DTU

Perception for Autonomous Systems 31392:

Image Feature Detection and Description

Lecturer: Evangelos Boukas—PhD

Image Features

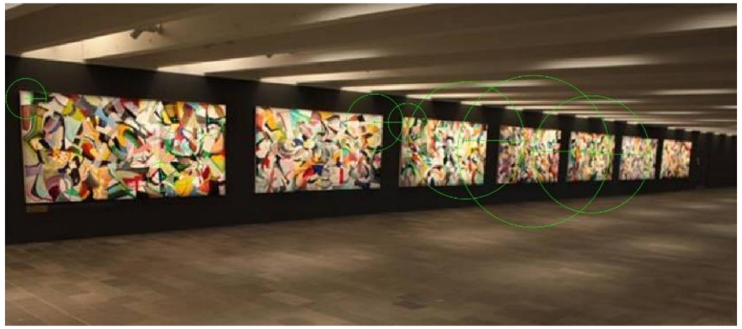
- Feature Detection:

  Find the most “prominent” Points (areas) in an image.

  The ones which are likely to be detected in other images, as well
- Feature Description:

  Create a “unique” descriptor fingerprint for each Feature point
- Feature Matching:

  Find correspondences among different images



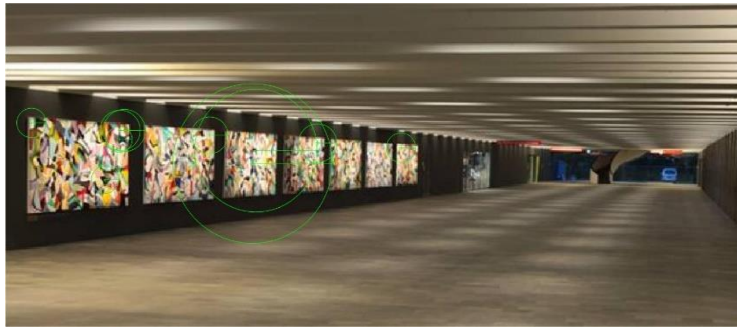
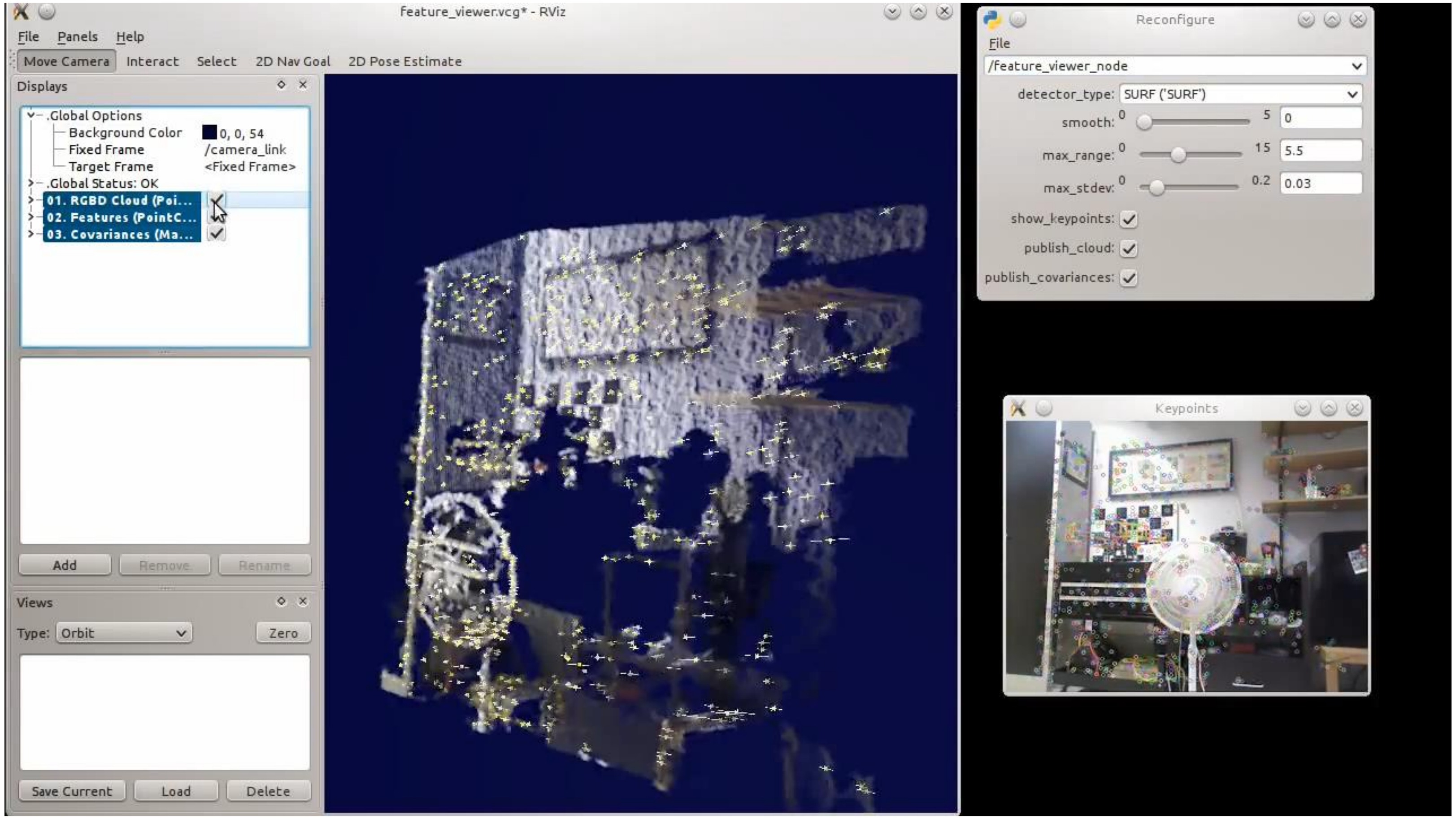


