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Chapter 4

4.1 For the following systems where $x[n]$ *is input and* $y[n]$ *is output, determine whether the system is linear.*

(a) $y[n] = \log(x[n])$

-> $y[n] = \log(cx[n]) = \log(c) + \log(x[n]) \neq c\log(x[n])$이므로 non-linear

(b) $y[n] = x[n]\cos(\frac{n\pi}{2})$

-> $x[n] = ax_1[n] + bx_2[n]$

$y[n] = (ax_1[n] + bx_2[n])\cos(\frac{n\pi}{2})$

$y[n] = ax_1[n]\cos(\frac{n\pi}{2}) + bx_2[n]\cos(\frac{n\pi}{2}) = ay_1[n] + by_2[n]$ 이므로 linear

4.2 For the following systems where $x[n]$ *is input and* $y[n]$ *is output, determine whether the system is time-invariant.*

(a) $y[n] = x[n] + x[n-1]$

-> $y[n-n_0] = x[n-n_0] + x[n-n_0-1]$, $x[n] = x[n-n_0]$

$y[n] = x[n] + x[n-1] \quad \rightarrow \quad y[n] = x[n-n_0] + x[n-n_0-1]$이므로 time-invariant

(b) $y[n] = x[-n]$

-> $x[n] = x[n-n_0] \quad \rightarrow \quad y[n] = x[-n-n_0]$

$y[n-n_0] = x[-n+n_0] \quad \rightarrow \quad y[n] \neq y[n-n_0]$이므로 time-varying

4.3 Check for the causality and stability for the given system.

(a) $y[n] = x[n] + x[n-1] + x[n-3]$

-> $h[n] = \delta[n] + \delta[n-1] + \delta[n-3]$

causal since $h[-1] = 0$, $\text{for } n < 0$

stable since $\sum_{n=-INF}^{INF} |h[n]| = 1+1+1 = 3 < \infty$

(b) $y[n] = x[n]\cos(\frac{n\pi}{8})$

-> $h[n] = \delta[n]\cos(\frac{n\pi}{8})$

non-causal, non-stable since cosine curve

4.4 For the following system with impulse response, determine whether the system is FIR or IIR. Determine the stability and causality.

(a) A system with impulse response $h[n] = \{0,1,2\}$

-> FIR system

stable since $\sum_{n=-INF}^{INF} |h[n]| = 0+1+2 = 3 < \infty$,

causal since $h[-1] = 0$

(b) A system with difference equation $y[n] = x[n+1] - x[n] - 2x[n-1]$

-> FIR system

stable since $\sum_{n=-INF}^{INF} |h[n]| = 1-1-2 = -2 < \infty$

non-causal since $h[n] = \delta[n+1] - \delta[n] - 2\delta[n-1]$, $h[-1] = -1$

(c) A system with impulse response $h[n] = (0.7)^n u[n]$

-> IIR system

stable since $\sum_{n=-INF}^{INF} |h[n]| = \frac{1}{1-0.7} = 3.33 < \infty$

causal since $u[n] \rightarrow n \geq 0$

4.5 Given the following system difference equation, determine whether this system is recursive or non-recursive. Solve for the impulse response of this system. Assume causal system.

