Heighting Accuracy of SPOT

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ABSTRACT: Very few projects attempting to assess the feasibility of using SPOT stereodata as a source of height information have been carried out and few results have been presented. An investigation of SPOT manually captured DEM data were carried out of an area for which an accurate digital elevation matrix with 30-m spacing is available. This paper presents some results from the comparison of these two different sources of height information.

INTRODUCTION

The availability of SPOT data significantly changes the way in which satellite images may be used. SPOT can be used for applications in which only aerial photographs were used previously. The determination of heighting accuracy is very important in applications such as digital elevation model (DEM) measurements for mapping production. Although automated techniques are at an advanced stage of investigation, at the moment manual techniques remain an important production method for capturing the height information for DEM construction.

In this study a systematic error has been found in the SPOT data. An investigation is carried out to determine the reasons and the source of this error, and to find out the possible heighting accuracy levels which can realistically be achieved.

PREVIOUS EXPERIMENTS

A number of tests on the determination of DEM have been reported in the literature. The results from three are summarized here:

EXPERIMENT 1

In the southern Cyprus experiment (Ley, 1988) 14 grid elevation matrices were measured. The sizes were 1 by 1 km for 11 areas and 1 by 2 km for three areas. A SPOT stereopair with 23.8° and 21.1° view angles (*B/H* ratio = 0.96) was set up. Fifteen control points derived from maps were used to set up the SPOT model. The RMS error in orientation was 7.24 m in height, 15.65 m in Easting, and 9.15 m in Northing (planimetric error 18.13 m). From the examination of the mean differences, for each test area, it was found that, between the estimated map heights and the photogrammetrically measured SPOT , significant systematic errors occurred. The measured points were compared with points in the same position derived from the digitization to the 1:50,000-scale maps after a contour interpolation. The overall area average slope is 14.3 percent. The analysis of the errors showed a mean of +10.40 m and standard deviation 14.28 m. The largest mean difference was +22.72 m and the smallest -7.20 m. The largest standard deviation was 29.22 m and the smallest 7.58 m. The project operator was not experienced in photogrammetric observation.

The above experiment gave a strong positive systematic error in the mean. The standard deviation is in line with that predicted by theory.

EXPERIMENT 2

In the Mt. Fuji experiment in Japan, three areas were tested (Fukushima, 1988). The objective of this study was to estimate the accuracies of DEM generated by digital image correlation methods using three SPOT images near Mt. Fuji. The description of the tested areas is as follows:

Test area 1: Mountainous with steep slopes. Some areas were covered with a little snow.

Test area 2: The center of the area is flat and each side of this area is mountainous.

Test area 3: The east part of Mt. Fuji which is covered with coniferous forest. The slope is gradually changing.

The best results on the mean biases were -22 to -24 m and the worst were up to -28 m, depending on the test area and the correlation method. That means there is/are a source(s) that introduced a systematic influence or a systematic error in the measure of the central tendency of "average" in the data.

EXPERIMENT 3

In the Nepal experiment (Grabmaier *et al* , 1988), contours from a 1:100,000-scale map with a contour interval of 100 m were digitized. A SPOT stereopair with -25.1° and 29.3° inclination angles was set up. Contours were also interpolated from the stereo SPOT DEM measurements. A superposition of the two contour maps allowed the comparison of the two presentations. The differences between the two data sets are from a number of causes: the accumulated errors of the map contours; their digitization and the interpolation of grid points from the digitized contours; the orientation of the SPOT stereo scene; the measurements in it; and the interpolation of grid points from the SPOT stereomeasurements. A histogram of these differences shows 48 percent of all 16,895 differences to be between -25 m and +25 m, and 79 percent to be within -50 m and +50 m.

The above experiment gave very low accuracy results due to the errors introduced by the procedure which had been followed.

These studies show that DEMs derived from SPOT data are subject to systematic error and to a wide range of random errors in a way which is not normally expected from aerial photographs. It is clear that terrain and ground control influence the results in a significant way. The use of large data sets derived from aerial photography and from SPOT allow a thorough investigation of these influences to be carried out.

