Mapping on the Analytical Stereoplotter Using SAR Images

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ABSTRACT This paper analyses the mapping characteristics of SAR images, describes a kind of projection equations for the SAR image , emphatically discusses the principle and the method of reconstructing a stereomodel of SAR stereoimages on APS-1 analytical stereoplotter . Finally , the result of the experiment using practical SAR image data is given .

[KEYWORDS] SAR , Free-parallax stereomodel , Analytical plot

1. Introduction

A Mapping System SARMS has been developed on the China-made APS-1 analytical stereoplotter . The software packet SARMS has been proved practicable by some experiments with the radar images of GEMS radar system provided by china company of Aero - Remote - Sensing-Serving. While there were not navigation data and base-to-height ratio (B/H) was less than 0.27 , only the control points could be used as control conditions, the accuracy of location of sterromodel could be used to measure a planimetric map of scale range from 1:50,000 to 1:100,000 or a topographic map of scale 1:200,000 .

2. Mappping chracteristics of SAR images

The SAR image is distance projection image which is different from traditional centre projection ones. They are diffrent in the projection equations and the accuracy of the projection equations. There is not inner orientation mark in the SAR image and the SAR image's error source is more complex than the centre projection image's . On account of above factor , the software packet of mapping using the SAR images on analytical stereoplotter must be designed again .

3. Projection equations

There are two projection equations for SAR images:

(1) Range condition :

$$(X-X_s)^{2}+(Y-Y_s)^{2}+(Z-Z_s)^{2}=(y \cdot M_y+R_o)^{2}+H^{2}$$
...... (for distance range)

$$(X-X_s)^{2}+(Y-Y_s)^{2}+(Z-Z_s)^{2}=(y \cdot M_y+R_o)^{2}$$
...... (for slant range)

(1)

(2) Zero Doppler condition :

$$X_s' \cdot (X-X_s)+Y_s' \cdot (Y-Y_S)+Z_s' \cdot (Z-Z_s)=0 \qquad (2)$$

Where , in (1) and (2) :

X, Y, Z are point ground coordinates ;

Xs, Ys, Zs are ground coordinates of instantaneous sensor position . They are polynomils of flight time :

$$X_s = X_{so} + X_s' \cdot T + X_s'' \cdot T^{2} + \ldots\ldots$$
$$Y_s = Y_{so} + Y_s' \cdot T + Y_s'' \cdot T^{2} + \ldots\ldots$$
$$Z_s = Z_{so} + Z_s' \cdot T + Z_s'' \cdot T^{2} + \ldots\ldots$$
$$T = M_x \cdot x + T_o \qquad (3)$$

Where ,

x is radar image coordinate in the flight direction ;
y is radar image coordinate in the range direction ;
Mx, My are scales denominator of x, y ;
Ro = range delay ;
To = flight time correspond to zero of image coordinates system ;
Xs', Ys', Zs' = velocity vector of flight ;
Xs'', Ys'', Zs'' = acceleration vector of flight ;
H = flight height ;

4. The principle and the method of reconstructing a SAR images stereomodel

In order to set up a free-parallax radar stereo model , a new Real-Time-Loop program was designed which adapt to synthetic aperture radar. The new Loop program has following functions :

(1) Real-Time function .

The run time period of the new Loop program is less 20 ms so that the operator could follow the tracks of measurement marks .

(2) Image coordinates are corresponded to the ground coordinates each other .

Leading above equations into the new Real-Time-Loop program was very effective for setting a radar stereomodel .

When equation (3) was used in one order form , the radar image physcial coordinates were obtained as follows :

$$T = [Xs'*(X-Xso)+Ys'*(Y-Yso)+Zs'*(Z-Zs0)] / (Xs'**2 + Ys'**2 + Zs'**2) \quad (4)$$

$$R = SQRT((X-Xs)**2+(Y-Ys)**2+(Z-Zs)**2) \quad (5)$$

Then the radar images coordinates were obtained with the known orienation parameters .

$$x=(T-To) / Mx \quad (6)$$

$$y=(R-Ro) / My \quad \text{(for slant range)}$$
$$y=(SQRT(R**2-H**2)-Ro)/My \quad \text{(for ground range)} \quad (7)$$

According to equation (4), (5), (6) and (7) , the new Real_Time-Loop program can translate the point ground coordinates into image coordinates , so while operator inputs the point ground coordinates X, Y, Z, the image coordinates x and y are calculated automatically, driving system of the analytical stereo plotter would drive the measurement marks to locate in the corresponing position of the images .

(3) Free-parallax .

Using the principle of interpolation of multilayer two order curved surface to correct remain parallaxes.

