Scale invariant interest points/regions

Overview

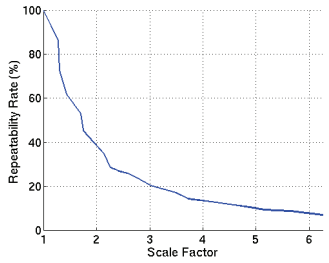
- Scale invariance - motivation
- Multi-scale detection
- Scale selection
- State of the art on scale invariant points/regions

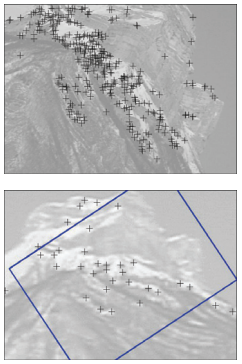
Scale invariance - motivation

- Description regions have to be adapted to scale changes

- Interest points have to be repeatable under scale changes

Harris detector + scale changes





Scale adaptation

Scale change between two images

$$I_1\begin{pmatrix} x_1 \\ y_1 \end{pmatrix} = I_2\begin{pmatrix} x_2 \\ y_2 \end{pmatrix} = I_2\begin{pmatrix} sx_1 \\ sy_1 \end{pmatrix}$$

Scale adapted derivative calculation

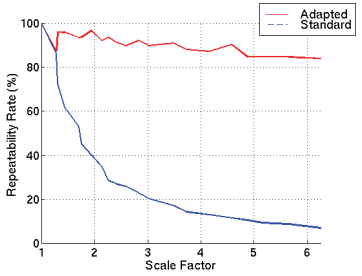
$$I_1\begin{pmatrix} x_1 \\ y_1 \end{pmatrix} \otimes G_{i_1 \ldots i_n}(\sigma) = s^n I_2\begin{pmatrix} x_2 \\ y_2 \end{pmatrix} \otimes G_{i_1 \ldots i_n}(s\sigma)$$

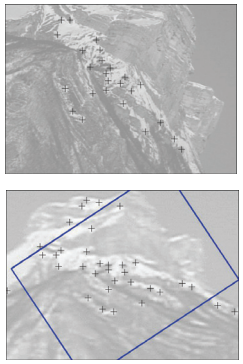
Scale adaptation

Scale adapted auto-correlation matrix

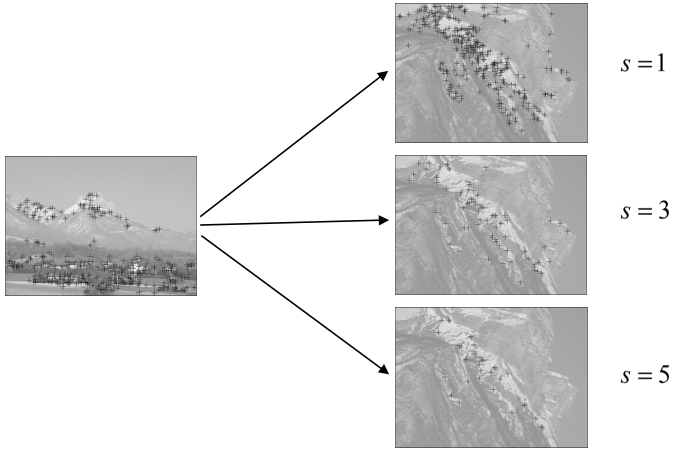
$$s^2 G(s\tilde{\sigma}) \otimes \begin{bmatrix} L_x^2(s\sigma) & L_x L_y(s\sigma) \\ L_x L_y(s\sigma) & L_y^2(s\sigma) \end{bmatrix}$$

