Speeded-Up Robust Features (SURF)

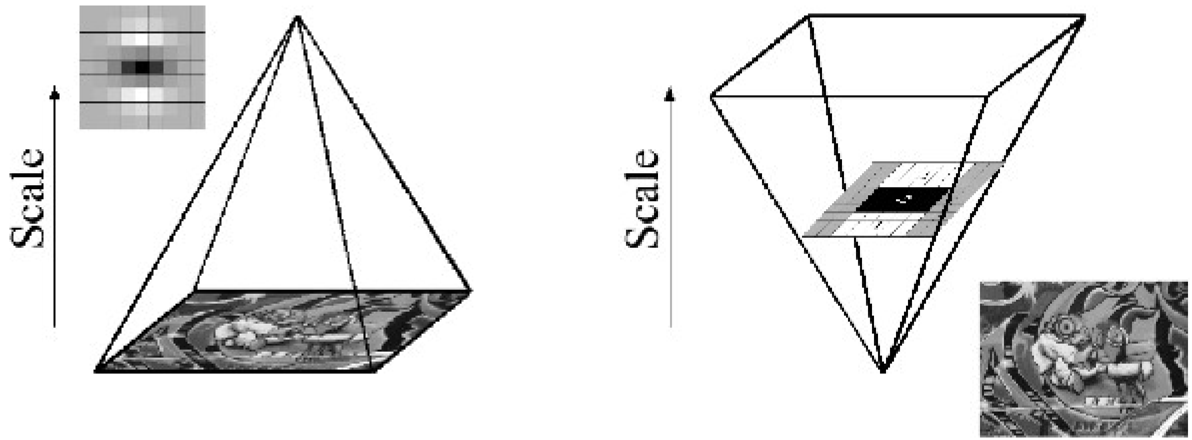
- Expected Properties of good Feature Point Descriptor
  - Repeatability
  - Distinctive to different objects
  - Speed -computation time to detect and describe, and also to match
  - Robust to
    - Noise
    - Geometric deformations (Skew, anisotropic scaling, and perspective)
    - Photometric deformations
- Drawback of SIFT:
  - High dimensionality of the descriptor
  - Time taken for convolution

Introduction to Speeded-Up Robust Features

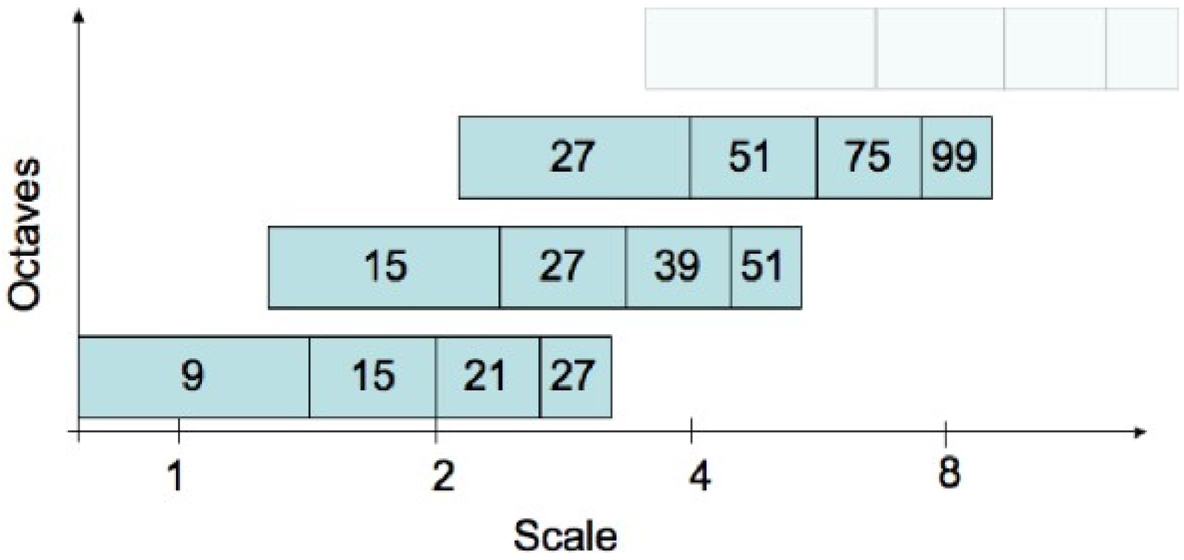
- (Bay et al. ECCV, 2006)
- Box filters
- Filtering is done using integral images to speed up the computation.
- Use of Hessian operator for key point detection Local maxima of det(H).
- Haar wavelets are used to find gradient.

