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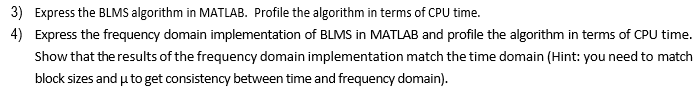

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Below is the output from my code in matlab comparing the time for the 2 algorithms. Nb is my block size, The first plots are in MSE since for parts 3 and 4 its not specified and the rest are in NEE. Its easy to see that with the right mu value that the algorithms behave almost identically. When looking at the MSE plots they converge at about the same time with the same slope and about the same mis adjustment.

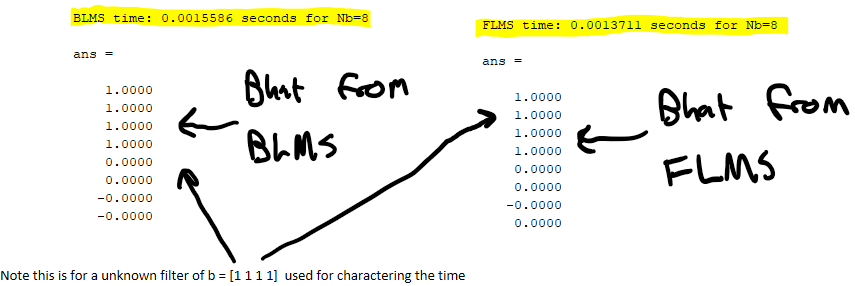
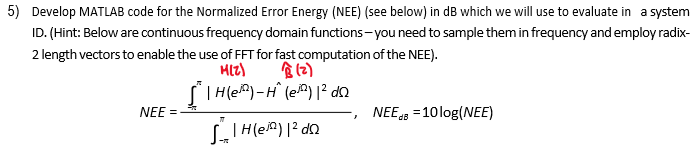
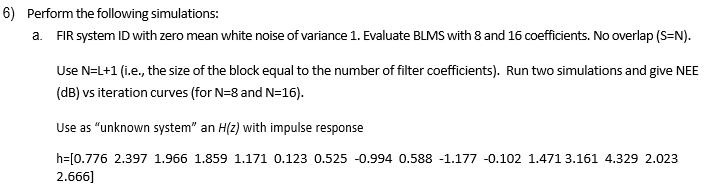


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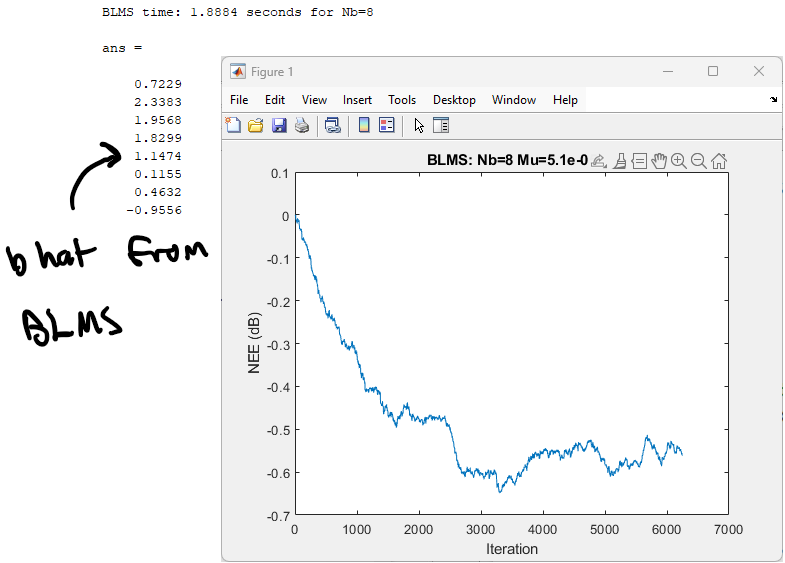


Here is the output of my plots after I got the NEE working. This is assuming the same unknown filter mentioned in the previous problems. The slopes here are about the same and it much easier to see what the algorithm is doing when comparing this to MSE plot up above.

