INVESTIGATION OF SPOT IMAGES ACCURACY BY USING SATELLITE EPHEMERIDES DATA

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1. INTRODUCTION

A number of software products have already been developped to evaluate SPOT images for map production. The programs running on today's analytical plotter configurations are the examples of such products. All of these programs require ground control points for processing the SPOT data. The number and the distribution of these ground control points vary depending on the desired accuracy and the software used. In practice, the control points are obtained by digitizing the easily-definable fetures on the existing maps or by photogrammetric methods. In case where there exist no maps or the existing maps are insufficient, then it becomes impossible to use the SPOT images for map production.

Some ephemerides data including the positions of the satellite at defined intervals satellite velocity vector parameters and the look angles of the first and last pixels can be supplied in addition to the SPOT images.

In this study, a software was developped and tested in order to investigate the accuracy which can be obtained by compiling the SPOT images with no ground control points at all.

2. DEFINITIONS AND INPUT DATA

Some definitions and the input data available in the ephemerides data are as follows; /1/

GEOCENTRIC AND LOCAL COORDINATE SYSTEM :

Some of the ephemerides data are referenced to the geocentric coordinate system and some are given in a local coordinate system (Fig.1).

The origin of the geocentric coordinate system is the earth center defined in the GRS 80 reference system, on the other hand the origin of the local coordinate system is the position of the satellite. The axes of these coordinate systems are;

Z_G : North direction

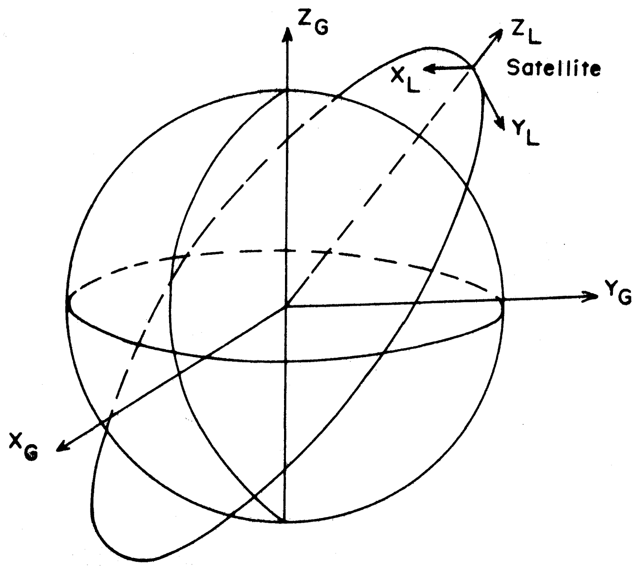
X_G : Perpendicular to Z_G and passes through the zero meridian.

Y_G : Defines the right hand coordinate system.

Z_L : The negative direction of the vector pointing the earth center from the local coordinate system origin.

X_L : Perpendicular to the Z_L and lies on the plane defined by the (Z_L) and the velocitiy vector.

Y_L : Defines the right hand coordinate system.



X_L, Y_L, Z_L = Local Coordinate System

X_G, Y_G, Z_G = Geocentric Coordinate System

Figure 1

LOOK ANGELS : Defines the directions of the first and last pixel of the scan line.These angels are annotated with Ψ_{x_1} , ψ_{y_1} , ψ_{x_2} , Ψ_{y_2} and defined on the (ZX) and (ZY) planes (Fig.2).

The look angels of each pixels are interpolated by using these first and last pixel look angels.

IMAGE PARAMETERS : These are some constant parameters pertaining to the SPOT images. These are;

* The observation time of the image center: This value is given in Julian time as milisecond.

* Image center line number : The SPOT image center line number is 3000.5 in the P-mode.

