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**A Four-Step Ortho-Rectification Procedure for Geo-
Referencing Video Streams from a Low-Cost UAV**

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Introduction

- **What?**

Ortho-rectification is the process of geometrically correcting an aerial image such that the scale is uniform.

- **Why?**

Ortho-rectification and geo-referencing are essential to pin point the exact location of targets in video imagery acquired by the UAV

- **How?**

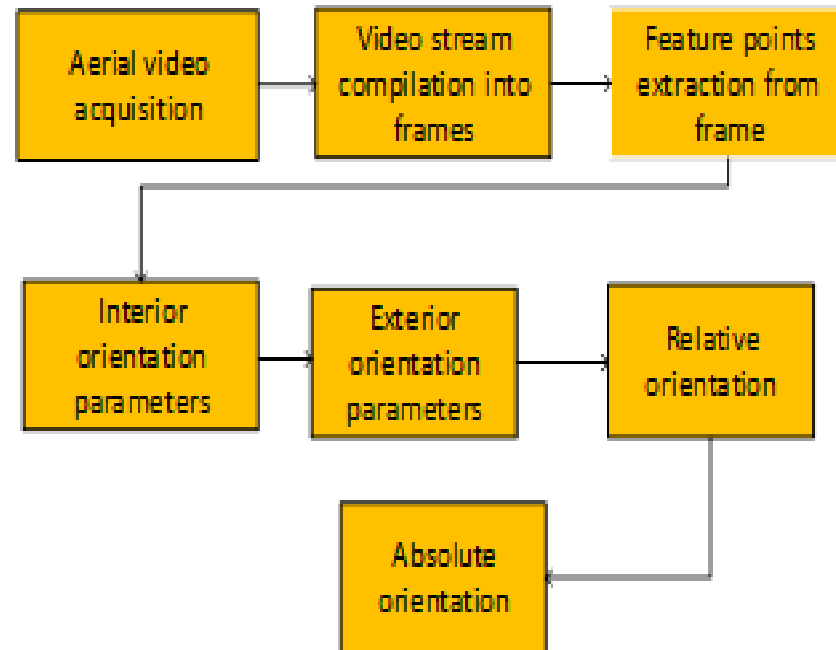
This can only be achieved by comparing the UAV video imagery with an existing well referenced map. However, it is only when the image is ortho-rectified with the same co-ordinate system as an existing map that such a comparison is possible.

The method used in this paper is based on the photogrammetry model, this is a form of geometric imaging system that makes use of the aerial image central perspective and the principle of collinearity.

Introduction (cont.)

The four basic step for ortho-rectification and geo-referencing of video streams captured by a low-cost multi-sensor UAV:

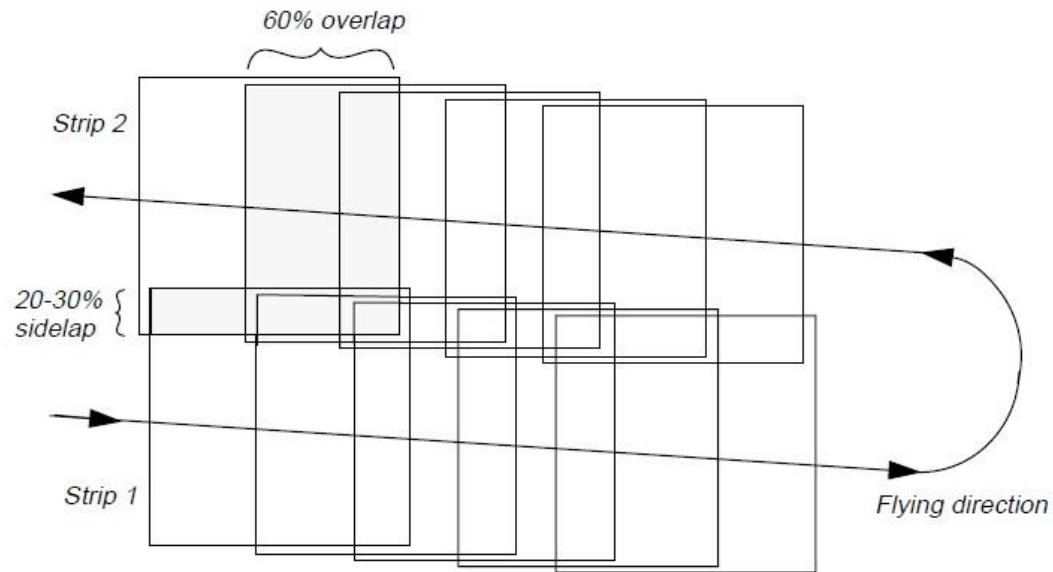
- De-compilation of video streams
- Establishing the video camera interior orientation parameters(IOPs)
- Determining the relative orientation parameters of each video frame
- Find the absolute orientation parameters using self-calibration bundle adjustment



