BHARATHIDASAN UNIVERSITY

Tiruchirappalli- 620024
Tamil Nadu, India

Programme : M.Tech., Remote Sensing and GIS

Course Title : PHOTOGRAMMETRY
Course Code : 24MTRS-02

UNIT IV - Digital Photogrammetry:

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UNIT III - Digital Photogrammetry:

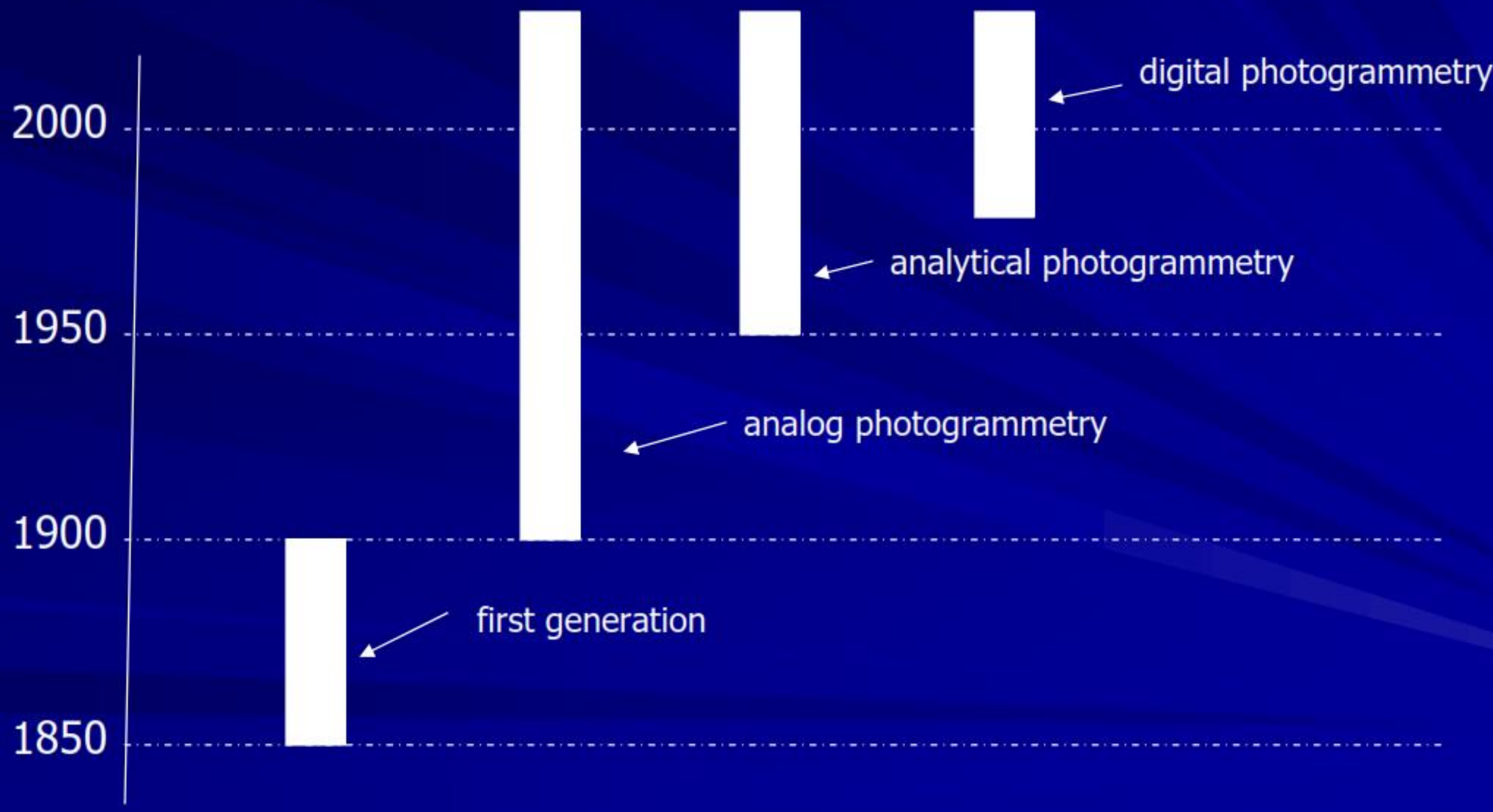
Definition and scope - Analog photogrammetry, fundamental concept of stereoplotters - Digital aerial cameras - Three-line pushbroom aerial sensor - DPWS (Digital Photogrammetric Workstation) - Hardware and software components of digital photogrammetry - Stereo viewing techniques - Concepts of interior, relative, absolute orientations - Georeferencing - Aerotriangulation - single frame and block triangulation, pass points, tie points; ground control points - DEM generation - Orthophoto generation - Applications of digital photogrammetric products - Concept of DEM, DTM, TIN, GRID and DSM.

Photogrammetry can be regarded as “the science and technology of obtaining spatial measurements and other geometrically reliable derived products from photographs” (Kiefer, Lillesand, 2000).

Photogrammetry is the process of deriving metric information about an object through photo measurements with the advent of computing and imaging technology

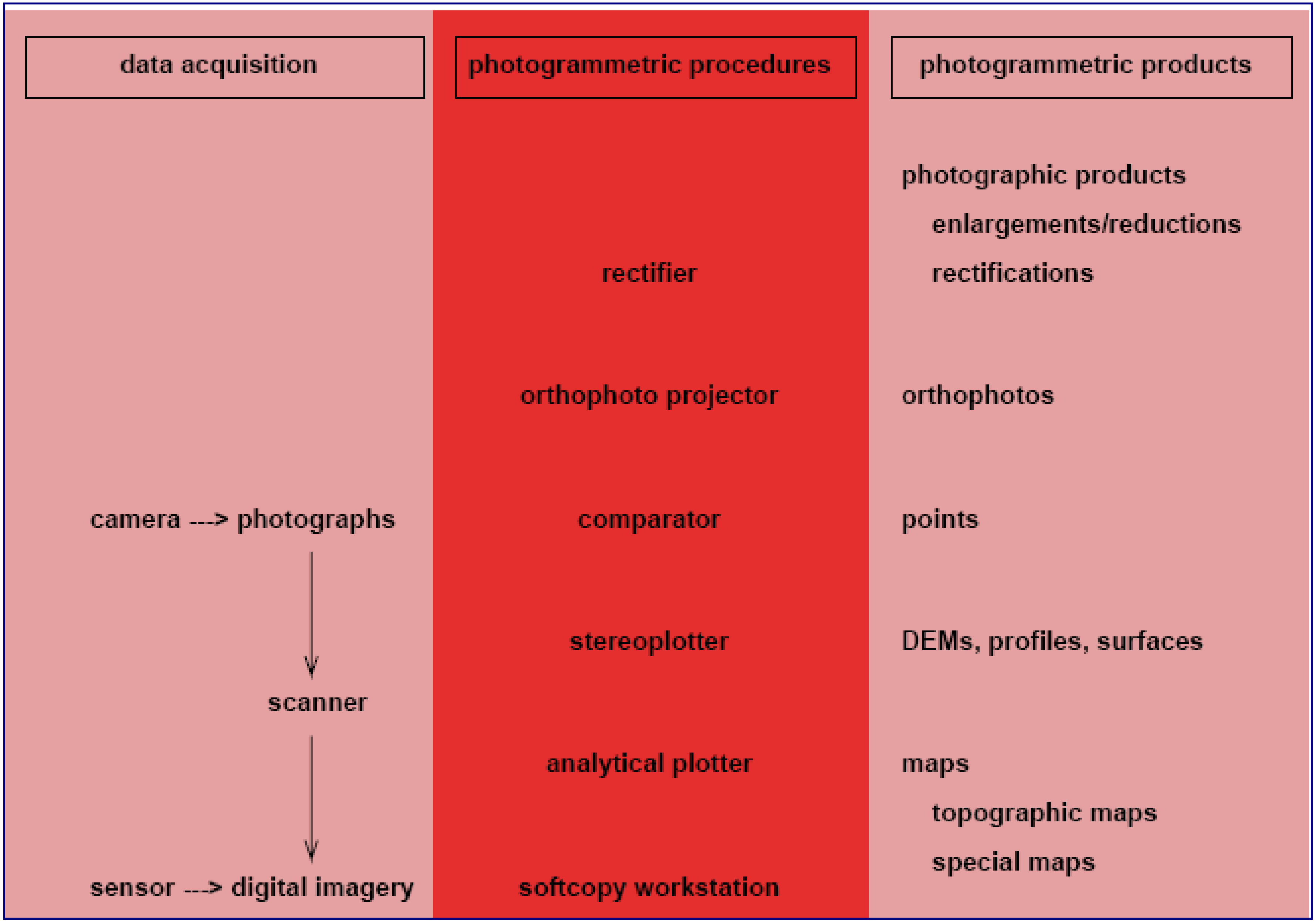
Contemporary definition: The art and science of tool development for automatic generation of spatial and descriptive information from multi-sensory data and/or systems.

Photogrammetric Generations



Computer Generations and Photogrammetric Discipline

Generation	Hardware	Software	Photogrammetric Discipline
1	-Vacuum tubes	-machine code	
2	-transistors -magnetic core memory	-higher level languages (FORTRAN-COBOL)	- analytical photogrammetry -aerial triangulation -correlation -analytical plotter
3	-IC memory -minicomputers -mag.disk storage	-time sharing -operating systems -Virtual memory	
4	-Microprocessors, PC -VLSI -networking	-new languages -(PASCAL-MODULA) -IGS, DBMS	Computer-assisted photogrammetry
5	-parallel processing -RISC architecture -VHSIC -optical disk storage	-knowledge based SW -expert systems - natural language processing	-digital photogrammetry -real-time photogrammetry



Photogrammetry portrayed as systems approach. The input is usually referred to as data acquisition, the “black box" involves photogrammetric procedures and instruments; the output comprises photogrammetric products.

Analogue Photogrammetry

optical or mechanical instruments were used to reconstruct three-dimensional geometry from two overlapping photographs. The main product during this phase was topographic maps.

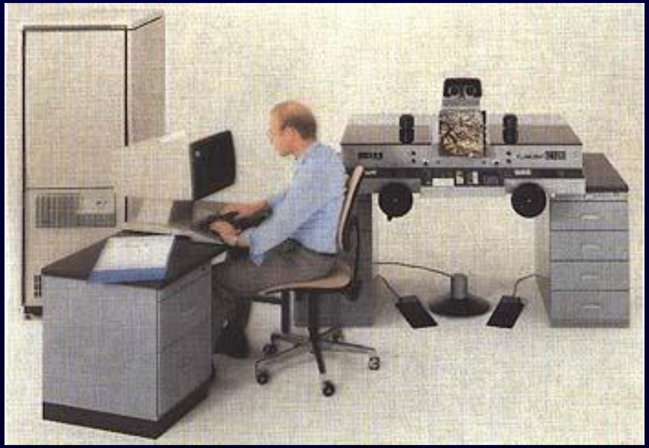
Analytical Photogrammetry

The computer replaces some expensive optical and mechanical components.

The resulting devices were analog/digital hybrids.

Analytical aerotriangulation, analytical plotters, and orthophoto projectors were the main developments during this phase.

Outputs of analytical photogrammetry can be topographic maps, but can also be digital products, such as digital maps and DEMs



Digital Photogrammetry

Digital photogrammetry is applied to digital images that are stored and processed on a computer.

Digital photogrammetry is sometimes called softcopy photogrammetry.

The output products are in digital form, such as digital maps, DEMs, and digital orthophotos saved on computer storage media.

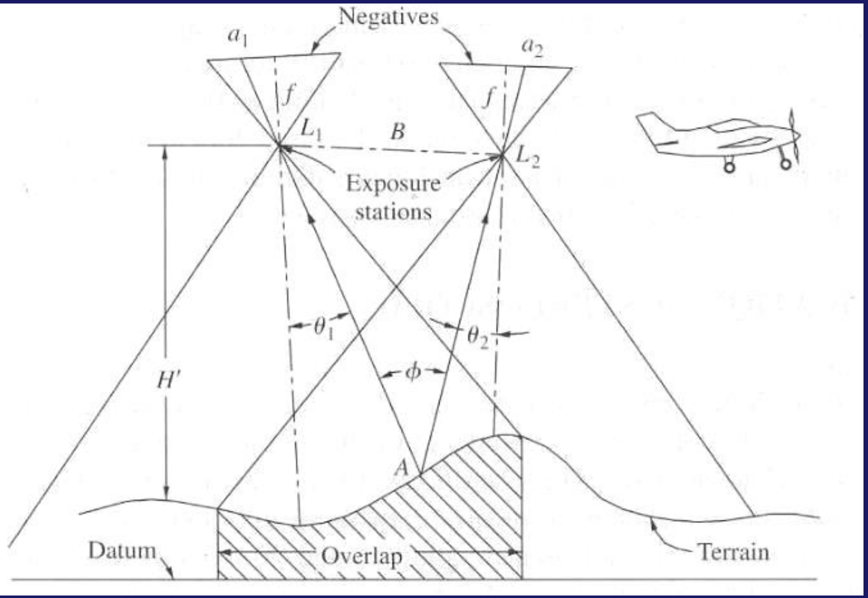
Analogue Photogrammetry

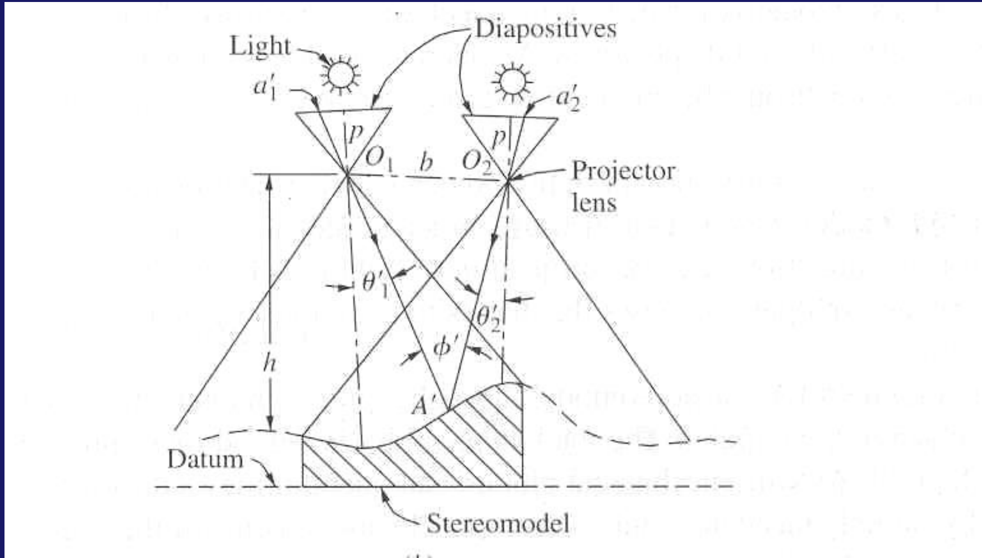
STEREOSCOPIC PLOTTING INSTRUMENTS

- **Stereoscopic plotting instruments (commonly called stereoplotteres or simply plotters) are designed to provide rigorously accurate solutions for object point position from their corresponding image position on overlapping pairs of photos.**

- **A stereoplotters is essentially a three dimensional digitizer, capable of producing accurate X,Y and Z object space coordinates when properly oriented and calibrated.**

The fundamental concept of stereoplotters design

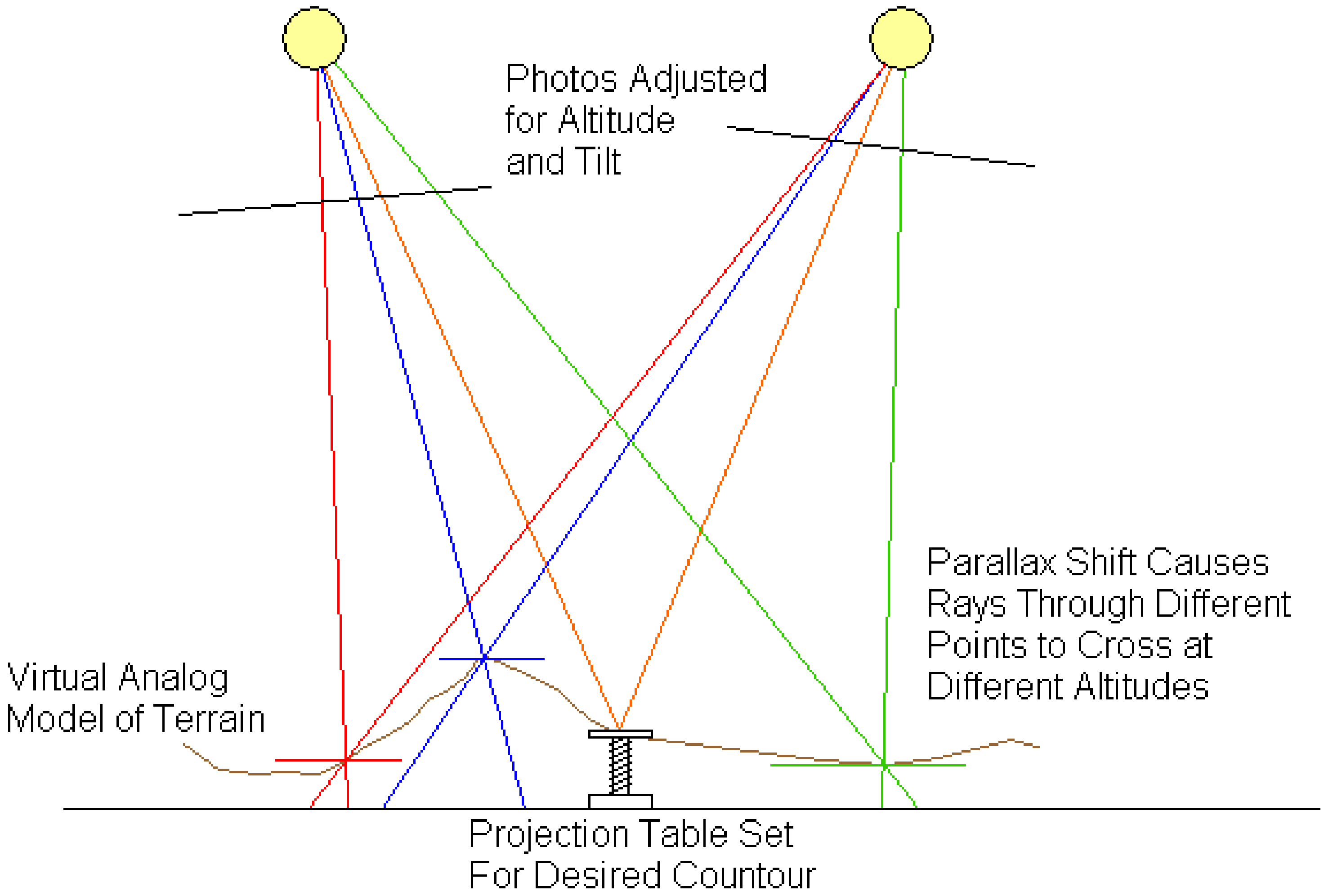




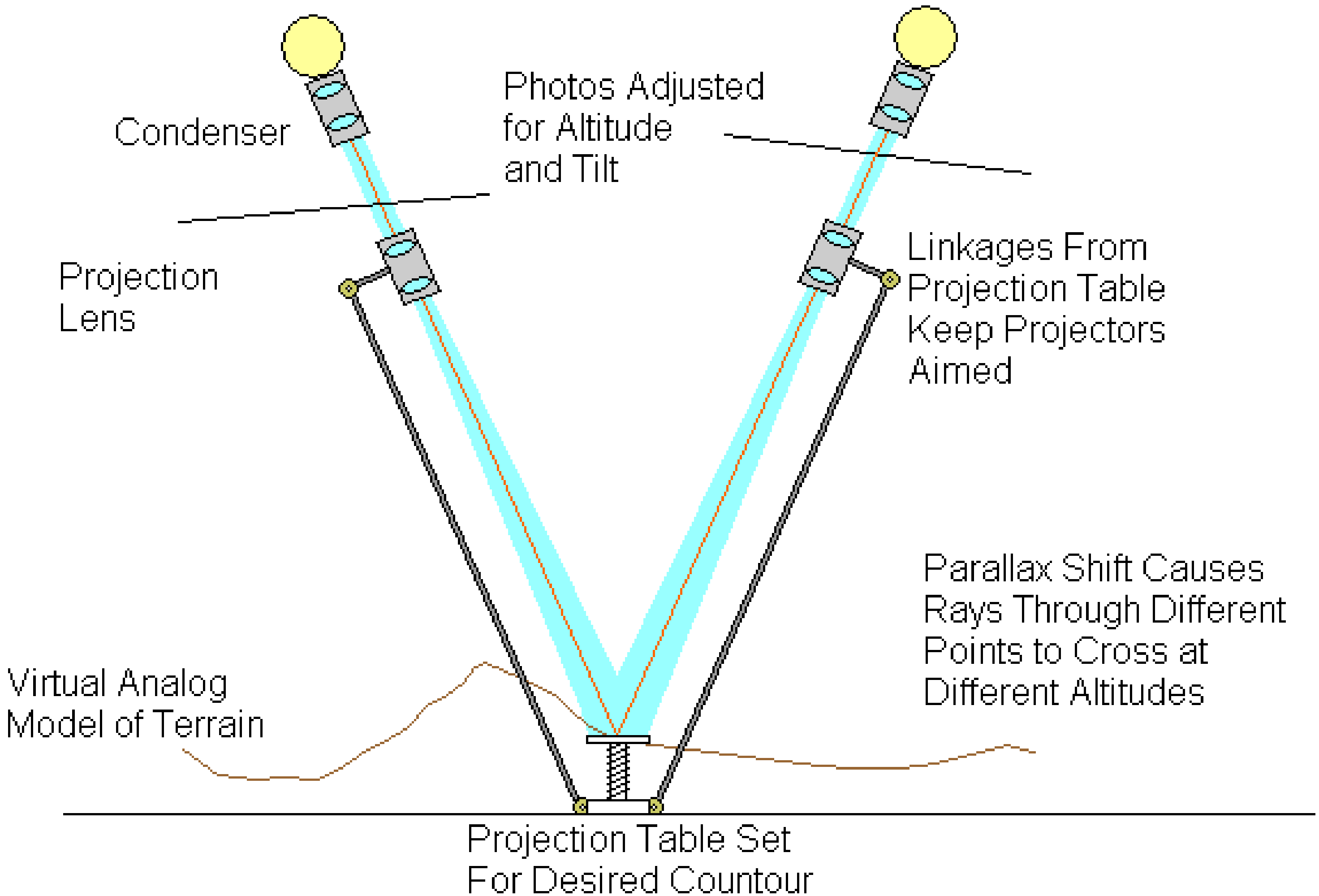
(*b*)

FIGURE 12-1
Fundamental concept of stereoscopic plotting instrument design. (*a*) Aerial photography; (*b*) Stereoscopic plotting instrument.

