**Lab 2： LTI System**

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| **Introduction**  The lab guide us to learn about inverse filtering of LTI systems through the example of echo cancelling. We will load the given file and use MATLAB to process them and discuss the properties of LTI systems.  an important property of discrete-time LTI systems: if h[n] is the response to the unit impulse b[n], then the response of the system y[n] to any input x[n] is determined by the convolution  Sum;  **Lab results & Analysis**：  **2.4**  Question(a)    Results    Analysis  The picture is like above.  Question(b)    Results    Analysis  The upper one is x1\*h1,and the other one is h1\*x1. They are the same.  Question(c)    Results    Analysis  The above one is x1\*h1+x1\*h2, the other one is x1\*(h1+h2). They are the same.  Question(d)    Results    Analysis  The upper one is w=(x1\*h1)\*h2,the other one is w=x1\*(h1\*h2). They are the same.  Question(e)    Results    Analysis  According the picture,ye1=ye2. The only difference is that the time shift n=2.  Question(f)      Results    Analysis  Absolutely yf1 does not equal to yf2. But it does not disobey the regular of associative property. The property only works when the systems are LTI system. But the first system y = (n+1)\*x is not time-invariant, and it is not LTI system. So we can not apply the property to it.  Question(g)    Results    Analysis  Absolutely yg1 does not equal to yg2. But it does not disobey the distributive property. Because the property only works when the systems are LTI system. And the first system y = x^2 is not linear, and it is not LTI system. So we can not apply the property to it.  **2.5**  Question(a)    Results  Sys1：    Sys2    Sys3    Analysis  Above are pictures of 3 systems.  Question(b)    Results:    Analysis:  The third equation does not equal to the fourth equation, so it is not linear.  Question(c)    Results:    Analysis:  The second picture is not the same picture as the first one.There is no z = 1 in the picture1, but there is one in the picture2. So, a time shift would change the result z of the system3, so it is not time invariant.  Question(d)      Results:    Analysis:  The upper picture is h1, and the other one is h2.  Question(e)    Results:    Analysis:  The upper picture is s1, and the other one is s2.  Question(f)    Results:    Analysis:  The upper picture is z1, and the other one is z2.  Question(g)    Results:  1.z1&s1    2.z2&s2    Analysis:  For z1&s1:The red part means that s1 = z1.So their are totally the same. Because s1 = y1 \* u[n] and z1 = u[n] \* h1 = u[n] \* y1 \* impulse[n] = u[n] \* y1 = s1  For z2&s2:z2 does not equal to s2. And i suppose that the reason goes like this: The first two y of both the result are the same, when the y2 combines an impulse,some information lost owing to the difference between filter and convolution functions. | |
| **Experience**  **课堂截图：**  **e350898981db379fb8695c459165a94 5b165d49fa7907052f5a8f24c6928c0**  **44d7b9e1c192412ebb06c79d6a61645** | |
| **Score** |  |

**Code:**

2.4(a)

clc;

clear;

nx1=0:9;

x1=[1 1 1 1 1 0 0 0 0 0 ];

subplot(3,1,1);stem(nx1,x1);

xlabel('0<=n<=9')

ylabel('x1')

title('x1[n]')

nh=0:4;

h1=[1 -1 3 0 1];

subplot(3,1,2);stem(nh,h1);

xlabel('0<=n<=4')

ylabel('h1')

title('h1[n]')

h2=[0 2 5 4 -1];

subplot(3,1,3);stem(nh,h2);

xlabel('0<=n<=4')

ylabel('h2')

title('h2[n]')

2.4(b)

clc;

clear;

nx1=0:9;

x1=[1 1 1 1 1 0 0 0 0 0 ];

nh=0:4;

h1=[1 -1 3 0 1];

w1=conv(x1,h1);

nw1=nx1(1)+nh(1):nx1(end)+nh(end);

subplot(2,1,1);stem(nw1,w1);

xlabel('0<=n<=13');

ylabel('x1\*h1');

w2=conv(h1,x1);

nw2=nh(1)+nx1(1):nh(end)+nx1(end);

subplot(2,1,2);stem(nw2,w2);

xlabel('0<=n<=13');

ylabel('h1\*x1');

