Lezione 9 Filtering

lunedì 18 ottobre 2021 14.06

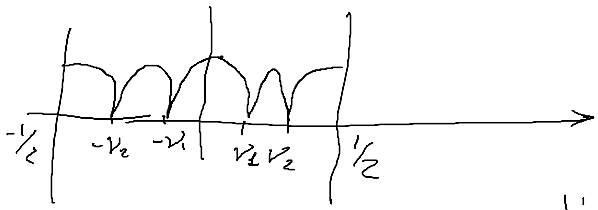
ESERCITAZIONE SUL FILTRAGGIO

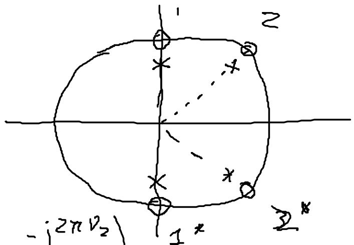
```
clear all
close all
%generate signals and noise
t=1:1/8000:2;
f1=1000;
f2=2000;
s=0.5*cos(2*pi*f1*t+0.3)+0.3*cos(2*pi*f2*t);
subplot(3,1,1)
plot(t, s)
sound(s,8000)
pause
noise=0.1*randn(1,length(t));
subplot(3,1,2)
plot(t, noise)
sound(noise, 5000)
pause
spn=s+noise;
subplot(3,1,3)
plot(t, spn)
sound(spn,8000)
save spn
```

$f_1 = 1\,KHz \quad \nu_1 = \frac{1000}{8000} = \frac{1}{8}$

$f_2 = 2\,KHz \quad \nu_2 = \frac{2000}{8000} = \frac{2}{8}$

FILTRO A 2 NOTCH





$$H(z) = \frac{(z - z_1)(z - z_2)(z - z_1^*)(z - z_2^*)}{(z - \rho_1)(z - \rho_2)(z - \rho_1^*)(z - \rho_2^*)}$$

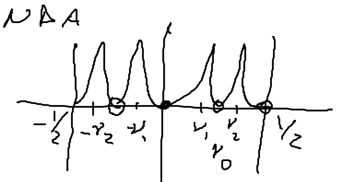
$$= \frac{(z - e^{j2\pi\nu_1})(z - e^{-j2\pi\nu_1})(z - e^{+j2\pi\nu_2})(z - e^{-j2\pi\nu_2})}{(z - \rho_1 e^{j2\pi\nu_1})(z - \rho_1 e^{-j2\pi\nu_1})(z - \rho_2 e^{j2\pi\nu_2})(z - \rho_2 e^{-j2\pi\nu_2})}$$

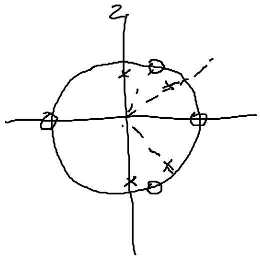
$$= \frac{(z^2 - 2\cos 2\pi\nu_1 z + 1)(z^2 - 2\cos 2\pi\nu_2 z + 1)}{(z^2 - 2\rho_1\cos 2\pi\nu_1 z + \rho_1^2)(z^2 - 2\rho_2\cos 2\pi\nu_2 z + \rho_2^2)}$$

$$= \frac{(1 - 2\cos 2\pi\nu_1 z^{-1} + z^{-2})(1 - 2\cos 2\pi\nu_2 z^{-1} + z^{-2})}{(1 - 2\rho\cos 2\pi\nu_1 z^{-1} + \rho_1^2 z^{-2})(1 - 2\rho\cos 2\pi\nu_2 z^{-1} + \rho_2 z^{-2})}$$

```
close all
clear all
load spn

%design filter
ni1=1/8;
ni2=2/8;
ni0=(ni1+ni2)/2;
ro1=0.99;
ro2=0.99;
B=[conv([1 0 -1],[1 -2*cos(2*pi*ni0) 1])]
% B=[conv([1 -2*cos(2*pi*ni1) 1],[1 -2*cos(2*pi*ni2) 1])]
A=[conv([1 -2*ro1*cos(2*pi*ni1) ro1^2],[1 -2*ro2*cos(2*pi*ni2) ro2^2])]
%verify filter response
[H W]=freqz(B,A,200); %get frequency response (abscissa in rad)
[h t]=impz(B,A);  %get impulse response
figure(1)
subplot(2,2,1)
plot(W/(2*pi),abs(H)/max(abs(H))) %plot magnitude (abscissa in norm freq.)
ylabel('magnitude')
xlabel('nu')
axis([0 0.5 0 1])
grid on
subplot(2,2,3)
plot(W/(2*pi),phase(H)) %plot phase (abscissa in norm freq.)
ylabel('phase')
xlabel('nu')
axis([0 0.5 min(phase(H)) max(phase(H))])
grid on
subplot(2,2,2)
zplane(B,A)      %compute and plot z plane
subplot(2,2,4)
stem(t,h)       %plot impulse response
ylabel('impulse response')
xlabel('n')
% %filter the signal
fs=filter(B,A,spn);
sound(fs,8000)
```

