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Emergency Preparedness in the Field of Photogrammetric Mapping

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Abstract

Are we ready for any eventual risk in photogrammetric Mapping? Risk may be using a camera whose calibration parameter is no longer valid or using incorrect Camera file. Sometimes after completing data capture, one may notice some mismatch along strips or blocks and on verification one may notice that some ground control points (GCP) has been dropped or incorrectly identified on image for which entire block adjustment need to be carried again. What will happen if one identifies the cause towards end of the project? Should one redo the whole project with new set of parameter or only some stereo models need to be corrected? How to find which stereo models would be well within required accuracy limits? But in most cases data already captured with old set of image parameter would not fit when model is created again with correctly calculated new set of parameters. The author presents a simple systematic approach to reuse completed stereo models from image Parameters and make all completed stereo models usable again without much effort. One should be careful enough to know and understand the image parameters used by the photogrammetric software, and be prepared for any eventual risk.

Introduction

For simplicity reasons only frame cameras are considered here, which have only one exposure for entire image. Since main issue is to deal with change in image parameters, the solution has to start with smallest portion of problem, i.e., a stereo model. So all formula presented would deal with image parameters of two photos and by the method presented one stereo model data can be corrected.

Since data is already captured with the old image parameters, so one can assume that old data would fit exactly on the model created with old parameters. So it is required to convert the ground coordinates (3D) of incorrect data to model coordinates. Then convert model coordinates to individual image coordinates (2D). These image coordinates on stereo-pair corresponds to the same feature available at that ground coordinate. This image coordinate on stereo pair would always represent that feature even if any image parameter is changed. So there is a need to find proper methodical procedure to calculate the new ground coordinate from these images coordinates using the new changed image parameters.

Inputs

Unknown parameters of one image include

1. Coordinate of Camera (X0,Y0,Z0)at the time of taking Image
2. Orientation of camera in space (ω, f, κ) at the time of taking Image

Most of the Digital photogrammetric workstation software stores these parameters in a plain ASCII readable file. Most often Software documentation provides enough information to make them usable for ground to image coordinate conversion and vice versa. For this study SocetSet was chosen, as complete details of image parameter (stored as *.SUP) was provided from BAE systems.

Calculation

The generalized procedure for converting ground to Image & vice versa requires the space orientation parameter to be a 3*3 matrix, which need to be generated from ω,f ,κ after knowing the sequence in which they need to be applied. This may differ for other Software and need to be clarified from software manufacturer. In this case SocetSet image parameters were used and ground coordinates need to be oriented ω,f ,κ in sequence to get coordinates w.r.t. image coordinates system. This can be represented mathematically as below.

$$\begin{Bmatrix} X_i \\ Y_i \\ Z_i \end{Bmatrix} = \begin{Bmatrix} cos\kappa & -sin\kappa & 0 \\ -sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{Bmatrix} \begin{Bmatrix} cos\varphi & 0 & -sin\varphi \\ 0 & 1 & 0 \\ sin\varphi & 0 & cos\varphi \end{Bmatrix} \begin{Bmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & \sin\omega \\ 0 & -sin\omega & cos\omega \end{Bmatrix} \begin{Bmatrix} X_G \\ Y_G \\ Z_G \end{Bmatrix}$$

Where $\begin{Bmatrix} X_i \\ Y_i \\ Z_i \end{Bmatrix}$ and $\begin{Bmatrix} X_G \\ Y_G \\ Z_G \end{Bmatrix}$ represents coordinates w.r.t. image and ground coordinate system respectively.

The above equation may be represented as

$$\begin{Bmatrix} X_i \\ Y_i \\ Z_i \end{Bmatrix} = \begin{Bmatrix} M_{11} & M_{12} & M_{13} \\ M_{21} & M_{22} & M_{23} \\ M_{31} & M_{32} & M_{33} \end{Bmatrix} \begin{Bmatrix} X_G \\ Y_G \\ Z_G \end{Bmatrix} \qquad \text{(E-1)}$$

Where M_{11}= cos(f)*cos(κ);

M_{12}= sin(ω)*sin(f)*cos(κ) +cos(ω)*sin(κ)

M_{13}= -cos(ω)*sin(f)*cos(κ)+ sin(ω)*sin(κ);

M_{21}=-cos(f)*sin(κ);

M_{22}= -sin(ω)*sin(f)*sin(κ)+ cos(ω)*cos(κ);

M_{23}= cos(ω)*sin(f)*sin(κ)+ sin(ω)*cos(κ);

M_{31}= sin(f);

M_{32}=-sin(ω)*cos(f)

M_{33}= cos(ω)*cos(f);

Following inverse matrix may be used to get coordinate w.r.t. ground coordinate system from coordinates w.r.t. image coordinate system as below.

