SURF

(SPEEDED UP ROBUST FEATURES)

Lecturer: Sang Hwa Lee

Reference

- Herbert Bay, Tinne Tuytelaars, and Luc Van Gool. SURF: Speeded Up Robust Features. *European Conference on Computer Vision*, May 2006.

Introduction

- Search for image correspondences
  - Detection
    - Interest points – corners, blobs, and T-junctions
    - Repeatability
  - Description
    - Descriptor – represented by a feature vector
    - Distinctive, robust
  - Matching
    - Based on distance between feature vectors

Introduction

- Interest Point Detectors
  - Harris corner detector
  - Harris-Laplace and Hessian-Laplace
  - DoG (Difference of Gaussians)

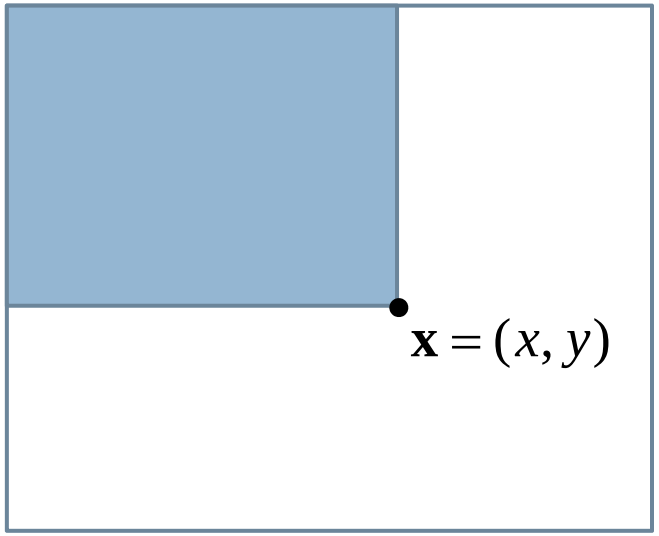
- Feature Descriptors
  - SIFT : Histogram of local oriented gradients around the interest point, 128-dimension
  - PCA-SIFT : 36-dimension

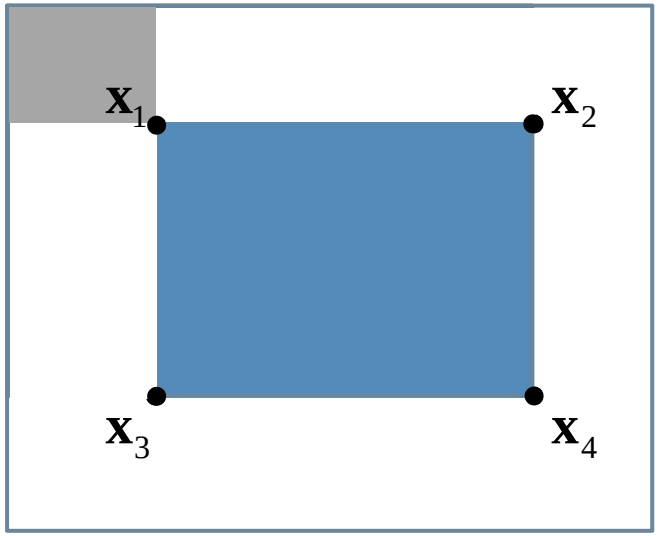
SURF

- Integral Image
- Detector
  - Approximated Hessian-based detector
- Descriptor
  - Based on distribution of Haar-wavelet responses within the interest point neighborhood
  - 64 dimensions
- Matching
  - New indexing step based on the sign of the Laplacian

SURF

- Integral Image



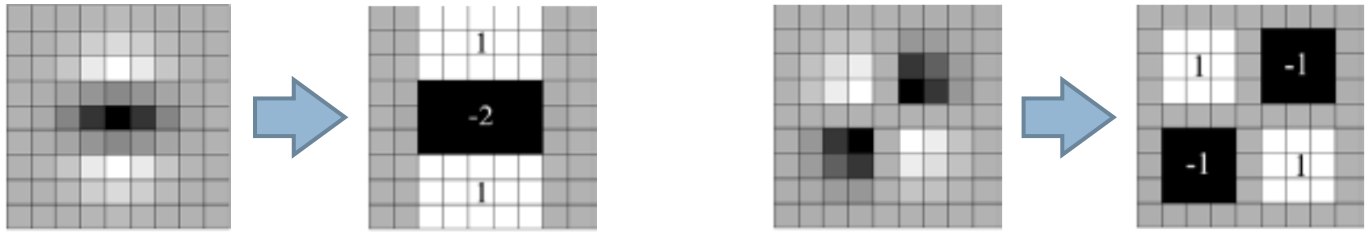


$$I_{\sum}(\mathbf{x}) = \sum_{i=0}^{i \le x} \sum_{j=0}^{j \le y} I(i, j)$$

$$I_{\sum}(\mathbf{x}_4) - I_{\sum}(\mathbf{x}_3) - I_{\sum}(\mathbf{x}_2) + I_{\sum}(\mathbf{x}_1)$$

