CE 59700: Digital Photogrammetric Systems

Fall 2020

Contact Information

- Instructor:
  - Ayman F. Habib
  - Office: **HAMP 4108 & DLR 204D**
  - Tel: (765) 496-0173
  - E-mail: ahabib@purdue.edu
  - Lectures (HAMP 1266):
    - Monday (3:30 p.m. – 6:20 a.m.)
  - Office Hours:
    - Monday & Wednesday(8:30 a.m. – 10:30 a.m.)
- Course webpage:
  - http://purdue.edu/CE/DPRG

Course Objectives

- Gain familiarity with the basic principles of photogrammetric operations
- Emphasis:
  - Definition and possible applications,
  - Electromagnetic radiation,
  - Optical principles, film development, and digital cameras,
  - Vertical photography,
  - Image coordinate measurement and reduction,
  - Mathematical and geometric principles,
  - Theory and procedures of photogrammetric orientation,
  - Photogrammetric geo-referencing,
  - Digital image matching, and
  - Digital orthophoto generation.

Course Notes and Textbooks

- Material presented in class, as well as supplemental notes, will be available through the course webpage.
  - Contains all the required material for the assignments and exams.
- Supplementary References (**optional**):
  - Mikhail, E., Bethel, J., McGlone, J., 2001. Introduction to Modern Photogrammetry. John Wiley & Sons, Inc.
  - McGlone, C, Mikhail, E., Bethel, J., 2012, Manual of Photogrammetry, Sixth Edition, American Society for Photogrammetry and Remote Sensing.
  - Wolf, P., Dewitt, B., 2000. Elements of Photogrammetry with Applications in GIS. McGraw-Hill.
  - Krauss, K., 1993. Photogrammetry, Volume 1: Fundamentals and Standard Processes. Dummler/Bonn.
  - Krauss, K., 1997. Photogrammetry, Volume 2: Advanced Methods and Applications. Dummler/Bonn.

Grading Scheme

- Assignments: (25% of Total Grade)
  - Assignments will be due within roughly two weeks after they are handed out. Grades for late assignments will be reduced by 10% per day for each day overdue.
  - Some assignments will require computer programming (Mat lab, C, or C++) and submissions must include a softcopy of the source code (well documented) and the program output.
- Mid-Term Exam: (25% of Total Grade)
- Final Exam: (50% of Total Grade)
  - Exams are closed book/notes – **oral exams are an option**.
- Bonus points for class participation

Syllabus (Course Content)

- Chapter 1: Introduction
  - Definition, concepts, and applications
- Chapter 2: Electro-Magnetic Radiation
  - Energy sources and radiation principles
- Chapter 3: Basic Optics
  - Principles of geometric optics and important optical conditions for photogrammetric applications
- Chapter 4: Film Development & Digital Cameras
  - Development of B/W and color films
  - Digital cameras (frame and line cameras)
- Chapter 5: Vertical Photography
  - Basic definitions, image scale, image to ground coordinate transformation, relief displacement

Syllabus (Course Content)

- Chapter 6: Image Coordinate Measurements
  - Measurements and necessary reductions of image coordinates
- Chapter 7: The Mathematical Model
  - Rotation matrices, the collinearity equations (concept and derivation)
  - Projective transformation, DLT, and RFM
- Chapter 8: Theory of Orientation
  - Interior, relative, and absolute orientation
- Chapter 9: Photogrammetric Bundle Adjustment
  - Sequential reconstruction of the normal equation matrix and derivation of the unknown parameters
- Chapter 10: Photogrammetric Geo-Referencing
  - Integrated sensor orientation and direct geo-referencing

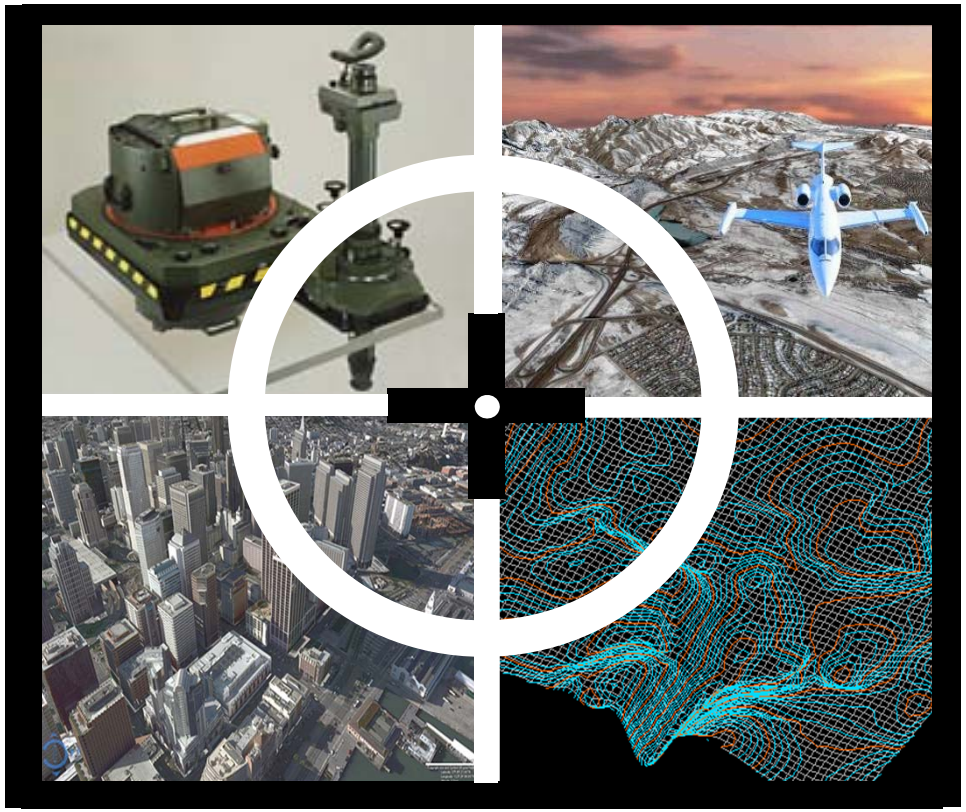
Syllabus (Course Content)

- Chapter 11: Digital Image Matching
  - Identification of conjugate points in overlapping images (cross correlation and least-squares matching)
- Chapter 12: Digital Orthophoto Generation
  - Polynomial rectification, differential rectification, and true orthophotos

Ch 1: Introduction

- Definition & Objectives
- Applications:
  - Reconnaissance
  - Production of Topographic Maps
  - DEM Generation
  - Close Range Photogrammetry:
    - Precision survey of buildings and engineering objects
    - Documentation of historical buildings
    - Medical applications
    - Mapping of roads and nearby objects (mobile mapping systems)

Ch 1: Introduction

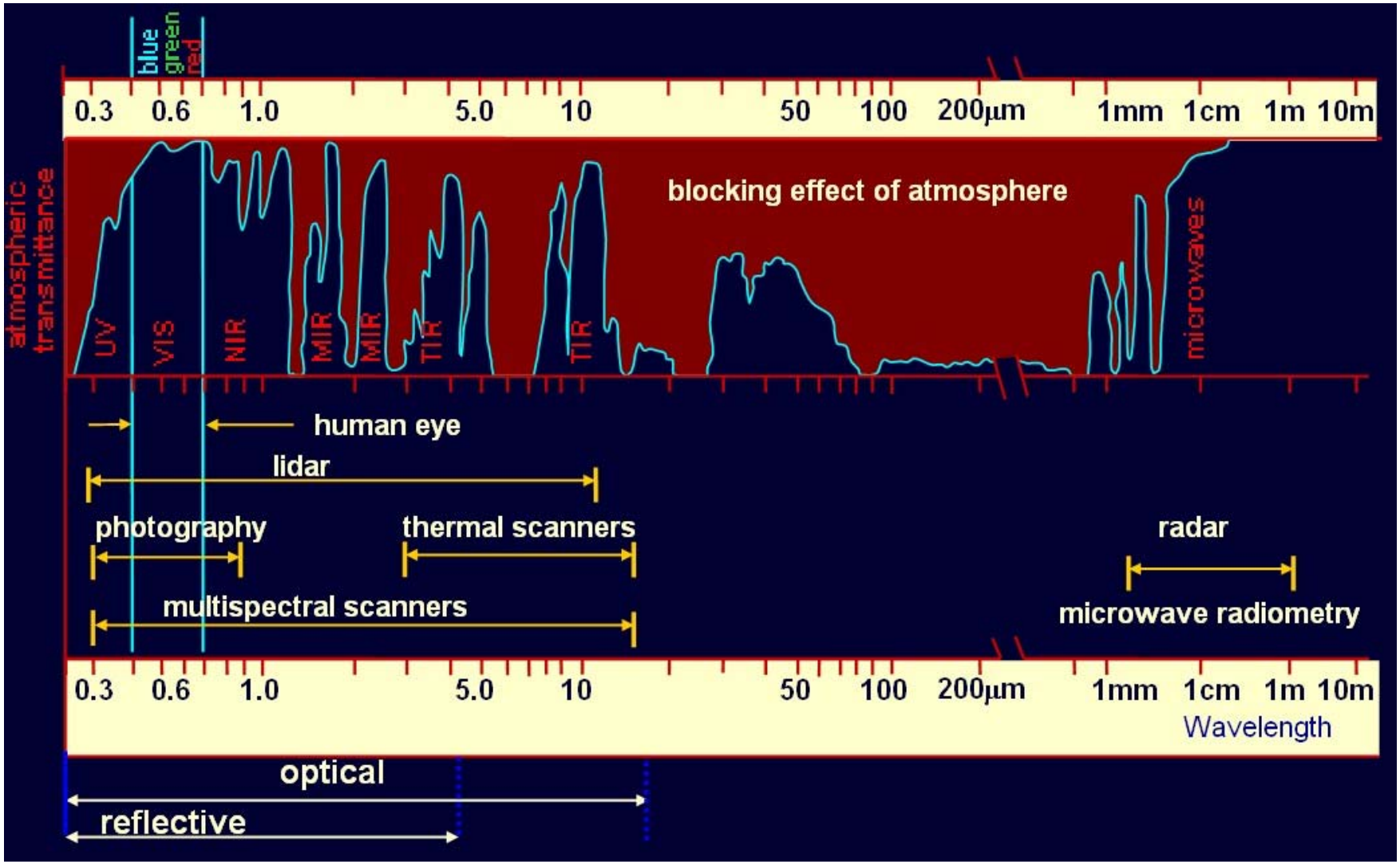


Art and science of tool development for automatic generation of spatial and descriptive information from multi-sensory data and/or systems

