Advanced Digital Signal Processing Coursework
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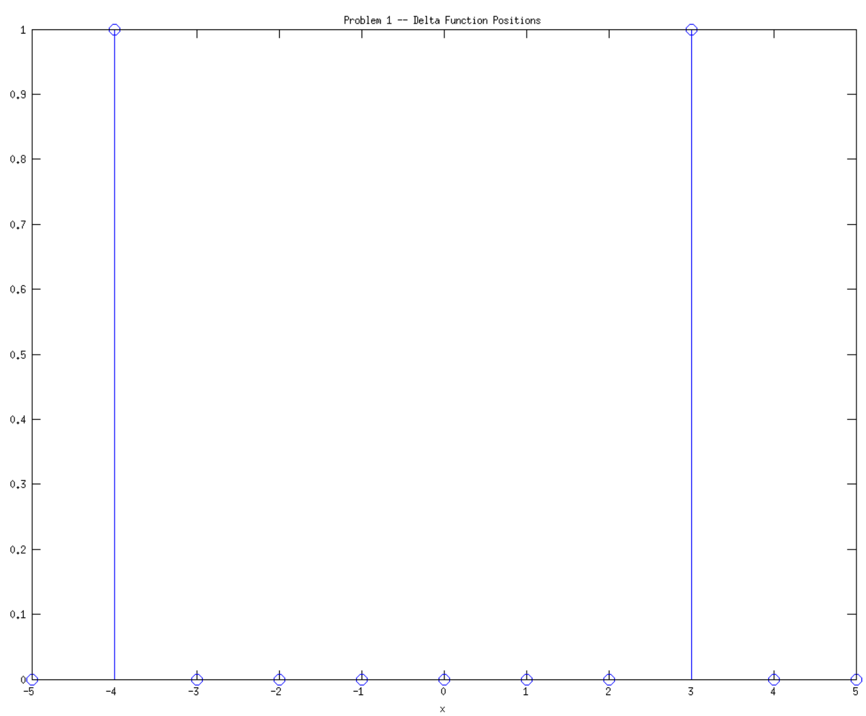
All programs also hosted at https://github.com/ACooperSussex/DSP-Coursework.git

1 Problem 1a

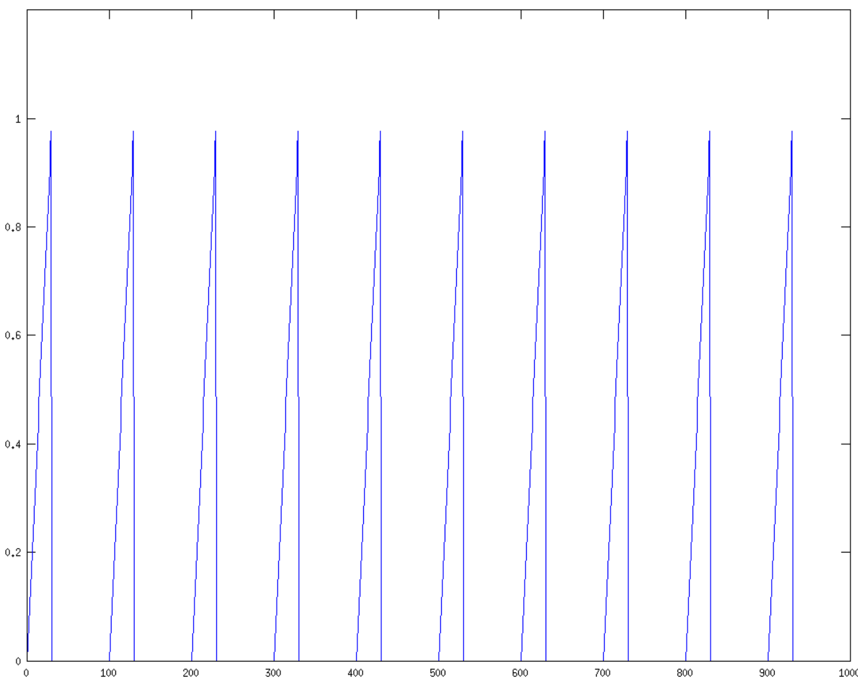
```
%Problem 1a - Generate the following discrete sequence:
% delta(n-3) + delta(n+4)
x=-5:5;
m = zeros(1,size(x,2));
% Delta function at x= -4
m(2) = 1;
% Delta function at x= 3
m(9) = 1;

h = figure;
circshift(m,-4,1);
stem(x,m)
xlabel('x')
title('Problem 1 -- Delta Function Positions')
```

