

CIVE 6374 Optical Imaging Metrology

Lecture notes based on material provided by:
Dr Derek Lichti, University of Calgary

What is Photogrammetry?

- ▶ A word comprised of three combining forms:

photo-

light

gram-

a drawing or recording

-metry

the process of measuring

What is Photogrammetry? (2)

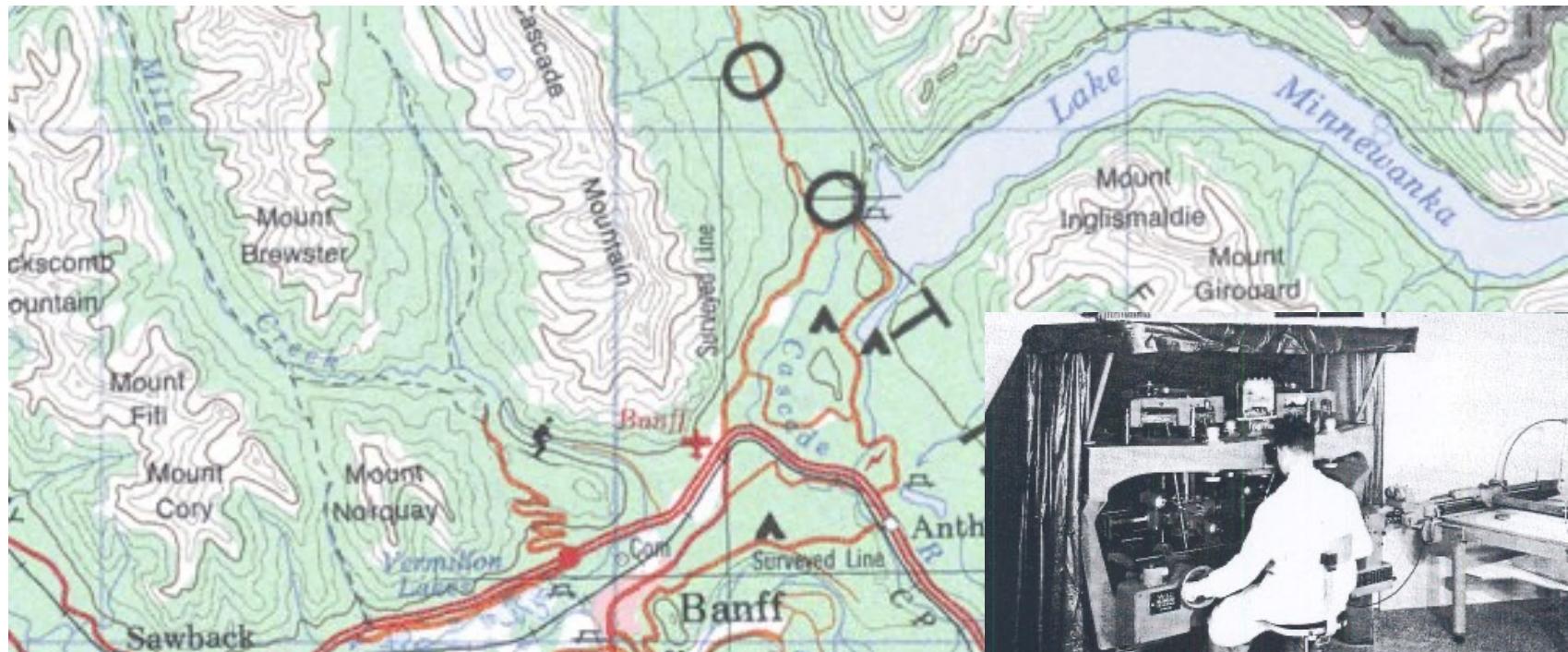
- ▶ A textbook definition
 - ▶ “The process of deriving metric information about an object through measurements made on photographs of the object.”
Mikhail et al. (2001)
- ▶ A bit awkward and dated (i.e. photographs)
- ▶ Much simpler and generic definition
 - ▶ 3D object or scene reconstruction from (2D) imagery

....also

- ▶ One of the reason I chose geomatics engineering

What is Photogrammetry Used For?

- ▶ Topographic mapping



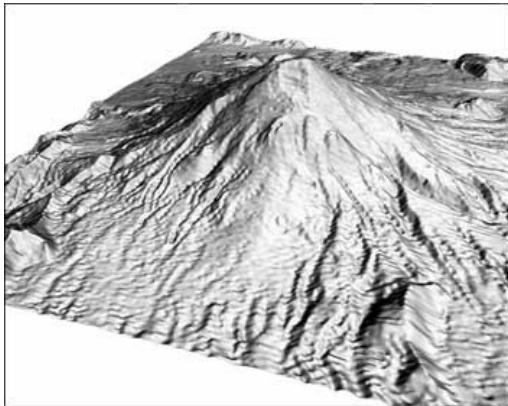
<http://geology.com/canada/topo-maps.shtml>

<http://www.wsdot.wa.gov/MapData/Photogrammetry/ImageFiles/WildAutographA7.jpg>

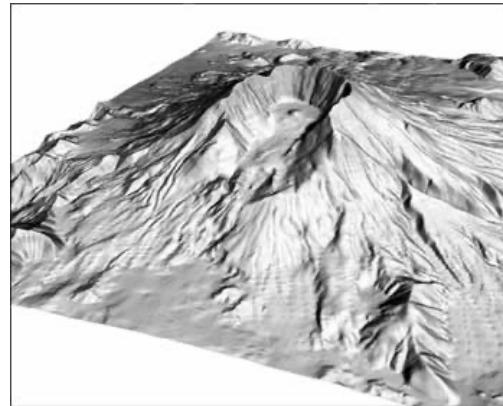
- ▶ A “traditional” photogrammetric product

What is Photogrammetry Used For? (2)

- ▶ Terrain modeling



<http://ned.usgs.gov/historic.html>



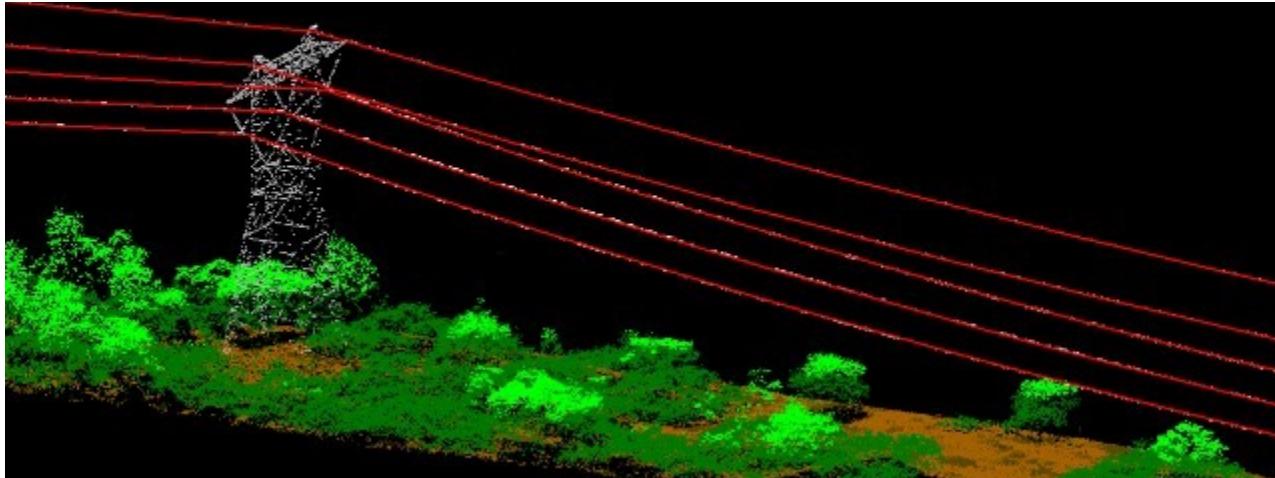
- ▶ 3D city modeling



What is Photogrammetry Used For? (3)