Ch 2: Electro-Magnetic Radiation

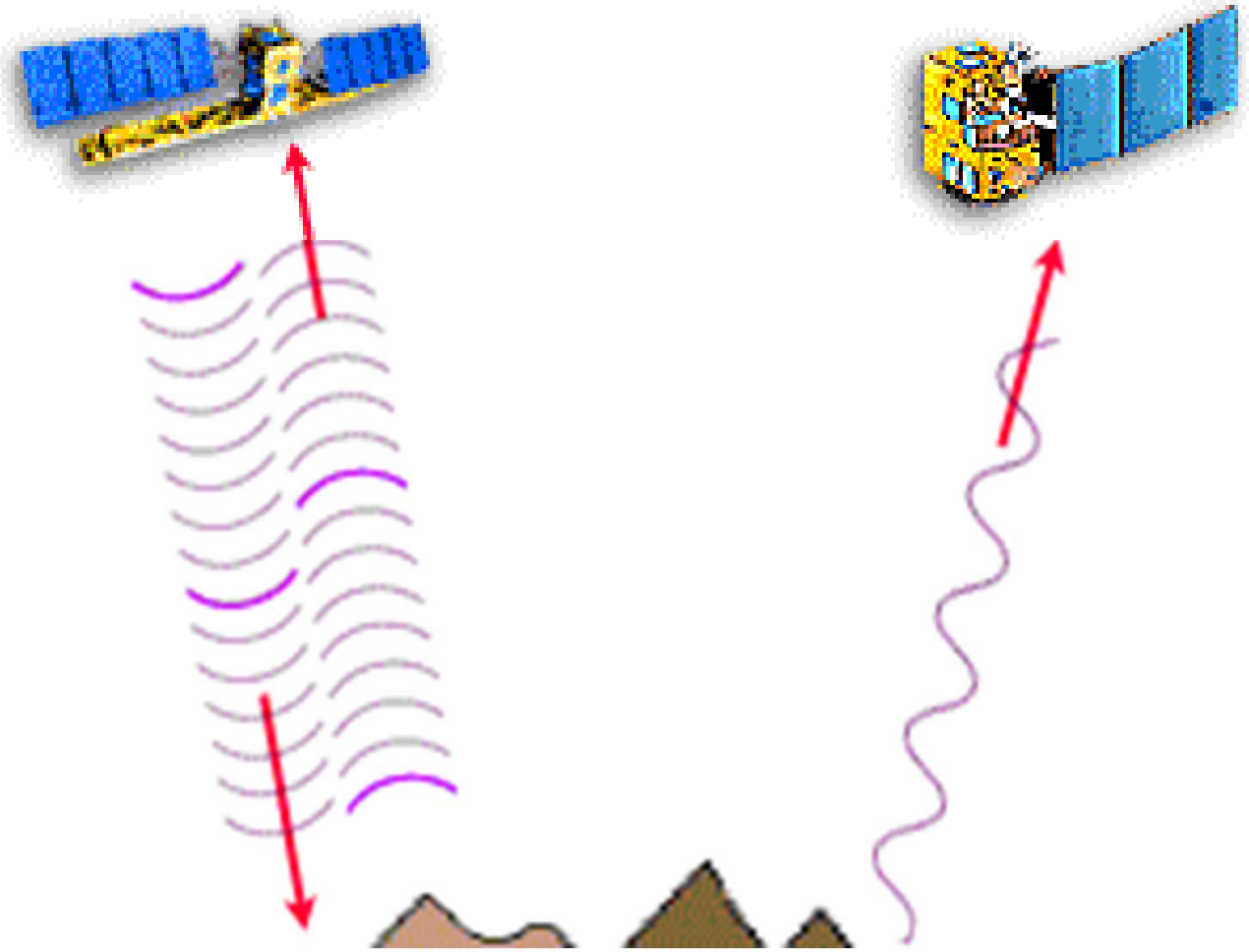
- Bands of the electro-magnetic radiation:
  - Radio waves
  - Microwaves
  - Infrared radiation
  - Visible light
  - Ultraviolet rays
  - X-rays
  - Gamma rays
- Properties of the electro-magnetic radiation
- Passive versus active remote sensing systems

Ch 2: Electro-Magnetic Radiation



http://foto.hut.fi/opetus/350/k04/luento6/luento6.html

Active Versus Passive Sensors



http://www.neis.gov.cn/kjddYG/index.jhtml

Ch 3: Basic Optics

- Basic camera components
- Reflection and refraction
- Lenses: Definitions
- Lens equation, aberrations, and distortions
- Diffraction
- Resolving power of optical systems
  - Depth of focus and depth of field
  - Motion blur

Ch 3: Basic Optics

http://www.dpreview.com/reviews/sonydscf828/3

Ch 4: Film Development & Digital Cameras

- Photographic film components
- Processing of Black and White (B/W) film
  - Negative film & inverse film
- Nature of color
- Processing of color film
  - Negative film & inverse film
- Digital cameras
  - Frame cameras
  - Line cameras (push-broom, three-line, and panoramic scanners)

Ch 4: Film Development & Digital Cameras

http://www.dpreview.com/reviews/sonydscf828/3

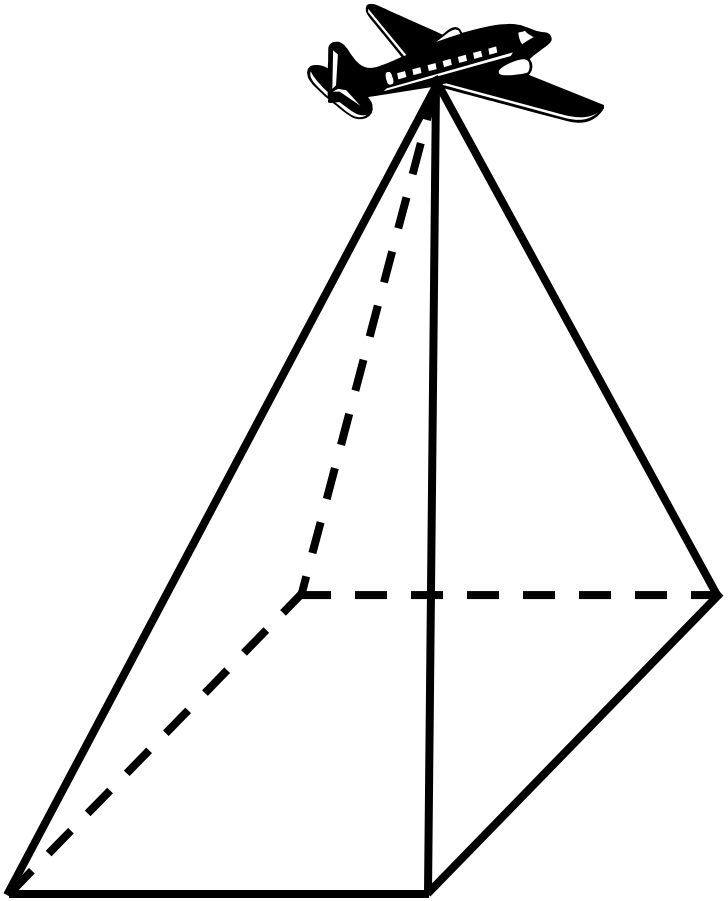
Ch 4: Analog Cameras

Negative Film

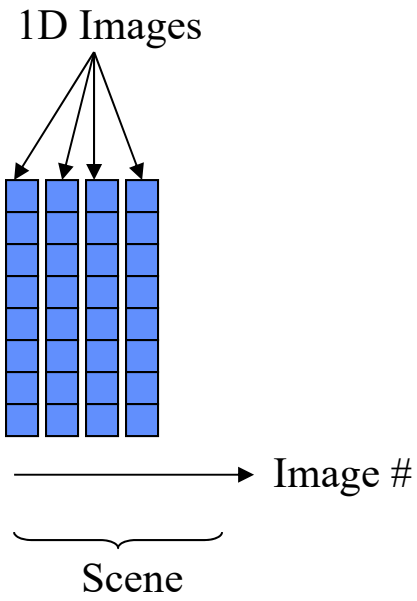
Positive Film

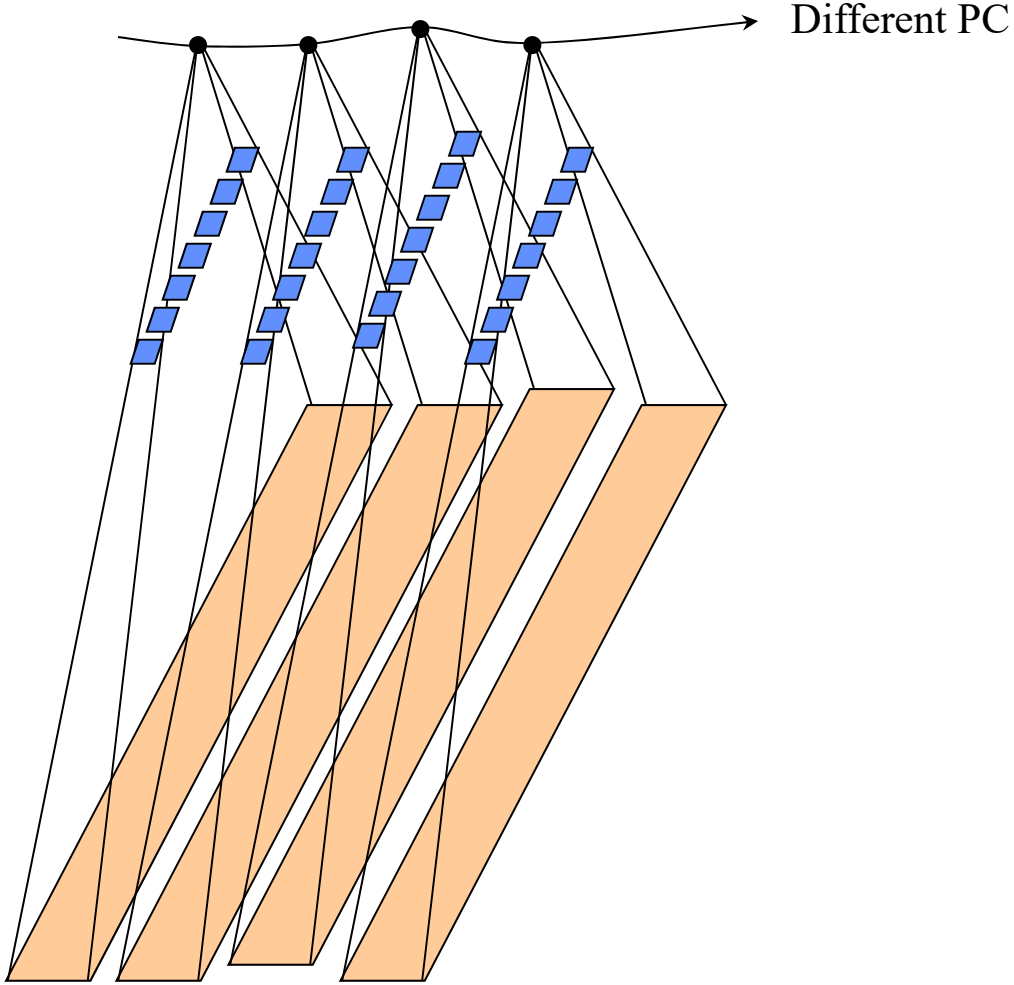
http://www.beautiful-landscape.com/

Frame Camera: Scene Acquisition



Line Camera: Scene Acquisition





Ch 5: Vertical Photography

- Image versus map characteristics
- Vertical photography: definitions and characteristics
- Image scale
- Mathematical relationship between corresponding image and ground coordinates
- Relief displacements

