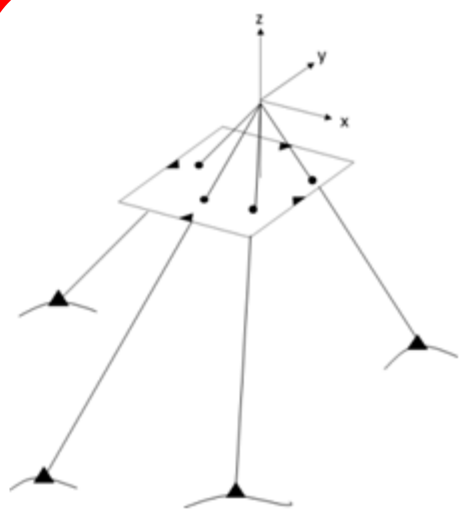
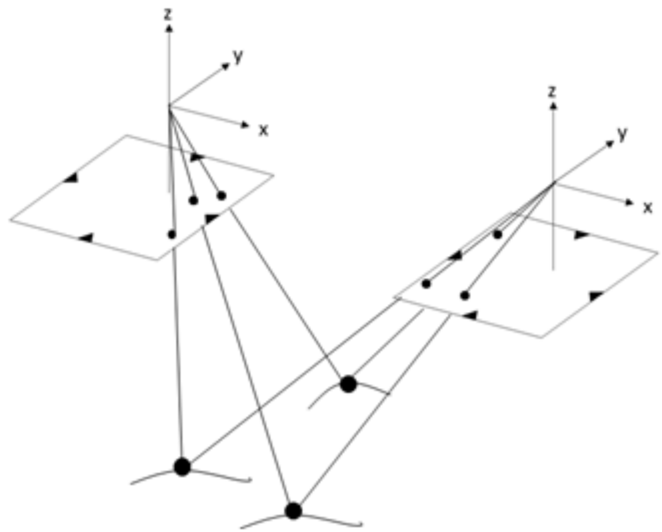
# Indirect Image Orientation



Single image



Stereo image pair

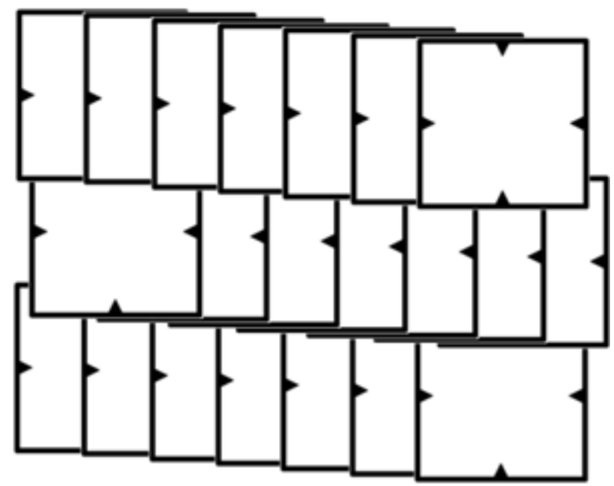


Image block

**All Slides Courtesy of:**

**Dr. Derek Lichti**
**University of Calgary**

# Indirect image orientation

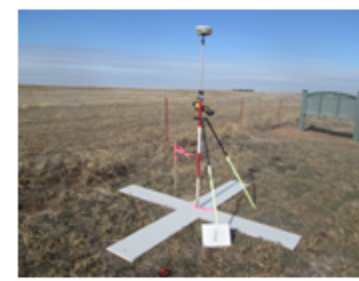
Single image

Vertical image assumption

Tilted image

Resection

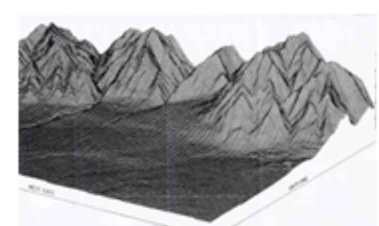
*GCPs*



Approximate ground measurements

Monoscopic mapping

*DEM*



Sources: http://www.rpsurveying.com/img/proj/ControlPoint.Full.png
http://egsc.usgs.gov/isb//pubs/teachers-packets/mapshow/graphics/dem.gif

