Rectification Algorithm for Linear Pushbroom Image of UAV

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SUMMARY

This research presents a method of rectification for the image flow acquired by UAV. The sensor on the UAV is a multi-channel push broom sensor. The linear array can cover a stripe with approximately 6 Km on the ground. The motions (roll, pitch, yaw, etc) of the UVA platform are influenced by the relatively low-altitude flying so that have the attitude changed which are terrible to produce severe distortion of image. Therefore, a three-step rectification method is developed by means of the DEM and GCPs (ground control points) of study area, as well as data of the positioning instruments (GPS, INS) on the UVA platform.

Firstly, The external orientation parameters (position, attitude, six for each image line) of each linear array are calculated with data provided by the positioning instruments (GPS, INS), and then, the collinearity equation for multi-lens sensors is adopted with combining with the DEM data, therefore, the original image can be rectified to level one (L1) image, which meets the requirements for accepted visibility. Secondly, a reference image is used and several GCPs are selected in order to produce Level two (L2) image with enhanced polynomials. The third step of the rectification is an essential process using partial distortion model which geometrically stretch the local image. Many experiments have been carried out in different conditions and areas using the method mentioned above. The results present the three step rectification is feasible and effective.

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1. INTRODUCTION

In recent years, unmanned aerial vehicle (UAV) has become a strong supplement and an important complement for satellite and manned aerial remote sensing, because UAV has the ability to cover a large area, flight at higher altitude than before, and be not restricted to traveling on the dangerous place. This research presents a method of rectification for the image flow acquired by UAV.
With regard of our project, different types of sensors have been loaded on the UVA, one of them is the multi-channel push broom sensor. Each linear array of the sensor consists of 6000 pixel array of CCDs which include blue, green, red and IR bands. The linear array can cover a stripe with approximately 6 Km on the ground. The motions (roll, pitch, yaw, etc) of the UVA platform are influenced by the relatively low-altitude flying so that have the attitude changed which are terrible to produce severe distortion of image. Therefore, a three-step rectification method is developed by mean of the DEM and GCPs (ground control points) of study area, as well as data of the positioning instruments (GPS, INS) on the UVA platform.

2. METHODOLOGY

The work follow of the three-step rectification method is expressed as Figure 1 as below:

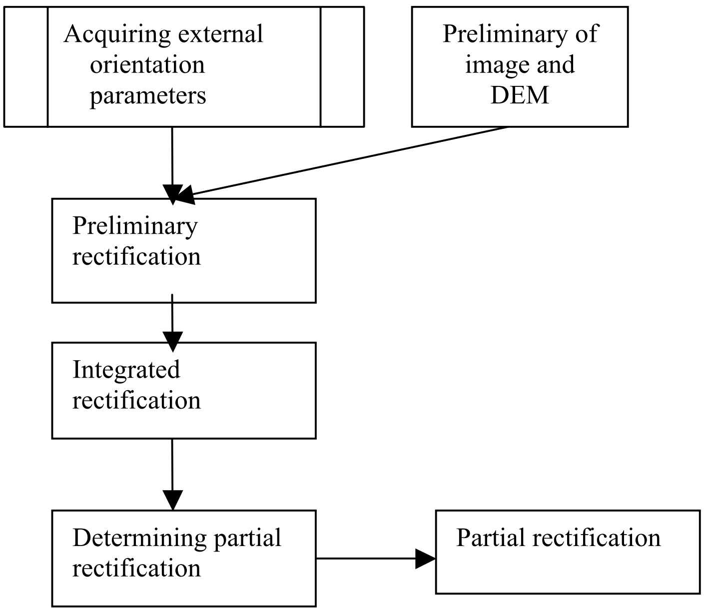

Figure 1. Flowchart of three-step rectification

2.1 Preliminary rectification

Firstly, The external orientation parameters (position, attitude, six for each image line) of each linear array are calculated with data provided by the positioning instruments (GPS, INS), and then, the collinearity equation for multi-lens sensors is adopted with combining with the DEM data, finally, the original image can be rectified to level one (L1) image, 6000X6000 pixels in size approximately, which meets the requirements for accepted visibility.

Function of calculating appoxmating coordinates of the correspoding ground point of each pixel by line:

$$X' = X_S(l) + (Z_0 - Z_S(l))\frac{a_1(l)x - a_3(l)f}{c_1(l)x - c_3(l)f}$$

$$Y' = Y_S(l) + (Z_0 - Z_S(l))\frac{b_1(l)x - b_3(l)f}{c_1(l)x - c_3(l)f}$$

Where:

X’,Y’ mean coordinates of ground point;
Z_0 means appoxmating coordinates of ground point;
Xs(l), Ys(l), Zs(l), a1(l), a2(l), a3(l),........c1(l), c2(l), c3(l) mean the external orientation paraments of line l;
f means the principle focus and
x means the coordinate of a pixel in a line.

Amount them , the coordinate of Z_i can be interpolzted by appoxmating coordinates of ground point;X’, Y’ and the given DEM. The iterateion is carried till the difference between $(X_{i+1},Y_{i+1},Z_{i+1})$ and (X_i,Y_i,Z_i) is less than a given difference.

