https://www.sworldjournal.com/index.php/swj/article/view/swj06-06-110
DOI: 10.30888/2663-5712.2020-06-06-110

UDC 004.932.72'1; 004.92

COMPUTER TECHNOLOGY OF IMAGES GEOMETRIC CORRECTION

Shedlovska Y. I.
ORCID: 0000-0003-4931-4070
Oles Honchar Dnipro National University, Dnipro, Gagarina Avenue, 72, 49010

Abstract. *This work is devoted to remote sensing imagery geometric transformation. In this work a method of geometric transformation of an aerospace image based on GCPs and linear elements of the image was proposed. To distinguish linear elements automatically, the author's algorithm of classification of high-resolution multispectral photogrammetric images was used.*

Key words: *CCD scanner, classification, geometric transformation, aircraft, digital image.*

Introduction.

At present information technologies are widely used in digital image processing. The highest demand tasks are pattern recognition and image classification. These tasks are particularly important in the remote sensing area for satellite image processing [1, 2]. Today a lot of aircrafts are able to provide high quality images of the Earth surface.

A geometric transformation is an important step in remote sensing data (RSD) preprocessing. Aerospace scanner images usually have geometric distortions caused by the spacecraft motion, imaging conditions, and scanner system type. As distinct from analog photography, which covers a certain surface area at a time, pushbroom CCD scanners onboard today's satellites capture images by successively scanning the Earth's surface with a CCD line perpendicular to or along the spacecraft flight direction. Images captured by pushbroom CCD scanners have systematic and non-systematic distortions because each scanned line is obtained independently of the previous one and the spacecraft's geometric parameters at the instant of scanning of each individual line may differ [3]. So, this requires the development of geometric correction method for the Images captured by pushbroom CCD scanners

Methods of geometric correction of distortions caused by instability in the attitude position of an aerospace platform.

According to the RSD distortion type, appropriate methods of geometric correction are used. A 2D image of a ground surface area is obtained by combining individual scanned lines. Each line is captured at certain exterior orientation parameters that describe the ERS system position in the global coordinate system. For CCD scanners, the line capture frequency is several hundreds of hertz; along with scanners, ERS systems have positioning and orientation systems (POSs), which record data on the ERS system position and the exterior orientation parameters. The ERS system motion results in geometric distortions caused by instability in the attitude position of the aerospace platform and the velocity and height variation. This is especially clearly visible in images with linear objects. Fig. 1 shows a fragment of an aerospace image captured by a pushbroom CCD scanner.

No geometric transformation was applied to this image; angular, scale, and panoramic distortions can be seen therein. Fig. 2 shows an image of the same area; it was captured at another time and underwent a geometric transformation.

Figure 1 – Fragment of an aerospace image

Authoring

The image processed in this section was captured from an aircraft equipped with a multispectral CCD scanner. The aircraft height is 800 m, and the spatial resolution is about 0.6 m.

Figure 2 – Aerospace image with the geometric distortions removed

Authoring

The geometric position of the pixels in the image plane relative to the object plane is described by the collinearity equation:

$$\begin{bmatrix} x_s \\ y_s \\ -f \end{bmatrix} = \lambda \cdot \mathbf{R}^{\mathrm{T}} \begin{bmatrix} X_i - X_s \\ Y_i - Y_s \\ Z_i - Z_s \end{bmatrix} \tag{1}$$

where x_s and y_s are the coordinates of a point in the image coordinate system, f is the calibrated focal distance of the optical system, and λ is a scaling factor. For images produced by pushbroom CCD scanners, y_s=0. X_s , Y_s , and Z_s are the ground coordinates of the projection center, X_i , Y_i , Z_i are the coordinates of the point in the terrestrial coordinate system, and **R** is the rotation matrix of the coordinate system, which describes the rotation angles of the scanner system in space. If 6 exterior orientation parameters X_s , Y_s , Z_s, and 3 angles of the rotation matrix are known for each scanned line of a satellite image, it can be corrected by geometric transformation.

In actual practice, exterior orientation elements are not always perfect. For images captured by pushbroom CCD scanners, a method of correction with the use of the imaging device positioning and orientation system is employed. Positioning and orientation systems give the imaging parameters of each line for the calculation of the image exterior orientation parameters and the ground coordinates of the scanned lines. The method is efficient and may easily be automatized. However, the final correction accuracy may be affected by such factors as a low accuracy of the positioning and orientation system, poor synchronization between imaging and telemetry data, and a misalignment of the geometric center of the inertial navigation system, the perspective center of the lenses, and the phase center of the GPS antenna.

