ORIENTATION DETERMINATION OF UAV IMAGES USING POINT AND LINE CONTROL

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ABSTRACT:

Compared to traditional aircrafts, unmanned aerial vehicles (UAV) practice lower cost of operation with higher flexibility in photogrammetric measurements. However, the exterior orientation parameters (EOPs) of many UAV cameras may not be precise enough for direct georeferencing without ground control. This study is to adjust the EOPs of an UAV by the combination of point and line control. In addition to the ground control points (GCPs), ground control lines (GCLs) are also employed in the orientation modeling.
Based on the colllinearity condition equations, GCPs and GCLs are integrated in the orientation modeling. Line-based collinearity condition equations are formulated, where each GCL is expressed in parametric form. Thus, the extracted feature lines are represented using parametric equations. The proposed model takes those parameters into consideration instead of the start and end point of the linear features.
The GCPs and GCLs are employed in the orientation modeling using space resection. This study utilizes three kinds of collinearity condition equations. The first one is based on point control. The second one is based on line control. The third one is the combination of point and line control. The experimental results of this study were validated using a Canon EOS Mark 5D II camera on a Microdrones MD4-1000 UAV. The contribution of GCPs and GCLs were analyzed.

1. INTRODUCTION

Orientation determination is an important part of in photogrammetric measurements. To determinate the EOPs of imagery, we select the straightforward approach which is called space resection. Different control entities can be used for orientation determination, such as control points, control lines, control surfaces, etc. Control points are the basic control features so that point-based space resection is widely used. Linear features can be measured from artificial constructions. This study used both point and line control for orientation determination simultaneously.

2. METHODOLOGY

This study utilizes three kinds of adjustment models for UAV image orientation determination, i.e., space resection by point control, by line control and by both point and line control. The adjustment model is based on the collinearity condition.

2.1 Space Resection by Point Control

Space resection employs the collinearity condition equations to determine the orientation of imagery. The collinearity condition equations utilize the geometric position of a perspective center, an image point and its corresponding object point. The equations are shown in Equation 1. Since the equations are non-linear, the linearlized equations are needed to determine the exterior orientation parameters. Equation 2 and 3 shows the linearlized equations.

$$
\begin{aligned}
x &= x_0 - f\frac{m_{11}(X-X^C)+m_{12}(Y-Y^C)+m_{13}(Z-Z^C)}{m_{31}(X-X^C)+m_{32}(Y-Y^C)+m_{33}(Z-Z^C)} \\
y &= y_0 - f\frac{m_{21}(X-X^C)+m_{22}(Y-Y^C)+m_{23}(Z-Z^C)}{m_{31}(X-X^C)+m_{32}(Y-Y^C)+m_{33}(Z-Z^C)}
\end{aligned}
\qquad (1)
$$

In Equation 1, x, y are the image coordinates; x_0, y_0 are the principle point offsets; f is the focal length; m_{11}~m_{33} are the rotation matrixes of the rotation angle; X, Y, Z are the object coordinates; X^C, Y^C, Z^C are the object coordinates of perspective center.

$$V_P = B_P \Delta_P - L_P \tag{2}$$

$$\begin{bmatrix} v_{x1} \\ v_{y1} \\ \vdots \\ v_{xn} \\ v_{yn} \end{bmatrix}_{n\times 1} = \begin{bmatrix} \frac{\partial F_{x1}}{\partial X^C} & \frac{\partial F_{x1}}{\partial Y^C} & \frac{\partial F_{x1}}{\partial Z^C} & \frac{\partial F_{x1}}{\partial \omega^C} & \frac{\partial F_{x1}}{\partial \varphi^C} & \frac{\partial F_{x1}}{\partial \kappa^C} \\ \frac{\partial F_{y1}}{\partial X^C} & \frac{\partial F_{y1}}{\partial Y^C} & \frac{\partial F_{y1}}{\partial Z^C} & \frac{\partial F_{y1}}{\partial \omega^C} & \frac{\partial F_{y1}}{\partial \varphi^C} & \frac{\partial F_{y1}}{\partial \kappa^C} \\ & & & \vdots & & \\ \frac{\partial F_{xn}}{\partial X^C} & \frac{\partial F_{xn}}{\partial Y^C} & \frac{\partial F_{xn}}{\partial Z^C} & \frac{\partial F_{xn}}{\partial \omega^C} & \frac{\partial F_{xn}}{\partial \varphi^C} & \frac{\partial F_{xn}}{\partial \kappa^C} \\ \frac{\partial F_{yn}}{\partial X^C} & \frac{\partial F_{yn}}{\partial Y^C} & \frac{\partial F_{yn}}{\partial Z^C} & \frac{\partial F_{yn}}{\partial \omega^C} & \frac{\partial F_{yn}}{\partial \varphi^C} & \frac{\partial F_{yn}}{\partial \kappa^C} \end{bmatrix}_{2n\times 6} \begin{bmatrix} dX^C \\ dY^C \\ dZ^C \\ d\omega^C \\ d\varphi^C \\ d\kappa^C \end{bmatrix}_{6\times 1} - \begin{bmatrix} F_{x1} \\ F_{y1} \\ \vdots \\ F_{xn} \\ F_{yn} \end{bmatrix}_{2n\times 1} \tag{3}$$

In Equation 2, V_P is the vector of residual errors, B_P is the matrix of coefficients; Δ_P is the vector of unknown corrections (rotation angles); L_P is the vector of observation functions. In equation 3, n is the number of point control.

