Yale University
Department of Computer Science

CS475/CS575/EE475: Computational Vision and Biological Perception

Problem Set #2

Due on Friday, March 7, 2008.

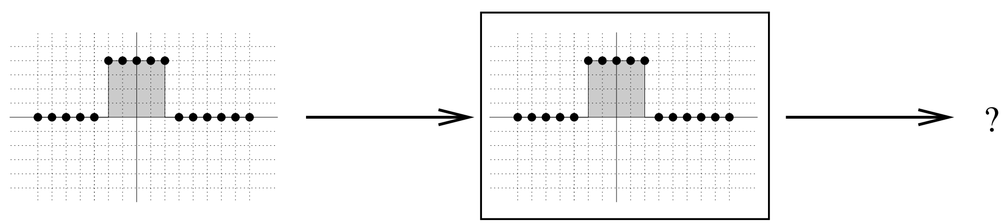
General Instructions

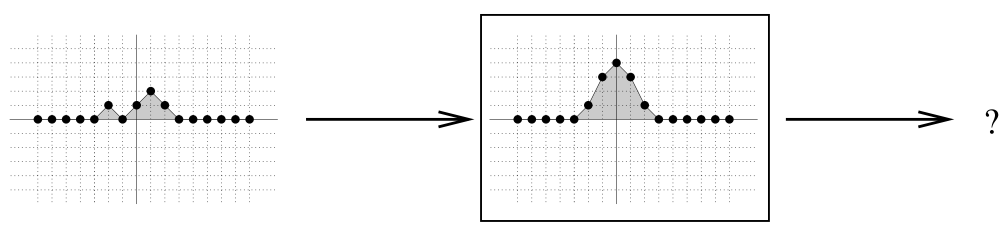
Images available at `http://zoo.cs.yale.edu/classes/cs475/image.html`.

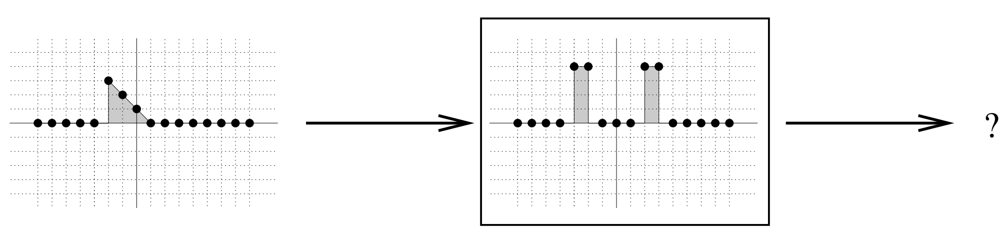
If you would like to submit your answers electronically (problems 2 and 3), please leave a copy in your zoo cs475 directory. Create a subdirectory called `hw2` and name the file `hw2-yourname.pdf` or `hw2-yourname.doc`.

1 Convolution

Inside the following boxes you are given the impulse response of a few linear systems (left column). Manually compute and draw the output of each system to the signal (right column). Assume the grid represents integers centered at (0,0). Apply your computations only to the integer points.







2 Smoothing Filter

Design and implementation of a linear, space-invariant 2-by-2 smoothing filter using MATLAB.

(a) Define a 2-by-2 matrix `L` that performs smoothing. You should give the four entries of the matrix and use `conv2` to apply it to an image. Explain your reasoning.

(b) Apply the filter $n = 0, 1, 5$, and 20 times to the Paolina image and display the result as an image. After each of the four cases, answer the following:

i. Where does smoothing help? Where does it not help?

ii. Take the histogram (using `imhist`) of the result. Note the dynamic range – the difference between the minimum and the maximum intensity. What do you observe?

(c) Add noise to the original image with `imnoise`. Repeat part (a).

3 Lateral Inhibition

Design and implementation of a linear, space-invariant, 3-by-3 Difference of Gaussian (DoG) filter using MATLAB. Recall that the 2-D Gaussian is given by the following equation:

$$G_\sigma(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-x_0)^2+(y-y_0)^2}{2\sigma^2}}$$

where (x_0, y_0) is the center and σ^2 is the variance. Now, the Laplacian of Gaussian is

$$LoG_\sigma(x,y) = \frac{\partial^2}{\partial x^2}G_\sigma + \frac{\partial^2}{\partial y^2}G_\sigma = -\frac{1}{\sqrt{2\pi\sigma^2}} \frac{(x-x_0)^2+(y-y_0)^2-2\sigma^2}{\sigma^4} e^{-\frac{(x-x_0)^2+(y-y_0)^2}{2\sigma^2}}$$

(a) Define a 3-by-3 matrix of integer coordinates for the LoG where (x_0, y_0) is the center of the matrix, i.e. the entry (2,2). Use $\sigma = 0.5, 1, 2$.

(b) Define two 3-by-3 matrices G_1 and G_2 each of which is a Gaussian filter with variance σ_1 and σ_2. Choose σ_1 and σ_2 so that $DoG = G_1 - G_2$ best approximates the LoG computed above. The DoG matrix is known as the Difference of Gaussian approximation to the Laplacian of Gaussian.

(c) Apply your smoothing filter as in 2(b) above. After each of the four cases, apply your DoG filter. What happens?

(d) Add noise to the original image as in 2(c). Repeat 3(c).

(e) Does this procedure have anything in common with the lateral inhibition system of the Limulus? Explain briefly.

(f) Repeat 3(c) and, for each of the four cases, run `edge(image, 'zerocross', thresh, L)` where `thresh` is a positive threshold value and `L` is your filter. Comment briefly.