SURF – Detector

- Hessian matrix
  - $$\mathrm{H}(\mathbf{x},\sigma)=\begin{bmatrix} L_{xx}(\mathbf{x},\sigma) & L_{xy}(\mathbf{x},\sigma) \\ L_{xy}(\mathbf{x},\sigma) & L_{yy}(\mathbf{x},\sigma) \end{bmatrix}, \quad L_{xx}(\mathbf{x},\sigma)=\frac{\partial^2}{\partial x^2}g(\sigma)$$

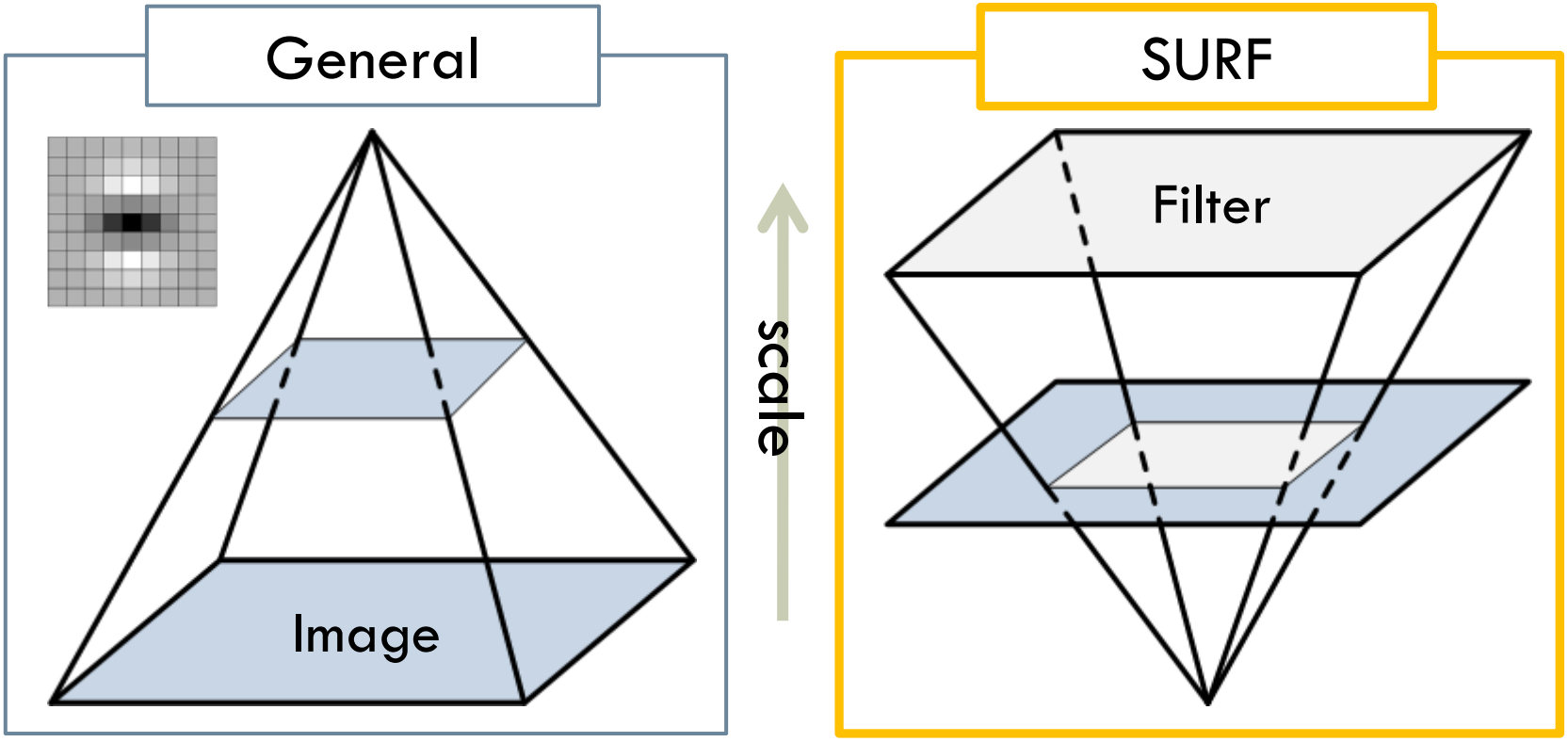


L_{yy} D_{yy} L_{xy} D_{xy}

  - $$\det(\mathrm{H}_{\text{approx}})=D_{xx}D_{yy}-(0.9D_{xy})^2$$

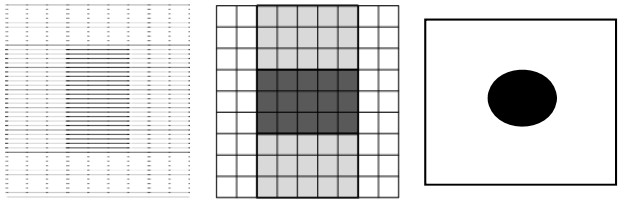
SURF – Detector

- Scale-space

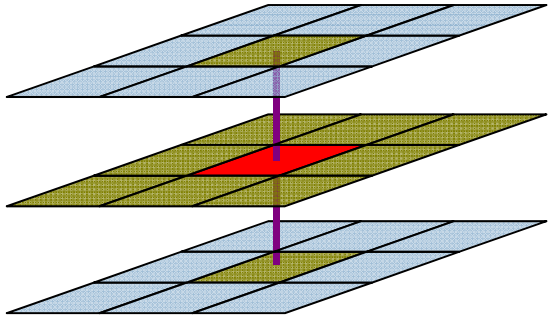


SURF – Detector

- Local maximum detection
  - Blob-like features
    - $\det(\mathrm{H}_{\text{approx}}) = D_{xx}D_{yy} - (0.9D_{xy})^2$



