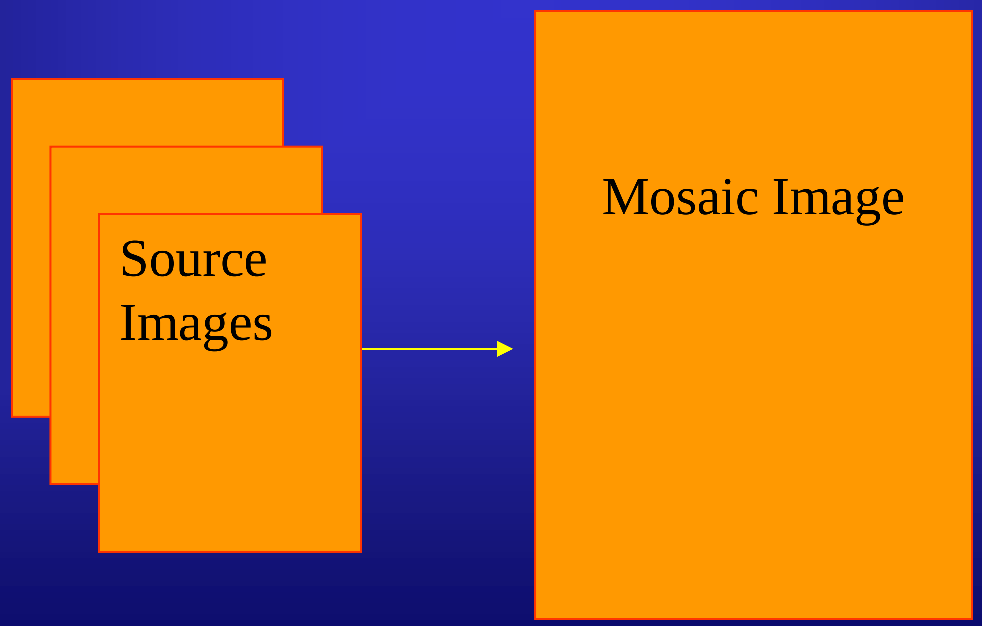
Panoramic Mosaicing and Video Geo registration - Advance Technologies of Computer Visin

Dr. Jharna Majumdar, Former Sc G DRDO
Dean R & D, Prof, Dept of CSE
NITTE Meenakshi Institute of Technology
Bangalore – 560 064

Image Mosaicing

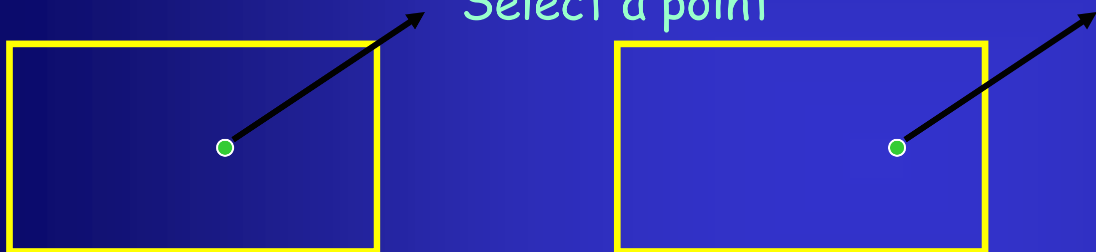
Process of constructing a single image covering the entire visible area of a scene by merging the overlapped areas in a set of images

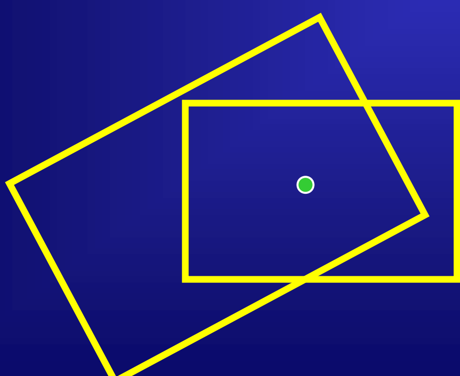
In Aerial or Ground Based Image Exploitation System, it is the task of assembling individual frames of a video stream to generate a terrain



Mosaicing is a complex task

- Images taken at different times
- Change in scene conditions
- Camera movement (panning, zooming, rotation, translation, tilting etc.)





Images have translation , rotation, scaling and perspective between them

History of Image Mosaicing

Started 1839 - after the development of photographic process

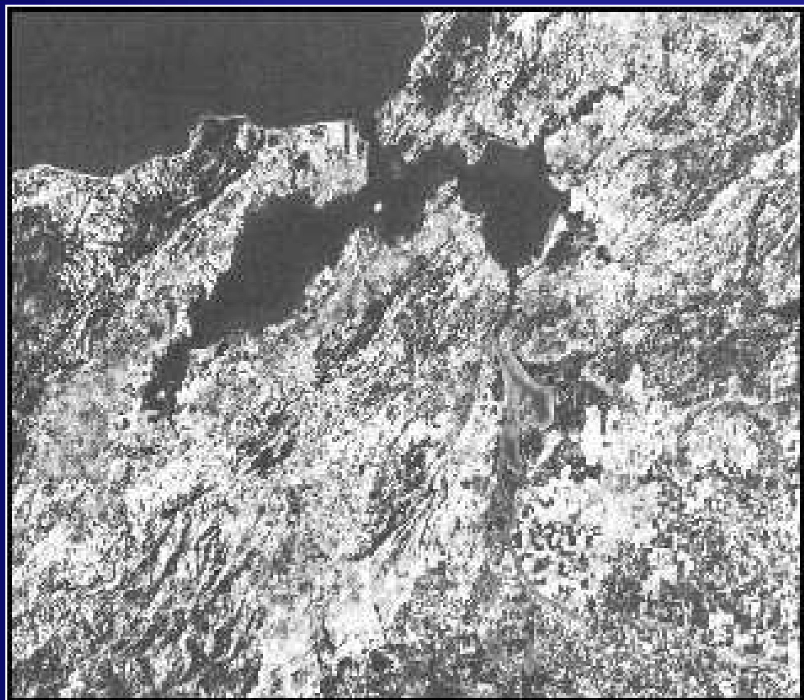
1903- became more popular after the development of air plane technology by Wright Brothers

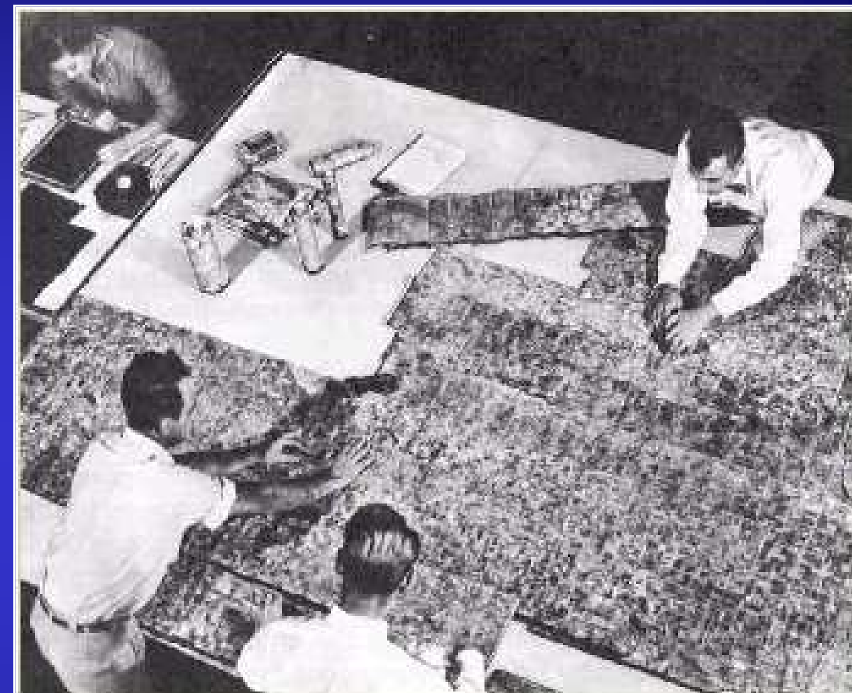
→ To produce large photomaps

Problems

- Tedious and time consuming involving hard manual labor
- Difficult to maintain as duplication is tough
- Types of transformations between images are limited