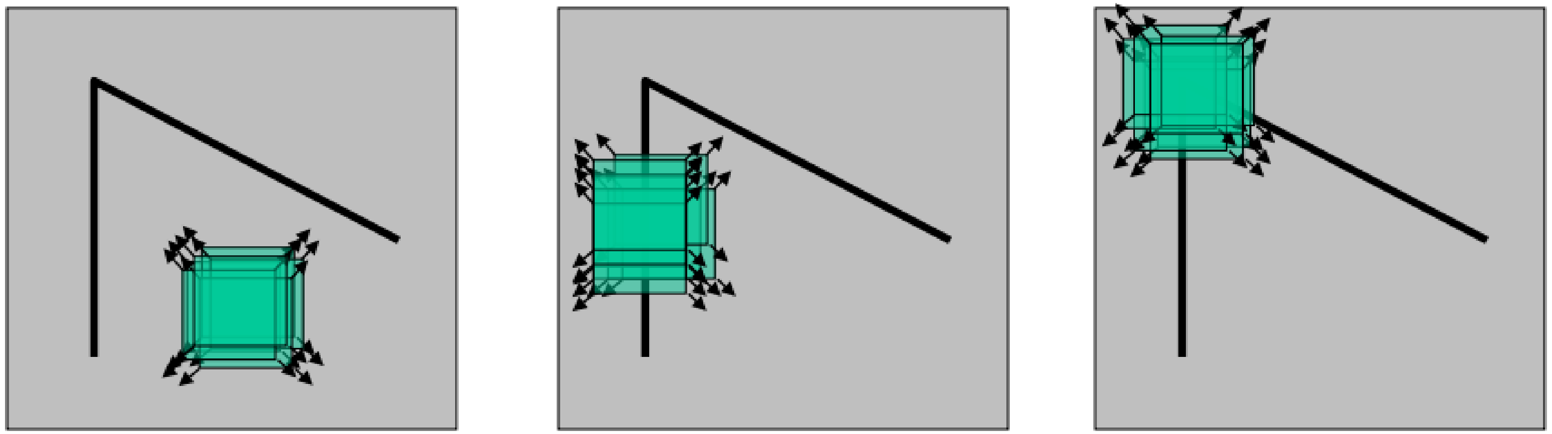
Image Features

- A quick view



Feature Detection: Harris corner detector

- Corners are great for features



"flat" region:
no change in
all directions

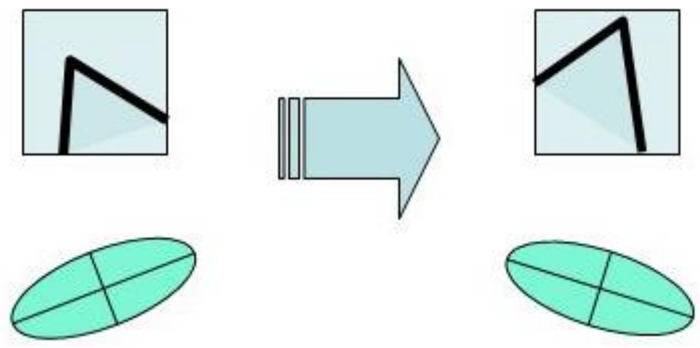
"edge":
no change along
the edge direction

"corner":
significant change
in all directions

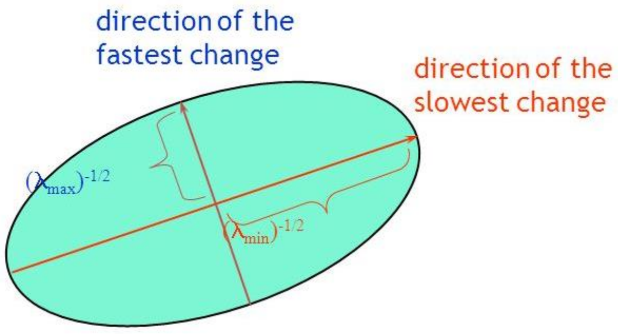
- Lines not so, why

Feature Detection: Harris corner detector

- Harris can discriminate among **edge**, **flat** and **corners**



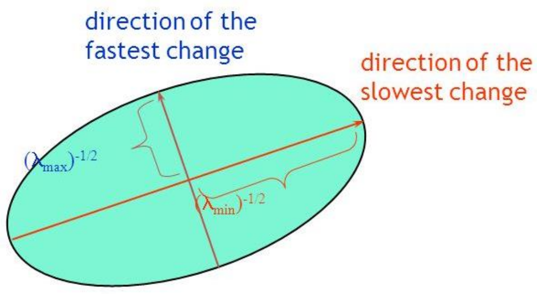
- Notice how by rotating it does not change
- Linear algebra



λ_1, λ_2 – eigenvalues of M

Feature Detection: Harris corner detector

- So how are these eigenvalues useful?