D_{xx} D_{yy}



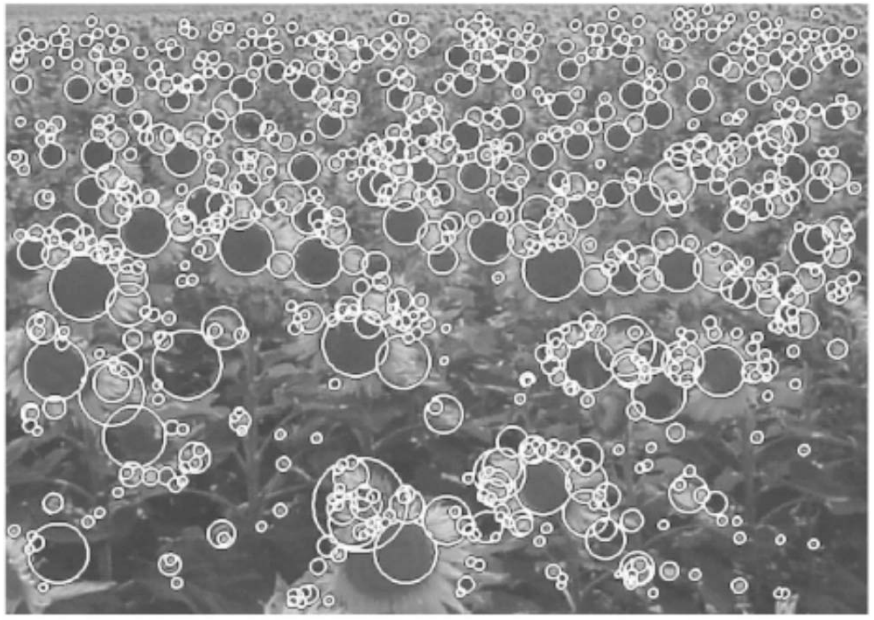
26 neighbors

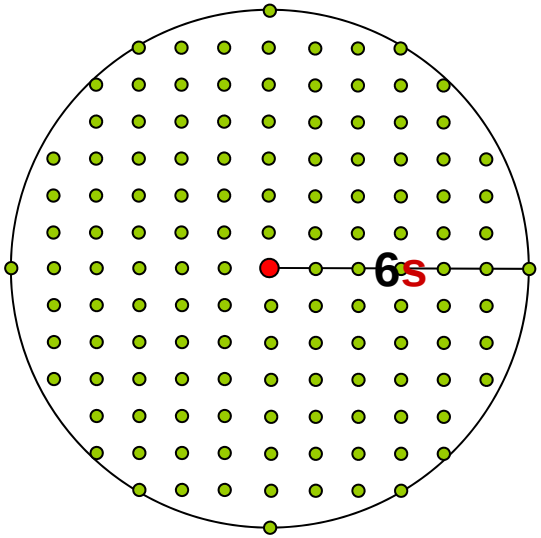
SURF – Descriptor

- Two steps
  1. Orientation Assignment
  2. Descriptor Components

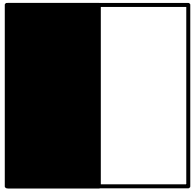
SURF – Descriptor

- Orientation Assignment





(**s** = the scale at which the point was detected)