▶ Power line modeling

<http://www.energydimensions.net/wp-content/uploads/2009/04/lidar5.jpg>



▶ Face modeling

<http://pixogram.co.uk/?p=699>

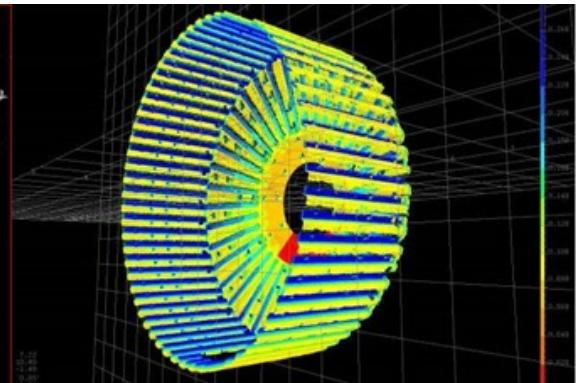
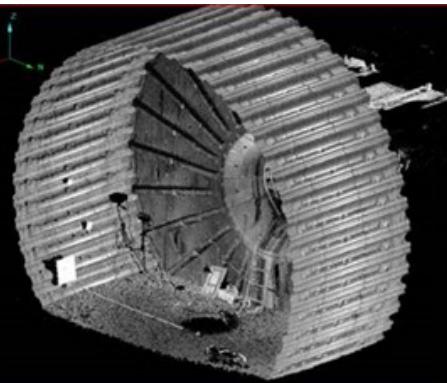


What is Photogrammetry Used For? (4)

- ▶ Deformation monitoring

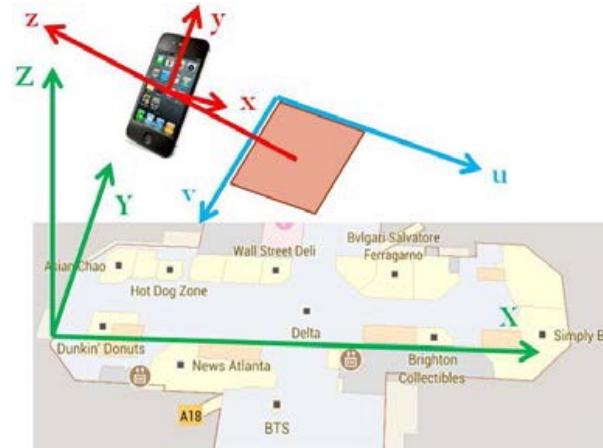
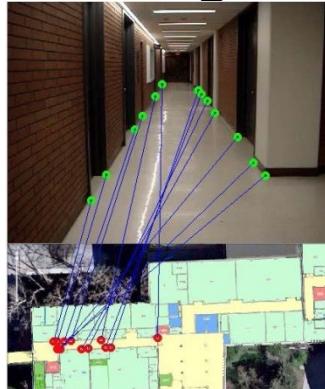


- ▶ Industrial monitoring



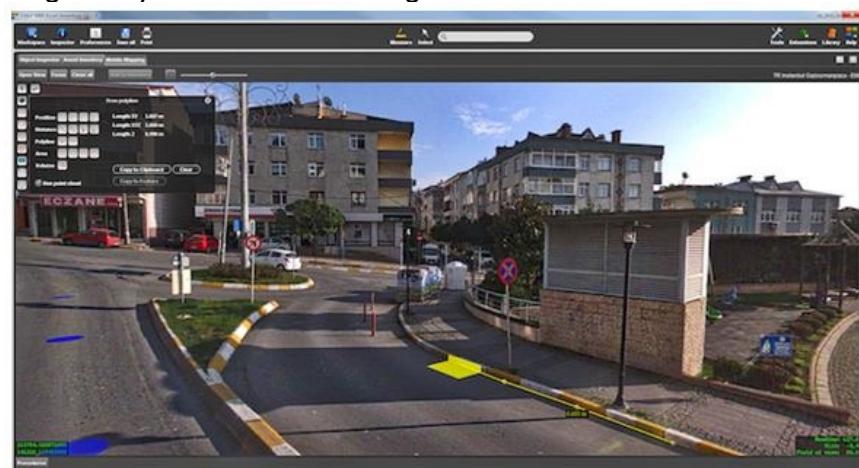
What is Photogrammetry Used For? (5)

► Pedestrian navigation



Images source: Bei Huang and Yang Gao, 2012. A Floor Plan based Vision Navigation System for Indoor Navigation with Smart Device. Journal of Global Positioning Systems, 11 (1) : 71-79.

► Asset inventory compilation



http://www.environment.uwaterloo.ca/research/isprs/tests_datasets.html

<http://gisuser.com/2015/07/orbit-gt-releases-mobile-mapping-feature-extraction-portfolio-v11-1/>

What is Photogrammetry Used For? (6)

► Computer-assisted surgery

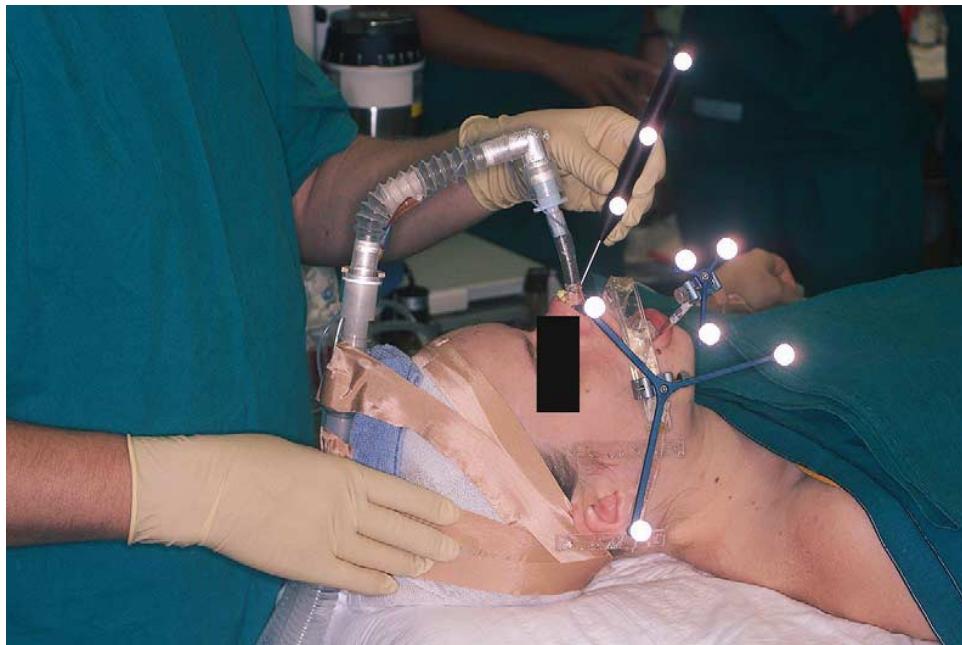
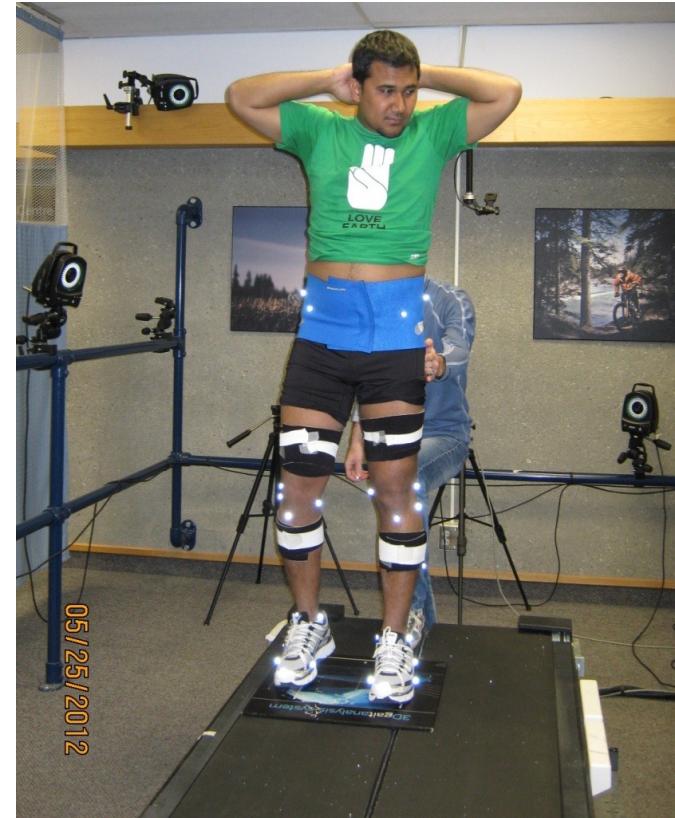


