
Image Features (I)

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Image Features

Image features – may appear in two contexts:

- Global properties of the image (average gray level, etc) – **global features**
- Parts of the image with special properties (line, circle, textured region) – **local features**

Here, assume second context for **image features**:

- Local, meaningful, detectable parts of the image
- Should also be invariant to changes in the image

Detection of image features

- Detection algorithms – produce feature descriptors
 - Feature descriptors – often just high dimensional vectors
- Example – line segment descriptor: coordinates of mid-point, length, orientation

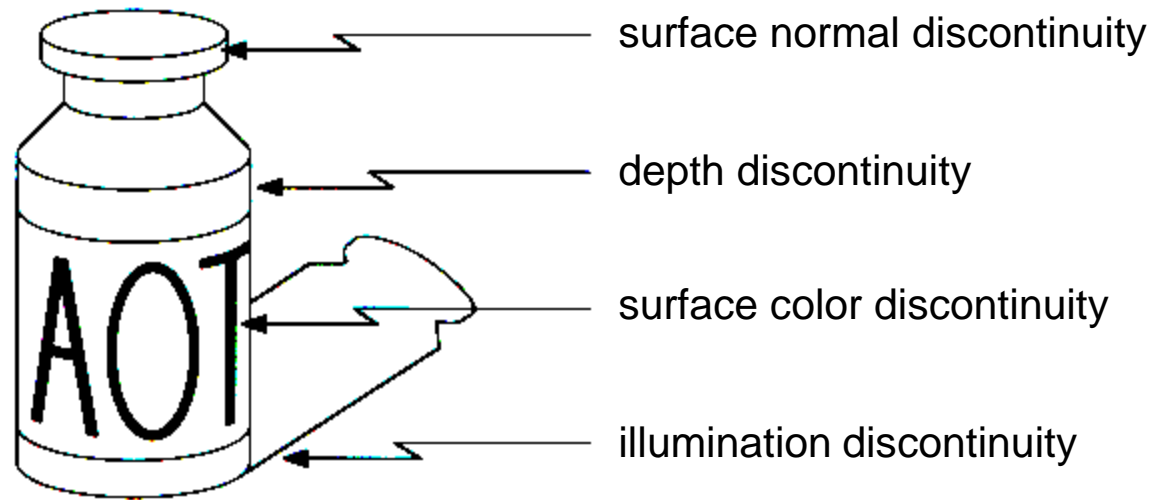
Edges in Images

Definition of **edges**

- Edges are significant local changes of intensity in an image.
- Edges typically occur on the boundary between two different regions in an image.



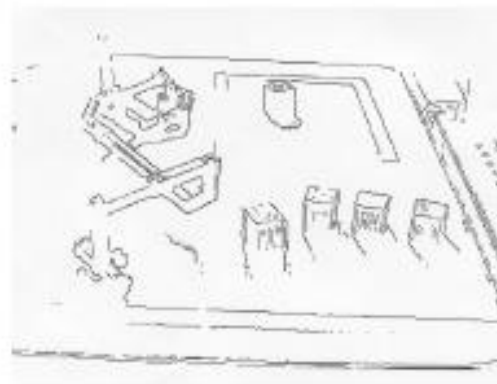
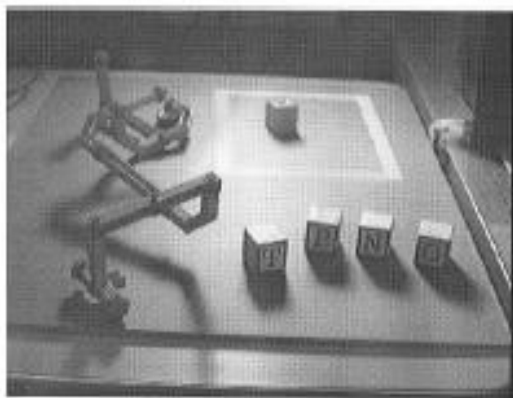
Origin of Edges



Edges are caused by a variety of factors

What causes intensity changes?