2.4(c)

clc;

clear;

nx1=0:9;

x1=[1 1 1 1 1 0 0 0 0 0 ];

nh=0:4;

h1=[1 -1 3 0 1];

h2=[0 2 5 4 -1];

w1=conv(x1,h1);

nw1=nx1(1)+nh(1):nx1(end)+nh(end);

w2=conv(x1,h2);

nw2=nx1(1)+nh(1):nx1(end)+nh(end);

subplot(2,1,1);stem(w1+w2);

xlabel('0<=n<=13');

ylabel('x1\*h1+x1\*h2');

c=h1+h2;

w3=conv(x1,c);

nw3=nx1(1)+nh(1):nx1(end)+nh(end);

subplot(2,1,2);stem(w3);

xlabel('0<=n<=13');

ylabel('x1\*(h1+h2)');

2.4(d)

clc;

clear;

nx1=0:9;

x1=[1 1 1 1 1 0 0 0 0 0 ];

nh=0:4;

h1=[1 -1 3 0 1];

h2=[0 2 5 4 -1];

w1=conv(x1,h1);

nw1=nx1(1)+nh(1):nx1(end)+nh(end);

w2=conv(w1,h2);

nw2=nw1(1)+nh(1):nw1(end)+nh(end);

subplot(2,1,1);stem(w2);

xlabel('0<=n<=17');

ylabel('(x1\*h1)\*h2');

w3=conv(h1,h2);

nw3=nh(1)+nh(1):nh(end)+nh(end);

w4=conv(w3,x1);

nw4=nw3(1)+nx1(1):nw3(end)+nx1(end);

subplot(2,1,2);stem(w4);

xlabel('0<=n<=17');

ylabel('x1\*(h1\*h2)');

2.4(e)

clc;

clear;

nx1=0:9;

x1=[1 1 1 1 1 0 0 0 0 0 ];

nh=0:4;

h1=[1 -1 3 0 1];

nh2=2:6;

y1=conv(h1,x1);

y2=conv(x1,h1);

subplot(4,1,1);stem(0:13,y1);

xlabel('0<=n<=13,h1 and x1');ylabel('y1=h1\*x1');

subplot(4,1,2);stem(0:13,y2);

xlabel('0<=n<=13,x1 and h1');ylabel('y2=x1\*h1');

subplot(4,1,3);stem(2:15,y1);

xlabel('0<=n<=13,h1[n-2] and x1');ylabel('y1=h1[n-2]\*x1');

subplot(4,1,4);stem(2:15,y2);

xlabel('0<=n<=13,x1[n-2] and h1');ylabel('y2=x1[n-2]\*h1');

2.4(f)

clc;

clear;

nx1=0:9;

x1=[1 1 1 1 1 0 0 0 0 0 ];

nh=0:4;

h1=[1 -1 3 0 1];

nh2=2:6;

y1=conv(h1,x1);

y2=conv(x1,h1);

subplot(4,1,1);stem(0:13,y1);

xlabel('0<=n<=13,h1 and x1');ylabel('y1=h1\*x1');

subplot(4,1,2);stem(0:13,y2);

xlabel('0<=n<=13,x1 and h1');ylabel('y2=x1\*h1');

subplot(4,1,3);stem(2:15,y1);

xlabel('0<=n<=13,h1[n-2] and x1');ylabel('y1=h1[n-2]\*x1');

subplot(4,1,4);stem(2:15,y2);

xlabel('0<=n<=13,x1[n-2] and h1');ylabel('y2=x1[n-2]\*h1');

2.4(g)

clc;

clear;

nx1=0:9;

x1=[1 1 1 1 1 0 0 0 0 0 ];

nh=0:4;

h1=[1 -1 3 0 1];

h2=[0 2 5 4 -1];

xg=[2 0 0 0 0];

yga=xg.^2;

ygb=conv(xg,h2);

yga = [yga,zeros(1,4)];

yg1=yga+ygb;

hg1=[1 0 0 0 0].^2;

hparallel = hg1 + h2;

yg2 = conv(hparallel,xg);

subplot(211);stem(0:8,yg1);xlabel("0 <=n <=8, yg1");ylabel("yg1");

subplot(212);stem(0:8,yg2);xlabel("0 <=n <=8, yg2");ylabel("yg2");