PASSA-BANDA





$$\nu_0 = \frac{\nu_1+\nu_2}{2}$$

$$(z-1)(z+1)$$

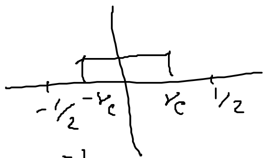
$$(z^2 - 2\cos 2\pi\nu_0 z + 1)$$

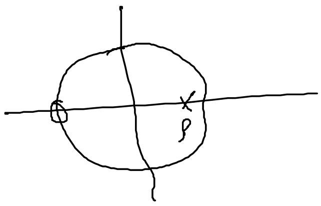
$$H(z) = \frac{(1-z^{2})\,(1-2\cos 2\pi\nu_0 z^{-1} + z^{-2})}{(1-2\rho\cos 2\pi\nu_1 z^{-1}+\rho_1^2 z^{-2})(1-2\rho\cos 2\pi\nu_2 z^{-1}+\rho_2 z^{-2})}$$

Acquire a speech signal

```
%script to create an audio file
Fs=8000; %frequency rate
Nbits=16; %number of bits
recorder=audiorecorder(Fs,Nbits, 1)
disp('Start speaking.')
recordblocking(recorder, 2);
disp('End of Recording.');
x= getaudiodata(recorder); % in x there is my sampled signal
%visualize the signal
plot(x)
%listen to the speech segment
sound(x,Fs)
% %reverse the signal
xr=fliplr(x')
%sound(xr,Fs) %strange!!!!???
figure
%visualize the histogram with 50 bins
hist(x,50)

% %saturate the signal to -1 1
%xs=sign(x)
%
% %listen
%sound(xs,Fs)
%
S=specgram(x); %S is a complex matrix with DFT in the columns
% DFT is computed by default on 256 sample windows
figure
pcolor(abs(S))
```

PASSA-BASSO





$$H(z) = \frac{z+1}{z-\rho} = \frac{1+z^{-1}}{1-\rho z^{-1}}$$

```
close all
clear all
%get signal and add noise
load x

s=x';
noise=0.1*randn(1,length(s));
spn=s+noise
sound(spn,8000)
pause

%progettiamo un passa-basso
ro=0.9;
B=[1 1];
A=[1 -ro];
%verify filter response
[H W]=freqz(B,A,200); %get frequency response (abscissa in rad)
[h t]=impz(B,A);  %get impulse response
figure(1)
subplot(2,2,1)
plot(W/(2*pi),abs(H)/max(abs(H))) %plot magnitude (abscissa in norm freq.)
ylabel('magnitude')
xlabel('nu')
axis([0 0.5 0 1])
grid on
subplot(2,2,3)
plot(W/(2*pi),phase(H)) %plot phase (abscissa in norm freq.)
ylabel('phase')
xlabel('nu')
axis([0 0.5 min(phase(H)) max(phase(H))])
grid on
subplot(2,2,2)
zplane(B,A)      %compute and plot z plane
subplot(2,2,4)
stem(t,h)       %plot impulse response
ylabel('impulse response')
xlabel('n')
%filter the signal
fs=filter(B,A,spn)
sound(fs,8000)
```

Trasf. BILINEARE

$$H_a(s) = \frac{1}{s+a} \qquad H(z) = H_a(s)\Big|_{s = \frac{2}{T}\frac{1-z^{-1}}{1+z^{-1}}}$$

$$= \frac{1}{\frac{2}{T}\frac{1-z^{-1}}{1+z^{-1}} + a} = \frac{T}{2}\,\frac{1}{\frac{1-z^{-1}}{1+z^{-1}} + \frac{T}{2}}$$

