GEOMETRIC CORRECTION OF SPOT IMAGE WITH USE OF DEM

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ABSTRACT

This work describes a theoretical and pratical methodology for geometric correction of satellite imagery including effects of relief. The methodology present here is applicable over the unfavourable situations, such as images obtained in lateral view with large inclination angle and pronounced height differences. The images already corrected must be supperposed to a topographic map at the scale of 1:50000 or smaller. The SPOT sensor has been chosen in face of the possibility of lateral views, which emphasizer the relief displacement. The correction process uses ephemeris and attitude data, ground control points, collinearity equations and a digital elevation model. The implementation is done in a microcomputer environment and it uses some functions at the Image Processing System (SITIM) and the Geographic Information System (GIS) developed at the Brazilian Space Research Institute.

KEY WORDS : DEM , Preprocessing , SPOT , Geometric Correction

1 - DESCRIPTION OF THE WORK

The present work describes the problem of geometric correction of satellite imagery in which the effects due to relief damage the image geometry. These effects occur in two cases :

a) images obtained in lateral view

b) images obtained in vertical view (or almost - vertical) in areas with difference relative in level ground above 1000 m . The image will be more affected if the highest parts are situated in the extremes of view.

In these cases, the methods already establishe for geometric correction need to be complemented by the use of a Digital Elevation Model - DEM (Machado e Silva, 1988)

By making use of a DEM to correct a spot image , it is reached , as defined by the SPOTIMAGE , cartographic pre-treatment level 3 , which is described below.

Level 3 - rectification of images obtained in lateral or vertical view in order to allow their superposition to a map or to other images taken by a different angle of view. Displacement due to relief is corrected .Beyond attitudes , ephemeris and control points , the use of a DEM is necessary in correction . The image is rectified in the desired cartography projection and directed north. Localization precision of 50 meters.

The SPOTIMAGE considers as vertical images those obtained with angle of inclination between -4,2 degrees to 4,2 degrees . In these cases , generally, it is not necessary the use of a DEM in the process of geometric correction.

All the process of correction is carried out through microcomputer having as origin a CCT (Compatible Computer Tape) which contains the image to be corrected where the auxiliary data for the construction of the corrected image are extracted from . In the implementation of the software were used various functions developed for the image treatment system - SITIM - and the DEM used was obtained through the geographic information system - SIG . Both softwares were developed by the staff of the Image Processing Department at INPE.

In the process correction the geometric distortions which have as origin the object viewed (rotation , sphericity and ground relief) , the satellite platform , (altitude , velocity and attitudes variation) an the sensor (displacement between bars of detectors in one band , relative disalignment of bars of detectors between bands and panoramic distortion) (Friedman et al ,1983).

A new image whose elements show more precise geometric relations is constructed by preserving as much as possible the radiometric caracteristics of the original image.

2 - PHASES OF GEOMETRIC CORRECTION

The process of geometric correction can be divided into three distinctive phases : direct mapping , inverse mapping and resampling.

2.1 - Direct_mapping

The direct mapping relates points of the raw image (level 1A)with points of the corrected image , This relationship becomes more efficient when the principle of collinearity , widely employed in plotogrammetry , is used . By this principle , the point object , the point image and the perspective center (focus) is situated on the same line.Once the position of these two points is known the third is automatically determined. In the present case, the position of the satellite is the focus image, the detector relative to the imaged part is the point image and the point to be determined over the ground surface is the point object.

The direct mapping is done for a group of points in the raw image regulary spaced . However, their homologs on the corrected image appear with irregular spaces.

For the application of direct mapping , it is necessary to know : the position of the satellite , the direction of the view and the equation of the ground surface.

The position of the satellite is based on the ephemeris, on the acquisition time of a line and the time relative to the central line of the scene.

The view is inicially determined in the system of reference of the instrument HRV with the knowledge of the position of the detector the form of aquisition of the scene (pancromatic or multispectral) and te angle of the take of the view , estabilished by the position of the mirror.