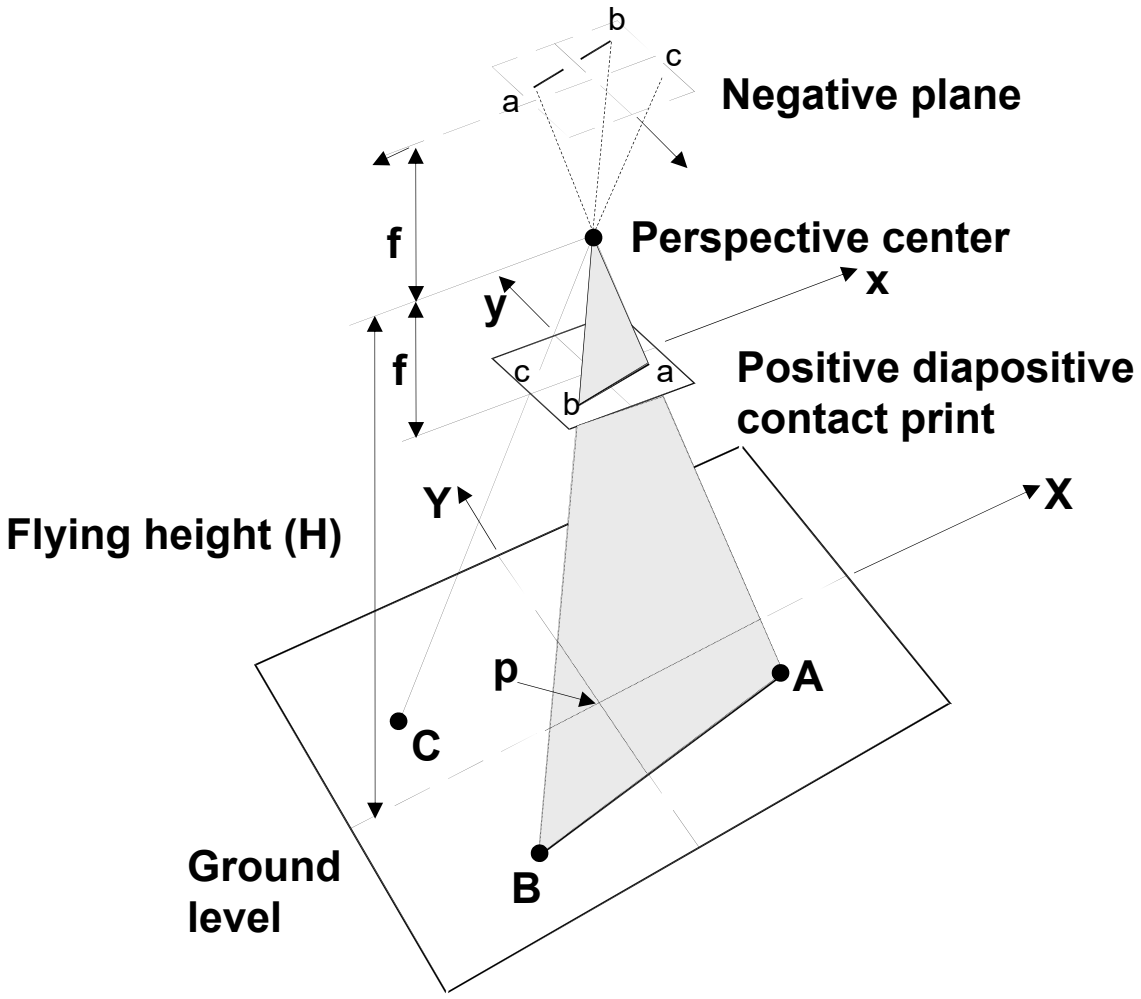
Ch 5: Vertical Photography

Vertical photographs

Oblique photographs

http://civisit.com/blog/?p=52

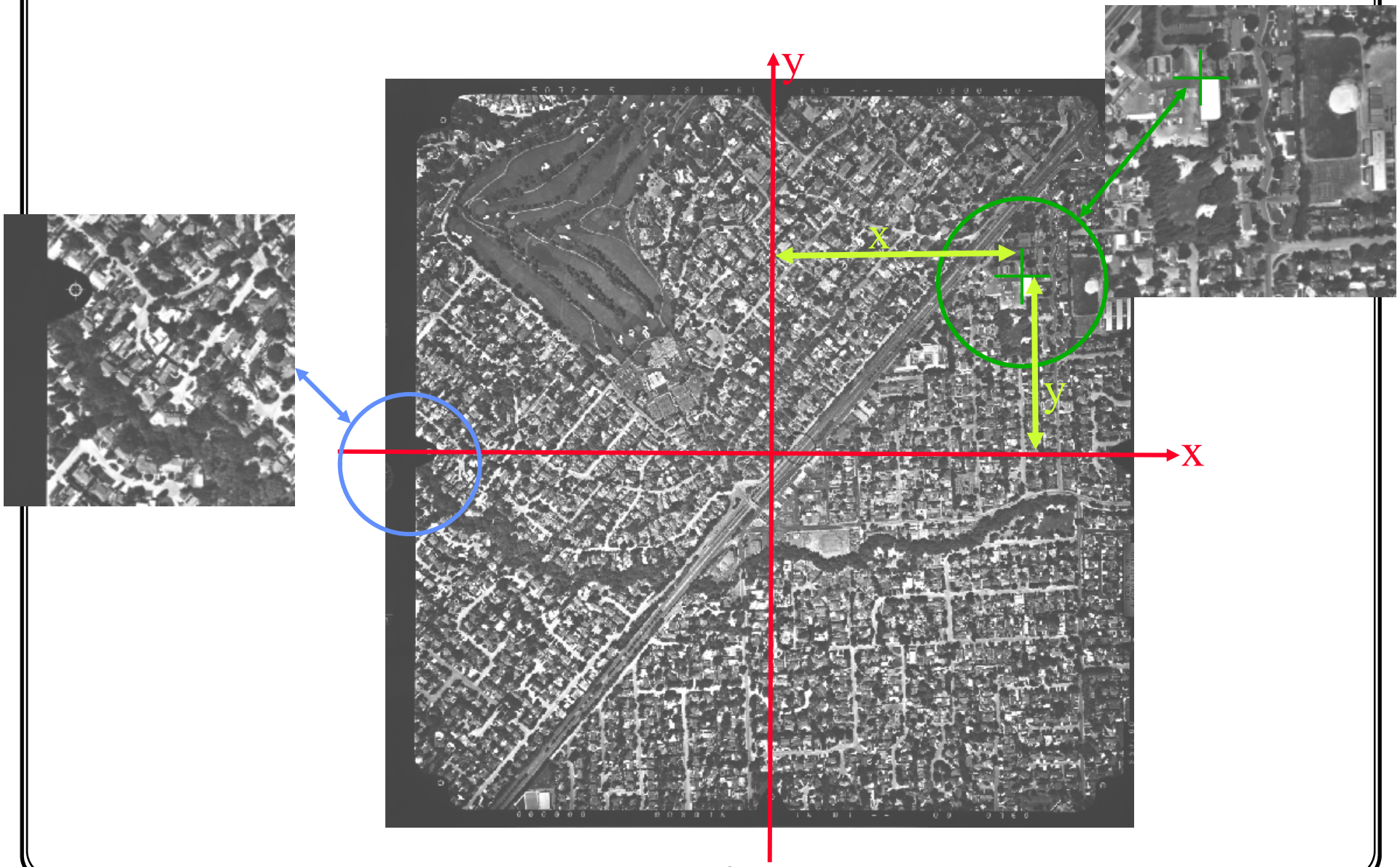
Ground Coordinates from Image Coordinates



Ch 6: Image Coordinate Measurements

- Image coordinate measurements in analog, analytical, and digital environments
- Comparators: mono and stereo-comparators
- Comparator to image coordinate transformations
- Reduction/refinement of image coordinate measurements:
  - Radial and de-centering lens distortions
  - Atmospheric refraction
  - Earth curvature

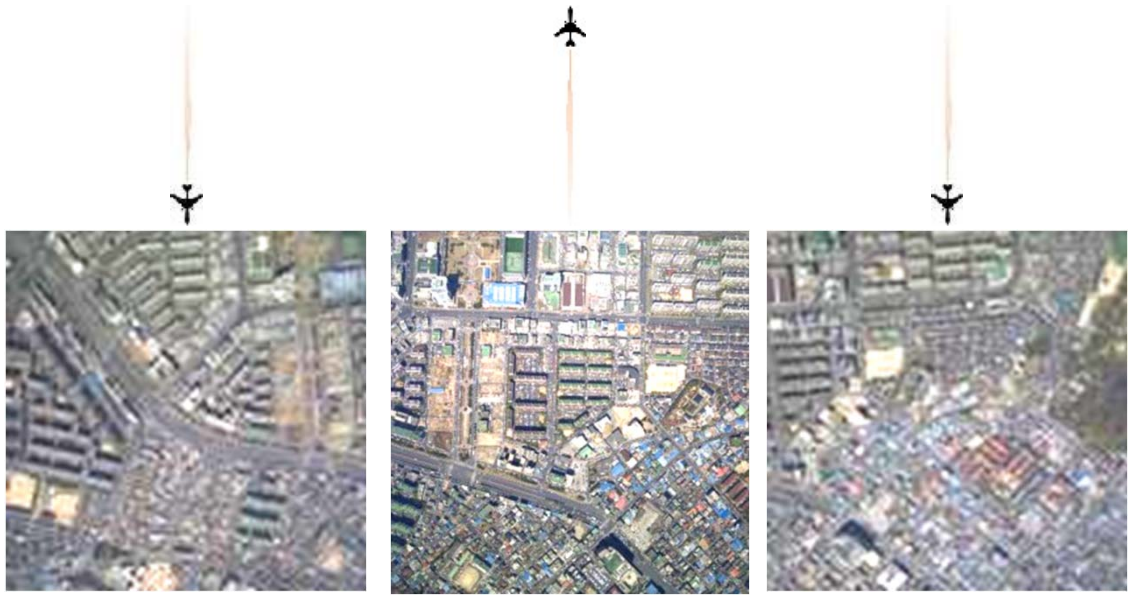
Ch 6: Image Coordinate Measurements



Ch7: Mathematical Model

- Objectives: Derive the general mathematical relationship between corresponding image and object space coordinates
- Projection alternatives
- Rotation matrices (2-D and 3-D)
  - Derivations and characteristics
- Collinearity equations
  - Concept and derivation
- Projective transformation, DLT, and RFM
- Least-squares adjustment in photogrammetry

