# DEEP PROCESSING FOR Beijing-1 SMALL SATELLITE

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ABSTRACT:

Beijing-1 small satellite was developed and launched by SSTL (Surrey Satellite Technology Limited), which was handed over to China during on-orbit test period. Two type of sensors were carried on the satellite, one was 3-band multi-spectral senor which spatial resolution was 32m, the other was panchromatic sensor which spatial resolution was 4m. Preliminary processing system has been developed for receiving, preprocessing, and data-distribution. But in order to ensure truly utility for small satellite data, several research parts must be focused. One is radiometric calibration; the second is deep processing for many levels of product; the third is application demonstration. The paper will focus on the works of the second and the third part. Main content includes how to optimize algorithms of high accurate geometric correction, image fusion, orthorectify which consider the feature of 600km scan range and high spatial resolution. The aim of all the works is an experiment to filling up the gap between the preprocessing and practice application for many launching similar satellites in future.

# 1. Introduction

Beijing-1 small satellite has joined the International Disaster Monitoring Constellation in 2005. Small satellite weighs 166 kg., orbital altitude 686 km., intending life-span on orbit is more than 5 years. The small satellite carries two sensors, one is 32 meter resolution multi-spectral scanner, and another is 4 meter resolution panchromatic CCD camera, which can detailed explore a key area. An organic combination of these two sensors will improve the analysis and evaluation performance for disaster situation on large area. But there exist some disadvantages in Beijing-1 small satellite now.

(1) Due to the limitation of mass and volume, attitude control that usually used on large satellite was leaved out and the system can't keep high control precision and good stability.

(2) Preceded calibration on the ground for the small satellite should be completed before the quantitative analysis of RS data since no onboard scaler installed.

(3) The coverage of 32 meter resolution multi-spectral scanner is very large (600km), which is several times than that of general resource satellite. Owing to the non-linear aberration form sub-satellite point to image margin, it will be difficult to do geometric calibration accurately.

(4) The spatial resolution rate of 4 meter resolution panchromatic image and 32 meter resolution multi-spectral image from this small satellite is 1:8, this will result in new problems for image fusion and

its precision evaluation.

# 2. Advanced processing system for the products of Beijing-1 small satellite

## 2.1 Major products

The advanced processing system is a tool for advanced products processing and thematic information extraction based on level-1 products after radiometric ratification. Major products include:

Tab.1 Major products of Beijing-1 small satellite

| No. | Products | Criterion |
|---|---|---|
| 1 | 32m precise rectification products | Root mean square error (RMS) is 1-2 pixels in plain and 2-3 pixels in mountain area. |
| 2 | 4m precise rectification products | Root mean square error (RMS) less than 2-3 pixels in plain and is 3-4 pixels in mountain area. |
| 3 | 4m orthographic products | Geometric error of orthographic rectification is 1-3 pixels |
| 4 | Cloud monitor | Recognition precision is 90% |
| 5 | 32m subdivision products without cloud | Cover all over China, 1:100,000 subdivision a time/quarter |
| 6 | 4m orthographic subdivision products | Can be used to produce1:10,000 subdivision products |
| 7 | Fused image product | 4m resolution, the spectrum hierarchy is very clear |
| 8 | NDVI/EVI | Cover all over China, a time/quarter |

## 2.2 Processing flow

●Module for geometric precise rectification algorithm

After radiometric ratification, we apply automatic registration technology to the small satellite's image data to realize the quickly geometric precise rectification and projection setting as a batch, and to produce standard image products with geo-code. We give emphasize on the non-linear aberration form sub-satellite point to image margin, and the character of large deformation, to develop an algorithm suitable for precise geometric rectification of small satellite.

●Module for orthographic rectification processing algorithm

We use RPC model to implement orthographic rectification according to sensors' parameters and control data.

●Module for removing cloud cover mosaic algorithm

To implement cloud detection, auto-processing and to join a multi-date mosaic image, to produce a removing cloud cover mosaic image and a subdivision Clipping map with standard scale.

●Module for high-resolution fusion algorithm

By comparison and analysis of existing fusion methods, we will design a new fusion method suitable for the small satellite data. It will preserve the spectral information of multi-spectral and the resolution precision of panchromatic band to the best, and produce the fused high-resolution image.

The detailed processing flow is as following chart.