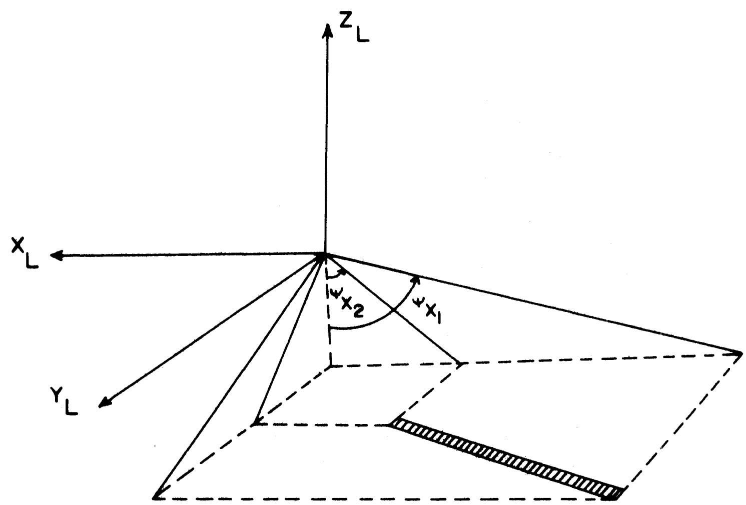


Figure-2

* The scan time of a line : A Line in the SPOT P-mode image is scanned within 1.504 milisecond by the sensor. So, a scene containning 6000 lines is approximately scanned in 9 seconds.

SPOT SATELLITE POSITION DATA : The SPOT position data are given in the geocentric coordinate system for every 60 seconds.

SPOT SATELLITE VELOCITY VECTOR DATA : The SPOT satellite velocity vector data are given in the geocentric coordinate system for every 60 second.

3. MATHEMATICAL MODEL

SPOT images don't have the same characteristics with the aerial photographs in terms of the perspective rules. So, taking a SPOT image as a single photographs and then appliying the space intersection rules is given wrong results. But, each line of a SPOT image is absolutely a perspective image. For these reason, it is sufficient to determine the exterior orientation of each line. The flow chart of the software which is developped by following the above approach is shown on figure 3.

Some important sections on the mathematical model are described in the following section.

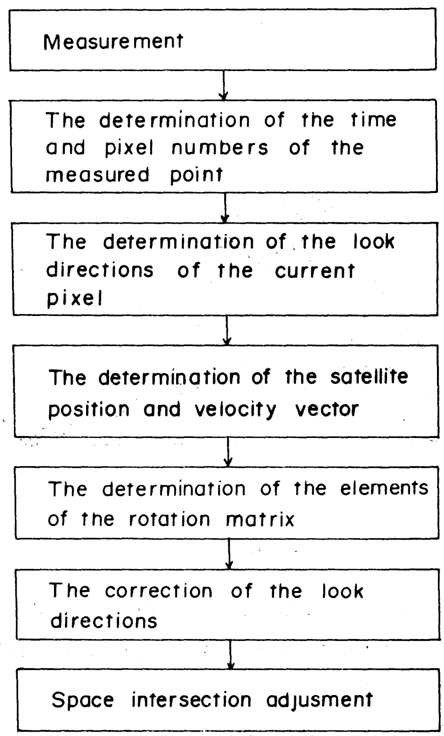


Figure-3

a. Position And Velocity Vector Of The Satellite

It is necessary to determine the position of the related line. This is obtain from the position and the velocity by interpolating the ephemerides data using lagrange polinomial. The value of the known discrette points such as x_o, x_1 , ..., x_n in the unknown f (x) functions are $f_o = f(x_o)$, $f_1 = f(x_1)$, ..., $f_n = f(x_n)$,so, the lagrange polinomial is defined as the following ;

$$F(x) = \sum_{i=o}^{n} L_i(x) . f_i$$

$$L_i(x) = \prod_{\substack{j=o \\ j \neq i}}^{n} \frac{x - x_j}{x_i - x_j}$$

b. Rotation Matrix

The rotation matrix defines the relationship between the local and geocentric coordinate system /2/,
That is;

$$\begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix} \begin{bmatrix} X_L \\ Y_L \\ Z_L \end{bmatrix}$$