- Geometric events
 - object boundary (discontinuity in depth and/or surface color and texture)
 - surface boundary (discontinuity in surface orientation and/or surface color and texture)
- Non-geometric events
 - specularity
 - shadows (from other objects or from the same object)
 - inter-reflections

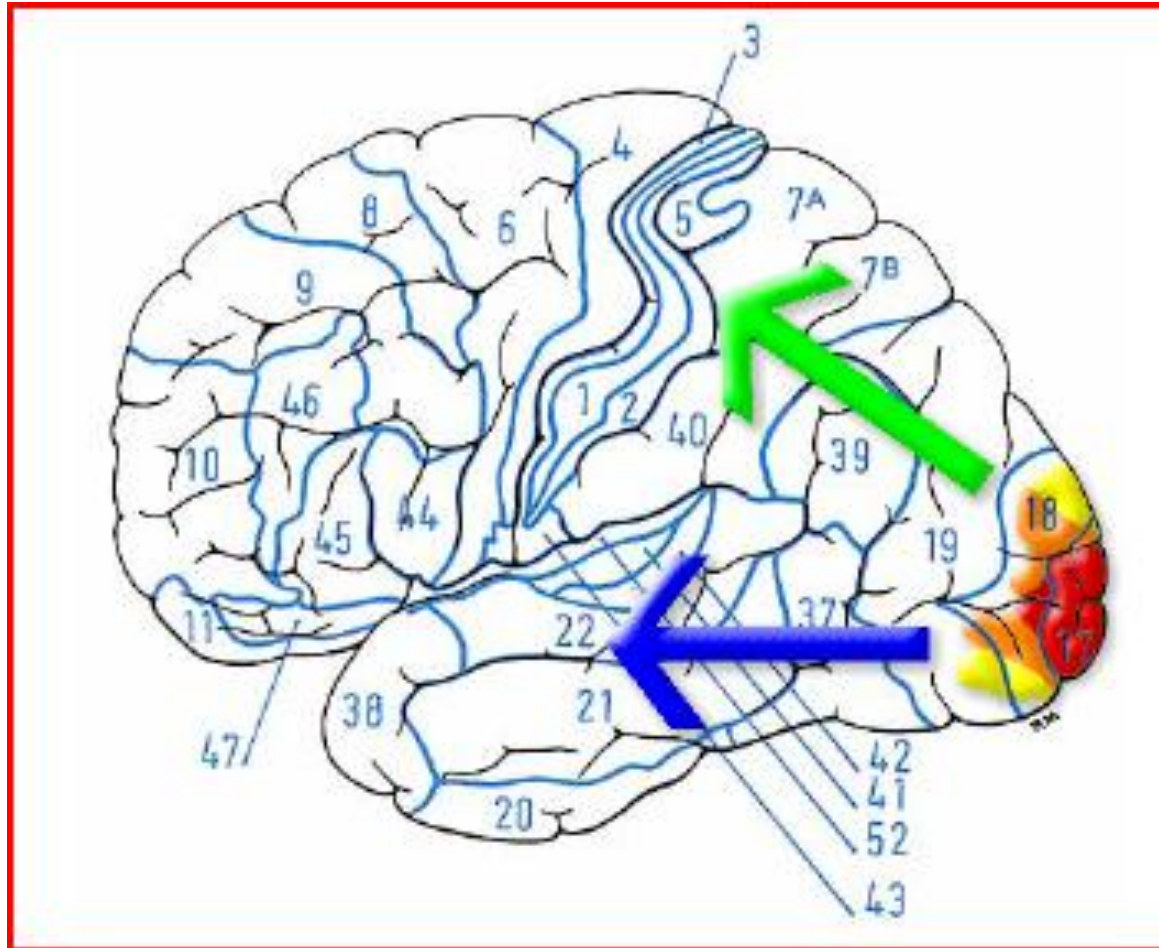


An edge is not a line...