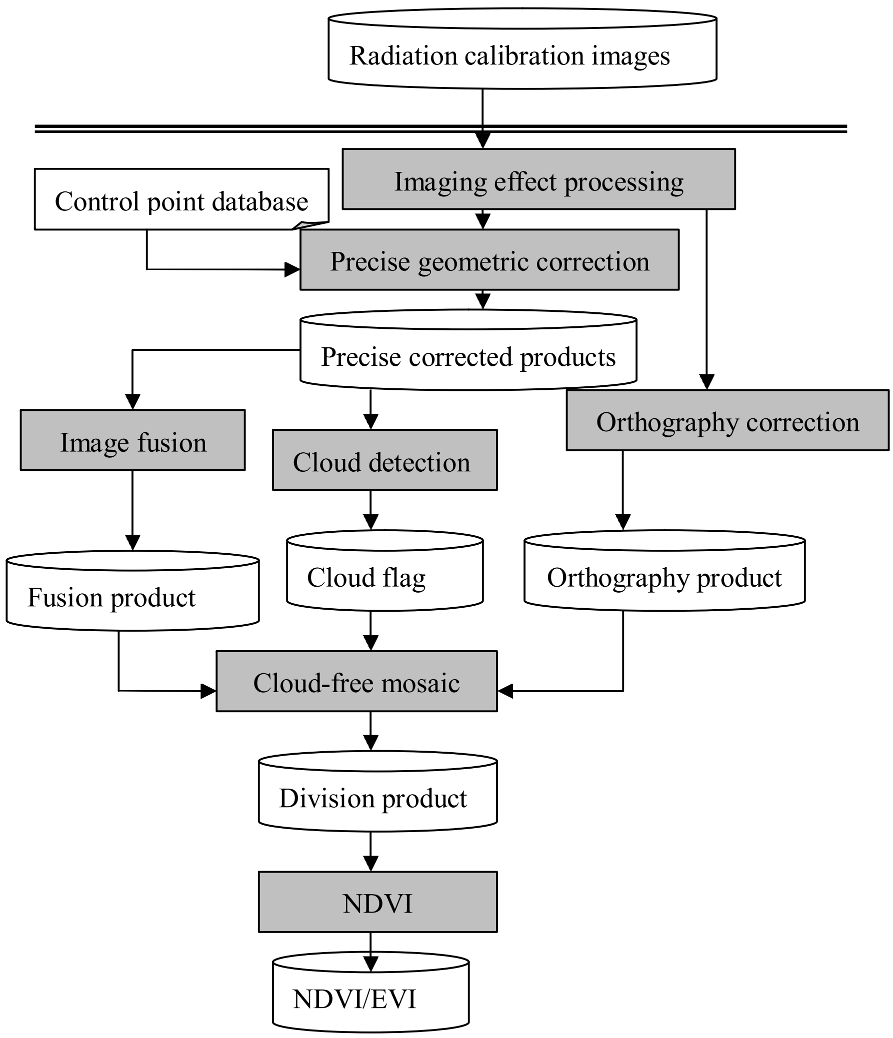


Fig.1 Processing flow for products of BJ-1

## 3 Result Analysis

### 3.1 Precise geometric correction

Selecting 19 control points, using two order polynomial, the values of remnant error of every point can be showed in the following table 2. Accuracy analysis can be showed as table 3.

Tab. 2 Error Information of Geometric Correction

| X_Pixel | Y_Pixel | X_Ref | Y_Ref | X_Residual | Y_Residual | RMS_Error | Contrib |
|---|---|---|---|---|---|---|---|
| 477.1093750000 | 32925.4218750000 | 528290.020 | 3995404.870 | 10.198484 | 6.501531 | 12.094585 | 0.053442 |
| 6033.5156250000 | 31993.3593749998 | 551876.740 | 3995420.570 | 2.845985 | -0.924206 | 2.992288 | 0.013222 |
| 5318.0781332826 | 754.6863887151 | 576544.400 | 3871623.340 | 7.345052 | 5.579190 | 9.223727 | 0.040756 |
| 3412.8342114119 | 30997.2867573932 | 541977.200 | 3989740.070 | -3.176518 | -7.583246 | 8.221672 | 0.036329 |
| 140.0064468411 | 29107.6245289181 | 530320.940 | 3980110.640 | -19.497886 | 2.370924 | 19.641509 | 0.086789 |
| 1286.9592039559 | 27262.7176254452 | 536596.780 | 3973575.280 | -7.658173 | 3.984387 | 8.632668 | 0.038145 |
| 1529.5090822917 | 24198.1031672836 | 540263.730 | 3961652.120 | 18.604168 | -14.542575 | 23.613588 | 0.104340 |
| 5056.5469084355 | 22740.5422719735 | 556028.800 | 3958221.160 | 1.148161 | 7.827916 | 7.911671 | 0.034959 |
| 460.6723430273 | 19962.2893085301 | 539660.100 | 3944218.080 | 11.510301 | -7.950726 | 13.989320 | 0.061814 |
| 5363.6280705309 | 16090.3730217929 | 563179.770 | 3932193.120 | -1.486454 | -10.135508 | 10.243928 | 0.045264 |
| 569.3167000517 | 13749.6585793035 | 545596.280 | 3919753.130 | -1.423899 | 0.847205 | 1.656878 | 0.007321 |
| 5464.0356449354 | 12571.5408191528 | 566699.480 | 3918344.980 | 5.719035 | 16.377840 | 17.347651 | 0.076653 |
| 1632.6191000911 | 8264.8190303448 | 554756.780 | 3898804.180 | 11.816001 | 0.010709 | 11.816006 | 0.052211 |
| 5174.3085089122 | 6081.9727836945 | 571249.750 | 3892573.960 | -3.194076 | -20.031787 | 20.284837 | 0.089631 |
| 871.0575182692 | 3513.0206093312 | 555869.490 | 3879544.590 | -13.558565 | 2.105488 | 13.721070 | 0.060628 |
| 1727.2058152737 | 5603.3648234208 | 557497.520 | 3888364.850 | 6.928005 | -2.551171 | 7.382799 | 0.032622 |
| 4886.8844640444 | 8215.3573269056 | 568184.610 | 3900780.930 | -11.496124 | -1.182230 | 11.556753 | 0.051065 |
| 2551.1604474616 | 10432.0548299286 | 556612.880 | 3907957.410 | -1.728506 | 9.844806 | 9.995396 | 0.044166 |
| 3259.4771279617 | 19310.8732143739 | 551683.800 | 3943477.960 | -12.894990 | 9.451453 | 15.987831 | 0.070644 |