In order to have a reference of the view in the same system of the position of the satellite and the ground ellipsoid ,three matrices or rotation constructed with fixed angles of the sustem HRV, attitude data and ephemeris data

2.2 - Inverse_mapping

After the conclusion of the direct mapping , a regular net of points on the raw image associated with an irregular net of points on a corrected image is obtained. However , what is necessary for the last phase of geometric correction , the resampling , is that the net on the corrected image be regular . The process by which it is possible the regularization of the net of the corrected image is known as inverse mapping and can be carried out through polinomial or projective transformations. In the present case , the polinomial transformation was used.

2.3 - Resampling

The third and last phase of the process of geometric correction is the resampling where for each point of the corrected image must be associated a grey level , to be obtained from the raw image . The determination of the grey level, generally involves an interpolation from the neighbors around the point on the raw image once the result of the inverse mapping not always provides a whole value for coordinates on the original image. Bernstein (1976) presents three methods as the most used which have their precision directly related to the volume of associated calculation : nearest neighbor, bilinear interpolation and cubic convolution.

In resampling for nearest neighbor the level of ash of the point-image is obtained from the four nearest neighbors of the original point-image .

The cubic convolution uses the nearest sixteen neighbors of the original point-image for the determination of the grey level .

It is common yet to combine these methods in search of an otimization between precision and time of processing.

In the present work , this phase was totally carried out through the adaptation of the program of registration of images in the system of treatment of images at INPE which can use any of the three methods.

3 - METHODOLOGY FOR APPLICATION OF A DEM A SPOT IMAGE.

The method for geometric correction with DEM is not separated from the geometric correction shown in the previous item . However, it is adopted that for each point of the net of the raw image P (l,c) , a direct mapping on the elipsoids that pass by the maximun (Hmax) and minimun (Hmin) altitudes of the scene must be done . Thus , with each know of the net the relation will be :

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         Hmax --- Q1 (i,j)
P (l,c)/
       \ Hmin --- Q2 (i,j)
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In the phase of the inverse mapping , the relation for each point of the net of the corrected image Q(i,j) will be :

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         Hmax --- P1 (l,c)
Q (i,j)/
       \ Hmin --- P2 (l,c)
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The correct position of a point of the corrected image Q(i,j) on the raw image P(l,c) is obtained through a linear interpolation in which the altitude (H) of the point Q(i,j), given by a DEM , is considered (1).

$$Q(i,j) \begin{cases} l = \dfrac{l1*(H-Hmin)+l2*(Hmax-H)}{Hmax - Hmin} \\[2ex] c = \dfrac{c1*(H-Hmin)+c2*(Hmax-H)}{Hmax - Hmin} \end{cases} \qquad (1)$$

The altitude (H) of the point Q (i,j) was obtained by connecting the systems of corrected image with the sustem of coodinates of projection through a third direct mapping carried out on the ellipsoid whose parmeters are identical to the ellipsoid of the projection of the topografics map where the DEM was extracted from.

This relationship carried out for a group of points and the use of minimum squares allowed to estabilish the relation (i,j)--)(E,N) where : (E,N) - coordinates of the projection UTM . Through these coordinates it was possible to obtain the value of the altitude (H) of the point from the DEM of the area of interest.

The system of coordinates of corrected image and the sustem of cartografic projection have their parallel axes. In order to connect the system of cartografic projection with the system of coordinates corrected image , the coordinates of the projection of the central knot of the net ,the space resolution and the number of lines and columns of the corrected image should be known.

The precision of the geometric correction will depend on the precision of the DEM , the precision, position and quantity of the control points and on the value of the angle of view.

The parameters of the auxiliary lipsoids that pass by the maximum and minimun altitudes of the scene (Hmax , Hmin) were estabilished by adding the difference between the maximum and minimum altitudes of the scene to the mahor and minor semi-axes and by altering the eccentricity of the ellipsoid of the sustem of projection of the topografic map.