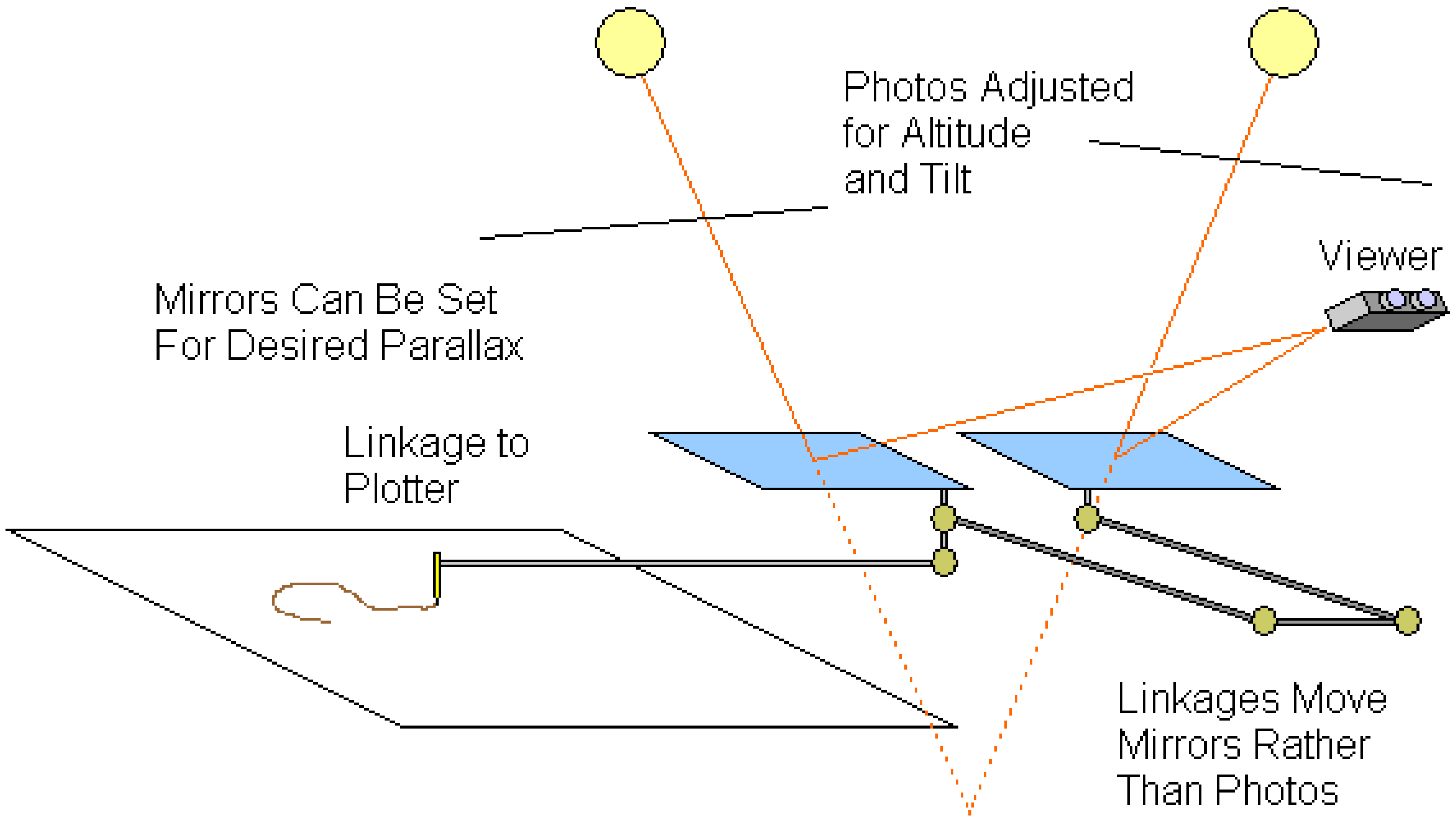
Kelsh Stereoplotter: Concept



Kelsh Stereoplotter in Practice



Analog Stereoplotter



Analog and analytical plotters

Wild A-10 Analog Stereoplotter

Wild BC-2 Analytical Plotter

There are three important factors in orienting and placing the diapositives in stereoplotters

Interior orientation: Transparencies or diapositives are carefully prepared to exacting standards from the negatives and placed in two stereoplotter projectors. This process is called **interior orientation**

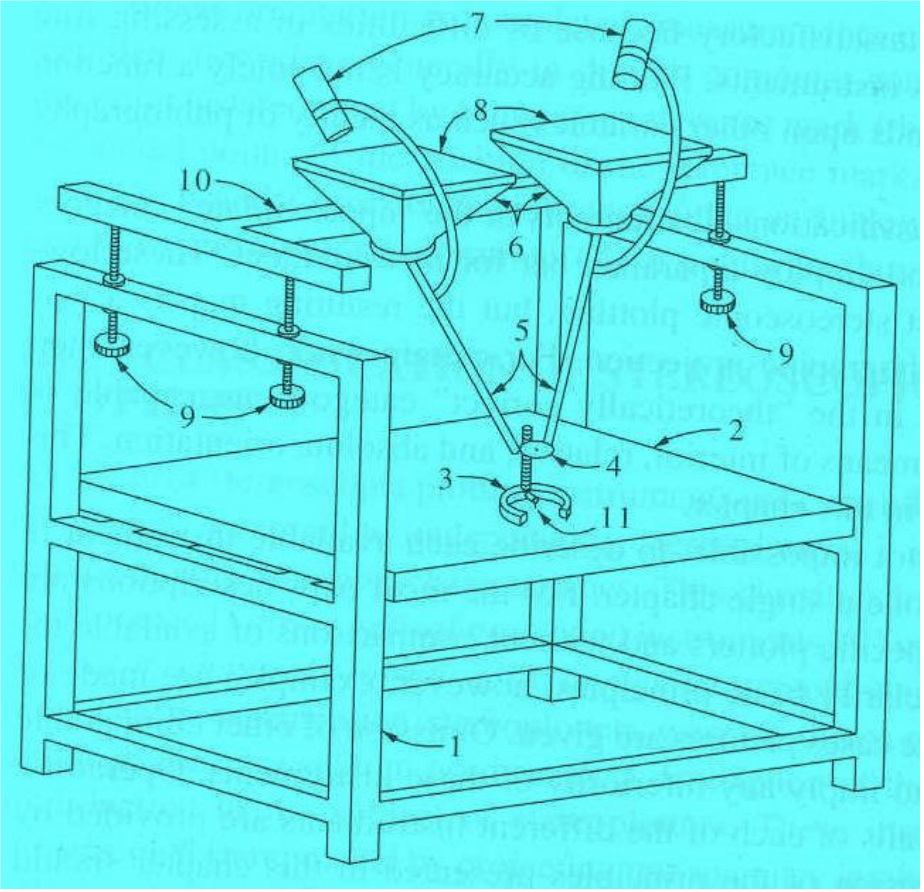
Relative orientation: The diapositives are in place and light rays are projected through them and when rays from corresponding images on the left and right diapositives intersect below, they create a stereo model. In creating the intersections of corresponding light rays, the two projectors are oriented so that the diapositives bear the exact relative angular orientation to each other in the projectors that the negatives had in the camera at the time of exposure. This process is called **relative orientation** and creates in miniature, a true three diamensional stereo model of the overlap area.

Absolute orientation: In this process the stereomodel is brought to the desired scale and leveled with respect to reference datum.

After the orientations is completed, measurements of the model may be made and recorded, nowadays generally in digital computer-compatible form.

The primary uses of stereo plotters are compiling topographic maps and generating digital files of topographic information and because these are the mostly widely used practiced photogrammetric applications. The stereoplotters is one of the most important in the study of photogrammetry.

The principal components of a typical direct optical projection stereoplotters are



1) Main frame: This supports the projectors tightly in place, threrby maintaining orientation of a stereomodel over a long period

2) Reference table: A large smooth surface which serves as the vertical datum to which model elevations are referenced and which also provides the surface upon which the manuscript map is compiled.

3) Tracing table: platen and tracing pencil are attached.

4) Platen: the viewing screen which also contain the reference mark.

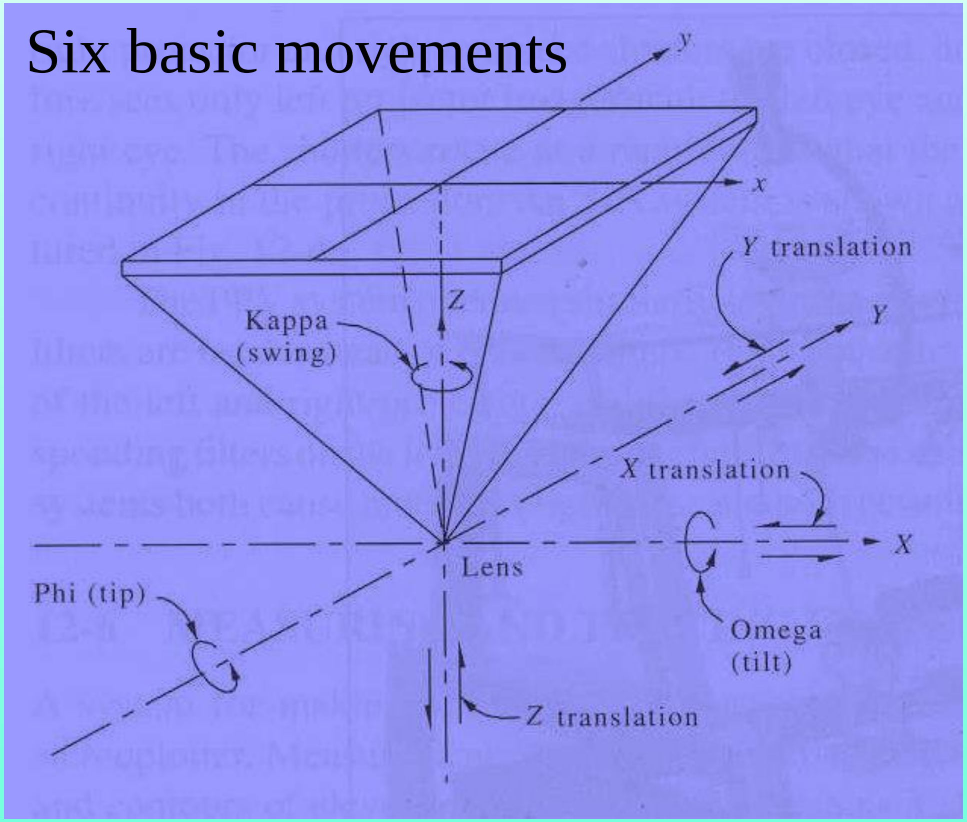
5) Guide rods: Which drive the illumination lamps causing projected rays to be illuminated on the platen and stereomodel viewed.

6) projectors, 7) illumination lamps, 8) diapositives

9) leveling screws: which may be used to tilt the projectors in absolute orientation, 10) projector bar: to which the projector attached, 11) tracing pencil, which is located vertically beneath the reference mark platen.

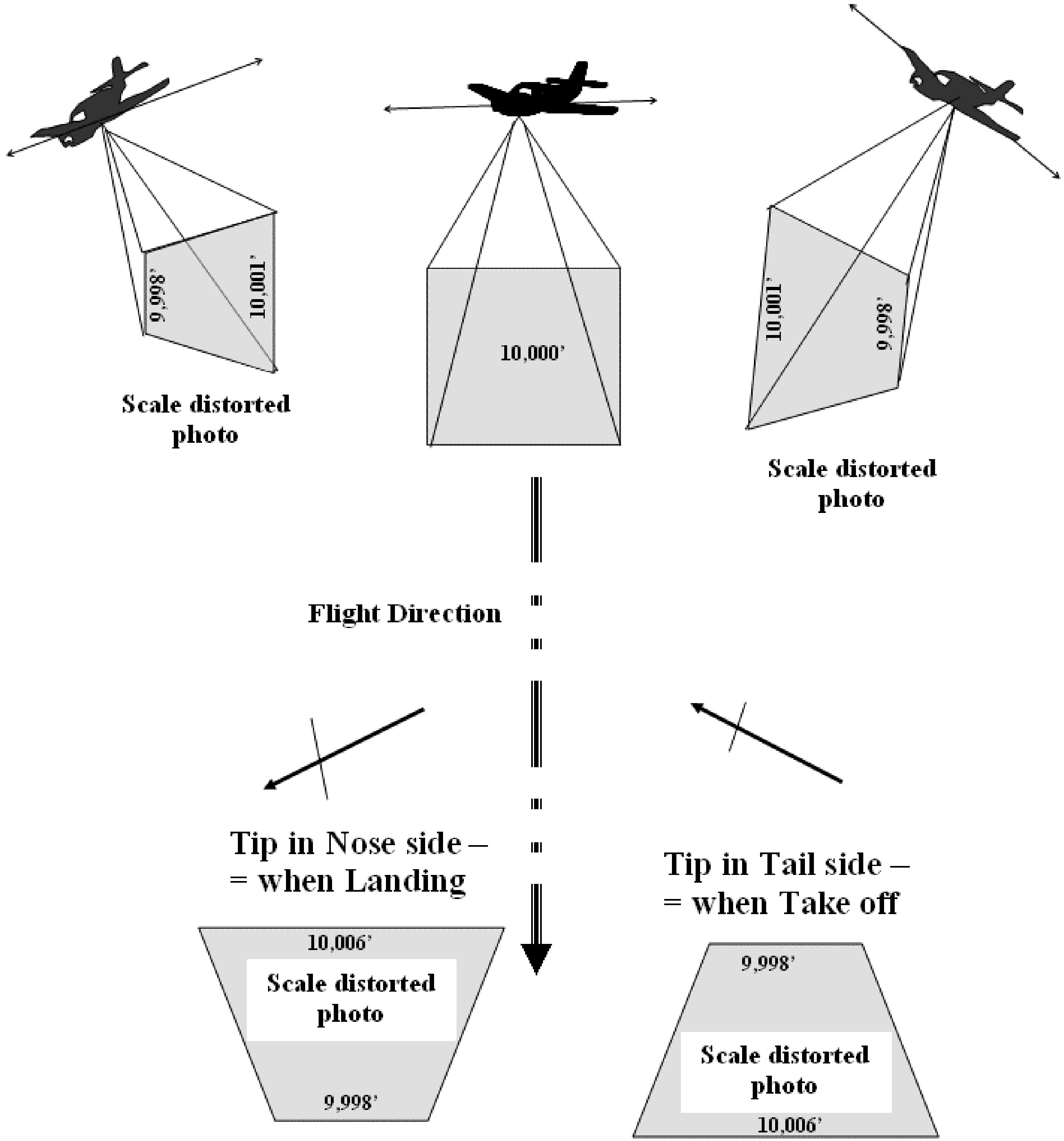
To create the relative angular relationship of two photographs exactly as they were at the instants of their exposures, it is necessary that the projectors have rotational and translational movement capabilities

Six basic movements



Three of the movements are angular rotations about each of three mutually perpendicular axes. X rotation called omega or tilt, y rotation called phi or tip, z rotation called kappa

The three of the other movements are linear translations along each of the three axes such as X translation, Y translation, Z translation


9,998'
10,001'
Scale distorted photo
10,000'
10,001'
9,998'
Scale distorted photo
Flight Direction
Tip in Nose side – = when Landing
Tip in Tail side – = when Take off
10,006'
Scale distorted photo
9,998'
9,998'
Scale distorted photo
10,006'

The image shift in X and Y can be removed by the above three translational movements and three rotational movements

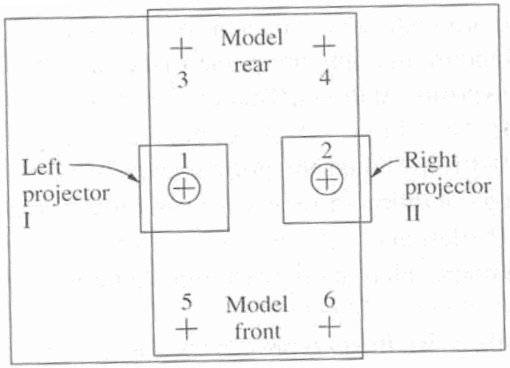


FIGURE 12-6
Stereomodel locations of six points conventionally used in relative orientation.

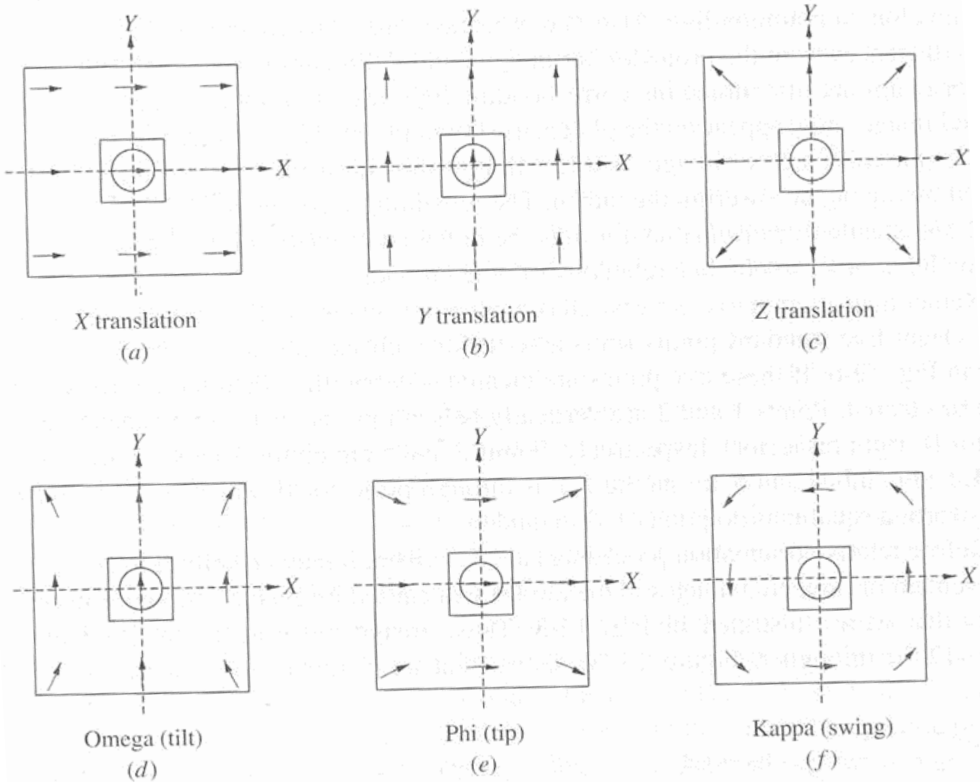


FIGURE 12-7
Movement of projected images in the model caused by the six projector motions.

The image shift in X and Y can be removed by the above three translational movements and three rotational movements

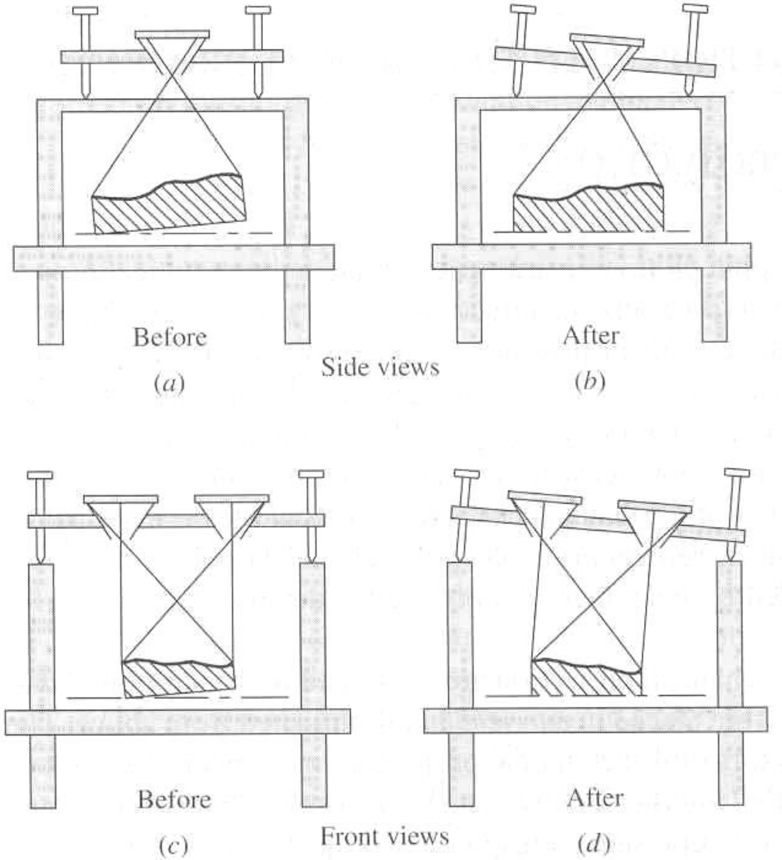


FIGURE 12-11
(*a*) and (*b*) Correcting *X* tilt of a model by *X* tilt of projector bar. (*c*) and (*d*) Correcting *Y* tilt of a model by *Y* tilt of projector bar.

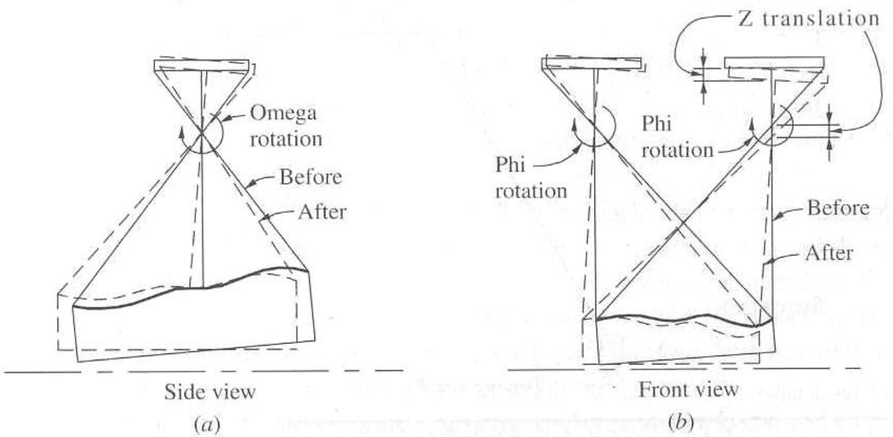


FIGURE 12-12
(*a*) Correcting *X* tilt of a model with equal omega rotations of both projectors. (*b*) Correcting *Y* tilt of a model with equal phi rotations of both projectors followed by a *Z* translation.

Data Capturing

Digital photogrammetry utilizes digital imagery as an input.

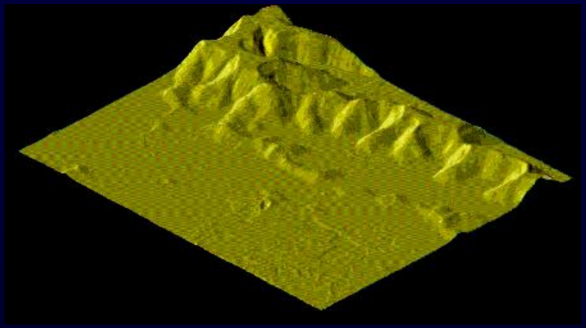
The rapid technological advances in computer hardware and software has motivated the shift from analog to digital imagery.

How can we get digital images?

- Scanning analog images.
- Using digital camera.

DIGITAL PHOTOGRAMMETRY

- Single or pairs of digital images are loaded into a computer with image processing capabilities.
- Images may be from satellite or airborne scanners, CCD cameras or are conventional photographs captured by a line scanner.
- Images are either displayed on the screen for operator interpretation, enhanced by image processing or subjected to image correlation in order to form a digital elevation model (DEM) or extract details.



Digital Frame Cameras

- A digital frame camera has similar geometric characteristic to a single-lens frame camera which employs film as its recording medium.

- Instead of film, the digital camera consists of a two-dimensional array of CCD elements (charge-coupled device) is called full frame sensor

- CCD is the type of solid-state detector in current. There are number of variations of CCD configurations, the basic operating principle is the same.

- At specific pixel location, the CCD elements is exposed to incident light energy and it builds up an electric charge proportional to the intensity of the incident light.

- The electric charge is subsequently amplified and converted from analog to digital form. A large number of CCDs can be combined on a silicon chip in a one-dimensional or two-dimensional array.

- Full frame sensor is mounted in the focal plane of a single-lens camera.

- Acquisition of an image exposes all CCD elements simultaneously, thus producing the digital image.

Full-frame sensor consists of an array of 4096 rows by 4096 columns of CCD elements and thus produces an image having nearly 16,800,000 pixels.

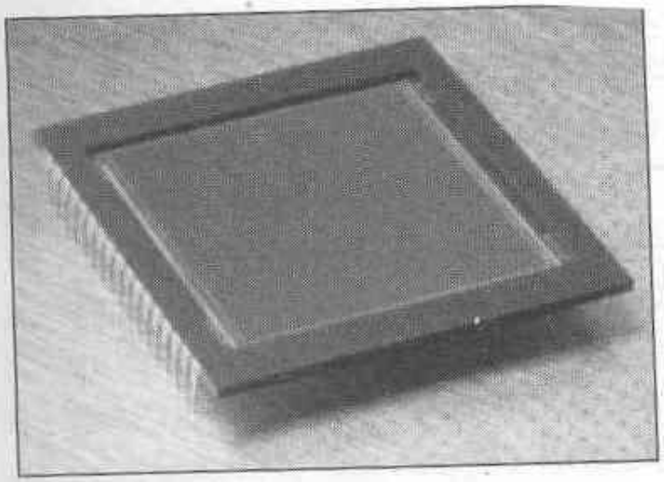


FIGURE 3-19
Kodak Digital Science KAF-16800 Image Sensor.
(*Courtesy © Eastman Kodak Company.*)

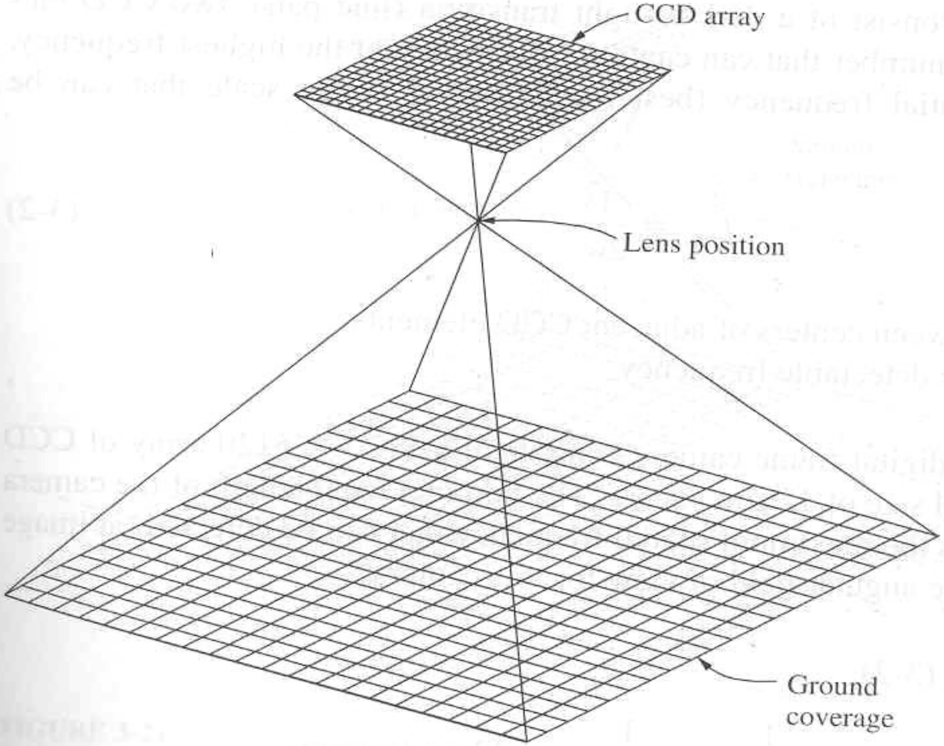
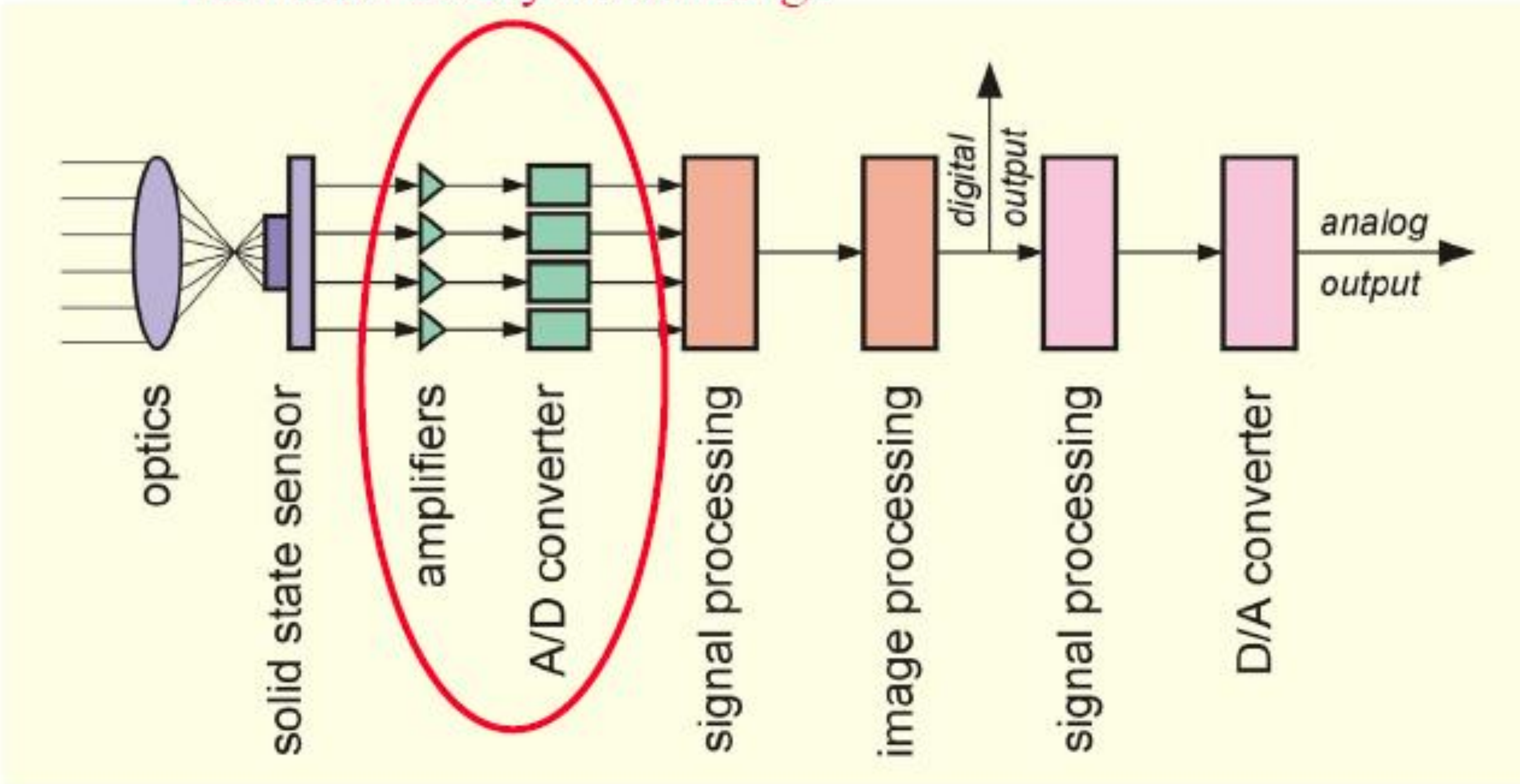


FIGURE 3-20
Geometry of a digital frame camera.