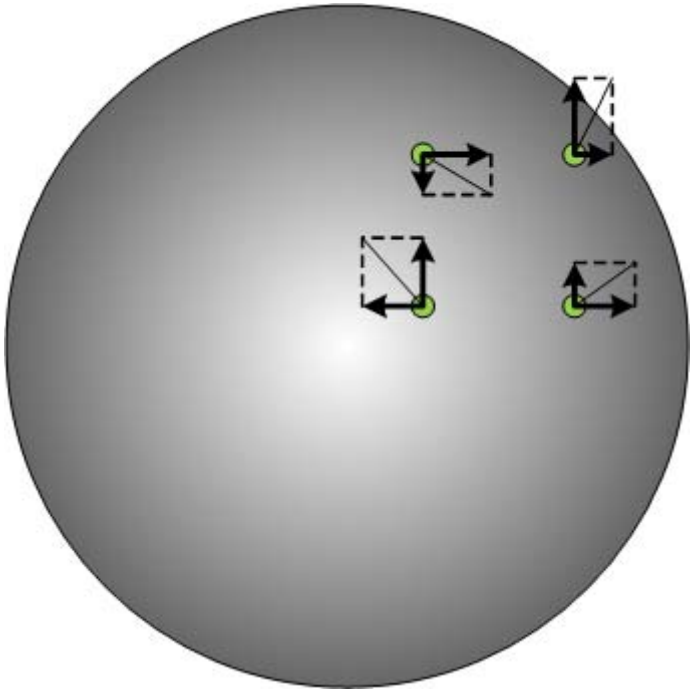


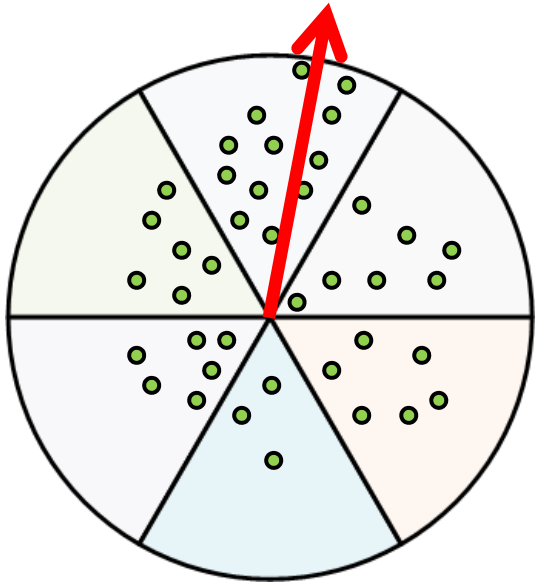
x response

y response

SURF – Descriptor

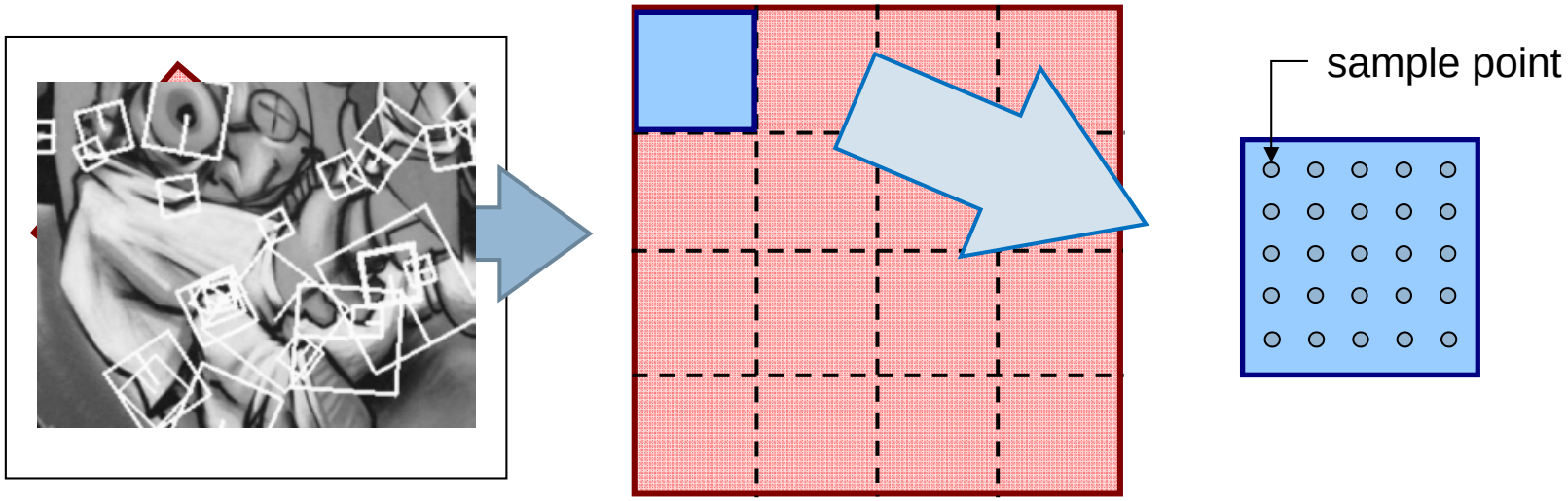
- Orientation Assignment





SURF – Descriptor

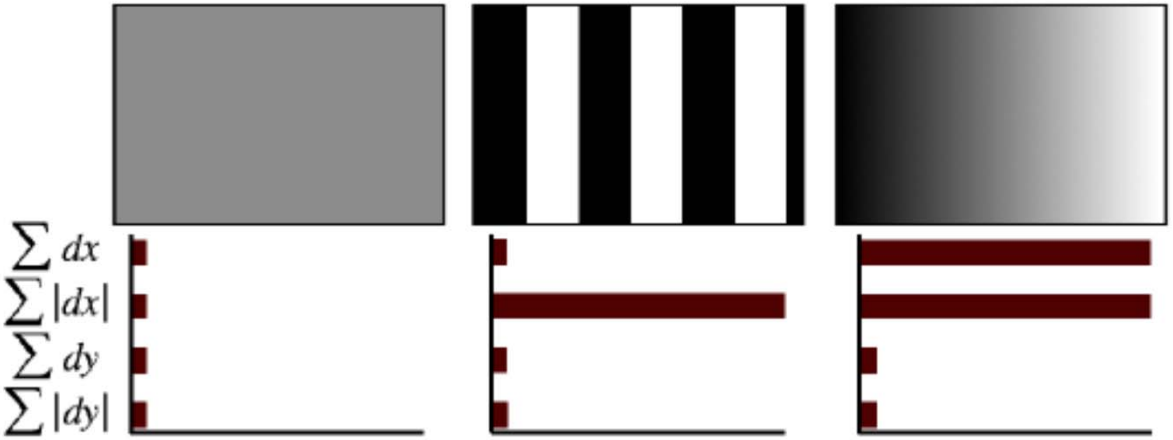
- Descriptor Components



- At sample point, calculate d_x, d_y, $|d_x|$, and $|d_y|$
- At each sub-region, $\mathbf{v} = (\sum d_x, \sum d_y, \sum |d_x|, \sum |d_y|)$
- A descriptor vector for all 4x4 sub-regions of length 64

