Geometric Rectification Technique for Landsat Multispectral Scanner Data

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Abstract

In many cases, the geometric relationship between Landsat Multispectral Scanner (MSS) data and the earth surface (including map coordinates or other images) has to be established. But these data comprise a variety of geometric distortions. A CCT's data of Landsat have not been, in general, corrected for systematic distortions. Though some of CCT's data have been done, only a few items of correction are considered. The geometric correction of systematic errors (pre-processing) and the fine rectification using control points, in fact, are included in the geometric rectification. This paper presents a technique of correction, according to actual situation of the sensor, i.e. assuming a frame of scanned data consists of 390 sweeps, then correct systematic distortions of each sweep. The parameters of the sweep are obtained by fitting and interpolating with orthogonal polynomial according to SIAT's records and CCT's manual. Using orthogonal polynomial is for the purpose of direct solution. A mathematical model for the fine rectification is a ordinary bi-variable polynomial. The rectified result is presented in the final part, including an output image with scanner S-201 (developed in China).

Introduction

A digital image of Landsat Multispectral Scanner (MSS) belongs to a "dynamic image" (due to Satellite flying,scanning mirror oscillating and the earth rotating). There are many of systematic geometry distortions mainly originated from the internal or external of a sensor. The quality of scanning mirror, non-linear sweep and detector permutation are major internal error sources, and the variation for the orbit, altitude, velocity and tri-axial attitude of satellite as well as the earth rotation , earth curvature and rungh surface are the external error sources.

An aero-photo is a frame photograph exposed under rigorous central projection at a time. There is only one projection centre and a set of exterior orientation elements for each photograph. Whereas a digital image of MSS is a hybrid projection type. In orbital direction, it is orthogonal, across orbit-panormic central perspective. A MSS's frame is fully scanned in about 25.5 second. A six lines of image data is simultaneously taken with one sweep. Hereby a MSS's frame data should, in general, included several projection centres and sets of exterior orientation elements.

As mentioned above, a six lines data (i.e. one sweep) is considered as an unit to correct systematic geometry errors(fig. 1). The systematic errors corrected in such unit are considered as following:

- sampling ratio difference between horizontal and vertical directions
- panormic distortion
- non-linear scan sweep
- the earth rotation for a six lines unit
- the earth curvature
- satellite orbital inclination
- satellite altitude variation
- tri-axial attitude of sensor (Wi,ϕi, Ki)

Attitude calculation for any sweep

At first, using an orthogonal polynomial fit into nine given attitude points provided by a SIAT record of the frame, and then, the attitude values of each sweep are interpolated.

An orthogonal polynomial is :

$$Y = Ao * {}_{(o,n)}F(X) + A1 * {}_{(1,n)}F(X) + A2 * {}_{(2,n)}F(X) + \ldots + Am * {}_{(m,n)}F(X)$$

$$= \sum_{i=o}^{m} Ai * {}_{(i,n)}F(X) \qquad \ldots\ldots(1)$$

where : Ai..... orthogonal polynomial coefficients

m..... order of orthogonal polynomial

n..... number of point used

${}_{(m,n)}F(X)$..... items of orthogonal polynomial

It is equal to

$${}_{(m,n)}F(X) = \sum_{k=o}^{m} (-1)^{k} * C_{k}^{m} * C_{k}^{m+k} * \frac{X^{(k)}}{n^{(k)}} \qquad \ldots\ldots(2)$$

where : $X^{(k)}$ .... factorial

C_k^m .... combination

The coefficients can be directly found by the property of orthogonal polynomial.

$$Ai = \frac{\sum_{k=o}^{n} F_{(i,n)}(X_k) * y_k}{\sum_{k=o}^{n} (F_{(i,n)}(X_k))^2} \qquad \ldots\ldots(3)$$

Non-linear sweep

In the perfect case, scan velocity should be a constant. Because of mechanical reason, the scan velocity variation is, in fact, non-linear vary with distances. There is not any information for compensation in the CCT. But the relationship curve between the scan distance and its correction can be found from "LANDSAT DATA MANNUL". Some space points may be appropriately chosen with this curve. Thus a sweep equation of scan mirror would be established by orthogonal polynomial ((1), (2) and (3)), and then the correction value of each cell can be calculated.

Tri-axial attitude influence

After other systematic errors have been corrected within a sweep, a transformation is performed as follows :

$$X_r = \frac{Kx}{N+\frac{1}{P}} + \frac{M_1}{P}$$

$$Y_r = \frac{K_y}{N+\frac{1}{P}} + \frac{M_2}{P} \qquad \ldots\ldots (4)$$

where N is the pixel number in the scanned direction, and the rest are a function of the direction cosines or pixel space which are all given in a sweep.