Image source: L. Ewers, K. Schicho, G. Undt, F. Wanschitz, M. Truppe, R. Seemann, A. Wagner, 2005. Basic research and 12 years of clinical experience in computer-assisted navigation technology: a review. International Journal of Oral and Maxillofacial Surgery. 34 (1): 1–8.

R: Edward R. Valstar, Charl P. Botha, Marjolein van der Glas, Piet M. Rozing, Frans C.T. van der Helm, Frits H. Post, Albert M. Vossepoel (2002) Towards computer-assisted surgery in shoulder joint replacement. ISPRS Journal of Photogrammetry & Remote Sensing 56 (2002) 326– 337

What is Photogrammetry Used For? (7)

- ▶ Human motion capture



http://images.digitalmedianet.com/2009/Week_5/7qix5ws6/story/vicon_uc%20merced.jpg

Course Objectives

- ▶ At the end of this course, you will be able to:
 1. Extract measurements from a single image to obtain approximate three-dimensional information.
 2. Rigorously model the geometry of central perspective imagery and associated distortions for the purpose of three-dimensional object reconstruction.
 3. Use overlapping images to create 3D models of imaged objects

Assessment

Grading:

Final Exam	50%
Labs/Projects	40%
Participation	10%
Total semester grade	100%

- Participation includes showing up to class and being actively engaged in class discussions

Course Delivery

- ▶ **Lecture delivery method**
 - ▶ A few PPT-only lectures
 - ▶ Mainly writing on the white board augmented with PPT notes of figures and images
 - ▶ The PPT notes will be made available in Blackboard
- ▶ **Examples**
 - ▶ Many worked examples are provided (e.g. least-squares solutions)

Reference Material

- ▶ No required textbook for the course
- ▶ Suggested references:
 - ▶ Luhmann, T., Robson, S., Kyle, S. and Boehm, J., 2013. Close Range Photogrammetry: Principles, Techniques and Applications. Whittles Publishing, Caithness. 683 pages. (LU) (**available as pdf on blackboard**)
 - ▶ Wolf, P.R., Dewitt, B.A., Wilkenson, B.E., 2014, Elements of Photogrammetry, 4th edition, McGraw Hill: Boston, 676 pages. (WD)
- ▶ Suggested readings from each textbook for each course topic are provided in the syllabus
- ▶ Additional reading material listed in syllabus will be provided on blackboard

Ground Rules

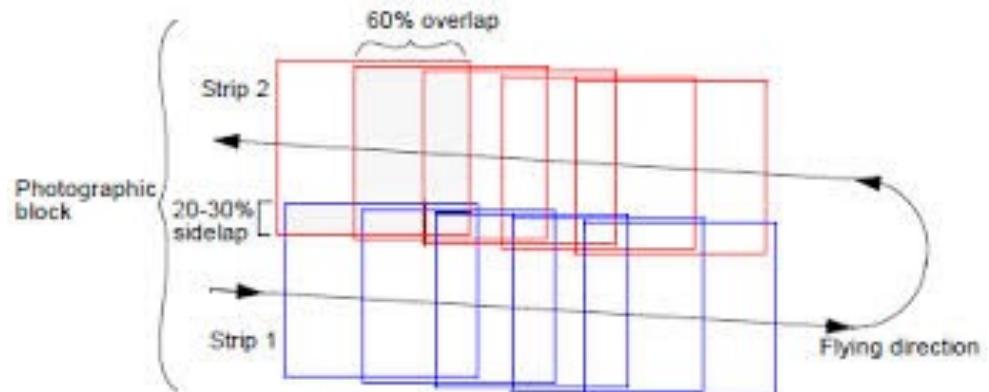
- ▶ Use of laptops and tablets is fine for note taking
- ▶ Please turn off phones
- ▶ Please ask questions and ask me to slow down or speed up as appropriate
- ▶ My office hours: **tentatively M/W 1130 to 130**
- ▶ My contact are details in the course syllabus
- ▶ Email me any time with questions: clglenne@uh.edu
- ▶ My response won't likely be immediate, but I will reply in a timely manner

How Does Photogrammetry Work?

▶ Image acquisition



https://wiki.hexagongeospatial.com/index.php?title=Image_and_Data_Acquisition



▶ Analogue camera (L), digital line sensor (C), UAV (R)



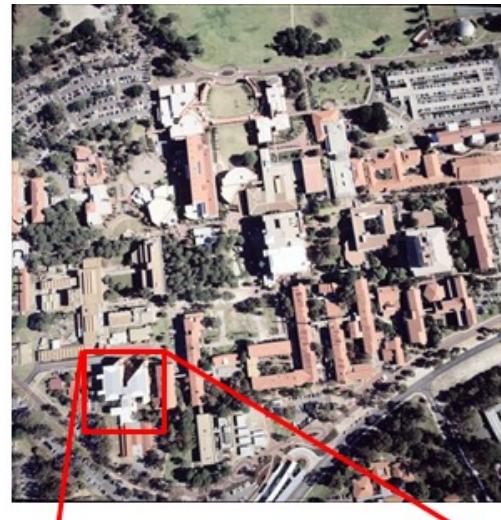
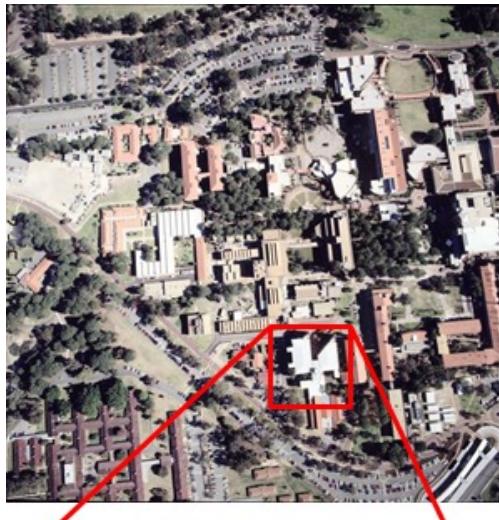
<http://www.inlandaerial.com/services.htm>