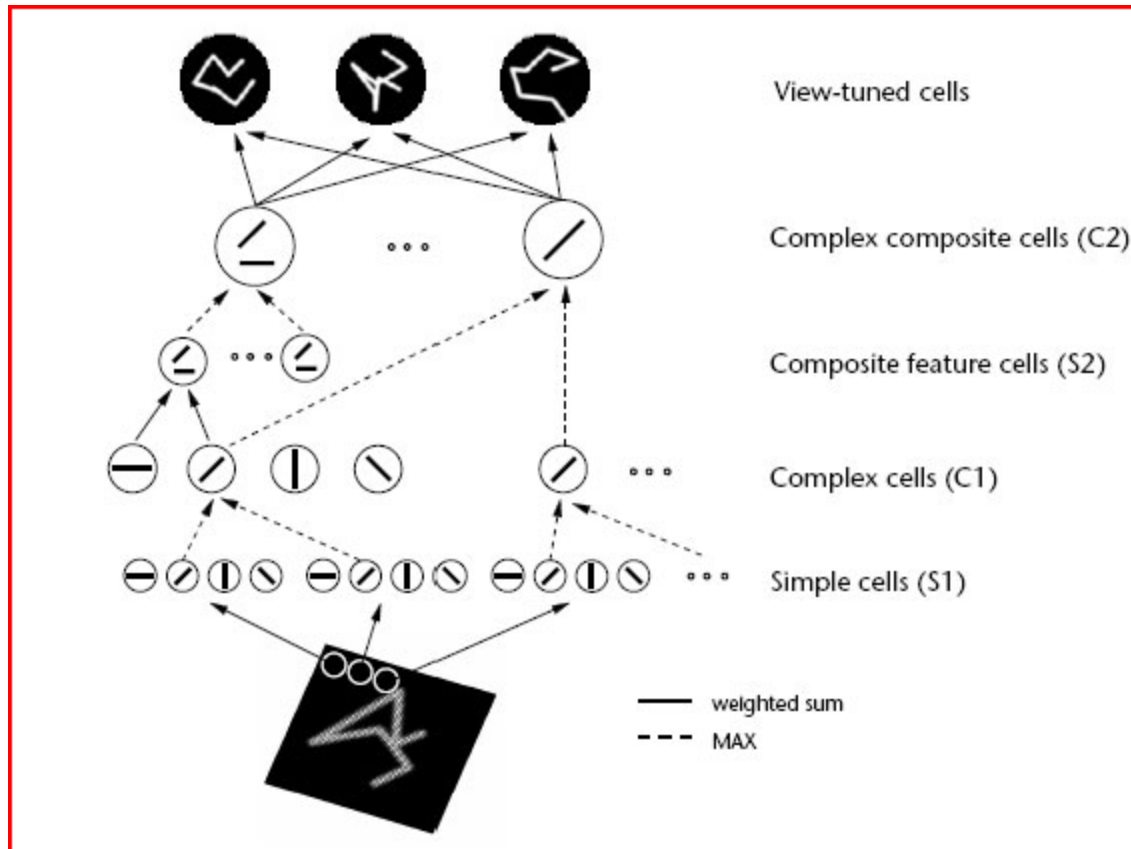
Human visual system computes edges

- Regions of brain called V1 (in red) find edges

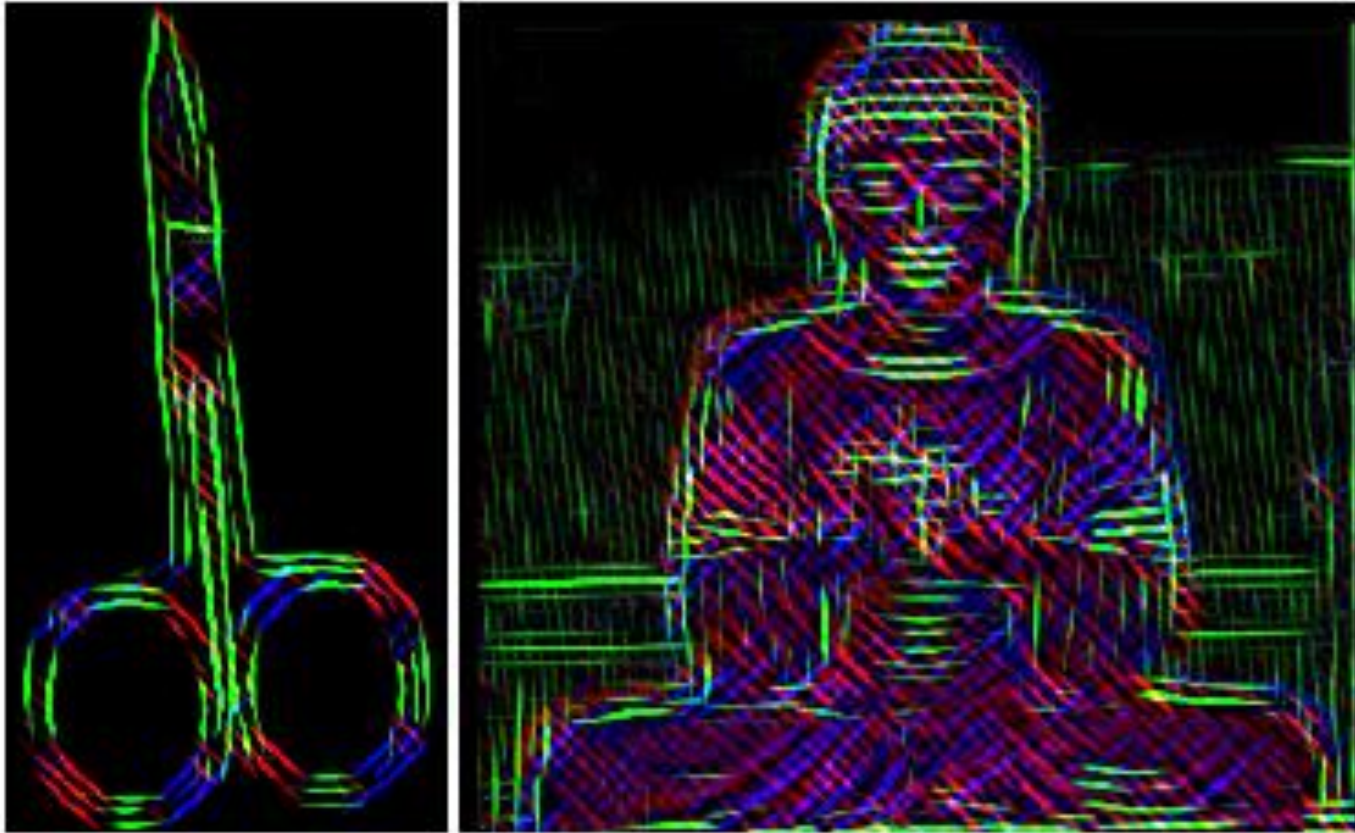


Simple and Complex cell

- These cells are local feature detectors

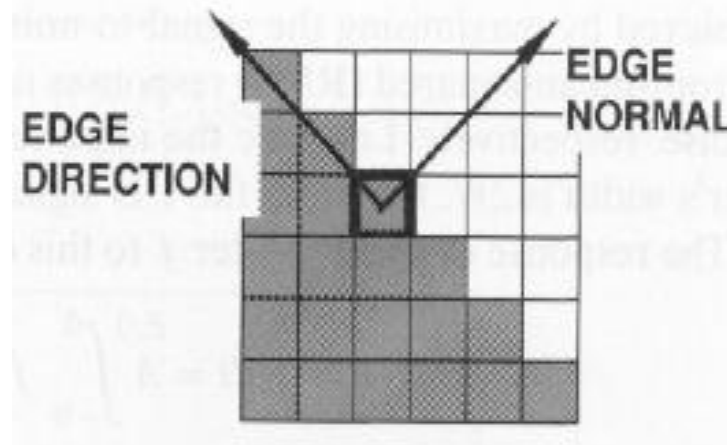


Result is an “edge like” representation



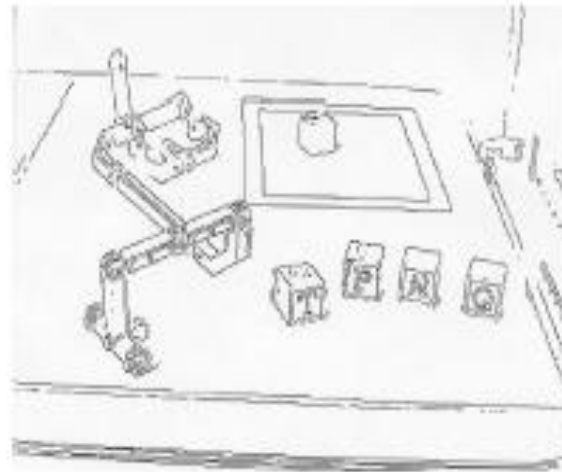
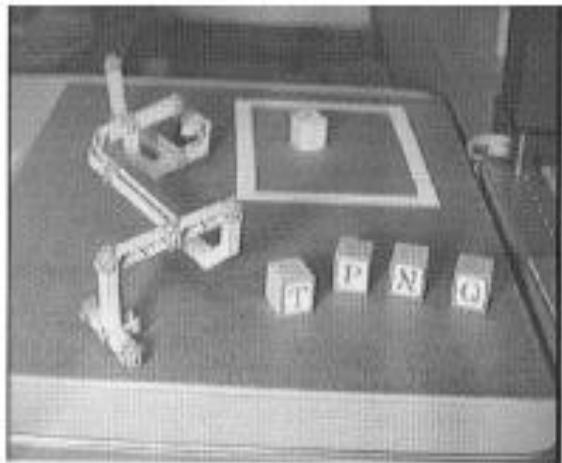
Edge Pixel Descriptors

- Edges are a connected set of edge pixels, each edge pixel has:
- **Edge normal**: unit vector in the direction of maximum intensity change.
 - Often called edge gradient (orthogonal to the edge direction)