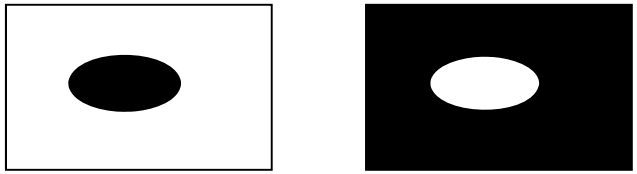
SURF – Descriptor

- Descriptor Components
  - Properties of the descriptor



SURF – Matching

- Based on the sign of the Laplacian
  - Laplacian
    - $|s^2(L_{xx}(\mathbf{x},s)+L_{yy}(\mathbf{x},s))|$
    - The trace of the Hessian matrix
    - Computed during the detection phase
  - Type



    - Compare features if they have the same type
- Euclidean distance
  - $\|\mathbf{p}_{1,n}-\mathbf{p}_{2,n'}\| < 0.7\times\|\mathbf{p}_{1,n}-\mathbf{p}_{2,n''}\|$

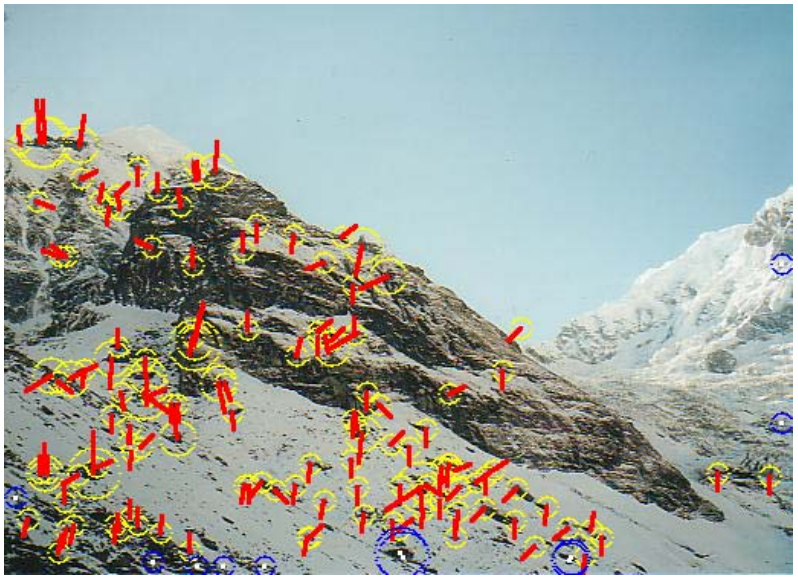
Experimental Results

- Environments
  - # of octaves : 1
    - No scale variant
  - # of layers : 4
    - Sigma : 1.2, 2.0, 2.8, 3.6
  - Threshold : 600 (database), 100 or 150 (previous real image)
  - Matching constraint
    - $\| \mathbf{p} - \mathbf{p}_{1^{st}\text{ cand.}} \| < 0.5 \| \mathbf{p} - \mathbf{p}_{2^{nd}\text{ cand.}} \|$

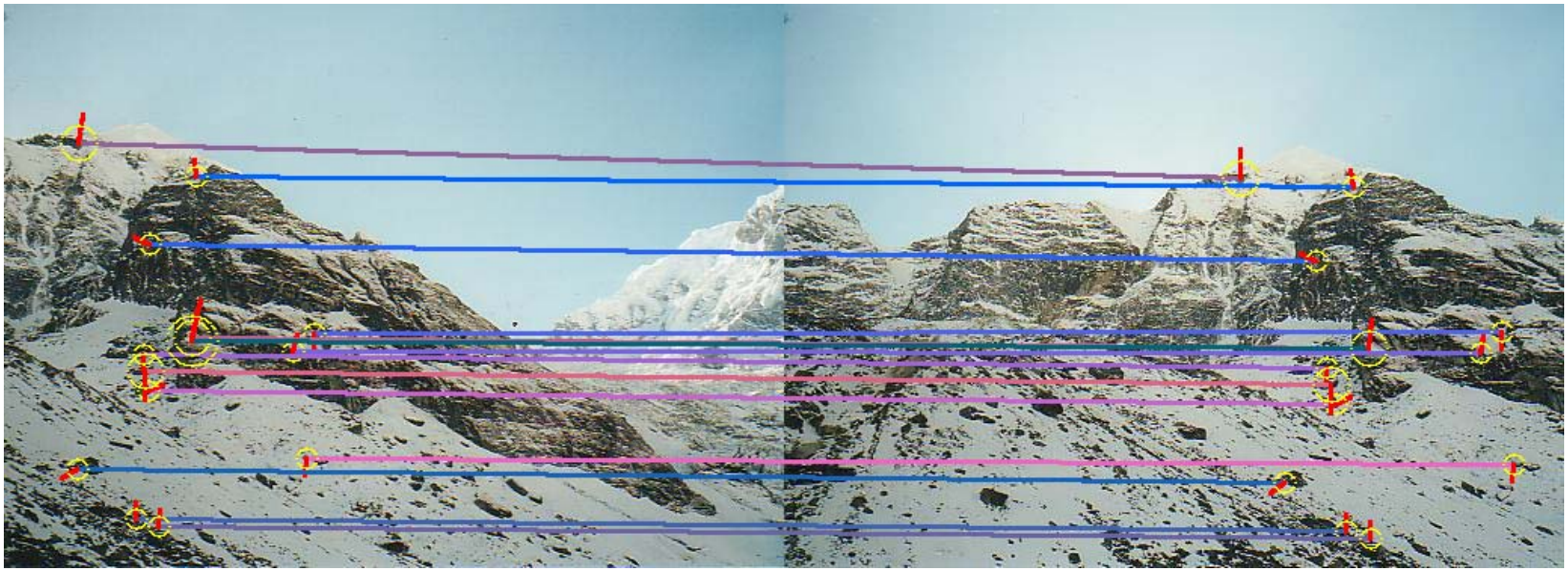
1st Test Image (517 x 374)