2.2 Space Resection by Line Control

This model employs linear features for orientation determination. Each GCL is expressed in parametric form, which means the feature lines are presented by parametric equations. The parametric model of a line is shown in Equation 1. By combining Equation 1 and 4, the model of collinearity condition equation using linear features is established. Equation 5 shows the space resection model using line control. In addition to the EOPs, the scale factors of the lines are also the unknowns in the adjustment.

$$\begin{cases} x = x_{a_0} + S_x\, t \\ y = y_{a_0} + S_y\, t \end{cases} \tag{4}$$

In Equation 4, x_{a_0}, y_{a_0} are the starting point of a line; S_x, S_y are the direction vector and t is the scale factor.

$$V_L = [B_{L1} \quad B_{L1}] \begin{bmatrix} \Delta_P \\ \Delta_L \end{bmatrix} - L_L \tag{5}$$

In Equation 5, V_L is the vector of residual errors, B_{L1}, B_{L1} are the matrixes of coefficients; Δ_P, Δ_L are the vector of unknown corrections (rotation angles and scale factors); L_L is the vector of observation functions.

2.3 Space Resection by Point and Line Control

In order to improve the accuracy of orientation determination, both GCPs and GCLs are integrated in the orientation modeling. The model (Equation 6) can be established by combining Equation 2 and 5.

$$\begin{bmatrix} V_P \\ V_L \end{bmatrix} = \begin{bmatrix} B_P & 0 \\ B_{L1} & B_{L1} \end{bmatrix} \begin{bmatrix} \Delta_P \\ \Delta_L \end{bmatrix} - \begin{bmatrix} L_P \\ L_L \end{bmatrix} \tag{6}$$

3. EXPERIMENTAL RESULTS

The experimental data is an UAV image. The UAV image was acquired by a Canon EOS Mark 5D II camera on a Microdrones MD4-1000 UAV. The image size is 5616 x 3744 pixels. The ground resolution is about 6cm. The reference data is measured from space triangulation model using two UltraCam images and three mid-frame images. The ground resolution of UltraCam is about 24cm. The ground resolution of mid-frame is about 15cm. The space triangulation model $RMSE_x$ is 0.632 pix and $RMSE_y$ is 0.694 pix. The 15 GCPs, 9GCLs and 20 check points are measured from these images. Figure 1 shows the distribution of GCPs, GCLs and check points with UAV image.
The results of UAV image orientation determination are shown in Table 1. The Figure 2 illustrates the results of different combination of GCPs and GCLs. The RMSE is decreased after adding GCLs to point-based model. The addition GCLs improved the accuracy of orientation determination.

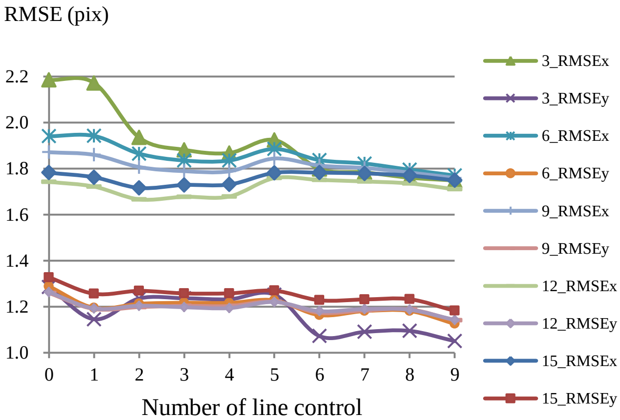
Table 1. Results of UAV image orientation determination

		Numbers of line control									
		0		1		3		6		9	
		$RMSE_x$	$RMSE_y$	$RMSE_x$	$RMSE_y$	$RMSE_x$	$RMSE_y$	$RMSE_x$	$RMSE_y$	$RMSE_x$	$RMSE_y$
Numbers of point control	0	-	-	-	-	2.127	1.801	2.136	1.402	1.697	1.064
	1	-	-	-	-	1.799	1.473	2.087	1.373	1.795	1.058
	3	2.185	1.286	2.172	1.145	1.882	1.236	1.798	1.072	1.748	1.050
	6	1.941	1.288	1.942	1.195	1.835	1.217	1.837	1.163	1.770	1.125
	9	1.871	1.259	1.860	1.190	1.789	1.203	1.813	1.173	1.759	1.140
	12	1.742	1.262	1.722	1.192	1.677	1.197	1.751	1.180	1.710	1.142
	15	1.782	1.327	1.762	1.256	1.729	1.258	1.782	1.228	1.749	1.182

(unit: pixel)

▲ GCPs — GCLs ● check points

Figure 1. Distribution of GCPs, GCLs and check points



(p_RMSE, p: number of point control)

Figure 2. Result of different combination of GCPs and GCLs

4. CONCLUSIONS

In this study, we obtained the EOPs of UAV image by the combination of GCPs and GCLs. The accuracy of two features' combination is better than using two features separately. In order to automate the entire scheme, the future work will concentrate on linear feature registration, which is to establish the correspondence of image features and object space automatically.

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