Harris detector – adaptation to scale

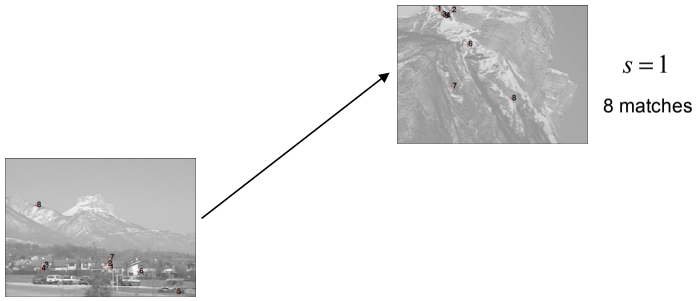




Multi-scale matching algorithm



Multi-scale matching algorithm

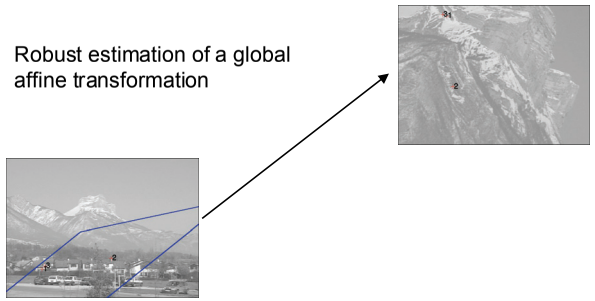


$s = 1$

8 matches

Multi-scale matching algorithm

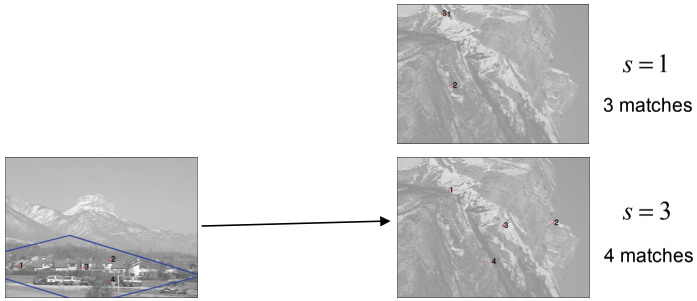
Robust estimation of a global affine transformation



$s = 1$

3 matches

Multi-scale matching algorithm



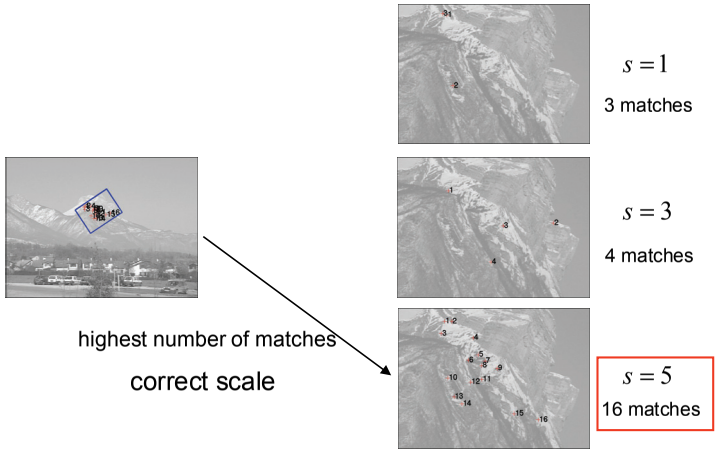
$s = 1$

3 matches

$s = 3$

4 matches

Multi-scale matching algorithm



$s = 1$

3 matches

$s = 3$

4 matches

highest number of matches

correct scale

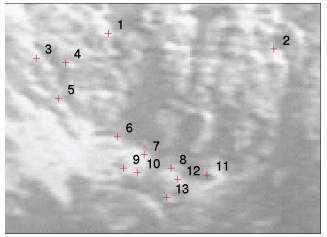
$s = 5$

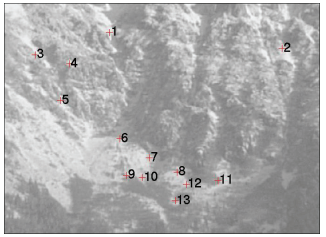
16 matches

Matching results


Scale change of 5.7

Matching results

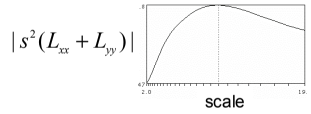




100% correct matches (13 matches)

Scale selection

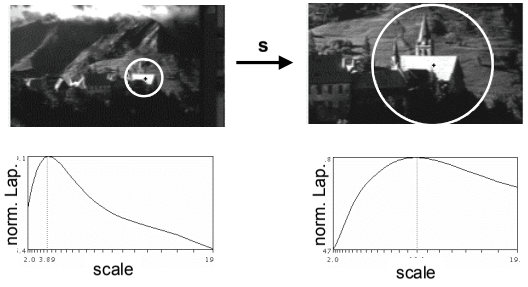
- In a point compute a value (gradient, Laplacian etc.) at several scales
- Normalization of the values with the scale factor
  e.g. Laplacian $|s^2(L_{xx}+L_{yy})|$
- Select scale s^* at the maximum → characteristic scale



- Exp. results show that the Laplacian gives best results

Scale selection

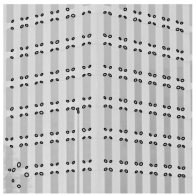
- Scale invariance of the characteristic scale



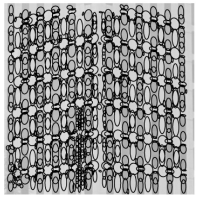
- Relation between characteristic scales $s \cdot s_1^* = s_2^*$