λ_1, λ_2 – eigenvalues of M

Feature Detection: Harris corner detector

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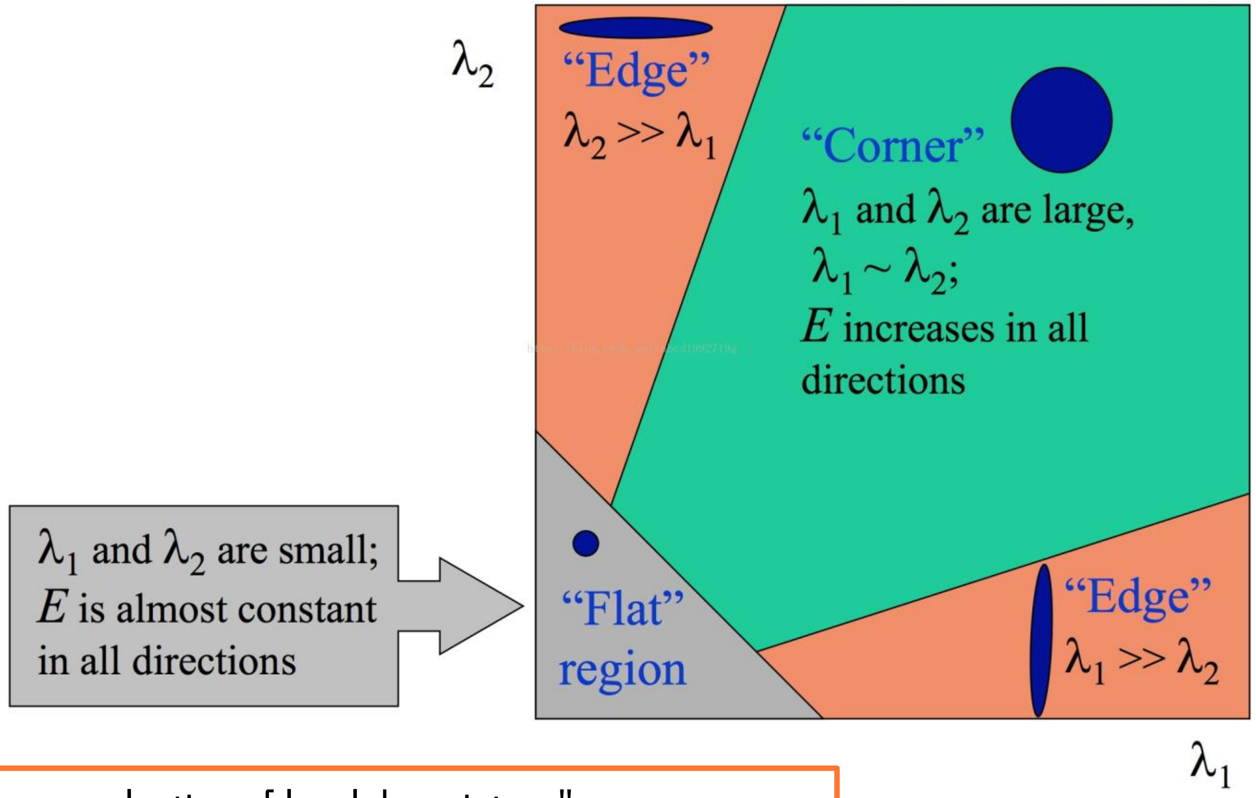

Mikolajczyk, K., and Schmid, C., "A performance evaluation of local descriptors",

IEEE Transactions on Pattern Analysis and Machine Intelligence, 10, 27, pp 1615--1630, 2005.

Feature Detection: Harris corner detector

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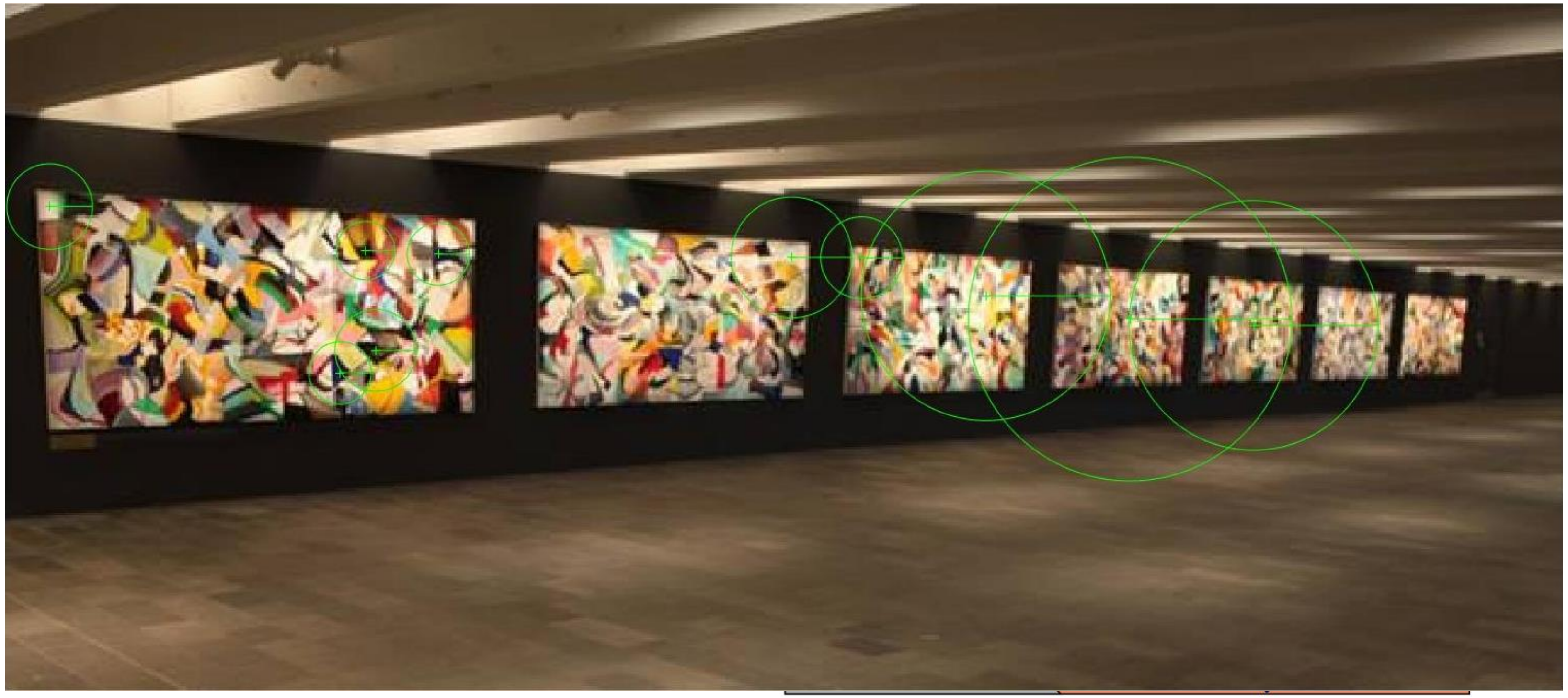


