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# Research on Block Adjustment of Airborne InSAR Images

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**Abstract.** Airborne InSAR system and InSAR data processing algorithm have been one of the hot topics in the international SAR field. Geometric constraint relation of images is set up through airborne InSAR block adjustment, adjustment parameters are adjusted and refined, and the three-dimensional(3D) ground coordinates of tie-points(TPs) are solved according to least squares theory. The number of the ground control points(GCPs) is reduced. The airborne InSAR block adjustment experiment was done using self-developed Airborne InSAR Block Adjustment Software System. The 76 airborne InSAR images which are 0.5 m resolution and cover an area of 472 square kilometers generated a block of 4 strips and 19 rows with approximately 30% overlap between adjacent strips. The study site is located in in Jiangyou Sichuan province and characterized by a hilly topography. The result meets DEM and DOM mapping accuracy requirements at scale of 1:10000.

## 1. Introduction

High-precision surface elevation information can be orbtained efficiently by airborne interferometric Synthetic Aperture Radar (InSAR) system. Airborne InSAR system and InSAR data processing algorithm have been one of the hot topics in the international SAR field.

Airborne InSAR calibration can provide a certain precision initial value of parameters for adjustment, but it is not satisfied the requirements of the photogrammetric mapping accuracy used parameters of airborne InSAR or of calibration when few control is available. So, block adjustment must be done when high precision mapping Using airborne InSAR. Block adjustment is the core of airborne InSAR mapping. Block adjustment instead of a single image adjustment, when no sufficient ground control is available. There are different advantages to the block adjustment.

- Number of ground control points (GCPs) can be reduced.
- Better relative accuracy between the images can be obtained.
- More homogeneous and accurate mosaic over large areas can be obtained.
- Homogeneous GCP network for geometric processing can be densified or generated.
- Positioning accuracy can be improved.

There are few scientific results and evaluation or applications were published on airborne InSAR block adjustment for our knowledge, most is for block adjustment of space-borne SAR[1,2,3]. Geometric constraint relation of images is set up through airborne InSAR block adjustment in this paper, adjustment parameters are adjusted and refined, and the three-dimensional(3D) ground

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coordinates of tie-points(TPs) are solved according to least squares theory. The number of the ground control points(GCPs) is reduced. The geography coordinates accuracy of TPs and the integrity of the block is increased by airborne InSAR block adjustment. So high-precision positioning can be achieved in large area with few control points.

The airborne InSAR block adjustment experiment was done using self-developed Airborne InSAR Block Adjustment Software System. The 76 airborne InSAR images which are 0.5 m resolution and cover an area of 472 square kilometers generated a block of 4 strips and 19 rows with approximately 30% overlap between adjacent strips. The study site is located in in Jiangyou Sichuan province and characterized by a hilly topography where elevation ranges from 430 to 680 m. The result meets DEM and DOM mapping accuracy requirements at scale of 1:10000.

## 2. Error equations of Airborne InSAR block adjustment

The Observations of airborne InSAR block adjustment includs 3D coordinates of GCPs and TPs, Distribution map of GCPs and TPs is as follow. At the same time the phase and POS data regard as observations, and the offset and drift system correction of GPS and IMU is brought into POS data. Before the adjustment, the weights of all kinds of observations were determined automatically according to observation accuracy or experience of the observations, After the adjustment, the posteriori weight of the various observations was determined based on the method to weight of posteriori variance component estimation, so that the more reasonable weight matrix was used for block adjustment.

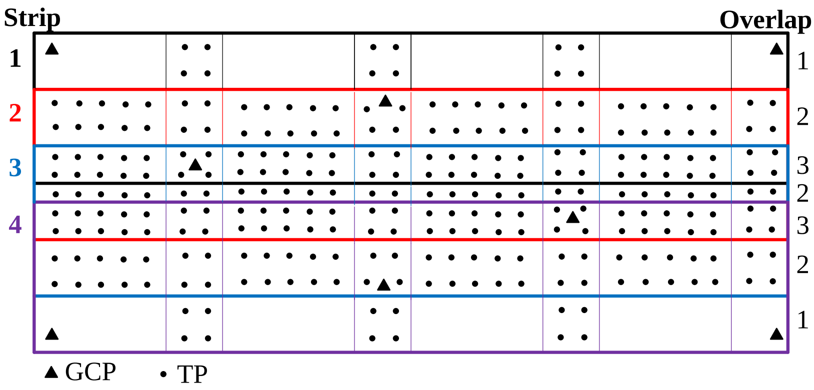


**Figure 1.** Distribution map of GCPs and TPs.

By above error model of airborne InSAR block adjustment was established, as follow:

$$\begin{aligned} V &= AX + BX_A + L_P, & E \\ V_{POS} &= E_1 X + CX_{POS} + L_{POS}, & P_{POS} \\ V_{\varphi} &= + DX_{\varphi} + L_{\varphi}, & P_{\varphi} \end{aligned} \quad (1)$$

