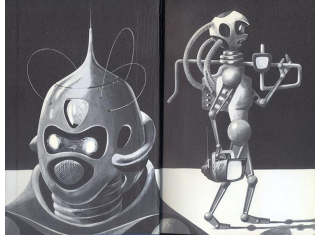


Edge Detection

Introduction to Computer Vision
CSE 152
Lecture 9



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Intro Computer Vision

Announcements

- Assignment 2 assigned and due Tuesday, May 3.
- Midterm: Thursday, May 5.

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Convolution

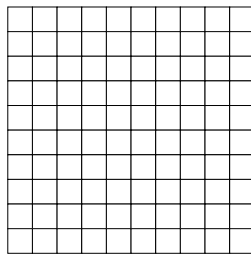
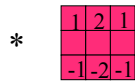


Image (I)



*

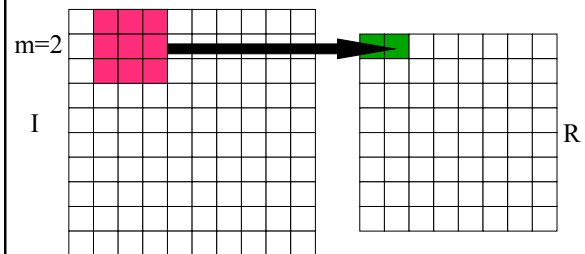
Kernel (K)

Note: Typically Kernel is relatively small in vision applications.

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Convolution: $R = K * I$



Kernel size is $m+1$ by $m+1$

$$R(i, j) = \sum_{h=-m/2}^{m/2} \sum_{k=-m/2}^{m/2} K(h, k) I(i-h, j-k)$$

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Properties of convolution

Let f, g, h be images and $*$ denote convolution

$$f * g(x, y) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(x-u, y-v) g(u, v) du dv$$

- Commutative: $f * g = g * f$
- Associative: $f * (g * h) = (f * g) * h$
- Linear: for scalars a & b and images f, g, h
 $(af + bg) * h = a(f * h) + b(g * h)$
- Differentiation rule

$$\frac{\partial}{\partial x} (f * g) = \frac{\partial f}{\partial x} * g = f * \frac{\partial g}{\partial x}$$

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Gaussian Noise:
sigma=1



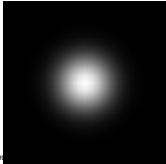
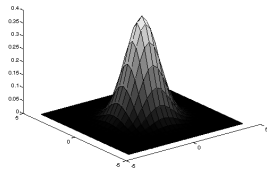
Gaussian Noise:
sigma=16



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An Isotropic Gaussian



- The picture shows a smoothing kernel proportional to

$$e^{-\frac{x^2 + y^2}{2\sigma^2}}$$

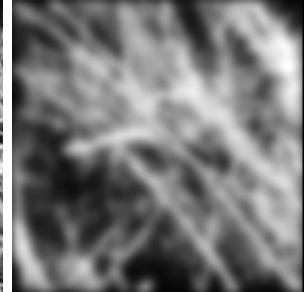
(which is a reasonable model of a circularly symmetric fuzzy blob)

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Smoothing with a Gaussian

Kernel:



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Other Types of Noise

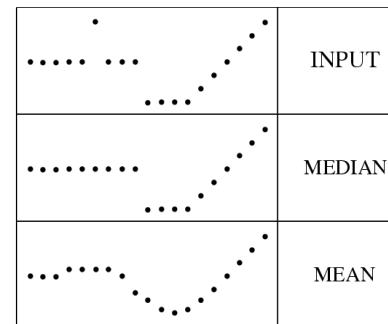
- Impulsive noise
 - randomly pick a pixel and randomly set to a value
 - saturated version is called salt and pepper noise
- Quantization effects
 - Often called noise although it is not statistical
- Unanticipated image structures
 - Also often called noise although it is a real repeatable signal.