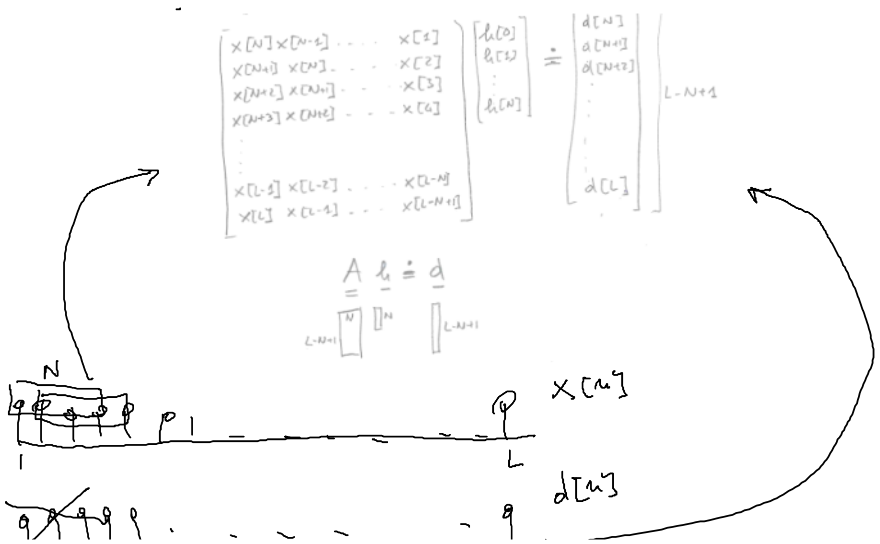
$$= \frac{T}{2}\,\frac{1}{\frac{2 - 2z^{-1} + aT + aTz^{-1}}{2(1+z^{-1})}} = \frac{T}{2}\,\frac{2(1+z^{-1})}{(2+Ta) + (Ta-2)z^{-1}}$$

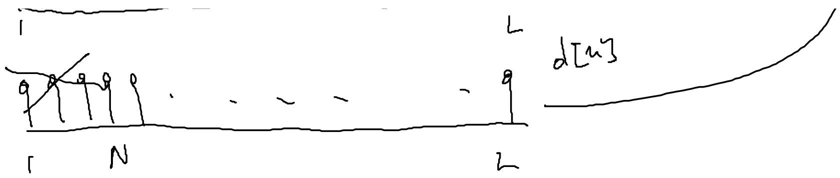
$$= \frac{T + Tz^{-1}}{(2+Ta) + (Ta-2)z^{-1}}$$

```
close all
clear all
%filtering2
%get signal
load x

s=x';
noise=0.1*randn(1,length(s));
spn=s+noise
sound(spn,8000)
pause

%progettiamo un passa-basso con la trsformazione bilineare
T=1/8000;
a=1000;
B=[T T];
A=[2+T*a  T*a-2]
%verify filter response
[H W]=freqz(B,A,200); %get frequency response (abscissa in rad)
[h t]=impz(B,A);  %get impulse response
figure(1)
subplot(2,2,1)
plot(W/(2*pi),abs(H)/max(abs(H))) %plot magnitude (abscissa in norm freq.)
ylabel('magnitude')
xlabel('nu')
axis([0 0.5 0 1])
grid on
subplot(2,2,3)
plot(W/(2*pi),phase(H)) %plot phase (abscissa in norm freq.)
ylabel('phase')
xlabel('nu')
axis([0 0.5 min(phase(H)) max(phase(H))])
grid on
subplot(2,2,2)
zplane(B,A)      %compute and plot z plane
subplot(2,2,4)
stem(t,h)       %plot impulse response
ylabel('impulse response')
xlabel('n')
%filter the signal
fs=filter(B,A,spn)
sound(fs,8000)
```

ORGANIZE DATA IN A AND b

WIENER FILER WITH THE PSEUDO INVERSE





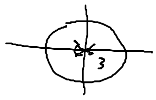

```
s=[1 2 3 4 1 2 3 4 1 3 4 ]
N=4;
d=rand(length(s)-N+1,1)
R=fliplr(s(1,1:N));
C=s(1,N:length(s));
A=toeplitz(C,R)

h=pinv(A)*d
```

```
s =

   1   2   3   4   1   2   3   4   1   3   4

d =

   0.8147
   0.9058
   0.1270
   0.9134
   0.6324
   0.0975
   0.2785
   0.5469

A =

   4   3   2   1
   1   4   3   2
   2   1   4   3
   3   2   1   4
   4   3   2   1
   1   4   3   2
   3   1   4   3
   4   3   1   4

h =

   0.0957
   0.1270
  -0.0577
   0.0321
```

PREPARE THE ALGORITHM ON A SMALL SET

$$H(z) = h[1] + h[2]z^{-1} + h[3]z^{-2} + h[4]z^{-3}$$

$$= \frac{1}{z^3}\left(h[1]z^3 + h[2]z^2 + h[3]z + h[4]\right)$$



Questo filtro non ha alcun senso perché s e d sono invertiti.