4 - PRATICAL APPICATION

For application of the process of geometric correction with DEM , the pancromatic scene GRS 722 - 396 obtained on june 28 , 1988 in lateral view of 15Ø (17Ø of incidence) with the instrument 2 of the satellite SPOT-1 was selected.

The scene comprises almost all the city of Rio de Janeiro with large areas at sea level (altitude zero) and elevations with maximum altitude of 1122 meters (Tijuca Peak) . The tests were carried out on part of the image due to the processing limitations of the microcomputer.

The control points to refine the ephemeris and the collecting of samples for the generation fo the DEM by SIG/INPE had as a basis topographic maps at the scale of 1/25000 of the area of interest . In the case of the generation of the DEM , the digitalization considered as samples points on isoli and other isolated which were organized for facility of the software .Then , the stage of generation of the DEM net followed in which the selection of an interpolator became necessary . Among the ones available within the SIG/INPE , it was chosen one which adopts for the a;totide pf tje çpomt considered the average of the altitude of the four neighboring points nearest to the point considered giving weight according to the distance by quadrant since the stated interpolator was the only which showed lesser discrepancy between altitudes extracted from the map and from the map and from the DEM for a group of points selected for test

5 - EVALUATION OF GEOMETRIC CORRECTION OF LEVEL 3.

Again, control points were used for the evaluation of the eficiency of the method of correction with DEM (level 3) .In order to make it possible to check the evolution of geometric correction , procedures of correction for levels 2A and 2B were adopted also.

It should be made clear that two groups of control points were used : one to refine the coordinates obtained in the direct mapping and the other for evaluation of the geometric correction.

The evaluation of the precision of the correction process was carried out with the coordinates obtained at the end of the direct mapping. Therefore , the erros due to the inverse mapping and resampling were not included.

The procedure for the evaluation of the correction with DEM is the following :

For each point P(l,c) selected for test ,the direct mapping on elipsoids which passed by maximum and minimum altitudes of the scene was accomplished .
By accomplishing twice the direct mapping to the point on the raw image of coordinate (l,c) of the control point considered . Two groups of coordinates of projection of the point were obtained which were refined by polinomial process of minimum squares for the elimination of the imprecision of the ephemeris .With the coordinate of real projection of the control point extracted from the topografhic map , its altitude (H) of the DEM is obtained.

The final coordinates of projection of the point (l,c) was obtained by adaptation of the formula (1) :

$$P(l,c) \rightarrow Q \begin{cases} E = \dfrac{Emax*(H-Hmin)+Emin*(Hmax-H)}{Hmax-Hmin} \\ N = \dfrac{Nmax*(H-Hmin)+Nmin*(Hmax-H)}{Hmax-Hmin} \end{cases}$$

The error of position in (Ere,Nre) was obtained by direct comparasion between the coordinates of the control point obtained in the process of direct mapping and the respective point coordinates extracted from the topographic map.

$$E_{re} = E_{model} - E_{map}$$

$$N_{re} = N_{model} - N_{map}$$

It was used 10 (ten) control points for the evaluation (table 1) and the results reached for the correction of levels 2A,2B and 3 are shown in table 2

Table 1
Points used in evaluation of results

POINT	LINE	COLUMN	COORDINATES OF THE MAP N	E	H
1	605	566	7468514.2	680414.1	0.0
2	847	5717	7466083.5	680501.7	0.0
3	2298	5024	7458022.9	670790.3	0.0
4	1419	5776	7460379.1	679665.9	683.8
5	1363	5870	7460774.4	680796.5	776.7
6	1359	5878	7460769.8	680871.4	776.3
7	1357	5884	7460804.3	680915.4	759.6
8	1344	5919	7460884.5	681457.2	743.4
9	1330	5936	7460954.9	681546.5	746.7
10	1935	5537	7455748.3	675815.1	845.2

Table 2
Discrepancies between the coordinates of the corrected points and the those of the topographic map