The beginning …





Construction of manual photo mosaic

Aerial mosaic of the San Francisco Bay Area compiled from 500 photographs. Courtesy - Pacific Aerial Surveys, Oakland California

…Scenario today

- Advancement in computer technology
- Availability of large volumes of imagery from multiple sensors
- Development of sophisticated algorithms implementable both in software and hardware

→ Give rise to fully automatic image mosaicing technology

Defense Applications - Video Surveillance

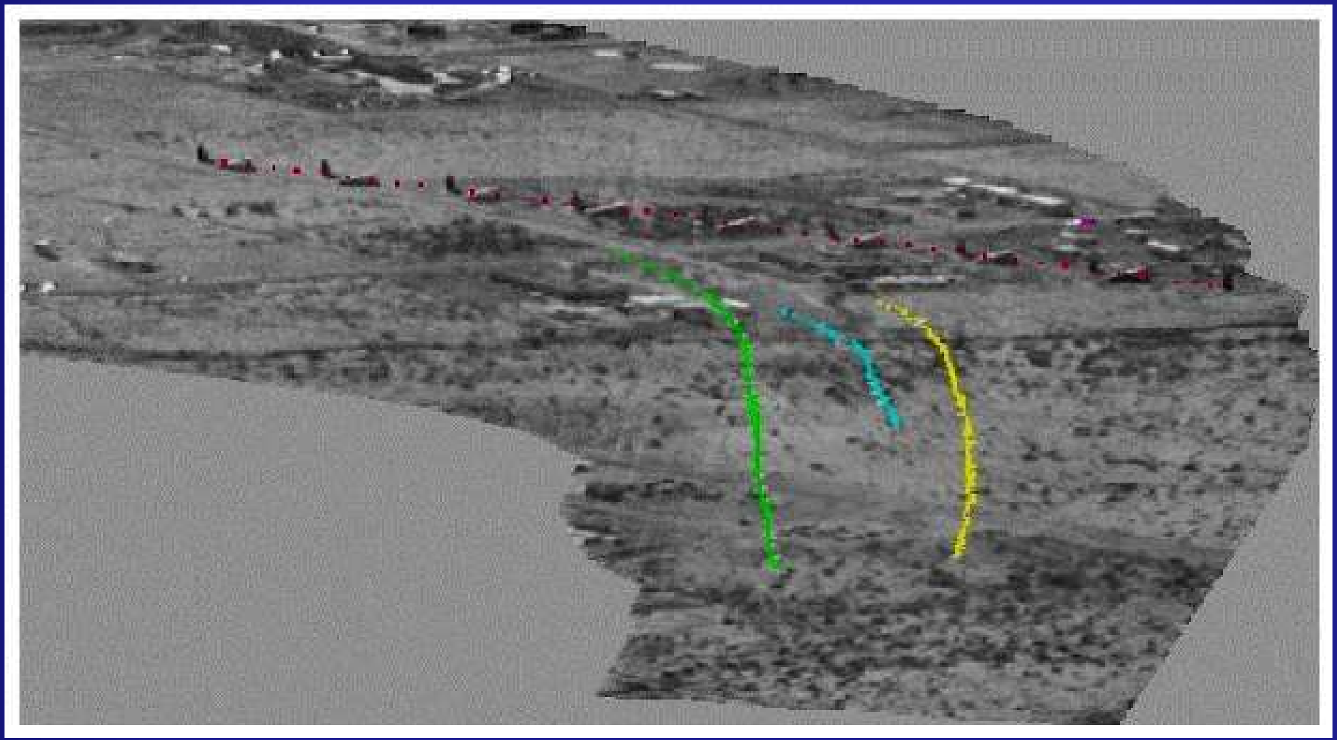
- Generation of knowledge base of an unknown terrain
- Site monitoring and Activity tracking
- Change detection
- Contextual exploitation

Non Defense Applications

- Document mosaicing
- Aligning images from different medical modalities for diagnosis
- Creation of Virtual Reality environment
- Monitoring global land usage using satellite imagery
- Planning relief in natural disaster like flood and storm

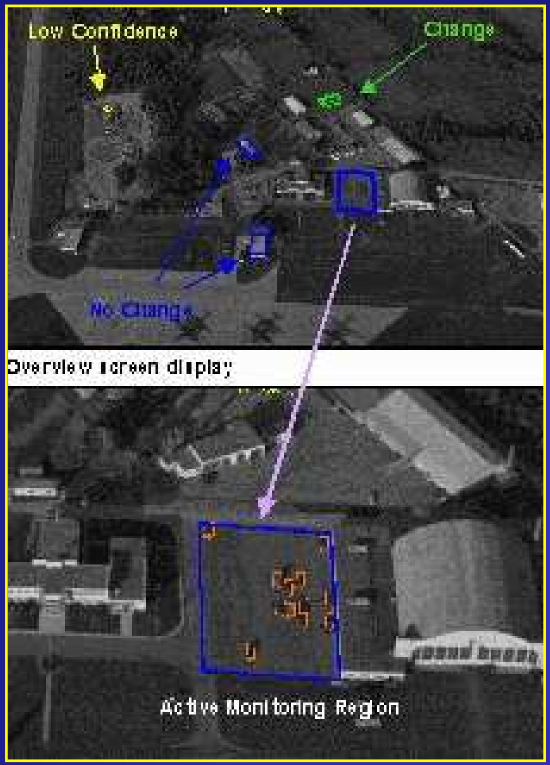
Examples - Surveillance Application

GENERATION OF KNOWLEDGE BASE OF AN UNKNOWN TERRAIN



COURTSEY : CMU with SARNOFF, USA (1998)

Examples – Site Monitoring



COURTSEY : DARPA Project on AVS (1999) – Site Monitoring

- Interaction between humans, vehicles and buildings
- Movement of personnel in a delineated area
- Abnormal number of cars in a parking lot

Examples - Change Detection

COURTSEY : HARRIS CORP, USA

1991 Melbourne, Florida

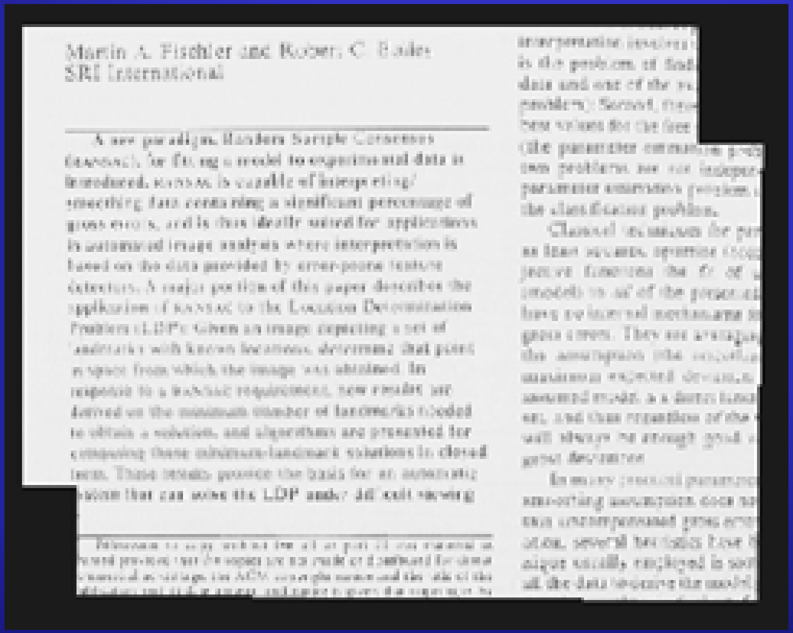
Melbourne, Florida 1993

- Identify significant change in a site due to
  - New construction
  - Bomb damage
  - Clearing of a forest
  - Construction of roads

Classes Of Mosaics

Planar Mosaics

Generated from a collection of images of a planar scene taken from different points of view


Martin A. Fischler and Robert C. Bolles
SRI International

A document mosaic

Panoramic Mosaics

360° horizontal field of view, created by rotating a camera about a vertical axis that passes through the camera optical center

The panoramic image is created by determining the relative displacements between adjacent images and compositing the displaced sequence of images