<http://www.geo-matching.com/category/id50-digital-aerial-cameras-.html>

<http://www.icg.tugraz.at/Members/irschara>

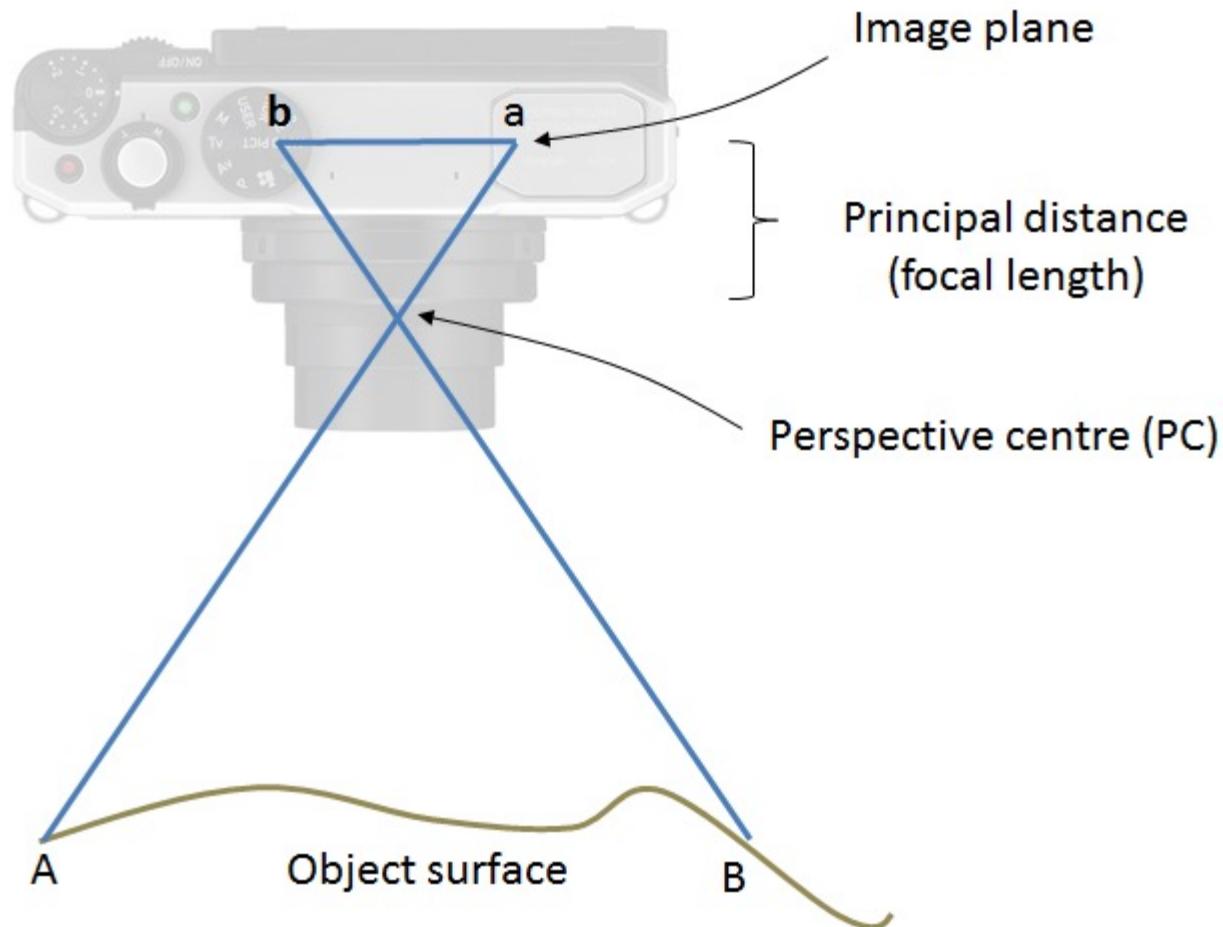
How Does Photogrammetry Work? (2)

- ▶ Identify and measure conjugate points in overlapping images



How Does Photogrammetry Work? (3)

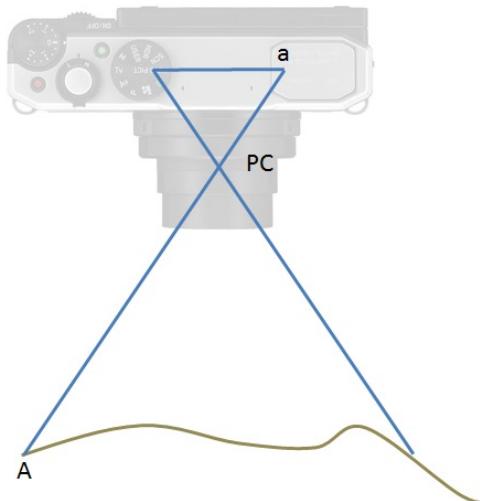
▶ Pinhole camera model



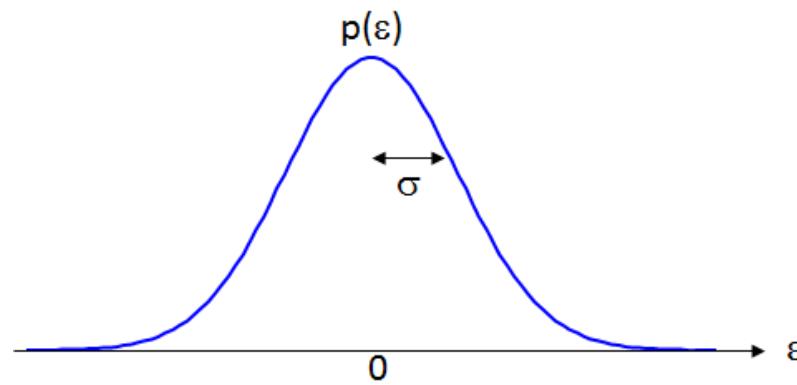
<http://www.photographyreview.com/reviews/pentax-mx-1-retro-premium-compact-camera#slider-pro-1-1>

How Does Photogrammetry Work? (4)