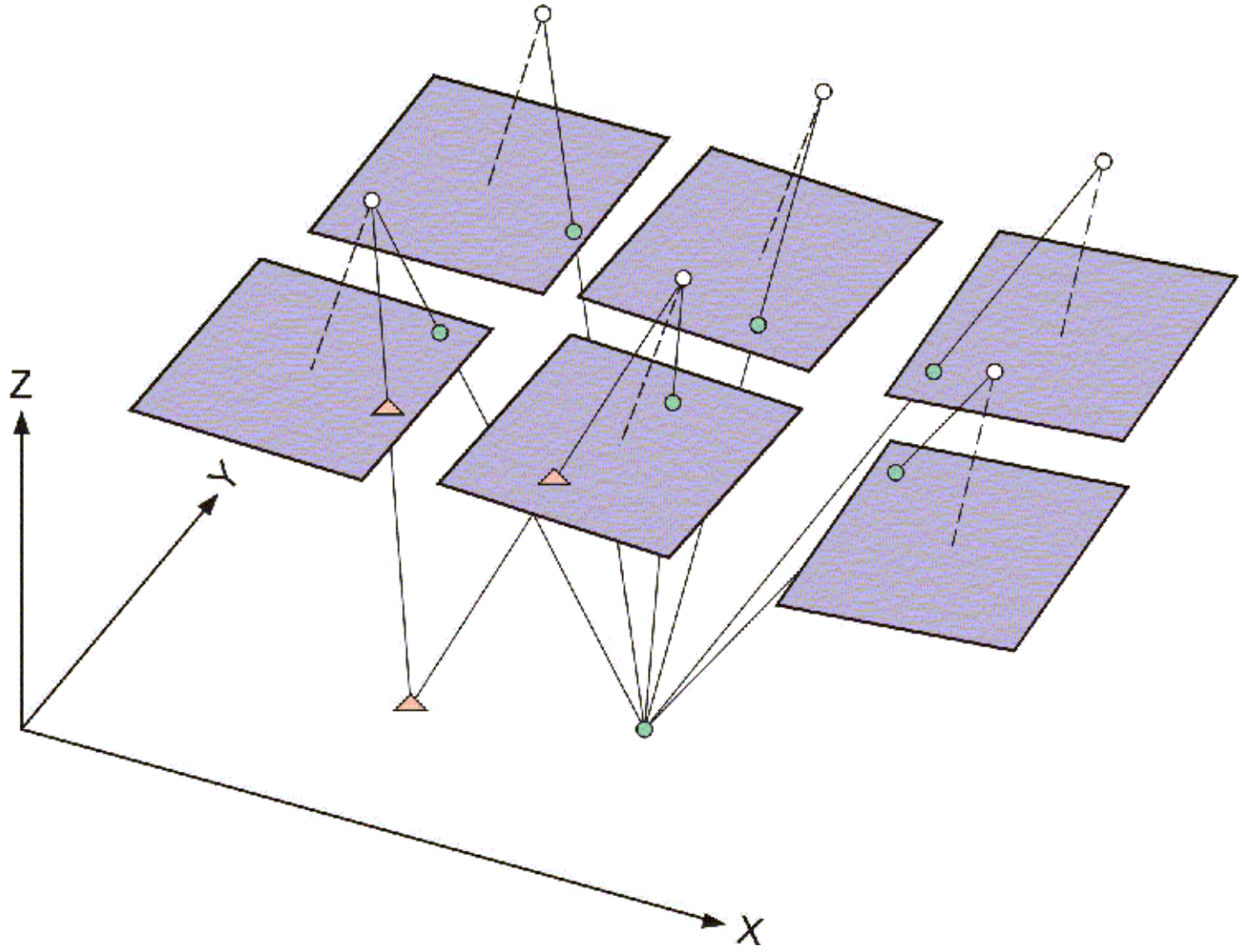
Ch7: Mathematical Model



7575 8092 8686

7582 8086 8692

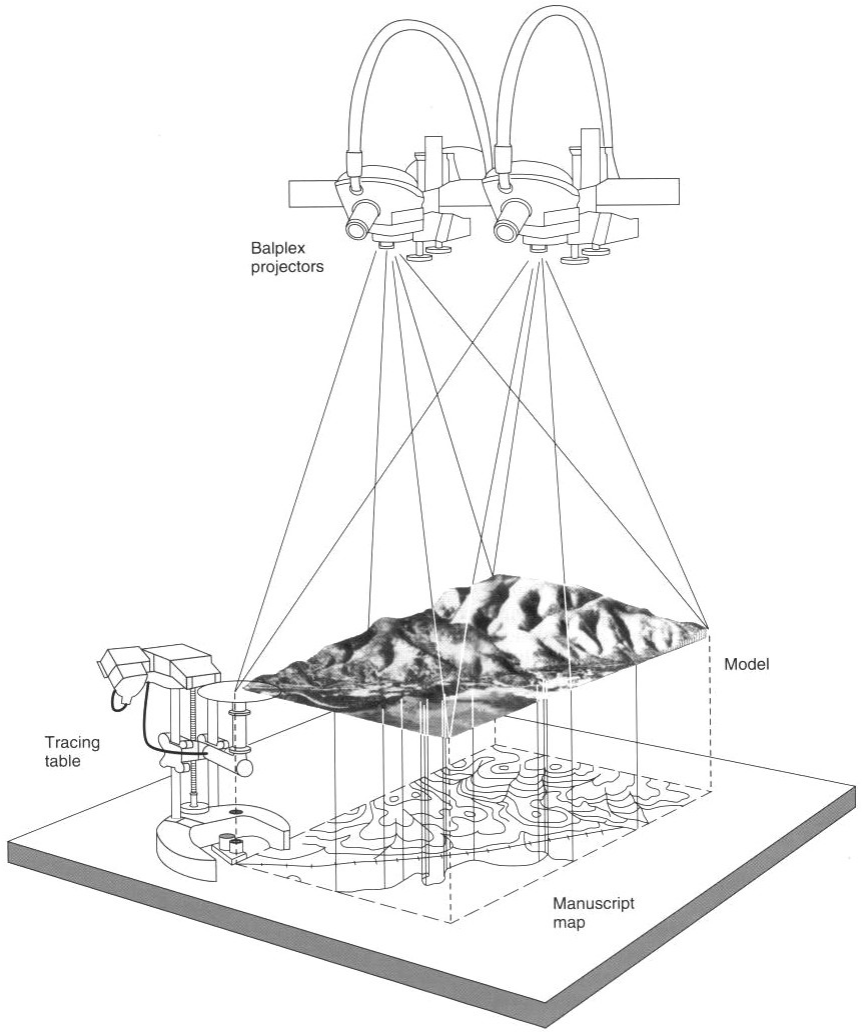
Ch7: Mathematical Model



Ch 8: Theory of Orientation

- Objective: Transform centrally projected images into a three-dimensional model which we can use to plot an orthogonal map
- Interior orientation
- Exterior orientation:
  - Relative orientation
    - X versus y-parallax
  - Absolute orientation
- Aerial Triangulation: Strip and block triangulation

Ch 8: Theory of Orientation



Ch 9: Bundle Block Adjustment

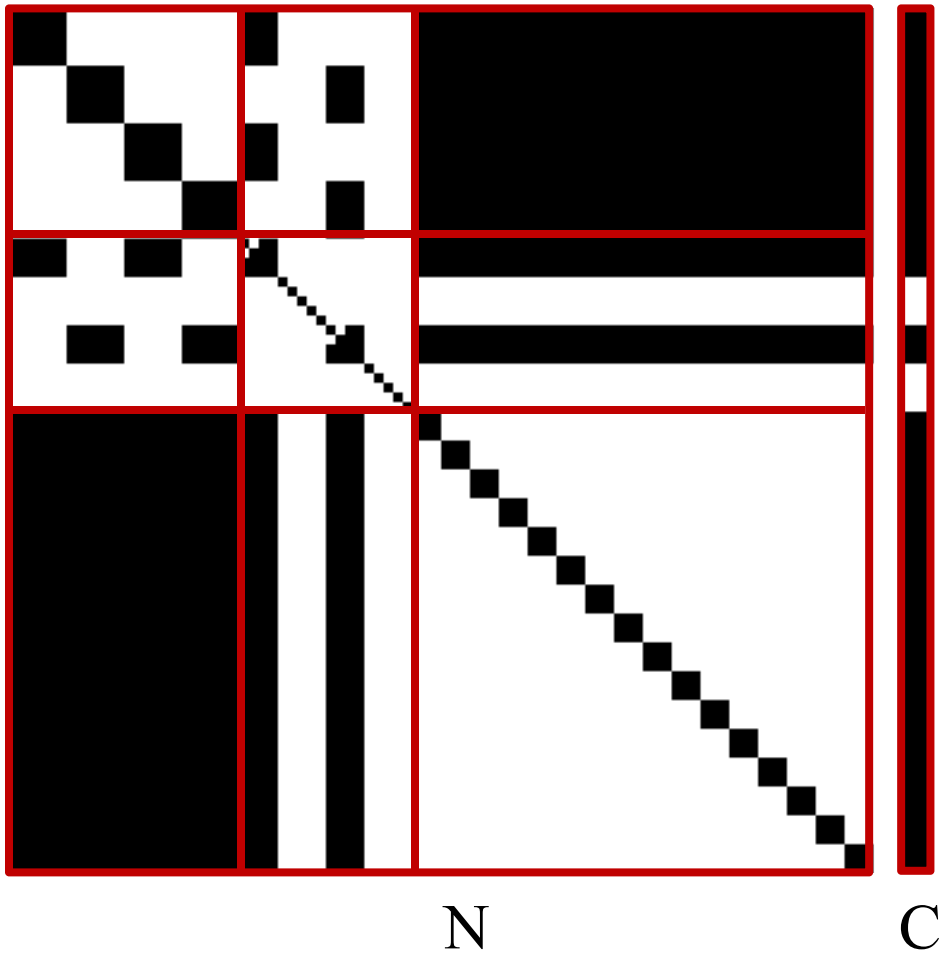
- Objective: Mathematical manipulation of the observation equations to speed up the
  - Formation of the normal equation matrix, and
  - Derivation of the unknown parameters
- Special cases:
  - Single photo resection,
  - Spatial intersection,
  - Relative orientation, and
  - Stereo-pair orientation

Ch 9: Bundle Block Adjustment

- 2 cameras
- 4 images
- 16 points

- All the points appear in all the images.
- Two images were captured by each camera.