Mosaic created from panoramic view

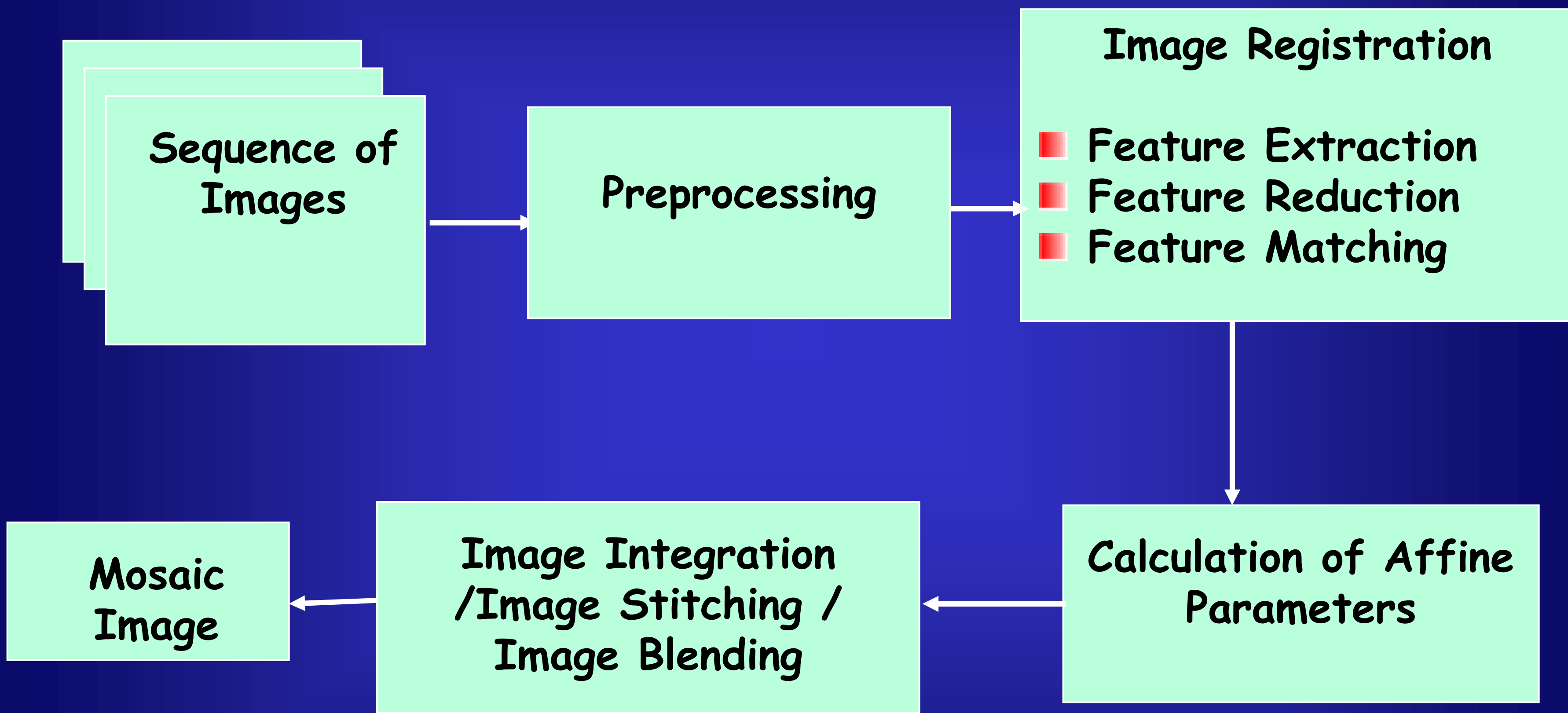
Example - Feature based Mosaicing

Courtesy : Masakatsu Kourogi, Muraoka Lab (1999)

Example - Feature based Mosaicing

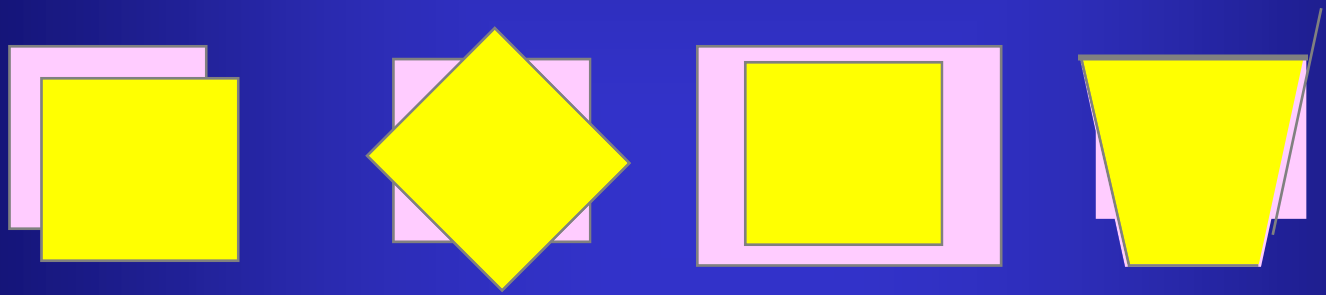
Courtesy : Peleg (1997)

General Steps



TRANSFORMATION – Translation, Rotation, Scaling, Perspective

Graphical



Mathematical – Affine Transformation

$$\begin{bmatrix} X'_1 & X'_2 & X'_3 & X'_4 \end{bmatrix} = \begin{bmatrix} a & b & m \\ c & d & n \\ e & f & 1 \end{bmatrix} \cdot \begin{bmatrix} X_1 & X_2 & X_3 & X_4 \end{bmatrix}$$

Feature Extraction

Method using features from intensity image

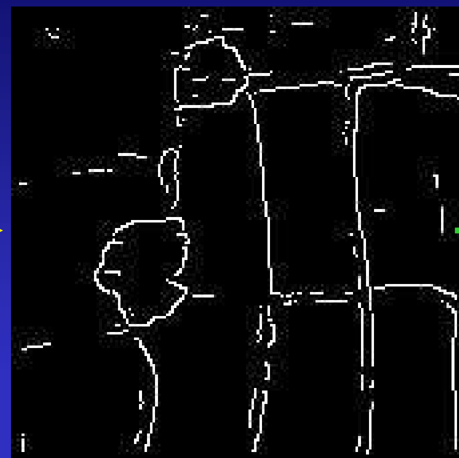
- Edges
- Corners
- Junctions
- Close connected regions

Method using features in segmented image

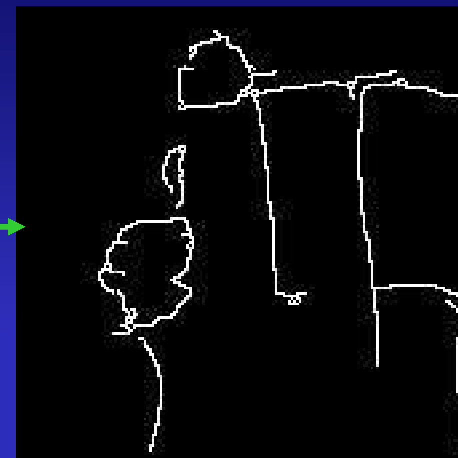
- Intensity segmentation
- Texture segmentation