- ▶ Functional model: collinearity condition: a, PC and A lie on a straight line

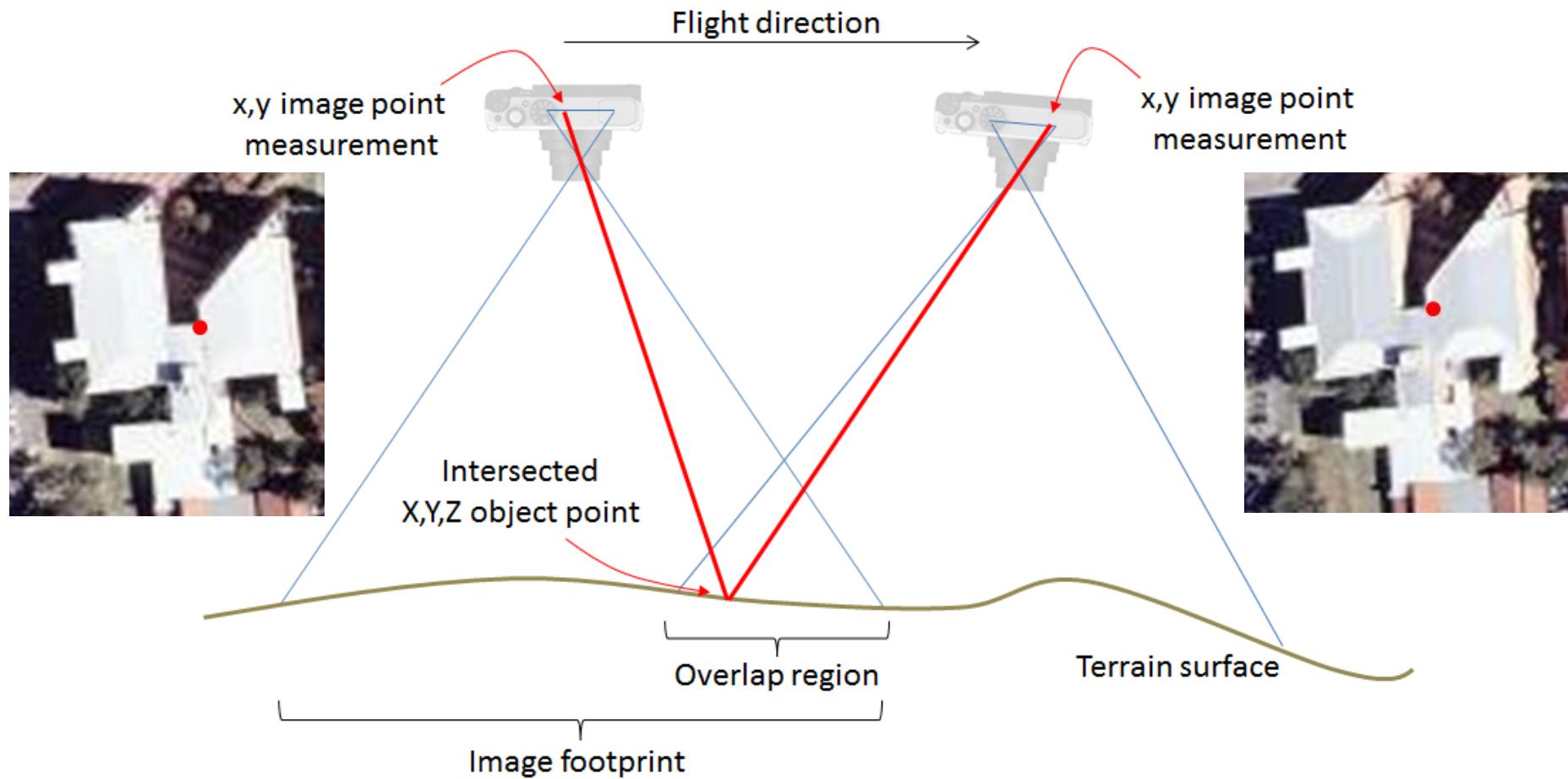


- ▶ Stochastic model for random measurement errors (ε)



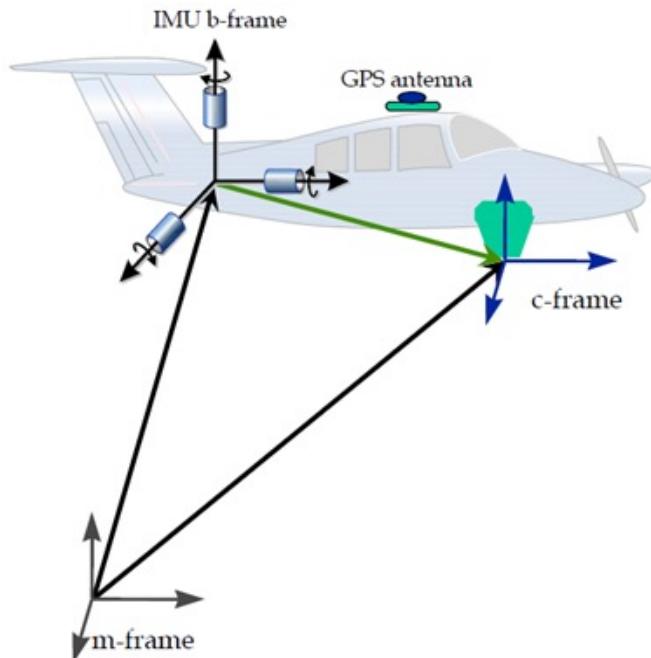
How Does Photogrammetry Work? (5)

- ▶ Ray intersection from two (or more) images



How Does Photogrammetry Work? (6)

- ▶ Image position and orientation needed!



$(X, Y, Z, \omega, \phi, \kappa)_1$



$(X, Y, Z, \omega, \phi, \kappa)_2$

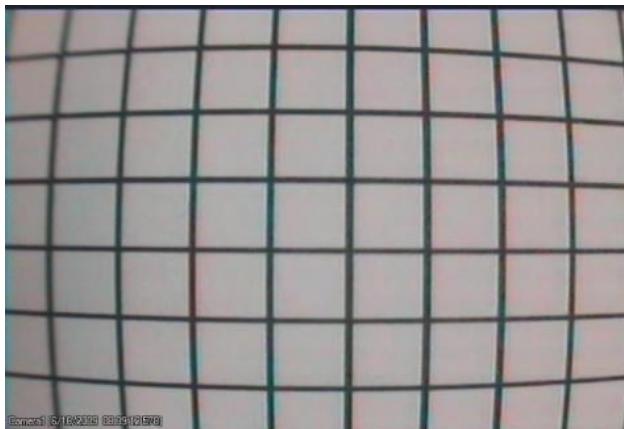


Image courtesy Ayman Habib

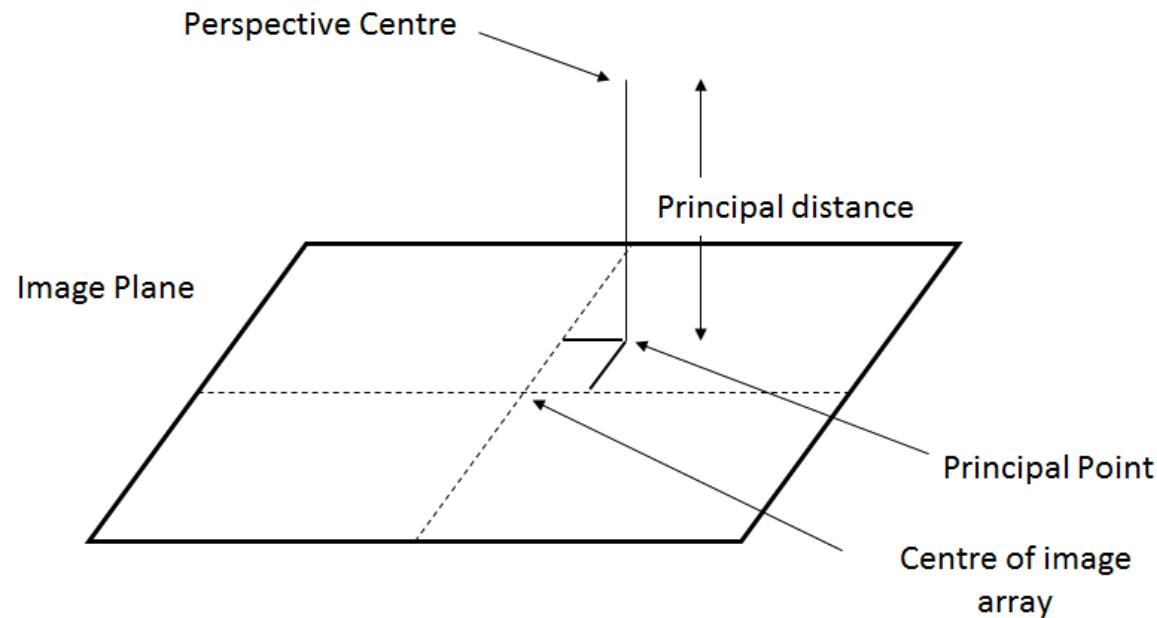
How Does Photogrammetry Work? (7)