(a) $y[n] = (x[n] + x[n-1] + x[n-2])/3$

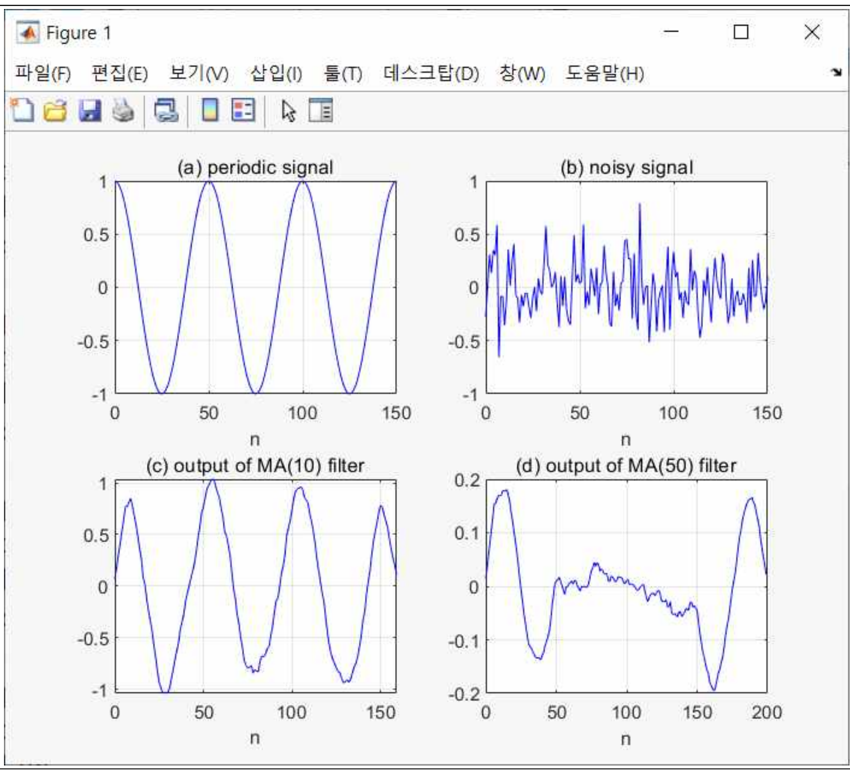
-> $h[n] = (\delta[n] + \delta[n-1] + \delta[n-2])/3$

$h[0] = 1/3$, $h[1] = 1/3$, $h[2] = 1/3$, $h[3] = 0$, $h[4] = 0$, ...

$h[n] = \{1/3, 1/3, 1/3\}$, non-recursive since output only depends on input

4.6 Write MATLAB programming code to implement the moving average (MA) filter and verify the simulation results in Fig. 4.7. Generate additive noise by MATLAB function, randn() which generates zero mean and unit variance white gaussian noise.

->




```
>> range = 6*pi / 150;
>> n = 0:range:6*pi;
>> len = length(n);
>> x = 0:length(n)-1;
>> y = cos(n);
>> random = randn(1, len)*0.25;
>> noise = y + random;
>> filt10 = 1/10 * ones(1, 10);
>> filt50 = 1/50 * ones(1, 50);
>> y1 = conv(noise, filt10);
>> y2 = conv(noise, filt50);
>> x1 = 0:length(y1)-1;
>> x2 = 0:length(y2)-1;
>> figure(1)
>> subplot(221)
>> plot(x, y, 'b');
>> grid on;
>> xlabel('n');
>> title('(a) periodic signal');
>> subplot(222)
>> plot(x, random, 'b');
>> grid on;
>> xlabel('n');
>> title('(b) noisy signal');
>> subplot(223)
>> plot(x1, y1, 'b');
>> grid on;
>> xlabel('n');
>> title('(c) output of MA(10) filter');
>> subplot(224)
>> plot(x2, y2, 'b');
>> grid on;
>> xlabel('n');
>> title('(d) output of MA(50) filter');
```

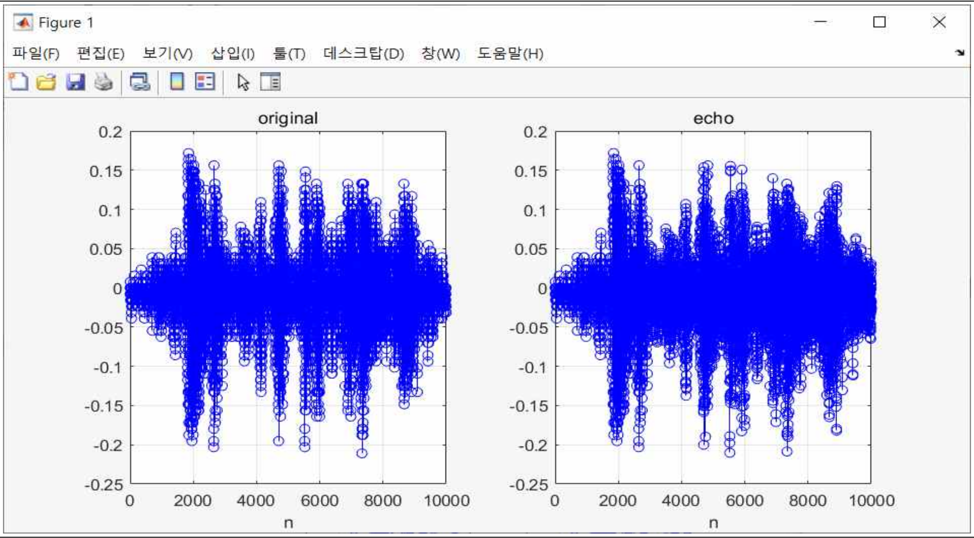
4.7 Write MATLAB programming code to implement the following reverberation generation system and verify the resulting sound by a practical listening test.