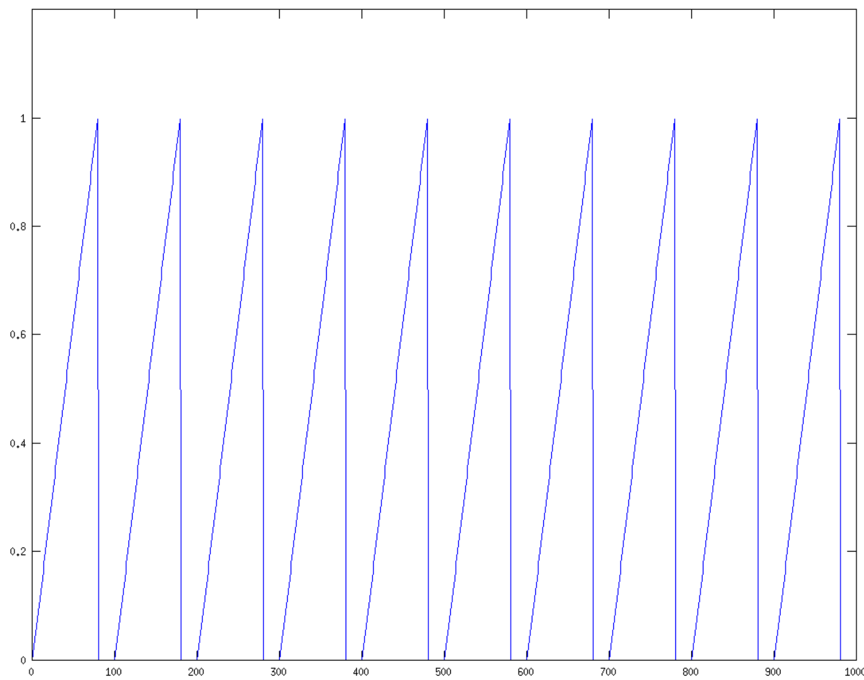


2 Problem 1b

```
%Problem 1b (i and ii)
%Generate a sawtooth waveform with a chosen duty cycle:
clear all; close all;

%Get the duty cycle percentage. Should be less than 100%.
duty = mod(ceil(input('Enter desired Duty Cycle (%) : '))
    ,100);

%Generate the sawtooth shape
f = @(x) [x/duty.*(0<=x & x<=duty)];
x = linspace(0,100);
y = f(x);

%Number of times to repeat sawtooth in plot
repetitions = 10;
yy = y;
for i=1:repetitions;
yy = cat(2,yy,y);
end

% Plot
h = figure(1);
plot(1:length(yy),yy)
ylim([0 1.2]);
xlim([0 repetitions*100]);
```

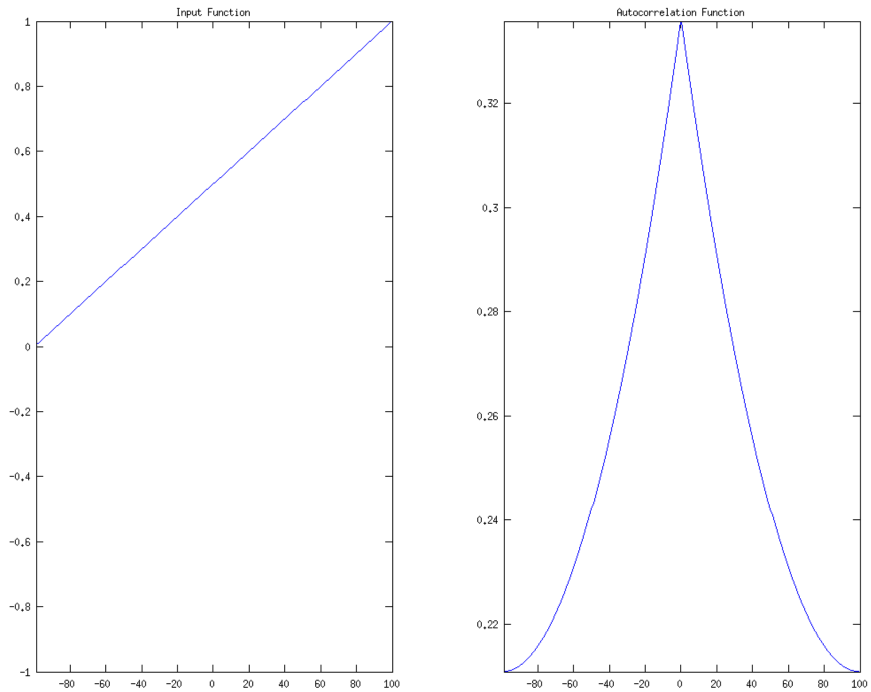
Showing output for 30% and 80% duty cycles respectively.




