Correction and Positioning of Remote Sensing Image Base on Orbit Parameter

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Abstract: The usual technique of correction and positioning of film image of RS require enough control points to provide the geographic coordinate. Some distortion and error caused by earth curvature and terrain and photograph tilt can't be eliminated by these ways. In this paper a set of technique of systemic correction and positioning of remote sensing image base on orbit parameter is described, some questions in its realization and their solvent also included.

Keywords: remote sensing image, orbit parameter, correction.

1. Introduction

Correction and positioning of remote sensing is an important part of earth observation.It can be done to reduce the distortion and error, and to gain the geographic coordinate of the object in the image. Owing to the development of the spatial orientation technique, we can get more and more accurate satellite ephemeris data, and the technique of the correction and positioning of remote sensing does not depend on the control points only any more. So how to utilize these information to build the model of orbit parameter and realize the image positioning using physical & geometrical model of the image and the imaging relation is important.

2.Correction And Positioning

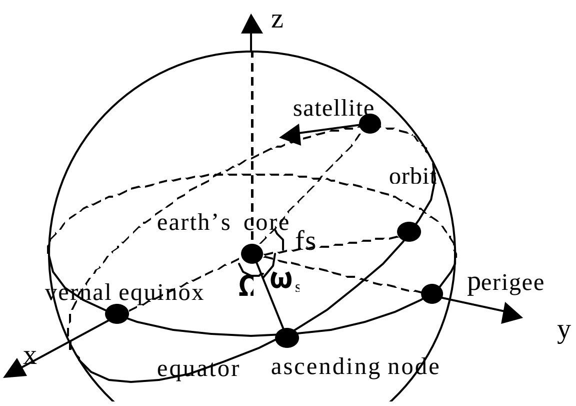

Fig.1. orbit parameters of the satellite, XYZ:coordinates of confer celestial sphere[1]

Orbit parameters of the satellite include the following parameters, longitude of ascending node (Ω), orbit obliquity (i),longer radius of the satellite orbit (a), eccentricity (e), argument of perigee (ω) and the true anomaly (fs). After getting the outer azimuth elements, systemic correction can be done with the orbit parameters of the satellite[1]. The process of the correction & positioning of film-style remote sensing image basing on the orbit parameters is as following: image scanning and interior orientation→coordinate of the film→ coordinate of the photography system on the ground→a series of transitional geocentric coordinates → Confer Geocentric Coordinates →rectangular coordinates or geodetic coordinates of reference ellipsoid→coordinate of Gauss-Kruger Projection system, Then follow the counter-process, we can resample the original image with the indirect method.

1) Interior Orientation

The aim of the interior orientation is to ascertain the relation of the coordinate of scan digital system and of the film image system, and also to find out the possible distortion of the digital image. The relation of scan coordinate system and film coordinate system can be denoted by the following formula.

$$\left.\begin{aligned} x &= m_0 + m_1 I + m_2 I \\ y &= n_0 + n_1 I + n_2 J \end{aligned}\right\} \qquad (1)$$

So the essence of the interior orientation is to calculate the follow six parameters, i.e. m_0, m_1, m_2 and n_0, n_1, n_2 . To calculate the above six parameters we must survey the scan coordinate and the film coordinate of the frame-marks .

2) Image Coordinate → Rectangular Coordinates of Reference Ellipsoid

After been scanned and interior oriented, the coordinate of the image can been transformed by the follow model.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = (1+m)R(w)(R_1(\Omega - \boldsymbol{a}_G, i, \boldsymbol{w})R_2(0,0,fs)(\boldsymbol{l}(\begin{bmatrix} X_0 \\ Y_0 \\ Z_0 \end{bmatrix} + A(BC\begin{bmatrix} x \\ y \\ -f \end{bmatrix} + \begin{bmatrix} \Delta X' \\ \Delta Y' \\ \Delta Z' \end{bmatrix})) + \begin{bmatrix} 0 \\ 0 \\ r_s \end{bmatrix})) + \begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} \qquad (2)$$

where x0,y0 =film image coordinates; X,Y,Z = coordinates of rectangular coordinates of reference ellipsoid; C = rotation matrix of the pose angle; B = rotation matrix of the pose angle from frame coordinates to the flat coordinates; A = rotation matrix of pose angle from flat coordinates to ground coordinates; X, Y, Z = offsets of the origin of the frame coordinates in the flat coordinates; Xo,Yo,Zo = offset of the origin of the plat coordinates in the ground coordinates; f = the photogrammetric focal length; rs = distance from earth's core to the satellite; R1,R2 = are both matrices; ë = the gene of scale; αG = the angle from vernal equinox to Greenwich zero meridian; ÄX,ÄY,ÄZ = the offset between Confer Geocentric Coordinates and coordinates of reference ellipsoid, R(w) = matrix for translating them; m = scale coefficient for coordinates of reference ellipsoid and Confer Geographic coordinates; fs,I,ω,Ω = parameters of the orbit(see fig.1).