The term digital or grid elevation matrix refers to manual measurements in a normal grid providing "raw" elevation data. That means that the data have not had any interpolation function applied.

TEST DATA

SPOT IMAGERY

The test area to the north of Marseille (Aix En Provence), southern France, is a European photogrammetric test area well mapped and controlled. The stereomodel falls entirely on IGN 1:100,000-scale map sheet 67 (Marseille - Carpentras). The stereopair (scene number 50-252), was provided as part of the SPOT-PEPS campaign. The SPOT images are at level 1A of processing. At this level only detector normalization has occurred, with no geometric correction for earth curvature or view angle effects having been applied.

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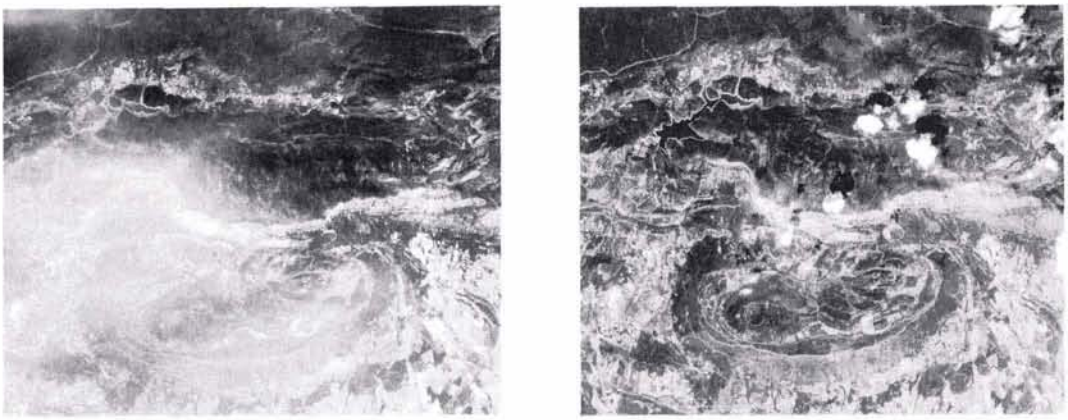

FIG. 1. Extracts from the SPOT scenes used for the test showing the area of the digital elevation model (see Figure 2.). Note the poor quality of the left image due to cloud.

The left image (viewing angle -17.5°) is affected by haze and about one-third of the scene is totally obscured. The right image (viewing angle 22.6°) contains a few small completely opaque clouds. The base/height ratio is 0.84. The images are also affected by horizontal and vertical striping originating in the pushbroom sensor and not correctable by SPOT -Image for these images. The original hard copy was provided by IGN The film quality was not considered to be very good and the images were reprinted from the CCT . The MacDonald Dettwiler Fire 340 at Hunting Surveys & Consultants gave a much superior film image, with radiometric differences at pixel level (Gugan, 1987). The inner orientation residuals after affine transformation were 2 μm in the x direction and 8 μm in the y direction for both images.

Parts of these scenes, showing the location of the 30-m digital elevation matrix derived from aerial photographs, are shown in Figure 1.

The ten control points which were used in order to define the orientations of the sensors were provided by IGN and selected so as to be well distributed over the whole model. The accuracy of those control points is estimated by IGN to be ± 1 m. The exterior orientation RMS vector error on the ground control points was ±8.70 m.

AERIAL PHOTOGRAPHY

Ten aerial photograph models at a scale of 1:30,000 were provided by IGN and were observed in two strips. Some of the control points were provided by IGN . The planimetric accuracy is in the range ±2 m. An aerotriangulation was carried out in order to estimate the rest of the control points to set up the aerial photographs. The overall accuracy (RMS) of the absolute orientation setting up procedure was ±0.71 m in plan and ±0.39 m in height.

A digital elevation matrix with a 30-m grid spacing of the Montagne Sainte Victoire area was manually measured (95,865 points) on a Kern DSR1 analytical plotter. This area (12.42 km by 6.9 km) contains a good range of relief ranging from 191.7 m to 1011.0 m.