Feature points using edge

Input image



Convolution, Thinning

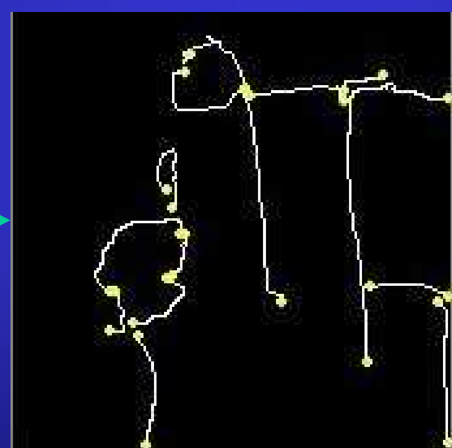


After linking

Total no. of edges
189

After refinement

Total no. of edges
= 13



Extraction of
salient points

Feature points using corners

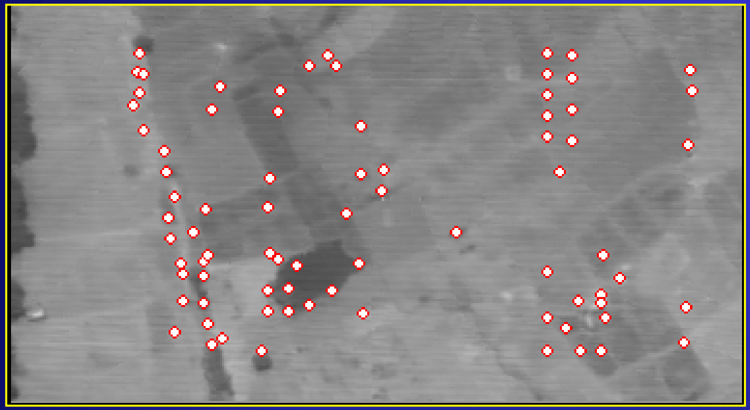


Image 1

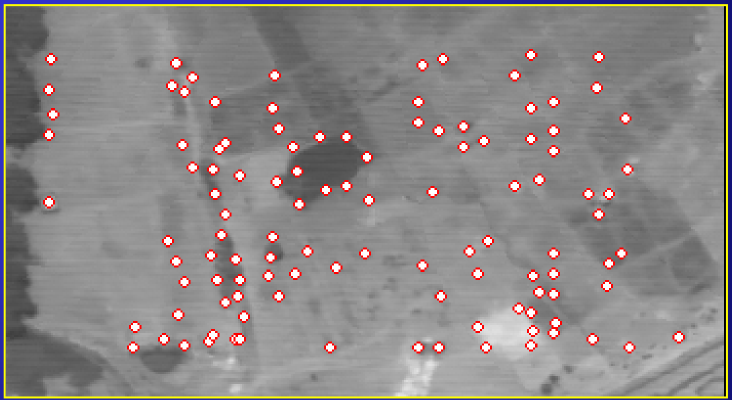


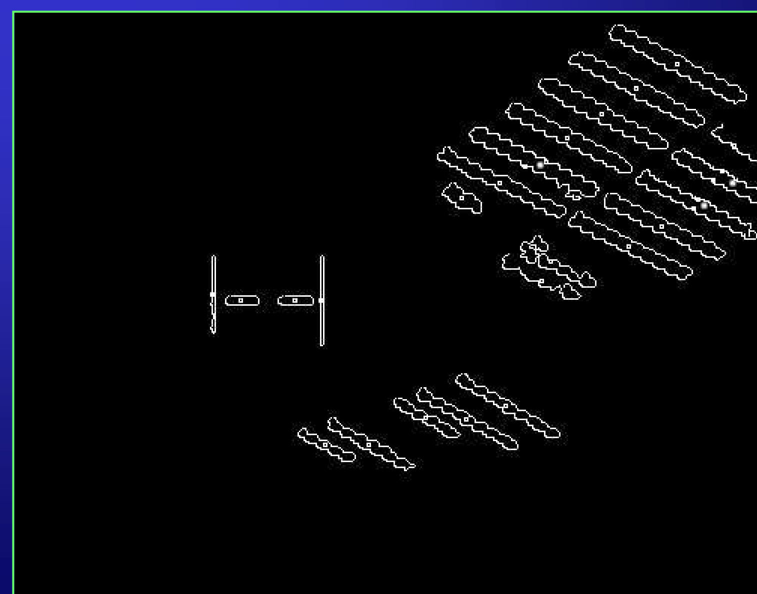
Image 2

Features in intensity segmented image

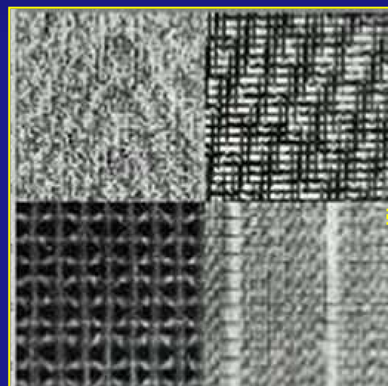
Intensity segmentation

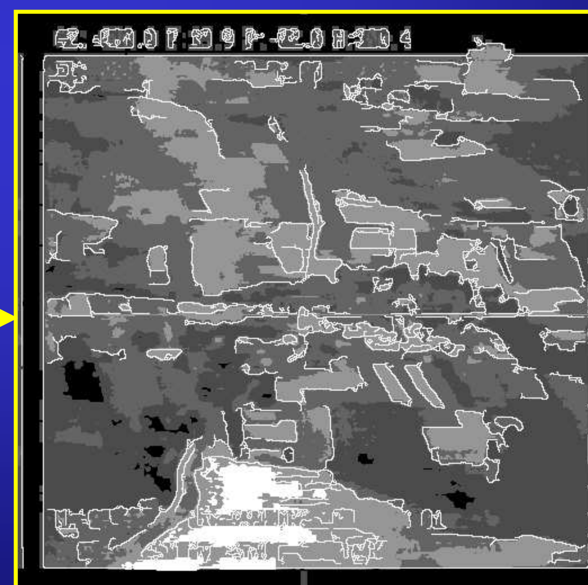
Input image

Extracted centriod



Features in texture segmented image





Input image

Image after texture segmentation

2D Transformations

Translation

Point P(x,y) can be translated by dx along the x-axis and by dy along the y-axis

The new points P(x′,y′) can be written as:

$$x = x + dx \qquad y = y + dy$$

In Matrix form, this can be written as:

$$\mathrm{p} = \begin{bmatrix} x \\ y \end{bmatrix}, \ \mathrm{p}' = \begin{bmatrix} x' \\ y' \end{bmatrix}, \ \mathrm{T} = \begin{bmatrix} \mathrm{dx} \\ \mathrm{dy} \end{bmatrix}$$

$$P' = P + T$$

Scaling

Points P(x,y) can be scaled by Sx along the x-axis and by sy along the y-axis

$$x' = sx \, . \, x$$

$$y' = sy . y$$

In Matrix form, this can be written as:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} sx & 0 \\ 0 & sy \end{bmatrix} . \begin{bmatrix} x \\ y \end{bmatrix}$$

$$P' = S.P$$

2D Transformations

Rotation

Points P(x,y) can be rotated by an angle θ about the origin

$$x' = x\cos\theta - y\sin\theta$$

$$y' = x\sin\theta + y\cos\theta$$

In Matrix form, this can be written as:

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{bmatrix} . \begin{bmatrix} x \\ y \end{bmatrix}$$

$$P' = R.P$$

Rigid Body Transformation

Composed of a combination of rotation, translation and scale

$$\begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = \begin{pmatrix} t_x \\ t_y \end{pmatrix} + s \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x_1 \\ y_1 \end{pmatrix}$$

(x2,y2) is the new transformed coordinate of (x1,y1)

t_x and t_y translation in x and y direction, θ is rotation and s is scale factor

Affine Transformation

More general than rigid-body, can tolerate more complex distortions

General 2D Affine transformation

$$\begin{bmatrix} x_2 \\ y_2 \end{bmatrix} = \begin{bmatrix} t_x \\ t_y \end{bmatrix} + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \end{bmatrix}$$

(x2,y2) is the new transformed coordinate of (x1,y1)

Rotation, scale or shear

$$\begin{bmatrix} \mathrm{a}_{11} & \mathrm{a}_{12} \\ \mathrm{a}_{21} & \mathrm{a}_{22} \end{bmatrix}$$

Rotation

$$\begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$$

Scale

$$\begin{bmatrix} \mathrm{S_x} & 0 \\ 0 & \mathrm{S_y} \end{bmatrix}$$

Shear

$$\mathrm{Shear_x} = \begin{bmatrix} 1 & \mathrm{a} \\ 0 & 1 \end{bmatrix}, \qquad \mathrm{Shear_y} = \begin{bmatrix} 1 & 0 \\ \mathrm{b} & 1 \end{bmatrix}$$

Perspective Transformation

Combines all transformations and has 8 degrees of freedom

More general than Affine transformation

General 2D Perspective transformation

$$x' = \begin{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & \mathrm{a}_{22} \end{bmatrix} & \begin{bmatrix} t_x \\ t_y \end{bmatrix} \\ \begin{bmatrix} a_{31} & a_{32} \end{bmatrix} & 1 \end{bmatrix} x$$

Left 2X2 matrix is the Affine transformation matrix

Right 2*1 matrix is the Translation matrix

Bottom 1*2 is the Perspective matrix.