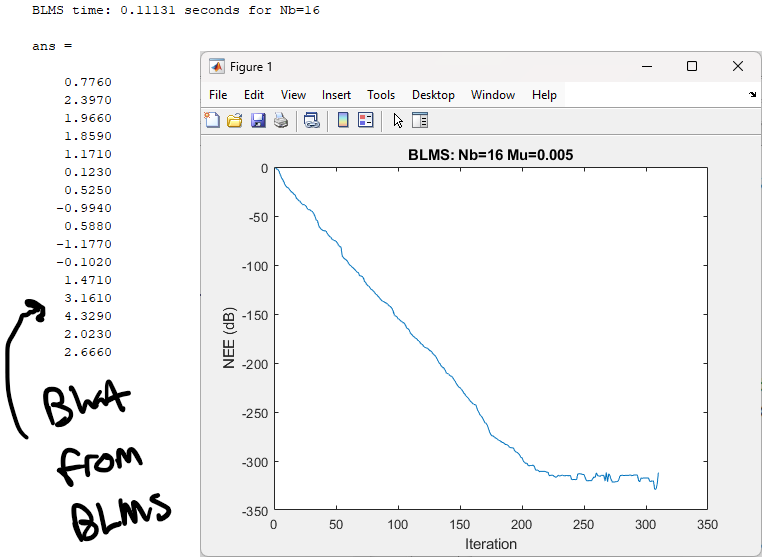
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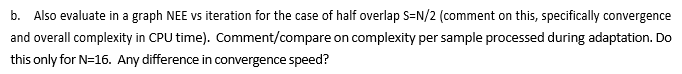
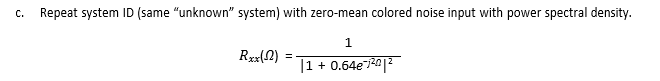
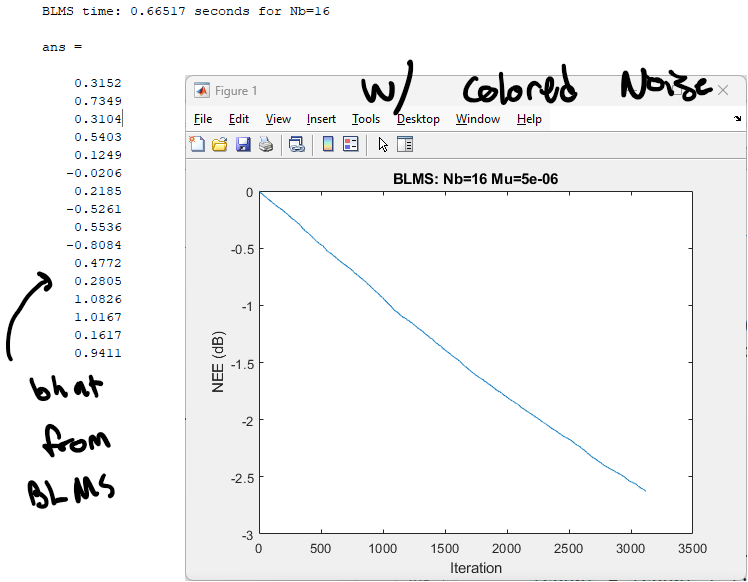


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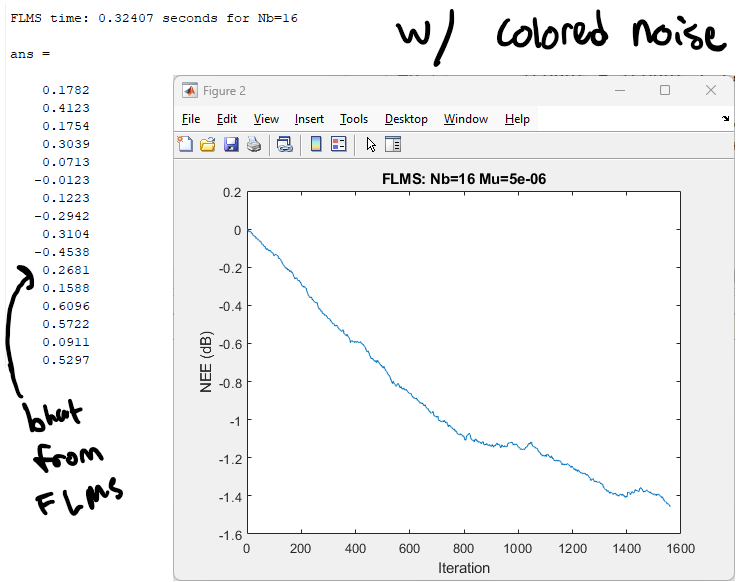
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What I learned:

I struggled very much with getting the BLMS algorithm to work. I spent a lot of time here trying to get this algorithm to work. I learned after reading the Clark and Mitra paper, they talked about how the LMS is a special case for the BLMS and since we had working code for the LMS algorithm I compared the 2 algorithms. To do this I had the BLMS with a block size of 1 and slowly stepped through the code in both algorithms to see where the differences were. I quickly noticed that my error and desired signal were different and realized that my issue was with indexing the output. I was starting at the Nbth input data but was grabbing the block from the desired signal at time equals zero to start. But that was after a whole weekend of studying the algorithm. I had a lot of fun getting this to work but it was tougher than I thought it would be. The FLMS, I followed the lecture notes and got it working almost right away. I think some of that was because I struggled so much with the BLMS that I knew how to be much more careful when writing out my code and I also didn't make the same mistakes that I did with the BLMS. I also started this test out using python because I am more comfortable in python syntax. But ended up switching over to MATLAB after realizing the filter function I was using in python was not working as intended. After switching over to MATLAB, my eyes were opened at how easy the debugging capability is and how well MATLAB is structured for matrix and vector math. I could see all my vector/matrix sizes and easily see the data updating as I stepped through my code. All in all, I had a blast with this test and I learned a ton about how to read the notation and how to apply it in a simulation. I learned how to write my code in a way that would make it easy to debug and rapidly iterate. After applying the BLMS I could easily see how it connects to the FLMS and FDAF. I understood better how the convolution worked in the BLMS and the advantages of the Frequency domain application. I also want to give a shout out to the Adaptive Filter Theory textbook by Simon Haykin. Reading through his description of the BLMS algorithm helped me understand quite a bit better how the algorithm worked and how to expect to code it.

**Appendix for Code**

The file labeled Midterm top is the main function. This then calls the BLMS algorithm and the FLMS algorithm at which point call the nee\_num and nee\_denom functions which is short for numerator and denominator respectively. The parameters for adjustment are near the top of the midterm\_top file. A quick rundown of those:

* Nb: Block Size
* mu: the step size
* N\_points: sets the number of samples for the input and desired signals.
* eflag: sets how to calculate and plot the error. 1 for NEE and 0 for MSE
* s: Shifting parameter for the how much to shift the block after each iteration
* d\_flag: sets the desired signal to by created by white noise or colored noise.

This file structure makes it easy to ensure same block size, mu, shifting parameter, input signal, desired signals, etc are arriving to both the BLMS and the FLMS algorithms to make comparison easier.

Function Tree

Midterm\_top

|

|🡪BLMS

|🡪 nee\_num

|🡪 nee\_denom

|-->FLMS

|🡪 nee\_num

|🡪 nee\_denom

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% Midterm top level

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clear;

close all;

%% Parameters

Nb = 16; %block size

mu = .0051; %step size

N\_points = 1008; %number of points

eflag = 0; %1 for NEE and 0 for MSE

s = Nb; %shifting parameter

d\_flag = 1; %1 for white noise input, 0 for colored noise input

%% Unknown systems

%b = [1 1 1 1];

b=[0.776 2.397 1.966 1.859 1.171 0.123 0.525 -0.994 0.588 -1.177 -0.102 1.471 3.161 4.329 2.023 2.666];

cb = [1];

ca = [1 0.64];

try

bpad = zeros(1, Nb -length(b));

catch

disp("b is already correct size")

end

b = [b, bpad];

a = [1];

%% Create the desired signal

rng(3) % seed the random number generator to produce the same numbers

x = randn(N\_points, 1); %white noise

d1 = filter(b, a, x); %nominal output

cd = filter(cb, ca, x); %colored noise

d2 = filter(b, a, cd); %colored output

if d\_flag == 1

d = d1; %desired signal for white noise input

else %d\_flag == 0

d = d2;

end

%% BLMS

blms(Nb, mu, x, d, N\_points, b, eflag, s)

%% Fast LMS

flms(Nb, mu, x, d, N\_points, b, eflag, s)

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% BLMS Function

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function bhat = blms(Nb, mu, x, d, N\_points, b, eflag, s)

%% Variable creation

%N\_points = 6000;

%eflag = 1;

%algorithm controls

%mu = .001;

%Nb = 16;

L = Nb-1;%Nb-1;

coef = L+1;

%s = Nb/2; % shifting parameter size

%% Algorithm

xb = zeros(Nb, coef);

xbb = zeros(Nb, coef);

yb = zeros(coef, 1);

eb = zeros(coef, 1);

e = zeros(N\_points,1);

E = zeros(floor((N\_points-Nb)/s),1);

bhat = zeros(coef,1);

tic

icount = 0;

for i = 1: s : N\_points- (3\*coef) % i is the block index

icount = icount + 1;

%disp(icount)