Procedure workflow

Decompilation of video streams

- BPS video converter Software
- Feature points extraction and tie points matched



Courtesy ERDAS Field Guide

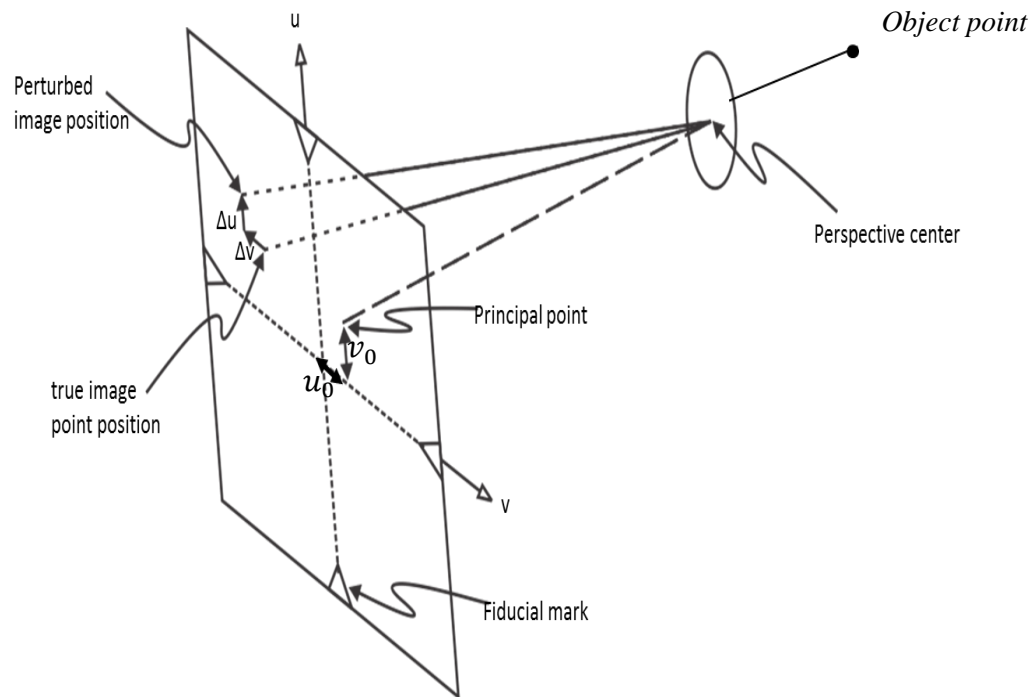
Finding the interior orientation

- Interior orientation is basically used to transform the image coordinate system to the image space system
- It defines the internal geometry of the camera as it existed at the time of data capture
- The internal geometry of the camera is defined by 3 parameters:
 - 1). Principal point
 - 2). Focal length
 - 3). Lens distortion

Finding the interior orientation (cont.)

➤ *Image point offset*

In the simplest terms, finding interior orientation involves shifting the actual point to satisfy the collinearity conditions



Interior orientation and the effect of perturbations to collinearity

Finding the interior orientation (cont.)

