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RESEARCH OF THE ATTITUDE DATA CORRECTION METHOD FOR THE UAV REMOTE SENSING IMAGES OF INACCESSIBLE AREAS IN LANDSCAPE ARCHITECTURE

Получение изображений высокого разрешения с применением малой авиации играет все более значительную роль в области применения фотограмметрии и дистанционного зондирования. Для коррекции данных дистанционного зондирования без опорных точек необходимы точные данные внешнего ориентирования. Начальные данные ориентирования могут быть получены с помощью GPS/INS. В данной статье проводится анализ ошибок данных ориентирования и предлагается метод высокоточной коррекции без использования опорных точек.

As an important way to obtain the high-resolution remote sensing images, the unmanned aerial vehicle (UAV) aviation remote sensing plays a more and more important role in the area of photogrammetry and remote sensing application. The correction of the UAV remote sensing images without the ground control points needs high-resolution attitude data. The original attitude data can be obtained from the UAV airborne GPS/INS.

The attitude data error analysis and correction method is proposed, and the corresponding error calibration mode is established in this paper to realize high-precision correction without the ground control points.

Introduction.

With the rapid development of civil remote sensing recently, the demand for remote sensing image is increasing, especially large-scale and high-resolution remote sensing images.

At present, the main information acquisition platforms of the world are still satellite and manned plane. The shortcomings of the satellite remote sensing platform are high price and long return cycle, so when high-resolution images are got, the update speed of the images is slow. While the manned-plane remote sensing system is mainly limited by rising-landing and safety condition, it is unable to satisfy the users' requests about safety.

As a new and effective type of earth observation system, the UAV remote sensing information platform is proposed to obtain remote sensing images at present.
Its main characteristics are as follows:

1. Without considering human factors by auto-control flight;
2. The flight mode is flexible and have long flight time;
3. High flight trajectory precision;
4. Flying under the clouds.

These characteristics enable the UAV aviation remote sensing information platform to become an effective supplement way to the satellite and manned-plane remote sensing UAV can realize auto-control flight as an aviation remote sensing platform, and the position and attitude data of the airplane can be obtained directly through the airborne GPS/INS integrated navigation system. But if we regard this group of posture data as the corrected exterior orientation elements for the images, it must carry on coordinate transformation and systematic error compensation in order to convert the aircraft attitude data obtained from inertial navigation system to the high-precision exterior orientation elements for the images. This systematic error mainly refers to the spatial displacements and the deviation angle error. Though the spatial displacement between the GPS antenna phase centre and the camera projection center is easy to get, the deviation angle error can't be determined directly through the traditional method. This error seriously affects the correction precision of the UAV remote sensing images.

At present, in aerial photogrammetry assisted by the manned plane airborne GPS/INS, two calibration methods are generally used to correct the deviation angle error:

- one way is that the ground control points is firstly laid out in the survey area, then each photo's exterior orientation elements directly obtained from GPS/INS as weighted observation value participate in the photogrammetry block adjustment. So we can obtain higher precision exterior orientation elements for the images;

- another method is that the region which includes two (or more) flight strips in or near the survey area as calibration field is firstly selected, then the exterior orientation element of each aerial photo is exactly determined through the method of aerial triangulation. After that, matrix operation is carried out using the exterior orientation elements computed above and observation values including deviation angle error obtained from the GPS/INS system, then the deviation angle error can be got. This way is called direct orientation method.

The first way needs to lay out ground control points in the whole operation range, which not only restricts operation range, but also decreases work efficiency and enlarges the cost of operation.

Based on the second way, according to the UAV’s operation standard and corresponding instrument indexes, in this paper the attitude data correction mathematical model of the UAV aerial remote sensing image is established and the right deviation angle error is calculated.

So the original aerial attitude data obtained from the GPS/INS system can be transformed to the images’ exterior orientation elements which are needed for direct georeferencing in aerial photogrammetry (Hongying, 2008).

Systematic error correction model for the UAV airborne GPS/INS.

The UAV airborne GPS/INS integrated navigation system is a position and azimuth determining system composed of GPS receiver and Inertial Measurement Unit (IMU), it can be used to obtain the moving vehicle’s spatial three dimensional position and attitude data.