The DEM produced from those data is shown in Figure 2. The digital elevation matrix derived from this aerial photography is considered as error free for the purpose of evaluation, for the reasons that

- the scale of the SPOT scenes is 1:400,000 compared with the aerial photography scale of 1:30,000 (much higher resolution); and
- the standard deviation of the aerial photograph measurements was estimated as 1.34 m.

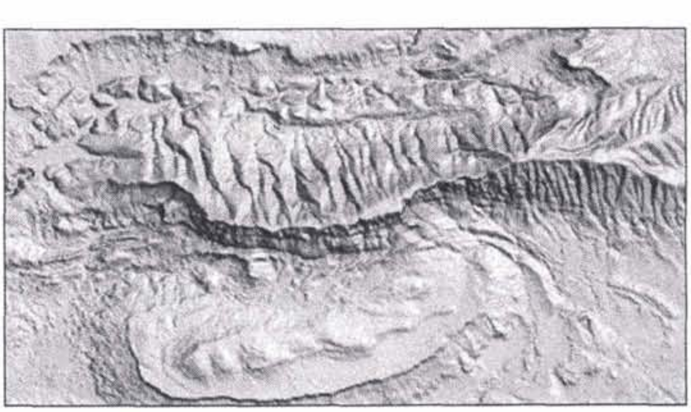

FIG. 2. Lambertian shaded nadir view of the data derived from aerial photography.

The digital elevation matrix, derived from aerial photographs, is unusual in that the operator measured the top of the trees in the forested parts of the area instead of attempting to measure the underlying ground level. This makes data from the two sources directly comparable. Figure 3 shows the relative position of the two sources of grid elevation blocks.

DATA CAPTURE FROM SPOT IMAGES

The Aix En Provence SPOT model was set up on a DSR1 analytical plotter and 16 digital elevation matrix blocks were measured (14,400 points). The SPOT derived spatial data covers a larger area than that derived from aerial photographs. Each SPOT derived block contains 900 points in a normal grid with 100-m grid interval. The data were measured using the same exterior orientation parameters for all blocks. The output from the DSR1 data capture program (Saksono, 1987) is strings of coordinates in UTM projection. The coordinates were transformed from UTM to geographical coordinates (latitude, longitude, height) and then to the French Lambert Conformal Conic map projection system (using the Clarke 1880 ellipsoid).

Due to atmospheric effects, the measuring conditions were not good. The surface illumination is poor. The southern side of the Montagne Sainte Victoire is in sunlight, but the northern part is poorly illuminated (in shadow).

The operator who observed the SPOT model has 5-years experience in plotting maps at large scales, but no previous experience in small scale mapping and SPOT images. It is also four

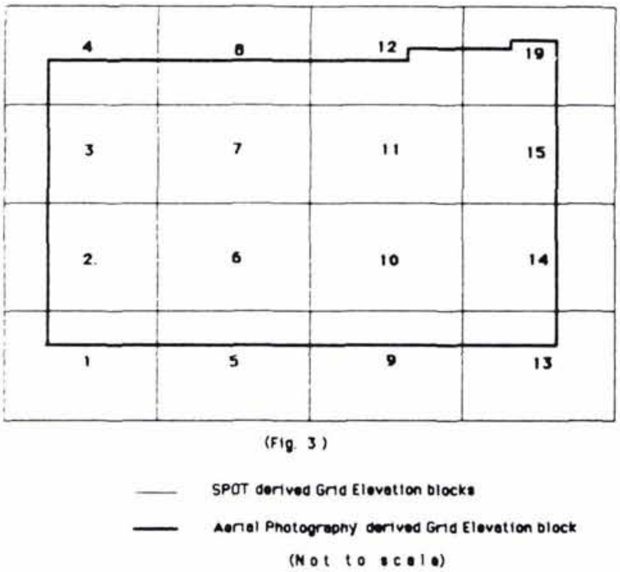

FIG. 3. Diagram shown the elevation blocks from the two sources.