# Resection Example

- Input data

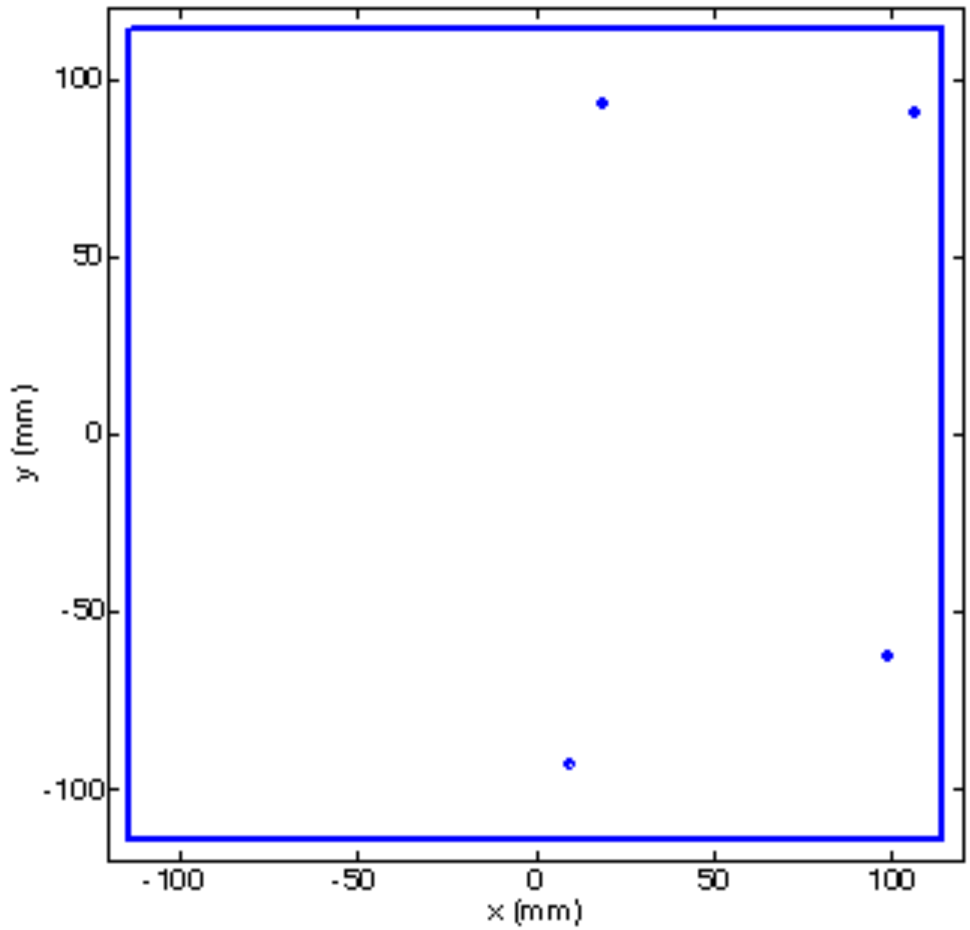
| Image Point Observations (reduced to PP) | | |
|---|---|---|
| **ID** | **x (mm)** | **y (mm)** |
| 30 | 106.399 | 90.426 |
| 40 | 18.989 | 93.365 |
| 50 | 98.681 | -62.769 |
| 112 | 9.278 | -92.926 |

| Control Point Co-ordinates | | | |
|---|---|---|---|
| **ID** | **X (m)** | **Y (m)** | **Z (m)** |
| 30 | 7350.27 | 4382.54 | 276.42 |
| 40 | 6717.22 | 4626.41 | 280.05 |
| 50 | 6905.26 | 3279.84 | 266.47 |
| 112 | 6172.84 | 3269.45 | 248.10 |

| Other Information | |
|---|---|
| c (mm) | 152.150 |
| Approximate image format size (mm x mm) | 229 x 229 |
| $\sigma_{obs}$ (μm) | 15 |