- **Edge direction**: unit vector to perpendicular to the edge normal.
- **Edge position or center**: the pixel position at which the edge is located.
- **Edge strength**: related to the local image contrast along the normal.



Applications of Edge Detection

- Produce a line drawing of a scene from an image of that scene.
- Important features can be extracted from the edges of an image (e.g. corners, lines, curves).
- These features are used by higher-level computer vision algorithms (e.g., segmentation, recognition, retrieval).

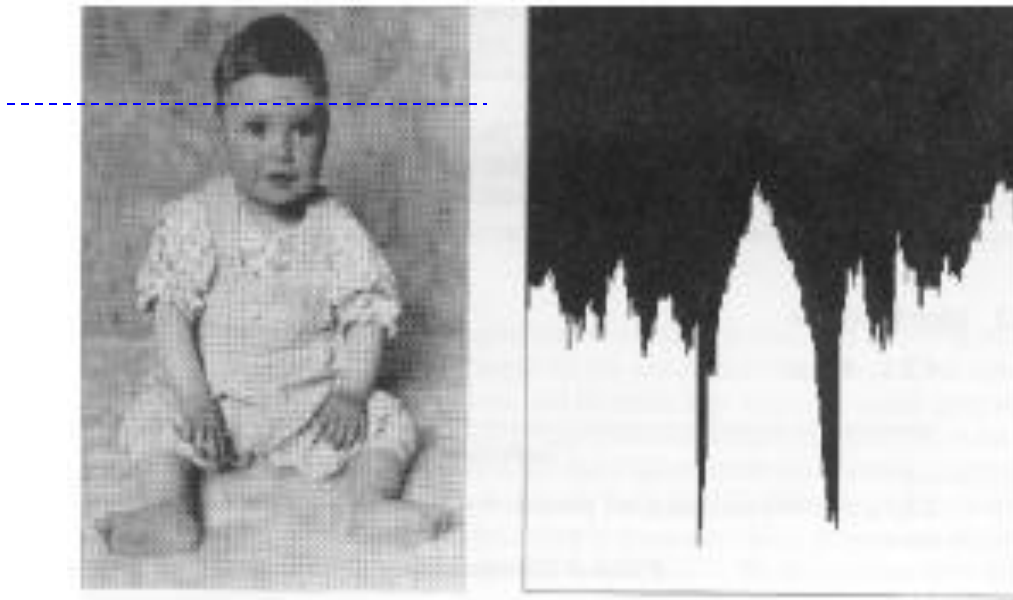


Three Steps of Edge Detection

- Noise smoothing
 - Suppress the noise without affecting the true edges
 - Often blur the image with Gaussian kernel of a given sigma
- Edge enhancement
 - Design a filter responding to edges, so that the output of the filter is large at edge pixels, so edges are localized as maxima in the filters response
- Edge localization
 - Decide which local maxima in the filters output are edges, and which are caused by noise. This usually involves:
 - Thinning the edges to 1 pixel width (non-maxima suppression)
 - Establish the minimum value to declare a local maxima as a true edge (thresholding)