This collinearity condition is used by the Direct Linear Transformation (DLT) to facilitates a perspective projection between the 2D image data and the 3D object space, it requires foreknowledge of 3 ground control points and is of the form:

$$u - \Delta u = \frac{L_1X + L_2Y + L_3Z + L_4}{L_9X + L_{10}Y + L_{11}Z + 1}$$

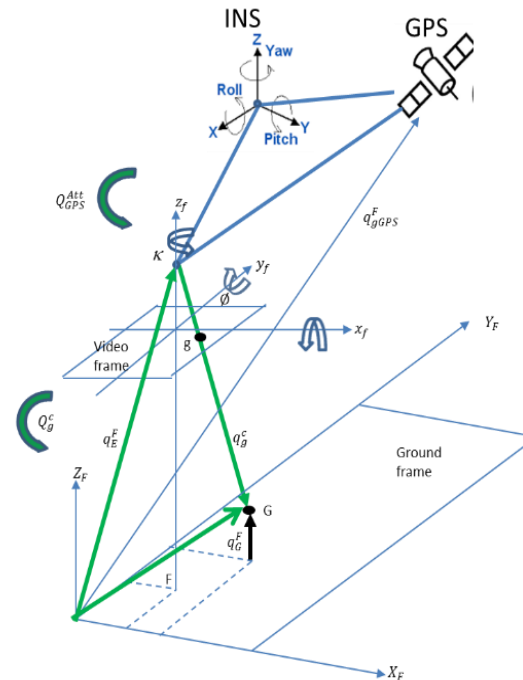
$$v - \Delta v = \frac{L_5X + L_6Y + L_7Z + L_8}{L_9X + L_{10}Y + L_{11}Z + 1}$$

Finding the interior orientation (cont.)

- *Orientation offset between camera sensor frame*

This is express by (Guoqing) as:

$$q_G^F = q_{GPS}^F(t) + Q_{INS}^F(t)[S_F * Q_C^{INS}(q_g^C(t) + q_{GPS}^C)]$$



Geometric Relationship between GPS/INS, Video frame and the 3D world coordinates

Finding the interior orientation (cont.)

- *Orientation offset between camera sensor frame*

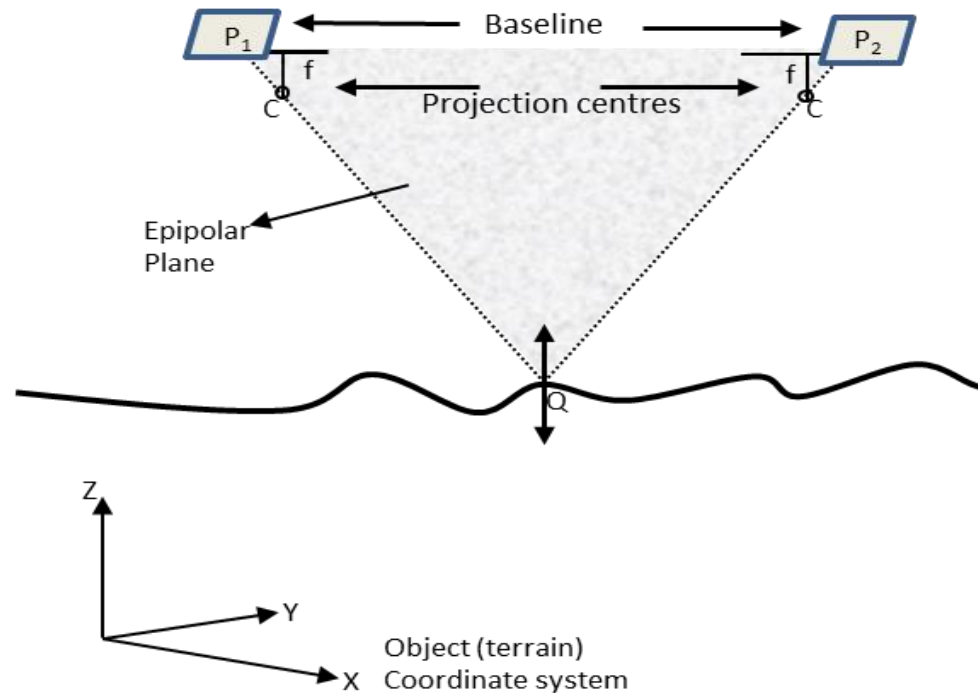
$$q_G^F = q_{GPS}^F(t) + Q_{INS}^F(t)[S_F * Q_C^{INS}(q_g^C(t) + q_{GPS}^C)]$$