TABLE 1. STATISTICAL ANALYSIS OF THE 1958 DUPLICATED POINTS.

Data Set	Number of Compared Points	Mean (m)	SD (m)	Average Slope (%)
1	709	−2.40	6.78	30
2	709	1.46	10.29	42
3	252	−0.88	11.75	45
4	288	4.22	3.57	10

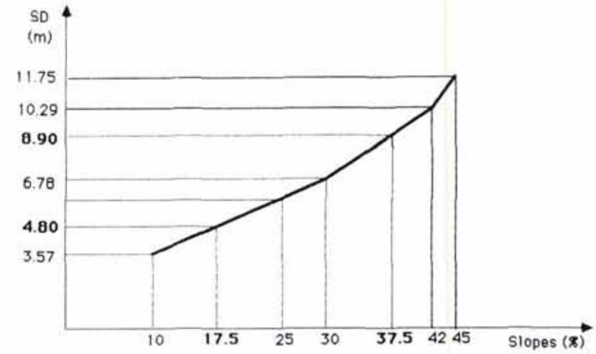

FIG. 4. Changes in standard deviation with slope.

years since he last carried out production work using photogrammetric instruments. The operator who observed the DEM from the aerial photography was very experienced.

During the SPOT data capture procedure, samples from four blocks were remeasured. This reobservation of the same data was carried out to test the observer's ability to consistently measure height at the same planimetric position. From the two measured sets the height differences were estimated. Statistical analysis of the 1,958 duplicated points are given in the Table 1.

If h_i' and h_i'' are two observations of the same point and dh_i is the difference $(h_i' - h_i'')$, then the mean difference (m) is $(\Sigma dh_i / n)$ and the standard deviation is

$$(\Sigma(dh_i - m)^2 / (n - 1))^{1/2}.$$

The overall mean is 0.17 m and the standard deviation 8.64 m. It can be seen that the mean value is not consistent with terrain slope, whereas the standard deviation is.

The project operator measured a number of well defined (clear to observe) points on four different days. The standard deviation of the measurements was found to be 2.55 m.

Figure 4 shows a graph relating the standard deviation to the average slopes.

Terrain type and slope categories (terrain classification) which are used in this work were grouped in four categories shown in the Table 2.

From Figure 4, we can extract the terrain classification corresponding to standard deviation values for the chosen bounds (Table 2). This will be useful for the estimation of height limit (standard deviation of random error) which will have to be applied in additional statistical analysis or in the blunder detection procedure.

The terrain classification and the estimated standard deviation (height limits) are shown in the Table 3.

TABLE 2. TERRAIN CLASSIFICATION.

Terrain Classification	Angle (Degrees)	Slopes (%)
Flat Areas	0-6	0-10
Gently Rolling Areas	6-14	10-25
Semi-Rough Terrain	14-26.5	25-50
Rough and Steep Terrain	above 26.5	above 50

TABLE 3. TERRAIN CLASSIFICATION AND HEIGHT LIMITS.

Terrain Classification	Height Limits (m)
Flat Areas	2.80
Gently Rolling Areas	4.80
Semi-Rough Terrain	8.90
Rough and Steep Terrain	14.00

QUALITY ASSESSMENT

The comparison of the SPOT points with the base data utilizes the nearest reference point, if this exists within a specified distance. The distance is chosen with the criteria of minimizing the additional error due to the variation of the terrain height.

In the following statistical analysis, the slope for the SPOT digital elevation matrix data was estimated as an overall average slope.

The derived statistical results from the compared heights which lie within 15 m of points derived from the aerial photographs are shown in Table 4.

The entire sample yields a mean of 2.94 m, a standard deviation 15.82 m, and an absolute mean of 6.16 m (absolute mean is estimated from the summation of the absolute values of the residuals divided by the number of the observations). It is remarkable that, although some blocks appear to show a strong systematic bias in the mean value, the overall mean of these blocks is 2.94 m which is acceptable.