The elements of the rotatin matrix,

$$a = 1/\sqrt{X^2 + Y^2 + Z^2}$$

$$m_{13} = X/a$$

$$m_{23} = Y/a$$

$$m_{33} = Z/a$$

$$b = 1/\sqrt{(V_y Z - V_z Z)^2 + (V_z X - V_x Z)^2 + (V_x Y - V_y X)^2}$$

$$m_{11} = (V_y Z - V_z Y)/b$$

$$m_{21} = (V_z X - V_x Z)/b$$

$$m_{31} = (V_x Y - V_y X)/b$$

$$c = 1/\sqrt{(m_{23}m_{31}-m_{33}m_{21})^2 + (m_{33}m_{11}-m_{13}m_{31})^2 + (m_{13}m_{21}-m_{23}m_{11})^2}$$

$$m_{12} = (m_{23}m_{21} - m_{33}m_{21})/c$$

$$m_{22} = (m_{33}m_{11} - m_{13}m_{31})/c$$

$$m_{32} = (m_{13}m_{21} - m_{23}m_{11})/c$$

4. SPACE INTERSECTION ADJUSTMENT

The space intersection is defined as the computation of the coordinates of points by using image coordinates and the exterior orientation paremeters of the two or more images. The fixed parameter model was applied in this implementation. The formulae of the space intersection is given as follows;

$$A = \begin{bmatrix} A_1 \\ A_2 \\ A_3 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \quad B = \begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix}$$

$$V_x = x - f \frac{A_1 B}{A_3 B}$$

$$V_y = y - f \frac{A_2 B}{A_3 B}$$

The coordinates of the points are determined by the intersection of the bundles of the points according to the least square adjustment rules(Fig.4).

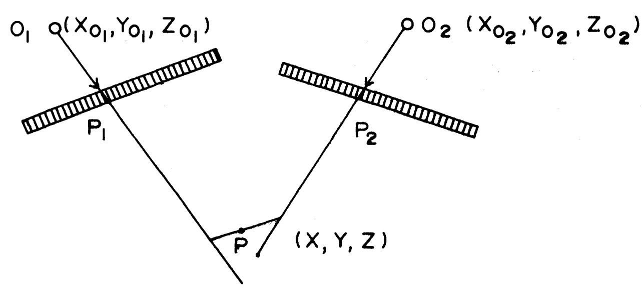


Figure-4

5. IMPLEMENTATION

The measurement of SPOT images was done at the PLANICOMP analytical stereoplotter and the software was developped on the HP 1000 minicomputer with fortran 77 programming language. The developped software has been tested on two different SPOT images. In this implementation the coordinates of the selected points were taken form the existing maps. The ground coordinates of the selected points were determined by using ephemerides data only. The RMS value of the coordinate discrepancies at the end of the abjustment gives the relative accuracy. The RMS gives value of the discrepancies between the adjusted coordinates and their coordinates taken from existing maps are the absolute accuracy. The number of check points for control purposes are 79 and 48 in the first and second trials respectively, The results are listed at the table 1.

Application	The number of Check point	ACCURACY				
		RELATIVE RMS (meter)		ABSOLUTE RMS (meter)		
		X	Y	X	Y	Z
I	79	11	2	226	216	571
II	48	46	22	267	318	661

Table-1

6. CONCLUSIONS

In this study, the compilablity of the SPOT images without any ground control points were analysed. The following results were concluded at the end of the analysis.

a. The absolute accuracy of the test points approximates to $\mp$ 200-300 m in (x); (y) and $\mp$ 500-600 m in the (z) coordinates.

b. On the contrary of this poor absolute accuracy, a better relative accuracy was obtained. The relative accuracy figures obtained are 11 m. (x) and 2 m. (y) in the first trial and 46 m. (x) and 22 m. (y) in the second trial.

ACKNOWLEDGEMENT

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LITERATURE

/1/ : Spot User's Handbook,CNES and SPOT image,1988

/2/ Tateishi, R. Kuronuma, Y. Anzai, F. : Evaluation of SPOT Data for topographic Mapping without GCP. ISPRS Kyoto, 1988 VOL. IV.