2.5(a)

clc;clear;

n = 0:5;

x1 = impulse(n,0);

x2 = impulse(n,1);

x3 = x1 + 2\*x2;

w1 = x1 - impulse(n,1) - impulse(n,2);

w2 = x2 - impulse(n,2) - impulse(n,3);

w3 = x3 - (impulse(n,1) + 2\* impulse(n,2)) - (impulse(n,2) + 2\*impulse(n,3));

w4 = w1 + 2\* w2;

subplot(4,1,1);stem(n,w1);xlabel("0<=n<=5, w1 = x1[n] - x1[n-1] - x1[n-2]");ylabel("w1");

subplot(4,1,2);stem(n,w2);xlabel("0<=n<=5, w2 = x2[n] - x2[n-1] - x2[n-2]");ylabel("w2");

subplot(4,1,3);stem(n,w3);xlabel("0<=n<=5, w3 = x3[n] - x3[n-1] - x3[n-2]");ylabel("w3");

subplot(4,1,4);stem(n,w4);xlabel("0<=n<=5, w4 = = w1 + 2 \* w2");ylabel("w4");

y1 = cos(x1);

y2 = cos(x2);

y3 = cos(x3);

y4 = y1 + 2 \* y2;

subplot(411);stem(n,y1);xlabel("0<=n<=5, y1 = cos(x1)");ylabel("y1");

subplot(412);stem(n,y2);xlabel("0<=n<=5,y2=cos(x2)");ylabel("y2");

subplot(413);stem(n,y3);xlabel("0<=n<=5, y3 = cos(x3)");ylabel("y3");

subplot(414);stem(n,y4);xlabel("0<=n<=5, y4 = y1 + 2 \* y2");ylabel("y4");

z1 = n.\*x1;

z2 = n.\*x2;

z3 = n.\*x3;

z4 = z1 + 2\*z2;

subplot(411);stem(n,z1);xlabel("0<=n<=5, z1 = n\*x1");ylabel("z1");

subplot(412);stem(n,z2);xlabel("0<=n<=5,z2=n\*x2");ylabel("z2");

subplot(413);stem(n,z3);xlabel("0<=n<=5, z3 = n\*x3");ylabel("z3");

subplot(414);stem(n,z4);xlabel("0<=n<=5, z4 = z1 + 2 \* z2");ylabel("z4");

Self-defined function impulse(n,x):

function y = impulse(n,x)

for i = 1:length(n)

if(n(i) ~= x)

y(i) = 0;

else

y(i) = 1;

end

end

2.5(b)

clc;clear;

n = [0:5];

x1 = impulse(n,0);

x2 = impulse(n,1);

x3 = x1 + 2\*x2;

y1 = cos(x1);

y2 = cos(x2);

y3 = cos(x3);

y4 = y1 + 2 \* y2;

subplot(411);stem(n,y1);xlabel("0<=n<=5, y1 = cos(x1)");ylabel("y1");

subplot(412);stem(n,y2);xlabel("0<=n<=5,y2=cos(x2)");ylabel("y2");

subplot(413);stem(n,y3);xlabel("0<=n<=5, y3 = cos(x3)");ylabel("y3");

subplot(414);stem(n,y4);xlabel("0<=n<=5, y4 = y1 + 2 \* y2");ylabel("y4");

2.5(c)

clc;clear;

n = [0:5];

x1 = impulse(n,0);

x2 = impulse(n,1);

x3 = x1 + 2\*x2;

z1 = n.\*x1;

z2 = n.\*x2;

z3 = n.\*x3;

z4 = z1 + 2\*z2;

subplot(411);stem(n,z1);xlabel("0<=n<=5, z1 = n\*x1");ylabel("z1");

subplot(412);stem(n,z2);xlabel("0<=n<=5,z2=n\*x2");ylabel("z2");

subplot(413);stem(n,z3);xlabel("0<=n<=5, z3 = n\*x3");ylabel("z3");

subplot(414);stem(n,z4);xlabel("0<=n<=5, z4 = z1 + 2 \* z2");ylabel("z4");

2.5(d)

clc;clear;

n = 0:19;

h1 = filter(1,[1,-3/5],impulse(n,0));

h2 = twoFiveD(n,impulse(n,0),0);

subplot(211);stem(n,h1);xlabel("0 <= n <= 19");ylabel("h1[n]=(3/5)\*h[n-1]+x[n]");