$$Q_{INS}^F = \begin{bmatrix} \cos\emptyset \cos k & \cos\psi \sin k + \sin\psi \sin\emptyset \cos k & \sin\psi \sin k - \cos\psi \sin\emptyset \cos k \\ -\cos\emptyset \sin k & \cos\psi \cos k - \sin\psi \sin\emptyset \sin k & \sin\psi \cos k + \cos\psi \sin\emptyset \sin k \\ \sin\emptyset & -\sin\psi \cos\emptyset & \cos\psi \cos\emptyset \end{bmatrix}$$

In this step, the camera calibration process considers the focal length and principal point coordinates only, because the IOPs and EOPs that was solved by DLT and the boresight values will be used as initial values for the final bundle adjustment model.

Finding the Relative Orientation

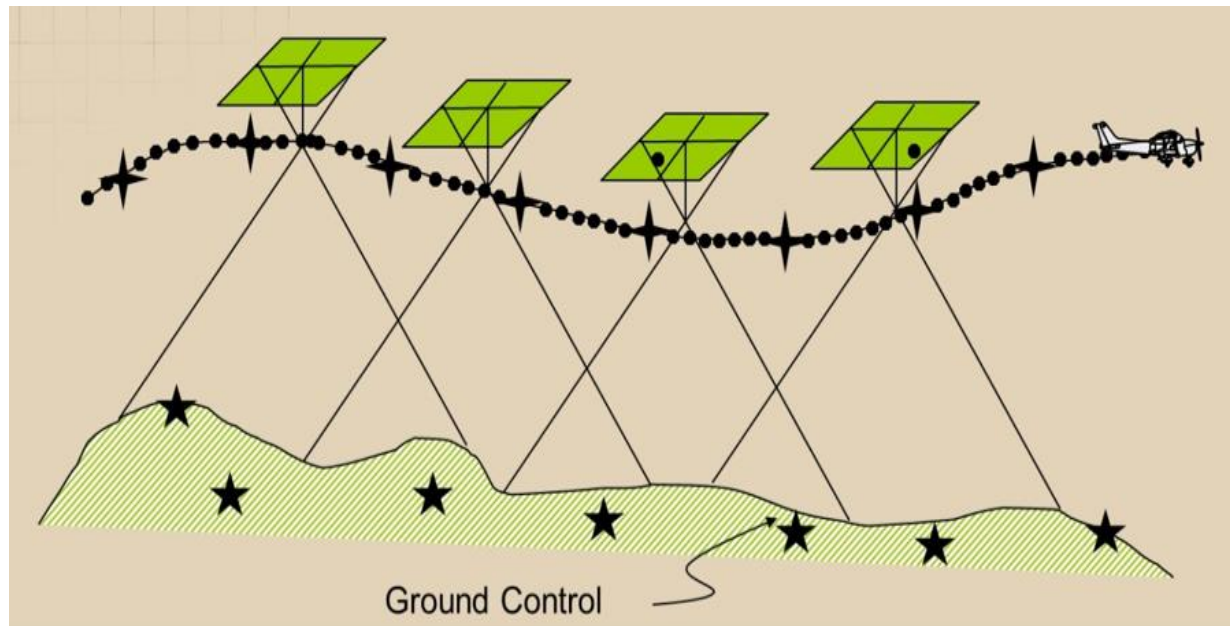
- What is relative orientation?
- How is this achieved?



stereoscopic viewing with two different camera positions

Finding the Absolute Orientation

- Absolute orientation
- Self-calibration



Absolute orientation showing ground control

Experimental results

The four steps procedure mentioned was evaluated using data collected from a low-cost UAV.

Our results show that, the 2-D planimetric accuracy when compared with the 6 control points is between 3 to 5 metres.



Mosaicked images covering test area

Conclusions

- Our method for ortho-rectification, although, is automatic but is not autonomous, it does not require significant operator interaction.
- Error assessment during the matching of conjugates on frames shows that the image RMS residual is small.
- Cost and turnaround time for production of ortho-rectified mosaics are quite small when compared with the traditional method.

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Thank you