Photogrammetry: DTM Extraction & Editing

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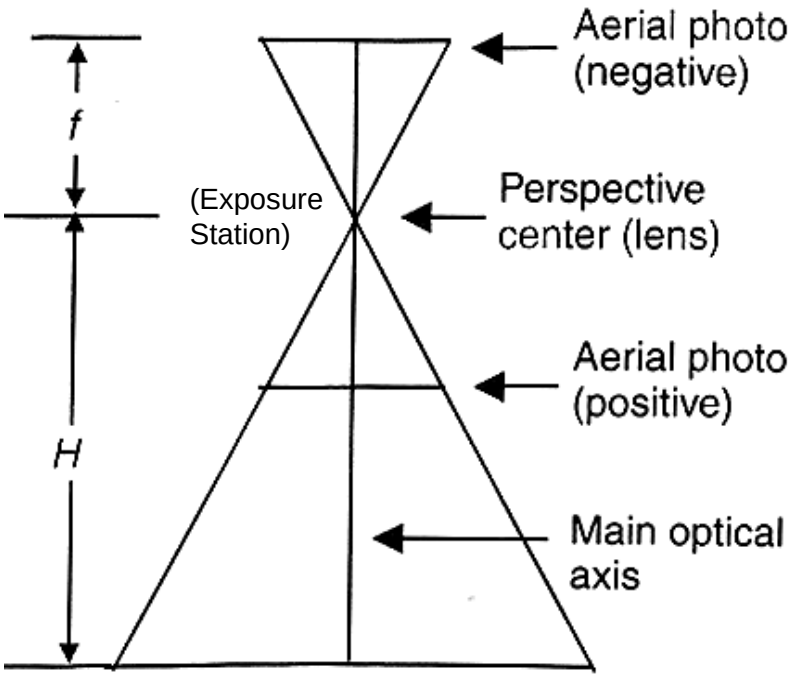
Review of terms

- Vertical aerial photograph
- Perspective center
- Exposure station
- Fiducial marks
- Principle point
- Air base



Digital Photogrammetry:

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Softcopy Photogrammetric Systems

- Scanned stereopair photos
- Interior and exterior orientations (Aerial Triangulation)
  - Camera & photo parameters
  - Flight parameters
  - GCPs
  - Tie points (image matching algorithms)
- Generate DEM and orthophotos

What DPI should I use?

Dots per inch (DPI)

e.g., 200 DPI = 200 dots/inch

= 200 dots/2.54 cm

= 2.54/200 cm/dot

= 0.0127 cm/dot

= 127 microns/dot

e.g., scan a 1:4000 photo at 200 DPI

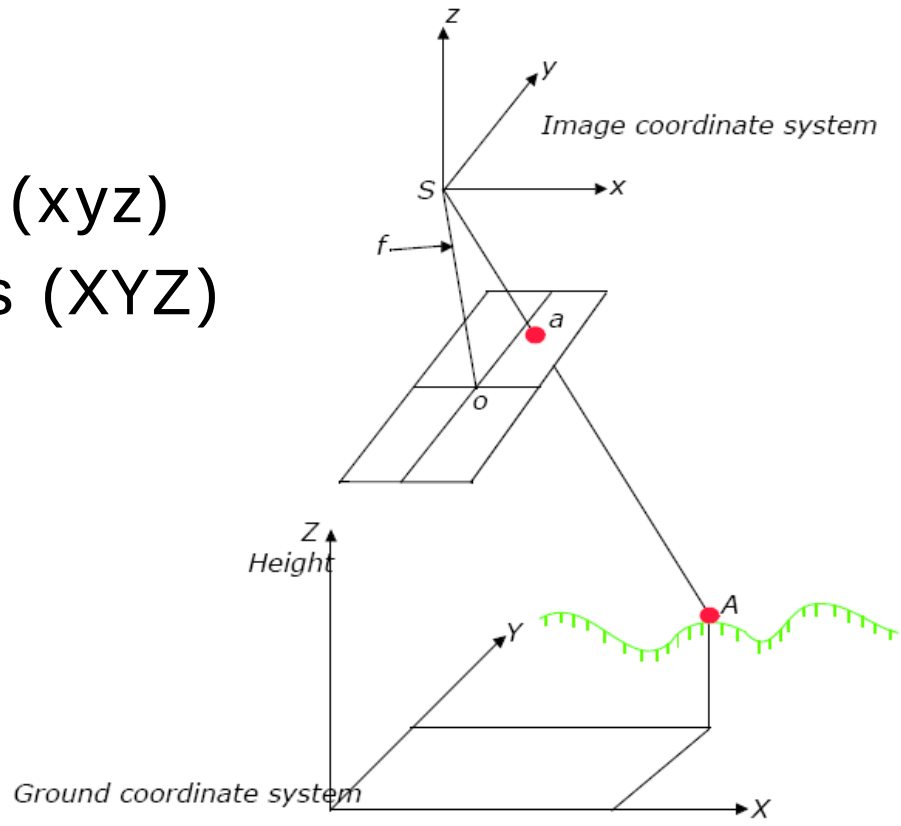
127 microns/dot (map) = 127 x 4000 microns/dot (ground)