Digital Cameras: Block Diagram

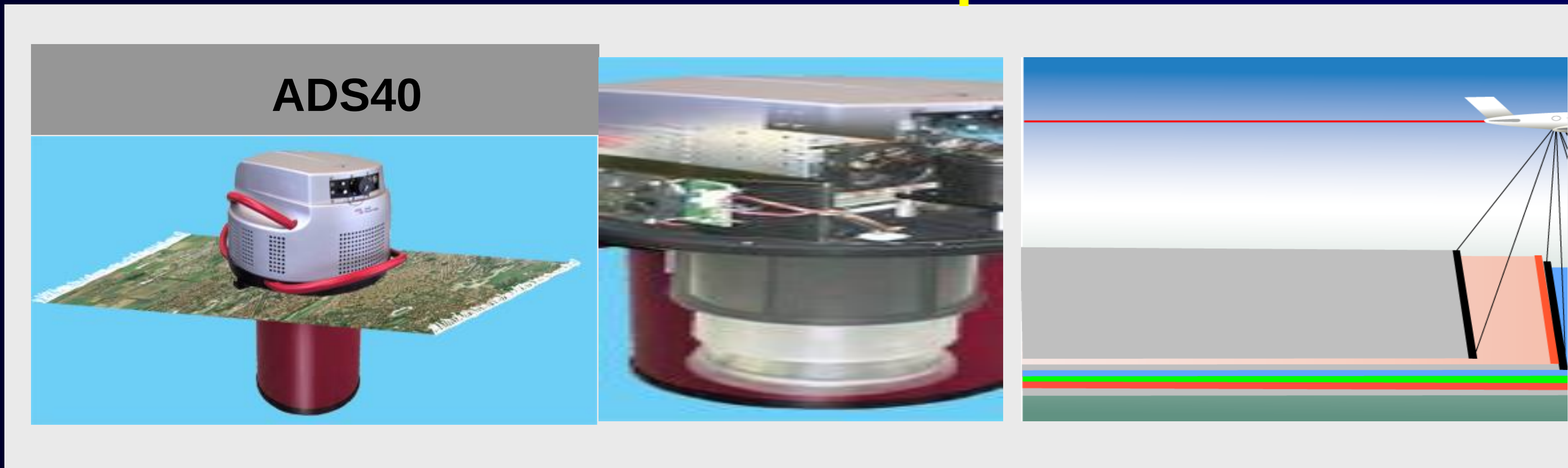
Controls the dynamic range



Analog Versus Digital Cameras

Components	Analog Cameras	Digital Camera
Optics	Lenses and Mirrors	Lenses and Mirrors
Detectors	Film	Solid State Detectors (CCD , CMOS)
Processors	Chemistry	Digital Computers
Output Media	Film	Computer Readable Disks and/or Tapes and Monitors

Camera Concepts



Single lens sensor with 10 channels generates endless pixel carpets

Multi lens sensors with up to eight lenses generates patchwork frames

High Resolution Digital Aerial Cameras
Three-line Pushbroom Scanner

- Two solutions for development of digital aerial camera now available
  - **Three linear arrays** look forward, vertically and backwards to form three separate images as the aircraft moves over the terrain surface.
    - Images not perspective projections
    - System must include GPS/INS
  - **Images from smaller area arrays** are stitched together to form a larger frame image, which will have similar dimensions to a frame aerial film camera
    - Images will be perspective projections
    - No GPS/INS system required

Push-broom sensors

- The geometry of the complete image is not a perspective projection. Hence, special software is required.
- GPS/IMU system is essential to determine the camera exterior orientation (positions and attitude) during flight – extra cost
- Linear arrays are less subject to loss of pixels
- If bad pixels do occur, fewer pixels available to interpolate lost data
- Linear arrays are claimed to have larger dynamic range
- Linear arrays in principle are more suited to smaller scale imaging because of motion of the aircraft.
- Linear array systems have recently demonstrated GSD of 5cm
- Most linear array systems enable the acquisition of only 3 images per point along-track, but multiple imaging is possible across-track

	Leica Geosystems ADS40	Wehrli 3-DAS-1
Focal length	62.5 mm	110mm (or 80mm)
Pixel size (pitch)	6.5 µm	9 µm
Panchromatic line	2 * 12000 pixel (staggered)	3 * 8023 pixels
RGB and NIR line	12000 pixels	n/a
FoV (across track)	46°	36°
Stereo angle forward to nadir	26°	26°
Stereo angle forward to backward	42° - B/H=0.77	42° - B/H=0.77
Stereo angle nadir to backward	16°	16°
Dynamic range	12-bit	14-bits
Ground sample distance	16 cm at 3000 m altitude	18cm at 2200m
Swath width (3000 m Altitude)	3.75 km	3.75km at 2200m

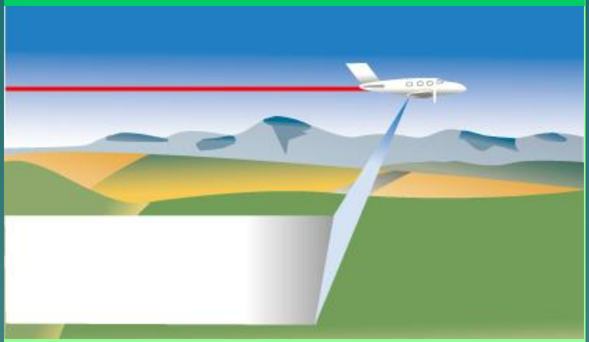
Digital Camera Concepts

digital frames

pixel carpets

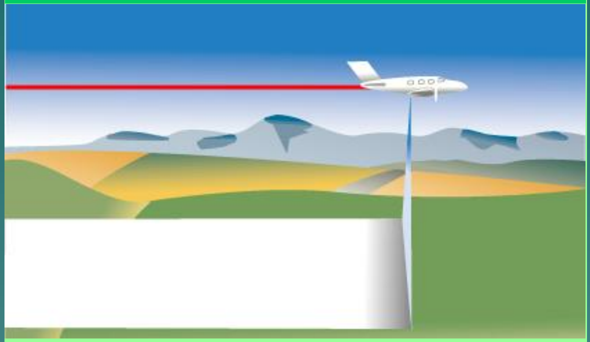
Three-line Pushbroom Scanner

Backward scene



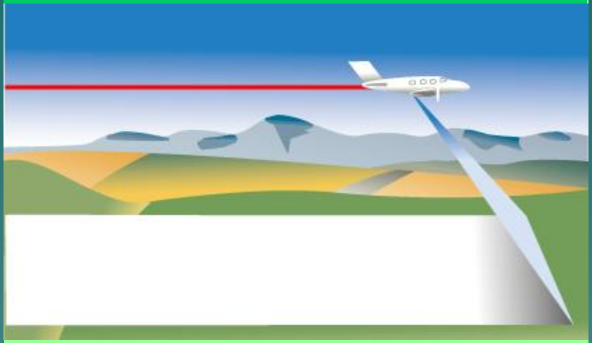
composed of backward view lines

Nadir scene

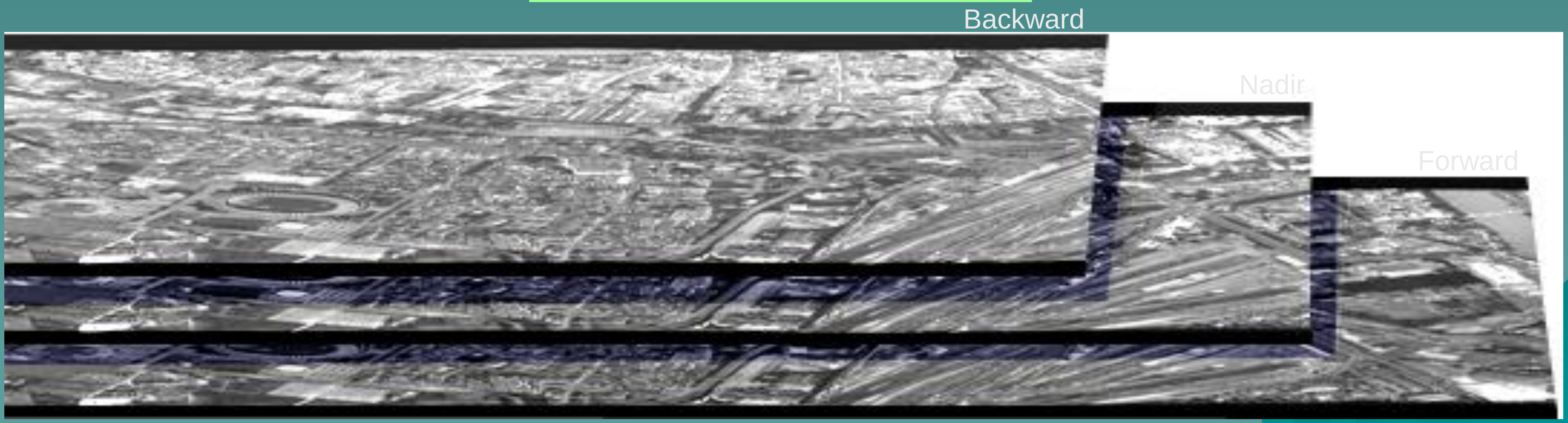


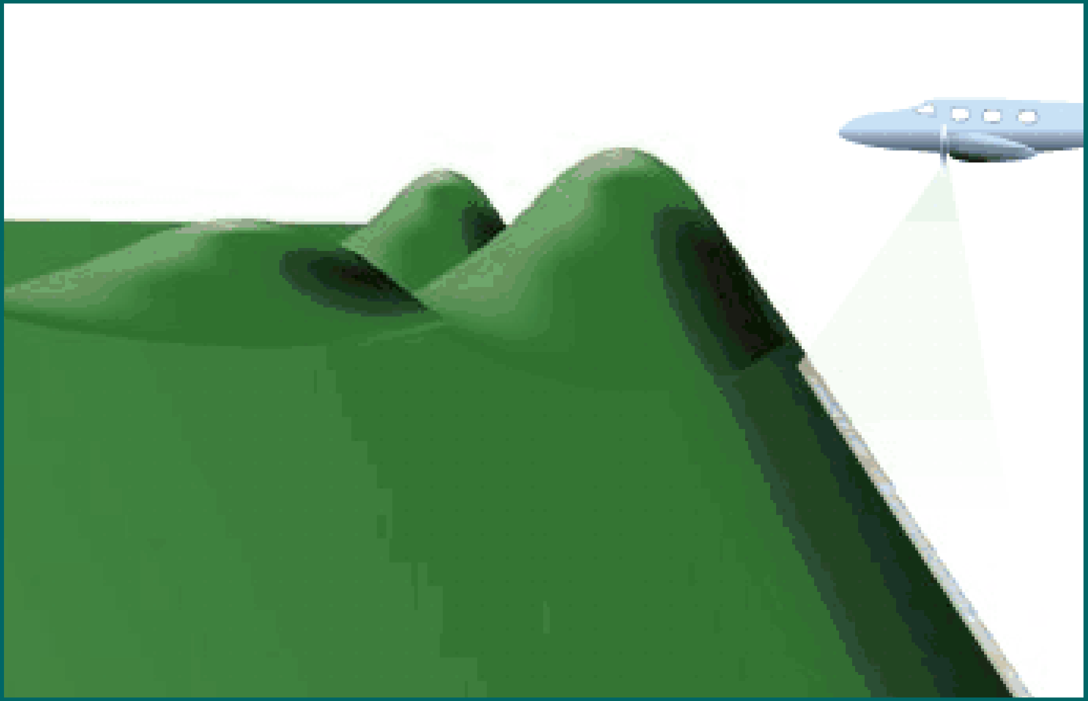
composed of nadir view lines

Forward scene



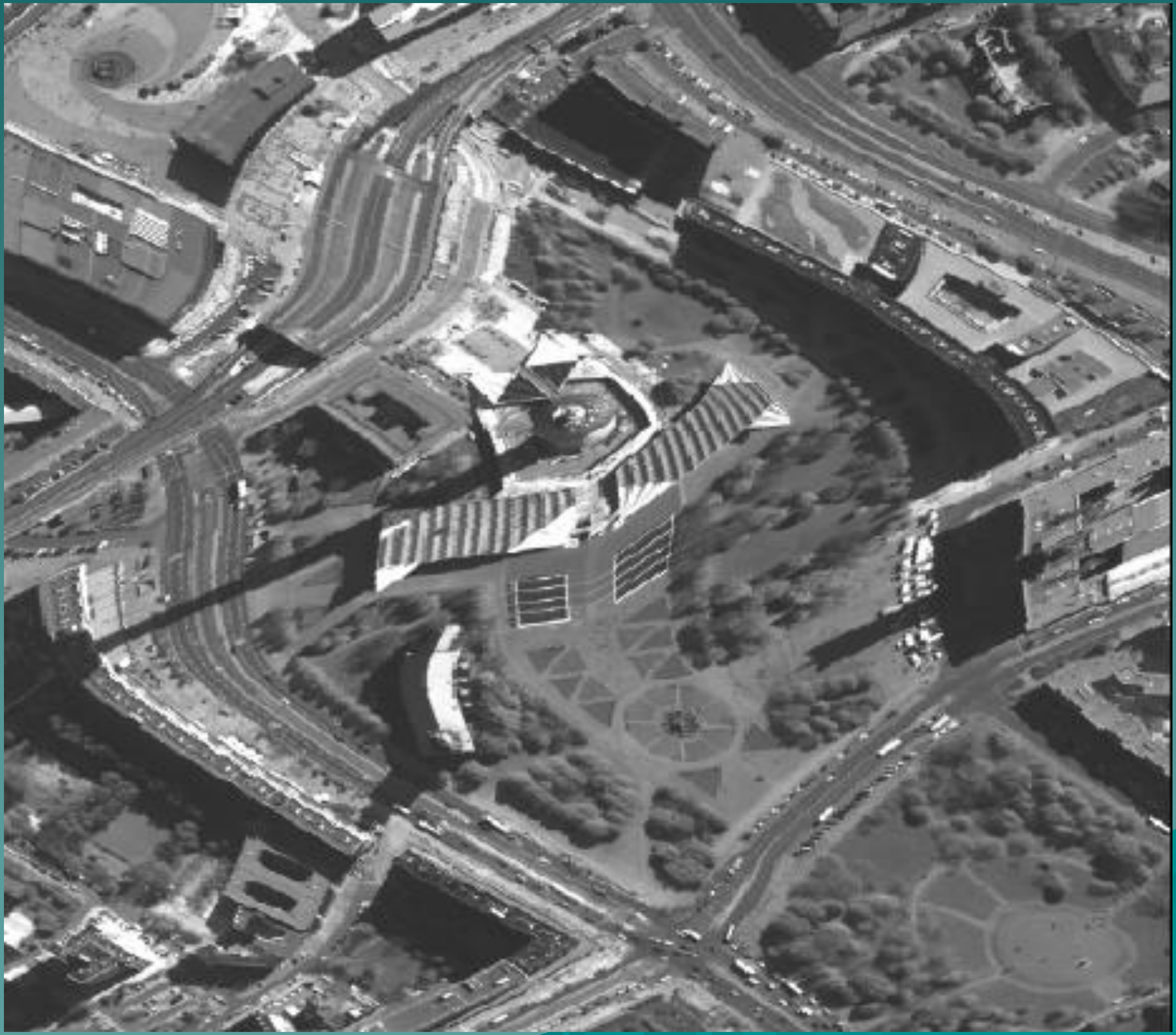
composed of forward view lines





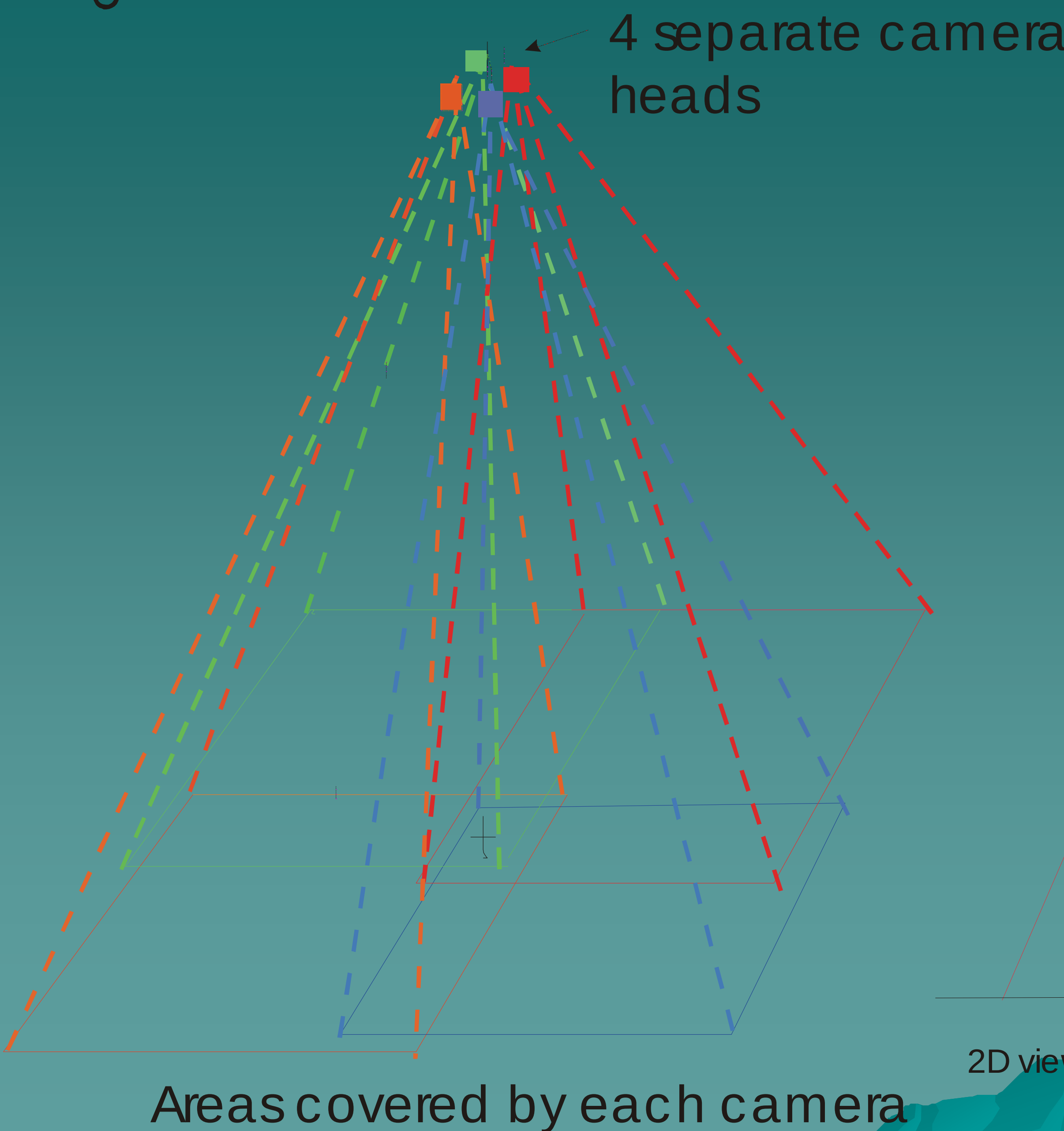
DATA ACQUISITION BY LEICA GEOSYSTEMS ADS40