λ_1

Mikolajczyk, K., and Schmid, C., "A performance evaluation of local descriptors",

IEEE Transactions on Pattern Analysis and Machine Intelligence, 10, 27, pp 1615--1630, 2005.

Feature Detection: Scale Space Theory

- So we can find corners.
- But how descriptive are these corners?
  - Not really,
  - Think that the roof of a building has corners
  - And you desk has corners…
- Finally a revelation:

Lindeberg, T. 1994. Scale-space theory: A basic tool for analysing structures at different scales. Journal of Applied Statistics, 21(2):224-270

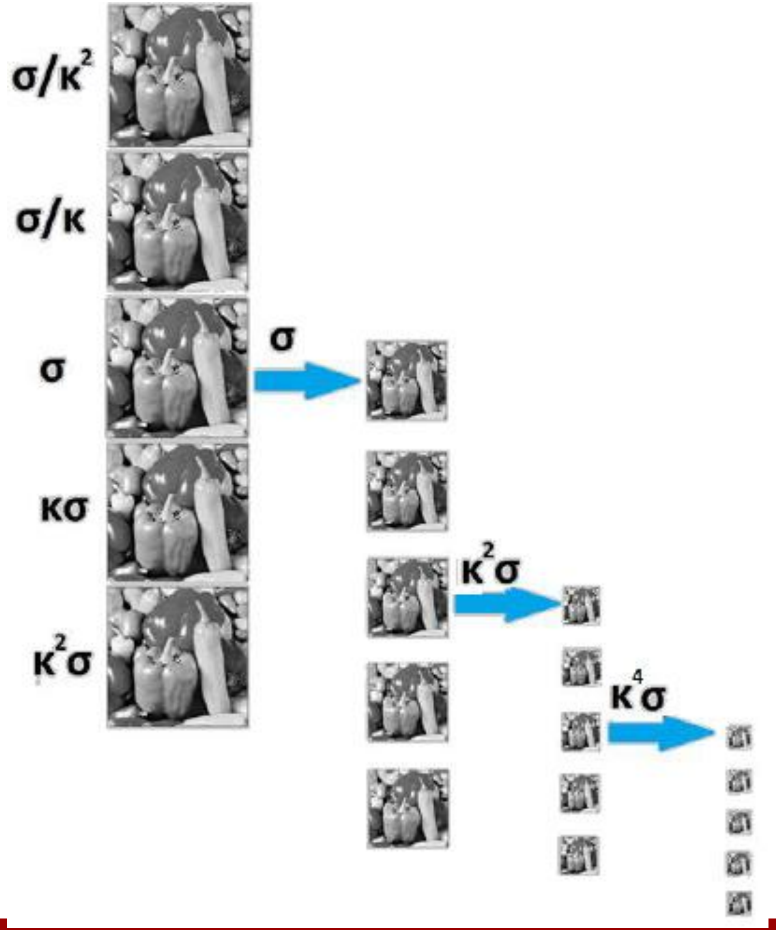
Lindeberg, Tony (1998). "Feature detection with automatic scale selection". International Journal of Computer Vision 30 (2): 79–116.

Feature Detection: Scale Space Theory

- We should be able to find these points which are prominent in different scales

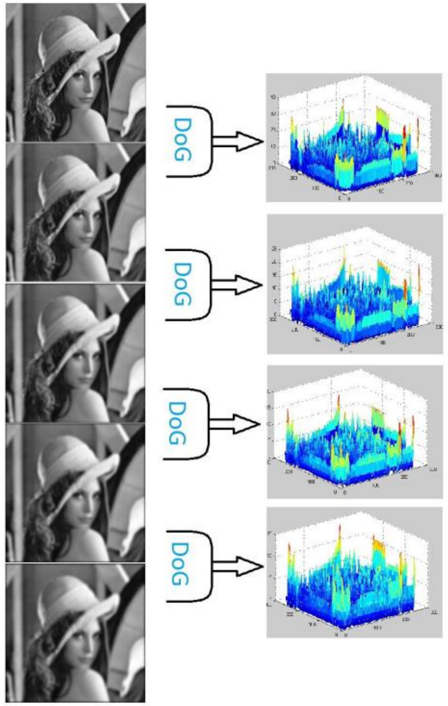
- Create octaves with different scale among them

- Different blur level (Gaussian) in them



Feature Detection: Difference of Gaussians

- The main point is the difference of Gaussians
- We can then do this on our scale-space:



The mother of Features - SIFT

- Ok, we’ve seen how we can find interest points, but how about matching??
- David Lowe published the most influential paper in computer vision:

> Lowe, D. Distinctive Image Features from Scale-Invariant Keypoints.International Journal of Computer Vision, 60, 2 , pp 91-110 (2004).

- How many people do you think have cited this?
- 60000!!!!