%create the input block

for j = 1:Nb

xv = (x(i+j-1 : i+j-1+L)); %the ith block and the jth sample to the jth+L sample

xbb(j, :) = xv';

xb(j, :) = flip(xv');

end

xbt = xb';

%calculate output

yb = xb \* bhat; % Nbx(L+1) \* (L+1)x1

%calculate the error

db = d(coef + i-1 : Nb + coef + i-2); %get the current block %this is where I had all my issues, since I am starting the convolution at the Nbth sample I need to get the Nbth desired sample

eb = db - yb;

e(coef + i-1 : Nb + coef + i-2) = eb; %save the error

%calc gradient

grad = xb' \* eb;

%update weights

bhat = bhat + (2) \* mu \* grad;

if eflag == 1

B = fft(b);

Bhat = fft(bhat);

num = nee\_num(B, Bhat, Nb); %freq of B - freq of Bhat

denom = nee\_denom(B, Nb);

E(icount) = trapz(num)/trapz(denom);

end

end

elapsed\_time = toc;

disp(['BLMS time: ', num2str(elapsed\_time), ' seconds for Nb=', num2str(Nb)]);

figure;

title\_str = ['BLMS: Nb=', num2str(Nb), ' Mu=', num2str(mu)];

if eflag == 1

plote = 10\*log10(E);

plot(plote(:));

title(title\_str);

ylabel('NEE (dB)')

xlabel('Iteration')

else

plote = 10\*log10(e.\*e +0.0000001);

plot(plote(:));

title(title\_str);

ylabel('MSE (dB)')

xlabel('Iteration')

end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% BLMS Function

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function bhat = flms(Nb, mu, x, d, N\_points, b, eflag, s)

%Nb = block size

%mu = step size

%x = input signal

%d = desired signal

%N\_points = number of points in the signal

%% Variable creation

%eflag = 0;

%algorithm controls

%mu = .001;

%Nb = 8;

%s = Nb; % shifting parameter size

%% Algorithm

Ek = zeros(2\*Nb, 1);

e = zeros(N\_points,1);

E = zeros(floor((N\_points-Nb)/s),1);

Bhat = zeros(2\*Nb,1);

zpad = zeros(1, Nb);

b = [b, zpad];

tic

icount = 0;

for i = 1: s : N\_points- 2\*Nb % i is the block index

icount = icount + 1;

%get the input block

xv = x(i : (i-1)+Nb\*2); %the ith block and the jth sample to the jth+L sample

db = d(Nb + (i-1) : Nb + (i-1) + (2\*Nb-1)); %get the current block, which to start is the Nbth d sample

%do the ffts

Xk = fft(xv);

Dk = fft(db);

%calculate output

Xkd = diag(Xk);

Yk = Xkd \* Bhat; % Nbx(L+1) \* (L+1)x1

%calculate the error

yb = ifft(Yk);

yn = yb(Nb+1: Nb\*2); %grabbing the last N points

dn = d(Nb+1 + (i-1) : Nb+1 + (i-1) + (Nb-1)); %get the Nbth output from desired signal

en = dn - yn; %generating the error in time domain

e(Nb + (i-1) : Nb + (i-1) + (Nb-1)) = en;

eb = [zpad'; en]; %pad the error signal before ffting

Ek = fft(eb);

%calc gradient + update weights

Bhat = Bhat + 2\*mu\*Xkd'\*Ek ;

if eflag == 1

B = fft(b);

num = nee\_num(B, Bhat, Nb); %freq of B - freq of Bhat

denom = nee\_denom(B, Nb);

E(icount) = trapz(num)/trapz(denom);

end

end

b = ifft(Bhat);

bhat = b(1:Nb);

elapsed\_time = toc;

disp(['FLMS time: ', num2str(elapsed\_time), ' seconds for Nb=', num2str(Nb)]);

figure;

title\_str = ['FLMS: Nb=', num2str(Nb), ' Mu=', num2str(mu)];

if eflag == 1

plote = 10\*log10(E);

plot(plote(:));

title(title\_str);

ylabel('NEE (dB)');

xlabel('Iteration');

else

plote = 10\*log10(e.\*e +0.0000001);

plot(plote(:));

title(title\_str);

ylabel('MSE (dB)');

xlabel('Iteration');

end

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% NEE Functions for integration

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

function num = nee\_num(B, Bhat, N)

freqB = freqz(B, 1, N);

freqBhat = freqz(Bhat, 1, N);

num = abs(freqB - freqBhat).^2;

end

function denom = nee\_denom(B, N)

freqB = freqz(B, 1, N);

denom = abs(freqB).^2;

end