Steps in Feature Descriptor

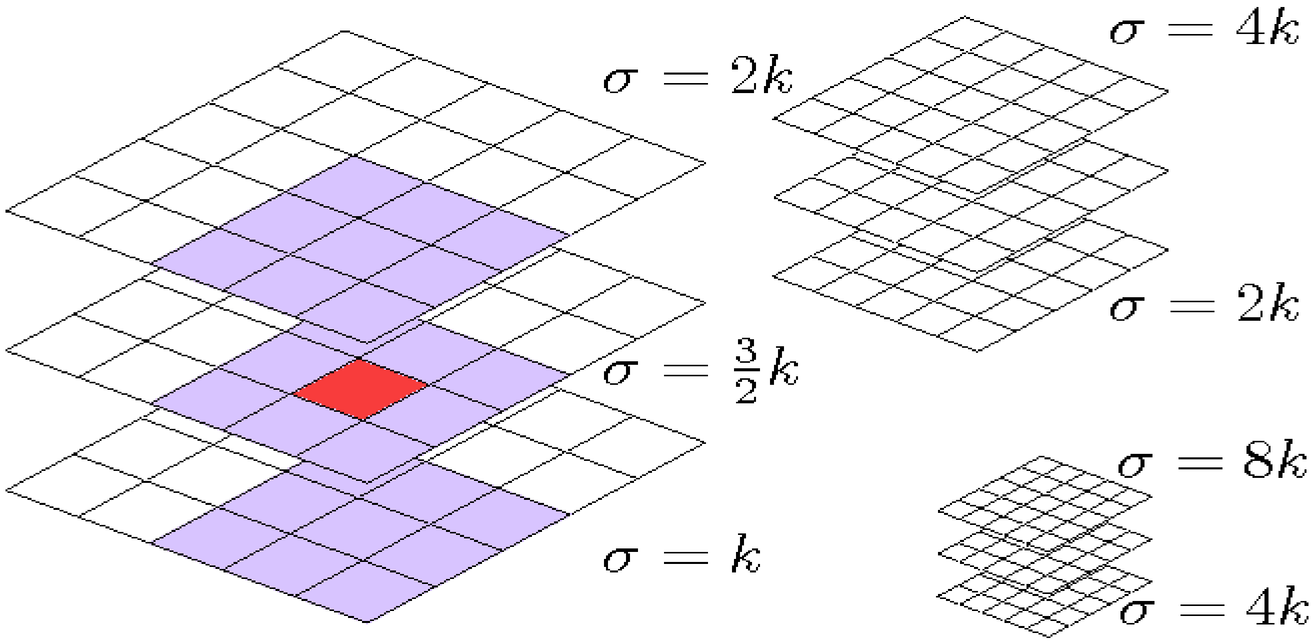
- Key point detection
  - Extrema in Scale space
    -Similar to SIFT
- Feature Description
- Feature Matching



Scale Space Organization



Key point detection in scale space



Hessian Operator

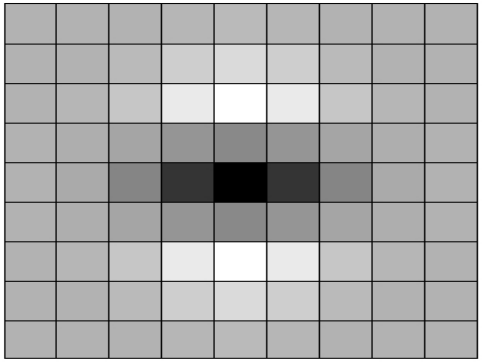
Convolution with the Gaussian second order derivative with image.