= 508000 microns/dot

= 50.8 cm/dot = 0.5 meters/dot

Coordinate Systems in Digital Photogrammetry

- Pixel coordinates (rc)
- Image coordinates (xy)
- Image space coordinates (xyz)
- Ground space coordinates (XYZ)



Interior Orientation

- Interior orientation defines the internal geometry of a camera or sensor as it existed at the time of data capture.

- It defines image space coordinates based on pixel and image coordinates and camera parameters (e.g., f and lens distortion model).
  - Principal point & fiducial marks
  - Focal length & lens distortion
  - No GCPs

Exterior Orientation

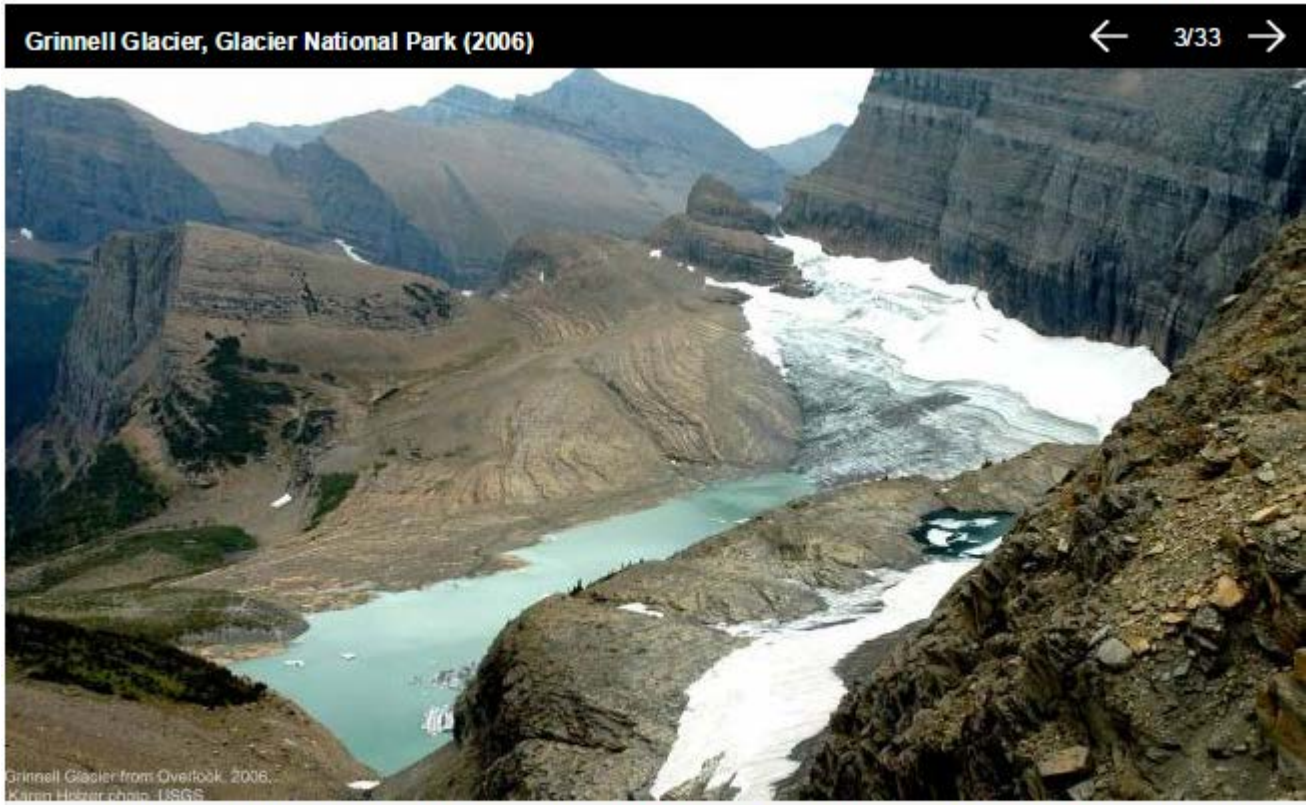
- Exterior orientation defines the position and angular orientation associated with the camera to achieve collinearity condition.