Because of the affection of image resolution, terrain types, sensor position and orbital parameters, ground - control points , the mathematical concept of radar geometry , and the geometry of steromodel, the base-to-height ratio, there were still remain vertical parallaxes in every model . Those parallaxes were analysed and were found that they showed some systematic natures . If the vertical parallax of model point was regarded as Z coordinate and the planmetric coordinates as X , Y coordinates , then the surface of model was a smooth and irregular curved surface . We adopted the method of interpolation of mutilayer two order curved surface to describe the irregular curved surface .

The multilayer two order curved surface had a form as follows:

$$f(XY)=Z=K*Q(XYX_1Y_1)+K*Q(XYX_2Y_2)+......+K*Q(XYXnYn) \quad (8)$$

$$Qj=Q(XYXjYj)=SQRT\{(X-Xj)**2+(Y-Yj)**2+\&\}$$

where , j=1, 2, ..., n

if the amount of the known vertical parallax points is m , then n must be less than m , according to equation (8) , the equation can be listed as follows :

$$V = Q K - Z \quad (9)$$

Where,

$$V = [V1\ V2\ \dots\ Vm]^T$$
$$Z = [Z1\ Z2\ \dots\ Zm]^T$$
$$K = [K1\ K2\ \dots\ Kn]^T$$

$$Q = \begin{pmatrix} Q11 & Q12 & \dots & Q1n \\ Q21 & Q22 & \dots & Q2n \\ . & & & . \\ . & & & . \\ . & & & . \\ Qm1 & Qm2 & \dots & Qmn \end{pmatrix}$$

$$Qij=Q(XiYiXjYj)=SQRT\{(Xi-Xj)**2+(Yi-Yj)**2+\&\}$$

The solution of equation (9) with LSM is :

$$K = (Q^TQ)^{-1}(Q^TZ) \quad (10)$$

A any point would obtain correction Zp :

$$Zp = [Qp1\ Qp2\ \dots\ Qpn]\ K \quad (11)$$

When the new Real-Time-Loop program is running in the " model work " way , if operator input the inner parameters , the exterior parameters, the point model coordinates , the scales of model and the corection parameters into the common area of the Real-Time-Loop , in the view system of the APS-1 analytical stereoplotter , a free-patallax stereomodel of SAR images would be seen clrealy .

5. The result of experiment

A SAR Mapping System SARMS has been designed , it consists of :

. Real-Time-Loop program
. Interior orientation program
. Exterior orientation program
. Contouring program
. Other applying programs

SARMS has been proved practicable by some experiments with the radar images of GEMS radar system provided by China company of Aero - Remote - Sensing - Serving . The specifications of experiment image data is listed in Table 1 :

Specifications of image data Tab.1

items	flight line	flight line 2
image record form	horizontal distance record	horizontal distance record
designed flying height	10,000 m	10,000 m
scan delay	126.6 us	244.0 us
scale in distance direction Mx	1:100,000	1:100,000
scale in azimuth direction My	1:100,000	1:100,000
distance resolution	3 m	3 m
azimuth resolution	3 m	3 m
elevation difference	900 m	
B/H ratio	0.16	
radar stereo config	stereo in the same side	

The accuracy of the location of a stereomodel listed in Table 2 and the results of accuracy is obtained by statistics of the the errors between the known ground coordinates and the reading in the model.

Results of accuracy test Tab.2

points \ RMSE number \	mx (m)	my (m)	mz (m)
control points 9	13.8	16.2	13.2
target points 22	26.7	23.9	33.1
known points 31	23.7	21.9	28.7

※ The known points include the control points and the target points .

The topographic map of scale 1:2000,000 is shown as fig.1 , the altitude length of contour is 20 m .

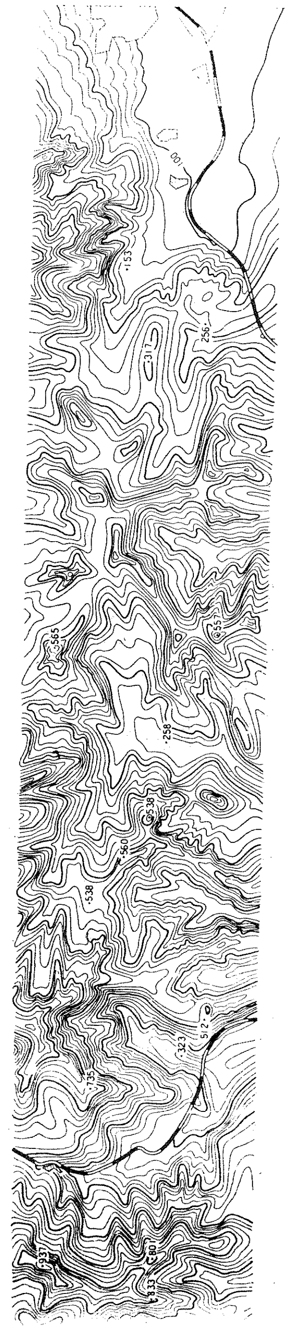

Fig.1

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