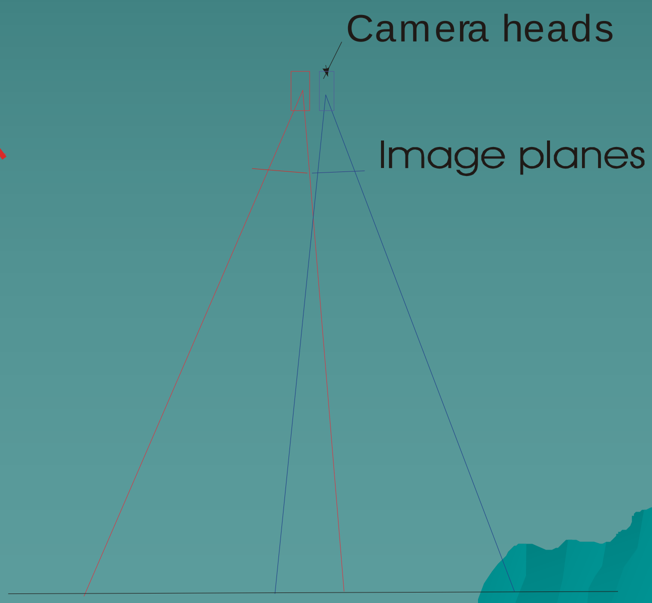
ADS40 unrectified



ADS40 rectified

Schematic diagram of DMC panchromatic digital camera

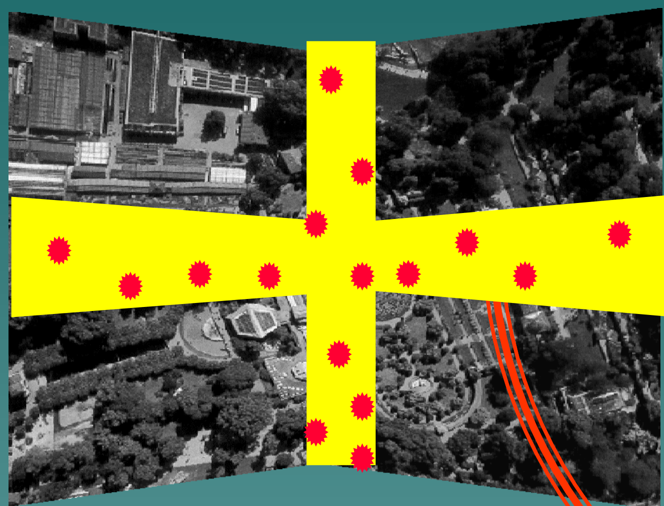




2D view of two camera heads

Image Processing

4 overlapping images



tie point area

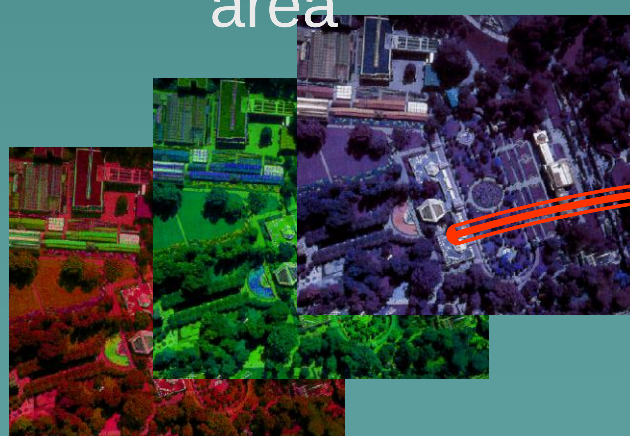
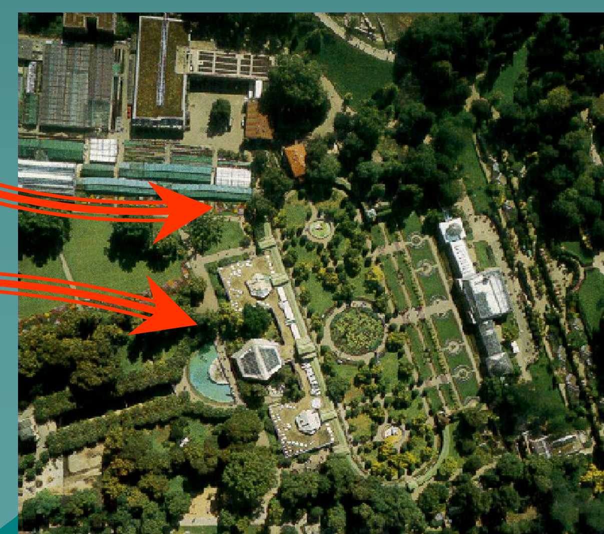


image mosaicing

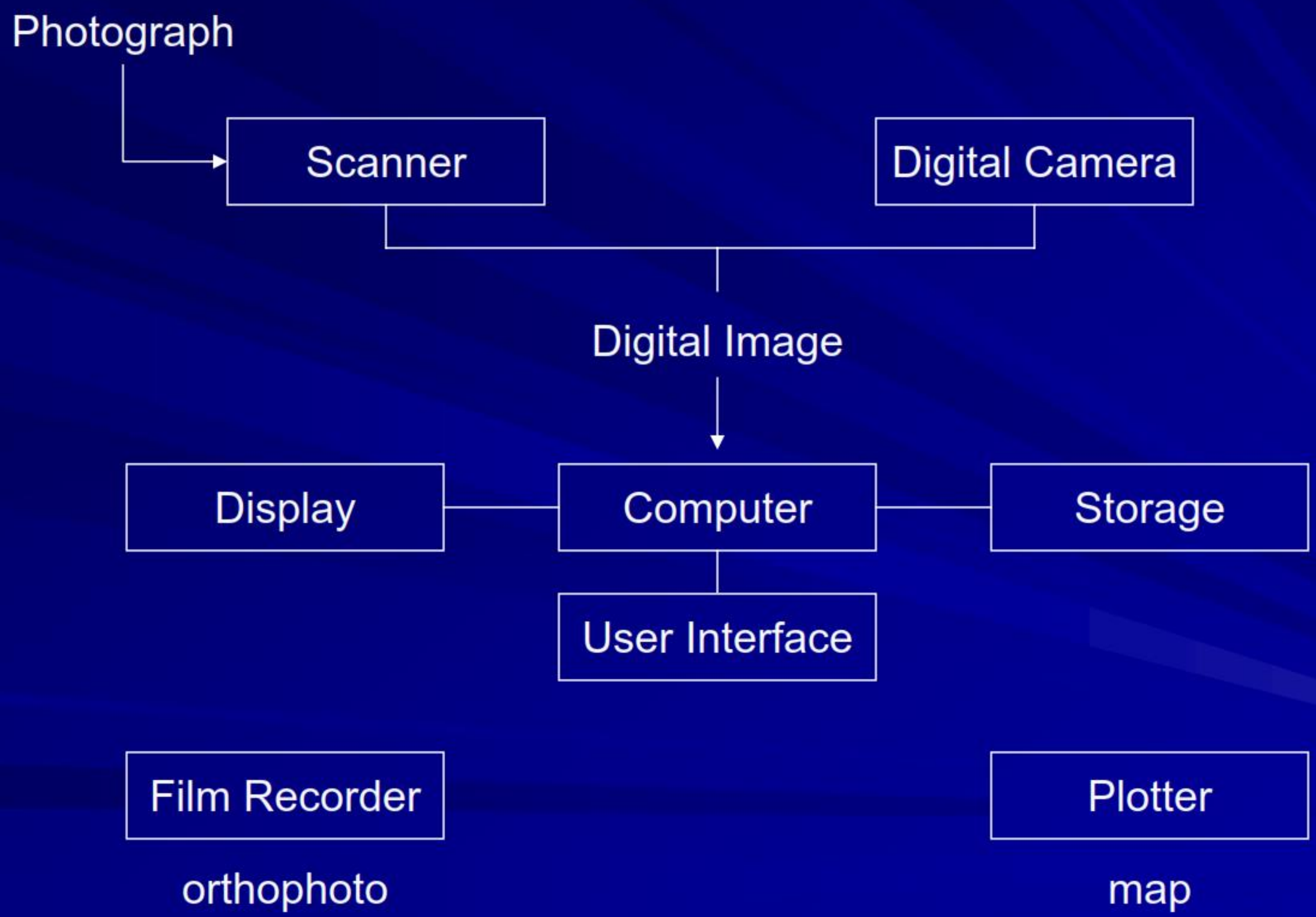
- apply camera calibration parameters
- apply platform calibration

- tie point check
- robust adjustment
- projection to virtual perspective
- fusion with colour composite

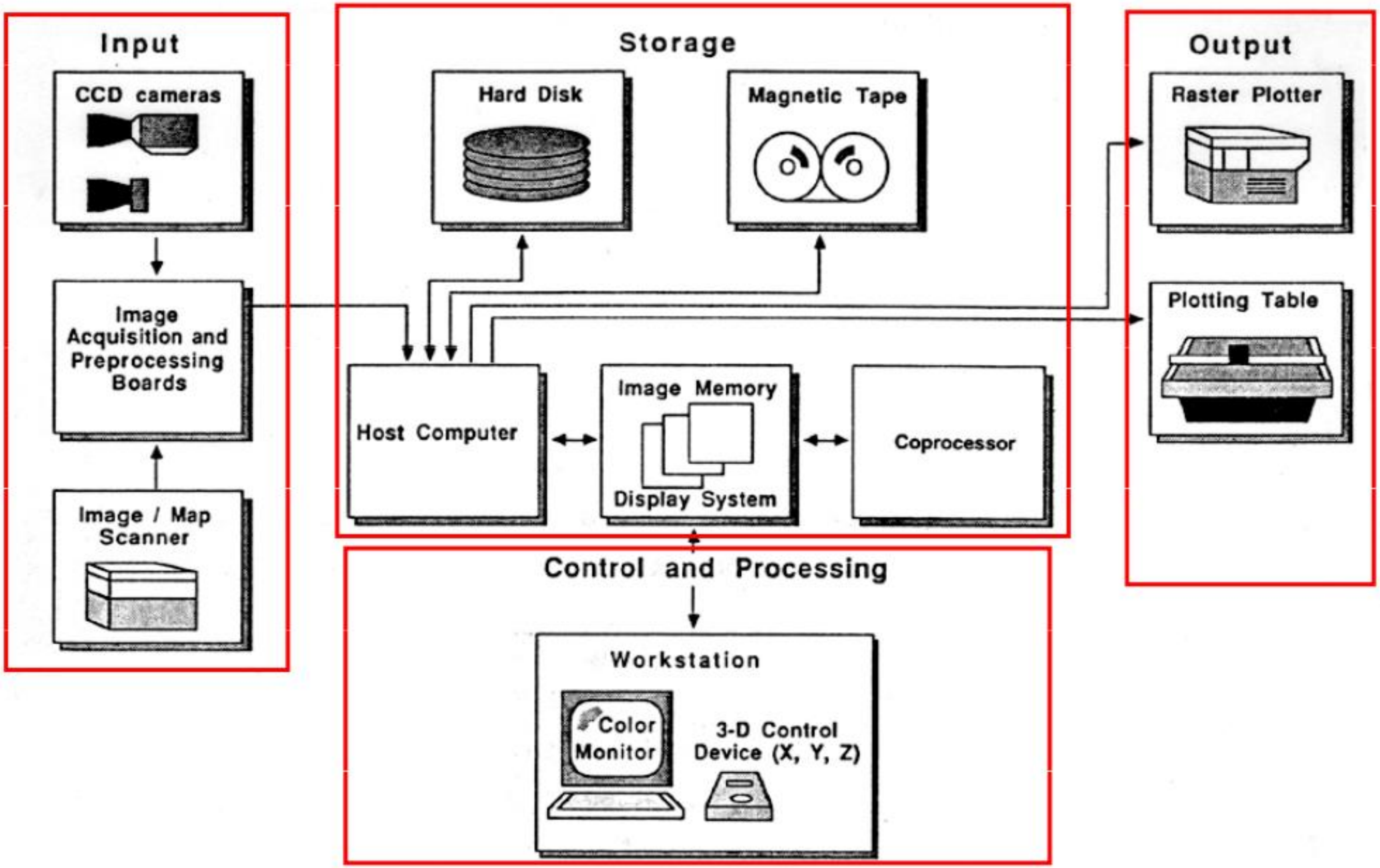


Pan-Sharpening

Generic Digital Photogrammetry Environment



Hardware architecture of a Digital Station



Digital Photogrammetric Equipments and Processes

A DPW combines computer hardware and software to allow photogrammetric operations to be carried out on digital image data.

DPWS

Digital Photogrammetric Workstation: ”Hardware and software to derive photogrammetric products from digital imagery using manual and automated techniques.” (ISPRS)

Typically, a DPW consists of a graphics workstation with, in most but not all cases, a stereo viewing device and a 3-D mouse.

Hardware for Digital Photogrammetry

- Basic Hardware Requirements
  - High Resolution Display
  - Flexible image memory with fast access for real time roaming
  - Interface capability for scanners and cameras
  - Interface with output devices
  - Image enhancement processor
  - 3D measurement with special control devices
  - Subpixel accuracy
  - Data capture in a GIS or CAD
- Stereoscopic Viewing
- Special Hardware requirements

Software Requirements for DP

- Standard Requirements:
  - Handling Image Display
  - Measurement
    - Recording Pixel Coordinates
  - Determination of Orientations
    - Inner Orientation including Calibration parameters
    - Relative and absolute orientations, **B**undle Adjustment
  - Transformations
  - Image Processing Functions
    - Image Matching
    - Edge Detection
  - Digital Rectification
  - Visualization
- Automation

VIEWING SYSTEMS

3D Viewing

The human brain requires separation of stereoimages in order to get a 3D view.

Separation method	Practical implementation
Spatial	2 monitors + stereoscope 1 monitor (split screen) + stereoscope 2 monitors + passive polarisation
Spectral	Anaglyphic Passive polarisation
Sequential	Alternated synchronised display, active polarisation or LCD

VIEWING SYSTEMS

The function of the viewing system of a stereoplotter is to enable the operator to view the stereomodel three dimensionally.

An **anaglyphic system** uses filters of complementary colors usually red and cyan (blue-green) to separate the left and right projections. Assume that a cyan filter is placed over the light source of the left projector while a red filter is placed over the right.

Then, if the operator views the projected images while wearing a pair of spectacles having cyan glass over the left eye and red glass over the right eye, the stereomodel can be seen in three dimension. This is simple and inexpensive. However, it prevent the use of color diapositives and causes considerable light loss, so that the model is not bright.

The **Stereo-Image Alternator (SIA)** system uses synchronized shutters to achieve stereoviewing. A shutter is placed in front of each projector lens. Also, a pair of eyepiece shutters, through which the operator must look is situated in front of the platen. The shutters are synchronized so that the left projector and left eyepiece shutters are open simultaneously while the right projector and right eyepiece shutters are closed and vice versa.

The **Polarized-Platen Viewing (PPV)** system operates similarly to the anaglyphic system except that polarizing filters are used instead of coloured filters. Filters of orthogonal polarity are placed in front of the left and right projectors and the operator wears a pair of spectacles with corresponding filters on the left and right. In contrast to the anaglyphic system, the SIA and PPV systems both cause much less light loss and both permit the use of colour diapositives.

polarizing filters

In the polarizing filters, a computer monitor is fitted with an active polarizing screen, while operator wears a simple pair of spectacles consisting of orthogonally polarizing filters.

The active polarizing screen has the capability of alternating the orientation of its polarity between horizontal and vertical (120 times per second).

The computer display has the capability of alternatively displaying the left and right images at same rate.

The spectacles are constructed so that the filter over one eye is oriented vertically and the other filter oriented horizontally.

At the particular instant, the polarity of the left filter of the spectacles has the same orientation as that of the screen, the left image passes through to the operator's left eye, while right eye see nothing and the same way for the right image.

This alternating display of left and right images with synchronized alteration of the screen, the left image set with left eye and right image set with right eye and thus stereomodel will evolved.

The DPW770 system by LH systems having above setero viewing tools.

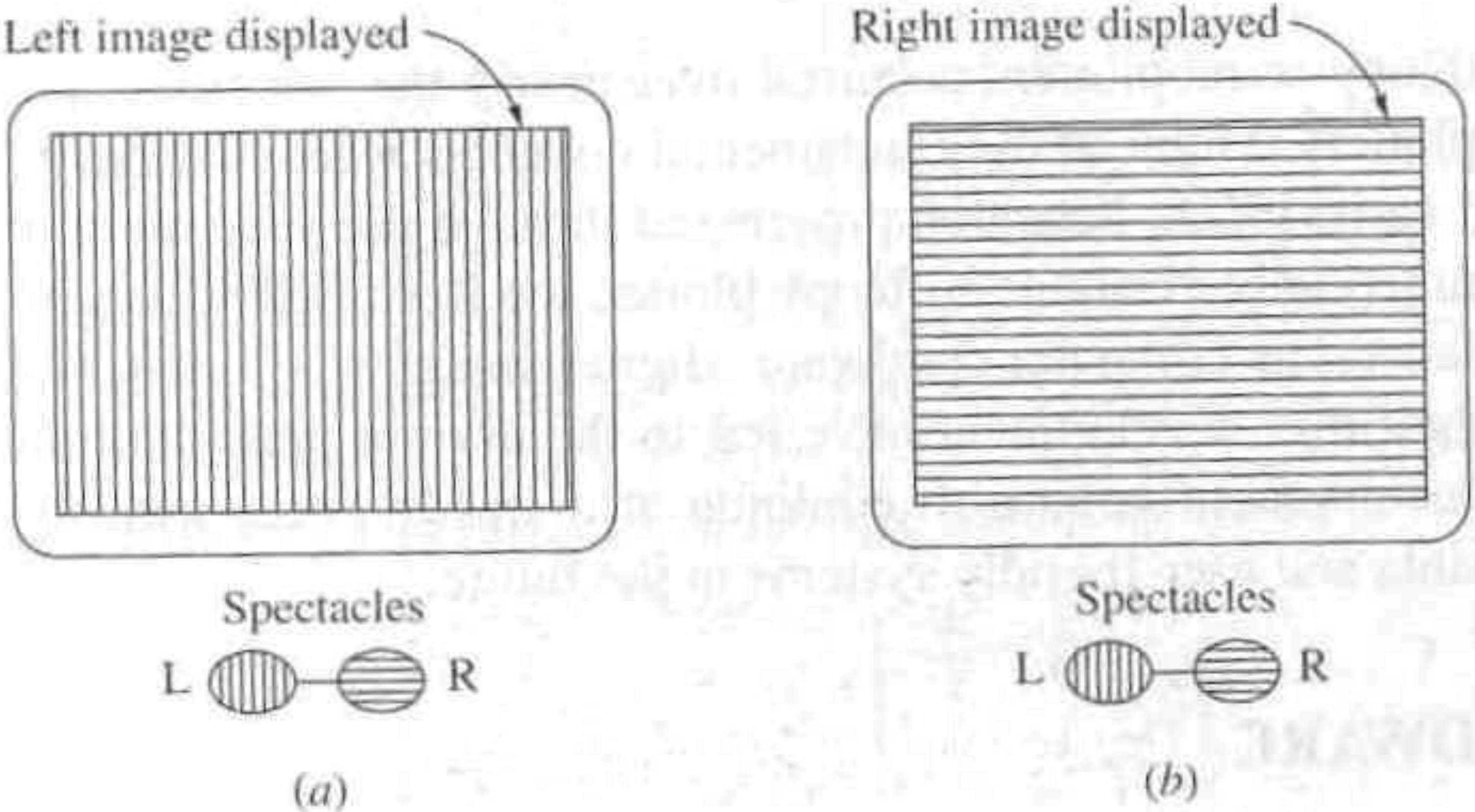
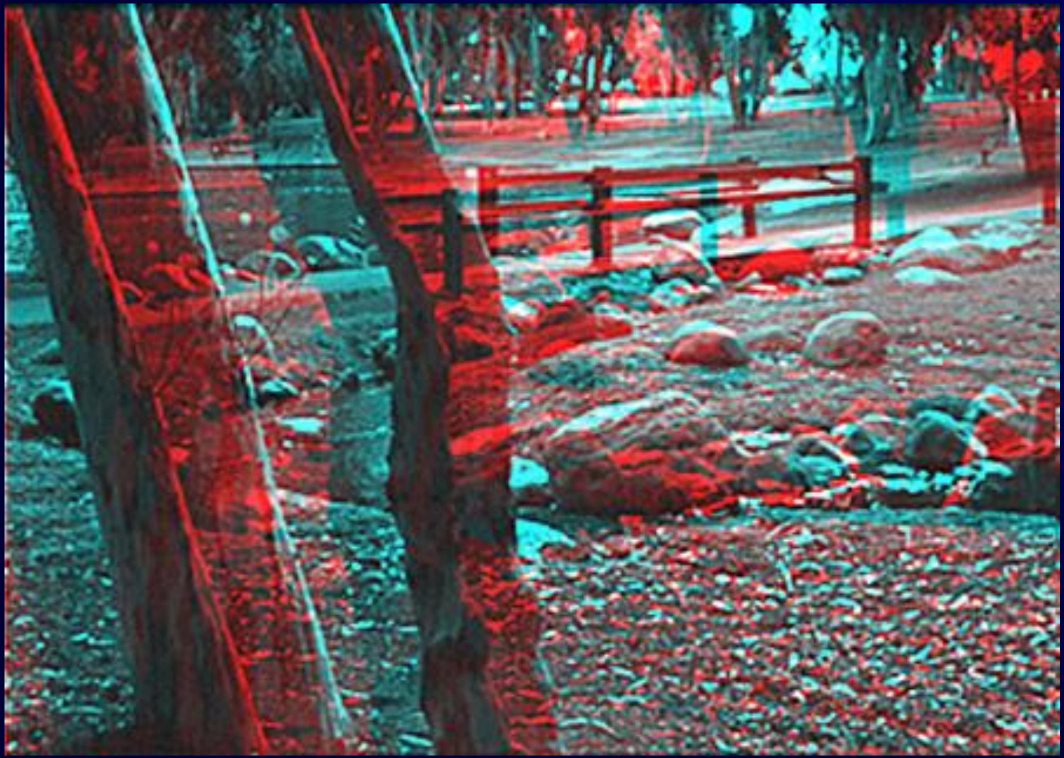
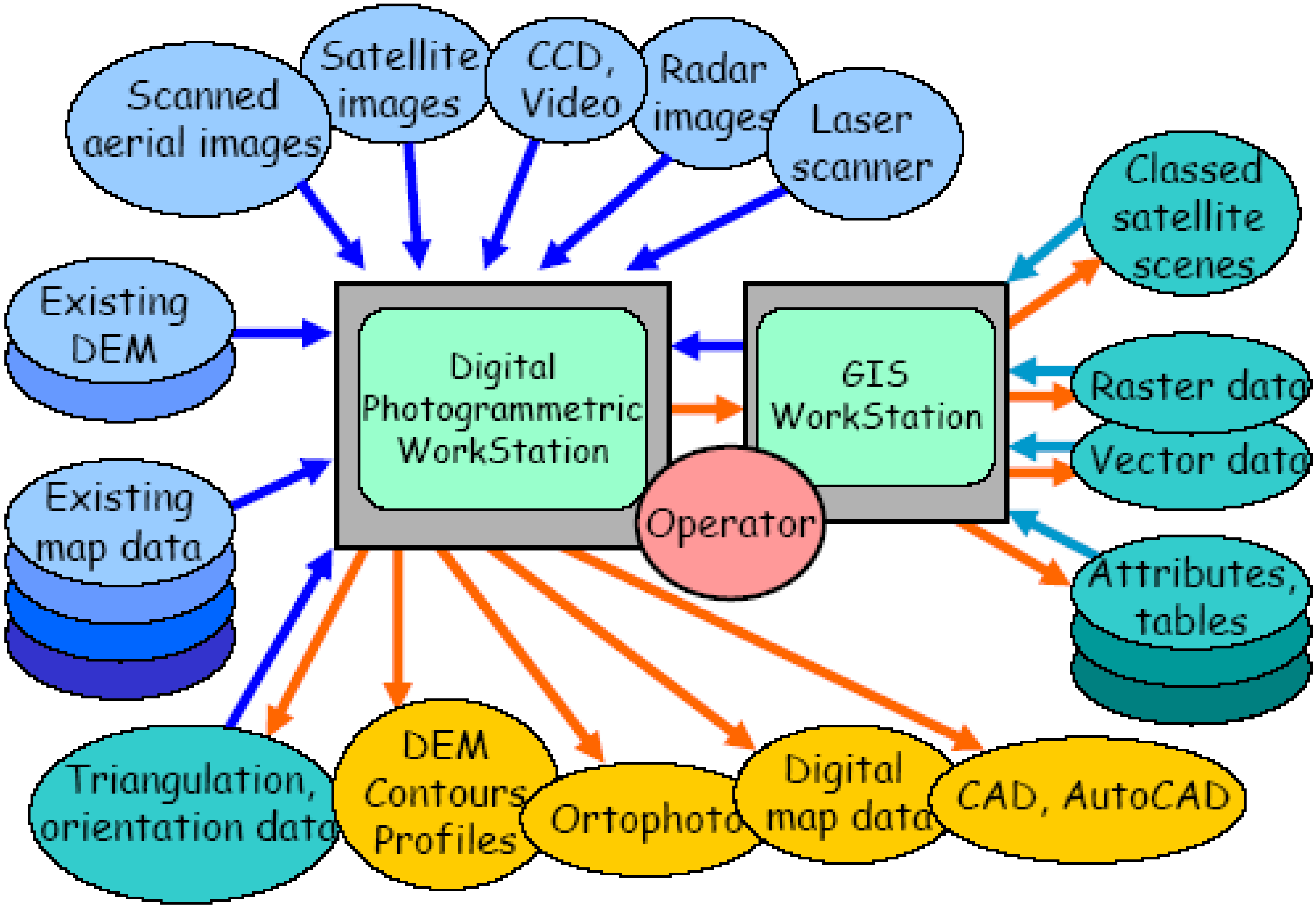


FIGURE 15-1
Stereoviewing principle of the active polarizing screen display.