$$\begin{Bmatrix} X_G \\ Y_G \\ Z_G \end{Bmatrix} = \begin{Bmatrix} M_{11} & M_{12} & M_{13} \\ M_{21} & M_{22} & M_{23} \\ M_{31} & M_{32} & M_{33} \end{Bmatrix}^{-1} \begin{Bmatrix} X_i \\ Y_i \\ Z_i \end{Bmatrix}$$

Which is same as below, as inverse of orthogonal rotation matrix is same as its Transpose.

$$\begin{Bmatrix} X_G \\ Y_G \\ Z_G \end{Bmatrix} = \begin{Bmatrix} M_{11} & M_{21} & M_{31} \\ M_{12} & M_{22} & M_{32} \\ M_{13} & M_{23} & M_{33} \end{Bmatrix} \begin{Bmatrix} X_i \\ Y_i \\ Z_i \end{Bmatrix} \qquad \text{(E-2)}$$

Solution

First step: Coordinates w.r.t. image coordinate system for both images to be obtained from coordinate w.r.t. ground coordinate system using old incorrect image parameters only. Before proceeding it is required to obtain ground coordinates w.r.t. the position of the Camera for each image and apply Eqs. (E-1) separately to both images. Both image coordinates may be projected to focal plane which would remain same even if the image parameter changes.

Second step: Coordinates w.r.t. ground coordinate system to be obtained from coordinates w.r.t. image coordinate system using only new correct image parameters. First convert Image coordinates to a coordinate system parallel to ground reference system using Eqs. (E-2) using new corrected image parameters. Now project these coordinates from perspective centre to meet at corrected coordinate on ground which can be mathematically represented as

$$\begin{Bmatrix} X0_L \\ Y0_L \\ Z0_L \end{Bmatrix} + S_L \begin{Bmatrix} X_{GL} \\ Y_{GL} \\ Z_{GL} \end{Bmatrix} = \begin{Bmatrix} X0_R \\ Y0_R \\ Z0_R \end{Bmatrix} + S_R \begin{Bmatrix} X_{GR} \\ Y_{GR} \\ Z_{GR} \end{Bmatrix} \qquad \text{(E-3)}$$

where S_L and S_R are the Scaling Factor for left and right image coordinates respectively.
and (X_{GL}, Y_{GL}, Z_{GL}) is coordinate in left Image w.r.t. ground coordinate system.
and (X_{GR}, Y_{GR}, Z_{GR}) is coordinate in right Image w.r.t. ground coordinate system.

On solving the above Eqs. (E-3) for 2 unknowns (S_L and S_R) from 3 equations, one may use least square or one of the two solution provided below. Author would suggest to use first one if $(X0_R - X0_L) > (Y0_R - Y0_L)$ and second one if $(X0_R - X0_L) < (Y0_R - Y0_L)$.

$$S_L = \{ (X0_R - X0_L) - (Z0_R - Z0_L) * (X_{GR}/Z_{GR}) \} \;/\; (X_{GL}/Z_{GL} - X_{GR}/Z_{GR})$$

or

$$S_L = \{ (Y0_R - Y0_L) - (Z0_R - Z0_L) * (Y_{GR}/Z_{GR}) \} \;/\; (Y_{GL}/Z_{GL} - Y_{GR}/Z_{GR})$$

On applying values of S_L one can get Corrected Ground coordinates as below.

$$\begin{Bmatrix} Corrected_X \\ Corrected_Y \\ Corrected_Z \end{Bmatrix} = \begin{Bmatrix} X0_L \\ Y0_L \\ Z0_L \end{Bmatrix} + S_L \begin{Bmatrix} Xi_L \\ Yi_L \\ Zi_L \end{Bmatrix}$$

This way one can correct one stereo model. After individual stereo models are corrected, then each model can be edge matched to get merged seamless data. But if merged seamless data can provide information about the images from which each vertex has been captured, then the correction process can be applied on merged seamless data also.

Conclusion

This method may save most of the reworking time in case of accidental change in image parameter. This problem was reported to the author for the first time by Mr. Rakesh Rana, who was handling one Canadian project, for which AT parameters were supplied. On observing huge differences among strips, the problem was reported and AT was done again and new set of photo parameters were supplied. Since then author has developed this idea to automatically correct model and the methodology has been successfully applied for several projects in Cowi since then on several occasion. This method can also be extended to handle cases where the error might have been due to out of date camera calibration report. In that case Inner Orientation parameter must be included in the calculation to convert image coordinates (in mm) to pixel and back. Understanding the method to convert image to ground coordinates using Image parameters can save time in case of emergency. If models need to be edge matched to prepare a seamless data, then one must keep a backup of model wise data for future correction if required.