Image Features

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Example Application: Image Matching
Image Mosaicing
How can This be Done Automatically?
Image Local Structures

Step

Ridge

Valley

Peak

Corner

Junction
Image Local Structures

Line Structures: “Edge”

Point Structures: “Corners”
Regions
An Example

corners

dge

Region
Edge Detection in Matlab

```
>> im = imread('flower.jpg');
>> im = im2double(im);
>> im = rgb2gray(im);
>> ed = edge(im, 'canny', 0.15);
```
How to Find an Edge?

A 1D edge
Extend to 2D

There is a direction in which image \( f(x,y) \) increases the fastest. The direction is called the gradient direction.

Gradient \([df/dx \, df/dy]\)
Magnitude: \( \sqrt{fx^2 + fy^2} \)
Direction: \( \text{atan2}(fy, fx) \)
Finite Difference

- Approximating derivatives using finite difference.

- Finite difference and convolution
Noise Reduction

0.01 noise

0.03 noise
Noise Reduction
Gaussian Filtering in Edge Detection
Gaussian Filtering in Edge Detection

\[ h \ast (g \ast f) = (h \ast g) \ast f \]

Difference Kernel  Gaussian Kernel  Difference of Gaussian Kernel

![3D graph of Gaussian kernel](image1)

![3D graph of difference kernel](image2)
Edge Detection in Images

- Gaussian smoothed filtering in x and y directions: $I_x, I_y$
- Non-maximum suppression for $|I_x| + |I_y|$

- Edge Tracing – double thresholding.
Edge Detection Using Matlab

- Canny edge detector:
  ```
  edge(image, 'canny', threshold)
  ```
- Sobel edge detector:
  ```
  edge(image, 'sobel', threshold)
  ```
- Prewitt edge detector:
  ```
  edge(image, 'prewitt', threshold)
  ```
Berkeley Segmentation DataSet [BSDS]

Corner Detection

- Corner is a point feature that has large changing rate in all directions.

![Diagram showing Corner Detection with Step, Line, Corner, and Flat region illustrations.]
Harris corner detector

- C.Harris, M.Stephens. “A Combined Corner and Edge Detector”. 1988
The Basic Idea

- We should easily recognize the point by looking through a small window.
- Shifting a window in *any direction* should give a *large change* in intensity.
Harris Detector: Basic Idea

“flat” region: no change in all directions

“edge”: no change along the edge direction

“corner”: significant change in all directions
Find a Corner

Compute matrix $H =$

$$\begin{bmatrix}
\sum f_x^2 & \sum f_x f_y \\
\sum f_x f_y & \sum f_y^2 \\
\end{bmatrix}$$

$$= \begin{bmatrix}
I_{x2} & I_{xy} \\
I_{xy} & I_{y2} \\
\end{bmatrix}$$

in each window. If the ratio

$$(I_{x2} * I_{y2} - I_{xy}^2)$$

$R = \frac{(I_{x2} + I_{y2} + \text{eps})}{(I_{x2} + I_{y2} + \text{eps})} > T$

We have a corner
Harris Detector: Workflow
Harris Detector: Workflow

Compute corner response $R$
Harris Detector: Workflow

Find points with large corner response: $R > \text{threshold}$
Harris Detector: Workflow

Take only the points of local maxima of $R$
Harris Detector: Workflow
Corner Detection Programming
Harris Detector: Some Properties

- Rotation invariance

Ellipse rotates but its shape (i.e. eigenvalues) remains the same

Corner response $R$ is invariant to image rotation
Harris Detector: Some Properties

- Partial invariance to affine intensity change

✓ Only derivatives are used $\Rightarrow$ invariance to intensity shift $I \rightarrow I + b$

✓ Intensity scale: $I \rightarrow a I$

![Graph showing the Harris Detector properties](image)
Harris Detector: Some Properties

- But: non-invariant to *image scale*!

All points will be classified as *edges*.

Corner!