© Takashi Sekitani



DPWS "in the center"



Fundamentals of Digital Photogrammetry

- Why use Digital Images?
- Advantages of using Digital Images:
  - Appropriate way for displaying and Measurement
  - Stability
  - Applying image Enhancement is possible
  - Automation can be applied
  - Real time phptogrammetry is not out of access

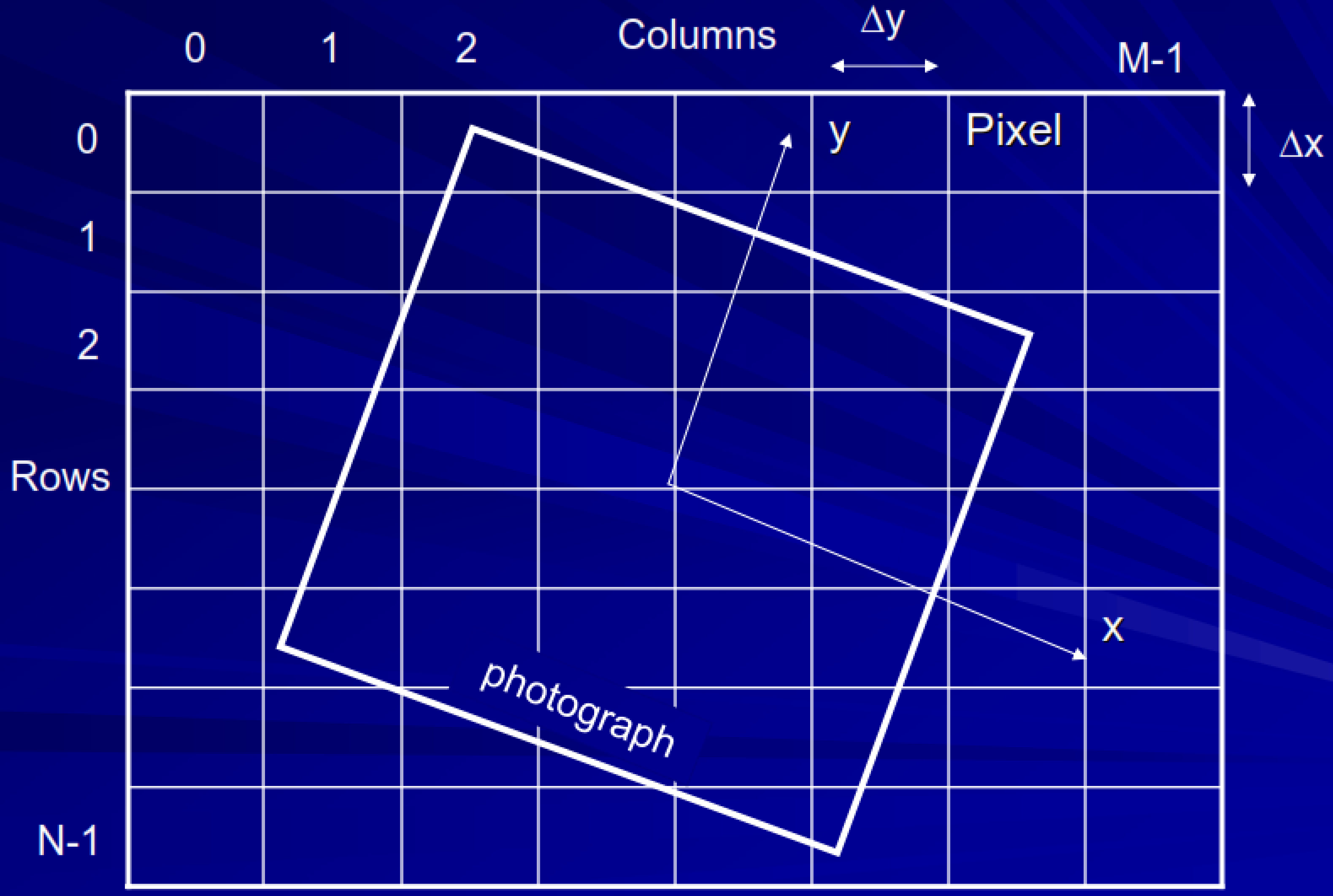
Characteristics of Digital Data

- Digitization
  - Intensity
  - Gray Value
  - Density
- Sampling
- Quantization of gray levels
- Noise

Properties of Digital Imagery

- Definition of Digital Image
- Spatial Resolution and Geometric Accuracy
- Radiometric Resolution

Definition of Digital Image



Spatial Resolution and Geometric Accuracy

Pixel Size(micron)	Number of Pixels	Storage Requirement (MB)
960	240 * 240	0.058
480	480 * 480	0.230
240	960 * 960	0.922
120	1920 * 1920	0.686
60	3840 * 3840	14.746
30	7680 * 7680	58.982
15	15360 * 15360	235.931
7.5	30720 * 30720	943.721

Classification of Processes and Tasks in Digital Photogrammetry

Category	Processes, Algorithms	Tasks
System level	Store, access, display, images	Manipulate digital imagery
Low level	Process, match images, extract features	Image processing: orientations, digital orthophoto, DEM, AT
Middle level	Group, segment images	Surface reconstruction Feature reconstruction
High level	Understand images	Object recognition Image interpretation

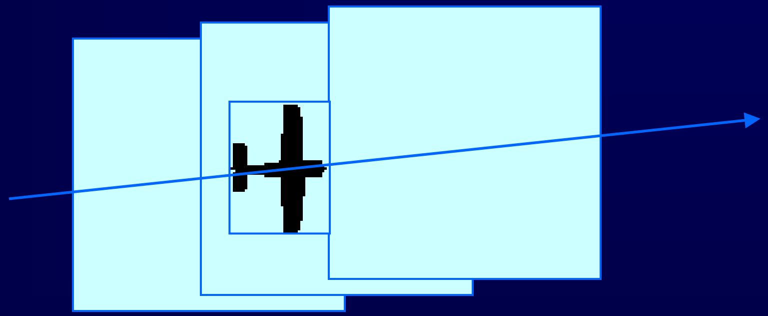
DIGITAL PHOTOGRAMMETRIC WORKFLOW

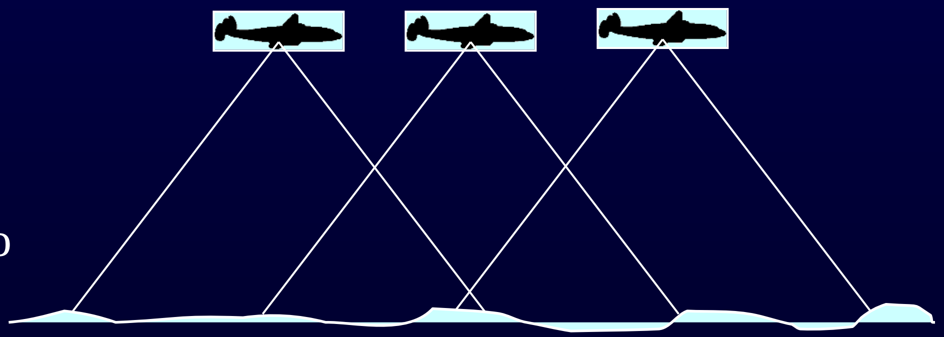
Creating a 3-D model or map is a straight and linear process that includes several steps-

- Sensor model defenition
- Ground Control Point (GCP) measurement
- Automated tie point collection
- Block bundle adjustment (i.e. Aerial Triangulation)
- Automated DEM extraction
- Ortho-rectification
- 3-D feature collection and attribution

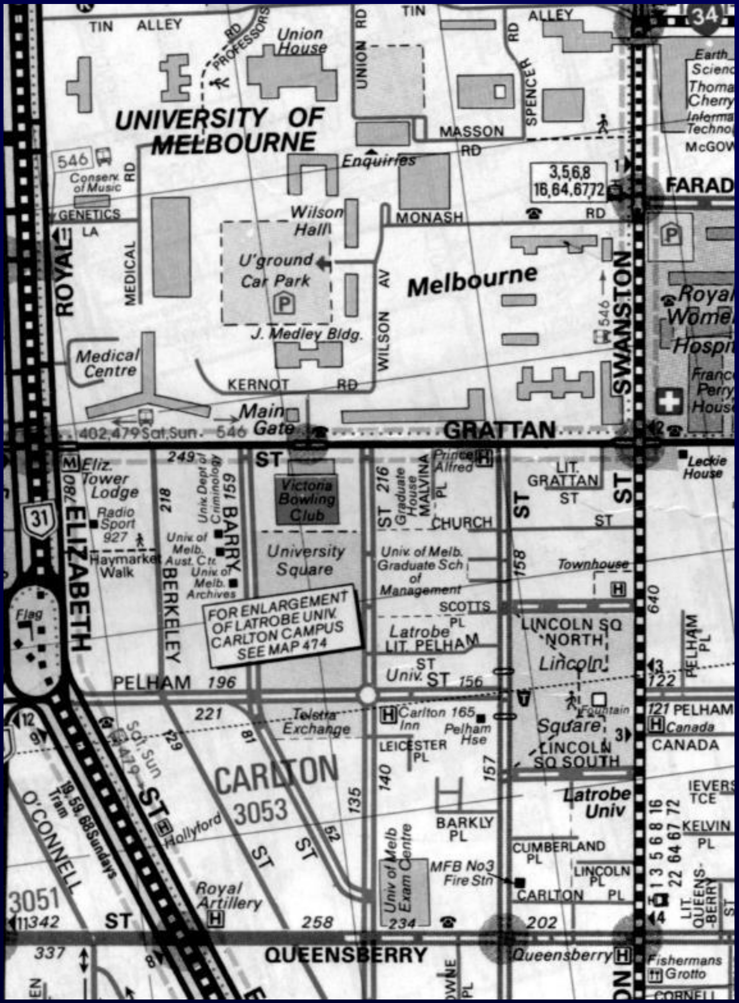
Applications of Photogrammetery

- Topographic mapping
- Creation of value added products:
  - Orthoimages
  - Digital Elevation Models
  - Virtual landscapes
- Nadir imagery is essential for mapping
- Overlap and sidelap is required to give 3D information





Example products: maps



Example of feature extraction and their perceptual organization

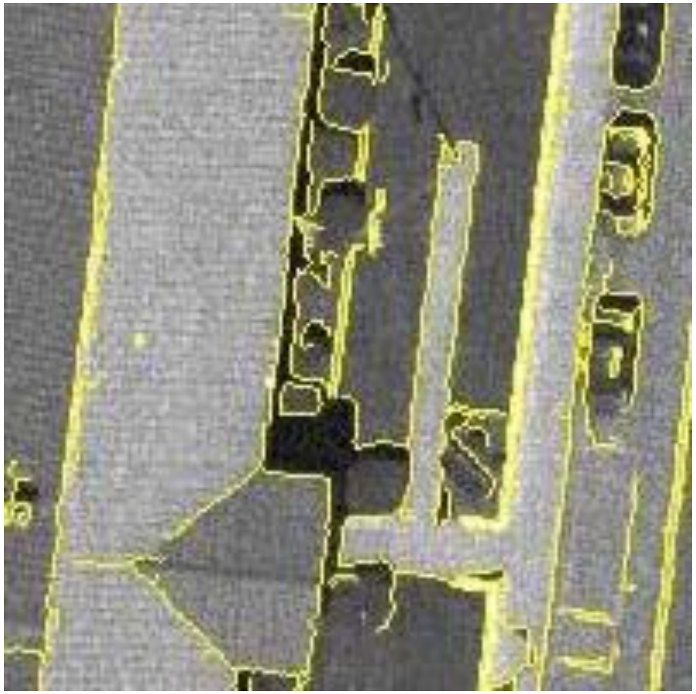
- features are likely to correspond to object boundaries (pixels carry no explicit information about scene)
- perceptual organization of features leads to structures that can be used to generate hypotheses about objects

Test Site

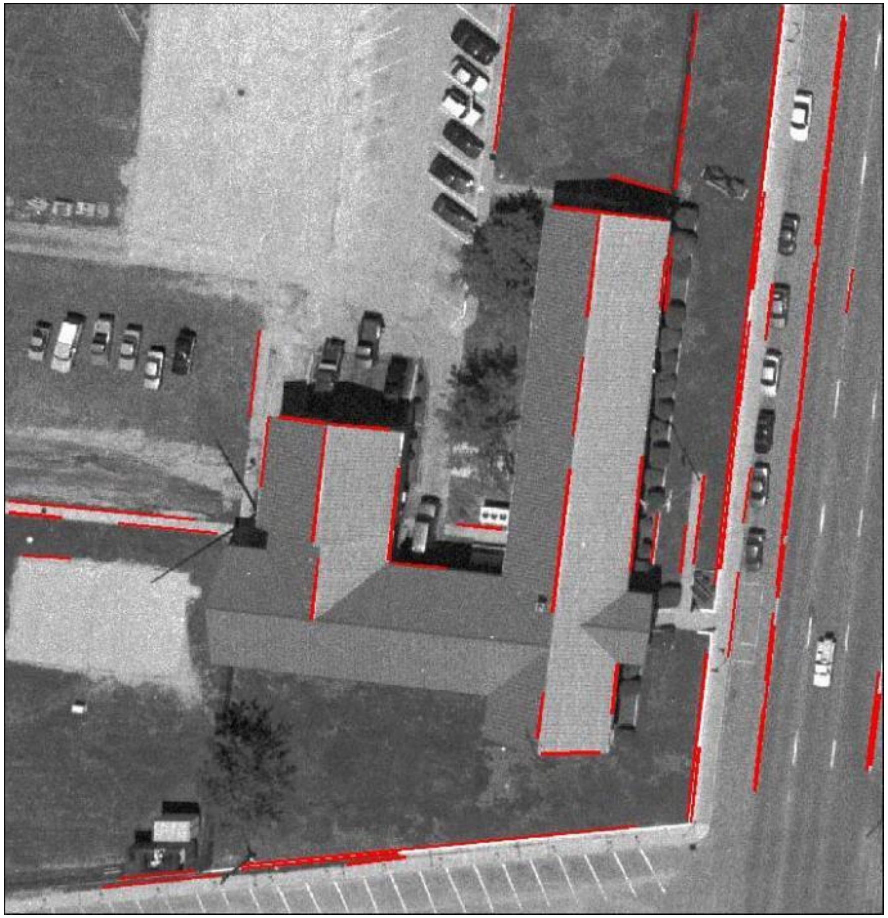
Test Site Ocean City

Detail View

Edge Detection



Edge Segmentation



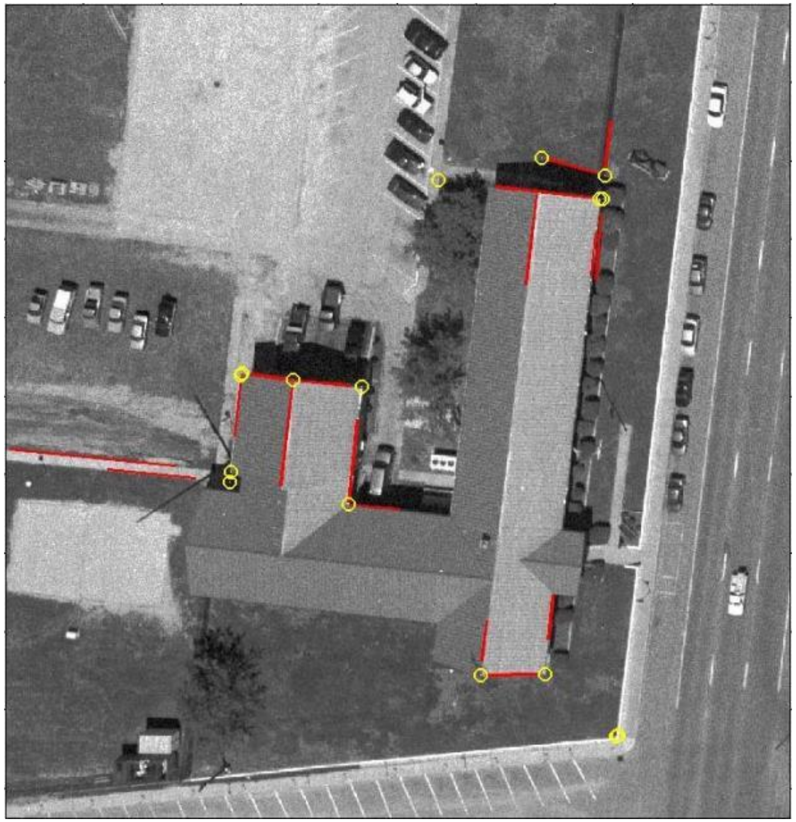
segmentation of raw edges into straight lines

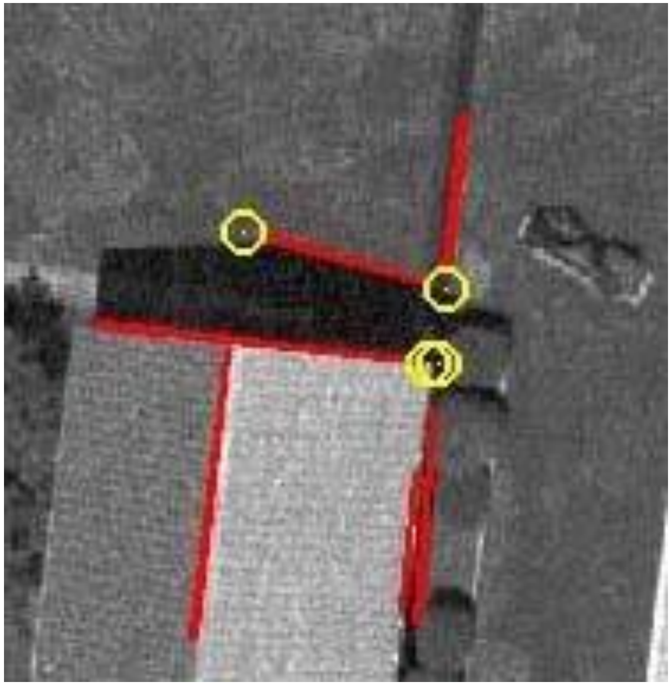
threshold criteria

- straightness
- length

from pixels to vectors

Grouping:
Rectangular Edges and Corners

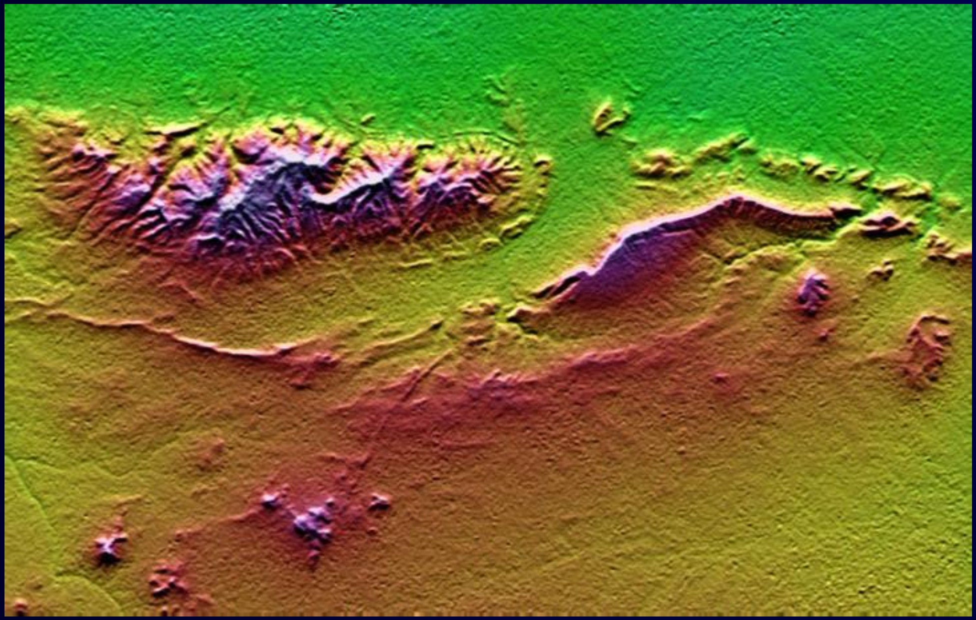


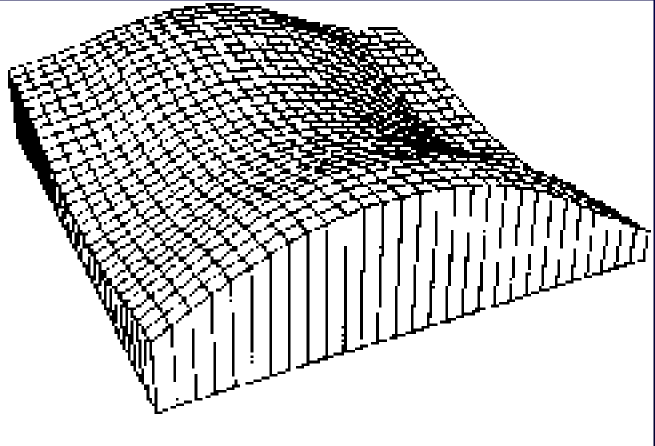


Edge Information

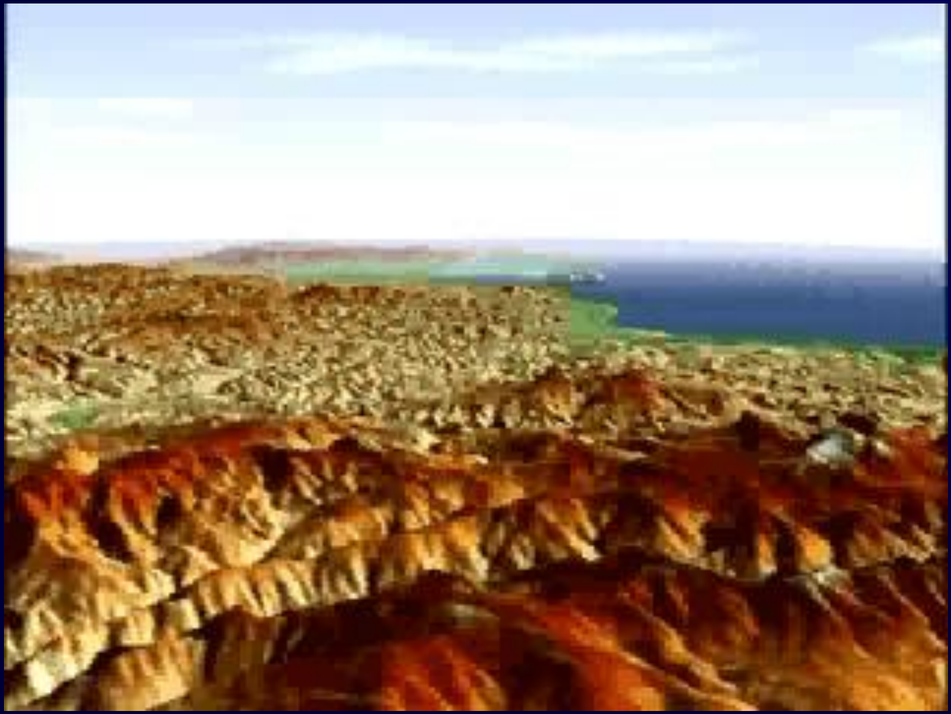
- segmentation and grouping are perceptual processes
- perceptual organization transforms data (edge pixels) into information (parallel edges, rectangular edges, corners,…)
- edge information enters spatial reasoning process

Example products: DTMs



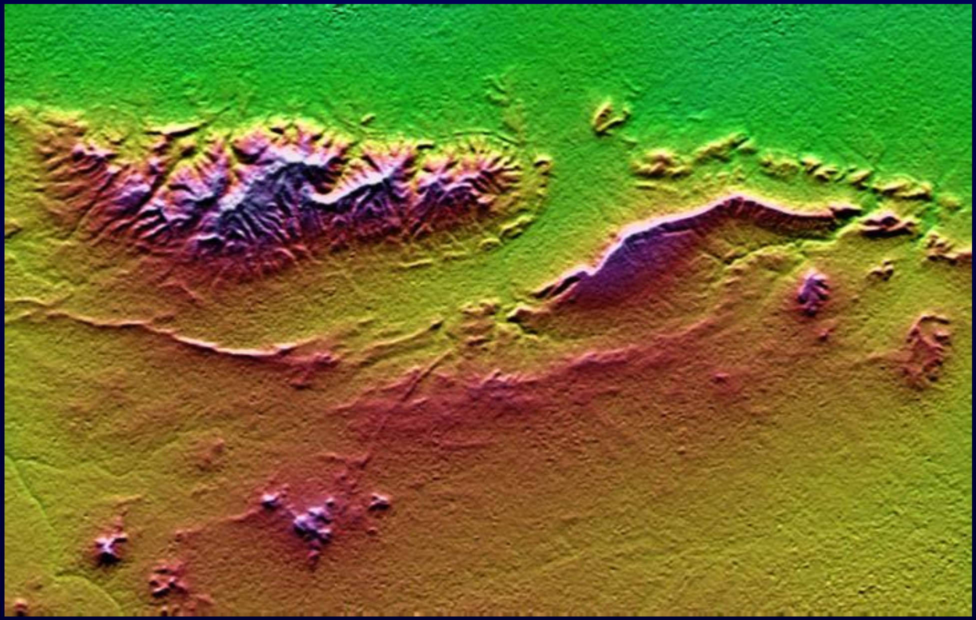


Example products: Virtual landscapes



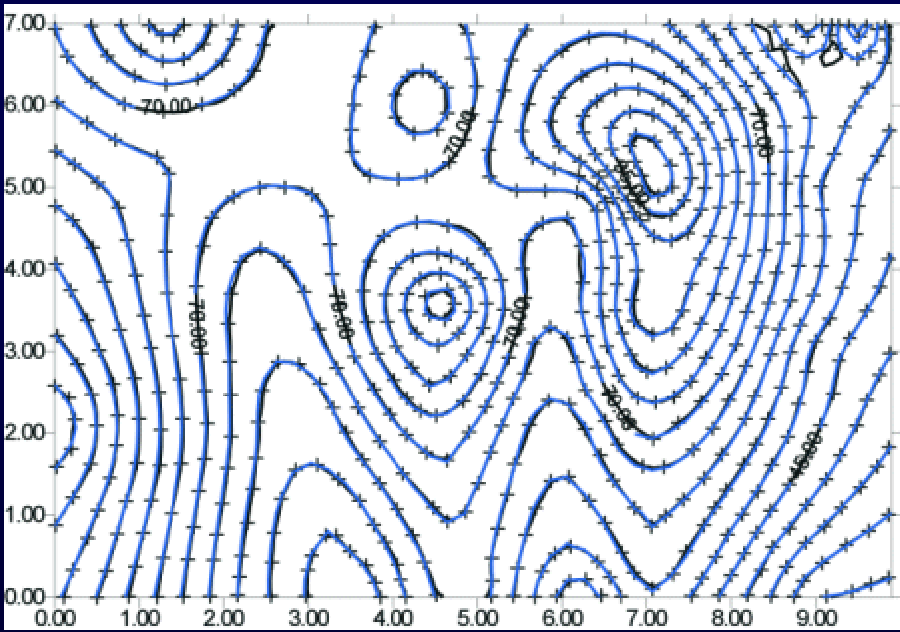
DTMs

- Sources of terrain models
  - Stereo photogrammetry
  - Interferometric radar
  - Stereo radar
  - Laser scanning
  - Digitising maps