- Coordinate System Transformation:

The original attitude data (θ ,φ ,ψ) acquired from UAV airborne IMU is the corresponding coordinate axes’ angles between IMU Coordinates System and Navigation Coordinates System (moving); while the exterior orientation elements of the images (φ,ω,κ) is the corresponding coordinate axes’ angles between image Coordinates System and terrestrial photogrammetry coordinates system.

Therefore, we must first transform the UAV airborne IMU attitude data (θ ,φ ,ψ) from navigation coordinates system (moving) to terrestrial photogrammetry coordinates system in order to obtain the exterior orientation elements of the images (Bäumker, 2002).

Figure 1 shows the concrete conversion process.

- Deviation Angle Error:

For apparatus installation technology’s reasons, the axes of IMU coordinates system aren’t exactly parallel to that of camera coordinates system when installing. Generally there exists exiguous angle deviation (< 3deg) between the corresponding axes of this two coordinates. We call it deviation angle error usually (Figure 2).

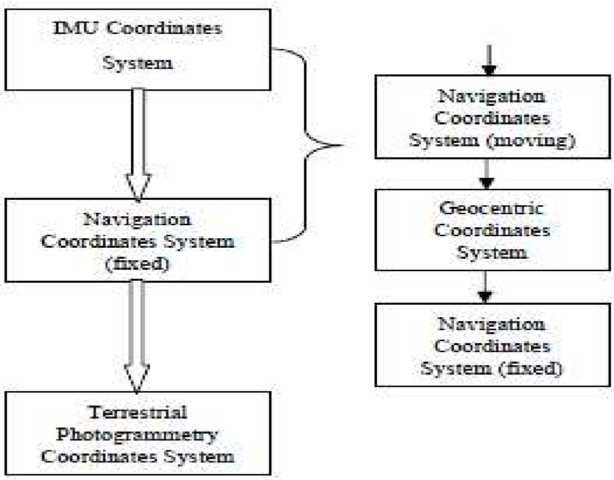

Fig. 1. The flow chart of coordinate transformation for UAV attitude data.

In Figure 2, *xb*, *yb*, *zb* respectively represents three axes of IMU coordinate system, and *xc*, *yc*, *zc* respectively represents three axes of camera coordinate system. Camera coordinates system separately rotates a*z*, *ay*, *ax* around the z axis,y axis and x axis relatively to IMU coordinate system. This group of deviation angle error can't be determined directly by the conventional measurement method, so other methods are needed to use to obtain them.

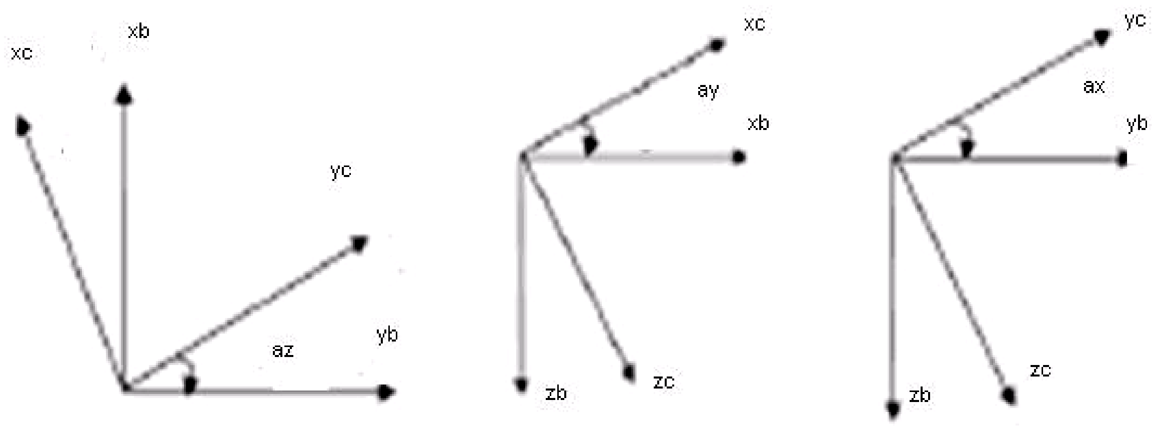

Fig. 2. Deviation angles (az, ay, ax) from camera coordinate to IMU Coordinate.