► Required quantities

- **Exterior orientation parameters:** $X, Y, Z, \omega, \phi, \kappa \rightarrow$ camera orientation (by direct georeferencing or ground control points)
- **Camera interior orientation parameters:** principal distance, principal point offset, lens distortions coefficients \rightarrow camera calibration

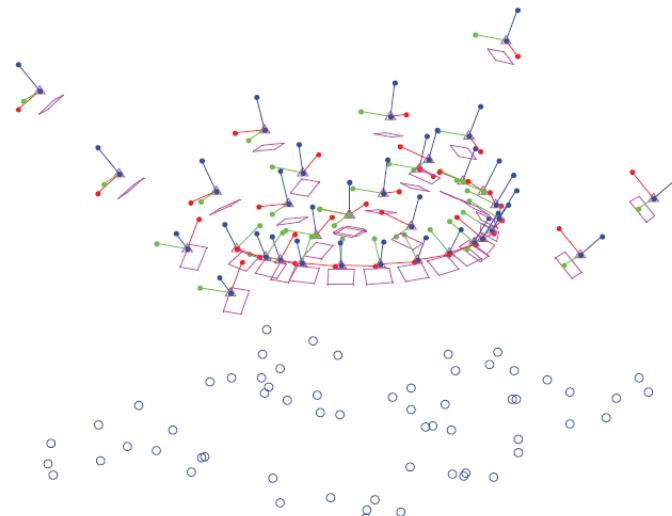


“Barrel” lens distortion

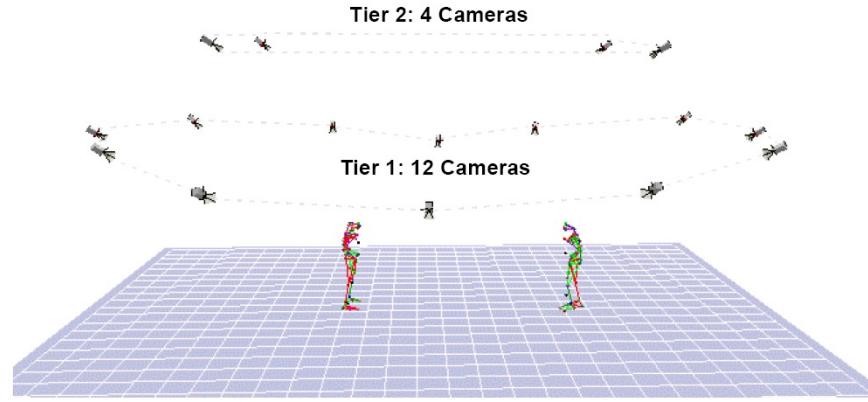
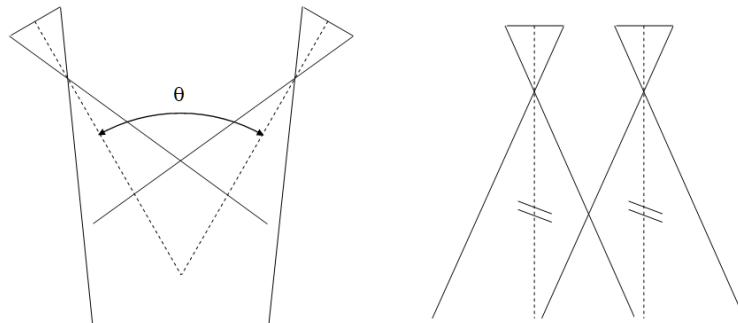


How Does Photogrammetry Work? (8)

- ▶ Quality assurance (before):
 - ▶ Imaging system calibration



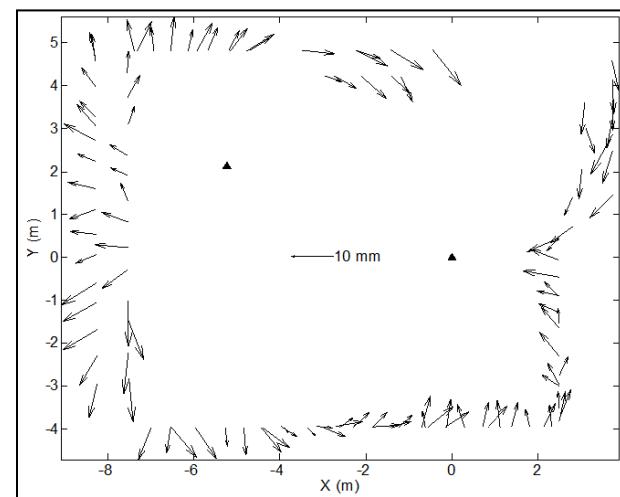
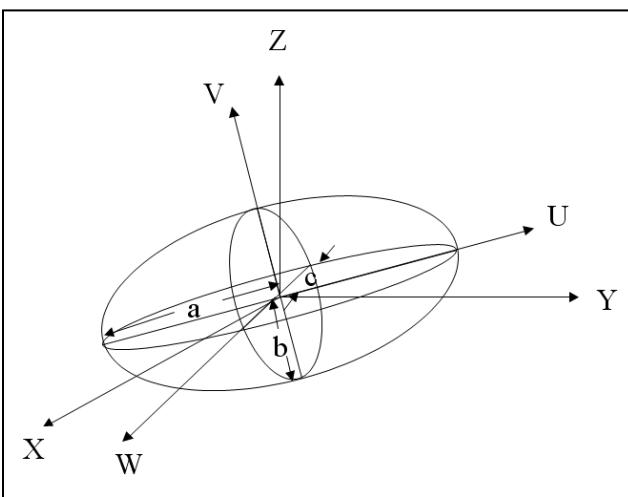
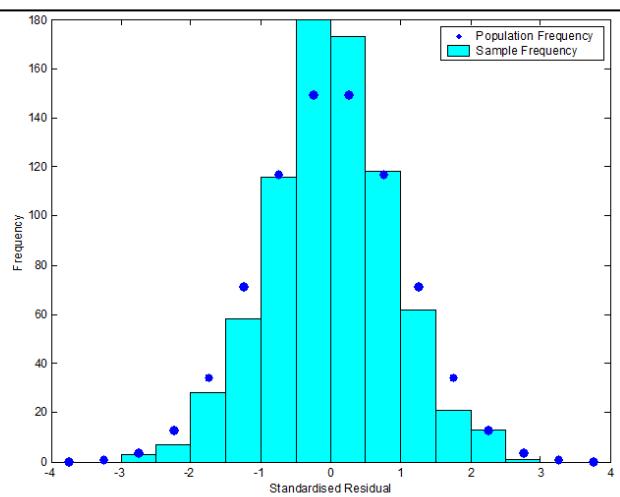
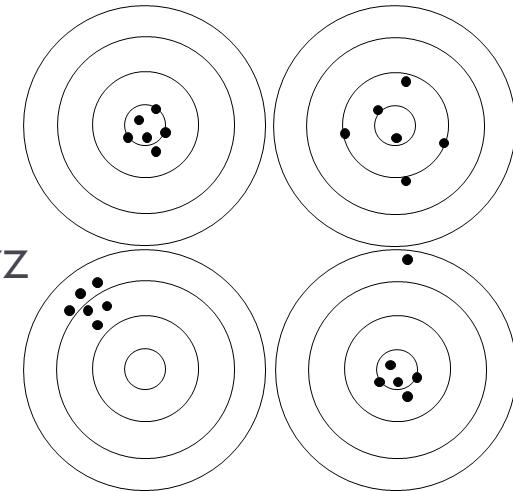
- ▶ Network design



Images source: EVaRT 5.0 User's Manual, Motion Analysis Corporation, Santa Rosa, CA, 2006

How Does Photogrammetry Work? (9)