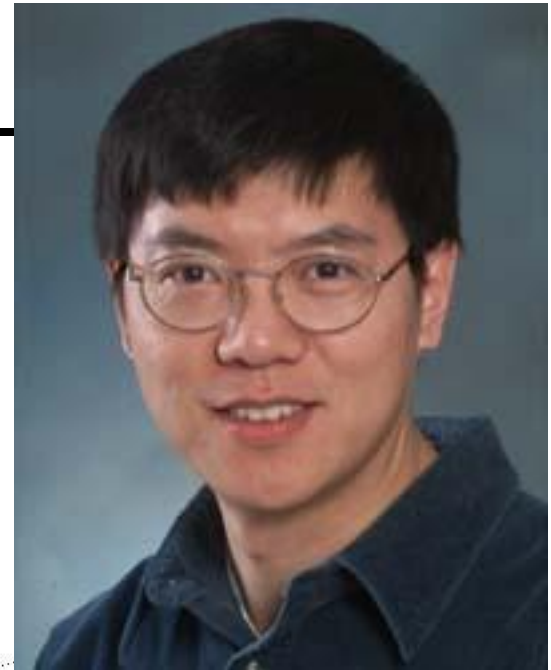
Images as Functions

1-D

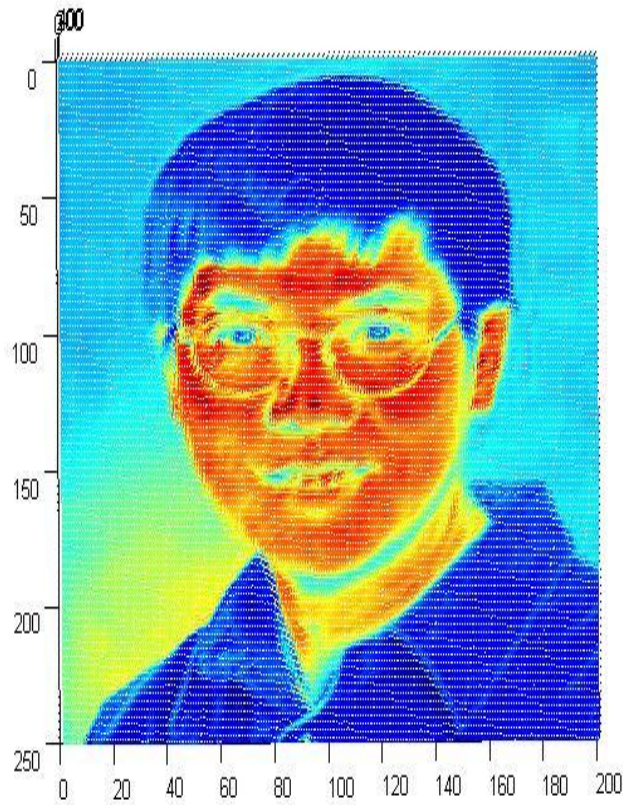


$$I = f(x)$$

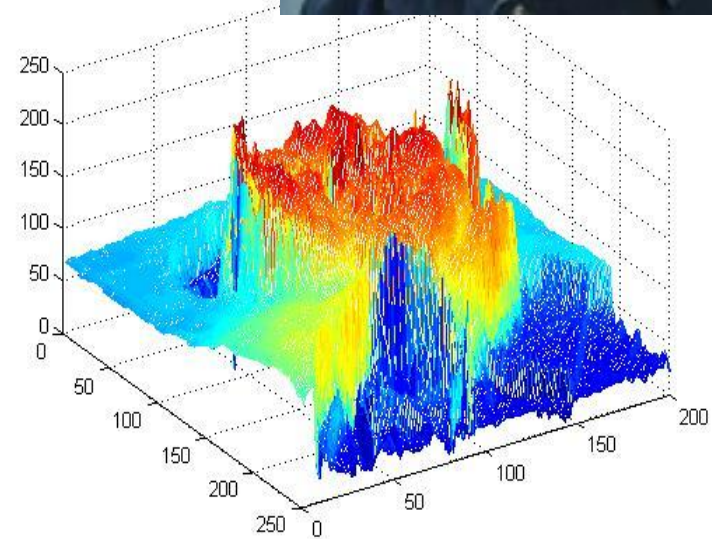
Images as Functions



2-D



Red channel intensity



$$I = f(x, y)$$

Edge Detection using Derivatives

- Calculus describes changes of continuous functions using *derivatives*.
- An image is a 2D function, so operators finding edges are based on *partial derivatives*.
- Points which lie on an edge can be detected by either:
 - **detecting local maxima or minima of the first derivative**
 - **detecting the zero-crossing of the second derivative**
- Here we assume that there is no smoothing in the edge detection process
 - We are only looking at enhancement and localization

