ECE3230 - Practicum VII

Discrete Time Systems

Reporting Requirements: Follow report instructions given in Practicum I.

Background: Read Subsection 1.2.3 of Dr. Kevin Buckley's Notes posted on Blackboard.

Procedures: This is a two-week Practicum. Procedures 1(a), 2(a) and 3(a) should be completed before the lab sessions.

1. **Finite Impulse Response (FIR) Filter:**

Consider the following DT system:

$$y[n] = \sum_{k=0}^{M-1} b_k x[n-k] \quad (1)$$

(a) On paper, for input $x[n] = \delta[n]$, determine the output $y[n] = h[n]$, i.e. find the impulse response. ($h[n]$ is standard notation for the impulse response of a system.) Note that we can also express the FIR filter I/O equation in terms of the impulse response as

$$y[n] = \sum_{k=0}^{M-1} h[k]x[n-k] \quad (2)$$

Why is this general type of system called an FIR filter?

(b) In file *FIR_mine.m*, write a Matlab function that implements a general FIR filter which is called by the command

y = FIR_mine (h,x) ,

where

• x is the input array containing the N input values $x[n]$; $n = 0, 1, \ldots, N-1$,

• h is the M element array of impulse response values $h[k] = b_k$; $k = 0, 1, \ldots, M-1$, and

• y is the output array containing $y[n]$; $n = 0, 1, \ldots, N-1$.

Your code should look something like the following (completed)

```
function   y = FIR_mine(h,x)
%
% h = impulse response
% x = input
%
M = length(h);
N = length(x);                    % N>M assumed
%
% initial outputs
%
for n=0:M-2
y(n+1) = 0.;
   for k=0: n
    y(n+1) = y(n+1) + h(k+1) *x(n+1-k);
   end
```

```
end
%
% steady state
%
for n=M-1: N-1
        y(n+1) = 0.;
          for k=0:M-1
               ???????????? (fill in)
           end
end
```

(c) Test your *FIR_mine* function for a 20-point averager (i.e. $h[n] = \frac{1}{20}p_{20}[n]$) with input $x[n] = p_{20}[n]$). Plot the output of n = 0, 1, …, 50.

2. A Simple Infinite Impulse Response (IIR) Filter:

Consider the following simple DT system:

$$y[n] = x[n] + ay[n-1] \tag{3}$$

where a called the feedback coefficient.

(a) On paper, for input $x[n] = \delta[n]$, determine the output $y[n] = h[n]$. Why is this system called an IIR filter?

(b) In file *IIR_simple.m*, write a Matlab function that implements this simple IIR filter which is called by the command

y = IIR_simple (a,x) ,

where

- x is the input array containing $x[n]$; $n = 0, 1, \ldots, N-1$,
- a is the feedback coefficient; and
- y is the input array containing $y[n]$; $n = 0, 1, \ldots, N-1$.

Your code should look something like the following (completed):

```
function y = IIR_simple(a,x)
%
% a = feedback coefficient
% x = input
%
N = length(x);
%
% initial output
y(1) = x(1);
%
% steady state
for n=2: N
 ???????????? (fill in)
end
```

(c) Test your *IIR_simple* function for an accumulator (i.e. a = 1) with input $x[n] = p_{20}[n]$. Plot the output of n = 0, 1, …, 50.

3**. Discrete Time Channel Equalization:**

Consider the following two DT systems. The first has input $x[n]$ and output $v[n]$. The second has input $v[n]$ and output $y[n]$.

$$v[n] = x[n] - .9x[n-1] \tag{4}$$

$$y[n] = v[n] + .9v[n-1] + .81v[n-2] + .729v[n-3] + .6561v[n-4] \tag{5}$$

For example, the first system might be a discrete model of a multipath communication channel, and the 2-nd system might be designed as part of a receiver to compensate for (or" equalize" or invert the effect of) the channel.

(a) On paper, determine and plot the impulse responses of the channel and the equalizer. Do the same for the overall impulse response of the *cascade* of the two systems (i.e. the response from the input to the first system to the output of the second, if the output of the 1-st system is the input to the second).

(b) Use *FIR_mine* to compute the response of the first system to input $x[n] = p_2[n]$. Plot this for n = 0, 1, …, 10. Do the same for the output of the cascade of the two systems. Comment on the effectiveness of the second system at *equalizing* the first. Reflecting on characteristics of y[n], suggest how the equalizer could be improved, describing this in terms of the impulse response of the equalizer.

(c) Instead of using the second system to equalize the first, consider the third system:

$$y[n] = v[n] + .9y[n-1] \tag{6}$$

Repeat Part (a).

(d) For the cascade of the first and third systems, use your *FIR_mine* and *IIR_simple* functions to compute the impulse response and the response to $x[n] = p_2[n]$. Plot the equalizer output for n = 0, 1, …, 10.

(e) In terms of the impulse responses of the two equalizers, explain why the 2-nd one works better than the 1-st.

4. Image Deblurring: For this procedure, you will process a black and white image. There are three files you will need, *cameraman.mat*, *cameraman1.mat* and *show_img.m*, which can be found in course website on Blackboard.

(a) Copy the three files into your working directory or otherwise assure that you have access to them within Matlab.

(b) Load *cameraman.mat* into Matlab. In Matlab, what is the image name? What size is it? Display the image using the command *show_img*(xx). Comment on the quality of the image. Do the same for *cameraman1.mat*.

(c) The image $yy[i,n]$ has been processed to simulate the effects of horizontal camera motion. That is, the original image $xx[i,n]$ has been blurred along the horizontal to generate *yy*. The blurring was simulated using the following equation for each horizontal image line (i.e. each row)

$$yy[i,n] = \sum_{j=0}^{10} 0.8^j xx[i,n-j]\,; \qquad i = 1,2,\dots,256; \qquad n = 1,2,\dots,256 \qquad (7)$$

To deblur the given image *yy*, use your *FIR_mine* function to process each row as follows to generate the deblurred image *zz*.

$$zz[i,n] = yy[i,n] - 0.8yy[i,n-1]; \qquad i = 1,2,\dots,256; \qquad n = 1,2,\dots,256 \qquad (8)$$

Use $yy[i,0] = 0.0$, $i = 1, 2, \dots, 256$.

(d) Display the deblurred image *zz*. Compare its quality to that of the *yy* image, and the original image *xx* stored in file *cameraman.mat*.

(e) How do the systems and results of this (Image Deblurring) Section relate to those of the previous (Channel Equalization) Section?

Practicum VII: Instructor/TA Sign Off Sheet, & Report Form

Student’s Name: ____

1. Procedures 1(c): 20-pt. averager output ____

2. Procedure 2(c): accumulator output ____

3. Procedure 3(a): below, sketch the three impulse responses.

4. Procedure 3(b): output plot of 1-st equalizer______________________________________

Record requested comments.

5. Procedure 3(c): sketch the impulse response from the channel input to the 2-nd equalizer output.

6. Procedure 3(d,e): output plot of 2-nd equalizer___________________________________

Record requested comments.

7. Procedure 4: displays of original, blurred and deblurred images _____________________

Record requested comments.