$$\text{Echo}\ :\ y[n] = x[n] + \alpha x[n-D],\ \alpha < 1$$

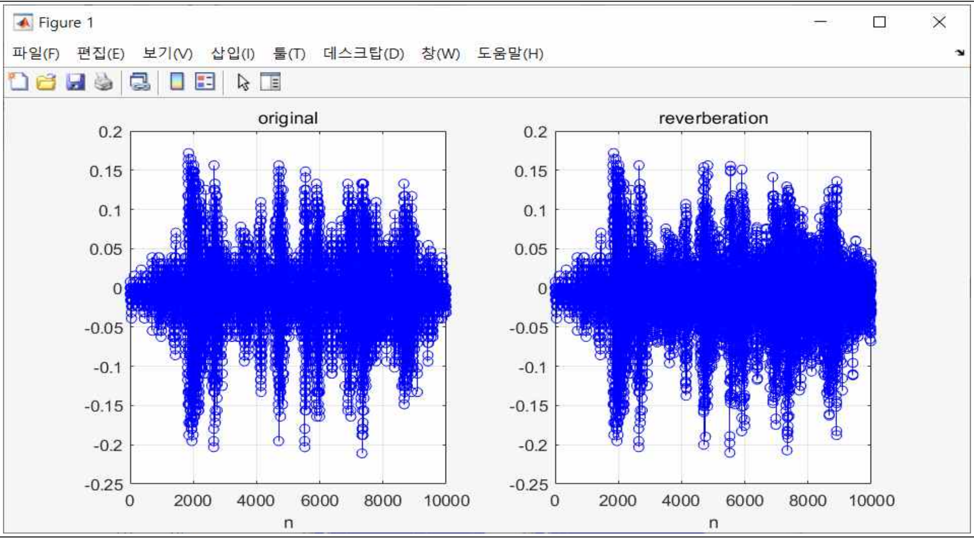
$$\text{Reverberation}\ :\ y[n] - \alpha y[n-D] = x[n]$$

->

Echo




```
>> x = audioread('C:/Users/sangmin/Desktop/보글.wav');
>> len = length(x);
>> y = zeros(1, len);
>> a = 0.3;
>> D = 3000;
>> for i = 1:D
y(i) = x(i);
end
>> for j = D+1:len
y(j) = x(j) + a*x(j-D);
end
>> figure(1)
>> subplot(121)
>> stem(x(1:10000), 'b');
>> grid on;
>> xlabel('n');
>> title('original');
>> subplot(122)
>> stem(y(1:10000), 'b');
>> grid on;
>> xlabel('n');
>> title('echo');
```

Reverberation


```
>> x = audioread('C:/Users/sangmin/Desktop/보글.wav');
>> len = length(x);
>> y = zeros(1, len);
>> a = 0.3;
>> D = 3000;
>> for i = 1:D
y(i) = x(i);
end
>> for j = D+1:len
y(j) = x(j) + a*y(j-D);
end
>> figure(1)
>> subplot(121)
>> stem(x(1:10000), 'b');
>> grid on;
>> xlabel('n');
>> title('original');
>> subplot(122)
>> stem(y(1:10000), 'b');
>> grid on;
>> xlabel('n');
>> title('reverberation');
```

4.8 Use the graphical approach to find the convolution output for the following input $x[n]$ *and impulse response* $h[n]$

$$x[n] = \{1,2,3,1\}, \quad h[n] = \{0,1,-1\}$$

->

```
      1 2 3 1                1 2 3 1               1 2 3 1
   -1 1 0            =>   -1 1 0           =>       -1 1 0
 --------------        --------------         --------------
     1+0=1=y[0]          -1+2+0=1=y[1]            -2+3+0=1=y[2]

      1 2 3 1                1 2 3 1
         -1 1 0      =>            -1 1 0
    --------------        --------------
        -3+1=-2=y[3]             -1=y[4]
```