- Threshold : 600

1st Test Image (517 x 374)



1st Test Image (517 x 374)



2nd Test Image (800 x 640)

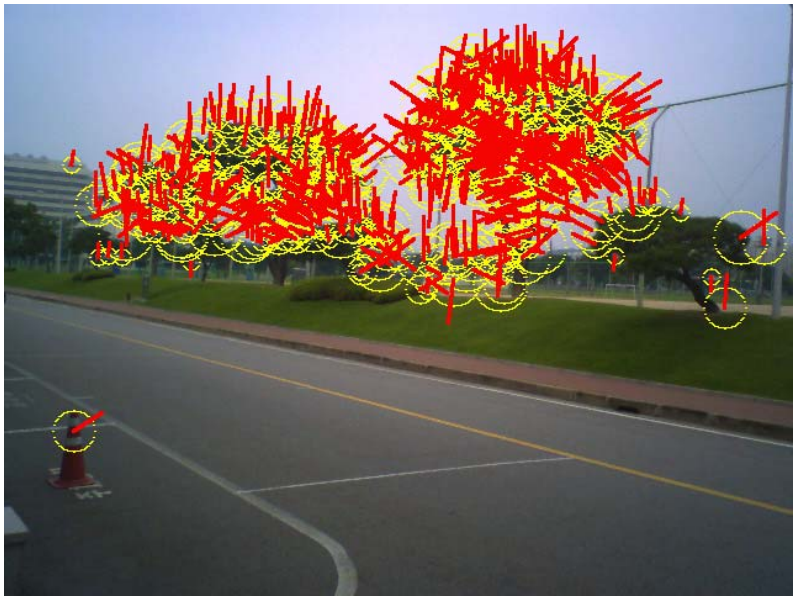
- Threshold : 600

2nd Test Image (800 x 640)

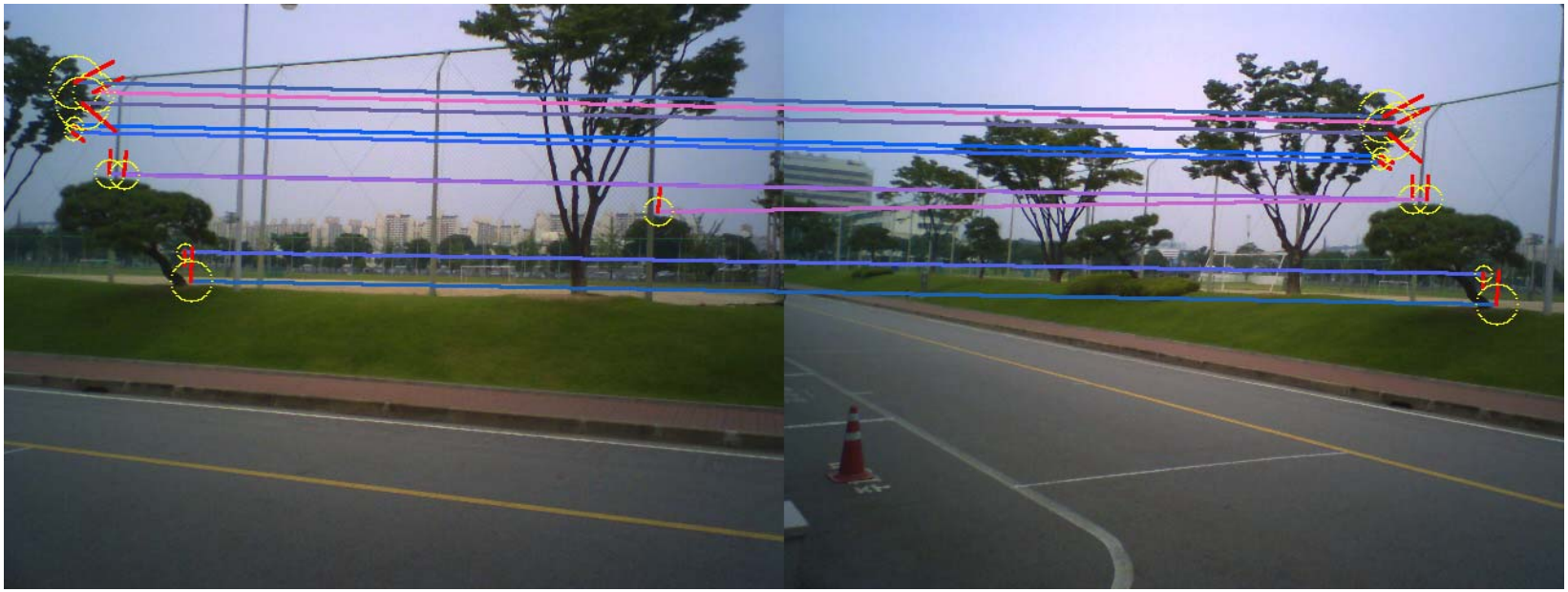
2nd Test Image (800 x 640)