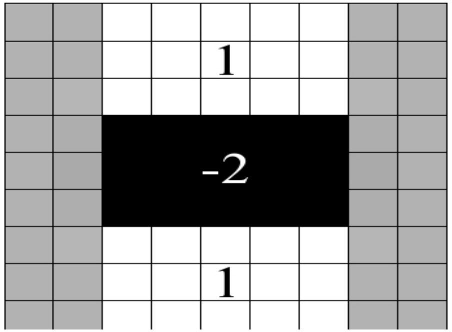
$$\mathcal{H}(\mathbf{x}, \sigma) = \begin{bmatrix} L_{xx}(\mathbf{x}, \sigma) & L_{xy}(\mathbf{x}, \sigma) \\ L_{xy}(\mathbf{x}, \sigma) & L_{yy}(\mathbf{x}, \sigma) \end{bmatrix},$$

where $L_{xx}(\mathbf{x}, \sigma)$ is the convolution of the Gaussian second order derivative $\frac{\partial^2}{\partial x^2} g(\sigma)$ with the image I in point $\mathbf{x}$, and similarly for $L_{xy}(\mathbf{x}, \sigma)$ and $L_{yy}(\mathbf{x}, \sigma)$.

Keypoint: Maximum of det(H(.)) over space and scale.

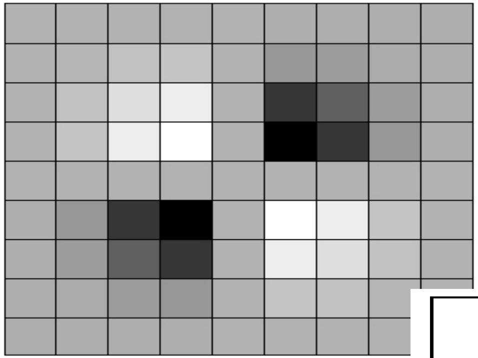
Approximation of Gaussian by Box filters

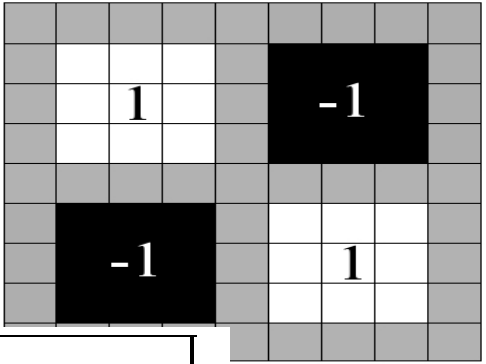




D_{yy}

9x9 Box-filters are approximation of Gaussian width 1.2.





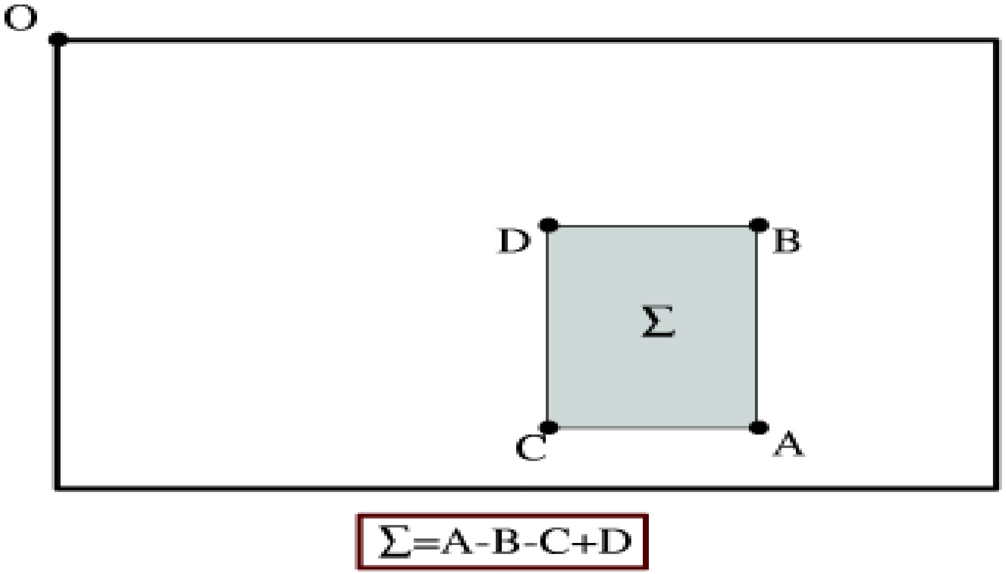
D_{xy}

$$\det(\mathcal{H}_{\text{approx}}) = D_{xx}D_{yy} - (wD_{xy})^2.$$

$w \sim 0.9$

Fast computation using the integral image

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

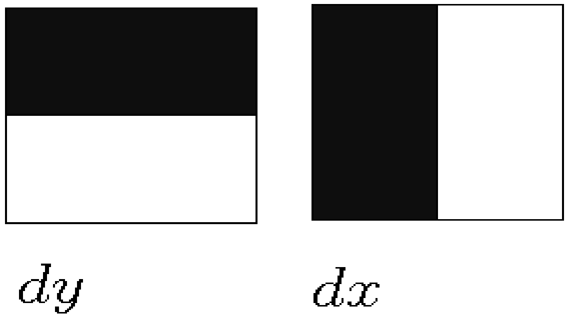


Only 3 add/sub and four memory access.