The line scattering diagram of all the height differences of the compared points is given in Figure 5. The class interval is 4 m. This diagram does not include the points in which the height differences were found to be greater than 2.7 x (standard deviation). It can be seen that the observations follow the normal distribution law.

Blocks numbered 6, 7, and 11, which showed the stronger systematic error and the greater standard deviations, were remeasured again by the experienced operator. These blocks contain the very rough and steep terrain ara of the Montagne Sainte

Victoire; moreover illumination, atmospheric conditions, and problems related to the terrain steepness make the measurements a difficult task.

The same comparison procedure was followed, and statistical results between the project operator and the experienced operator is shown in Table 5.

The standard deviation value is decreased by a substantial amount (better measurements), while it appears that a systematic bias remains in the mean value.

If we substitute the new values recorded by the experienced operator, the overall data statistical values become mean 2.18 m, standard deviation 13.13 m, and absolute mean 5.39 m.

Table 4. Comparison of Elevation Data from Aerial Photography and SPOT.

DEM Block	Number of Compared Points	Mean (m)	RMS (m)	SD (m)	Average Slope (%)
1	183	−3.88	11.21	10.52	26.1
2	514	4.80	16.88	16.18	35.5
3	514	−6.41	15.79	14.43	41.7
4	218	3.55	16.20	15.81	27.3
5	252	−3.81	9.67	8.89	30.3
6	708	4.35	19.44	18.95	43.3
7	708	16.03	28.17	23.16	64.6
8	300	4.56	12.60	11.74	35.4
9	249	−1.35	6.03	5.88	28.5
10	708	−3.53	8.80	8.07	36.4
11	708	11.78	27.53	24.88	66.4
12	301	9.37	17.97	15.34	38.6
13	185	2.97	5.68	4.85	7.6
14	531	−5.99	8.58	6.14	11.9
15	531	0.31	12.94	12.94	58.3
16	223	0.78	10.01	9.98	31.6

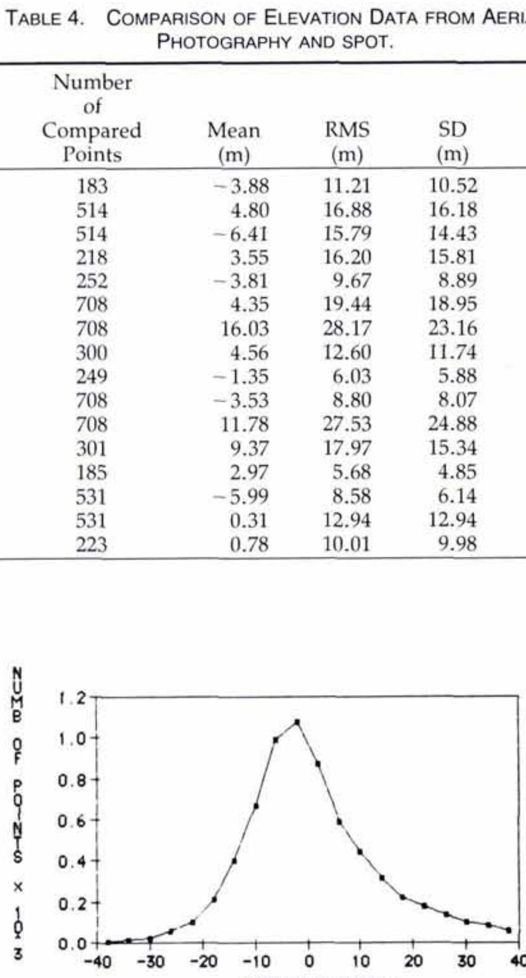

Fig. 5. Distribution of height differences.

Table 5. Comparison of Statistical Results between the Project and the Experienced Operators.