Image Integration, Stitching or Blending

a technique which modifies the image grey levels in the vicinity of a boundary to obtain a smooth transition between images by removing the seams and creating a blended image and determine how pixels in an overlapping area should be presented

Two main blending techniques are:

- Superimposing Method
- Averaging Technique

Superimposition method

Each pixel in the overlapped area takes its value from any one of the image

Averaging method

Simple Averaging Technique

Weighted Averaging Technique

o Simple Average Technique

Simple averaging technique implies that pixel value in the overlapping region is the average of the corresponding pixel values in each of the two images

$$(x, y) = 0.5 * f_1(x, y) + 0.5 * f_2(x, y)$$

If there are lots of intensity differences, this technique will not eliminate the seam effectively.

Result of simple Averaging

- Weighted Average Technique

Weighted average is given by:

$$f(x,y) = w_1(x,y) * f_1(x,y) + w_2(x,y) * f_2(x,y)$$

The weight function is a product of individual weight functions in the ‘x’ and ‘y’ directions

$$w(x,y) = w(x) * w(y)$$

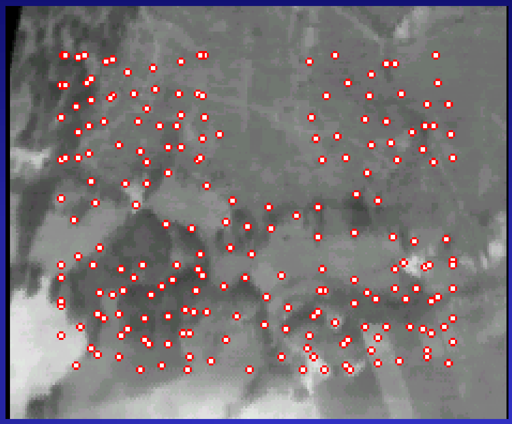
Some of the common weighting functions are:

Mexican Hat Function

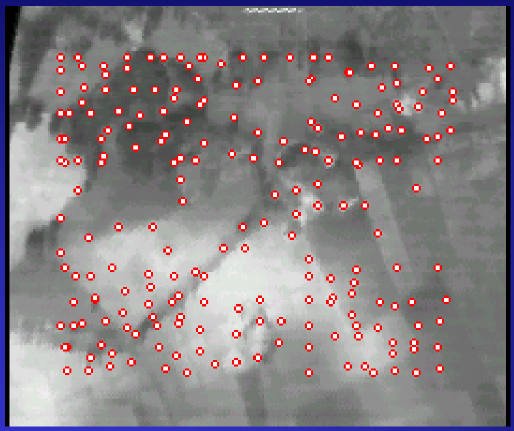
Gaussian Function

Result of Weighted Averaging

KLT Corner Detector

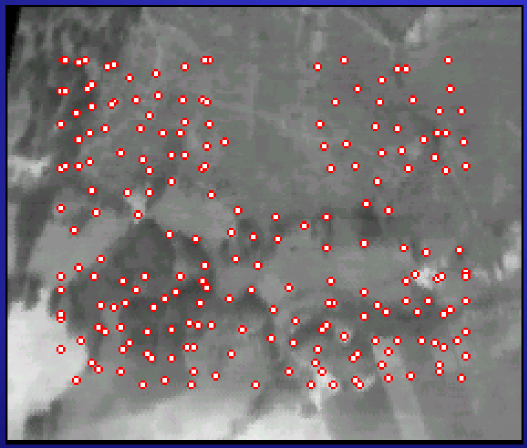


No. of points = 205

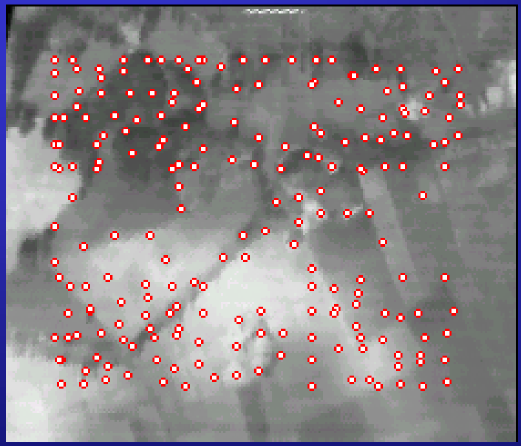


No. of points = 208

Harris Corner Detector



No. of points = 209

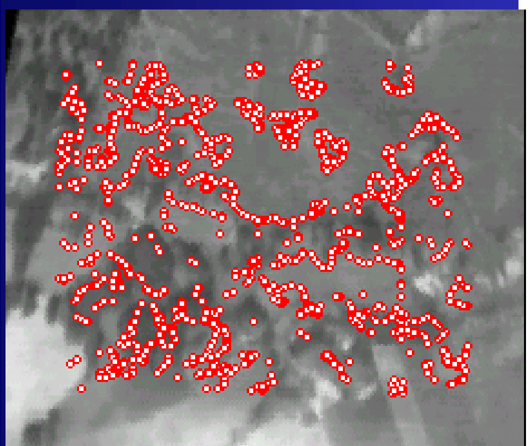


No. of points = 213

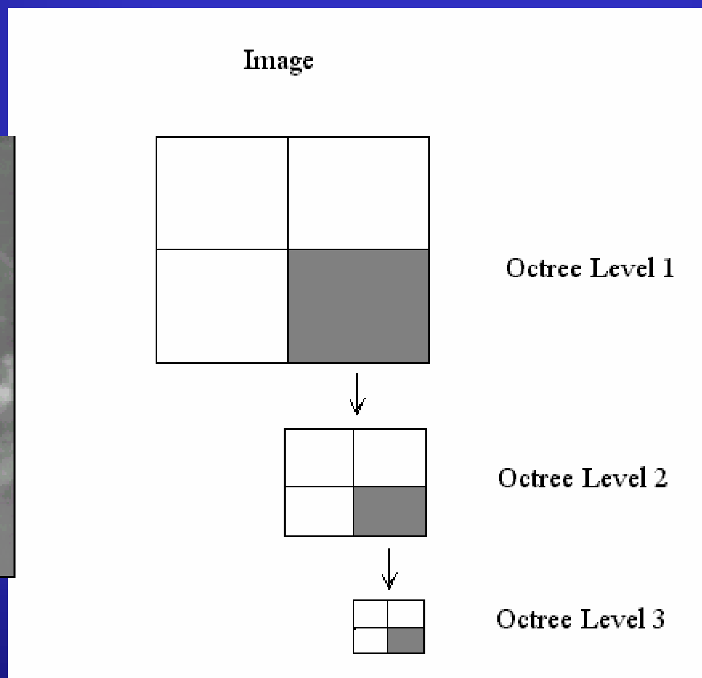
Behavior of feature detectors in adverse imaging conditions

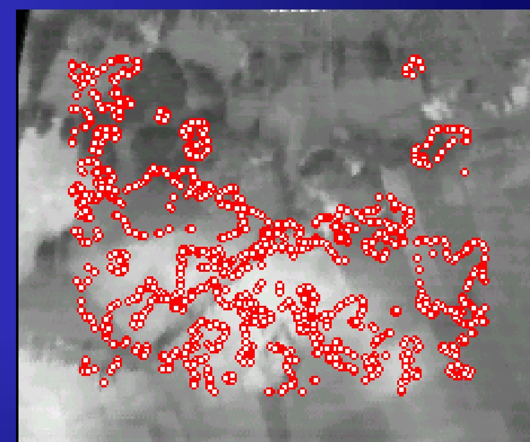
- Features may not be uniformly distributed throughout the image
- Large variation in the intensity at different parts of the images
- Leading to loss of information in the required region of overlap

Concept of a multi level Oct tree



No. of points = 1502





No. of points = 1502

Reduction of feature points

The KLT feature detector computes Eigen values (λ_1,λ_2) of the auto correlation matrix. An interest point is declared when they are higher than a given threshold.