Where V is the 3D coordinate correction vector of GCPs or TPs. $V_{POS}$ is the correction vector of POS data. $V_{\varphi}$ is the correction vector of phase. X is the increment vector of sensor position and attitude data. $X_A$ is the increment vector of adjustment parameters which include initial range, base length and orientation. $X_{POS}$ is the increment vector of offset and drift of GPS and IMU. $X_{\varphi}$ is the increment vector of phase adjustment parameters. A is the matrix of coefficients of POS data adjustment parameters. B is the matrix of coefficients of adjustment parameters. C is the matrix of coefficients of

POS observation error equations. D is the matrix of coefficients of phase observation error equations. $L_P$, $L_{POS}$ and $L_\varphi$ are constant vector.
As:

$$V=\left[V_X\ V_Y\ V_H\right]^T \tag{2}$$

$$V_{POS}=\left[V_{X_S}\ \ V_{Y_S}\ \ V_{H_S}\ \ V_{\theta_y}\ V_{\theta_r}\ \ V_{\theta_P}\right]^T \tag{3}$$

$$X=\left[\Delta X_S\ \ \Delta Y_S\ \ \Delta H_S\ \ \Delta\theta_y\ \Delta\theta_r\ \ \Delta\theta_P\right]^T \tag{4}$$

$$X_A=\left[\Delta R_0\ \ \Delta B\ \ \Delta\alpha\right]^T \tag{5}$$

The constraint of the adjustment is that the heights in overlapping areas should be identical. The observation equation follows the functional description for adjustment with constraints.

$$n=3(nCalGCP+nCalTP) \tag{6}$$

$$t=4nP+3nTP \tag{7}$$

When $n\geq t$, let $t_1=4nP$ and $t_2=3nP$, then the error equation is:

$$\underset{n\times 1}{V}=\underset{n\times t_1}{A}\,\underset{t_1\times 1}{t}+\underset{n\times t_2}{B}\,\underset{t_2\times 1}{X}-\underset{n\times 1}{L} \tag{8}$$

$$\begin{bmatrix} A^TA & A^TB \\ B^TA & B^TB \end{bmatrix}\begin{bmatrix} t \\ X \end{bmatrix}=\begin{bmatrix} A^TL \\ B^TL \end{bmatrix} \tag{9}$$

$$\begin{bmatrix} N_{11} & N_{12} \\ N_{21} & N_{22} \end{bmatrix}\begin{bmatrix} t \\ X \end{bmatrix}=\begin{bmatrix} N_1 \\ N_2 \end{bmatrix} \tag{10}$$

## 3. Process of Airborne InSAR block adjustment

First of all, reasonable layout design of GCPs and TPs was given. Next, airborne InSAR datas of large volumes, such as the image data of every sortie every strip and in the strip among strips in study site were organized and managed rationally. Error equations of high precision three-dimensional positioning model were established. Initial value of adjustment parameters can be provided by airborne InSAR calibration. Then according to the principle of least square, adjustment parameters of each images in the study site were calculated iteratively. Finally, the adjustment parameters were substituted into airborne InSAR high-precision three-dimensional positioning mathematical model, at the same time DSM and DOM were obtained [4].

Due to the slow rate of airborne InSAR block adjustment convergence or even not convergence caused by the inconsistent of elevation and plane coordinate precision, adjustment parameters of elevation and plane are resolved separately. They were divided into two steps. The first step is for airborne InSAR elevation block adjustment, elevation adjustment parameters were solved. The second step is for airborne InSAR plane block adjustment, plane adjustment parameters were solved when the correction of the elevation adjustment parameter were substituted into error equations.