2.2 Integrated rectification

The positioning accuracy of the L1 image is not sufficient for more precision mapping since the pose and attitude of the vehicle is not stable and the parameters provided by the GPS and INS have additional systematic errors in the measurements, therefore further correction to the L1 image is required. In our approach, the sensor geometry is modeled with enhanced polynomials because this kind of functions is very flexible and can be adapted to different flight conditions. In this step, it is necessary that a reference image is used and several GCPs are selected in order to produce Level two (L2) image.
Here an enhanced cubic polynomial is used as below:

$$x = a_0 + a_1X + a_2Y + a_3Z + a_4XY + a_5YZ + a_6ZX + a_7X^2 + a_8Y^2 + a_9Z\text{£¨} + a_{10}XY^2$$
$$+ a_{11}XZ^2 + a_{12}XYZ + a_{13}X^2Y + a_{15}X^2Z + a_{16}X^3 + a_{17}YZ^2 + a_{18}Y^2Z + a_{19}Z^3\text{£©}$$
$$y = b_0 + b_1X + b_2Y + b_3Z + b_4XY + b_5YZ + b_6ZX + b_7X^2 + b_8Y^2 + b_9Z\text{£¨} + b_{10}XY^2$$
$$+ b_{11}XZ^2 + b_{12}XYZ + b_{13}X^2Y + b_{15}X^2Z + b_{16}X^3 + b_{17}YZ^2 + b_{18}Y^2Z + b_{19}Z^3\text{£©}$$

Where:

X, Y, Z are the coordinates of the ground control point;

a_0~a_{19}, b_0~b_{19} mean the coefficient of the enhanced cubic polynomial;

x,y mean the coordinates of the pixel.

Here, more than ten ground control points shoud be required to implement the intergrated rectification.

2.3 Partial rectification

The original image generally has been rectified after two steps mentioned above, consequently, some errors caused by certain factors have been removed. However, the geometrical distortions of the pushbroom image are complicated and can not be simulated using a single function, which result in partial distortions in the L2 image. The third step of the rectification is an essential process using partial distortion model which geometrically stretch the local image.

Firstly, the dense GCPs are matched to L2 image, which display and calculate whether exist the partial distortions or not. Secondly, to segment the whole L2 image to neighboring partial images, Delaunay triangle transformation algorithm, a scheme of disassembling the entire image into multi-triangles to form a network, is introduced, and the GCPs are used as the vertexes of the triangle in the network.

The image is divided by 20 x 20 grids, which 300 x 300 pixels are included in each grid shown as figure 2 as below.

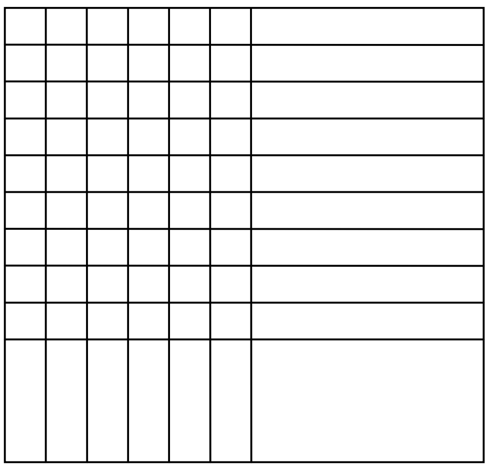

Figure 2. Image is divided by 20 x 20 grids

The partial rectification impulation is as following as below:

(1) 1- 3 GCPs are selected by manual in order to acquire X' and Y' coordinates of the image;

(2) obtain the actual coordinateds of X, Y and Z;

(3) calculating the difference of the X, Y and Z by the fomula:

$$\Delta X=X'-X,\quad \Delta Y=Y'-Y$$

(4) If $\Delta S = \sqrt{\Delta X^2 + \Delta Y^2} > T$

the GCP is marked as pending rectification, otherwise, the GCP is corrected.

Where: ΔS means the distance between the actual point and the pending rectification point;

T means a threshold value.

(5) Extracting all of the corrected points and the pending rectificated points, building TIN by the Delauney Triangulation or Angle Judgement.

(6) Determining the pixels which belong to some triangulation and then, the image is divided to several triangulations by the pixels.

(7) in each triangle, the partial image pixels are corrected using the geometrical stretch method and meanwhile, the adjacency of each triangle must keep the coherence. The L3 image can be obtained and is the final delivery after the third step of the rectification is completed. After the pending point of "a" is rectified to the corrction point of "A", the partial rectification of the image is implemented, which is shown in Figure 3.