'Cornerness' is a single scalar value representing the characteristic of an interest point 'p'

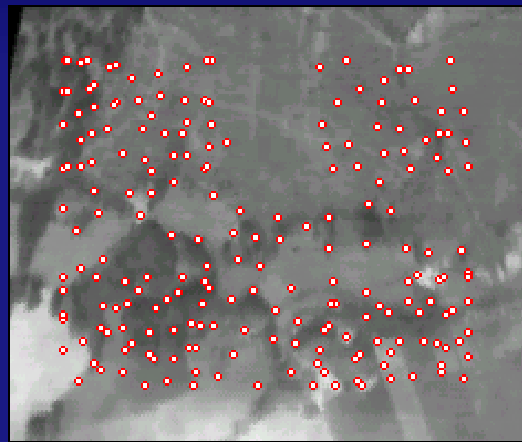
$$C_p = \left\| \lambda_1^2 + \lambda_2^2 \right\|$$

C_p measure the resemblances between two repeated points *p* and *q* in two images

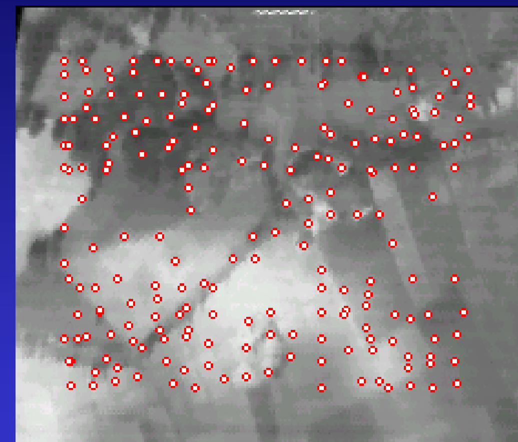
'Similarity' $S(p,q)$ is defined using the cornerness C_p and C_q:

$$S(p,q) = \frac{\min(C_p, C_q)}{\max(C_p, C_q)}$$

Reduction of Feature Points - Cornerness and Similarity measure

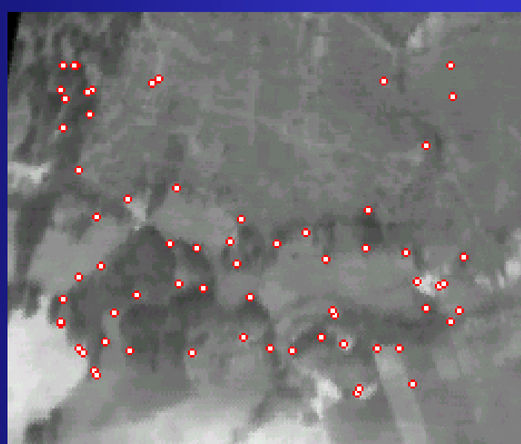


120

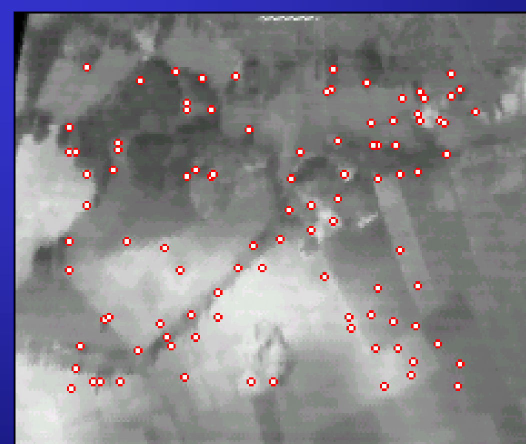


128

Features reduction using Cornerness and Similarity

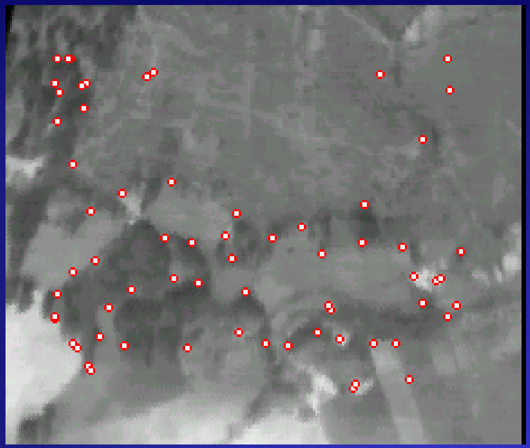


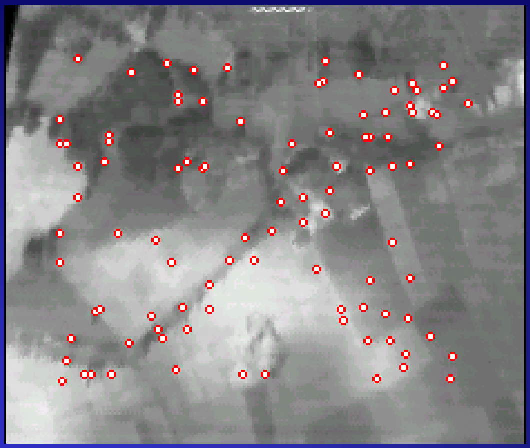
66



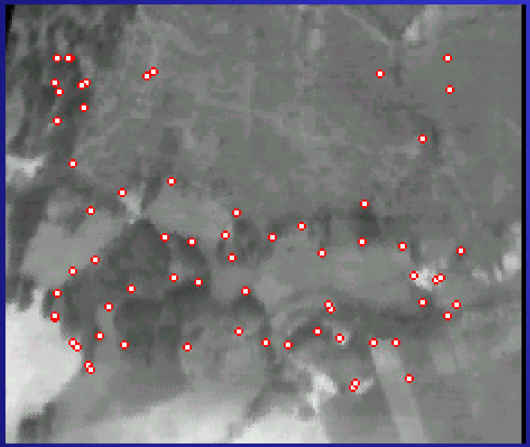
99

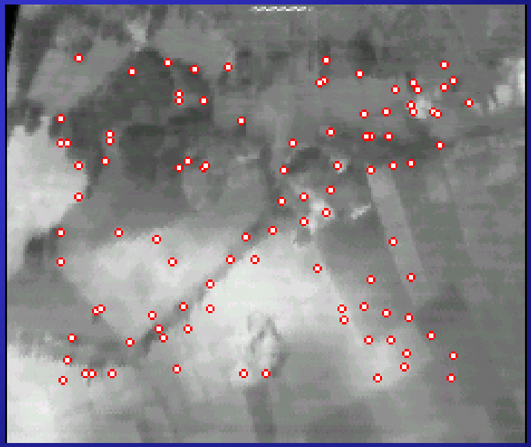
Features reduction using threshold on Corner strength - 1





Feature reduction using threshold on Corner strength - 2





Feature reduction using threshold on Corner strength - 3

Scoring Algorithm

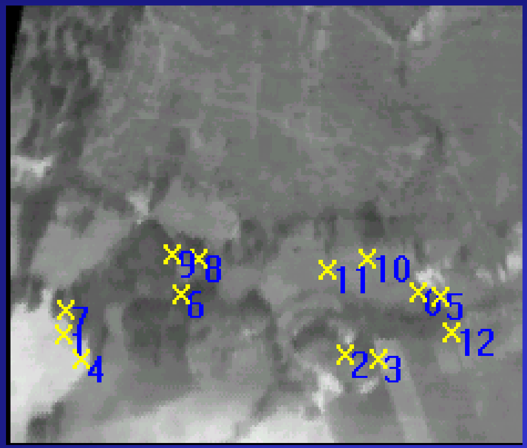
Evaluation of the score once a transformation H has been chosen as a potential candidate

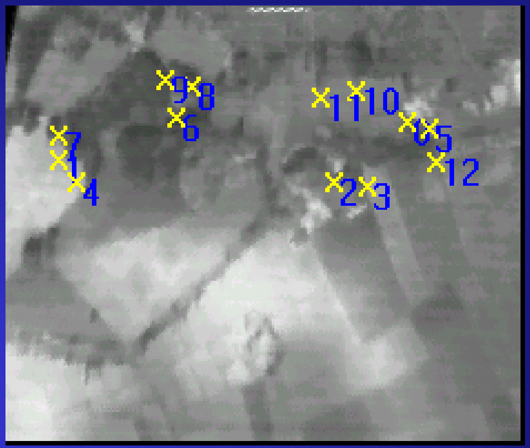
4 families of scoring method

Tradeoffs between execution time and reliability of the scores

- Pixel Cross Correlation
- The Hausdorff matching
- The bottleneck matching
- Discrete Approximate Matching