Eq.(1) figures the following flow, film coordinates→ sensor coordinates→ frame coordinates→ flat coordinates→ ground photogrammetic coordinates→a series of transition geocentric coordinates→ geocentric coordinates→ coordinates of reference ellipsoid.

To simplify the numeration,we can enact one point as the origin of coordinates. The point is the intersection of the line from the earth's core to the satellite with the ellipsoid. And the Z axial points to the satellite, X axial parallels to the direction of the flight and vertical to Z axial, Y axial points to the lateral. (see fig.2)To calculate the distance from the earth's core to the surface, the geocentric latitude of satellite is required. It can be calculated with the orbit parameters, i and ù.

$$\Phi = \arcsin(\sin(i) * \sin(w_s)) \quad (3)[4]$$

The distance from the earth's core to the surface of ellipsoid is,

$$OA = \sqrt{\frac{a^2 b^2}{b^2\cos^2\Phi + a^2\sin^2\Phi}} \quad (4)$$

The distance from the earth's core to the satellite is,

$$OC = eb^2 \Big/ \sqrt{a^2 - b^2(1 + e * \cos(fs))} \quad (5)[4]$$

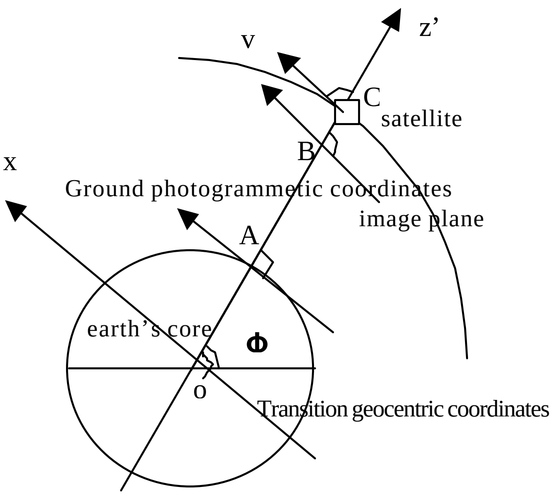

Fig. 2. relation among satellite,image plane,ground photogrammetic system, assistant coordinatesX' Y' Z'

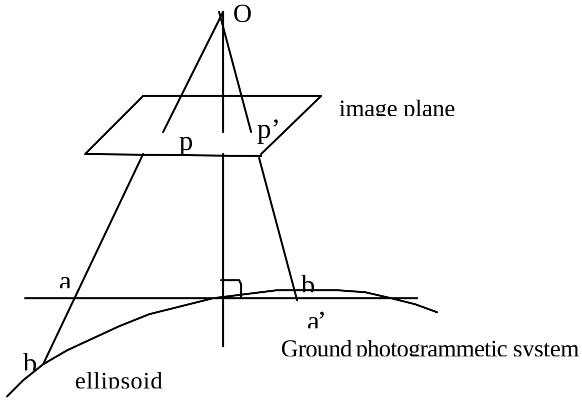

Fig.3. influence of the earth curvature

In Eq.(2), firstly the film coordinate is transformed to the ground photogrammetric system using the coordinate transformation function and collinear equation , and then move the origin of coordinates of the photogrammetric system to the earth's core, so it is the transition geocentric coordinates, You can get more information in fig.2. Following a series of transformation of the transition coordinates, At last transform the coordinates to rectangular coordinates of reference ellipsoid.

In the fig.2, the transition geocentric coordinates is X'Y'Z' system. It's origin is at the earth's core, the Z' axial points to the location of the satellite, X' axial is right to Z' axial and parallel to the direction of the flight of the satellite. Y' axial points to the lateral. This coordinate system is right-hand system.

In order to get confer rectangular geocentric is as following: First turn around the Y' axial (*ws+fs*) widdershins and make the Z' axial points to the ascending node, second turn around the new Z' axial (*i*) widdershins get a new Y' axial. Then turn around the new Y' axial (*áG*) widdershins, lastly interchange the X'Y'Z' and get the agreement geocentric coordinates of agreement. In order to get rectangular coordinates of reference ellipsoid, we can only translate the agreement geocentric coordinates of agreement with Bursa-Wolf formula.

3) Rectangular Coordinates of Reference Ellipsoid→ Geodetic Coordinates of the Reference Ellipsoid

After being converting to the rectangular coordinates, the corresponding points on the ground of the image points can be transformed to the geodetic coordinates of the reference ellipsoid using the following model.

$$\begin{cases} L = arctg\,\dfrac{Y}{X} \\ B = arctg\left[\dfrac{Z}{NX^2 + Y^2}\left(1 - \dfrac{e^2 N}{(N+H)}\right)^{-1}\right] \\ H = \dfrac{\sqrt{X^2+Y^2}}{\cos B} - N \end{cases} \quad (6)[4]$$

In Eq.(6), (X,Y,Z) is the rectangular coordinates, *L,B,H* is the longitude, the latitude and the geographic high, *N* is radius of the ellipsoid.