Scale Invariant Feature Transform - SIFT

Contains all:

- Detection
- Description
- Matching

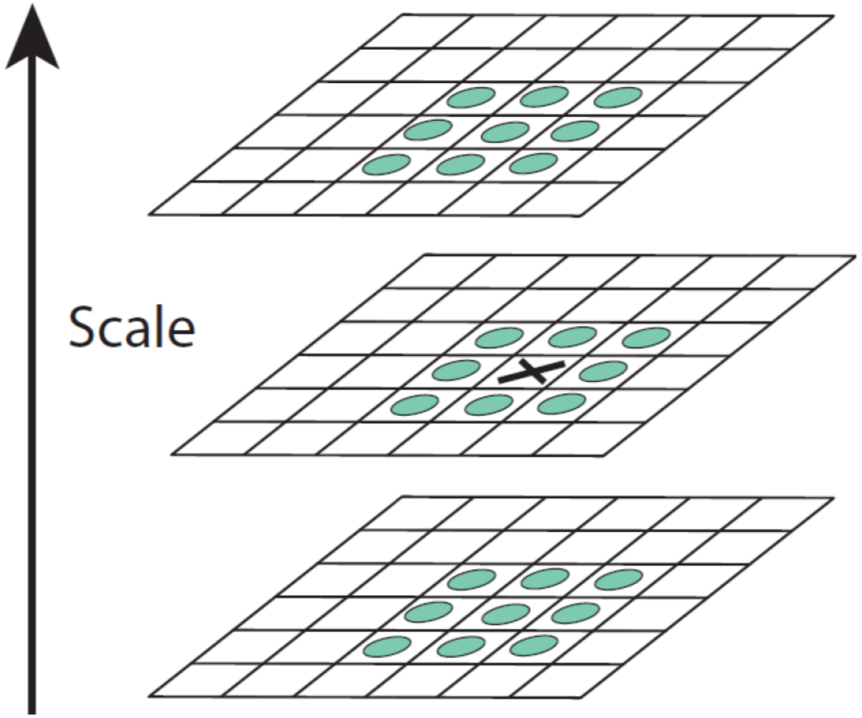
Main Feature is that it is robust in:

- Change of Translation
- Change in Scale
- Change in Rotation
- Change in 3D View Point
- Change in Illumination

Scale Invariant Feature Transform - SIFT

<u>Detection</u>

- Use DoG on Scale Space
  - Only the maximum or minimum in a neighborhood are considered
  - All octaves are investigated

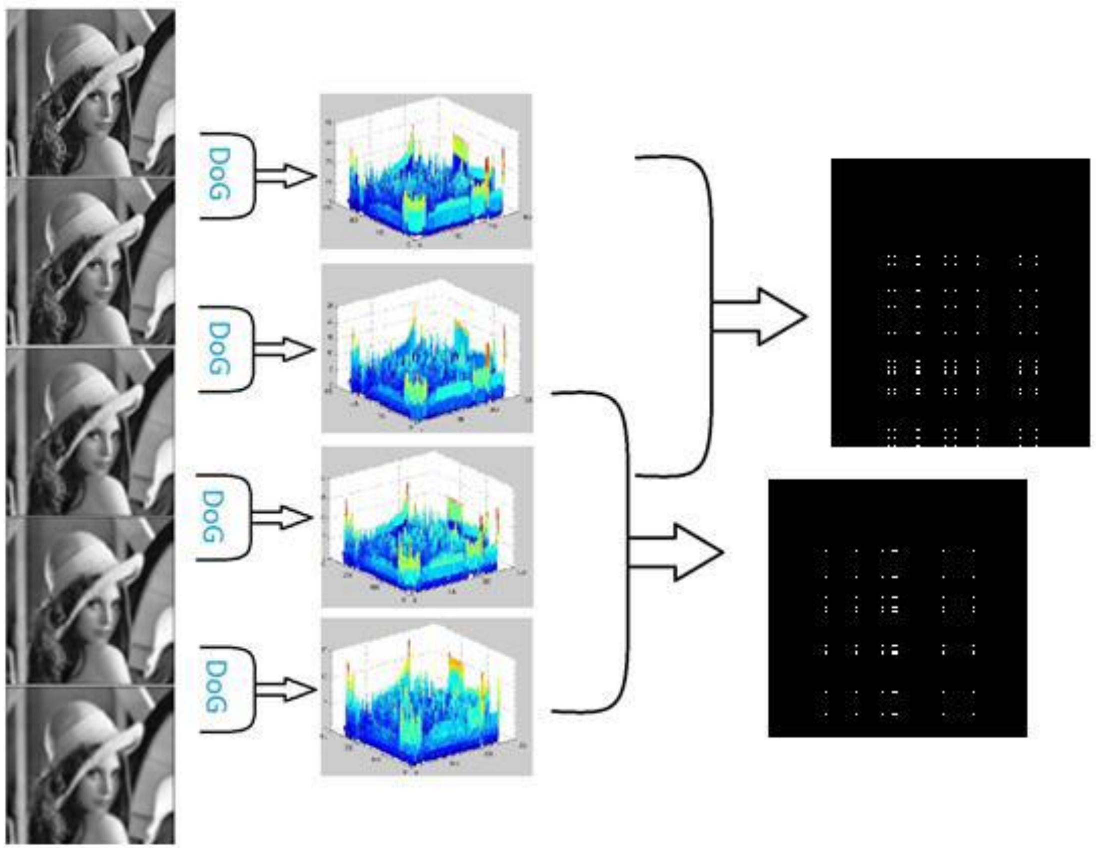


Scale Invariant Feature Transform - SIFT

<u>Detection</u>

- Use DoG on Scale Space
  - Only the maximum or minimum in a neighborhood are considered
  - All octaves are investigated

- Specifically,
  - In groups of 3
  - 2 Set of Points from each octave
  - 4 octaves -> 8 set of Points