- ▶ Quality control (after)
 - ▶ Statistical testing: $\varepsilon \sim n(0, \sigma^2)$?
 - ▶ Precision measures (confidence intervals): σ_{XYZ}
 - ▶ Reliability (robustness) measures: ∇_{xy}
 - ▶ Independent accuracy assessment: Δ_{XYZ}



Summary of The Photogrammetric Process

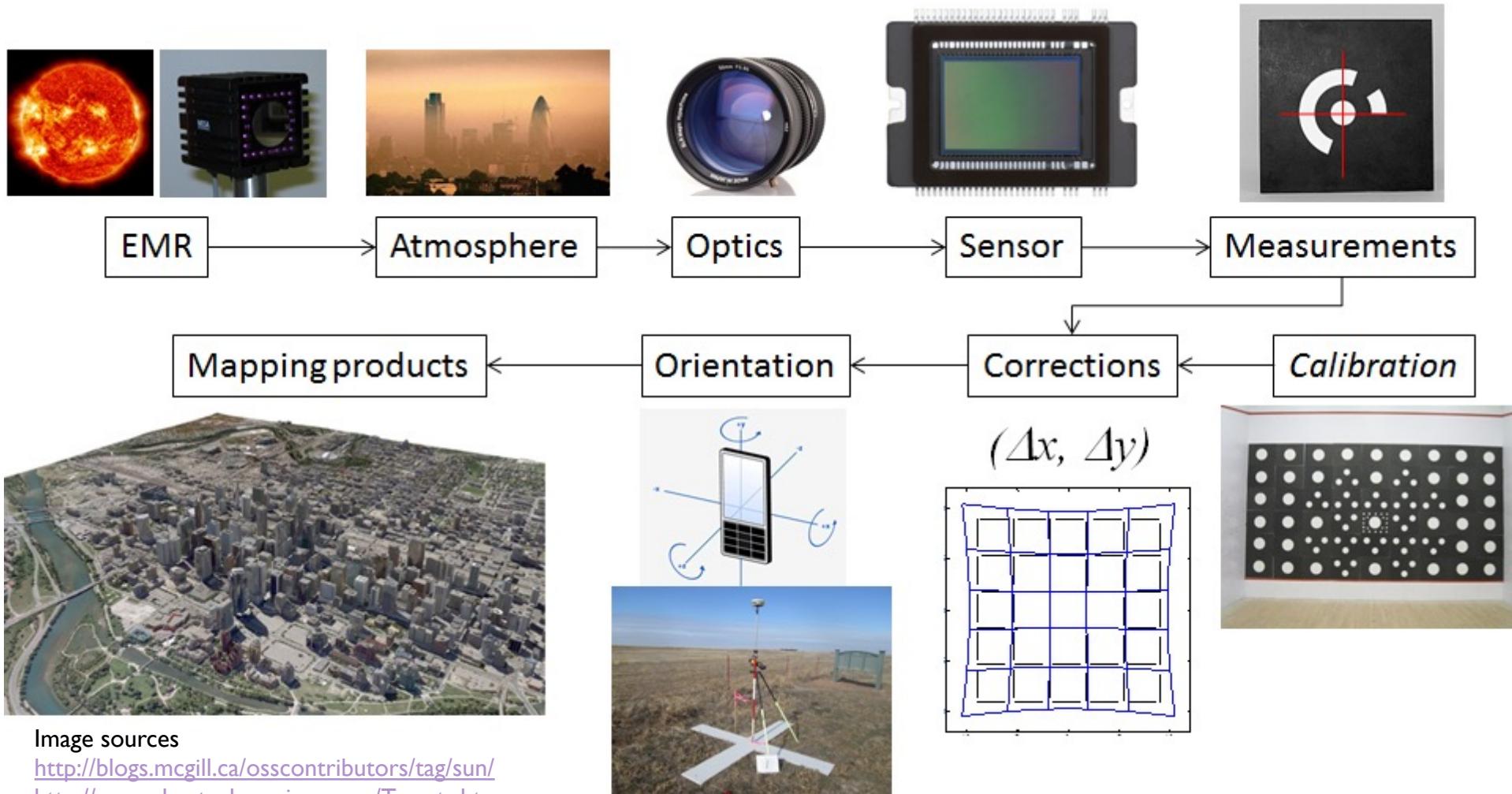


Image sources

<http://blogs.mcgill.ca/osscontributors/tag/sun/>

<http://www.dcmtechservices.com/Targets.htm>

<http://www.theguardian.com/environment/2011/jan/28/europe-air-quality-pollution>

<https://www.ephotozine.com/article/slr-magic-50mm-f-0.95-hyperprime-lens-review-23001>

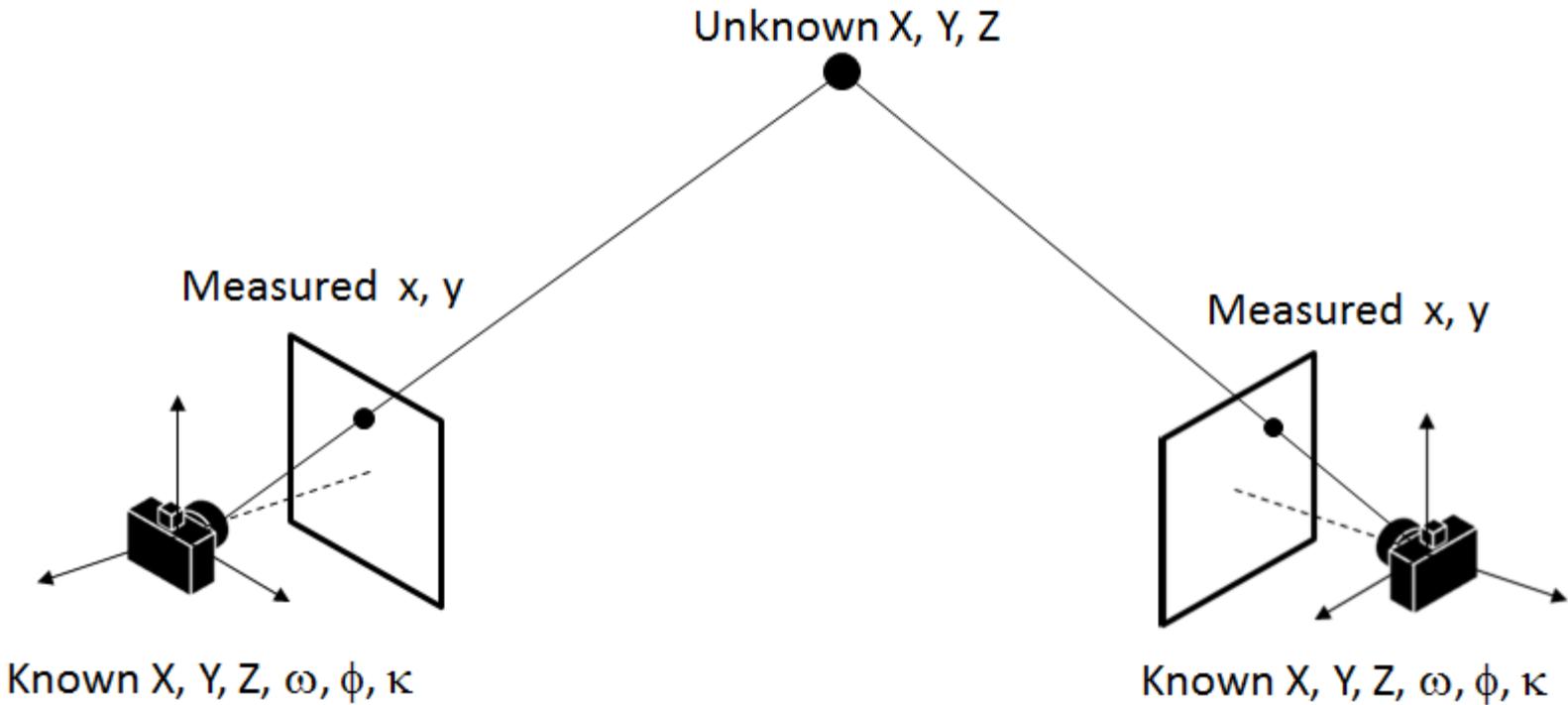
<http://oneslidephotography.com/ccd-vs-cmos-dslr-camera-which-one-is-better/>