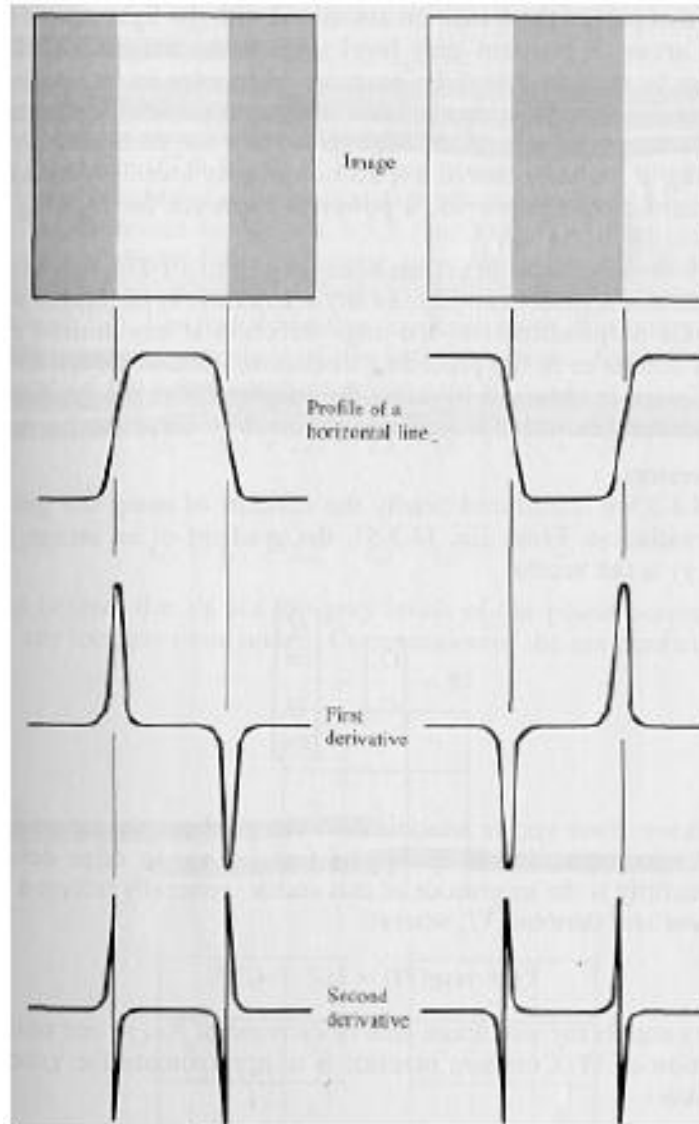
Edge Detection Using Derivatives

image

profile of a
horizontal line

first derivative

second derivative



Finite Difference Method

We approximate derivatives with differences.

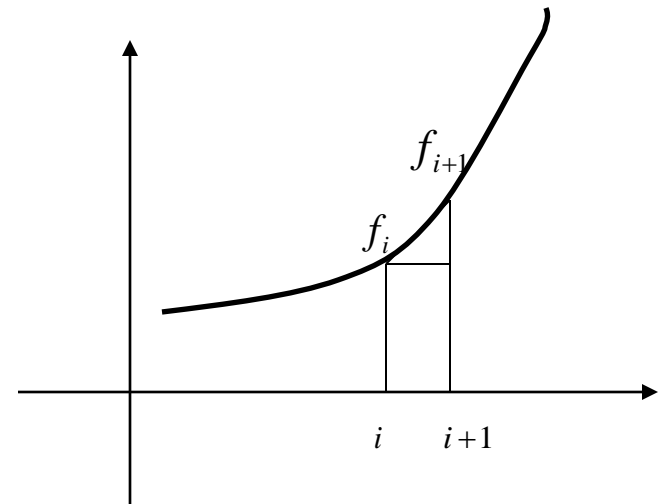
Derivative for 1-D signals:

Continuous function

$$f'(x) = \lim_{h \rightarrow 0} \frac{f(x+h) - f(x)}{h}$$

Discrete approximation

$$f'(x) \approx \frac{f_{i+1} - f_i}{i+1 - i} = f_{i+1} - f_i$$



Finite Difference and Convolution

Finite difference on a 1-D image

$$f'(x) \approx f(x_{i+1}) - f(x_i)$$

is equivalent to convolving with kernel: $\begin{bmatrix} -1 & 1 \end{bmatrix}$

Finite Difference – 2D

Continuous function:

$$\frac{\partial f(x, y)}{\partial x} = \lim_{h \rightarrow 0} \frac{f(x+h, y) - f(x, y)}{h}$$

$$\frac{\partial f(x, y)}{\partial y} = \lim_{h \rightarrow 0} \frac{f(x, y+h) - f(x, y)}{h}$$

Discrete approximation:

$$I_x = \frac{\partial f(x, y)}{\partial x} \approx f_{i+1,j} - f_{i,j}$$

$$I_y = \frac{\partial f(x, y)}{\partial y} \approx f_{i,j+1} - f_{i,j}$$

Convolution kernels:

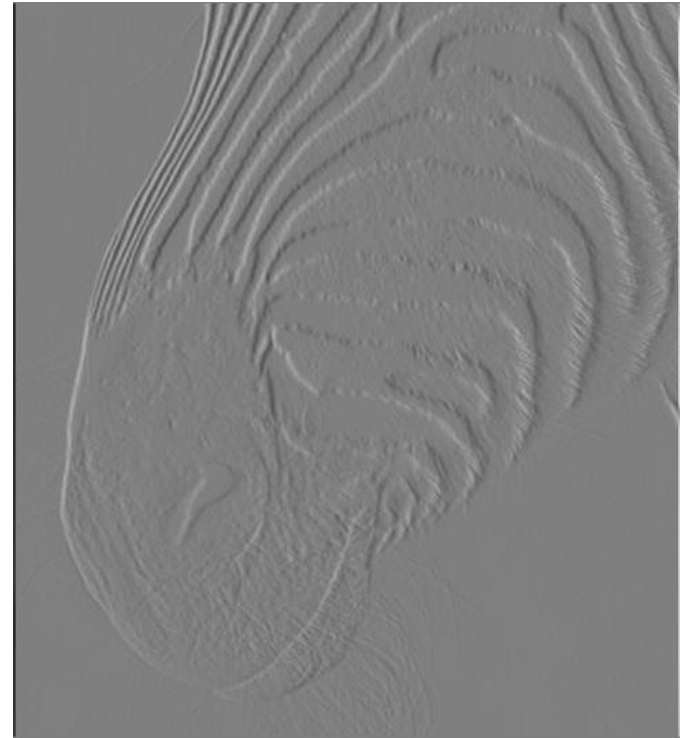
$$\begin{bmatrix} -1 & 1 \end{bmatrix}$$

$$\begin{bmatrix} -1 \\ 1 \end{bmatrix}$$

Image Derivatives



Image I



$$I_x = I * [-1 \ 1]$$

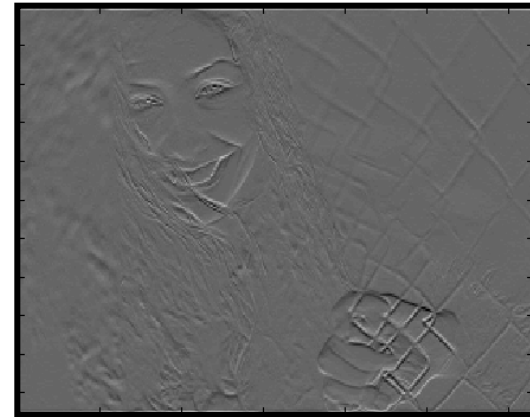
Image Derivatives



Image I



$$I_x = I * \begin{bmatrix} -1 & 1 \end{bmatrix}$$



$$I_y = I * \begin{bmatrix} -1 \\ 1 \end{bmatrix}$$