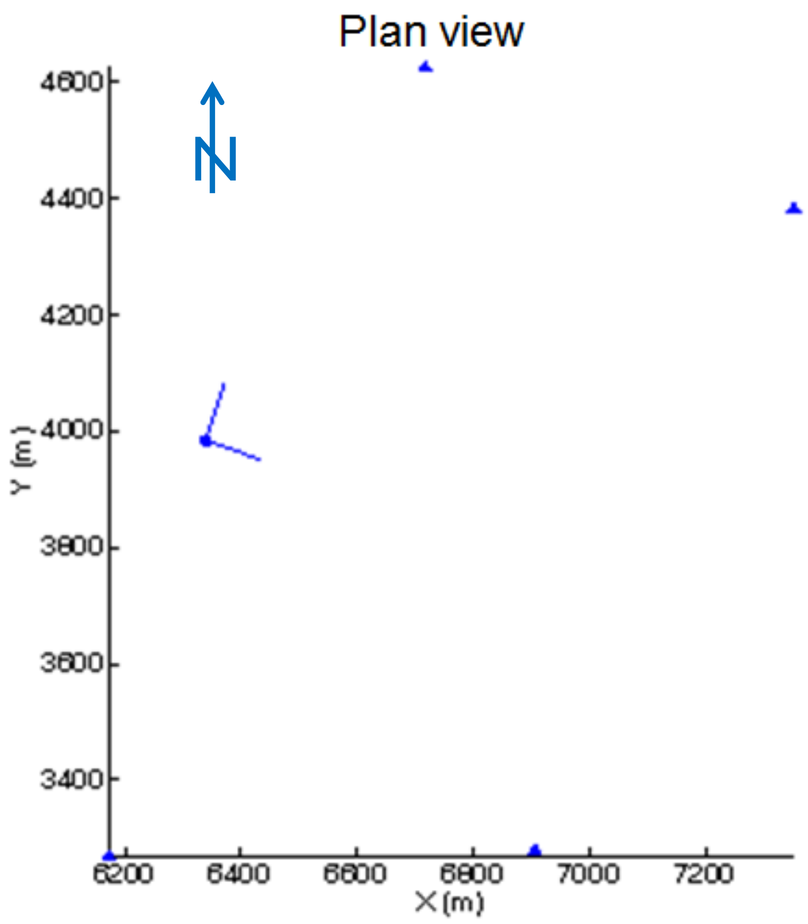
# Resection Example (cont'd)