- It defines ground space coordinates based on image space coordinates and flight information (e.g., flying altitude and attitude).

“Manual” Interior and Exterior Orientation

These photos taken from the Grinnell Glacier Overlook off the Highline Trail in Montana's Glacier National Park show the early formation of Upper Grinnell Lake, visible at the glacier's terminus. The 2006 photo reveals the dramatic increase in the size of the lake. (GNP Archives)

“Manual” Interior and Exterior Orientation



These photos taken from the Grinnell Glacier Overlook off the Highline Trail in Montana's Glacier National Park show the early formation of Upper Grinnell Lake, visible at the glacier's terminus. The 2006 photo reveals the dramatic increase in the size of the lake. (Karen Holzer/USGS)

Image source: http://www.weather.com/news/science/environment/stunning-photos-glaciers-retreating-alaska-20130717

See more examples at: http://www.landscapeandurbanism.com/2014/05/27/old-new-photos/ or Google Map Street view.

Collinearity Condition & Equations

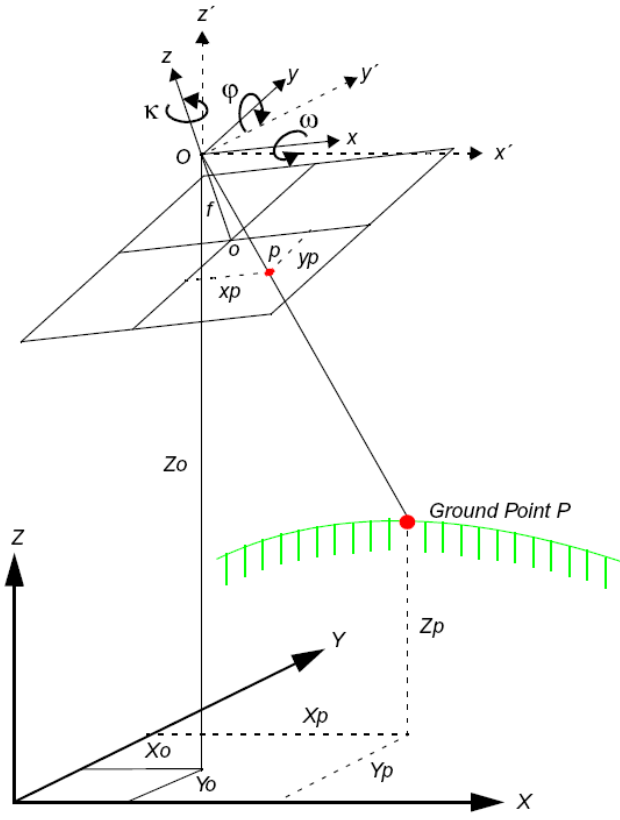
- Collinearity condition: a condition, expressed as a mathematic model, when the perspective center, an image point, and its corresponding ground point are on a straight line for all points on the image.

- If collinearity condition is achieved on both photos in a stereopair then the ground X, Y, Z can be computed from x and y within the image coordinate system on both photos.

- Six exterior orientation parameters
  - Angular orientation: (ω, ϕ, κ)
  - Perspective origin: (Xo, Yo, Zo)

- Collinearity equations can be derived using GCPs and tie points.

