images of Japan and one image of Peru were chosen for the study. 30 sites of 5km by 5km wide were selected as test sites of Japan and four sites of approximately 10km by 10km wide of Peru. In each test sites, ground objects expressed on corresponding topographic maps of 1:25,000 of Japan and 1:50,000 of Peru were examined if they were able to be identified or not. The results were displayed on the corresponding maps. Figure 5-1 and 5-2 show examples of the results.

① : Road ③－⑫ : Buildings
② : Railroad ⑬－⑰ : Petrorium tanks

Figure 5-1 Interpreted objects (Japan)

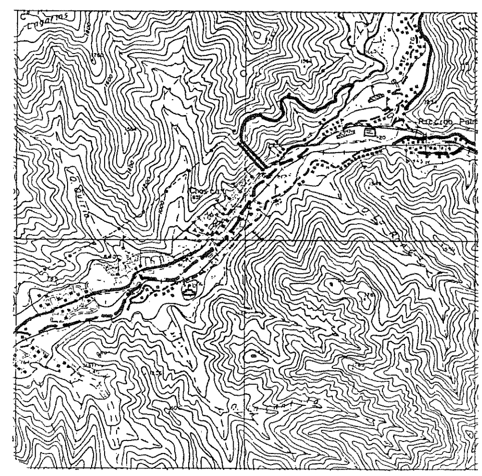

Figure 5-2 Interpreted objects (Peru)

5.2 Plottable objects

(1) Water

Since water absorbs infrared ray, water can clearly be discriminated from others. It is possible to plot even a thin stream or a reservoir except the case that it flows in deep forest.

(2) Road

Wide roads and highways are possible to be plotted except the case it run through densely urbanized area. Plottability depends on gray level contrast against its surroundings. If there exist very little contrast between a road and i'ts neighborhood, it is hard to be plotted even it runs through country side.

(3) Railway

Railway is more difficult to be identified than road, in general.

(4) Buildings

Plottability of buildings depends rather on its contrast than its size. Buildings larger than SPOT image resolution are not always identified, while smaller independent building may sometimes be identified.

6. FIELD COMPLETION SURVEY WITH GPS

Since plottability of SPOT image is rather limitted, field completion survey to compensate SPOT image plotting should be inevitable. However, the more field completion survey is necessary the less economical advantage of SPOT mapping is expected. Therefore, it is necessary to develop practical and economical method for field completion survey.

As for topographic mapping, linear features as principal roads and railways are very important but relatively difficult to be plotted. Therefore, practical field completion survey method for linear features using GPS were studied.

6.1 Concept of field completion with GPS

The basic idea of this method is such that a vehicle equipped with GPS antenna on the roof is driven on a road to be plotted. Road shape is to be plotted from the GPS observed positions.

Independent positioning may show some hundred meter error. However, differential point positioning gives sufficient accuracy for medium scale mapping. Therefore, synchronized observation of a fixed point and a vehicle was executed.

6.2 Experiment and result

GPS equipped vehicle was driven on a highway while another GPS was set on a triangulation point. Three dimensional coordinates were observed and recorded every one second. Then road shape was drawn from observed points and compared with a topographic map.

Figure 6-1 and 6-2 show the GPS observed point tracing and the corresponding map draft plotted from aerial photographs respectively.

The planimetric position well satisfies the specification of medium scale mapping. This method needs very short time for surveying because it is executed just by driving on a target road. Therefore, this method should be able to be used as practical field completion survey compensating SPOT image plotting.

7. MANUAL FOR SPOT IMAGE INTERPRETATION

Image interpretation is very important to make topographic maps using SPOT data. SPOT image appears quite different from aerial photographs. Therefore, new instruction for interpretation suitable for SPOT data should be established.

In order to make use for training of SPOT interpretation technique, SPOT image examples of certain ground objects were collected and compiled as training cards with aerial photos, maps and descriptions of key points for interpretation.

7.1 Interpretation training cards

An interpretation training card was prepared as one card for one item. It is composed of 1:100,000 scale SPOT stereo images of multi-spectral image on the left and panchromatic image on the right, as well as 1:60,000 aerial photo pair, 1:100,000 scale topographic map and comments, key points with ancillary data.

Subject items were selected from the items of the Manual Technico de Conveciones Topograficas which is commonly used in Latin American countries. 32 cards were prepared, in total, in this study.

8. SPOT MAPPING SPECIFICATION

As the result of this study the Standard Procedure and Specification of Topographic Mapping using SPOT imagery was proposed. This specification was compiled as an addition to the Overseas Mapping Specification of Japan International Cooperation Agency for the use of Japanese technology transfer program.

The document is devided into three chapters as follows.

(1) Topographic mapping using satellite data.

This is expected to be applied for 1:100,000 scale topographic mapping or smaller.

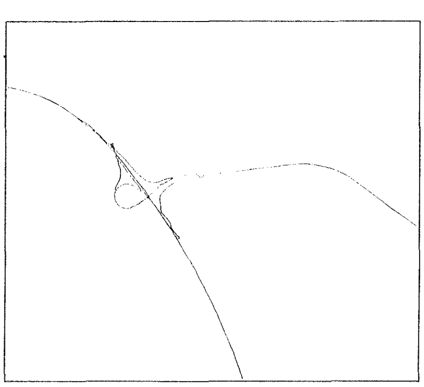

Figure 6-1 Trace of GPS outputs

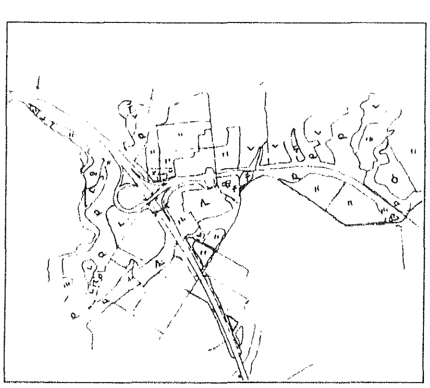

Figure 6-2 Aerial photogrammetric plotting

(2) Supplimental mapping using satellite data.

This is expected to be applied for 1:50,000 scale topographic mapping or smaller executed to suppliment aerial photogrammetry only in the area where aerial photos are not available because of cloud cover, etc..

(3) Photomap making using satellite data.

This is expected to be applied for 1:50,000 scale photomap making or smaller with 40m interval contours or longer.

9. CONCLUSION

Through the four year study, we could be convinced that SPOT data can practically be used for 1:100,000 scale topographic mapping. Moreover, we could establish the practical method of SPOT image mapping. The results are expected to be used for international cooperation programms of Japan.

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