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Median filters : example

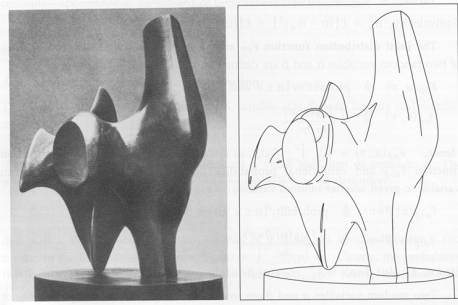
filters have width 5 :



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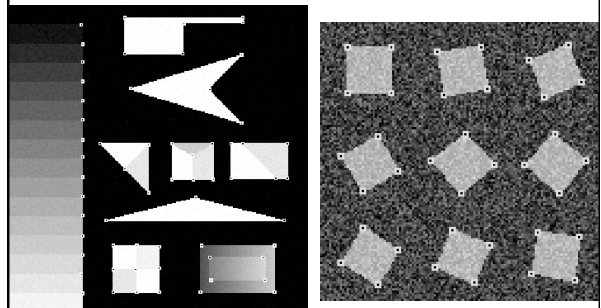
Edges



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Corners



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Physical causes of edges

1. Object boundaries
2. Surface normal discontinuities
3. Reflectance (albedo) discontinuities
4. Lighting discontinuities (shadow boundaries)

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Object Boundaries



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Surface normal discontinuities

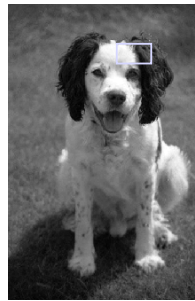


Surface
normal
changes

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Boundaries of materials properties



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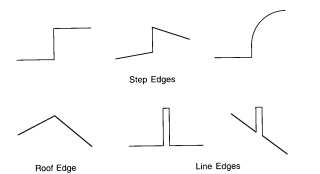
Boundaries of lighting



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Profiles of image intensity edges

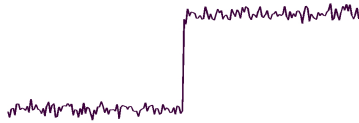


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Noisy Step Edge

- Derivative is high everywhere.
- Must smooth before taking gradient.

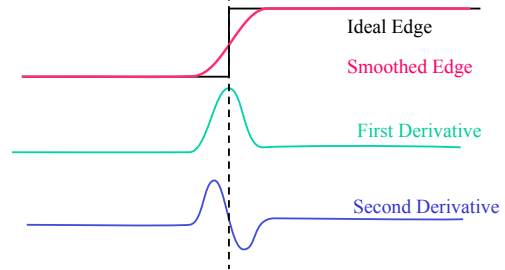


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Edge is Where Change Occurs: 1-D

- Change is measured by derivative in 1D

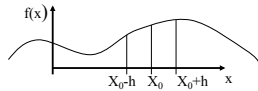


- Biggest change, derivative has maximum magnitude
- Or 2nd derivative is zero.

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Numerical Derivatives



Take Taylor series expansion of $f(x)$ about x_0

$$f(x) = f(x_0) + f'(x_0)(x - x_0) + \frac{1}{2} f''(x_0)(x - x_0)^2 + \dots$$

Consider Samples taken at increments of h and first two terms, we have

$$f(x_0 + h) = f(x_0) + f'(x_0)h + \frac{1}{2} f''(x_0)h^2$$

$$f(x_0 - h) = f(x_0) - f'(x_0)h + \frac{1}{2} f''(x_0)h^2$$

Subtracting and adding $f(x_0 + h)$ and $f(x_0 - h)$ respectively yields

$$f'(x_0) = \frac{f(x_0 + h) - f(x_0 - h)}{2h}$$

$$f''(x_0) = \frac{f(x_0 + h) - 2f(x_0) + f(x_0 - h))}{h^2}$$

Convolve with

First Derivative: $[-1/2h \ 0 \ 1/2h]$

Second Derivative: $[-1/h^2 \ 2/h^2 \ -1/h^2]$

Can often drop h or h^2 in denominator
Yielding $[-1 \ 0 \ 1]$ and $[-1 \ 2 \ -1]$

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