3rd Test Image (640 x 480)

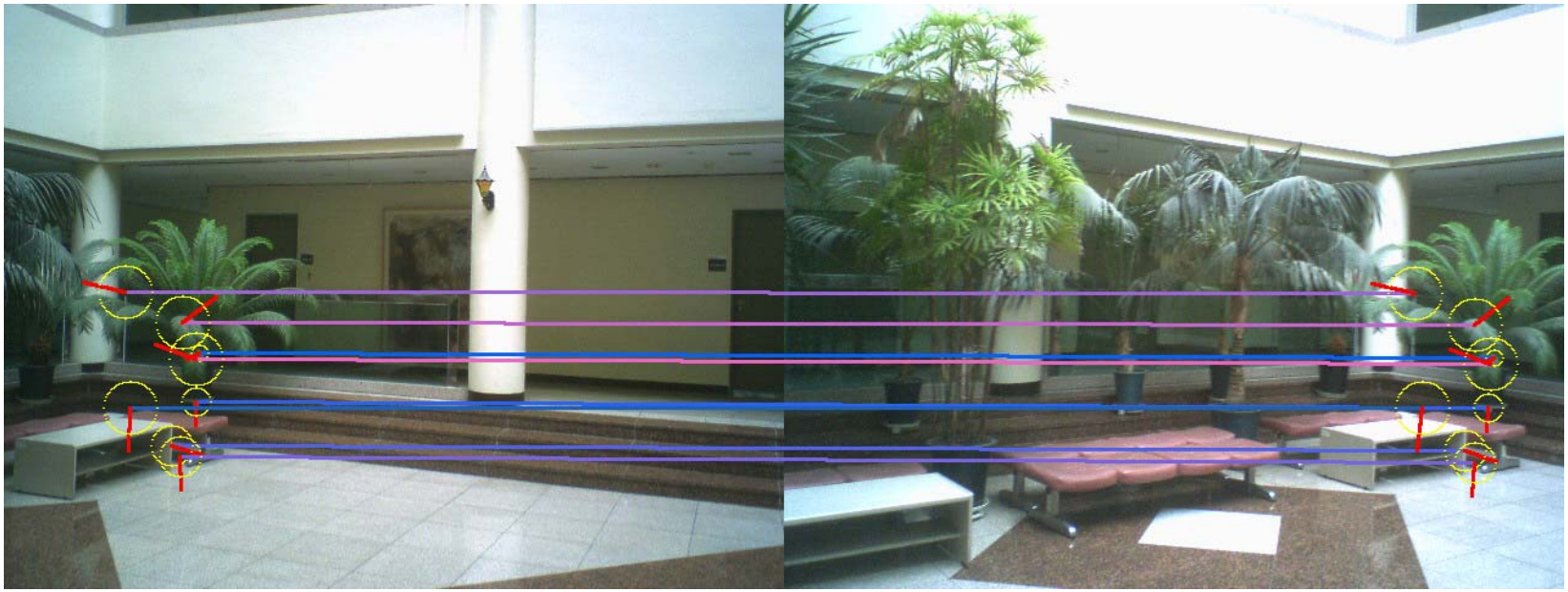
- Threshold : 150



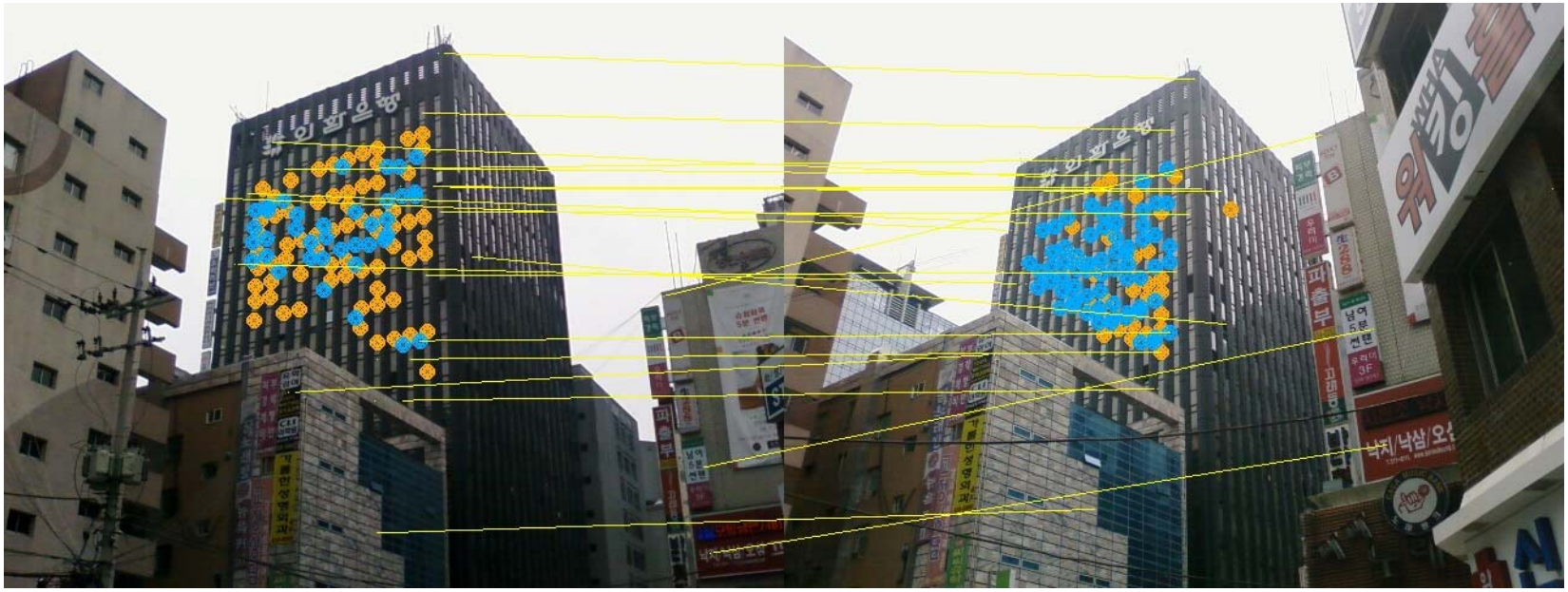
3rd Test Image (640 x 480)



4th Test Image (640 x 480)