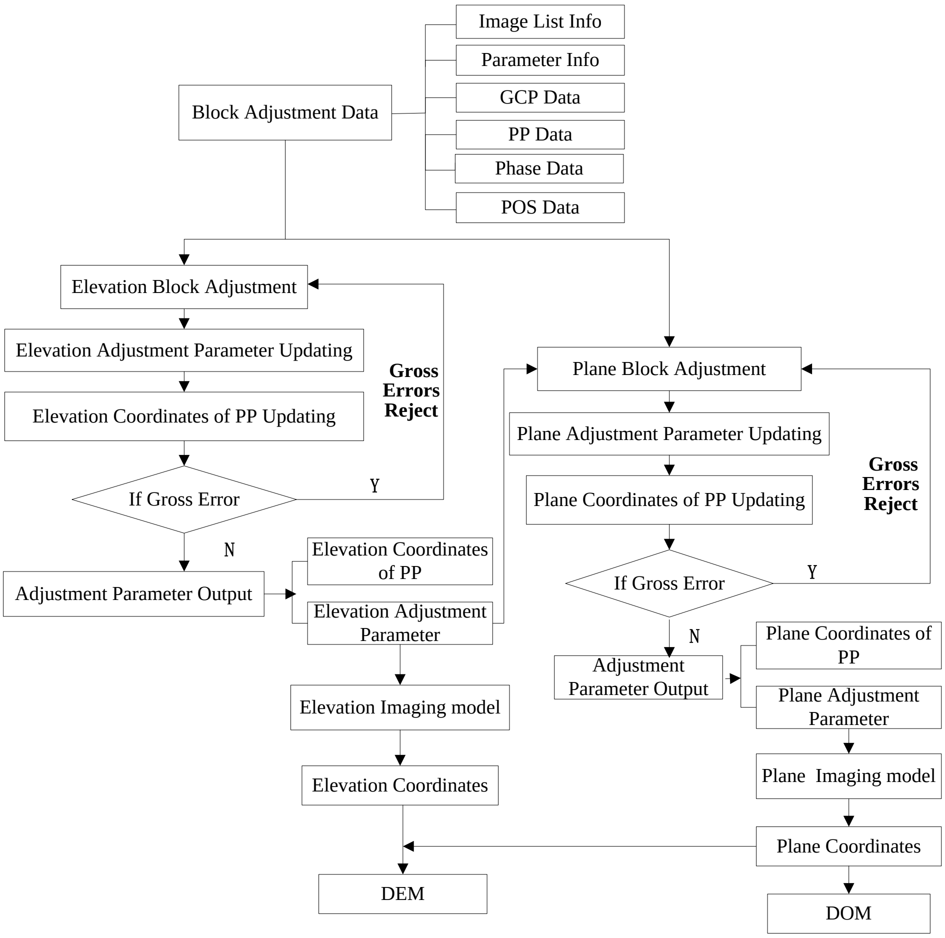


**Figure 2.** Calculating flow chart of Airborne InSAR Block Adjustment.

The Whole Technological Process of Airborne InSAR Block Adjustment is as follow:

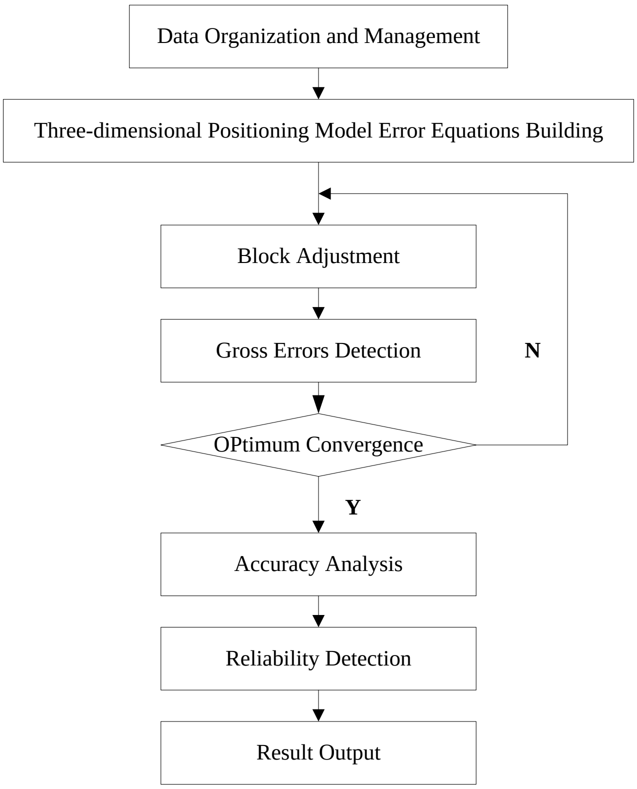


**Figure 3.** The Whole Technological Process of Airborne InSAR Block Adjustment.

## 4. Experiment

### *4.1. Experimental data*
The study area is in Jiangyou Sichuan province, and the landscape is plain and hill mainly. 0.5 m range and azimuth resolution of airborne InSAR data. 4 strips 76 scenes 472 square kilometers airborne InSAR data was processed in this experiment.

### *4.2. Results Analysis*
Several large-scale positioning experiments have done using self-developed Airborne InSAR Positioning Software System developed by the author, and 1:10 000 scale DEM and DOM can be generated efficiently at the same time under scarce control conditions. Airborne InSAR data high-precision positioning of 4 strips 76 scenes 472 square kilometers was completed by the software system, 9 GCPs and 3137 TPs were used, and the result meets 1:10000 scale DEM and DOM mapping accuracy requirements.

## 5. Conclusion
There are edge errors among SAR images after positioning, and the problem can be effectively solved through block adjustment technology. Image positioning can be done through every scene data position parameters were calculated unified when location in the large area using a few ground control points. The number of control points can be reduced, and efficiency was improved. The high precision positioning method based on airborne InSAR block adjustment was researched in this paper, the error equations of high precision three-dimensional positioning model was established and solved, and the airborne InSAR high precision positioning was achieved in a large scale and few control conditions.

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