Scale Invariant Feature Transform - SIFT

<u>Description</u>

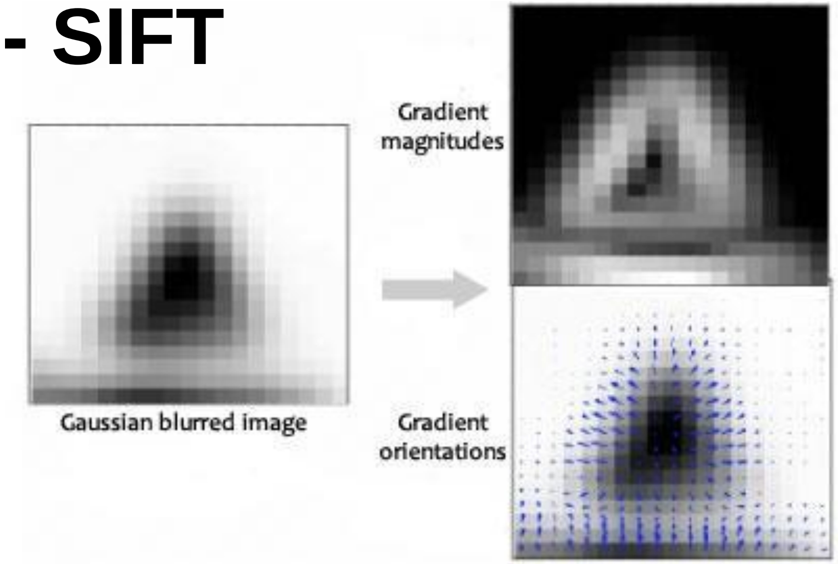
- Orientation:
  - Based on the gradient

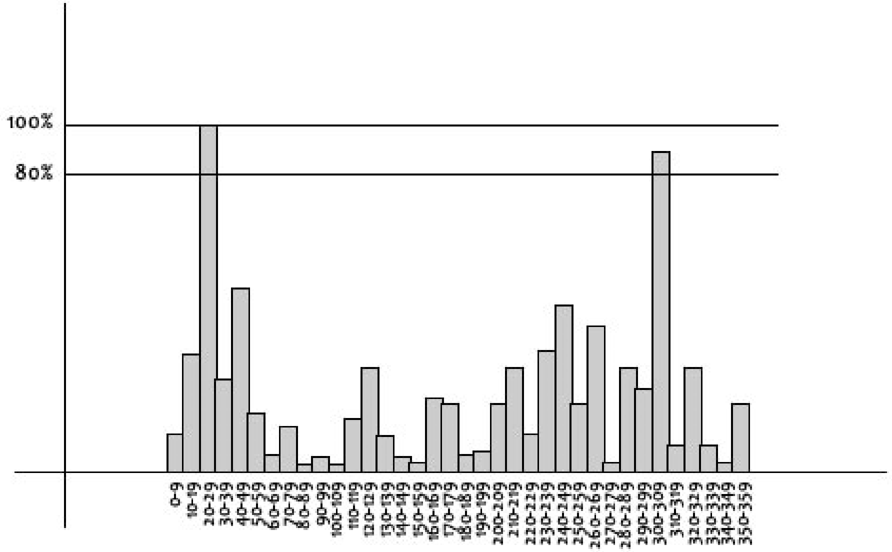
$$m(x,y) = \sqrt{(L(x+1,y) - L(x-1,y))^2 + (L(x,y+1) - L(x,y-1))^2}$$

$$\theta(x,y) = \tan^{-1}((L(x,y+1) - L(x,y-1))/(L(x+1,y) - L(x-1,y)))$$

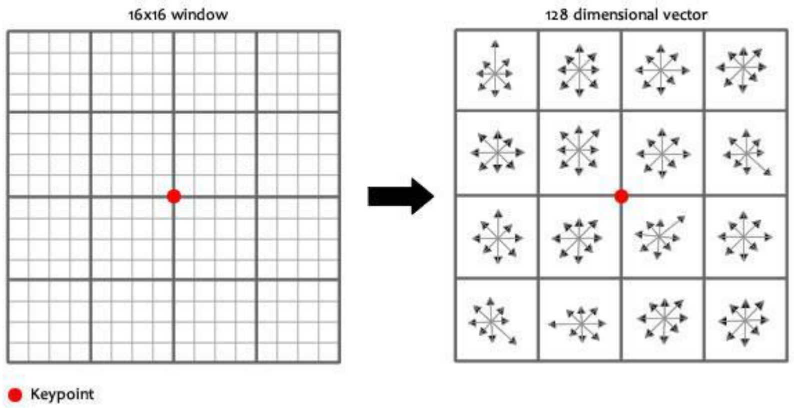
  - Create a histogram of orientations
    Consisting of 36 bins (every 10 degrees)

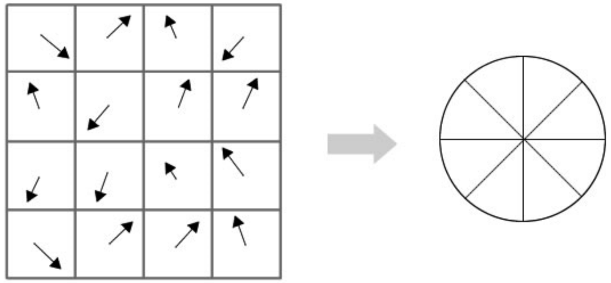
- Fingerprint

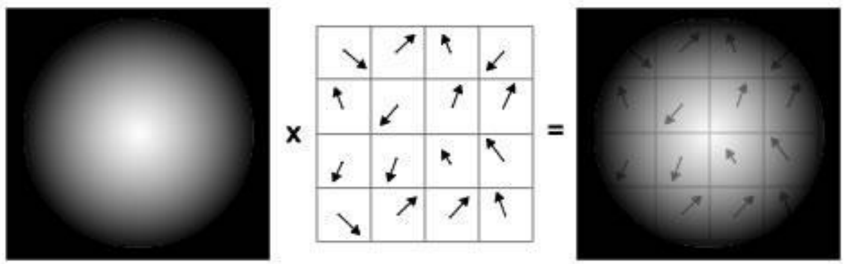




Scale Invariant Feature Transform - SIFT







<u>Description</u>

- Orientation
- Fingerprint:
  - Assume a 16 x 16 area around each Key Point
  - Create histogram with 8 bins (as before)
  - This gives out 128 values
    - Note that the values are scaled for proximity

