Journal of King Saud University – Engineering Sciences (2015) 27, 108–113

King Saud University

Journal of King Saud University – Engineering Sciences

www.ksu.edu.sa
www.sciencedirect.com

ORIGINAL ARTICLE

A solution for exterior and relative orientation in photogrammetry, a genetic evolution approach

Elgasim Elamin Elnima *

Ribat National University, Khartoum, Sudan

Received 8 January 2013; accepted 12 May 2013
Available online 22 May 2013

KEYWORDS
Exterior orientation;
Photogrammetry;
Genetic;
Ground Control

Abstract Space resection is a technique that is commonly used to determine the exterior orientation parameters associated with one image or many images based on known Ground Control Points (GCPs). The term "exterior orientation" of an image refers to its position and orientation related to an exterior coordinate system. Several methods can be applied to determine the parameters of the orientation of one, two or more photos. Several methods have also been developed for the orientation of single photo. They are based on some characteristics of imaged objects. Chen and Shibasaki (1998), Cooper and Robson (1996), Dewitt (1996).

In this paper, we present a solution for the determination of the exterior orientation parameters (space resection) based on genetic evolution algorithms. This optimization model for space resection can be implemented with or without redundancy and requires no linearization. The proposed model is simple and converges to the global optimal solution.

1. Introduction

The exterior orientation aims to define the position and rotation of the camera at the instant of exposure. In photogrammetry, three fundamental conditions are frequently used to compute the exterior orientation parameters. These conditions are known as collinearity, coplanarity and coangularity conditions. All the solutions based on the conditions mentioned so far, use point coordinates as input data.

Several methods can be applied to determine the parameters of the orientation of single photo.

If we consider the orientation of a single image, the topological and geometrical characteristics of the imaged scene are used with the measurements in the image to determine the orientation parameters. These characteristics are considered as scene constraints (e.g. perpendicularity, parallelism, co-planarity). The relationship between camera space and object space is given by the perspective projection model of the camera.

The method presented in this paper implements genetic evolution algorithms for determining exterior orientation parameters in aerial and terrestrial photogrammetry. Good results are achieved which are comparable to the well-known methods.

* Mobile: +249 919391971.
E-mail address: Elgasim@gmail.com.

Peer review under responsibility of King Saud University.

ELSEVIER Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jksues.2013.05.004
1018-3639

2. Related research

This section is a brief review of the research pertinent to our work. Liu et al. (1990) solved for the camera rotation first and then the camera translation which works for both point and line data. They considered three camera rotation angles as obtained from a nominal orientation by small perturbations, e.g., 0°. Based on this assumption, their algorithm only works if the three camera Euler rotation angles are less than 30°. Kumar and Hanson (1989) solved for the rotation and translation simultaneously by adapting an iterative technique. The initial estimates for translation and rotation are required to make the nonlinear algorithm converge. They reported that the initial rotation estimates for some data sets must be within 40° for all the three Euler angles representing the rotation. Taylor et al. (1991) estimated both the camera positions and the structure of the scene from multiple images. Based on a random initial estimate of rotation, the translation and model parameters are computed as initial inputs for the subsequent model-to-image fitting procedure. If the disparity between predicted edges and the observed edges is smaller than some preset threshold, the minimum is accepted as a feasible estimate.

Other Solutions for Exterior Orientation are presented by:

Chen and Shibasaki (1998), determination of camera's orientation parameters based on line features;
Grussenmeyer and Al Khalil (2002), solutions for exterior orientation in photogrammetry: a review;
Seedahmed (2006), direct retrieval of exterior orientation parameters using a 2-D projective transformation;
Smith and Park (2000), absolute and exterior orientation using linear features;
Wang (1992), a rigorous photogrammetric adjustment algorithm based on co-angularity condition;
Zeng et al. (1992), a general solution of a closed-form space resection.

3. Collinearity conditions

The collinearity condition expresses the basic relationship in which an object point and its image lies on a straight line passing through the perspective center (Fig. 1):

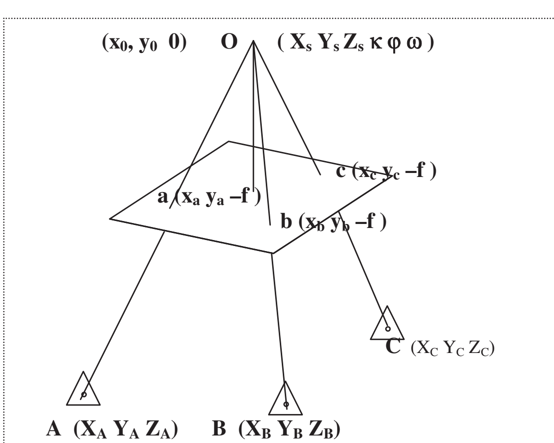

Figure 1 Collinearity conditions.