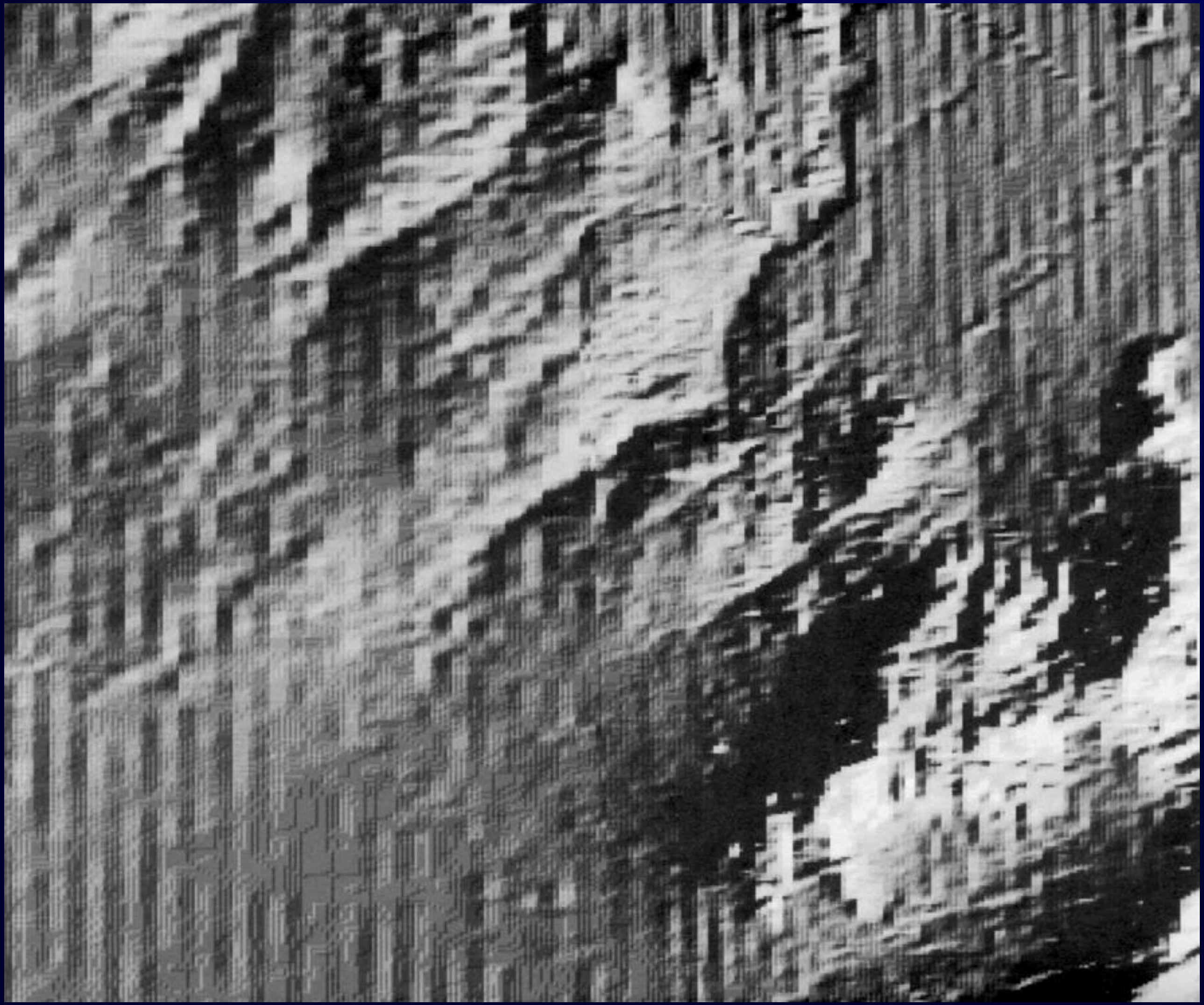


Contour digitizing

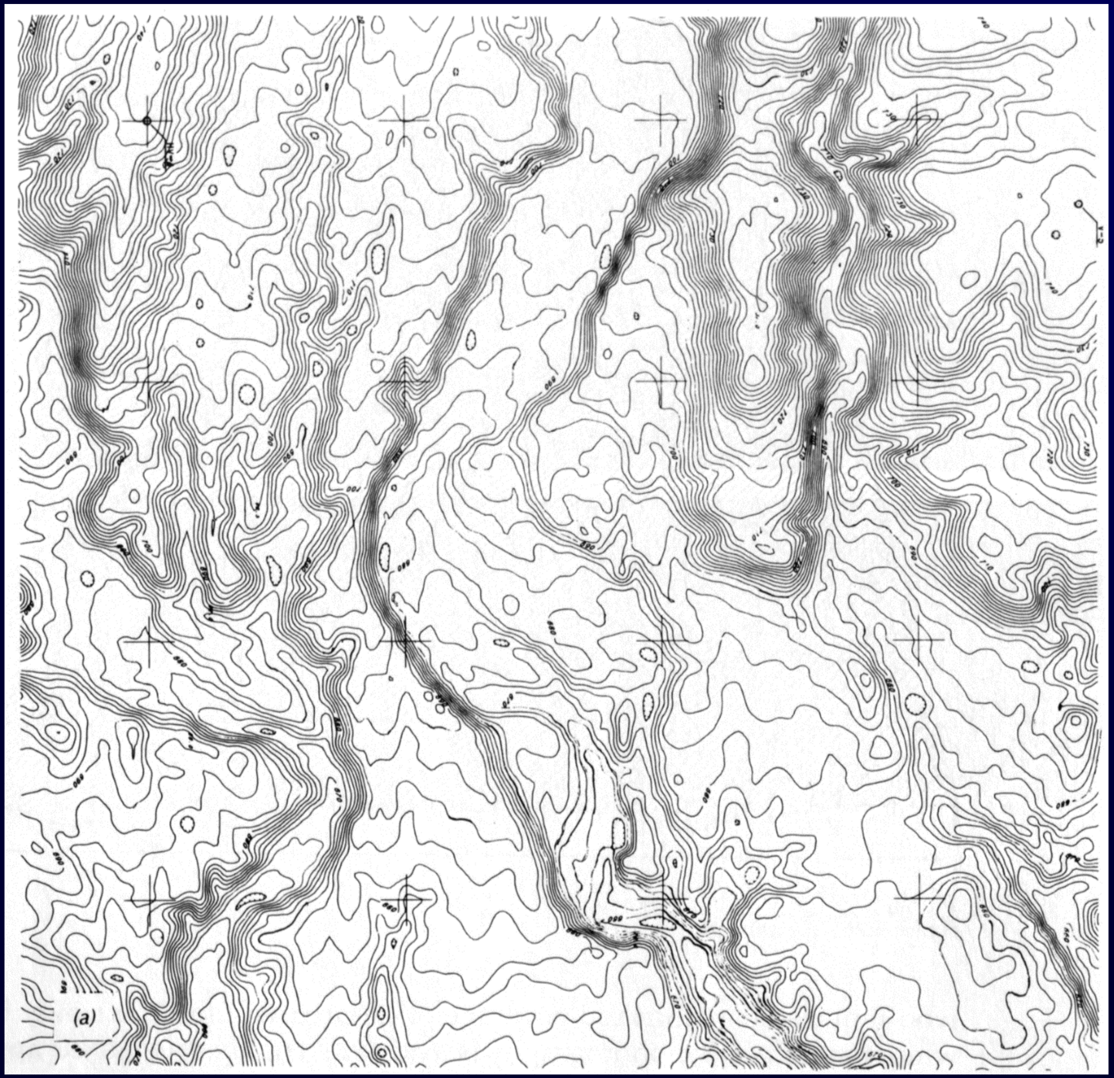
- Digital terrain model – Digitizing contour maps
- Two step procedure: click on the contours, then grid the data
- Liable to error if the DEM spacing grid is too large



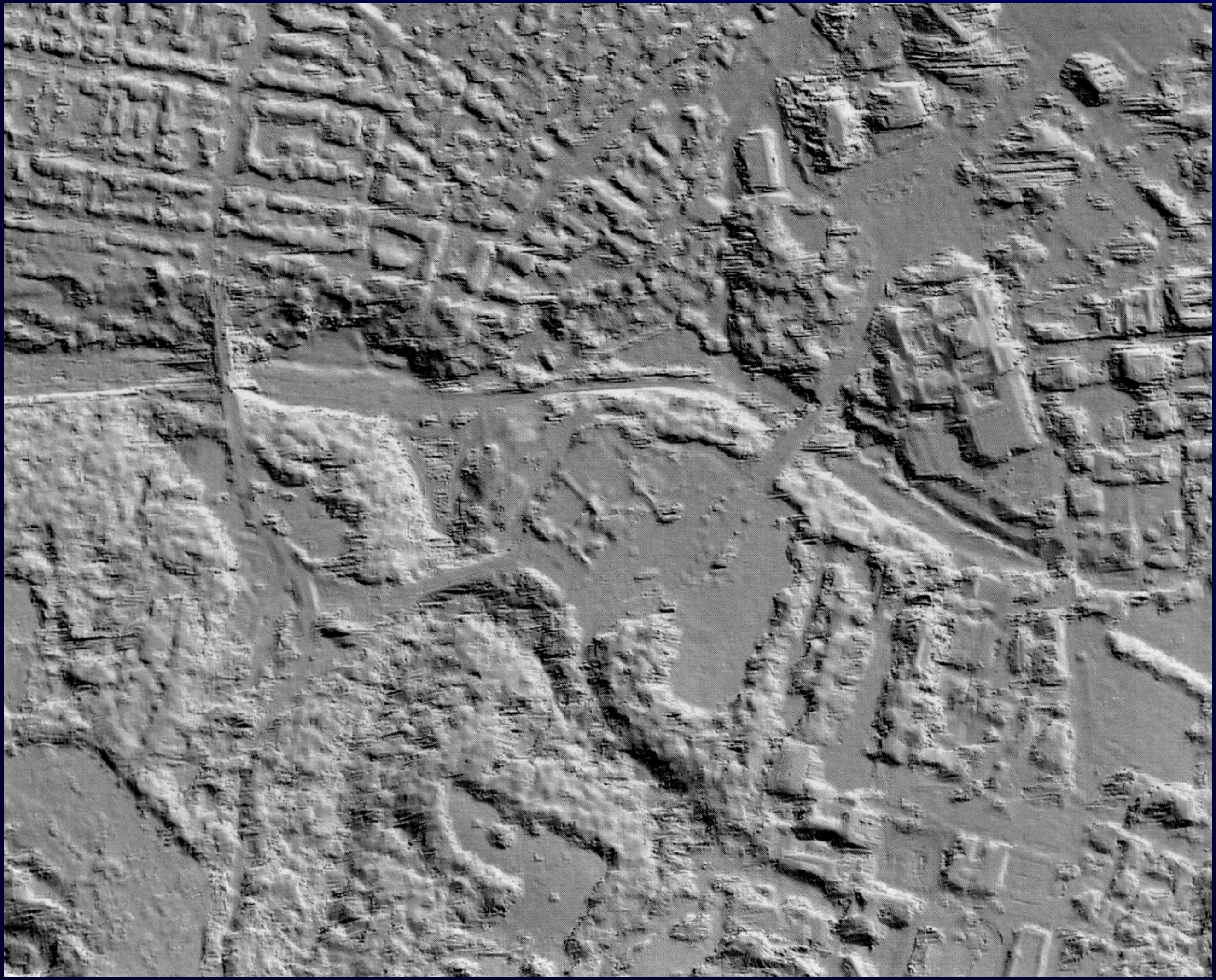
Contour digitizing



Contour map

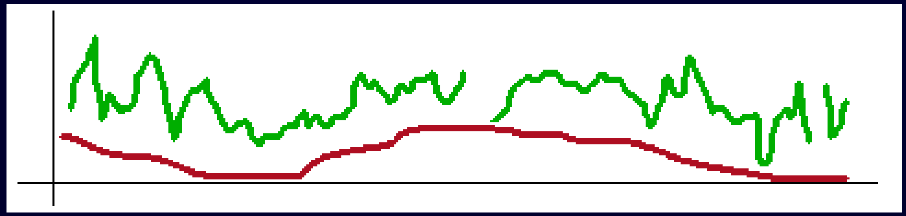


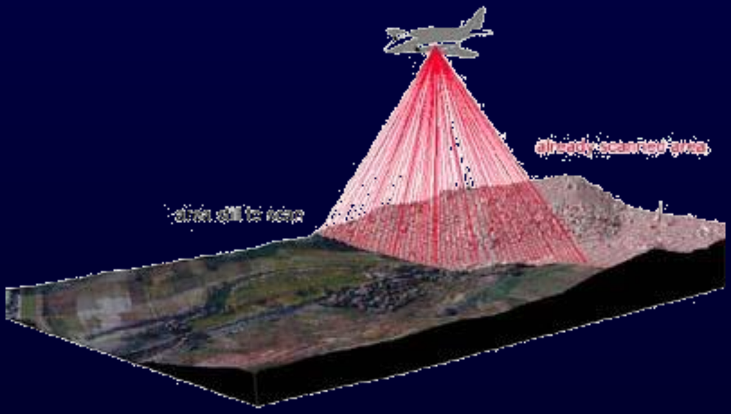
Stereo photogrammetry



Airborne laser scanning

- Digital terrain model generation – airborne laser scanning
- Laser pulse is emitted from the sensor – return journey time is measured, giving distance between sensor and target
- Location of the sensor is determined by GPS
- Therefore target can be located
- Significant post processing is required:
  - Data thinning
  - Gridding



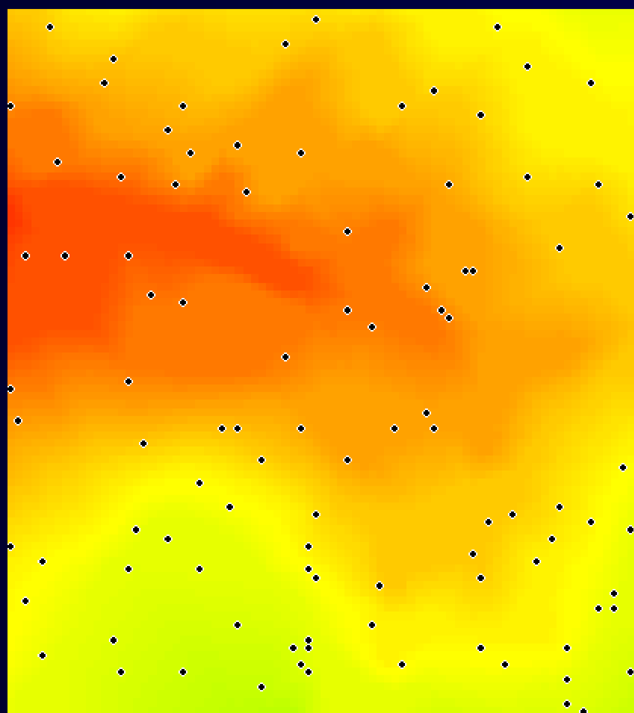


Modelling building and topological structures

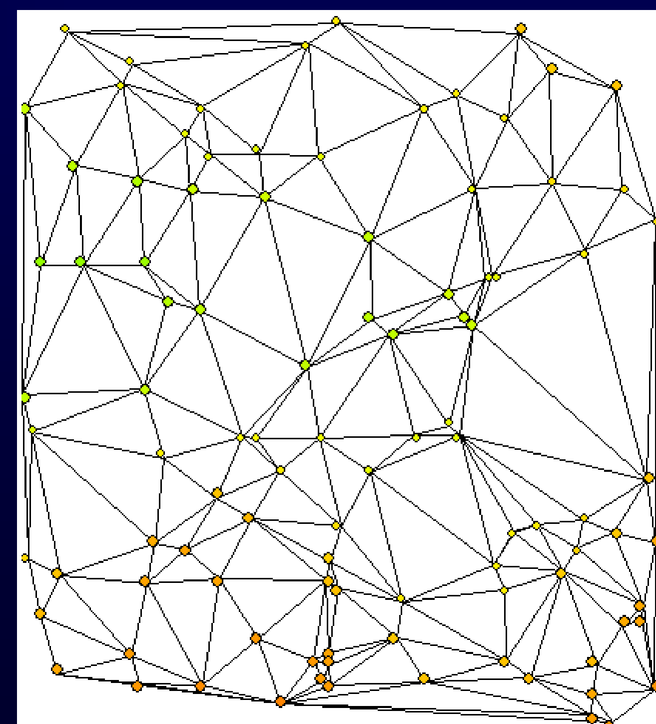
- Two main approaches:
  - Digital Elevation Models (DEMs) based on data sampled on a regular grid (lattice)
  - Triangular Irregular Networks (TINs) based on irregular sampled data and Delaunay triangulation

DEMs and TINs

DEM with sample points



TIN based on same sample points

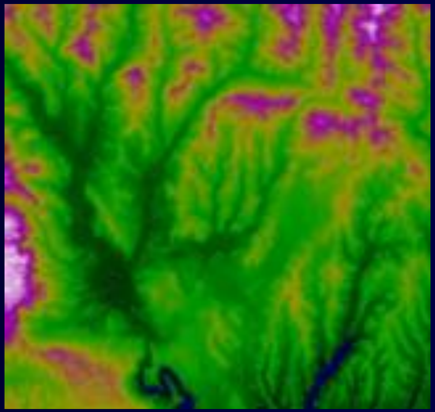


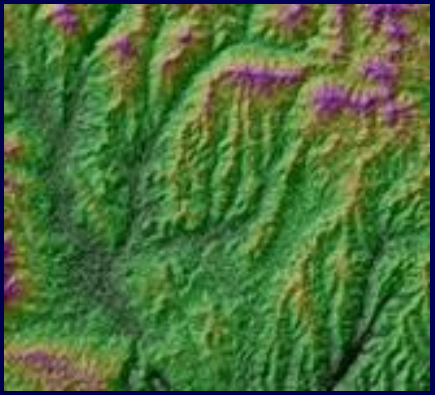
Advantages/disadvantages

- DEMs:
  - accept data direct from digital altitude matrices
  - must be resampled if irregular data used
  - may miss complex topographic features
  - may include redundant data in low relief areas
  - less complex and CPU intensive
- TINs:
  - accept randomly sampled data without resampling
  - accept linear features such as contours and breaklines (ridges and troughs)
  - accept point features (spot heights and peaks)
  - vary density of sample points according to terrain complexity

DEM derived Variables

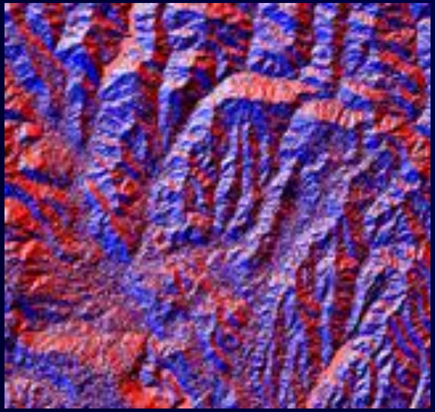
DEM

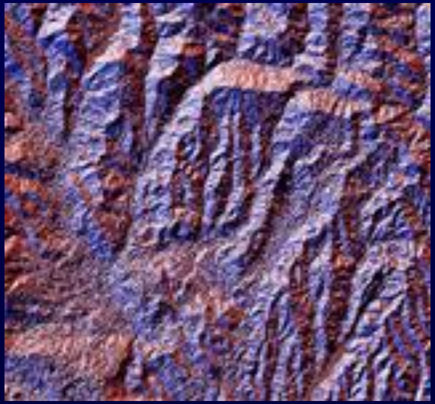




Hill shaded DEM

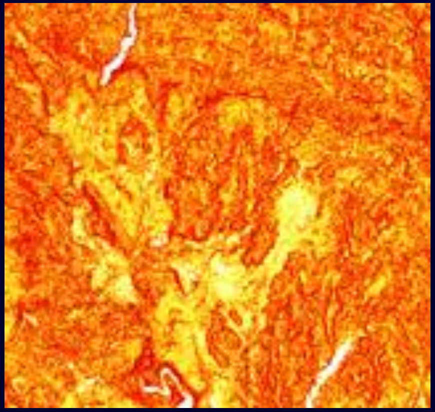
Aspect

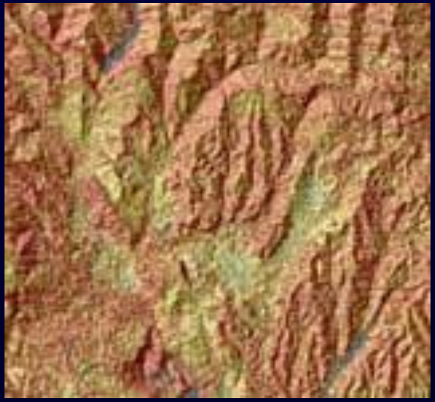




Shaded Aspect

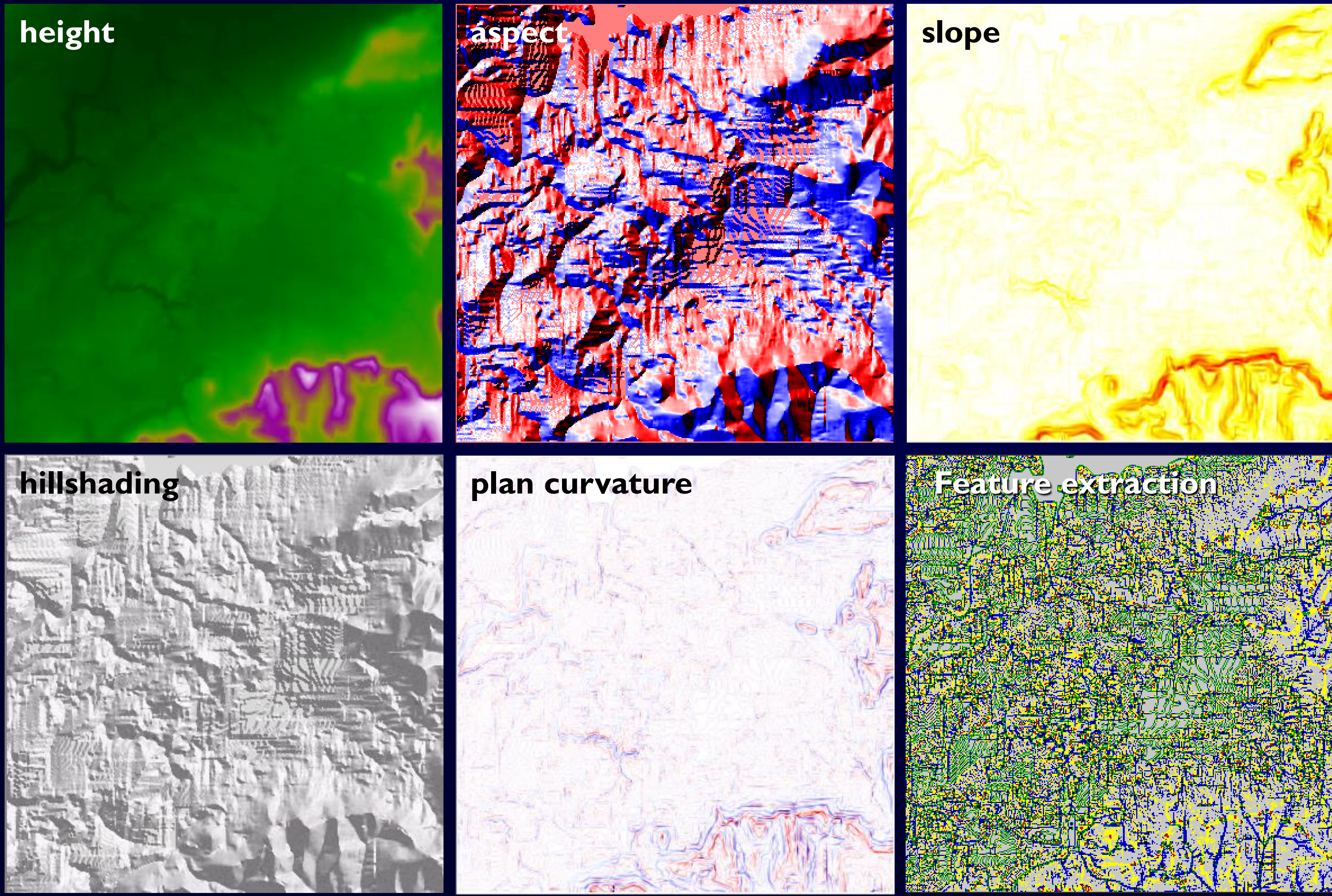
Slope





Slope draped on DEM

DEM derived Variables



Leica Photogrammetry Suite

LPS 2010

ERDAS

LPS Introduction

- Digital photogrammetry program that allows for
  - triangulation and
  - orthorectification

  of images from various cameras and satellites

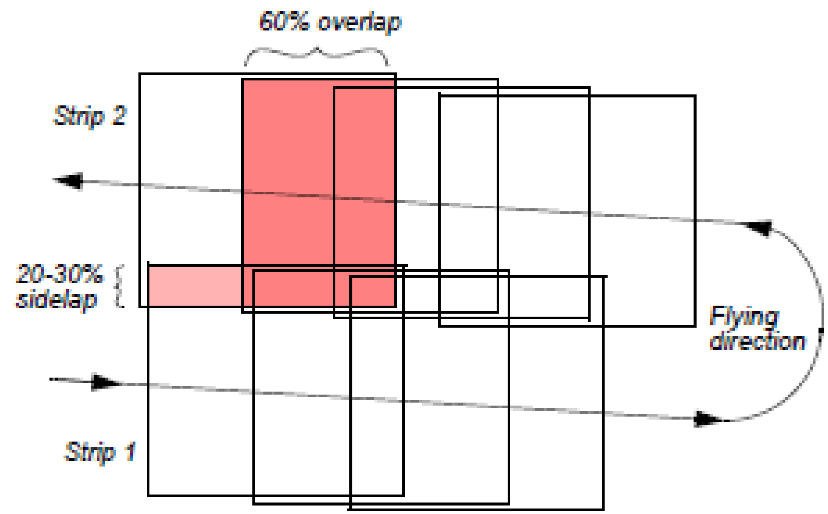


Figure 7: A Regular Rectangular Block of Aerial Photos

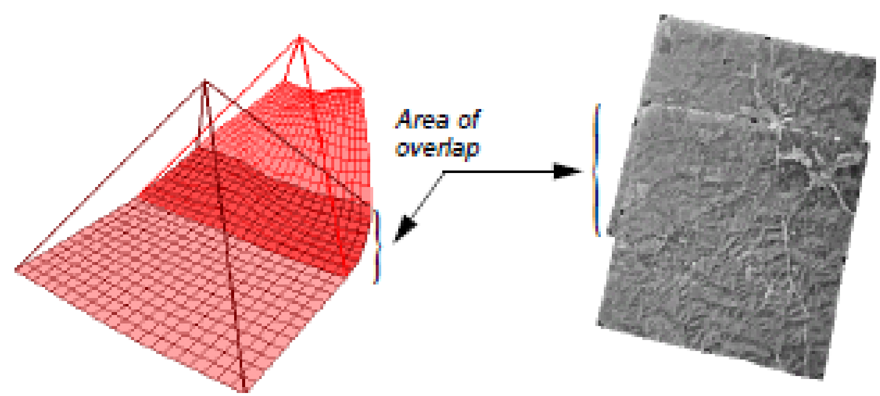


Figure 8: Overlapping Images

Geometric Distortions

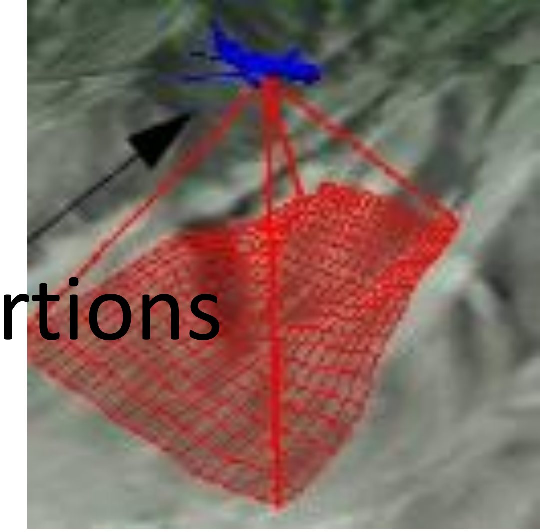
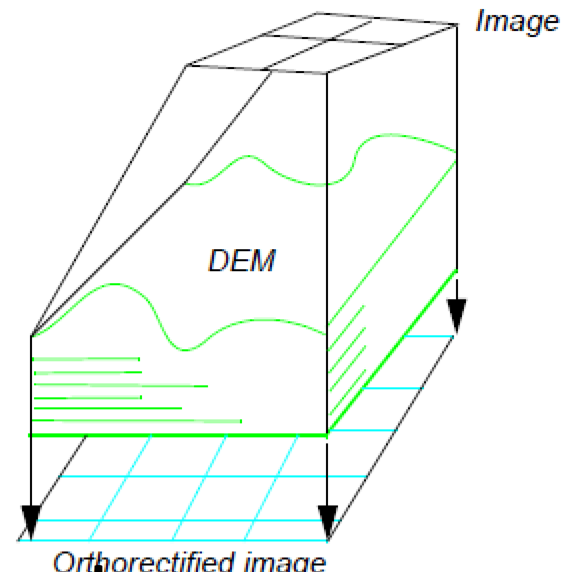