DEM Block	Number of Compared Points	Project Operator		Experienced Oper.	
		Mean (m)	SD (m)	Mean (m)	SD (m)
6	708	4.35	18.95	8.58	12.36
7	708	16.03	23.16	10.08	18.02
11	708	11.78	24.88	6.14	16.83
Overall values	2124	10.72	22.46	8.27	15.92

SPOT HARD COPY MEASUREMENTS ON A SECOND PAIR

An OEEPE experiment on triangulation of SPOT data has been carried out in the Department of Photogrammetry and Surveying of University College London. The chosen test area is the European test site extending from Marseilles to Grenoble. The Aix En Provence area is a part of this European test site. Because of the test, another SPOT hard copy pair is available.

The available hard copy is better quality than that used in the original test. The scenes are clear from atmospheric effects. One scene has some cloudy parts, but these are far from the test area. Details of the second images used are as follows:

Scene	Date	View angle
050-262	28 July 86	20.5°
050-262	30 August 86	−22.3°

Thus, the *B/H* ratio is 0.91.

The SPOT model was set up on a DSR1 analytical plotter. The 15 control points which were used in order to define the orientations of the sensors were provided by IGN and selected so as to be well distributed over the whole model. All the used control points were derived from 1:60,000-scale aerial photography after aerotriangulation. The accuracy of those control points is estimated to be ±4 to ±6 m for the coordinate compultation. The exterior orientation RMS vector error on the ground control points was ±7.80 m.

Six digital elevation matrix blocks were measured (5,400 points) in a normal grid with a 100-m grid interval.

The SPOT elevation data were compared again with the independently measured dense grid elevatoin matrix which was derived from underflight photographs. The statistical results derived from the compared heights are given in Table 6.

Statistical values for the new data sets (six blocks) are mean +3.60 m, standard deviation 12.75 m, and absolute mean 10.00 m, in the area with an average slope of 40.3 percent.

The mean and standard deviation of the height differences for the first and second SPOT stereopair, of the six data sets, are given together in Table 7.

From Table 7 we can see that the changes in the means are not very great. However, there is a similarity between the mean values of the two data sets. If we calculate the correlation coefficient ρ_{12}, which is defined as linear correlation

Table 6. Aerial Photography and Second SPOT Pair Elevation Data Comparison.

Data Set	Number of Compared Points	Mean (m)	SD (m)	Minimum-Maximum Elevation Differences		Average Slope (%)
1	177	−3.76	6.90	−17.84	18.08	26.1
2	640	4.17	10.77	−26.65	58.53	35.5
3	650	4.88	10.67	−37.90	42.62	41.7
5	157	−6.25	7.49	−46.94	11.14	30.3
6	664	0.09	12.22	−95.64	55.98	43.3
7	648	9.75	18.12	−29.86	82.57	64.6

Table 7. Statistical Results from the Two SPOT Stereopairs.

Data Set	First SPOT Stereopair		Second SPOT Stereopair	
	Mean (m)	SD (m)	Mean (m)	SD (m)
1	−3.88	10.52	−3.76	6.90
2	4.80	16.18	4.17	10.77
3	−6.41	14.43	4.88	10.67
5	−3.81	8.89	−6.25	7.49
6	4.35	18.85	0.09	12.22
7	16.03	28.17	9.75	18.12

$\rho_{12} = (\sigma_{12} / \sigma_1 * \sigma_2)$ where σ_{12} is the covariance between the groups mean1 and mean2, σ_1 is the standard deviation of the group mean1 and σ_2 is the standard deviation of the group mean2. The ρ_{12} is calculated to be 0.67.

Because this value lies within the empirical limit $0.35 < |\rho_{12}| < 0.75$ (Nassar, 1985, page 23), we can say that the two different SPOT stereopair derived mean values are positively significantly correlated (Cooper, 1974, page 19).

Comparing the values derived from the six new data sets with the values of the same original six data sets (mean 4.14 m, standard deviation 17.83 m), we can see that the standard deviation value of the new measurements become much better (30 percent better). This happened because the second SPOT image quality is better (no atmospheric effects or strong shadowed parts) than the original one.

MEASURING TIME ASSESSMENT

It is very important to measure the time which is required to complete each procedure because time is related to the cost.