To correct images captured by pushbroom CCD scanners, ground control points (GCPs) and linear elements of images are successfully used [4], [5], [6]. In Ref. [7], an algorithm was proposed for correcting distortions caused by aerospace vehicle attitude position instability and the features of satellite image capture by pushbroom CCD scanners.

Using linear objects of images together with GCPs makes the geometric transformation process much easier and improves the image quality. In this work, a geometric transformation was applied to an aerospace image using linear objects and GCPs.

Geometric transformation by the proposed algorithm and evaluation of the results.

In the proposed algorithm of geometric transformation, an image is corrected using GCPs and linear objects. An image in which most of the distortions have already been eliminated is used as the reference image; this may be a panchromatic or multispectral image of the same area captured at the same or another time. It is desirable that the spatial resolution of the reference image be higher than or the same as that of the image to be corrected. GCPs are chosen in the reference image and the image to be corrected. In this work, they were chosen manually. According to Ref. [7], GCPs should be uniformly distributed over the images and cover nearly all their area. The GCP number was chosen according to experimental data; in Ref. [7], from 4 to 14 GCPs were used in processing RSD of high spatial resolution by similar methods.

To correct the effect of scanned line shift caused by a spacecraft inclination, use is made of linear objects that extend along the whole of the image to be corrected. These objects should have an elongated shape and a small width so that they may be interpreted as lines; they need not be straight. For this purpose, one may choose such objects as roads, rivers, and boundaries of two different surface types. At the start and the end of a line, GCPs are put in the reference and the uncorrected image.

The input data in the implemented method are the GCP coordinates and the linear elements distinguished in the uncorrected and the reference image (Figs. 3, 4).

Automatic identification of linear objects.

As distinct from GCPs, which can be chosen manually, distinguishing linear objects of an image is a very laborious process. Because of this, an automatic identification of linear objects was implemented.

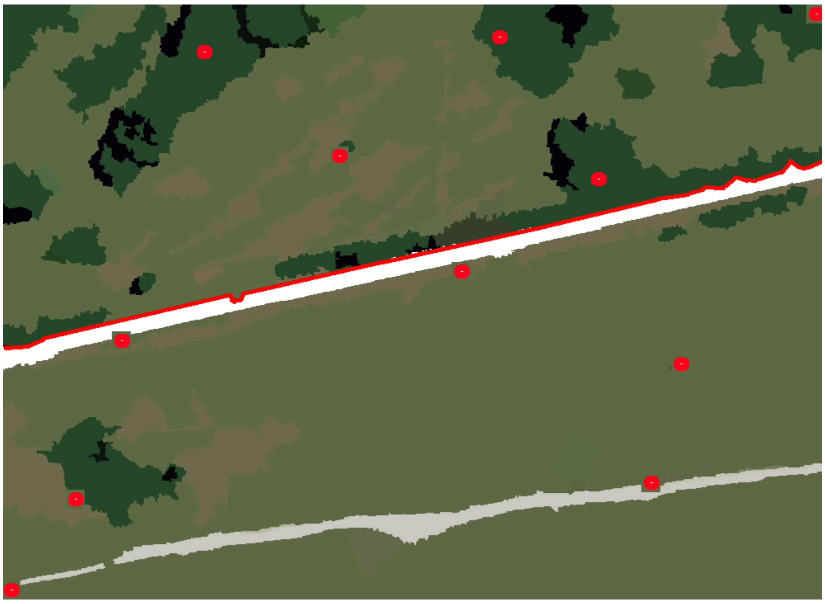

Figure 3 – Result of the classification and distinguishing of GCPs and linear objects in the reference image

Authoring

To identify linear objects, the classification algorithm proposed in Refs. [5] and [7] was applied to the reference and the uncorrected image. As a result, different classes were distinguished in the images.

Figure 4 – Result of the classification and distinguishing of GCPs and linear objects in the uncorrected image

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To apply a geometric transformation, one must have a linear element 1 pixel in width that extends throughout the fragment to be corrected in the craft flight direction. In the images shown in Figs. 3 and 4, a segment that falls into the "*road*" class was taken, and its boundaries were distinguished. In the geometric transformation, the boundary marked in Figs. 3 and 4 in red was used.