4) Rectangular Coordinates of the Reference Ellipsoid→ Plane Projective Coordinates

The ground points of the geodetic coordinates can be converted to the Gauss plane coordinates

$$\begin{cases} Y = S_m + \frac{N}{2} \boldsymbol{l}^2 \sin \boldsymbol{j} \cos \boldsymbol{j} \\ + \frac{N}{24} \boldsymbol{l}^2 \sin \boldsymbol{j} \cos^3 \boldsymbol{j} (5 - tg^2 \boldsymbol{j} + 9\boldsymbol{h}^2 + 4\boldsymbol{h}^4) + \ldots \\ X = N \boldsymbol{l} \cos \boldsymbol{j} + \frac{N}{6} \boldsymbol{l}^3 \cos^3 \boldsymbol{j} (1 - tg^2 \boldsymbol{j} + \boldsymbol{h}^2) \\ + \frac{N}{120} \boldsymbol{l}^5 \cos^5 \boldsymbol{j} (5 - 18 tg^2 \boldsymbol{j} \\ + tg^4 \boldsymbol{j} + 14\boldsymbol{h}^2 - 58\boldsymbol{h}^2 tg^2 \boldsymbol{j}) + \ldots \end{cases} \quad (7)\ [4]$$

λ, longitude (radian), j ,latitude (radian), S_m ,the length of the longitude from the equator to the corresponding latitude, **η** is the auxiliary function, x, y is the coordinate on map being corrected, the formula is the Guass-Kruger projection formula.

5) Correction of the Image

According to the flow above all,we can convert the coordinate to the Gauss-Kruger projective plane, Because of the large data amount and the complicated calculation while convert the image coordinate to the Gauss-Kruger projection system, the correction of large image will cost too much time. To saving time and ensured the necessary precision, we correct it by region, and resample it by indirect method.

The range of the image can be obtained from its four corner coordinates, and then detached it into small rectangular regions. By the contrary flow of the system correction, the four corner coordinates of each small region can be calculated to get the coefficients of the polynome which are used in indirect resampling.

Correct each region by the polynomial method and resample them. If only the region is small enough the correction precision is good enough. The polynome for transformation is as follow:

$$\begin{cases} x_p = A_1 + A_2 X_p + A_3 Y_p + A_4 X_p Y_p \\ y_p = B_1 + B_2 X_p + B_3 Y_p + B_4 X_p Y_p \end{cases} \quad (8)\ [2]$$

The process from geographic coordinate to photo-coordinate is as following:Gauss plane coordinates→geodetic coordinates of reference ellipsoid→geocentric coordinates of →a series of transition geocentric coordinates→ground photogrammetic coordinates→original image coordinates.

3. Questions And Solvent

1) Elimination of the Influence of theEarth Curvature

In the photogrammetic coordinates system, there is difference between the true coordinates and the coordinate transformed from the image coordinates to the ground photogrammetic coordinates, because of the influence of the earth curvature and flat ratio. From fig.3. you can find the difference from a and b, and the difference from a' and b'. This type of difference is evident when the pose angle is large. So it must be eliminated.

The iteration method is a good way to eliminate the difference. Firstly, take the elevation of point p(p') in ground coordinate system as initial height in the ground photogrametic system ,Secondly, convert the image points to the ellipsoidal coordinates using the collinear equation and convert function. So point a(a') in geo-ellipsoid coordinates corresponding to point p(p') of image coordinates. Compare Za elevation of point a with Zb(initial elevation), you can get the difference, And add this difference to the elevation of point a(a') in the ground photogrammetic coordinates, then rebuild the collinear equator and the coordinate transformation function. Usually, after one or two times iteration, point a(a') which corresponding to point p(p') can be move to point b(b') in the ground photogrammetic coordinates. So the elevation we got in the ellipsoid coordinates is consistent with the initiation elevation which we use in the collinear equation.

2) The Span-zone Problem

While rectifying one image, we should pay attention to which zone it locate. All the points of the image span different zone should be corrected into the zone which the centric point stand, for reason that different zone may make it difficult to ascertain the range of the image. In addition, while calculating the meridian spacing between longitude and the center of the projection zone, the 360 degree-periodicity often be taken into account when projective at 0 degree- longitude approximately.

3) Precision and Virtue of This Correction Method

The precision of correction and positioning of remote sensing image base on orbit parameter is major lied on precision of pose angle, it rise rapidly along with the precise of outer azimuth and position elements improving. Though without GCPs the high-precise of absolute positioning is not good enough , the technology eliminate the error caused by the earth's curvature and the tilt of photograph and terrain and so on which is difficult to remove by multinomial correction ,it can get a good relatively precise between pixels of image.

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