The project operator estimated the time of measuring one block (990 points) as 45 minutes (1 point in 3.0 seconds) in the overall area with an average slope 36.5 percent. The same number of points in the overall area with an average slope 58.1 percent needed 49 minutes (1 point in 3.3 seconds). The time of setting up the model and the preparation is not included.

Ackermann (1978) and Dowman *et al* . (1986) show some figures of scanning a stereomodel from 2.3 sec to 6.1 sec per point.

The time of setting up a SPOT varies from model to model and depends on the number, the quality the distribution of control points, the model geometry in relation to the overlapping area, the distribution of control points, etc. The average time from editing the control points to the final control points arrangement in order to get the best possible exterior orientation results is five to six hours. The time of resetting the SPOT model is about 15 minutes.

DISCUSSION

Sources of error in the height measurement of the SPOT stereoimage have been examined in this project. The results of this analysis mainly concern the first SPOT hard copy pair which was more problematic. The results are as follows:

IMAGE (PHYSICAL) QUALITY

Some parts of the image are not well illuminated because of the sun angle (time that the images are recorded) and the satellite attitude with respect to the sun. SPOT images are convergent images, so the sun angle becomes more critical. This causes problems not only to the shadowed part of the mountains but also is evident along valleys combined with the differences in illumination.

HUMAN OPERATOR ERROR

Operators interpret problematic parts of the model in different ways. From the statistical analysis it was found that the operator had difficulty only in the problematic parts of the model and under certain circumstances. The project operator had difficulties in "finding the ground" in several instances. For example, it was difficult to set the floating mark accurately on surfaces with a very dark appearance, and steep-sided valleys often seen to be almost bottomless. The operator had a tendency to set the floating mark over the ground in gently sloping areas with high vegetation cover and deep shadow, which have a very dark appearance, but also had a tendency to set the floating mark deep in the ground in very steep areas with dense vegetation cover. In the strongly lit and rough areas, the operator had a tendency to set the floating mark deep below the "ground" surface level. This becomes more critical in the measurements of the rough south part of Montagne Sainte Victoire which is over illuminated.

ATMOSPHERIC CONDITIONS

Haze which is particularly in evidence in one image caused problems. The coordinates of the erroneous points and the height difference values of those points are known from the comparison of the two DEMs. The Kern DSR1 has the facility to drive to a point if the coordinates of this point are input from the terminal. After this check it was found that the gross errors occurred in areas that were affected by haze. The project operator tried not to skip any point in the data capturing procedure, but this procedure proved to be unsuitable because the uncertainty in the SPOT observations gave totally wrong height measurements. This procedure was followed in the parts which were covered by clouds (in one scene). In the cloud covered area it is difficult to have a good impression of relief not only for the observing point, but also for areas obscured by cloud shadow on one of the two images.

VEGETATION

Another source of errors is in areas of high vegetation (forests). In the aerial photographs the operator can see the height variation of the trees. In the SPOT images the vegetation gives the impression of a "cloud" covering the area.

RELIEF

Relief is a very important factor in the measurement accuracy. From Table 1 we can see that some blocks contain very rough and steep areas. In the rough and steep parts very bad illumination conditions were found. The southern part of the Montagne Sainte Victoire is over illuminated, while the northern part is badly illuminated with dense vegetation cover. Moreover, a large part of this area is also covered by haze.

MODEL SET UP PROCEDURE AND CONTROL POINT ACCURACY

For the first SPOT model, the exterior orientation RMS vector error on the ground control points was ±8.70 m. The RMS plan accuracy at 20 check points (digitized from 1:25,000-scale IGN French maps with an estimated RMS plan accuracy of ±7 m and a height accuracy of about ±10 m) was found to be ±15.3 m.

For the second SPOT mode, the exterior orientation RMS vector error at the ground control points was ±7.80 m.

Comparing the absolute orientation accuracy of the models with that of IGN and of Simard *et al.* (1987), we can say that the model setting up procedure gave very good results.

MULTIPLE PROJECTION TRANSFORMATIONS

When setting up satellite imagery such as SPOT (a single stereopair or a block of them), a large area of ground is covered. If a map projection system is used, we have to take the effects of Earth curvature caused by flattening (mathematically) of the Earth surface to the map projection. In order to avoid this, a general Earth centered Cartesian coordinate system is used.