>> subplot(212);stem(n,h2);xlabel("0 <= n <= 19");ylabel("h2[n]=((3/5)^n)\*h2[n-1]+x[n]");

ps1、Self-defined function impulse(n,x):

function y = impulse(n,x)

for i = 1:length(n)

if(n(i) ~= x)

y(i) = 0;

else

y(i) = 1;

end

end

Ps2、Self-defined function twoFiveD(n,x,y0):

function y = twoFiveD(n,x,y0)

for i = 1:length(n)

if(i ~= 1)

y(i) = (3/5)^(n(1) + i - 1).\* y(i - 1) + x(i);

else

y(i) = (3/5)^(n(1) + i - 1).\* y0 + x(i);

end

end

2.5(e)

clc;clear;

n = [0:19];

s1 = filter(1,[1,-3/5],step(n,0,'+'));

s2 = twoFiveD(n,step(n,0,'+'),0);

subplot(211);stem(n,s1);xlabel("0 <= n <= 19");ylabel("s1[n]=(3/5)\*s1[n-1]+x[n]");

subplot(212);stem(n,s2);xlabel("0 <= n <= 19");ylabel("s2[n]=((3/5)^n)\*s2[n-1]+x[n]");

Ps1、Self-defined function twoFiveD(n,x,y0):

function y = twoFiveD(n,x,y0)

for i = 1:length(n)

if(i ~= 1)

y(i) = (3/5)^(n(1) + i - 1).\* y(i - 1) + x(i);

else

y(i) = (3/5)^(n(1) + i - 1).\* y0 + x(i);

end

end

Ps2、Self-defined function step(x,n,f):

function y = step(x,n,f)

if(f == '+')

for i = 1:length(x)

if(x(i) < n)

y(i) = 0;

else

y(i) = 1;

end

end

else

for i = 1:length(x)

if(x(i) < n)

y(i) = 1;

else

y(i) = 0;

end

end

end

2.5(f)

clc;clear;

n = [0:19];

h1 = filter([1],[1,-3/5],impulse(n,0));

h2 = twoFiveD(n,impulse(n,0),0);

u = step(n,0,'+');

z1 = conv(h1,u);

z2 = conv(h2,u);

subplot(211);stem([0:19\*2],z1);xlabel("0 <= n <= 38");ylabel("z1 = conv(h1,u)");

subplot(212);stem([0:19\*2],z2);xlabel("0 <= n <= 38");ylabel("z2 = conv(h2,u)");

Ps1 Self-defined function twoFiveD(n,x,y0):

function y = twoFiveD(n,x,y0)

for i = 1:length(n)

if(i ~= 1)

y(i) = (3/5)^(n(1) + i - 1).\* y(i - 1) + x(i);

else

y(i) = (3/5)^(n(1) + i - 1).\* y0 + x(i);

end

end

Ps2 Self-defined function step(x,n,f):

function y = step(x,n,f)

if(f == '+')

for i = 1:length(x)

if(x(i) < n)

y(i) = 0;

else

y(i) = 1;

end

end

else

for i = 1:length(x)

if(x(i) < n)

y(i) = 1;

else

y(i) = 0;

end

end

end

Ps3 Self-defined function impulse(n,x):

function y = impulse(n,x)

for i = 1:length(n)

if(n(i) ~= x)

y(i) = 0;

else

y(i) = 1;

end

end

2.5(g)

clc;clear;

n = [0:19];

h1 = filter([1],[1,-3/5],impulse(n,0));

u = step(n,0,'+');

z1 = conv(h1,u);

s1 = filter(1,[1,-3/5],step(n,0,'+'));

figure; stem([0:38],z1);hold on;stem(n,s1);

xlabel("0 <= n <= 38 for z1, 0 <= n <= 19 for s1");ylabel("z1 and s1, the red part means that z1 = s1");

h2 = twoFiveD(n,impulse(n,0),0);

z2 = conv(h2,u);

s2 = twoFiveD(n,step(n,0,'+'),0);

figure;subplot(211); stem([0:38],z2);xlabel("0 <= n <= 38");ylabel("z2");

subplot(212);stem(n,s2);xlabel("0 <= n <= 19");ylabel("s2");

Ps1 Self-defined function twoFiveD(n,x,y0):

function y = twoFiveD(n,x,y0)

for i = 1:length(n)

if(i ~= 1)

y(i) = (3/5)^(n(1) + i - 1).\* y(i - 1) + x(i);

else

y(i) = (3/5)^(n(1) + i - 1).\* y0 + x(i);

end

end

Ps2、Self-defined function step(x,n,f):

function y = step(x,n,f)

if(f == '+')

for i = 1:length(x)

if(x(i) < n)

y(i) = 0;

else

y(i) = 1;

end

end

else

for i = 1:length(x)

if(x(i) < n)

y(i) = 1;

else

y(i) = 0;

end

end

end

Ps3 Self-defined function impulse(n,x):

function y = impulse(n,x)

for i = 1:length(n)

if(n(i) ~= x)

y(i) = 0;

else

y(i) = 1;

end

end