Scale-invariant detectors

- Harris-Laplace (Mikolajczyk & Schmid'01)
- Laplacian detector (Lindeberg'98)
- Difference of Gaussian (Lowe'99)



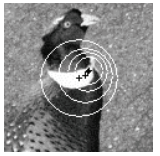
Harris-Laplace



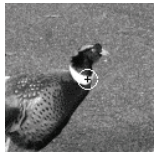
Laplacian

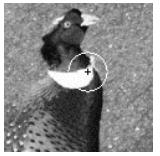
Harris-Laplace

multi-scale Harris points



selection of points at maximum of Laplacian





➡ invariant points + associated regions [Mikolajczyk & Schmid, ICCV'01]

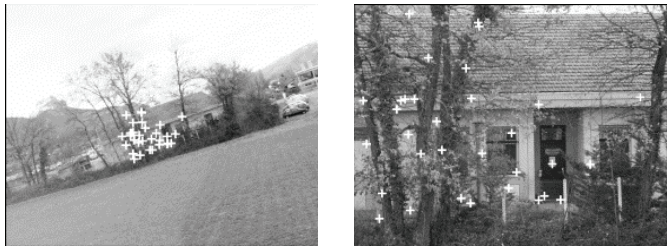
Matching results

213 / 190 detected interest points

Matching results

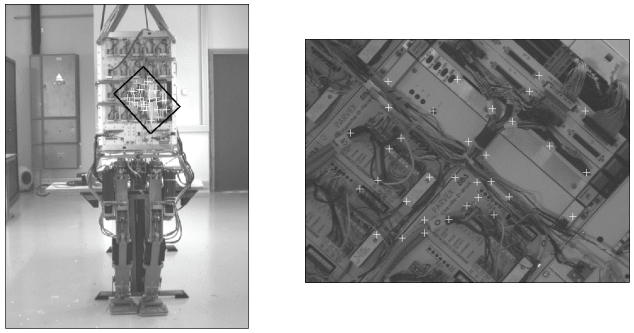
58 points are initially matched

Matching results



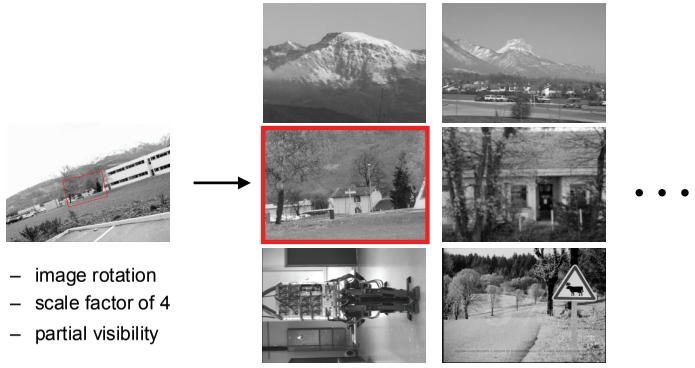
32 points are matched after verification – all correct

Matching results



all matches are correct (33)

Image retrieval

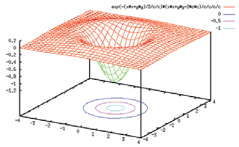


- image rotation
- scale factor of 4
- partial visibility

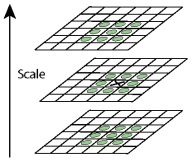
Laplacian of Gaussian [Lindeberg'98]

- Convolution with the Laplacian of Gaussian (LOG)

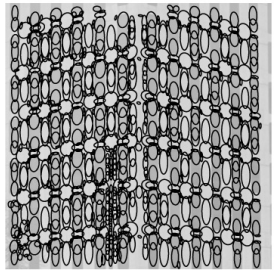
$$LOG = G_{xx}(\sigma) + G_{yy}(\sigma)$$

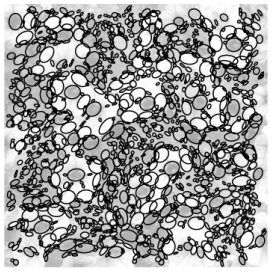


- Determine maxima & minima in space and scale



LOG – Blob detector

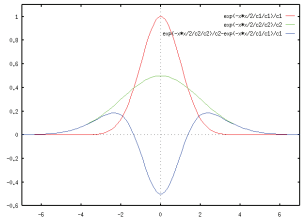




Difference of Gaussian (DOG)

- Difference of Gaussian (DOG) approximates the Laplacian

$$DOG = G(k\sigma) - G(\sigma)$$



- Fast computation by taking the difference between Gaussian smoothed images + sub-sampling