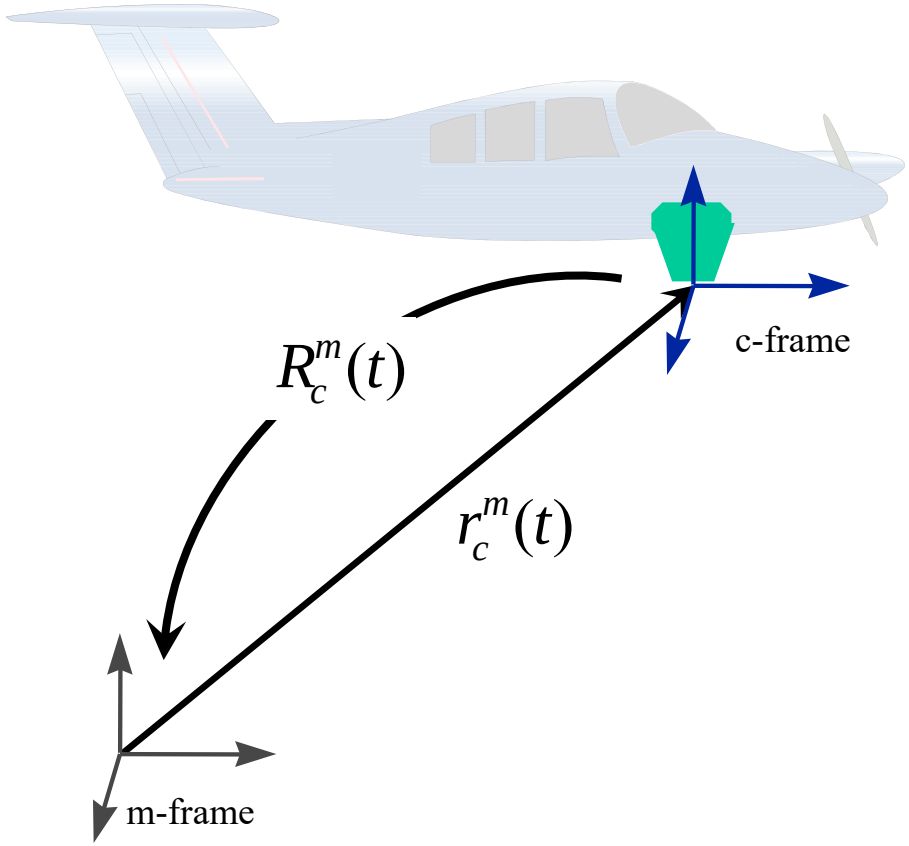
Ch 9: Bundle Block Adjustment



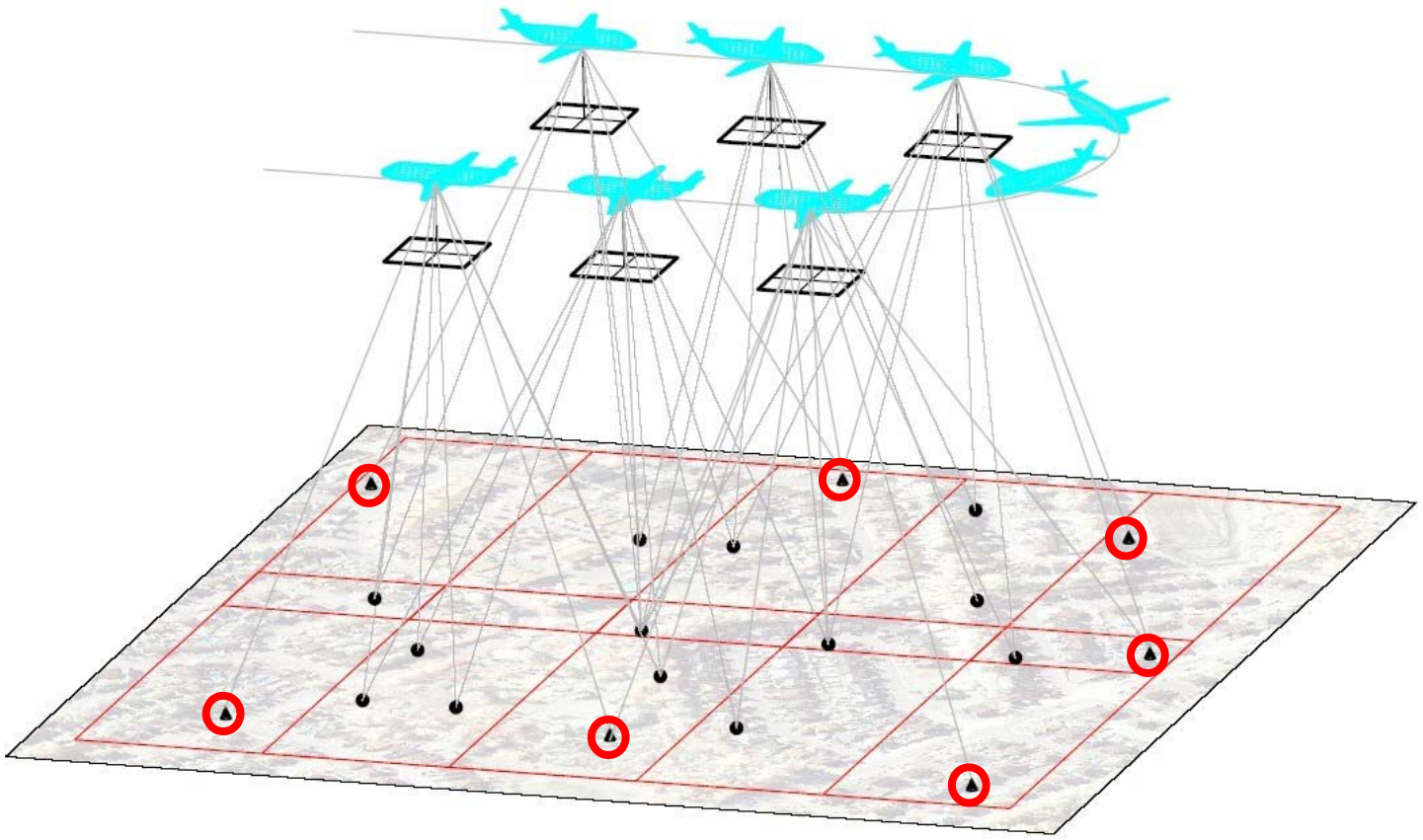
Ch 10: Photogrammetric Geo-Referencing

- Objective: Define the position and orientation of the different images at the moment of exposure
  - Exterior Orientation Parameters (EOP)
- Geo-referencing alternatives:
  - Indirect geo-referencing,
  - Integrated Sensor Orientation (ISO), and
  - Direct geo-referencing