$$\begin{pmatrix} x - x_0 \\ y - y_0 \\ -f \end{pmatrix} = \lambda \mathbf{R} \begin{pmatrix} X - Xs \\ Y - Ys \\ Z - Zs \end{pmatrix} \quad \text{or} \quad \mathbf{a} = k\mathbf{R}A \tag{1}$$

- A is the vector from the perspective center to the point expressed in the object space coordinate system,
- **a** is the corresponding vector expressed in the camera space coordinate system (f is the principal distance of the camera, x_0 and y_0 are the coordinates of the principal point),
- X, Y, Z are the coordinates of the object-point and Xs, Ys, Zs are the coordinates of the perspective center,
- **R** is the rotation matrix and λ is the scale factor.

This collinearity equation contains the coordinates of the object point as well as the exterior orientation and the interior orientation parameters. The image coordinates of each point are considered as observations.

Expanding Eq. (1), we get:

$$\left.\begin{aligned} x_a - x_o &= \lambda[r_{11}(X_A - X_o] + r_{12}(Y_n - Y_o) + r_{13}(Z_A - Z_o)] \\ y_a - x_o &= \lambda[r_{21}(X_A - X_o] + r_{22}(Y_n - Y_o) + r_{23}(Z_A - Z_o)] \\ -f &= \lambda[r_{31}(X_A - X_o] + r_{32}(Y_A - Y_o) + r_{33}(Z_A - Z_o)] \end{aligned}\right\} \tag{2}$$

By dividing and rearranging of Eq. (2), we have

$$\left.\begin{aligned} X_a - x_o &= \frac{-f[r_{11}(X_A - X_o] + r_{12}(Y_n - Y_o) + r_1 3(ZA - Z_o)]}{[r_{31}(X_A - X_o] + r_{32}(Y_A - Y_o) + r_{33}(Z_A - Z_o)]} \\ y_a - x_o &= \frac{-f[r_{21}(X_A - X_o] + r_{22}(Y_n - Y_o) + r_{23}(Z_A - Z_o)]}{[r_{31}(X_A - X_o] + r_{32}(Y_A - Y_o) + r_{33}(Z_A - Z_o)]} \end{aligned}\right\} \tag{3}$$

Rotation matrix:

$$R = \begin{bmatrix} \cos\phi\cos\kappa & \cos\varpi\sin\kappa + \sin\varpi\sin\phi\cos\kappa & \sin\varpi\sin\kappa - \cos\varpi\sin\phi\cos\kappa \\ -\cos\phi\sin\kappa & \cos\varpi\cos\kappa - \sin\varpi\sin\phi\sin\kappa & \sin\varpi\cos\kappa + \cos\varpi\sin\phi\sin\kappa \\ \sin\phi & -\sin\varpi\cos\phi & \cos\varpi\cos\phi \end{bmatrix}$$

The collinearity equations can be rearranged to give the object space coordinates X and Y as follows:

$$\left.\begin{aligned} X &= Xs + (Z - Zs)\frac{r_{11}(x - x_o) + r_{12}(y - y_o) - r_{13} * f}{r_{31}(x - x_o) + r_{32}(y - y_o) - r_{33} * f} \\ Y &= Y_s + (Z - Z_s)\frac{r_{21}(x - x_o) + r_{22}(y - y_o) - r_{23} * f}{r_{31}(x - x_o) + r_{32}(y - y_o) - r_{33} * f} \end{aligned}\right\} \tag{4}$$

If the inner and outer orientation are both known, and points are measured in a pair of overlapping photographs, we obtain the following equations:

$$\left.\begin{aligned} X &= X_{s1} + (Z - Z_{s1}) * K1 \\ Y &= Y_{s1} + (Z - Z_{s1}) * K2 \\ X &= X_{s2} + (Z - Z_{s2}) * K3 \\ Y &= Y_{s2} + (Z - Z_{s2}) * K4 \end{aligned}\right\} \tag{5}$$

where:

$$\begin{aligned} K1 &= \frac{r_{11}(x - x_o) + r_{12}(y - y_o) - r_{13} * f}{r_{31}(x - x_o) + r_{32}(y - y_o) - r_{33} * f} \\ K2 &= \frac{r_{21}(x - x_o) + r_{22}(y - y_o) - r_{23} * f}{r_{31}(x - x_o) + r_{32}(y - y_o) - r_{33} * f} \end{aligned} \tag{6}$$

$K1$ and $K2$ are for the first photo station,
$K3$ and $K4$ are identical parameters for the second photo station.

The solution of the above Eq. (5) will give the object space coordinates for the measured pair of overlapping photographs.