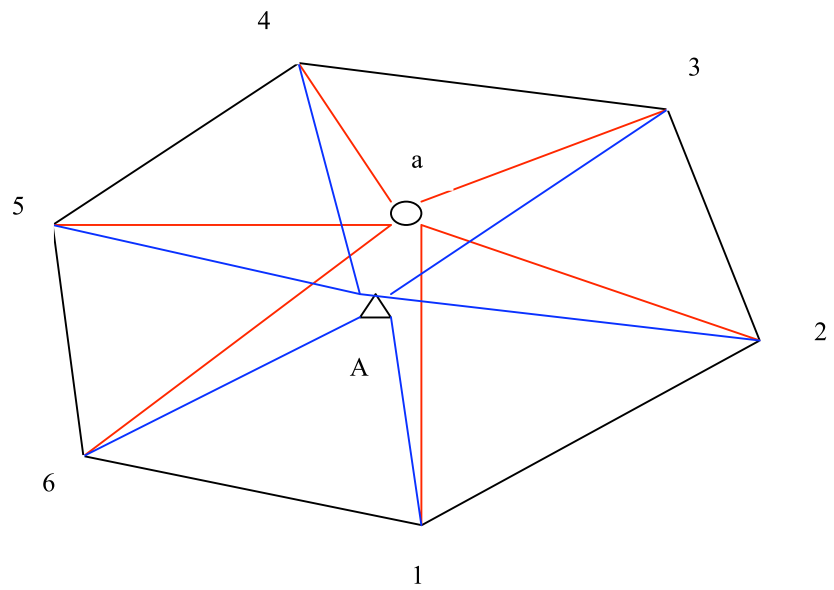

Figure 3. Partial rectification of the image

Figure 4 shows an example of the triangle12a rectified to the triangle12A, which the algorithm is following as below:

⊖ Computing the difference between point a and pint A in X direction and Y direction, $\Delta X = X_a - X_A$
$\Delta Y = Y_a - Y_A$

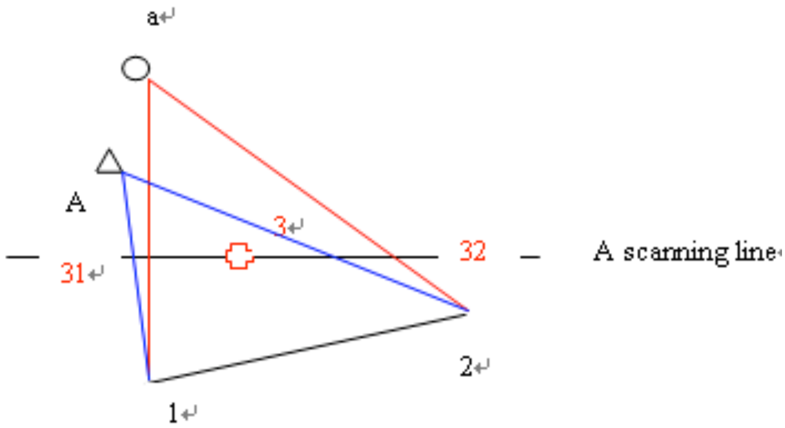

Figure 4. An example of the triangle12a rectified to the triangle12A

⊜ A pending point 3, its coodinate are $X_3^{'}, Y_3^{'}$, shown in Fig.4, along the scaning line of 3 point,computing two intersection points, 31(X_{31},Y_{31}) and 32(X_{32},Y_{32}), of the triangle 12a and the scaning line.

$$Y_{31} = Y_3, Y_{32} = Y_3$$

$$X_{31} = \frac{X_a - X_1}{Y_a - Y_1} \times (Y_{31} - Y_1) + X_1$$

$$X_{32} = \frac{X_a - X_2}{Y_a - Y_{21}} \times (Y_{32} - Y_{21}) + X_1$$

⊛ According to the placement of point a, along 1a and 2a, taking linear interpolation to calculate the placement values of point 31 and point 32 respectively.

$$DX_{31} = \frac{X_{31} - X_1}{X_a - X_1} \times \Delta X$$

$$DY_{31} = \frac{Y_{31} - Y_1}{Y_a - Y_1} \times \Delta Y$$

$$DX_{32} = \frac{X_{32} - X_2}{X_a - X_2} \times \Delta X$$

$$DY_{32} = \frac{Y_{32} - Y_2}{Y_a - Y_2} \times \Delta Y$$

④ Based on the placemnet values of point 31 and point 32 above, along the scanning line of 31 and 32, taking the linear interpolation to calculate ΔX_3 andΔY_3 of point 3.

$$\Delta X_3 = \frac{X_3 - X_{31}}{X_{32} - X_{31}}(DX_{32} - DX_{31}) + DX_{31}$$

$$\Delta Y_3 = \frac{Y_3 - Y_{31}}{Y_{32} - Y_{31}}(DY_{32} - DY_{31}) + DY_{31}$$

⑤ The coodinate values (X_3, Y_3) of geometrical stretched point 3 are obtained after $X_3^{'}, Y_3^{'}$ of point 3 plus ΔX_3, ΔY of point 3.

$$X_3 = X_3^{'} + \Delta X_3$$

$$Y_3 = Y_3^{'} + \Delta Y_3$$

⑥ Finally, the grey value of point 3 is acquired by resampling.

3. CONCLUSION

Many experiments have been carried out in different conditions and areas using the method mentioned above. The results that present the three step rectification are feasible and effective.

REFERENCES

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BIOGRAPHICAL NOTES

Dr. Ruoming Shi, associate professor, obtained PHD in China University of Geosciences and M.Eng in Asia Institute of Technology, teaches and works in remote sensing and GIS for about ten years.

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