Fine rectification with control points

Although the obvious geometric distortions have been modified, it may be not complete. Meanwhile a digital image must be located on a given coordinate system which user needs. A fine rectification must be, however, performed. A mathematical model for the fine rectification is a bi-variate polynomials.
The indirect way of the rectification is applied.
The bi-variate polynomial are :

$$X = Ao+A1x+A2y+A3x^2+A4xy+A5y^2 +A6x^3+A7x^2y+A8xy^2+A9y^3+...$$

$$Y = Bo+B1x+B2y+B3x^2+B4xy+B5y^2+ B6x^3+B7x^2y+B8xy^2+B9y^3+... \quad ...(5)$$

Tests and results

A subprogram of the geometric rectification have been packed into PIPS'(+) package at the Research Institute of Surveying and Mapping.

Test zone : (a) about 25x36 km^2
(b) about 35x70 km^2

test data : Feb. 10,1977 Landsat-2
CCT's data

map : standard topographic map , 1:50000

Point identification and measurement :
the point identification can be performed in the character image map printed or on CRT of the graphic terminal C-1o1. The numbers of row and culumn of a pixel are used to define the image coordinates (of course, scanned photograph can be alse measured with comparator, but have not been done in this test).

Test results are shown in table 1.

A fig. 2 is the rectified image , which is output by S-201 scannor developed in China.

(+) PRIME BASED IMAGE PROCESSING SYSTEM

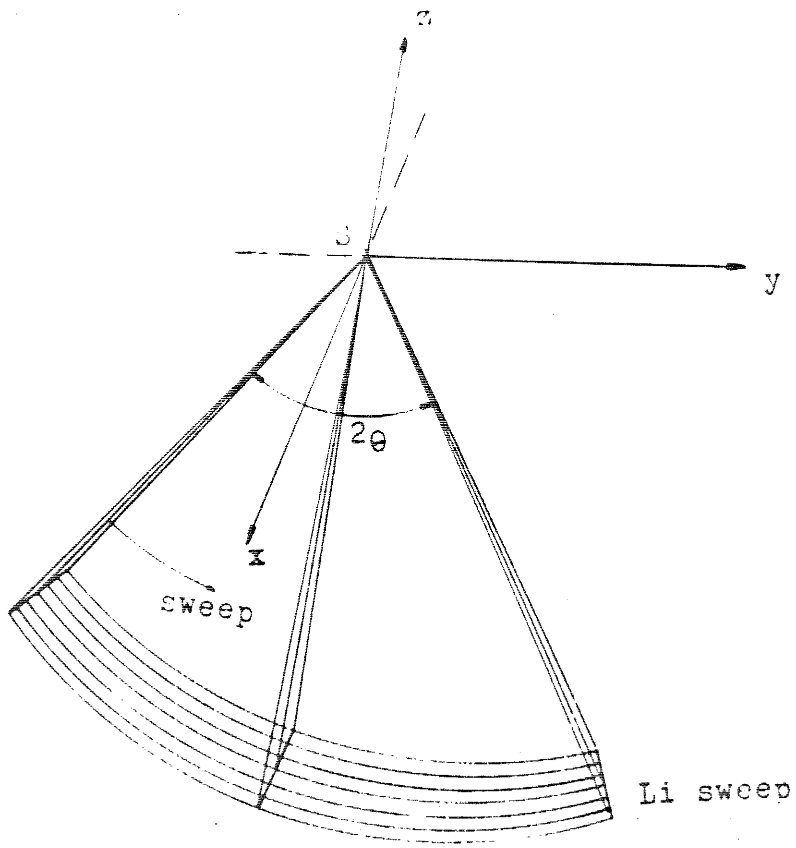

Fig. 1

Table 1

zone	ground area	image area	nu. of control point	nu. of check point	R. M. S. (check point) NO +	Mx (pix)	My (pix.)	time Sampl.	CPU ++ time
A	25x36 (km²)	3oo x 6oo (pix.)²	5o	12	2	o.72	o.98	N.n.	12.5'
								B.l.	14.5'
					3	o.66	o.95	N.n.	16.6'
								B.l.	18.5'
B	35x7o (km²)	4oo x 11oo (pix.)²	99	15	2	o.69	o.9o	N.n.	2o.5'
								B.l.	21.0'
					3	o.65	o.98	N.n.	23.[illegible]'
								B.l.	24.1'

\+ NO : the order of polynomial, ++ PRIME 250-IIb Computer.

Fig. IIa

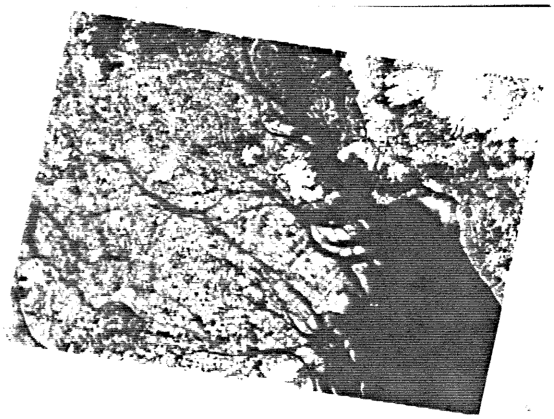

Fig. IIb

Fig. II a) image befor rectification

b) rectified image

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References

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