Ch 10: Photogrammetric Geo-Referencing



Indirect Geo-Referencing



Ground Control Points

Tie Points

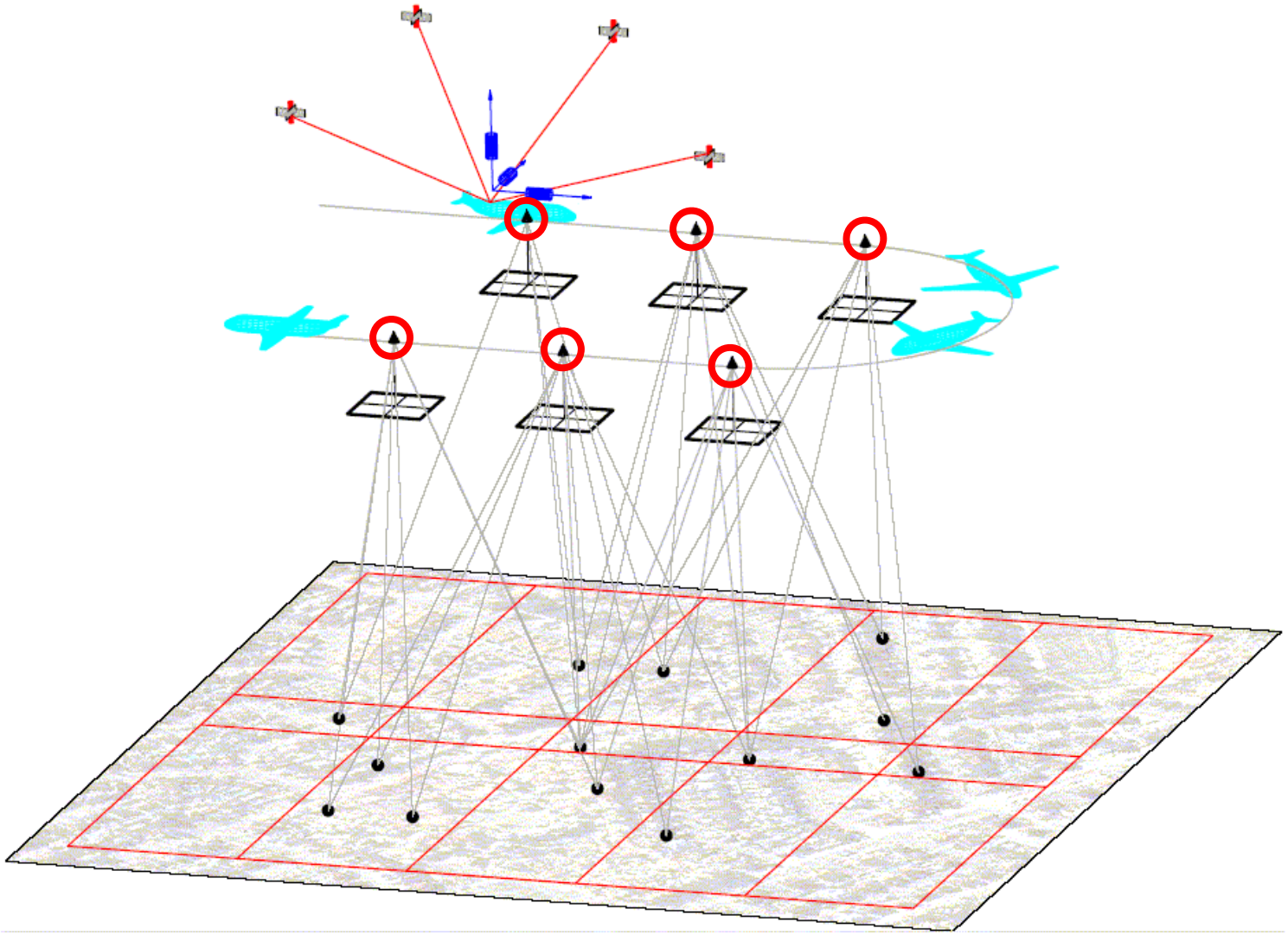
Indirect Geo-Referencing

Signalized Targets

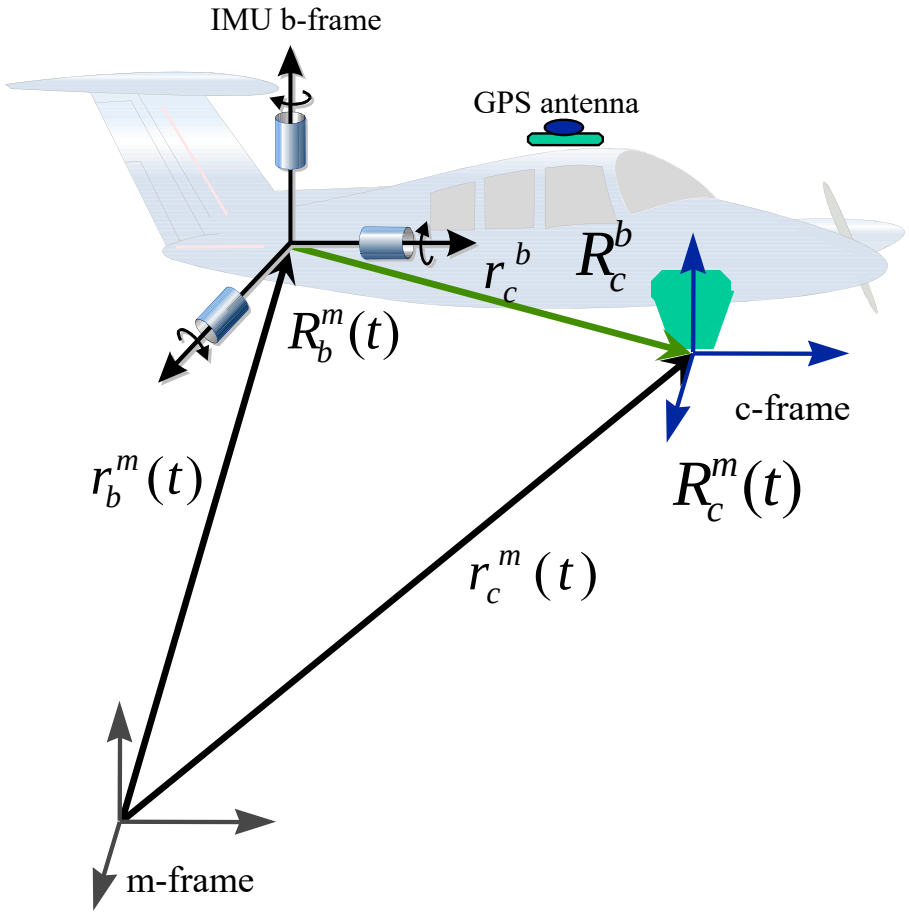
Indirect Geo-Referencing

Natural Targets

Direct Geo-Referencing



Direct Geo-Referencing



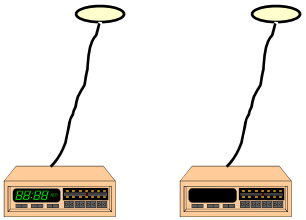
Direct Geo-Referencing: Airborne System

GPS Antenna

INS

PC

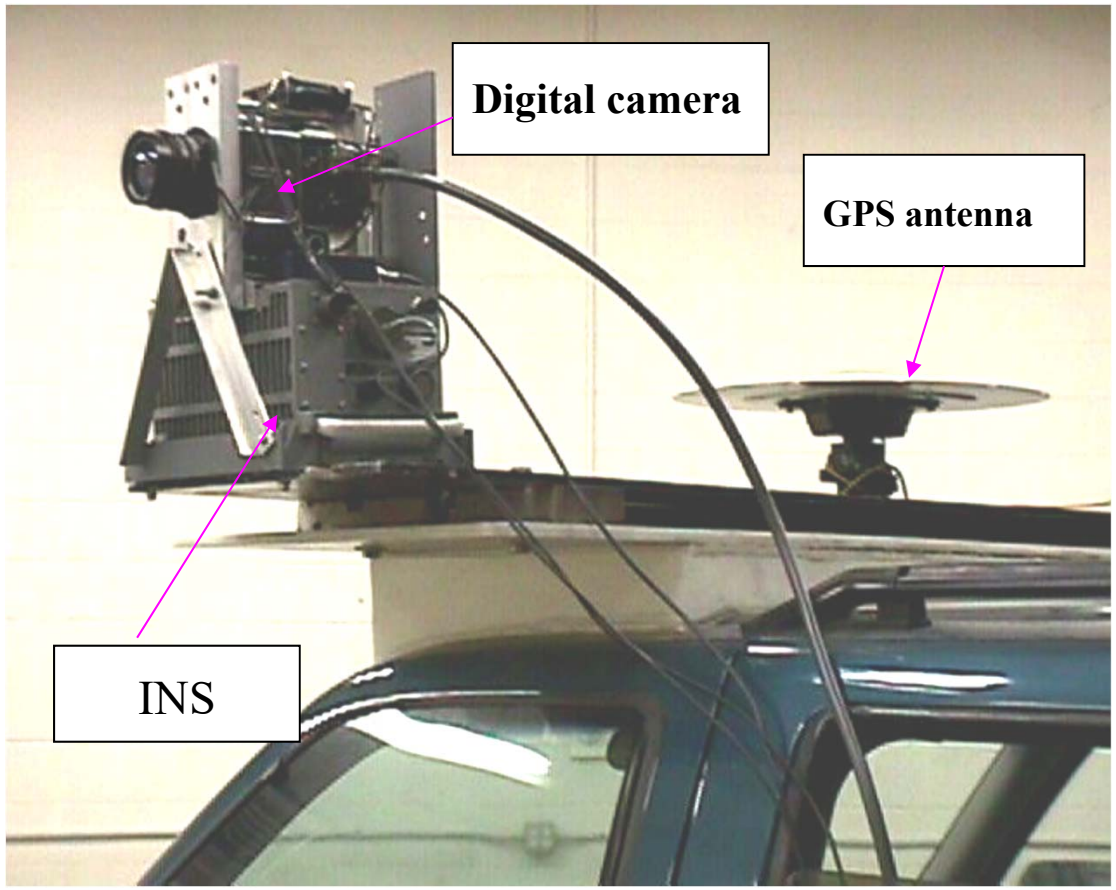
Two Base Stations



Camera

GPS Receiver

Direct Geo-Referencing: Land-Based System



Direct Geo-Referencing: Land-Based System

Ch 11: Digital Image Matching

- Objective: Automated identification of conjugate points in overlapping images
- Terminology
- Issues affecting the complexity of the matching problem
- Area-based matching:
  - Cross correlation, and
  - Least-squares matching
- Image resampling according to epipolar geometry

Image Matching

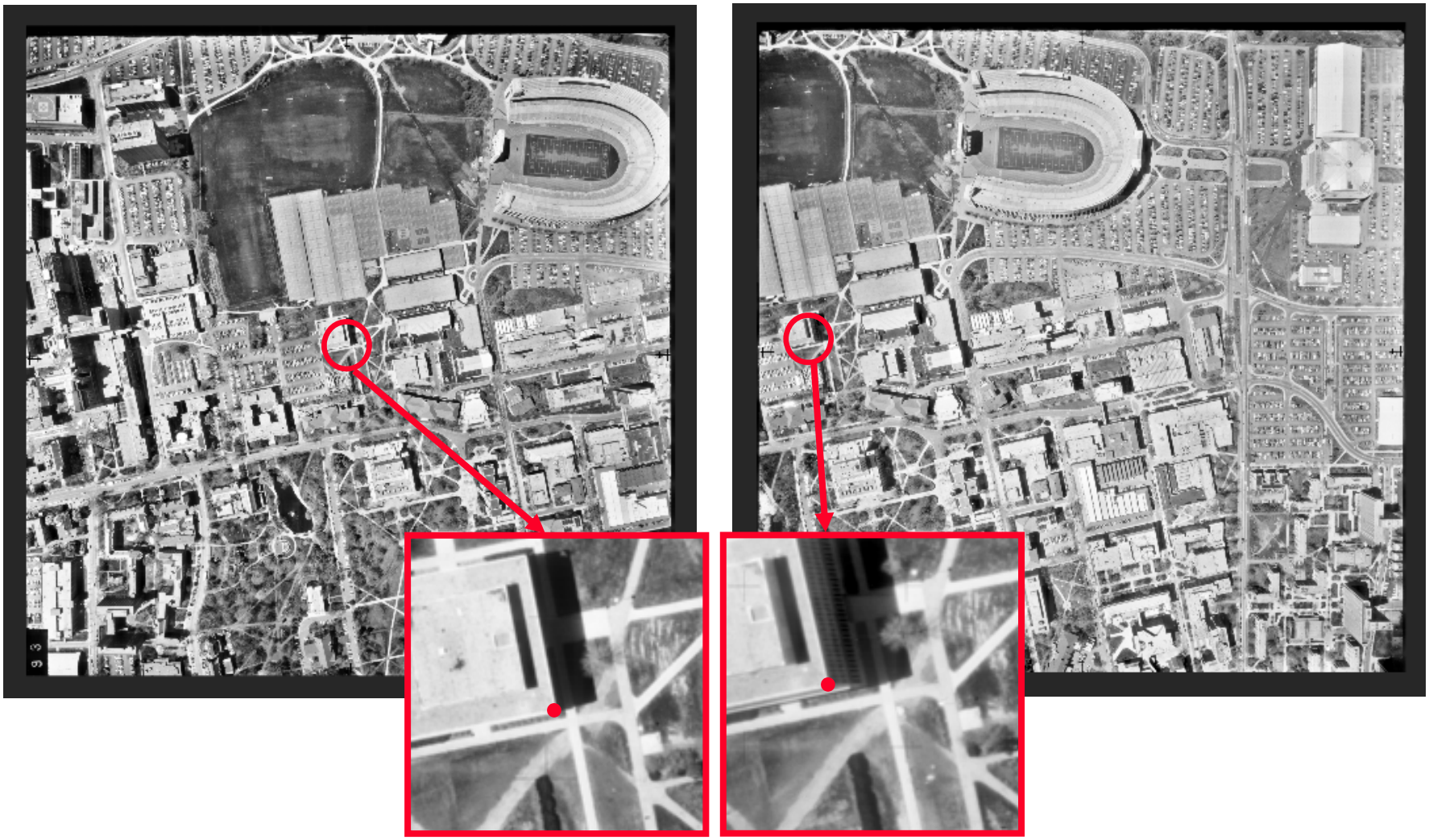
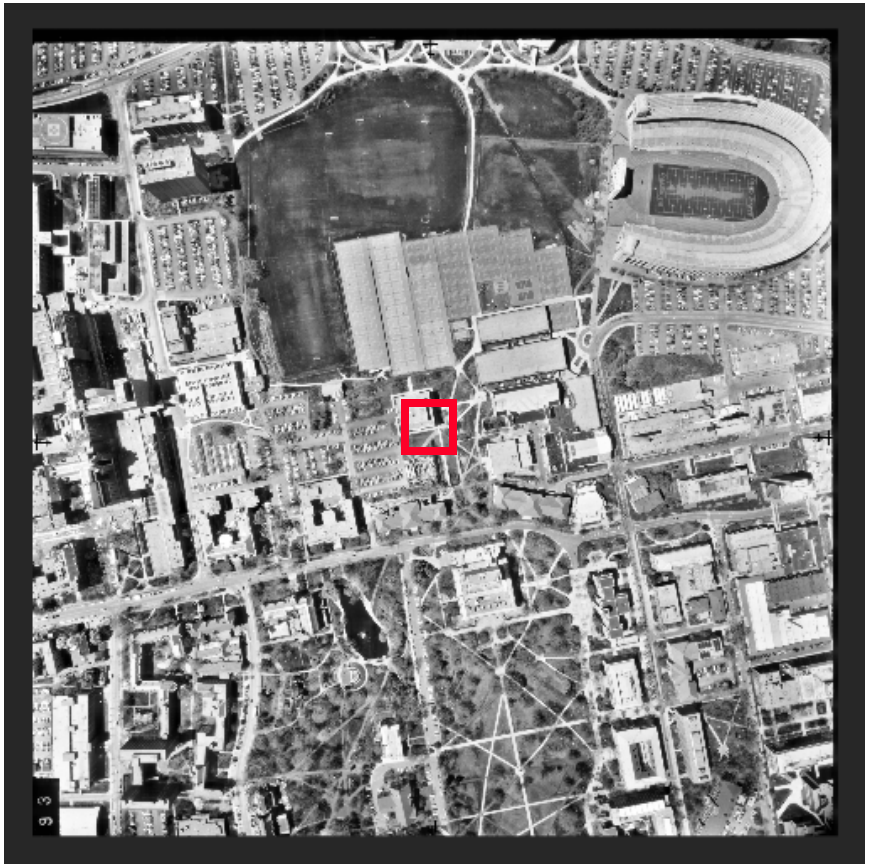