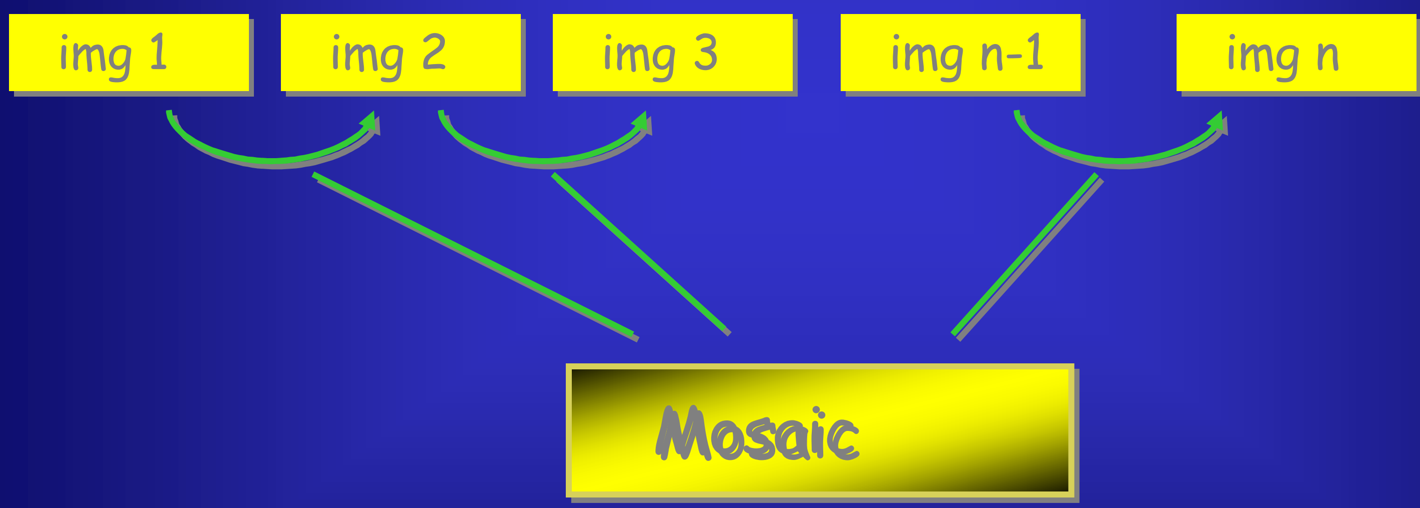
Computation of Homography- Matching Images