Scale Invariant Feature Transform - SIFT

<u>Matching</u>

- Given some features from (let’s say) 2 Images:
- Lowe proposed the ALL-ALL Euclidean distance:

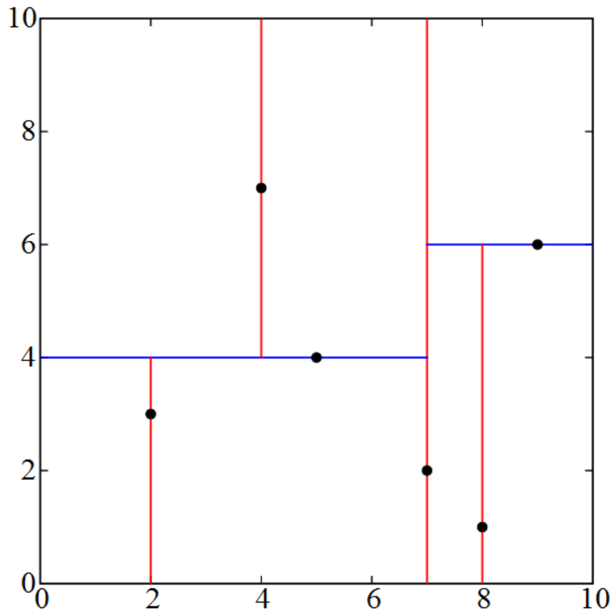
$$d(p,q)=\sqrt{(p1-q1)^2+(p2-q2)^2+(p3-q3)^2+\ldots+(pi-qi)^2+\ldots+(pn-qn)^2}$$

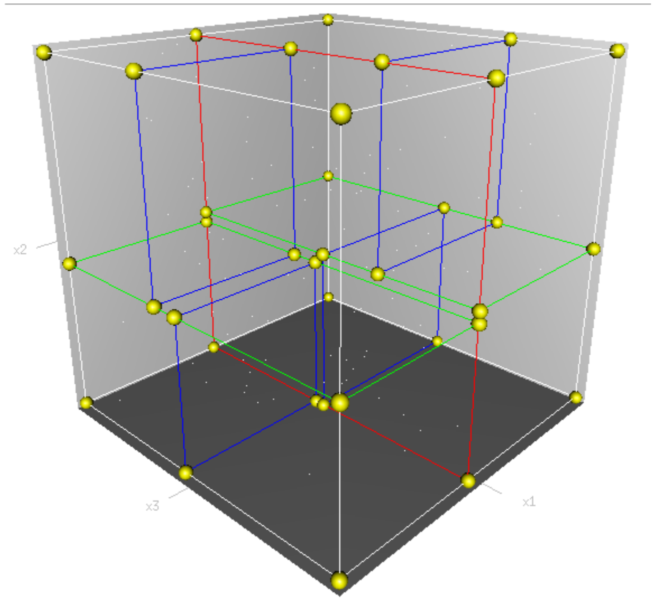
- For a 640x640 image we can get even 1000 features
- With 128 values each feature, you see how this can get ugly quickly

Scale Invariant Feature Transform - SIFT

<u>Matching</u>

- So our hero, proposed the usage of Kd-Trees:
- Creation:
  - You split the space in half based on distance
  - Then again
  - Then again,….
- Search:
  - Start from top
  - Is it closer to 1 than 2?
    - Go in 1
  - Is it closer to 1.1 than 1.2?
    - Go in 1.1
  - GO On until you find a feature