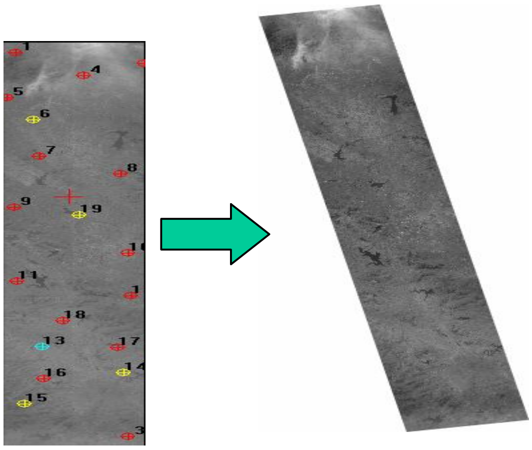

Fig. 2 Result of geometric correction

Tab.3 Accuracy Analysis of the Result Image

| Error | unit | X_Residual | Y_Residual | RMS_ERROR |
|---|---|---|---|---|
| Mean value | pixel | 2.003031 | 1.707933 | 2.977818 |
| | mile | 8.012125 | 6.831731 | 11.911272 |
| Maximum value | pixel | 4.874472 | 5.007947 | 5.903397 |
| | mile | 19.497886 | 20.031787 | 23.613588 |

### 3.2 Orthography Correction

Selecting 17 control points x,y,z, using RPC model, we can see the distribution of remnant error shown as fig3. and tab. 4.