The sequence of transformations which are used in the project are

(1) Control point transformation to set up the SPOT model on the analytical plotter - Lambert Zone III to Geographical system and Geographical to Geocentric system.
(2) Output coordinates from the DSR1 analytical plotter - Geocentric to Geographical system and Geographical to Universal Transverse Mercator.
(3) Data manipulation - Universal Transverse Mercator to Geographical and Geographical to Lambert zone III.

Small projection transformation errors were found in the whole procedure (control points, output data from analytical plotter, and data manipulation stage) from testing 20 points. These were

0.02 m in x, 2.48 m in y, and 0.00 m in z. For the project requirements, the results are acceptable. If it is necessary to obtain better results, an iteration should be used in the projection UTM to geographical transformation in order to minimize the approximation errors in the calculation of latitude and longitude.

Regular Grid Planimetric Positioning Error

The accuracy problem of the semi-automatic methods of the DEM capturing programs lies in the ability of the computer to set the floating mark on the precalculated grid node. The most important stage is avoiding the accumulation of error in planimetric positioning of the floating mark. In the data capture program on the DSR1 the coordinates of the grid nodes are computed directly with respect to the starting origin as reference. In a sample of two blocks, the planimetric coordinates were checked with respect to the grid normality and the grid interval. The grid RMS planimetric accuracy was found to be less than 1 m on the ground (for the SPOT model).

Other Factors

There are some other factors which introduce errors and which were not examined in this project:

- Relief induced distortion with the error introduced by the recording device and sensor noise;
- Scale, resolution, and radiometric quality of the image; and
- The base/height ratio.

CONCLUSIONS

These tests show that SPOT has a potential for providing data for topographic mapping. The necessary accuracy for mapping at 1:50,000 scale with 20-m contours is possible and, if the image quality is very good and the ground control is sufficient, 1:25,000-scale plotting is also possible (we do not include DEM interpolation and interpolation contouring errors in this assessment).

It has been shown that when observing a DEM there are significant systematic errors. An analysis of these showed some of the reasons such as the difficulty the operator had in responding to the variable image quality caused by processing, illumination conditions, atmospheric conditions, and relief. The variable systematic errors in the mean values derived from the additional statistical analysis creates the suspicion that another reason is the geometric fidelity of the image.

It may be that automated image correlating techniques would remove some of the problems related to the image printing procedure or some of the intepretation problem caused by manual measurements. Comparison of the data discussed in this paper with that derived from automated matching (Day and Muller, 1988) mean of 10.84 m, standard deviation of 18.19 m) indicates that some problems still remain which are related to the image and to Gruen's adaptive least-squares correlation algorithm (Chau and Otto, 1987).

RECOMMENDATIONS AND FURTHER RESEARCH

A SPOT image covers approximately a 60 by 60 km of the ground surface. The test area represents a small part of a SPOT scene. Thus, a further investigation is required with data samples in different parts of the image or different images with the same or different base/height ratio. The systematic biases of the SPOT measurements need further investigation in order to determine whether this is caused by physical image conditions or is due to errors in the SPOT camera model.

In further mapping projects using SPOT data, it is desirable that attention be paid to the quality aspects of the data and that some form of quality assessment be included in the output.

The particular problems which need investigation are

- quality of hard copy images;
- effect of haze, cloud, sun angle, and vegetation on measurement;
- effect on relief related to the problems above; and
- effect of camera geometry, for example, errors on the principal distance.

Research into these topics should go hand in hand with developments in automatic techniques, and improvements in one method should be used in others.

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Forthcoming Articles

Patrick A. Agbu and *Egide Nizeyimana*, Comparisons between Spectral Mapping Units Derived from SPOT Image Texture and Field Soil Map Units.

Sean C. Ahearn and *Catherine Wee*, Data Space Volumes and Classification Optimization of SPOT and Landsat TM Data.

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