<http://www.rpsurveying.com/img/proj/ControlPoint.Full.png>

<http://www.3dcadbrowser.com/download.aspx?3dmodel=20756>

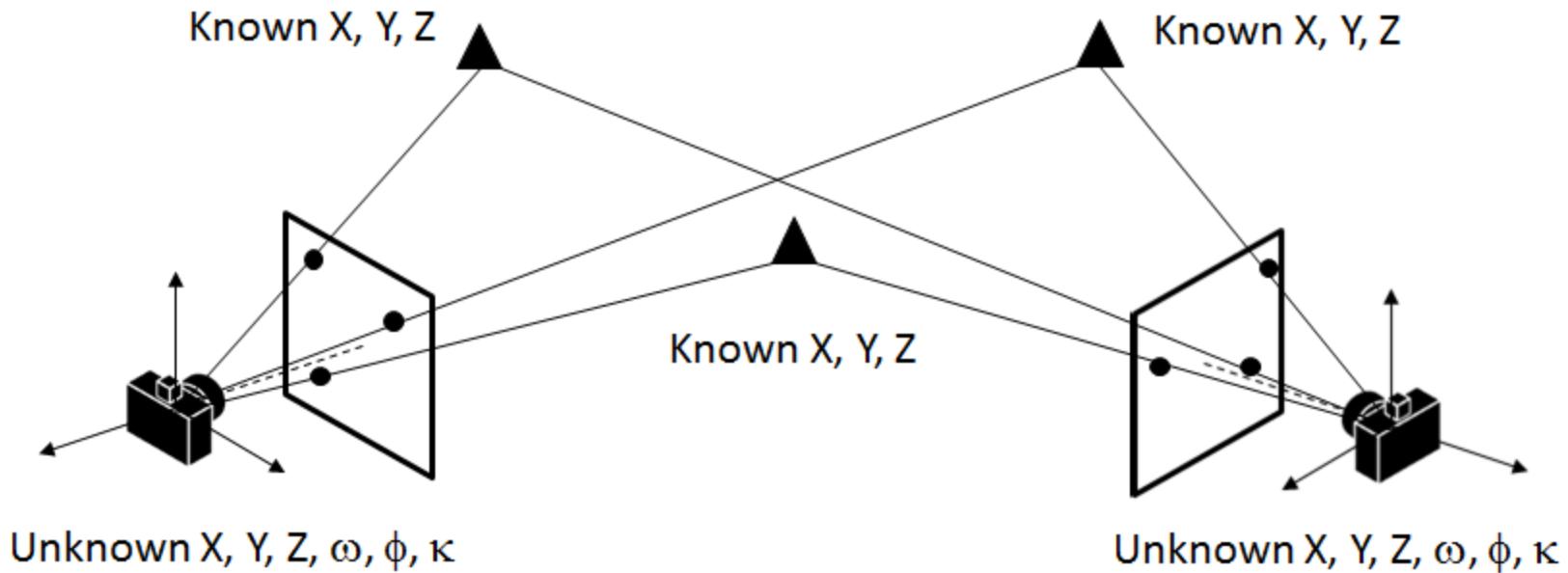
How Can We Determine Unknown Location?

▶ Photogrammetric intersection



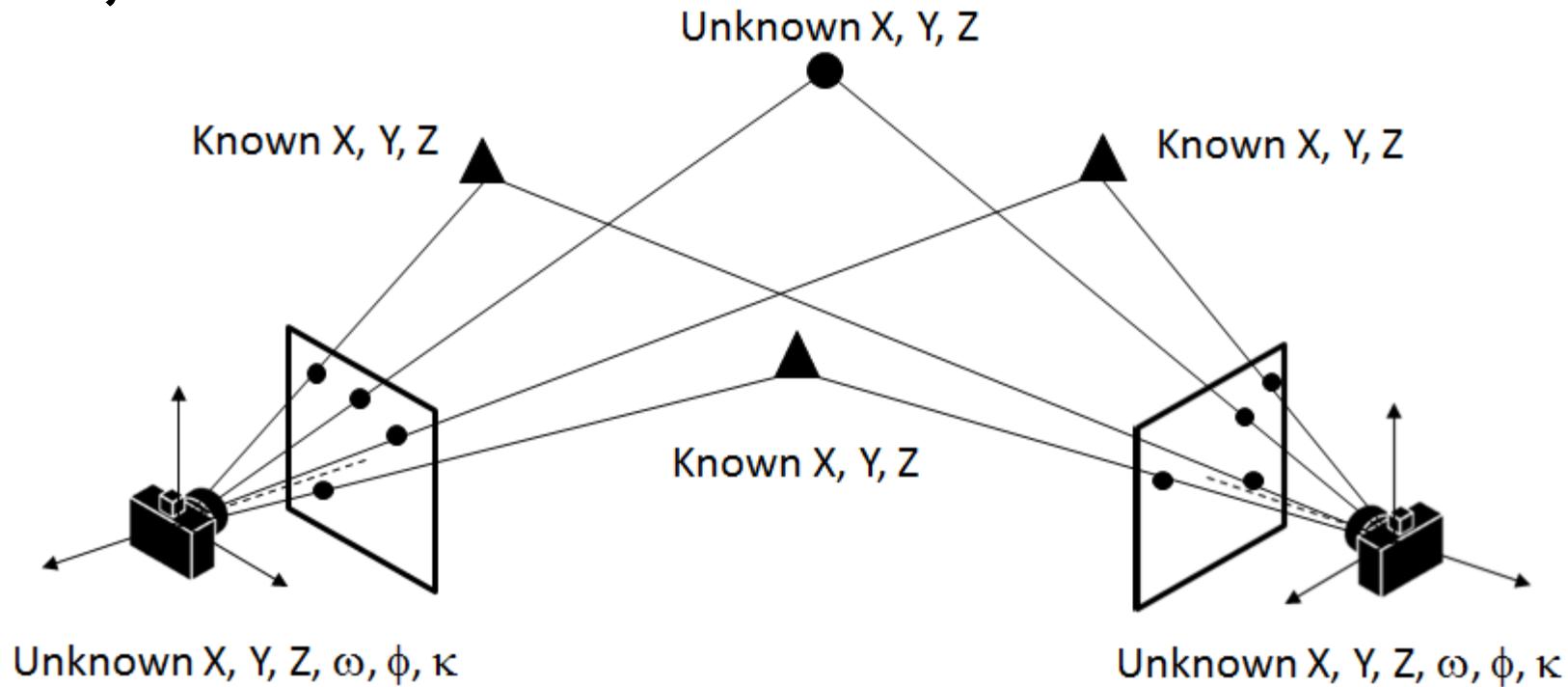
How Can We Determine Camera Location and Attitude?

► Photogrammetric resection



How can we map using images?

- ▶ Photogrammetric resection and intersection—bundle adjustment



How do we strengthen solution geometry?

► Photogrammetric networks