POINT	2A E (m)	2A N (m)	2B E (m)	2B N (m)	3 E (m)	3 N (m)
1	2378.89	2471.49	6.15	-9.44	6.15	-9.44
2	2370.62	2418.50	-23.39	-40.68	-23.39	-40.68
3	2393.97	2398.88	-7.77	3.74	-7.77	3.74
4	2650.88	2393.00	212.32	-16.50	-22.40	30.52
5	2686.08	2375.97	243.47	36.04	24.25	17.55
6	2708.76	2405.24	265.76	-6.93	-1.91	46.65
7	2735.76	2379.41	292.40	-32.78	30.40	19.66
8	2611.03	2363.02	165.62	-49.45	-91.17	1.93
9	2740.87	399.33	295.00	-13.92	36.86	37.72
10	2755.47	2395.04	301.33	23.44	14.26	81.04

The analysis of results in table 2 allows the following conclusions :

a) level 2a showed a residue bigger than that for seen by SPOTIMAGE which is of 1500 m . A probable cause of those discrepancies is the center time of scene, which is recorded on the CCT SPOT , and which is a basic datum for geometric correction . When that time altered , it was proved that the residues dropped right below 1500 m.

b) The points 1,2 and 3 with altitude zero , rapidly converged to a precision below 50 meters on level 2B . The other points , situated on elevated parts of the image , show residue below 50 m . For coordinates N . However , in corroboration to the fact that the displacement of relief act more in the direction of the sweepings , the coordinates and remained with residues above 50 m .

c) On level 3 , the residues remained compatible with the SPOTIMAGE prescriptions except for points 8 and 10 .The probable cause of those discrepancies may have been an incorrect extraction of coordinates of raw image (l,c) of those points .

6 - CONCLUSION

The present work has the purpose to correct a SPOT IMAGE , in which the effects due to relief were quite significant.

All the process of geometric correction was carried out in microcomputer.

The geometric correction with DEM is the highest level of correction that a digital image can receive.Obligatorily , direct mapping must be refined by control points. A corrected image with DEM is equivalent to an ortophoto (ortoimage) , excluding the aspects of space resolution far more significant in the products of air camera.

The geometric correction programs were developed in language C and the resampling made use of adaption of the software registration of images inherent to SITIM/INPE . They can be used in other pre-processings as, for instance :

a) obtainment of level 1B

b) resampling according to epipolar lines of image sterescopic pairs,intermediate phase for obtainment of level 4.

It can also be used in other sensors after altering the direct mapping , adapting it to angles of the new system.

From the phases of geometric correction , direct mapping ,inverse mapping and resampling, the last one causes worry as to the correction operationality in microcomputer . The complete resampling of a pancromatic image spot lasts approximately 19 hours . Whith the new microprocessors or with an " array processor " , this time can be greatly reduced.

Another aspect to be emplhasized is the DEM . The generation of DEM for an area of 12 x 12 km consumed 115 kytes for the samples and 45 kbytes for the net. A complete scene must occupy about 10 mb of a rigid disc space for the samples and 3 mb for the net. The generation of a DEM , from topographic map level curves , occupies a great deal of time in terms of digitalization and processing . The alternative for the digitalization of altitude samples on level curves is the dat collecting through automatized processes.

It was also clear to the author that the digitalization is not restricted to a mere act of extracting points over level curves and isolated points.

The relief needs to be studied so that significant points can be added . It is also necessary that the operator have a quite clear notion of how the interpolator operates so that, in a more rational digitalization, a more precise DEM can be produced .

During the process of geometric correction the author produced images on level 2A and 2B since the modeling for these levels is an intermediate part of the equating for level 3.

The fact that the necessary data for geometric correction appear in the heading of a CCT bring about researches on geometric correction at other teaching institutions .

Finally , as a more expressive result of the present work is the confirmation that methodology tested to correct a displacement image due to relief is efficient for SPOT images.

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