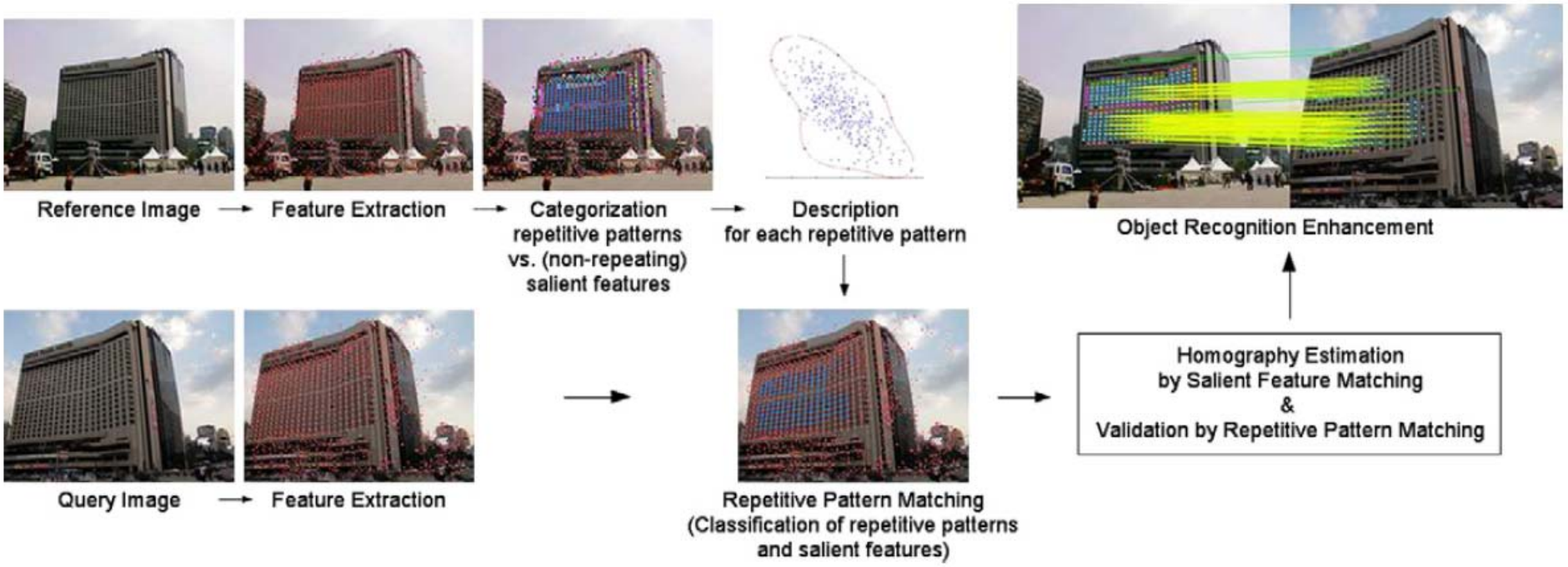


Problems of Repetitive Pattern (1)



Mismatching results by repetitive pattern in the building image

Problems of Repetitive Pattern (2)



Grouping the repetitive pattern and recognition