$\therefore y[n] = \{1,1,1,-2,-1\}$

4.13 Simulate radar target ranging problem with barker radar signal $x[n]$ *and various noise energy condition of noises* $p[n]$. *Assume white random gaussian noise (zero mean and unit variance gaussian distribution)* $p[n]$. *Perform MATLAB programming to simulate radar target ranging problem. Let the radar signal* $x[n]$ *be length 200 sequence including 13point barker sequence such as*

$$x[n] = \{1,1,1,1,1,-1,-1,1,1,-1,1,-1,1,zeros(1,187)\}$$

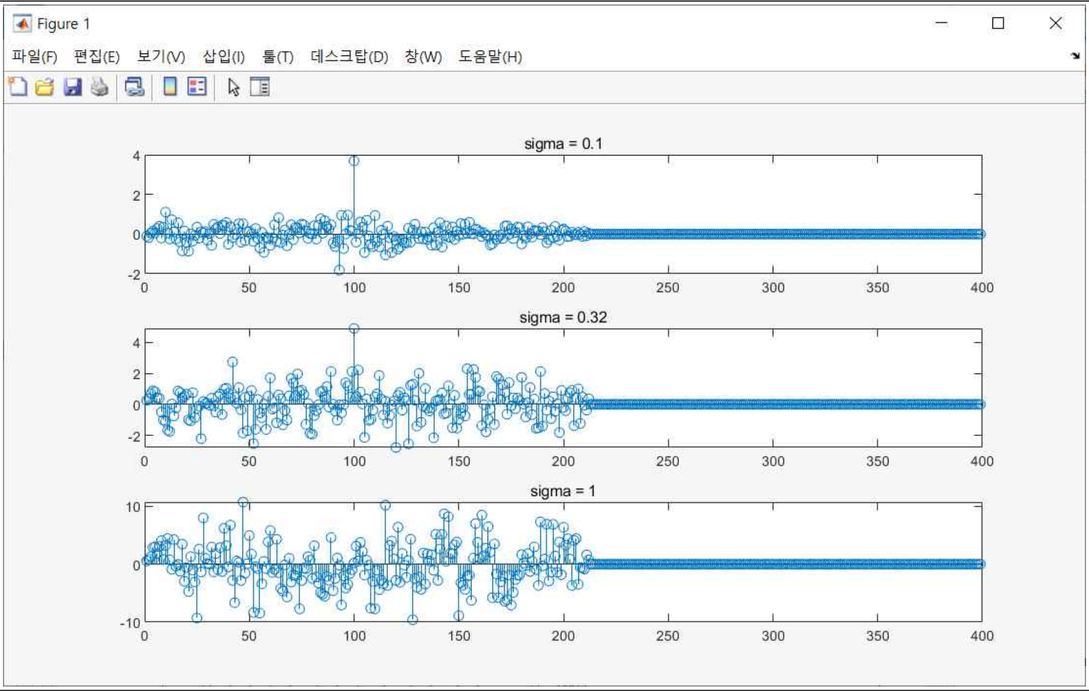
For noise signal $p[n]$ *of length 200 with various energies can be generated as follows*

$$s[n] = \alpha x[n-D] + p[n], \qquad p[n] = \sigma^{*} rnorm(200)$$

where σ *is standard deviation to be varied as 0.1, 0.32, 1*

-> $f_s = 8kHz,\ D = 100$

$$d = \frac{0.5 \times v \times D}{f_s} = \frac{0.5 \times 3 \times 10^8 \times 100}{8000} = 1500m$$




```
n = 1:200;
x = [1, 1, 1, 1, 1, -1, 1, 1, -1, -1, 1, -1, 1, zeros(1, 187)];
a = 0.3;
delay = 100;

y = a*[zeros(1, delay), 1, 1, 1, 1, 1, -1, 1, 1, -1, -1, 1, -1, 1, zeros(1, 87)] + 0.1*randn(size(x));
r = xcorr(x, y);
figure(1);
subplot(311)
stem(1:length(r), r);
title('sigma = 0.1');

y = a*[zeros(1, delay), 1, 1, 1, 1, 1, -1, 1, 1, -1, -1, 1, -1, 1, zeros(1, 87)] + 0.32*randn(size(x));
r = xcorr(x, y);
subplot(312)
stem(1:length(r), r);
title('sigma = 0.32');

y = a*[zeros(1, delay), 1, 1, 1, 1, 1, -1, 1, 1, -1, -1, 1, -1, 1, zeros(1, 87)] + 1*randn(size(x));
r = xcorr(x, y);
subplot(313)
stem(1:length(r), r);
title('sigma = 1');
```