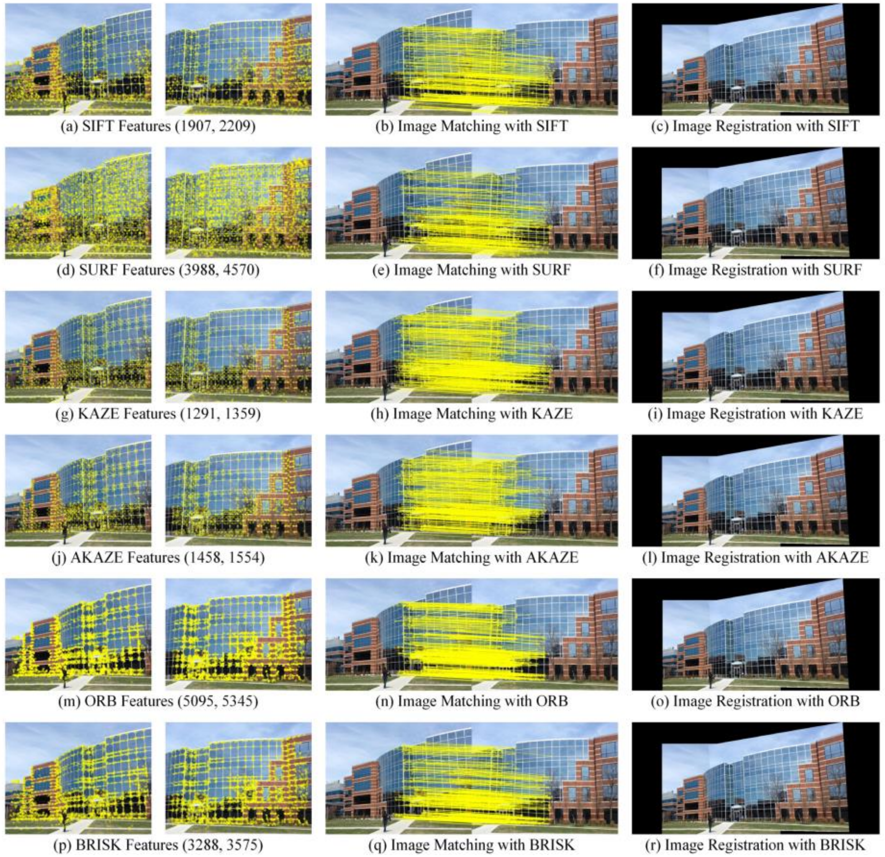
Feature points and areas

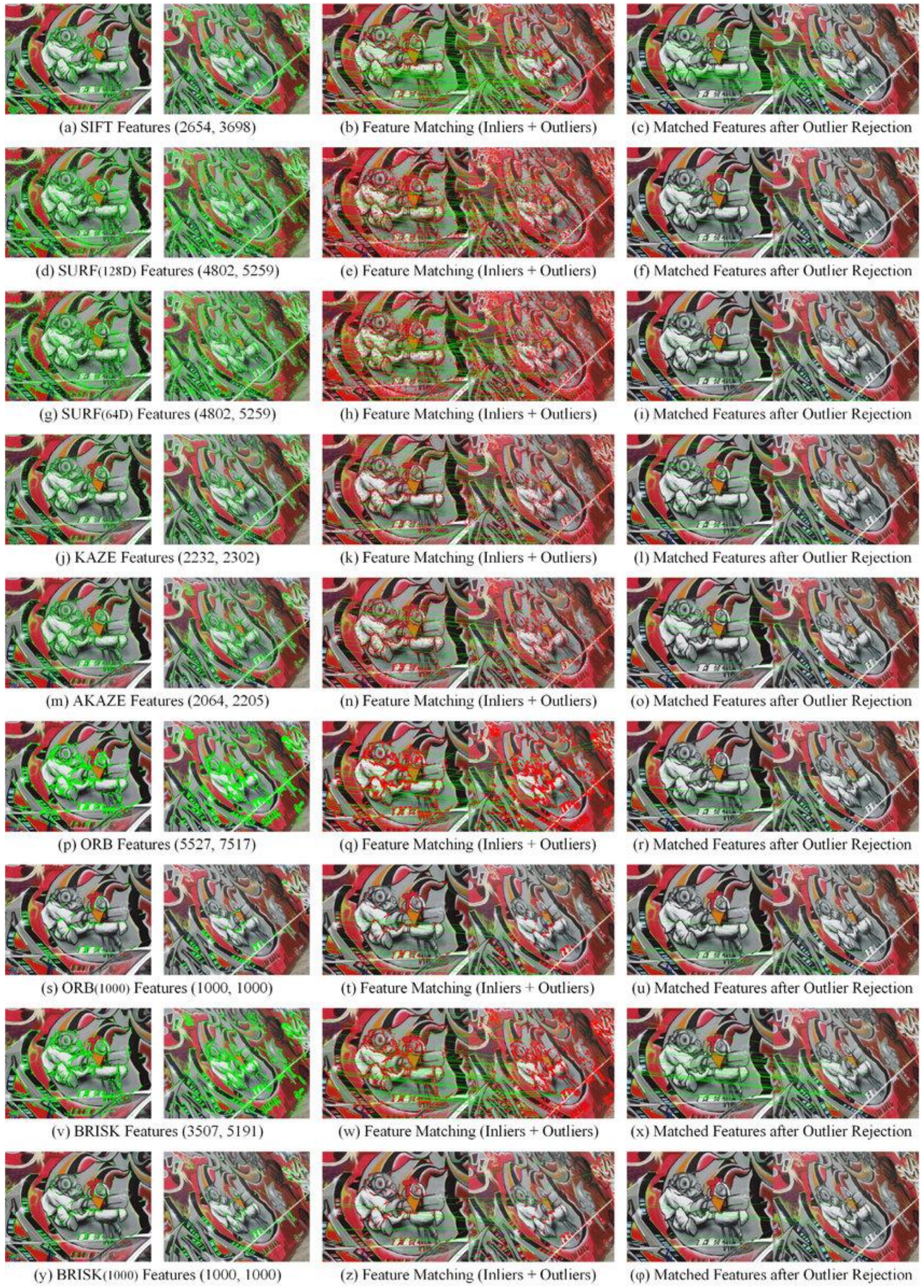
- A multitude of features have been proposed (specific for each application):
  - SIFT
  - SURF
  - BRISK
  - FREAK
  - MSER
  - ORB
  - …

Feature points and areas

- A multitude of features have been proposed (specific for each application):
  - SIFT
  - SURF
  - BRISK
  - FREAK
  - MSER
  - ORB
  - …
  - Patches

A special case to research





What applications do the Features have?

- More or less everything..

- Motion Estimation
- Localization
- Mapping
- Photogrammetry
- Image Retrieval
- Machine Learning
  - Object Detection
  - & Recognition
- Autonomous Driving
- ….
- More or less everything!

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- ….
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Image Feature Detection and Description

- What did we learn?
  - Is that a good feature?
  - How to get scale and rotational invariance in the features we get?
  - How to detect points of interest?
  - How to describe the feature of points so,
  - We can match them across multiple images.
  - How can we use features?

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