UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
Department of Electrical and Computer Engineering

ECE 498MH Signal and Image Analysis

Solutions 3

Fall 2013

Assigned: Friday, September 20, 2013 Due: Friday, September 27, 2013

Reading: Signal Processing First (SPF) Chapter 5

Problem 3.1

(a) $y[n] = x[n] - x[0]$ is linear.

(b) $y[n] = x[n] - 1$ is nonlinear (a system like this, nonlinear only because of the constant offset, is called "affine"). For example,

$$\begin{aligned} x_1[n] = \cos \pi n \quad &\Rightarrow \quad y_1[n] = \begin{cases} 0 & n \text{ even} \\ -2 & n \text{ odd} \end{cases} \\ x_2[n] = 1 \quad &\Rightarrow \quad y_2[n] = 0 \\ x_3[n] = x_1[n] + x_2[n] \quad &\Rightarrow \quad y_3[n] = \cos \pi n \neq y_1[n] + y_2[n] \end{aligned}$$

Problem 3.2

(a) $y[n] = x[n] - x[0]$ is time-varying. For example,

$$\begin{aligned} x_1[n] = \cos \pi n \quad &\Rightarrow \quad y_1[n] = \begin{cases} 0 & n \text{ even} \\ -2 & n \text{ odd} \end{cases} \\ x_2[n] = x_1[n-1] \quad &\Rightarrow \quad y_2[n] = \begin{cases} 0 & n \text{ even} \\ 2 & n \text{ odd} \end{cases} \neq y_1[n-1] \end{aligned}$$

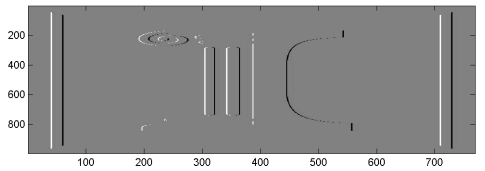
(b) $y[n] = x[n] - 1$ is time-invariant.

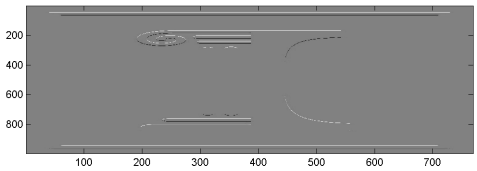
Problem 3.3

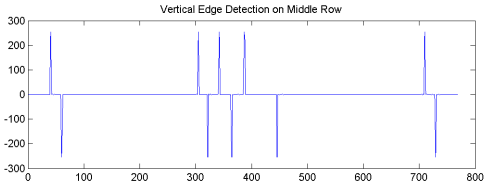
$$y[n] = \begin{cases} 0 & n \leq -2,\ n \geq 4 \\ 0.5 & n = -1,\ 3 \\ 1.5 & n = 0,\ 2 \\ 2 & n = 1 \end{cases}$$

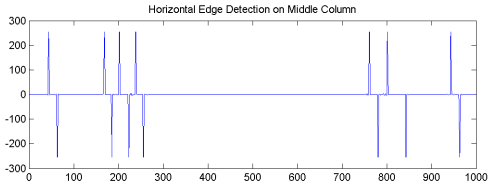
Matlab Exercises

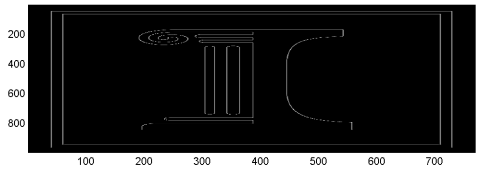
Problem 3.4

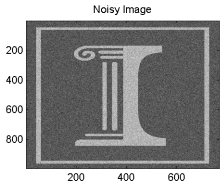


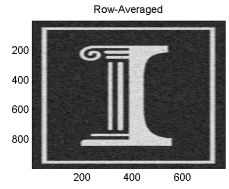


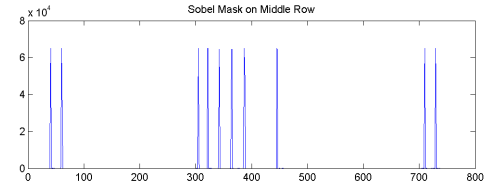

Vertical Edge Detection on Middle Row

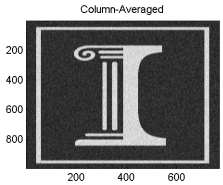

Horizontal Edge Detection on Middle Column

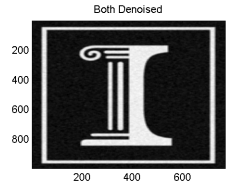



Noisy Image


Row-Averaged


Sobel Mask on Middle Row


Column-Averaged


Both Denoised