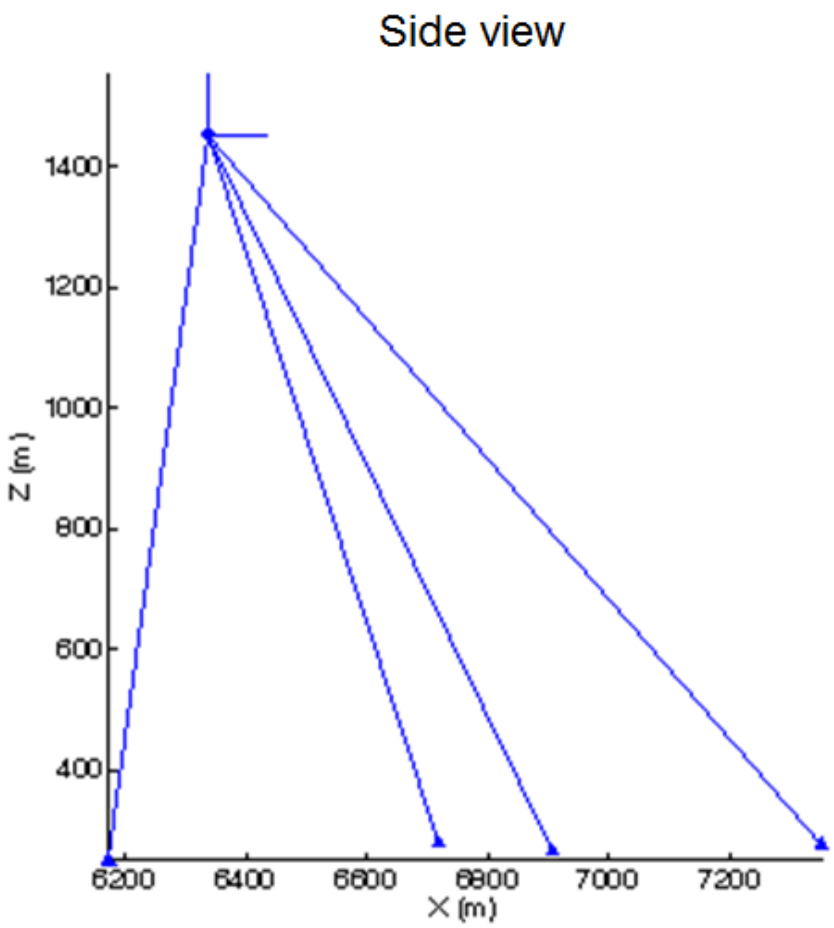
- Image point distribution



# Resection Example (cont'd)

- Object point distribution



# Resection Example (cont'd)

- Derived quantities

| **Approximate parameter values** | |
|---|---|
| **$X^c$ (m)** | 6338.6 |
| **$Y^c$ (m)** | 3984.6 |
| **$Z^c$ (m)** | 1453.1 |
| **$\omega$ (°)** | 0 |
| **$\phi$ (°)** | 0 |
| **$\kappa$ (°)** | -18.854 |

| **Convergence tolerances** | |
|---|---|
| $Tol_{coords}$ (m) | 0.012 |
| $Tol_{tilt}$ (°) | 0.00056 |
| $Tol_{\kappa}$ (°) | 0.00053 |

# Resection Example (cont'd)

- Partial solution—first iteration

| A matrix | | | | | | |
|---|---|---|---|---|---|---|
| | $X^c$ | $Y^c$ | $Z^c$ | $\omega$ | $\phi$ | $\kappa$ |
| $x_{30}$ | -0.12237 | 0.041786 | -0.09108 | 12.92595 | 236.1245 | 90.96798 |
| $y_{30}$ | -0.04179 | -0.12237 | -0.07731 | -174.751 | 127.3797 | -107.166 |
| $x_{40}$ | -0.12275 | 0.041915 | -0.01669 | 38.45985 | 150.3037 | 94.64906 |
| $y_{40}$ | -0.04192 | -0.12275 | -0.08069 | -195.772 | 79.7179 | -19.5723 |
| $x_{50}$ | -0.12134 | 0.041435 | -0.08255 | 107.3491 | 190.7664 | -62.0362 |
| $y_{50}$ | -0.04144 | -0.12134 | 0.052279 | -180.831 | 19.54384 | -97.9609 |
| $x_{112}$ | -0.11949 | 0.040804 | -0.00778 | 54.73177 | 142.6969 | -92.2175 |
| $y_{112}$ | -0.0408 | -0.11949 | 0.076529 | -198.716 | 61.8539 | -9.37397 |

| w vector (mm) | |
|---|---|
| $x_{30}$ | 0.76747 |
| $y_{30}$ | 0.54198 |
| $x_{40}$ | 0.58334 |
| $y_{40}$ | 1.28406 |
| $x_{50}$ | -0.72014 |
| $y_{50}$ | 0.73276 |
| $x_{112}$ | 0.09597 |
| $y_{112}$ | 0.70854 |

# Resection Example (cont'd)

- Final solution—after 3 iterations

| **Other quantities** | |
|---|---|
| $RMS_{vx}$ (mm) | 0.014 |
| $RMS_{vy}$ (mm) | 0.015 |
| Redundancy | 2 |
| Variance factor | 3.771 |

| **Residual vector v (mm)** | |
|---|---|
| $\mathbf{x_{30}}$ | -0.010 |
| $\mathbf{y_{30}}$ | 0.024 |
| $\mathbf{x_{40}}$ | 0.024 |
| $\mathbf{y_{40}}$ | -0.014 |
| $\mathbf{x_{50}}$ | -0.012 |
| $\mathbf{y_{50}}$ | 0.000 |
| $\mathbf{x_{112}}$ | -0.002 |
| $\mathbf{y_{112}}$ | -0.010 |