Image transformation.

First the image is scaled along the *x*- and the *y*-axis. In Figs. 3 and 4, the *x*-axis corresponds to the craft flight direction, and the *y*-axis is perpendicular thereto. The scaling parameters X_M and Y_M are calculated. Because the craft velocity is not constant, the *x*-axis scaling parameter X_M may vary along the image. The craft's exterior orientation parameters do not change instantaneously, and thus they may be considered constant over a certain time interval.

Let us take lines of the image in the flight direction between control points *i* and *i*+1. It may be assumed that the parameter $X_M(i)$ between points *i* and *i*+1 is constant and is determined as

$$X_M(i) = \frac{X_E(i+1) - X_E(i)}{X_T(i+1) - X_T(i)} \qquad (2)$$

where $X_E(i)$ and $X_T(i)$ are the *x*-coordinate of control point *i* in the reference and the transformed image, respectively.

The scaling along the *x*-axis eliminates the distortions caused by the craft velocity variation. Along the *y*-axis, the image may have panoramic or scale distortions; the scaling along the *y*-axis is performed similarly to that along the *x*-axis:

$$Y_M(i) = \frac{Y_E(i+1) - Y_E(i)}{Y_T(i+1) - Y_T(i)} \qquad (3)$$

where $Y_E(i)$ and $Y_T(i)$ are the *y*-coordinate of control point *i* in the reference and the transformed image, respectively.

When the images are brought to the same scale, the effect of angular distortions is eliminated.

Figure 5 – Aerospace scanner image after the geometric transformation
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On the scaling along the *x*- and the *y*-axis, the chosen linear element in the reference and the transformed image has the same length between GCPs. To each scanned line of the images, there corresponds one coordinate of the linear element, and thus the shift of the lines of the transformed image relative to those of the reference one can be calculated:

$$T_y^{\text{new}} = E_y - T_y \tag{4}$$

where T_y and E_y are the y-coordinates of the linear object in the transformed and the reference image, respectively.

On the geometric transformation, the image boundaries become uneven, which is caused by the line shift in the transformation process. The result of the geometric correction is shown in Fig. 5.

Summary and conclusions.

In this work, a method of geometric transformation of an aerospace image based on GCPs and linear elements of the image was implemented. To distinguish linear elements automatically, the author's algorithm of classification of high-resolution multispectral photogrammetric images was used.

References:

1. Shedlovska Y. I., Hnatushenko V. V. (2017). Visual search algorithm for high resolution satellite imagery. *Системні технології.*, No. 5 (112), pp. 18–25.

2. Shedlovska Y. I., Hnatushenko V. V. (2018) A Very High Resolution Satellite Imagery Classification Algorithm. *IEEE 38th International Scientific and Technical Conference "Electronics and Nanotechnology" ELNANO 2018*. April 24–28, 2018. Kyiv, Ukraine. Proceedings, pp. 654–657.

3. Gupta R. P. (2018). Remote Sensing Geology. Berlin, Springer. P. 428.
DOI: 10.1007/978-3-662-55876-8

4. Babapour H., Mokhtarzade M., Zoej M. A. (2016). Novel Post-Calibration Method for Digital Cameras Using Image Linear Features. International Journal of Remote Sensing, vol. 38, No. 8–10, pp. 2698–2716.
DOI: 10.1080/01431161.2016.1232875

5. Kim J., Kim T., Shin D., Kim S. (2017). Fast and Robust Geometric Correction for Mosaicking UAV Images with Narrow Overlaps. *International Journal of Remote Sensing*, vol 37, No. 8–10, pp. 2557–2576.
DOI: 10.1080/01431161.2017.1294779

6. Cao J. S., Yuan X. X., Fang Y., Gong J. Y. (2016) Geometric Calibration of Ziyuan-3 Three-Line Cameras Using Ground Control Lines. *Photogrammetric Engineering & Remote Sensing.*, vol. 82, No.11, pp. 893–902.
DOI: 10.14358/PERS.82.11.893

7. Hao Fang, Binlin Hu, Zhongjiang Yu, Huoxi Xu, Chuan He, Aihua Li & Yinnian Liu (2018) Semi-automatic geometric correction of airborne hyperspectral push-broom images using ground control points and linear features. *International journal of remote sensing*, vol.39, No.12. pp. 4115–4129.
DOI: 10.1080/01431161.2018.1455237