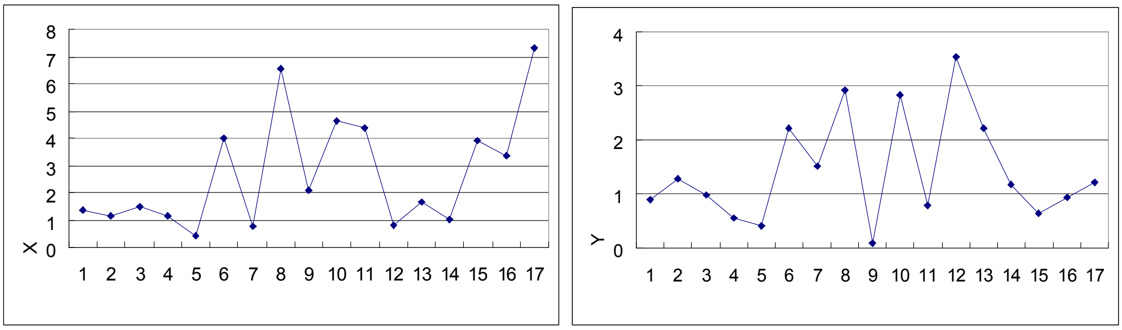


Fig. 3 Distribution of remnant error of control points

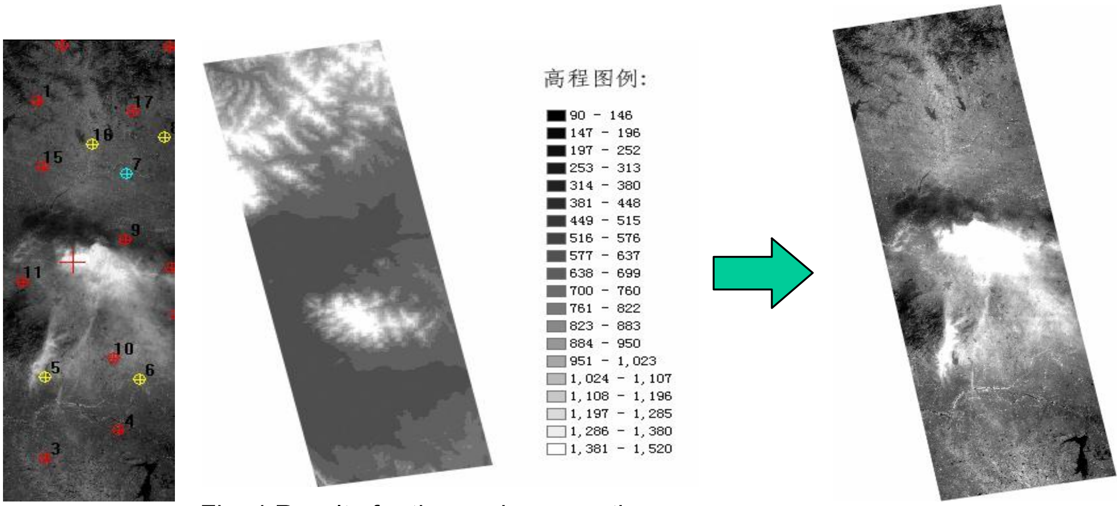


Fig. 4 Result of orthography correction

Tab. 4 Accuracy Evaluation of Orthography Correction

| Error | Unit | X_Residual | Y_Residual |
|---|---|---|---|
| Mean value | pixel | 2.7121 | 1.420176 |
| | mile | 10.8482 | 5.6807 |
| Maximum valus | pixel | 7.3190 | 3.532 |
| | mile | 29.2760 | 14.1280 |

## 3.3 Image Fusion

The fusion method of Imagesharp is developed. Its principle considers linearity combined relation of panchromatic, multi-spectral and integrated image, and to use the least square estimation and image statistic to integrate. The spectrally and spatially enhanced image is visually appealing, and can keep spectral character better than other fusion methods in common use.

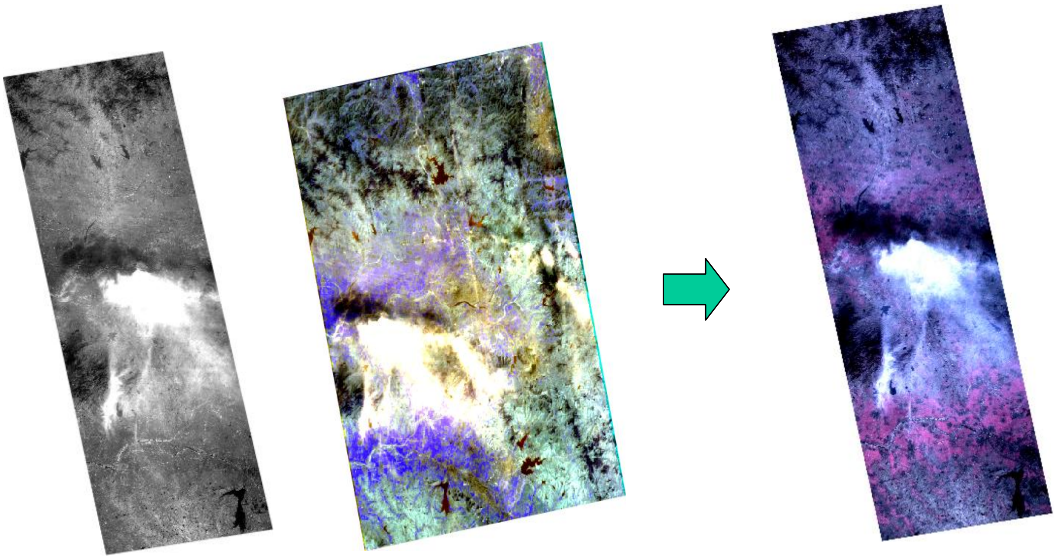

Fig. 5 Result of fusion image

## 4 Conclusion

Now the BJ-1 small satellite runs orderly, and the products are distributed to many users from surveying and mapping, agriculture, irrigation etc. al fields. The work of extraction of thematic information based on the products is researched and introduced in another paper. The aim of all the works is an experiment to filling up the gap between the preprocessing and practice application for many launching similar satellites in future.