# Resection Example (cont'd)

- Partial solution—after 3 iterations

| Parameters and standard deviations | | |
|---|---|---|
| $X^c$ (m) | 6349.488 | 0.323 |
| $Y^c$ (m) | 3965.252 | 0.536 |
| $Z^c$ (m) | 1458.095 | 0.154 |
| $\omega$ (°) | 0.98846 | 0.01879 |
| $\phi$ (°) | 0.40706 | 0.01387 |
| $\kappa$ (°) | -18.90485 | 0.00680 |

| Correlation coefficient matrix of the parameters | | | | | | |
|---|---|---|---|---|---|---|
| | $X^c$ | $Y^c$ | $Z^c$ | $\omega$ | $\phi$ | $\kappa$ |
| $X^c$ (m) | 1 | | | | | |
| $Y^c$ (m) | 0.00 | 1 | | | | |
| $Z^c$ (m) | 0.69 | -0.18 | 1 | | | |
| $\omega$ (°) | 0.07 | -0.99 | 0.25 | 1 | | |
| $\phi$ (°) | 0.97 | -0.13 | 0.79 | 0.20 | 1 | |
| $\kappa$ (°) | -0.18 | -0.77 | 0.01 | 0.72 | -0.07 | 1 |

*Precision estimates are NOT scaled by the estimated variance factor*

# Questions for Discussion

- Comment on the precision of the exterior orientation parameters
- Why is $\omega$ correlated with $Y^c$?
- Why is $\phi$ correlated with $X^c$?
- What is the cause of these correlations?
- How could the solution be improved?
- How should the convergence tolerances be set?

# Partial Derivative Analysis

$$\underset{8,6}{A} = \begin{pmatrix} \frac{\partial x_{30}}{\partial X^c} & \frac{\partial x_{30}}{\partial Y^c} & \frac{\partial x_{30}}{\partial Z^c} & \frac{\partial x_{30}}{\partial \omega} & \frac{\partial x_{30}}{\partial \phi} & \frac{\partial x_{30}}{\partial \kappa} \\ \frac{\partial y_{30}}{\partial X^c} & \frac{\partial y_{30}}{\partial Y^c} & \frac{\partial y_{30}}{\partial Z^c} & \frac{\partial y_{30}}{\partial \omega} & \frac{\partial y_{30}}{\partial \phi} & \frac{\partial y_{30}}{\partial \kappa} \\ \frac{\partial x_{40}}{\partial X^c} & \frac{\partial x_{40}}{\partial Y^c} & \frac{\partial x_{40}}{\partial Z^c} & \frac{\partial x_{40}}{\partial \omega} & \frac{\partial x_{40}}{\partial \phi} & \frac{\partial x_{40}}{\partial \kappa} \\ \frac{\partial y_{40}}{\partial X^c} & \frac{\partial y_{40}}{\partial Y^c} & \frac{\partial y_{40}}{\partial Z^c} & \frac{\partial y_{40}}{\partial \omega} & \frac{\partial y_{40}}{\partial \phi} & \frac{\partial y_{40}}{\partial \kappa} \\ \frac{\partial x_{50}}{\partial X^c} & \frac{\partial x_{50}}{\partial Y^c} & \frac{\partial x_{50}}{\partial Z^c} & \frac{\partial x_{50}}{\partial \omega} & \frac{\partial x_{50}}{\partial \phi} & \frac{\partial x_{50}}{\partial \kappa} \\ \frac{\partial y_{50}}{\partial X^c} & \frac{\partial y_{50}}{\partial Y^c} & \frac{\partial y_{50}}{\partial Z^c} & \frac{\partial y_{50}}{\partial \omega} & \frac{\partial y_{50}}{\partial \phi} & \frac{\partial y_{50}}{\partial \kappa} \\ \frac{\partial x_{112}}{\partial X^c} & \frac{\partial x_{112}}{\partial Y^c} & \frac{\partial x_{112}}{\partial Z^c} & \frac{\partial x_{112}}{\partial \omega} & \frac{\partial x_{112}}{\partial \phi} & \frac{\partial x_{112}}{\partial \kappa} \\ \frac{\partial y_{112}}{\partial X^c} & \frac{\partial y_{112}}{\partial Y^c} & \frac{\partial y_{112}}{\partial Z^c} & \frac{\partial y_{112}}{\partial \omega} & \frac{\partial y_{112}}{\partial \phi} & \frac{\partial y_{112}}{\partial \kappa} \end{pmatrix}$$

**column 2 / column 4**

**column 2 / column 6**

# Partial Derivative Analysis (cont'd)