Image Matching



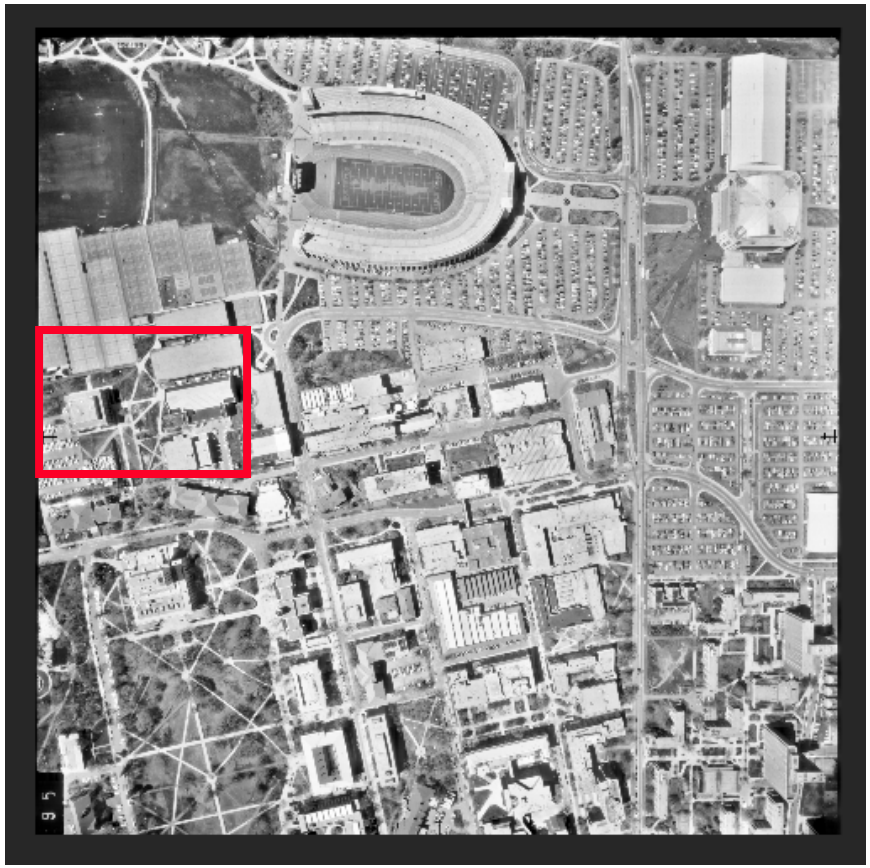
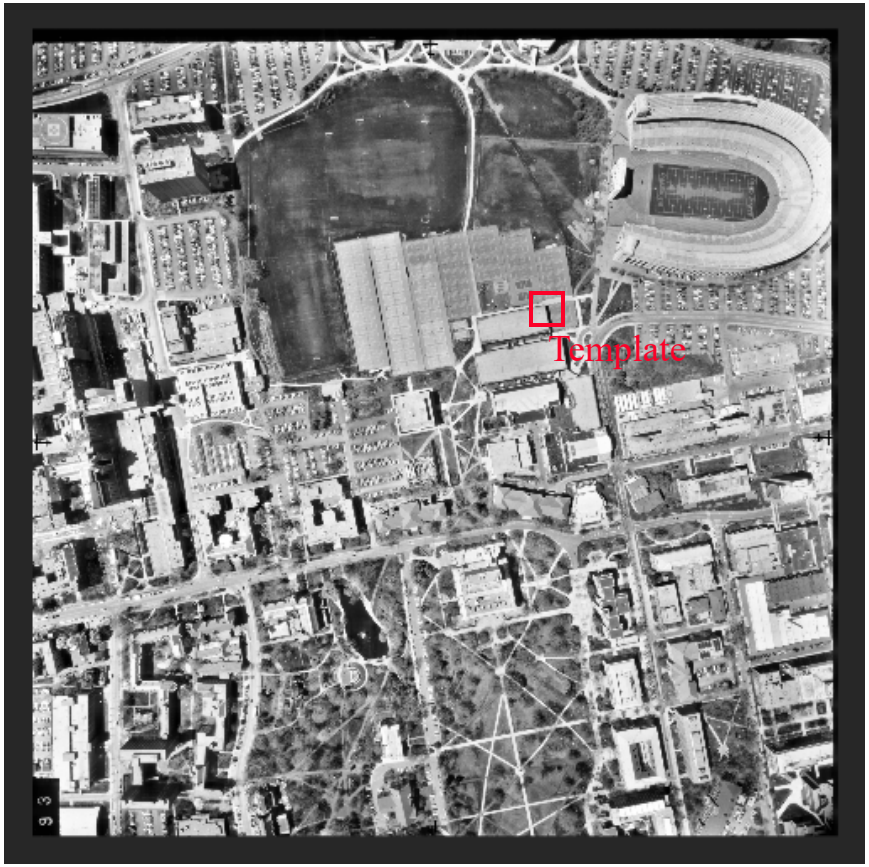
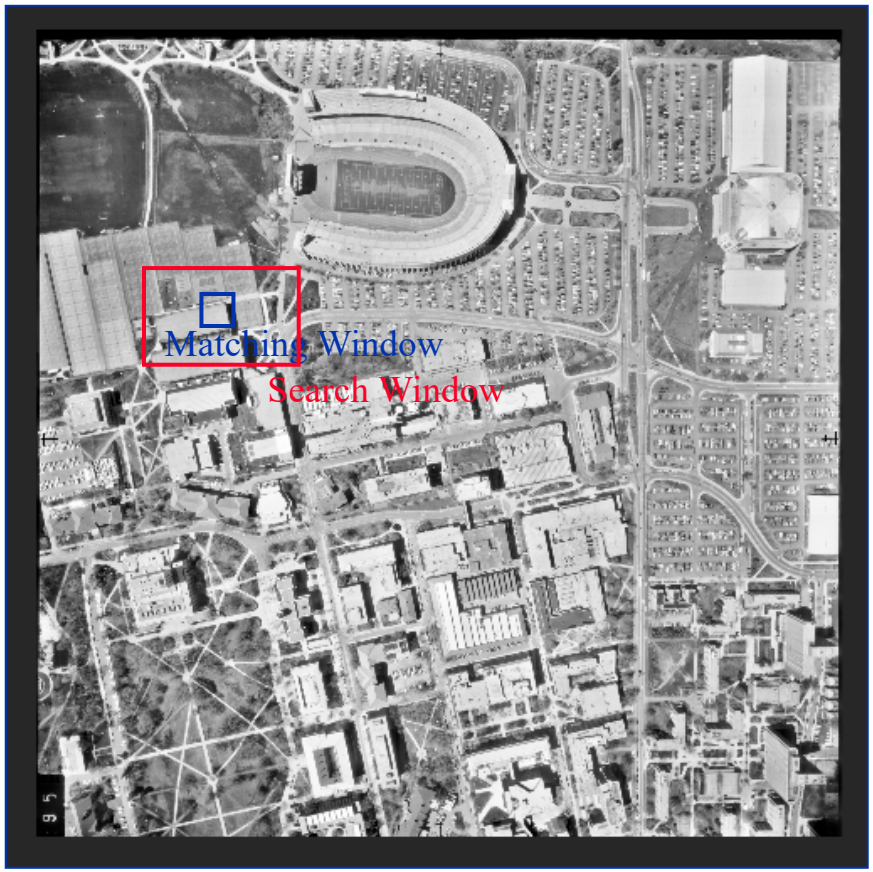