- Inertial Measurement Unit (IMU)



Collinearity Condition & Equations

$$x = -f\frac{a_1(X_A - X_S) + b_1(Y_A - Y_S) + c_1(Z_A - Z_S)}{a_3(X_A - X_S) + b_3(Y_A - Y_S) + c_3(Z_A - Z_S)}$$

$$y = -f\frac{a_2(X_A - X_S) + b_2(Y_A - Y_S) + c_2(Z_A - Z_S)}{a_3(X_A - X_S) + b_3(Y_A - Y_S) + c_3(Z_A - Z_S)}$$

x, y: coordinates of a point on image space

X_A, Y_A, Z_A: ground space coordinates of the point

X_S, Y_S, Z_S: coordinates of the perspective center (lens)

f: focal length

$$a_1 = \cos\phi\cos\kappa + \sin\phi\sin\omega\sin\kappa$$
$$b_1 = \cos\phi\sin\kappa + \sin\phi\sin\omega\cos\kappa$$
$$c_1 = \sin\phi\cos\omega$$
$$a_2 = -\cos\omega\sin\kappa$$
$$b_2 = \cos\omega\cos\kappa$$
$$c_2 = \sin\omega$$
$$a_3 = \sin\phi\cos\kappa + \cos\phi\sin\omega\sin\kappa$$
$$b_3 = \sin\phi\sin\kappa - \cos\phi\sin\omega\cos\kappa$$
$$c_3 = \cos\phi\cos\omega$$

Redundancy (DF) of Forming Collinearity Eqs.

Degree of Freedom (DF) =

Observation Eqs - # Unknown

- 1 GCP provides 2 obser. eqs. on one image
- 1 tie point provides 2 obser. eqs. on one image
- 1 photo has 6 unknown (X, Y, Z, ω, ρ, κ)
- 1 tie point has 3 unknown (X, Y, Z)

What is the DF when...