- Deviation Angle Error Correction Model:

Images' exterior orientation elements obtained after coordinate system transformation are still affected by the deviation angle error. This error can't be acquired through the conventional measurement method, so the images which have known exterior orientation elements can be utilized to obtain this error indirectly.

First, one calibration region which has enough quantity and precision ground control points is selected to proceed calibration flight, then the exterior orientation element of each image is calculated by the conventional method.

Finally, the best estimated value of the deviation angle error (ax,ay,az) is calculated using the exterior orientation elements computed above and the original attitude data obtained from IMU. The concrete computing process is as follows.

According to this group of deviation angle error(ax ,ay , az), the rotation matrix Rbc from camera coordinate system c to IMU coordinate system b is established. And because az, ay, ax are all less than 3deg , this matrix can be simplified according to the related knowledge of inertial navigation (Skaloud, 2003).

$$R_c^b = R_y(\alpha_y)\cdot R_x(\alpha_x)\cdot R_z(\alpha_z)$$
$$= \begin{bmatrix} \cos\alpha_y & 0 & -\sin\alpha_y \\ 0 & 1 & 0 \\ \sin\alpha_y & 0 & \cos\alpha_y \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha_x & -\sin\alpha_x \\ 0 & \sin\alpha_x & \cos\alpha_x \end{bmatrix} \cdot \begin{bmatrix} \cos\alpha_z & -\sin\alpha_z & 0 \\ \sin\alpha_z & \cos\alpha_z & 0 \\ 0 & 0 & 1 \end{bmatrix}$$
$$= \begin{bmatrix} 1 & -\alpha_z & -\alpha_y \\ \alpha_z & 1 & -\alpha_x \\ \alpha_y & \alpha_x & 1 \end{bmatrix} \quad (1)$$

According to the flow chart of coordinate transformation in Figure 1, the rotation matrix *Rlc* from camera coordinate system c to terrestrial photogrammetry coordinate system L is set up. *Rlb* is the rotation matrix from IMU coordinate system to terrestrial photogrammetry coordinates system. Thus, we can get formula (2) and (3)

$Rlc = Rlb \cdot Rbc = Ry\,\varphi \cdot Rx\,\omega \cdot Rz\,\kappa$ (2)

$Rlb = Ry\,\theta \cdot Rx\,\varphi \cdot Rz\,\psi$ (3)

In formula (2), the other parts can be all computed except *Rbc* , and the elements in *Rbc* are just the deviation angle error, which are we want to calculate. After expanding this formula, we can get a set of observation equations $AX = L$ about (ax ,ay ,az), where X = (ax ay Az)T is the unknown quantity, and the corresponding error equations is V=AX-L

For each image i, a set of Vi=AiX-Li can be list out. According to s the related knowledge of surveying adjustment, we can know

$X = (A^T \cdot A)^{-1} \cdot A^T \cdot L$

Supposed that there are two images, then:

$$X = \left(\begin{pmatrix} A_1 \\ A_2 \end{pmatrix}^T \cdot \begin{pmatrix} A_1 \\ A_2 \end{pmatrix} \right)^{-1} \cdot \begin{pmatrix} A_1 \\ A_2 \end{pmatrix}^T \cdot \begin{pmatrix} L_1 \\ L_2 \end{pmatrix} = \left(A_1^T \cdot A_1 + A_2^T \cdot A_2 \right)^{-1} \cdot \left(A_1^T \cdot L_1 + A_2^T \cdot L_2 \right) \quad (4)$$

Thus the deviation angle error (ax ay az) between IMU coordinate system and camera coordinate system can be obtained.

We can use this group of error through formula (2) to correct the IMU attitude data which have been transformed in the terrestrial photogrammetry coordinates system, in order to acquire the higher precision exterior orientation elements of the UAV images.

Thus we complete correcting the original attitude data obtained from the UAV airborne GPS/INS inertial navigation system (meanwhile, the accuracy of deviation angle error is affected by other systematic errors of the GPS / IMU, such as the error of gyro random drift etc.).

Test of UAV- low-height remote sensing images correction model showed upper will be executed in the future practice studies of landscape architecture imagery with small, unmanned aircraft.

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