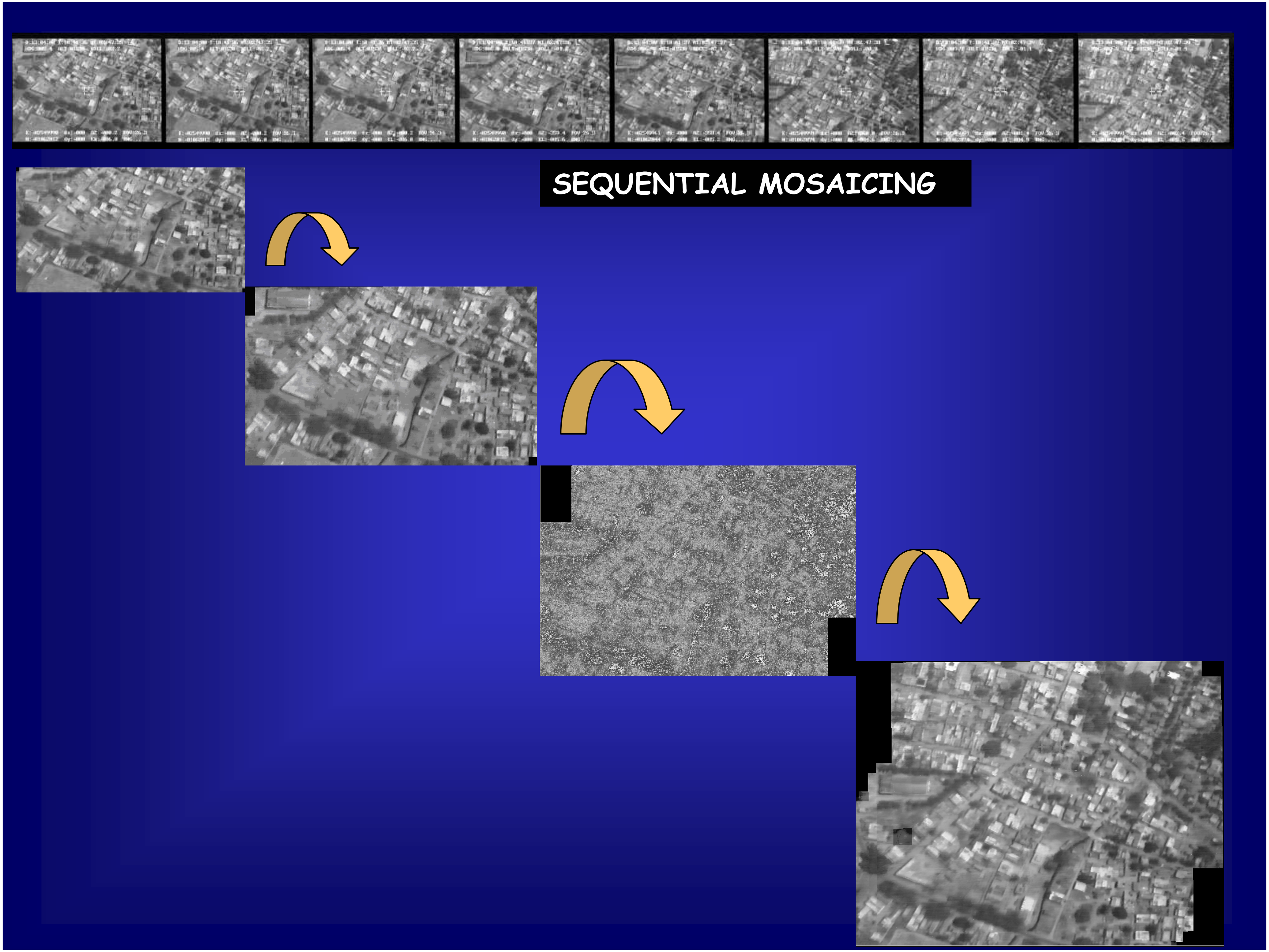




Two Ways of Constructing Mosaic

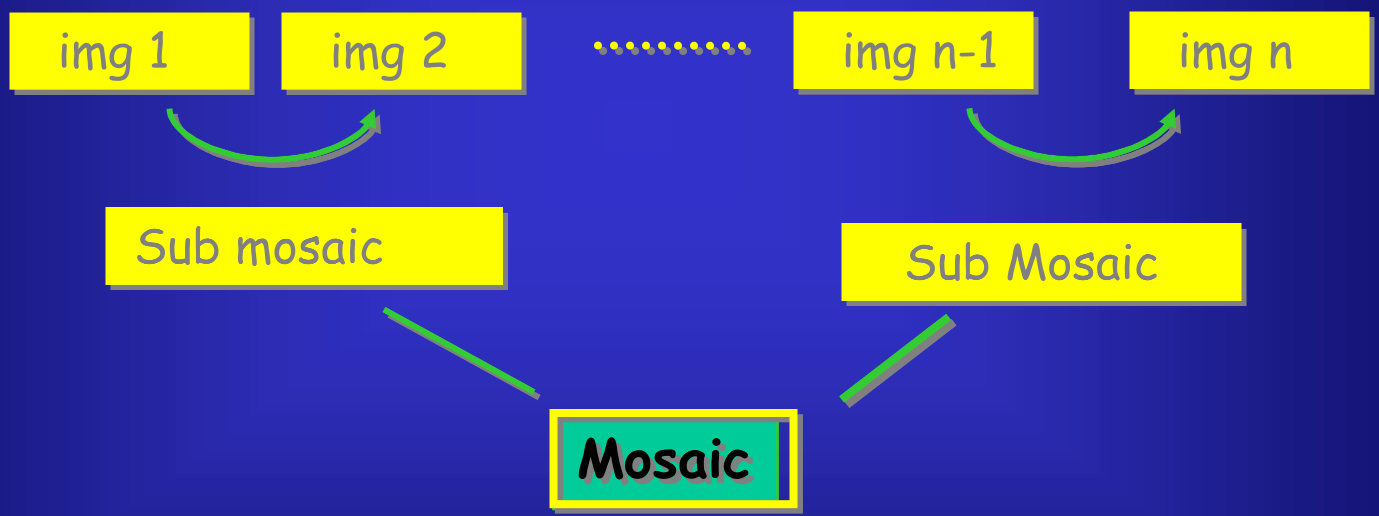
- Sequential Mosaicing




SEQUENTIAL MOSAICING

Two Ways of Constructing Mosaic

- Tree-based Mosaicing



LEVEL 1

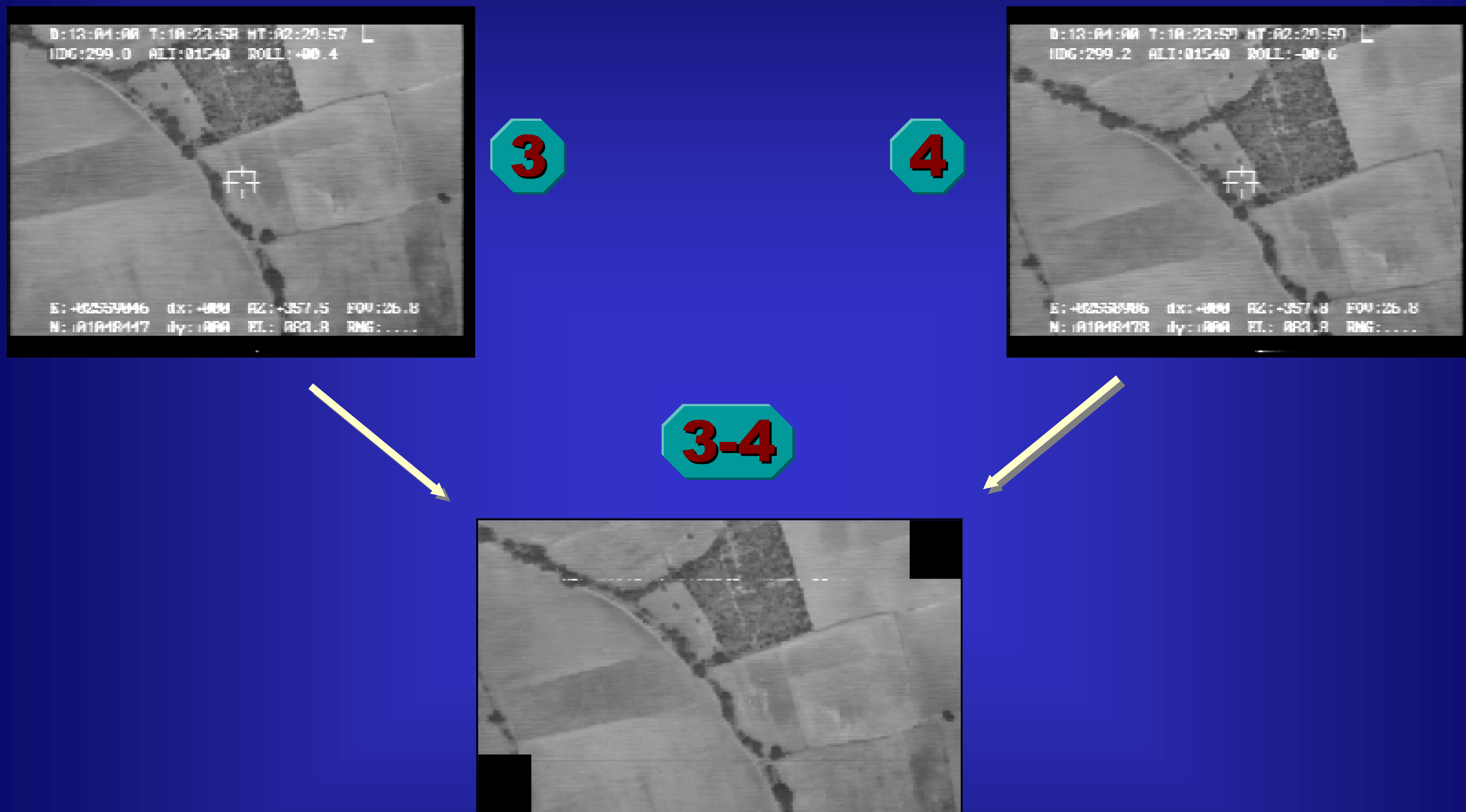
1

2

1-2

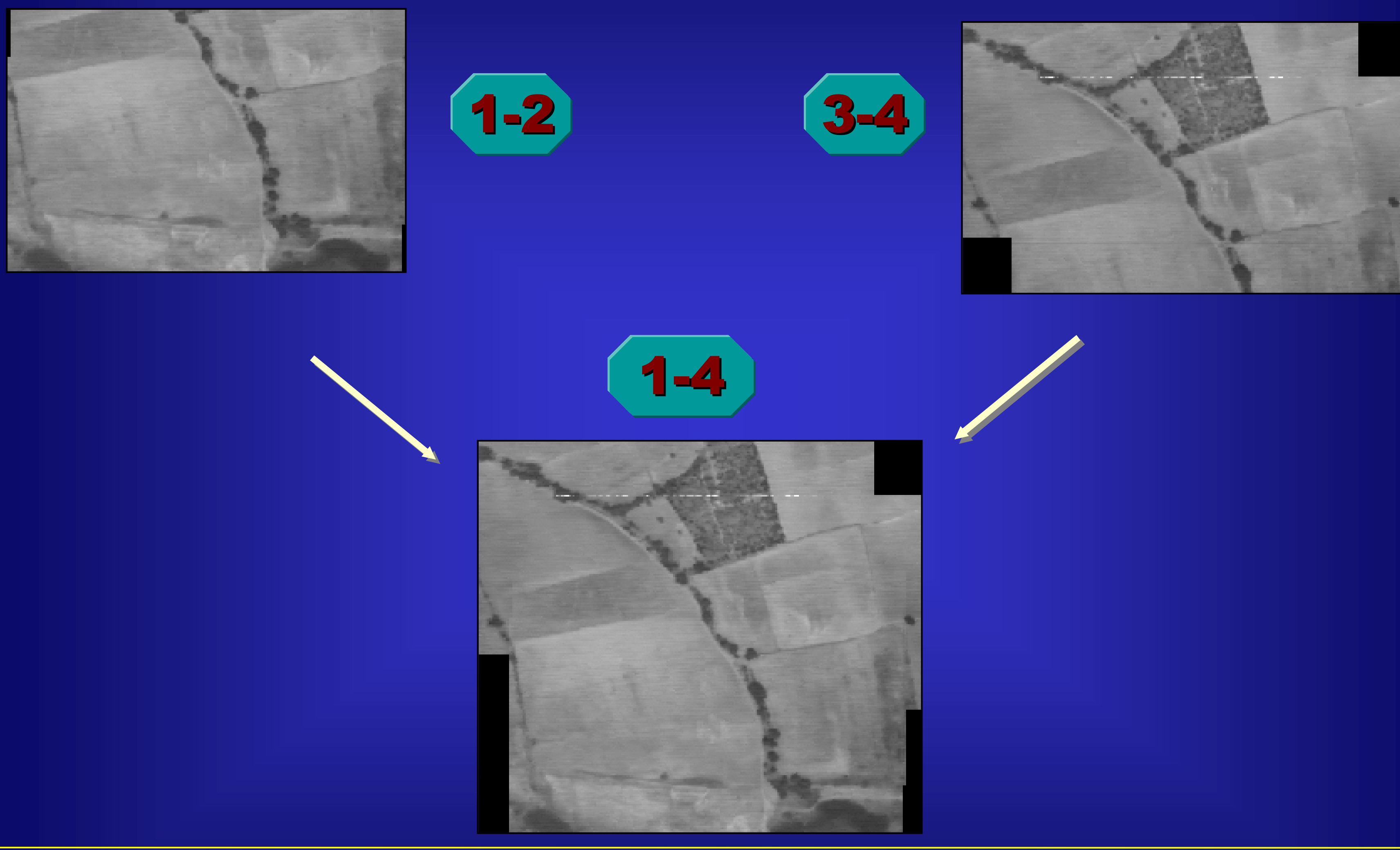
TREE-BASED MOSAICING

LEVEL 1



TREE-BASED MOSAICING

LEVEL 2



TREE-BASED MOSAICING

RESULTS

Mosaic from Flight Mission

Mosaic -Examples

AREA COVERAGE: (1.035 km X 0.250 km)

AREA COVERAGE: (0.95 km X 0.237 km)

Thank You