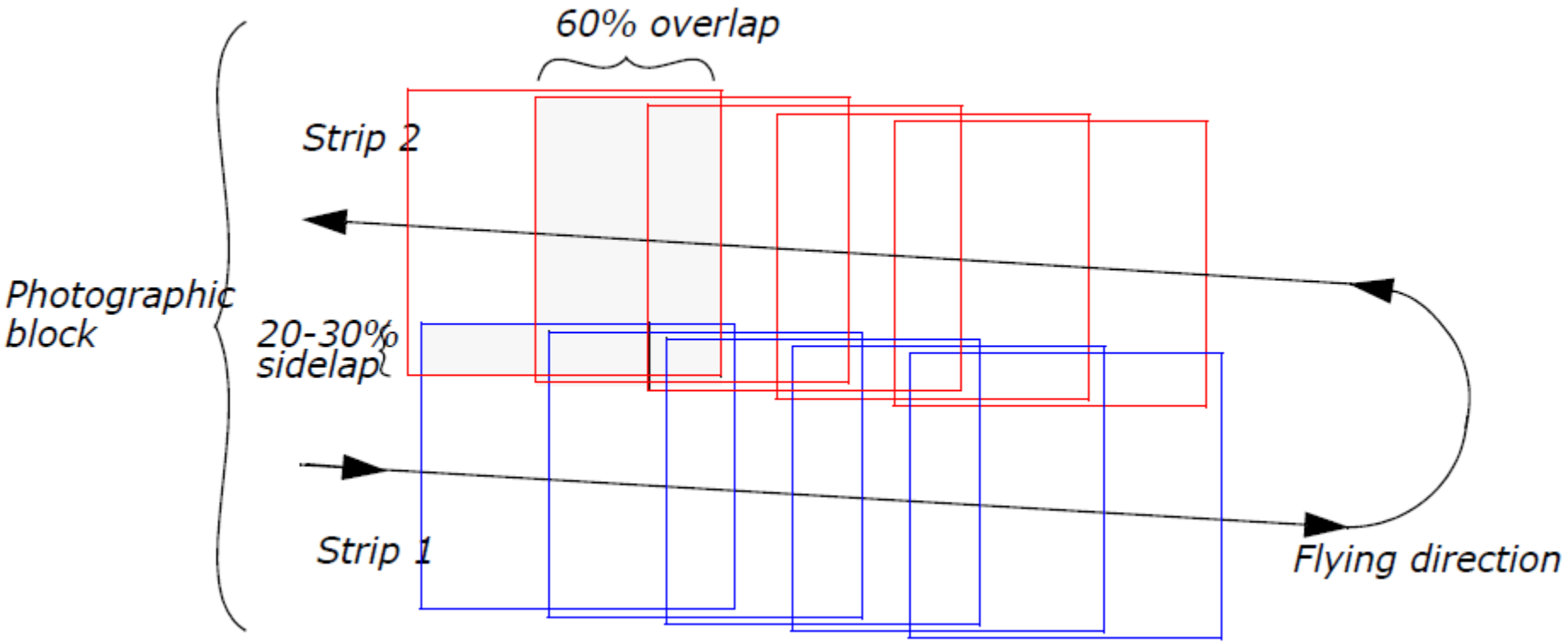
Case #1

- A stereo pair – two photos
- with 3 shared GCPs

Case #2

- A stereo pair – two photos
- with 3 shared GCPs
- and 4 tie points

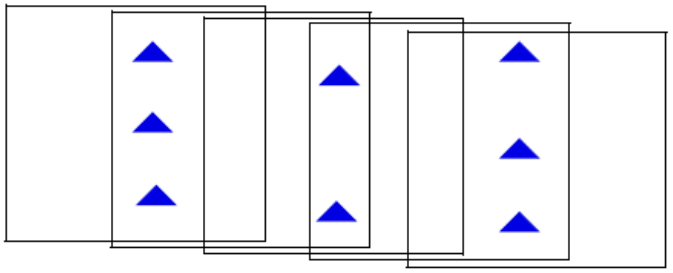
Bundle Block Triangulation

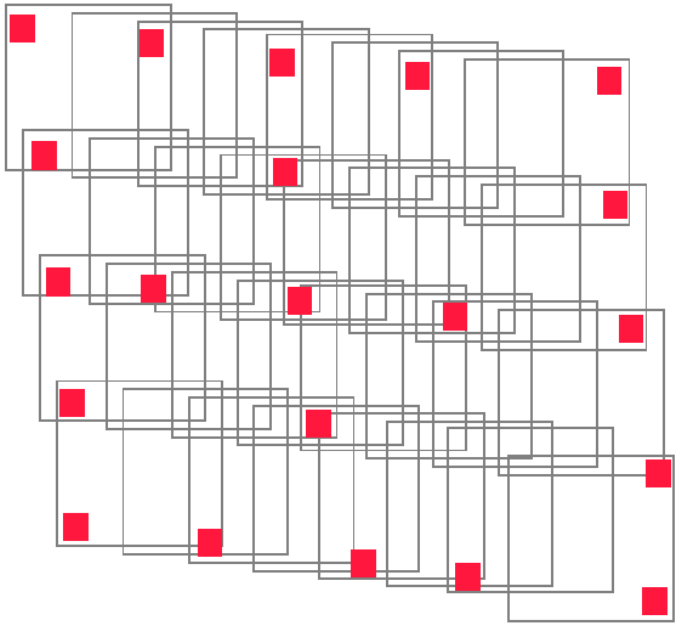


GCPs: How many do you need?

3 for single frame.
2 on every third image of a strip
1 on every third image of a block

Figure 8-12: GCP Configuration





Photogrammetry vs. Conventional Geometric Correction

Block Triangulation Photogrammetry	Single Frame Orthorectification (Reverse) Photogrammetry	Geometric Correction
Bundle block adjustment (Relies on image models, GCPs, and block triangulation)	Single frame orthorectification (relies on DEM, GCPs, and image models)	Single photo adjustment (Relies on GCPs and polynomial equations)
A minimum of 3 GCPs to achieve high accuracy. GCPs can be shared by the entire block of photos.	A minimum of 3 GCPs to achieve high accuracy	More GCPs are required to achieve satisfactory accuracy. GCPS are not shared.
Minimizes errors for the entire block of photos. Ideal for photo-mosaicking.	Single photo resection - minimizes GCP errors within a single photo.	Minimizes errors within a single photo.
Allows the correction of relief displacement and the generation of DEM when stereopairs are used.	Requires DEM to generate orthophotos	Unable to do orthorectification

RPC – Rational Polynomial Coefficient

- A mathematical (polynomial) model that link the pixel coordinate of an image to the ground space coordinate (without requiring a physical camera model).

- Orthophoto?
  - RPC only (not ortho-rectified)
  - RPC + DEM (e.g., RLIS 6 inches orthophotos)
  - RPC + DEM + GCP