Haar Filter Responses

- Dominant orientation
  - The longest vector provides the dominant direction.

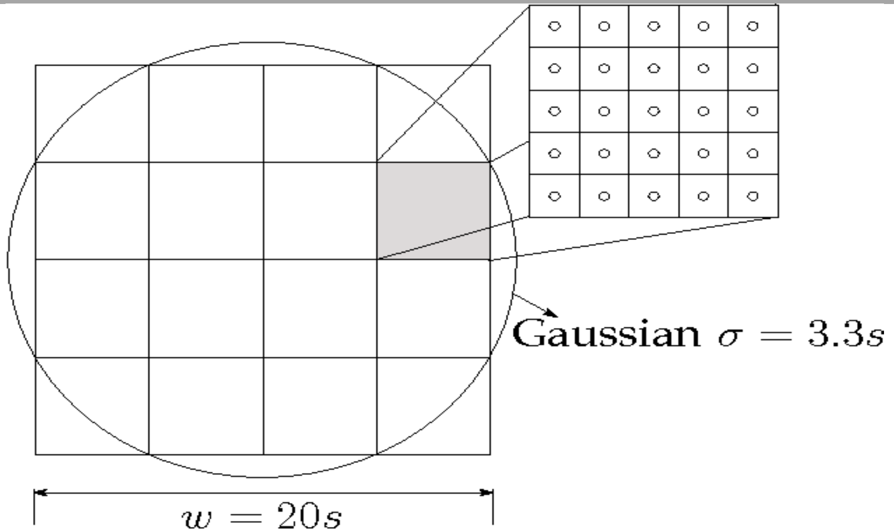
- Haar Filters -Box filter implementation.

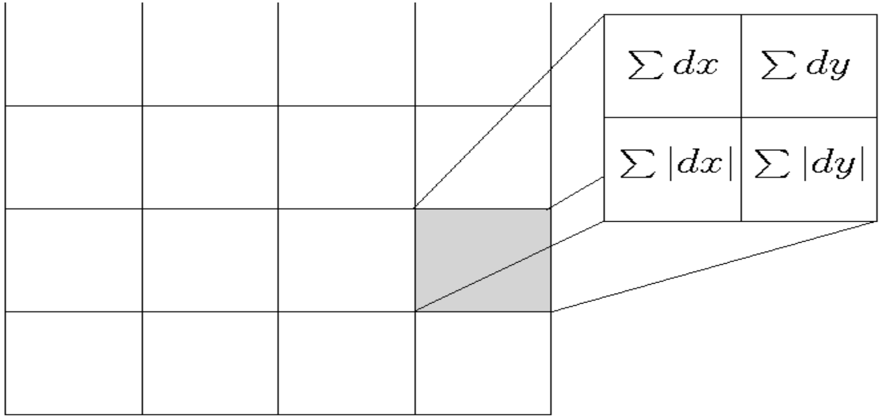


6 operations needed for computing each filt
response using integral image.

SURF Desc

- Partitioned into 4x4 square sub-regions.
- Haar wavelet responses at regularly spaced 5x5 sample patches in each sub-region.
- Each sub-region has 4D vector.
- Concatenate them to 64 D vector.





Matching

- Representation of a key-point by a feature vec
  - e.g. $[f_0 f_1 \dots f_n]^T$
- Use distance functions / similarity measures.
  - L_1 norm $$L_1(\vec{f},\vec{g}) = \sum_{i=0}^{n} |f_i - g_i|$$
  - L_2 norm $$L_2(\vec{f},\vec{g}) = \left(\sum_{i=0}^{n} |f_i - g_i|^2\right)^{\frac{1}{2}}$$
  - L_p norm $$L_p(\vec{f},\vec{g}) = \left(\sum_{i=0}^{n} |f_i - g_i|^p\right)^{\frac{1}{p}}$$