Figure 36: Orthorectification



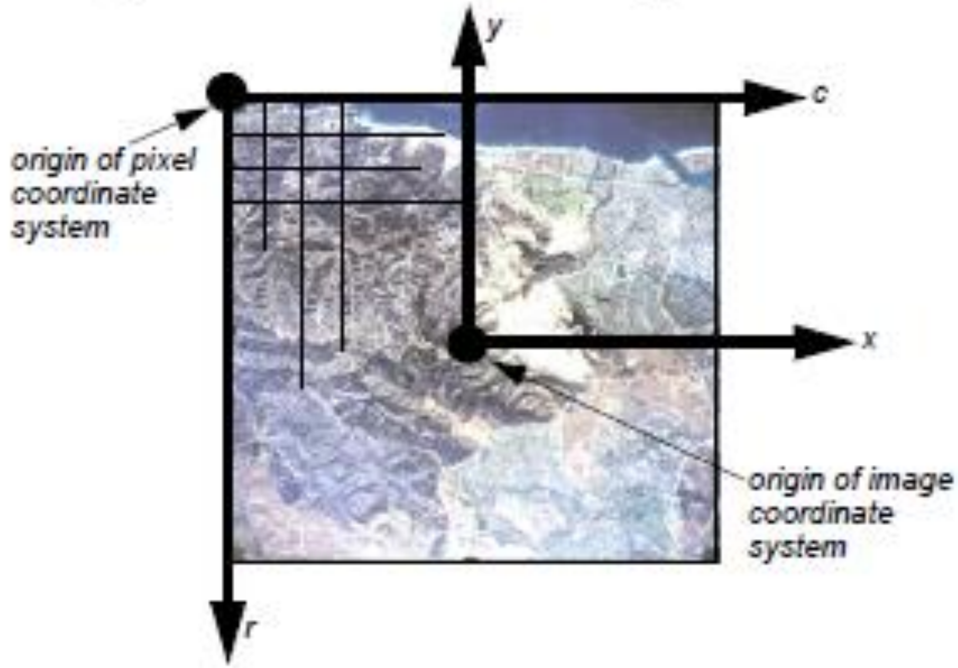
- Raw imagery has geometric distortions
- Distortion from
  - Camera and sensor orientation
  - Terrain relief
  - Earth curvature
  - Scanning distortion
  - Measurement errors
- Thus, raw imagery cannot be used as a planimetric map

Orthorectification

- Raw images need to be rectified in order to be used for geospatial information
- Ortho photos are the leading source for geospatial data.
- Goal of orthorectification-- make images planimetrically correct. i.e., constant scale or like a map.
- STEPS in LPS…similar to CLASS work

The Major Steps in Digital Orthorectification

Figure 9: Pixel Coordinates vs. Image Coordinates



In the LPS labs you will….

1. Create a new project
2. Add imagery to the block file
3. Define the camera model
4. Measure the GCPs and Check points
5. Use the automatic tie point collection
6. Triangulate the images
7. Orthorectify the images
8. Use orthoimages to create geospatial data

End Goal

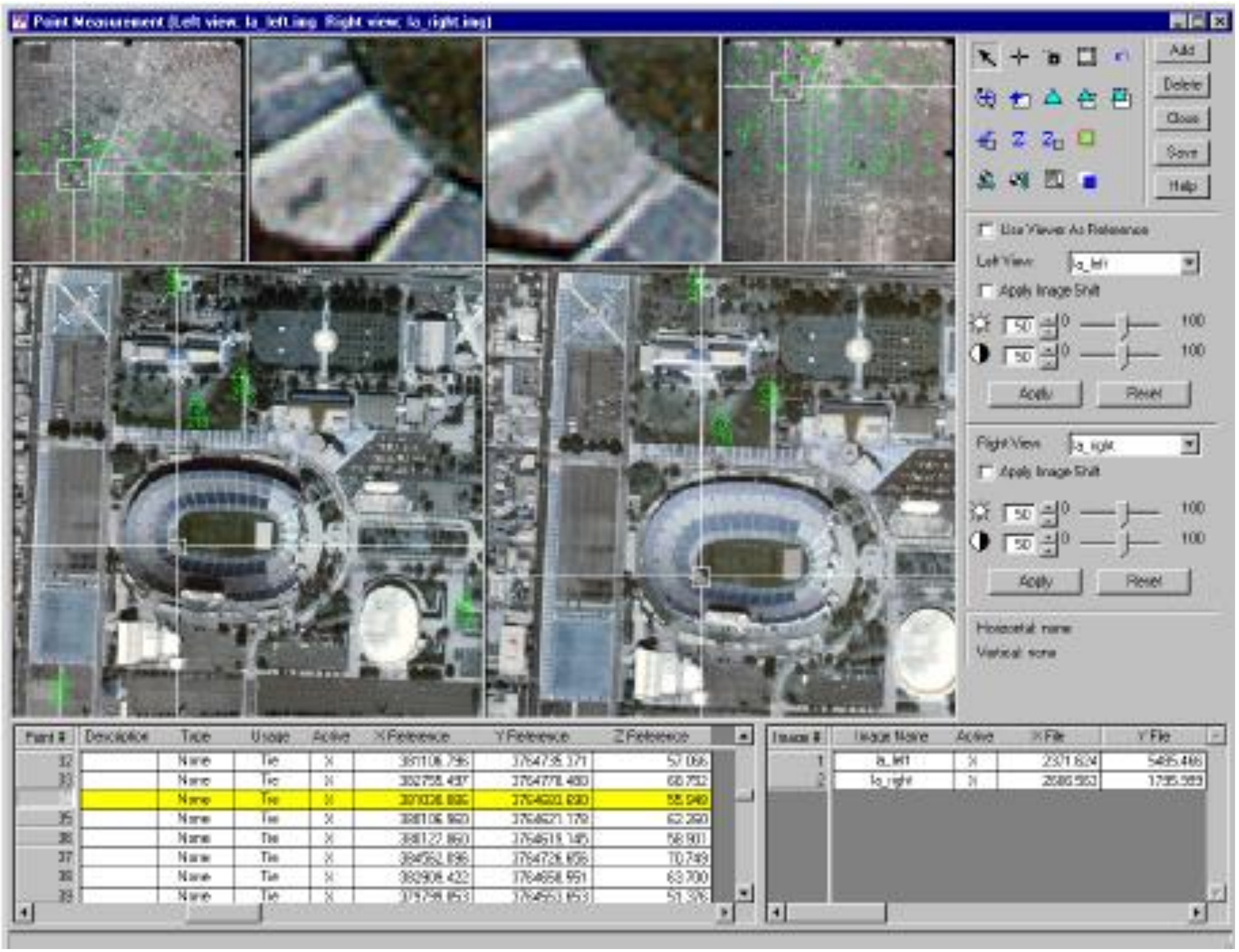
1. Orthorectified images of campus.

2. Use ortho images to create geospatial data that will be dropped into ArcGIS.

3. Understand how the concepts you are learning in class are utilized in a industry standard software package!

LPS Manual – We are going to start with Frame Camera Tour

This can be found w:\\farm\cce\fall2012\cce201-011\public_html\Photgrammetry



LPS – Orthorectification

- Imagery sources that can be rectified
  - Aerial Photography
  - Satellite imagery
  - Digital and video camera

- Satellite imagery – panchromatic or multispectral
  - Landsat
  - SPOT Image
  - GeoEye

Extracting Digital Terrain Models (DTM)

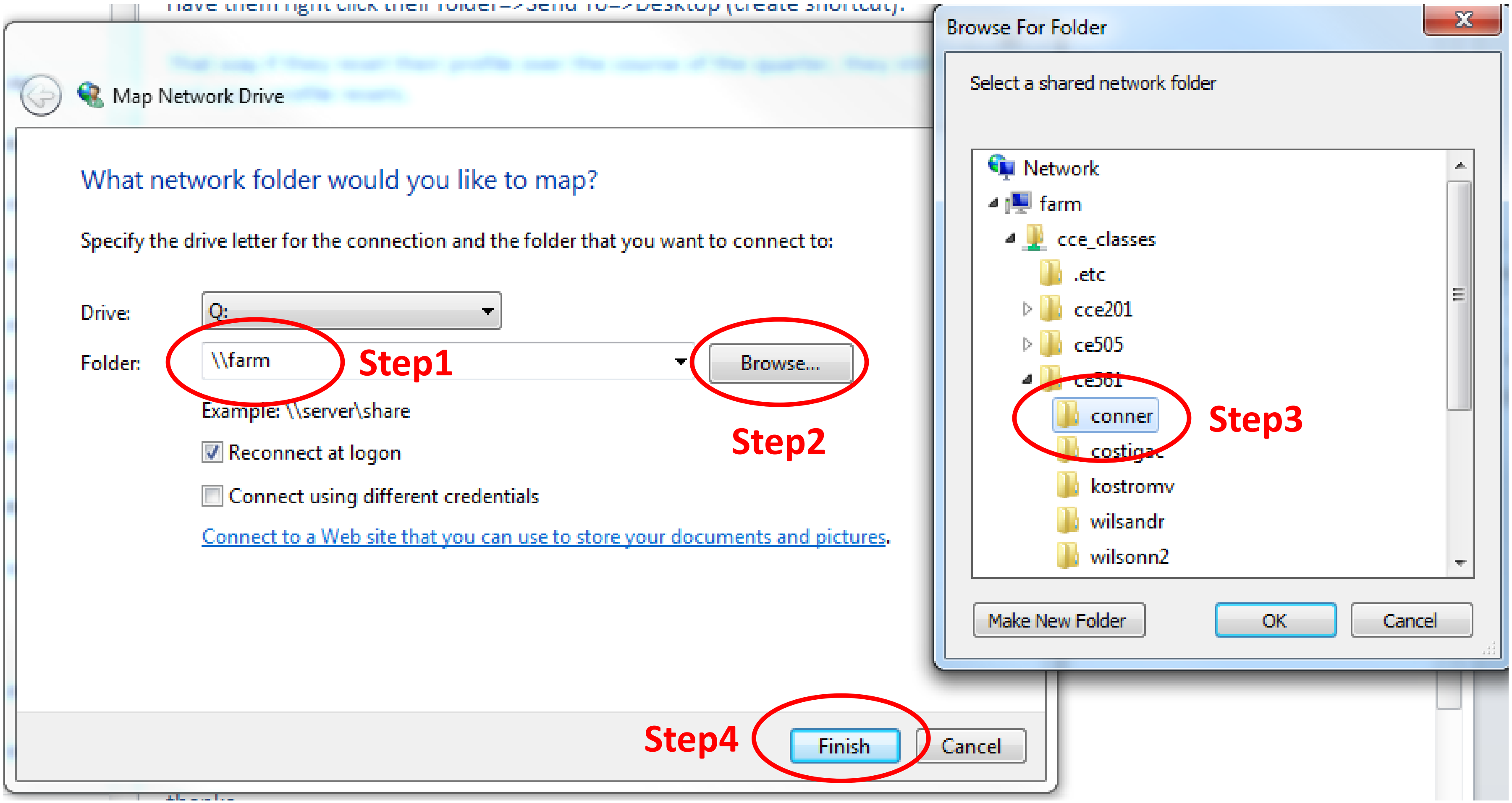
- Automatic terrain extraction (elevations)
  - DEM: digital elevation models
  - TIN: triangular irregular networks
  - 3D Shape files (ESRI)

Other Features

- Ortho Resampling – change cell size
- Ortho Mosaicking – merge images
- Feature Collection – collect GIS data

Lab 1

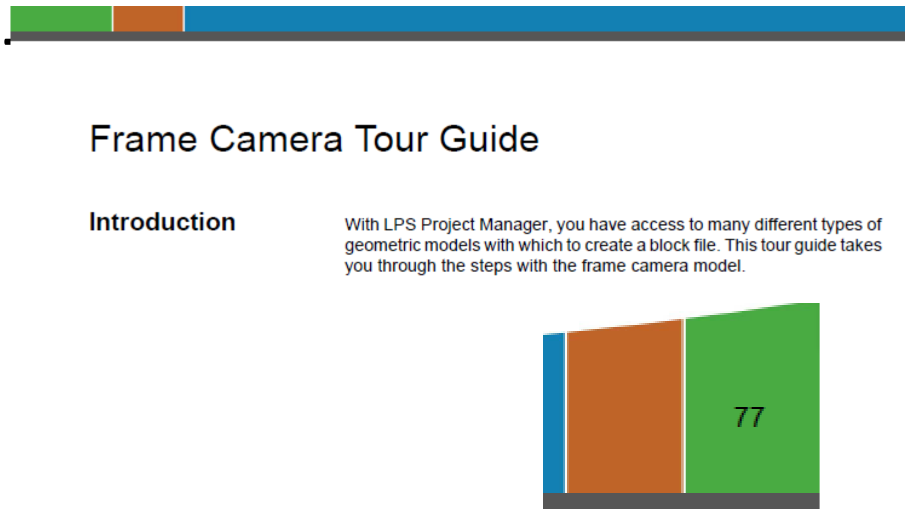
- Map Drive to FARM



Step 2: LPS- New Project and Camera

- Create new project
- Add imagery to block file
- Define camera model

- In the LPS Manual – we will start with the Tutorial: Frame Camera
  - LPS page 77
  - PDF page 99



Frame Camera Tour Guide

Introduction

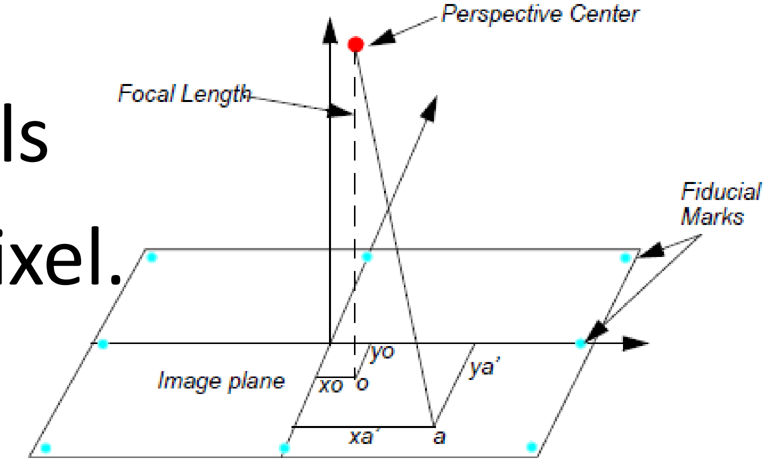
With LPS Project Manager, you have access to many different types of geometric models with which to create a block file. This tour guide takes you through the steps with the frame camera model.

77

Review – Interior Orientation

- Interior orientation defines the internal geometry of camera as it existed at the time of image capture
- Image positions of fiducials marks --referenced to a pixel.

Figure 12: Internal Geometry



The internal geometry of a camera is defined by specifying the following variables:

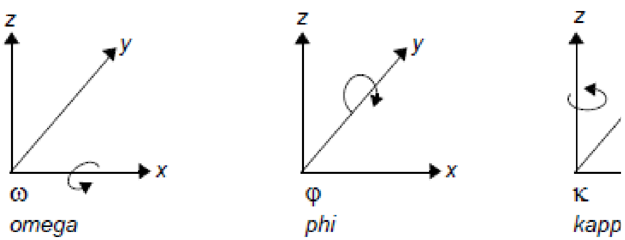
- principal point
- focal length
- fiducial marks
- lens distortion

Step 3: Exterior Orientation

- Defines the relationship between ground space coordinate system (X,Y,Z) and the image space coordinate system (x,y,z)
- Three rotation angles are commonly used to define angular orientation
  - Omega (ω)
  - Phi (ϕ)
  - Kappa (κ)

Elements of Exterior Orientation

Figure 16: Omega, Phi, and Kappa



- Omega is a rotation about the photographic x-axis
- Phi is a rotation about the photographic y-axis
- Kappa is a rotation about the photographic z-axis

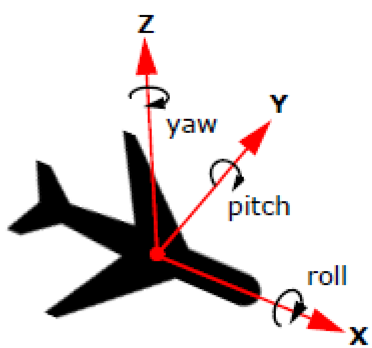
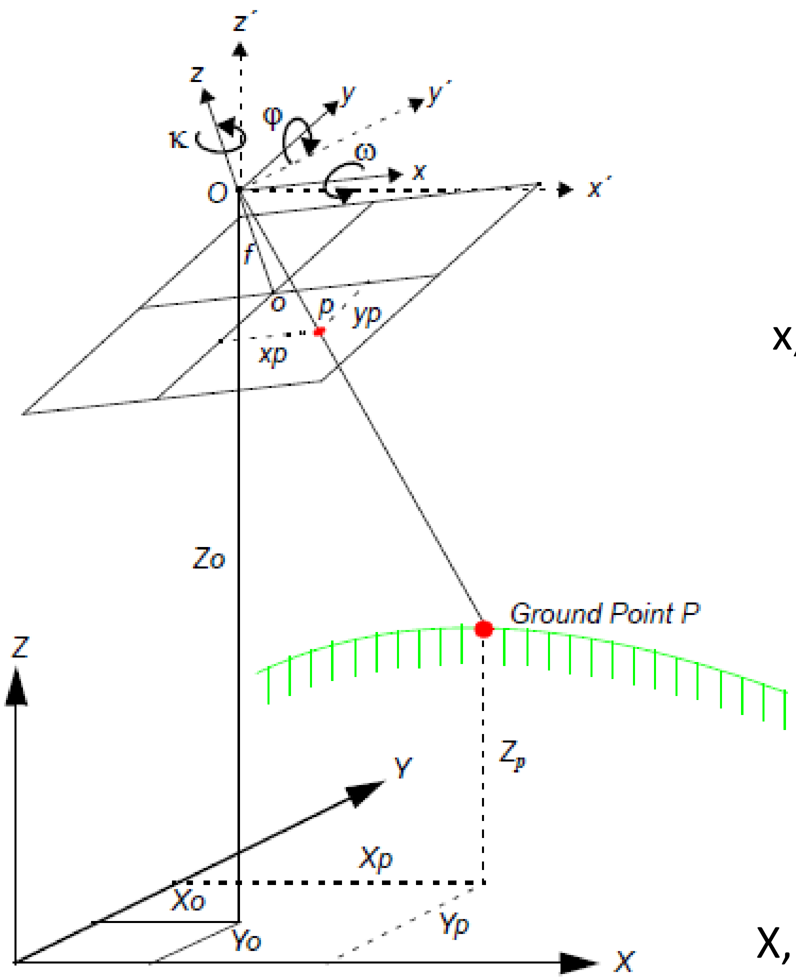


Figure 15: Elements of Exterior Orientation



x, y, z - image

X, Y, Z - ground

Collinearity Condition

- Specifies that the exposure station, ground point, and corresponding image point must ALL lie along a straight line, there by being collinear.
- Two equations comprise the collinearity condition

$$x_p - x_o = -f\left[\frac{m_{11}(X_p - X_{o_1}) + m_{12}(Y_p - Y_{o_1}) + m_{13}(Z_p - Z_{o_1})}{m_{31}(X_p - X_{o_1}) + m_{32}(Y_p - Y_{o_1}) + m_{33}(Z_p - Z_{o_1})}\right]$$

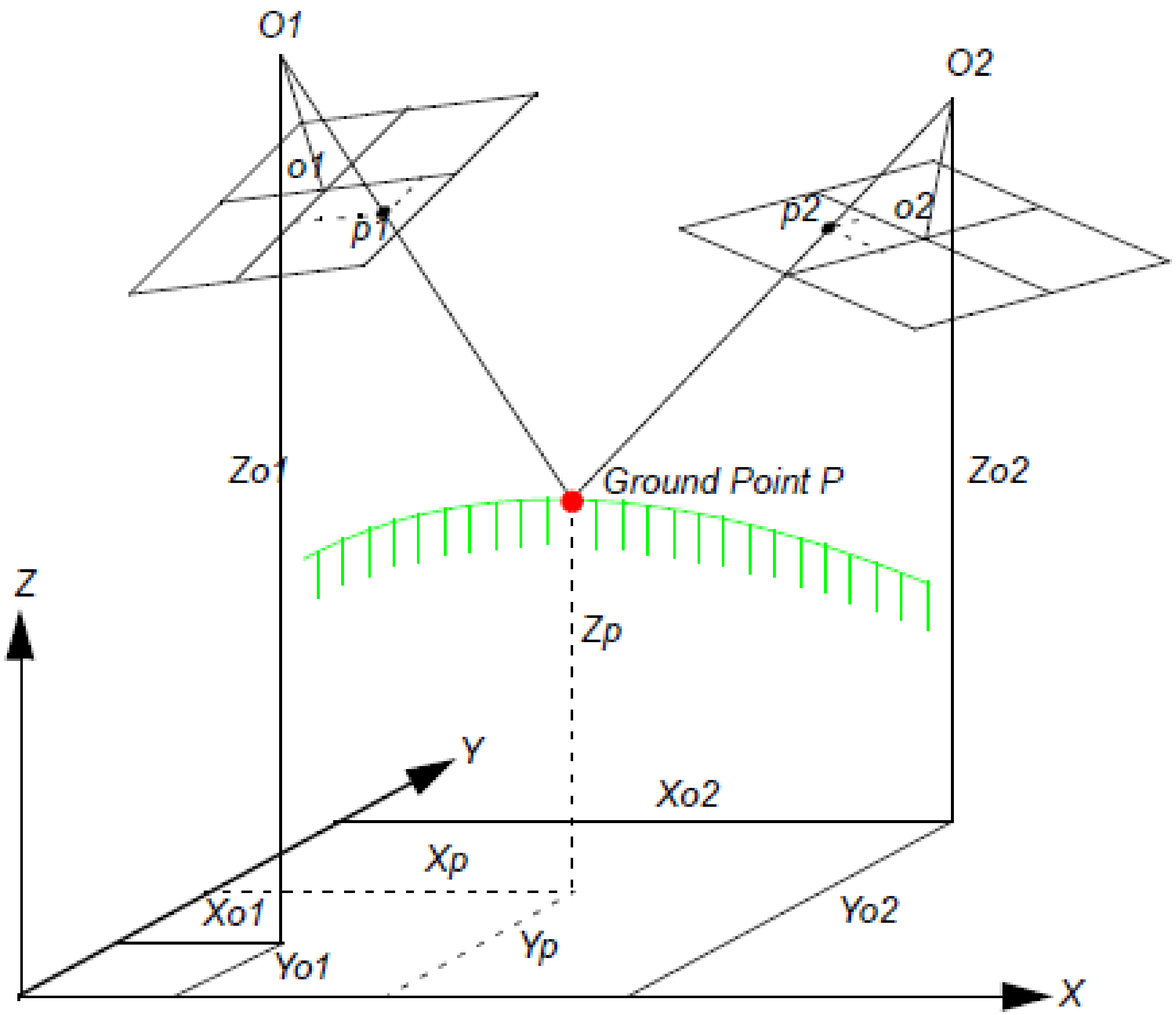
$$y_p - y_o = -f\left[\frac{m_{21}(X_p - X_{o_1}) + m_{22}(Y_p - Y_{o_1}) + m_{23}(Z_p - Z_{o_1})}{m_{31}(X_p - X_{o_1}) + m_{32}(Y_p - Y_{o_1}) + m_{33}(Z_p - Z_{o_1})}\right]$$

- This defines relationship between: camera, image and ground

Space Forward Intersection

- Determines ground coordinates in overlapping areas of two or more images.
- Collinearity condition enforced – stating that the light rays from the same points on the images intersect at same ground point.