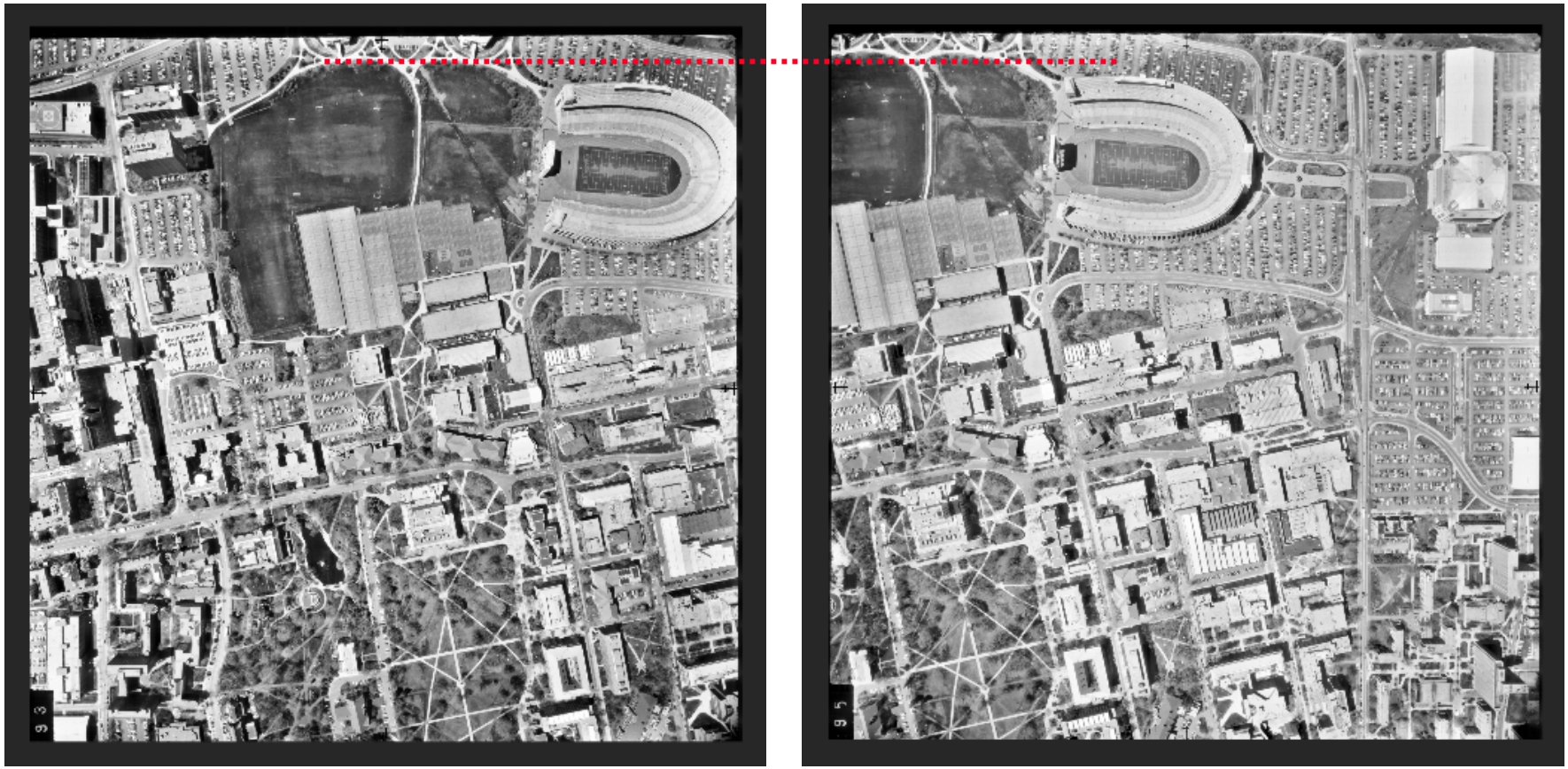
Image Matching





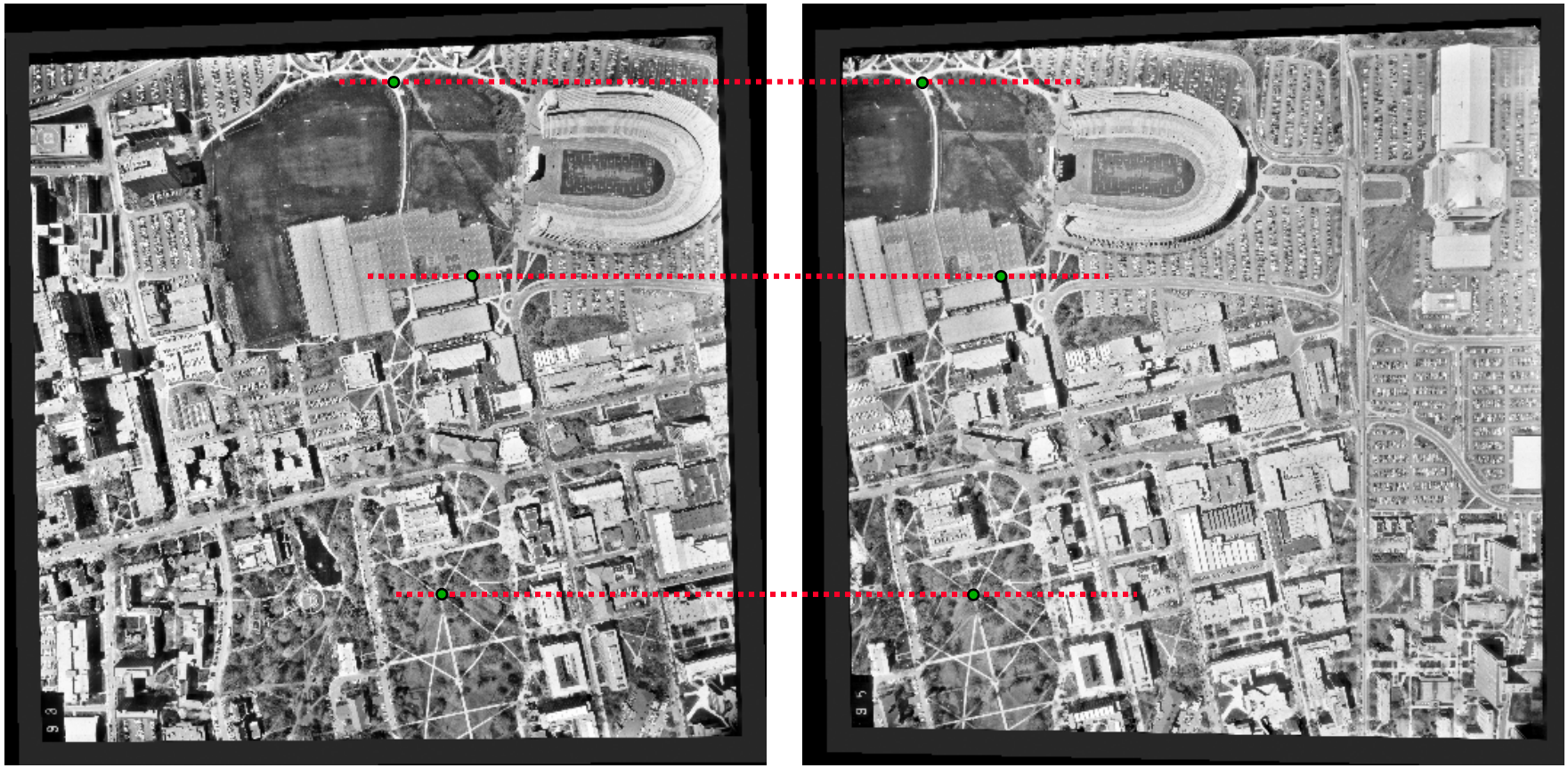
Original Images

- Conjugate points do not have the same y-coordinates.

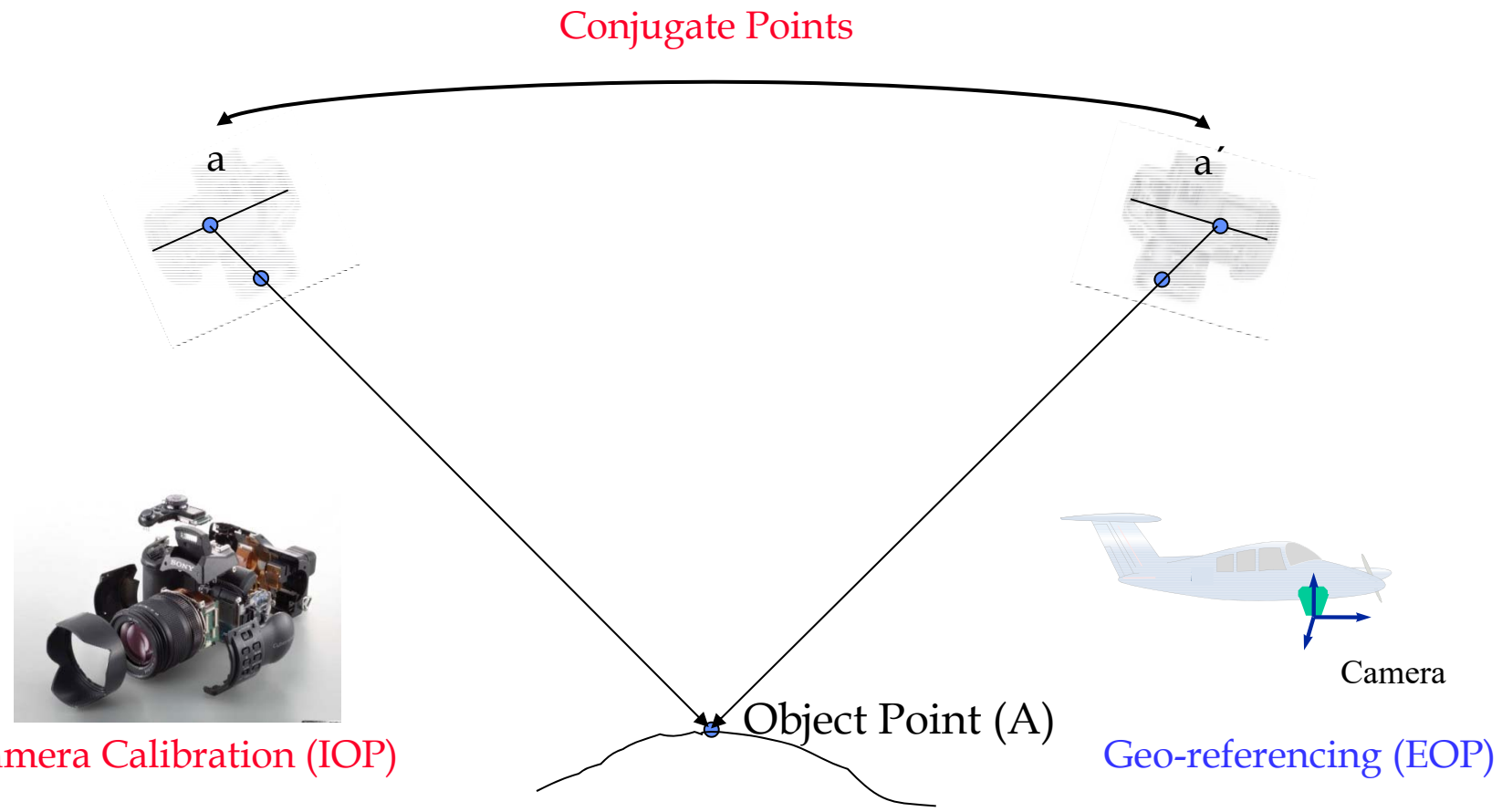


Normalized Images

- Conjugate points have the same y-coordinates.



3D Reconstruction



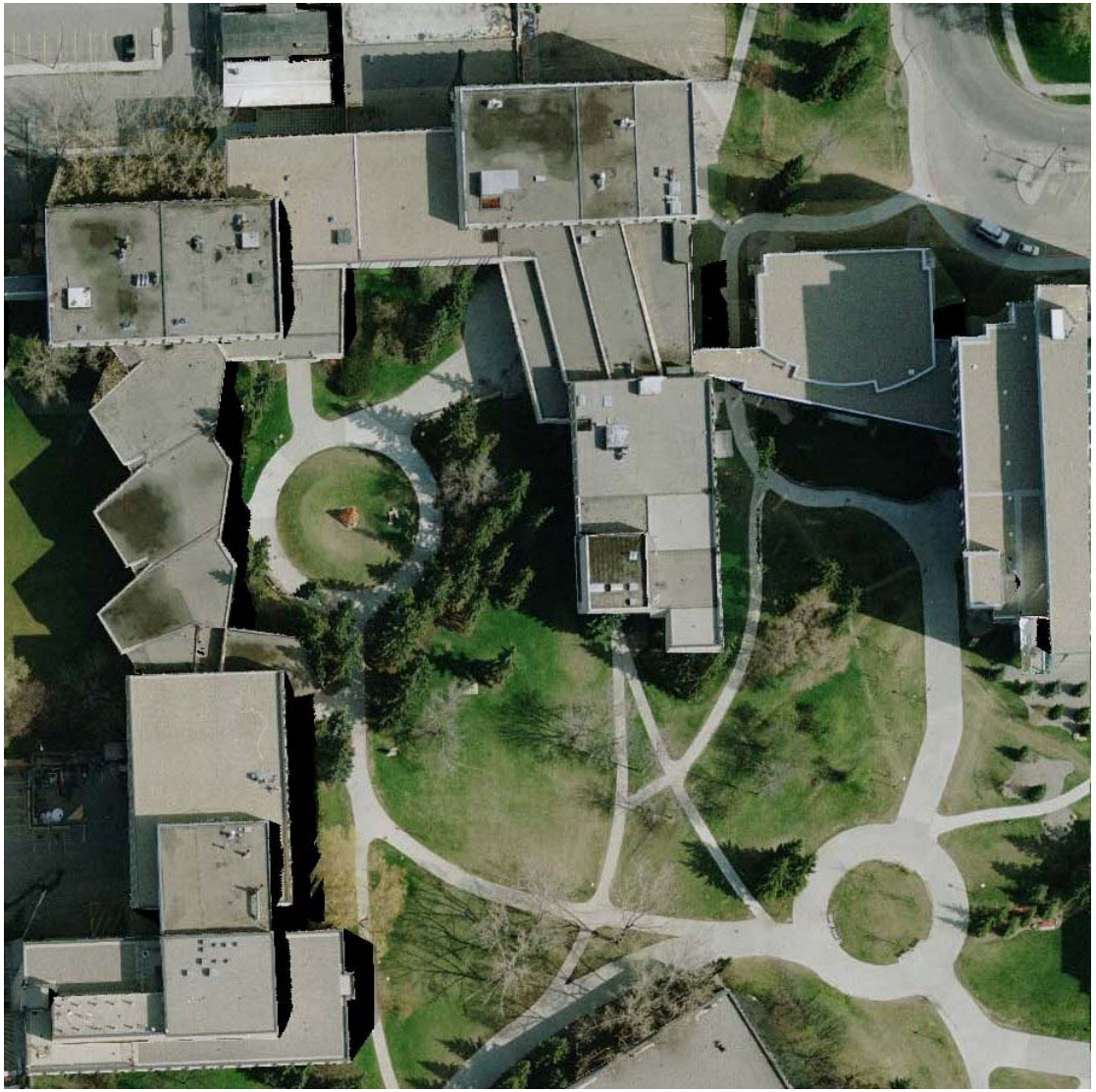
- The interior orientation parameters of the involved cameras have to be known.
- The position and the orientation of the camera stations have to be known.

Ch 12: Digital Orthophoto Generation

- Objective: Manipulate a perspective image to remove the sensor tilt and terrain relief effects
- Image resampling: Interpolation of intensity values
- Image transformation: Direct and indirect transformation
- Image Rectification:
  - Polynomial rectification,
  - Differential rectification, and
  - True orthophoto generation

Perspective Image

True Orthophoto



CE 59700: Roadmap

- Chapter 1: Introduction
- Chapters 2 – 4: Data acquisition
- Chapters 5 – 12: Data manipulation
  - Chapter 5: Vertical imagery
  - Chapter 6: Image coordinate measurements and refinements
  - Chapters 7 - 10: Mathematical model, bundle block adjustment, integrated sensor orientation, and direct geo-referencing
  - Chapter 11: Digital image matching
  - Chapter 12: Production of map-like images (orthophotos)