Figure 21: Space Forward Intersection



Lab2 – Exterior Orientation

- Enter ground control …s/b well-defined, dispersed, and permanent.
  - Utility infrastructure – manholes, fire hydrants
  - Benchmarks
  - Corner of sidewalks
  - Intersection of roads – fuzzy
- Minimum of 3 GPS – but really much more. You have 10 GCPs use 8 only.

Lab 3 – Exterior Orientation

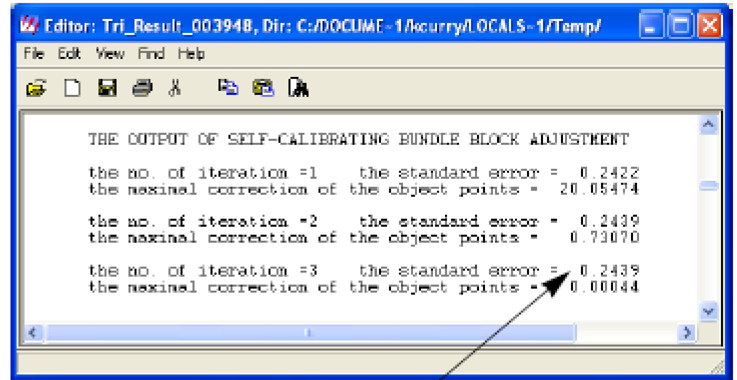
1. **Enter GCPs –**
   – Locate GCPs on image and then enter N/E (8 each)
2. **Save 2 to use as check points (additional GCPs)**
   – Entered same way as GCPs
   – Used to verify the accuracy of triangulation
3. **Perform automatic tie point generation**
4. **Perform aerial triangulation**
5. **Check and SAVE the results**

Check the Results and SAVE

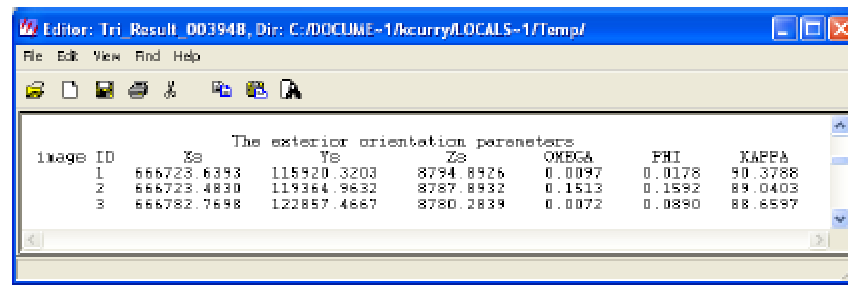
- Output – standard error of last iteration is most important

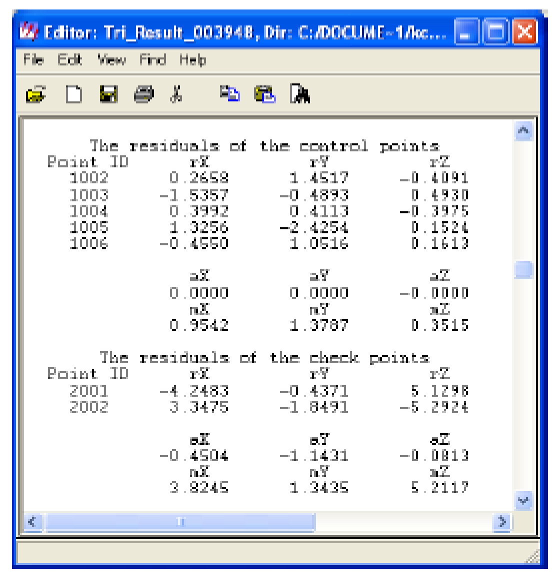
- Review Exterior Orientation parameters for each image: Omega, Phi, Kappa

- Note the residuals of control points and check points



The standard error of the last iteration is the most important



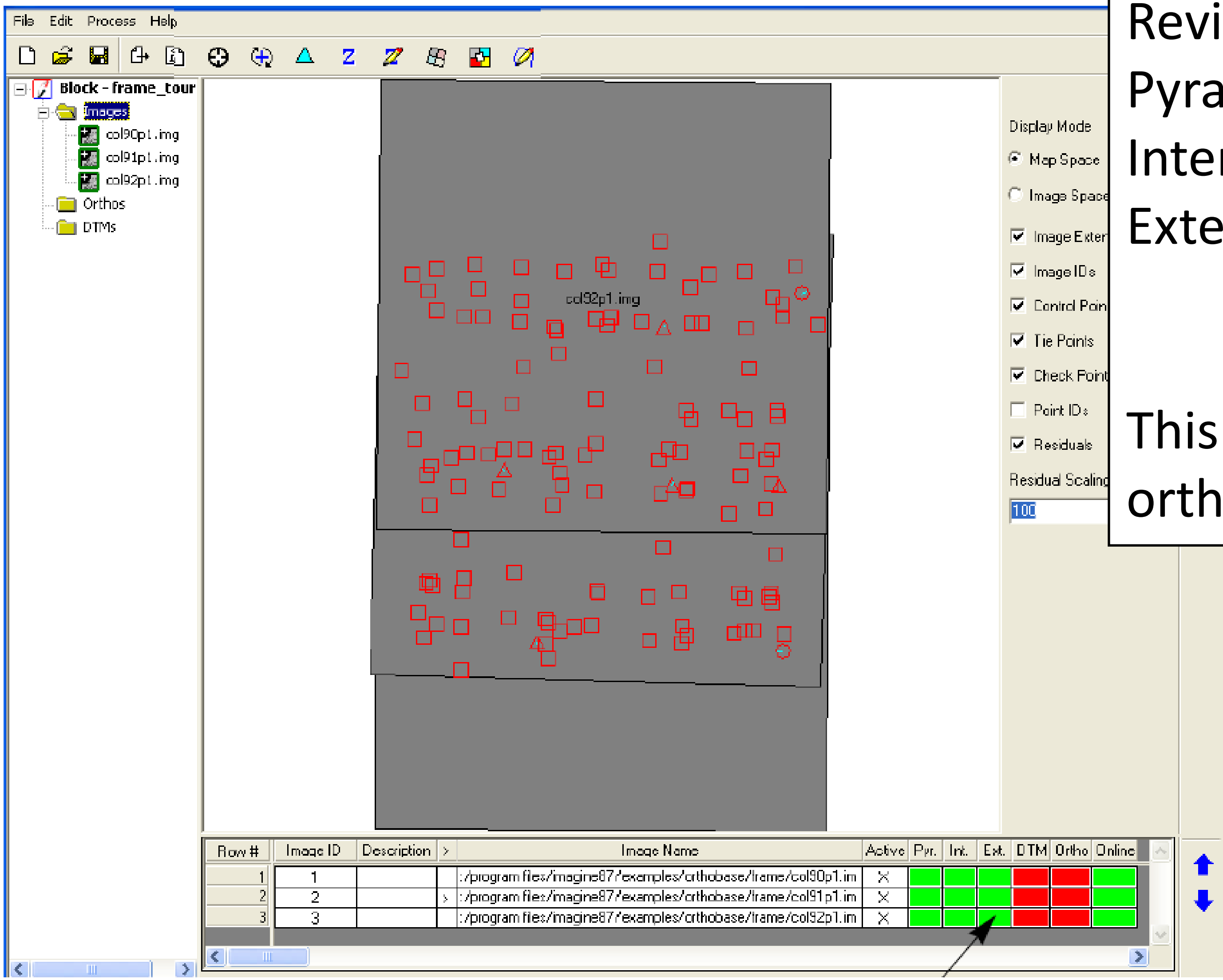


Lab 2 – Notes on entering GCPs

- Start on Page 99 in LPS

1. Convert GCPs to NAD83 feet and NAVD88 feet
   - divide GCPS by 0.3048 to convert meters to feet
2. Locate GCP on image and enter NEZ **in feet**
3. Locate same GCP on adjacent image
4. Repeat for all of GCPs except for last two

LAB 3 - Orthophotos



Review: past labs

Pyramids

Interior Orientation

Exterior Orientation

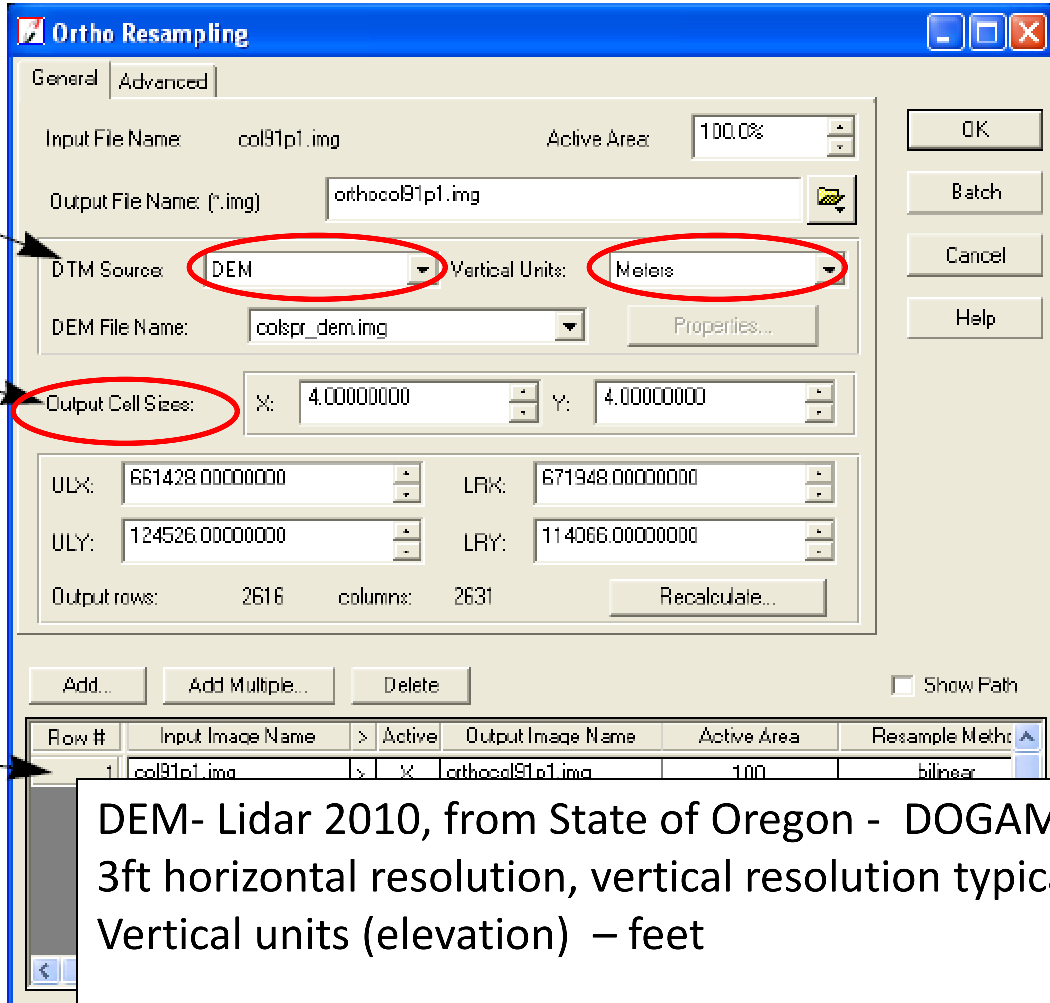
This lab – create orthophotos

Ortho Resampling

Choose DEM as the DTM Source

Set the Output Cell Sizes

The first image in the block is identified here



1. DEM –
Provides elevations
For every image pixel

2. Images need to line
Up with spatial
Referencing of DEM

DEM- Lidar 2010, from State of Oregon - DOGAMI,
3ft horizontal resolution, vertical resolution typically ~ 4-8 inches
Vertical units (elevation) – feet

3. Output cell size are image:
Related to scale and scanning resolution
Our images – 1" = 400' and 25 microns…you can determine cell size

Scanning Resolution

Our images are 1” = 400 ft and 25 microns

Table 3: Scanning Resolutions

Photo Scale 1 to	12 microns (2117 dpi) Ground Coverage (meters)	16 microns (1588 dpi) Ground Coverage (meters)	25 microns (1016 dpi) Ground Coverage (meters)	50 microns (508 dpi) Ground Coverage (meters)	85 microns (300 dpi) Ground Coverage (meters)
1800	0.0216	0.0288	0.045	0.09	0.153
2400	0.0288	0.0384	0.060	0.12	0.204
3000	0.0360	0.0480	0.075	0.15	0.255
3600	0.0432	0.0576	0.090	0.18	0.306
4200	0.0504	0.0672	0.105	0.21	0.357
4800	0.0576	0.0768	0.120	0.24	0.408
5400	0.0648	0.0864	0.135	0.27	0.459

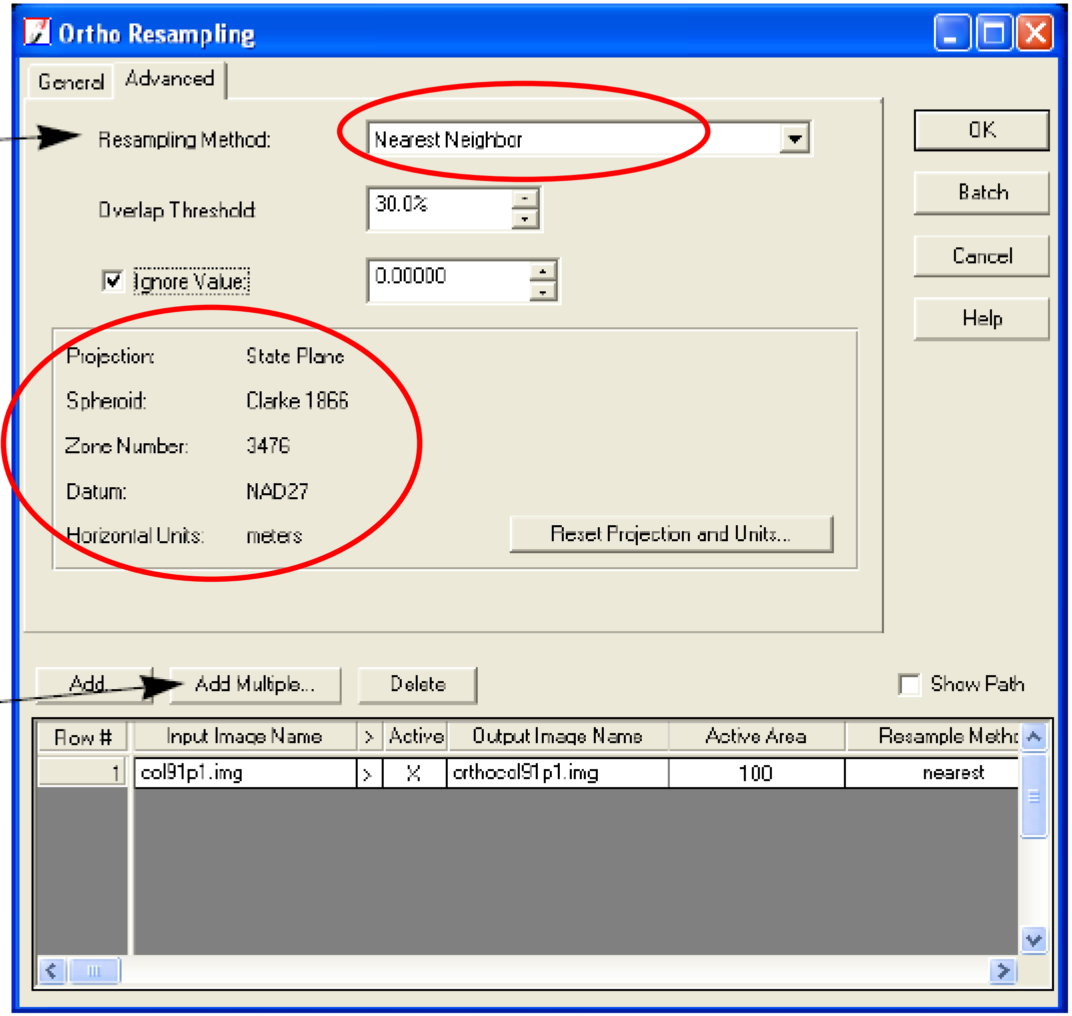
Resampling – Nearest Neighbor

Resample method displays here

N.N. – looks only at closest pixels

Map Projection – already set
SPCS, WGS 84, NAD83
Feet

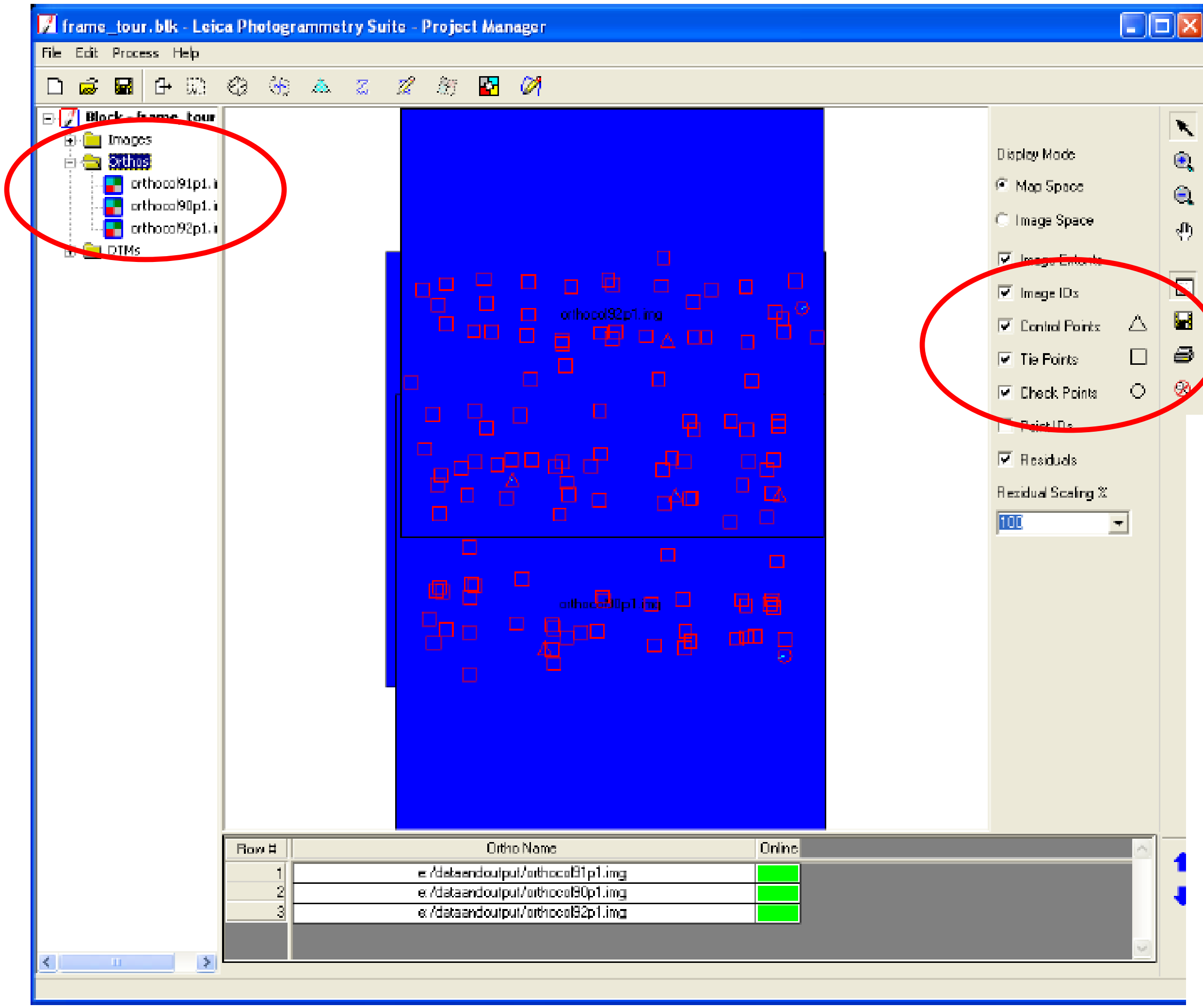
To add the other images in the block file, click this button

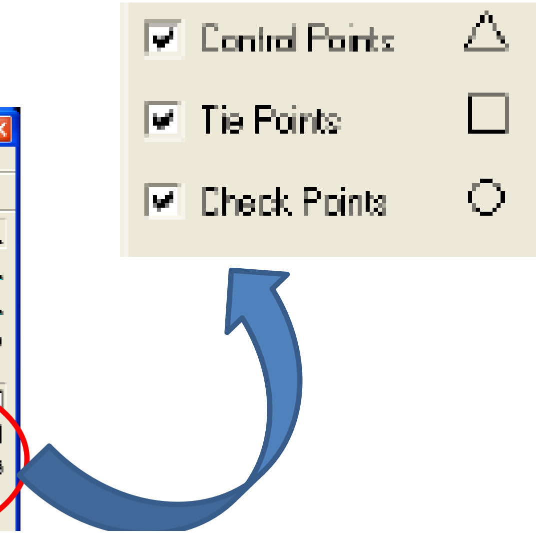


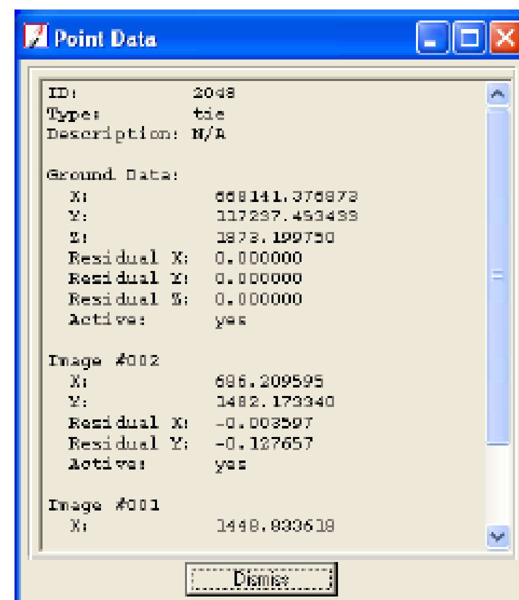
Orthophotos

Display Graphic View

1. Click the **Orthos** folder in the Block Project Tree View.

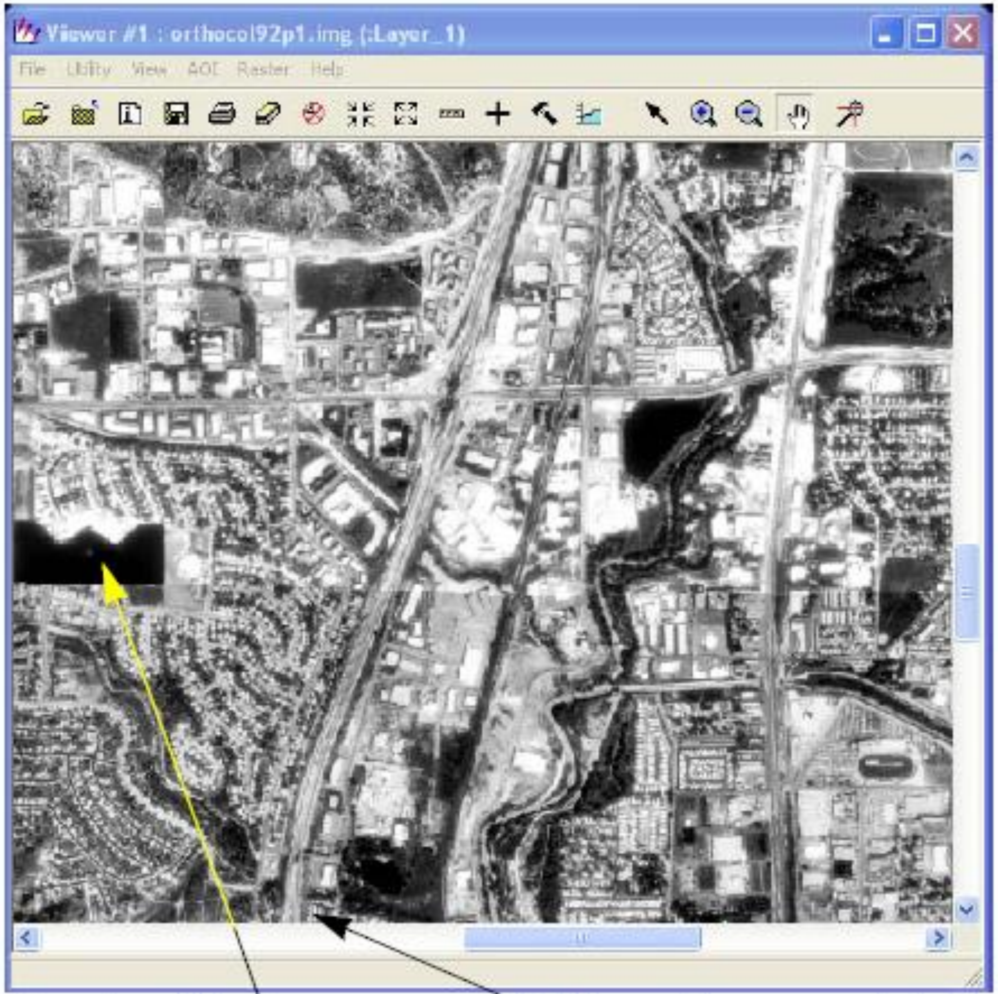






Click on Control point and see residuals

Viewer – review results



The edge of the image can be seen here, indicated by the side fiducial mark

This road is common to both images and matches well