1
0.8
0.6
0.4
0.2
0
0
100
200
300
400
500
600
700
800
900
1000

3 Problem 2(i)

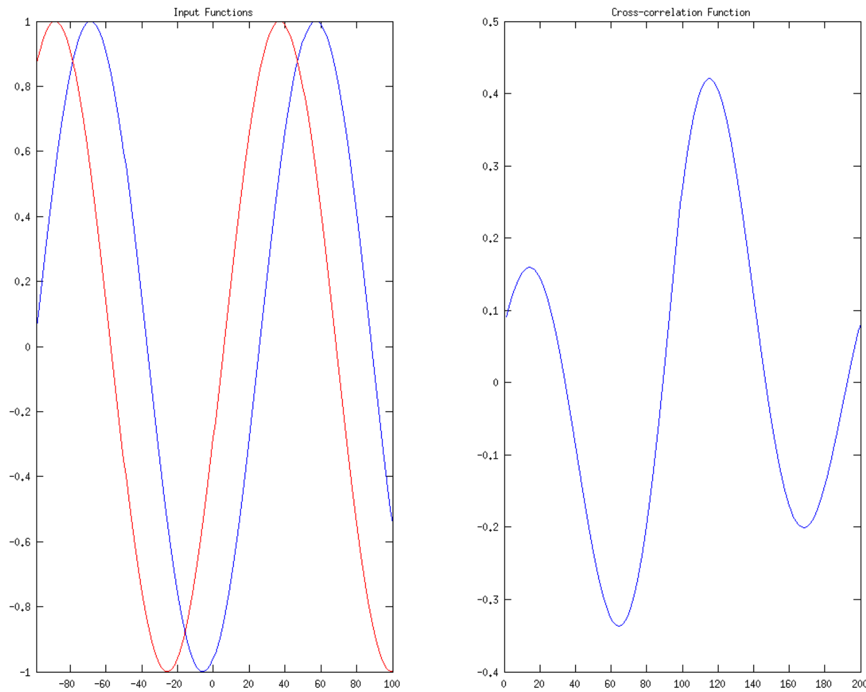
```
%Problem 2(i)
%Auto-correlate a sequence with itself
clear all; close all;

N = 200;
% Simple Line Input
x = (1:200)/N;


% Initialize array to hold the autocorrelation data
psi = x*0;

for i = 1:N
    xshift = circshift(x,[0,(i + N/2)]);
    psi(i) = N^-1 * sum(x .* xshift);
end

h= figure;
subplot(1,2,1)
plot(-floor(N/2)+1:floor(N/2),x);
title('Input Function');
axis([-floor(N/2)+1 floor(N/2) -1 1]);
subplot(1,2,2)
plot(-floor(N/2)+1:floor(N/2),psi);
title('Autocorrelation Function');
axis([-floor(N/2)+1 floor(N/2) min(psi) max(psi)])
```



Input Function
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-80
-60
-40
-20
0
20
40
60
80
100
Autocorrelation Function
0.32
0.3
0.28
0.26
0.24
0.22
-80
-60
-40
-20
0
20
40
60
80
100

4 Problem 2(ii)

```
%Problem 2(ii)
%Write a program to cross-correlate two sequences
clear all; close all;

N = 200;
% sin-shaped signal -- slowly varying
x(1:N) = sin((1:N) / 20);
y(1:N) = sin(((1:N)+20) / 20);

% Initialize array to hold the correlation data
psi = x*0;

for i = 1:N
    yshift = circshift(y,[0,(i + N/2)]);
    psi(i) = N^-1 * sum(x .* yshift);
end

h = figure
subplot(1,2,1)
plot(-floor(N/2)+1:floor(N/2),x,'b');
title('Input Functions');
axis([-floor(N/2)+1 floor(N/2) -1 1]);
hold on;
plot(-floor(N/2)+1:floor(N/2),y,'r');
subplot(1,2,2)
plot(1:size(psi,2),psi);
title('Cross-correlation Function');
```

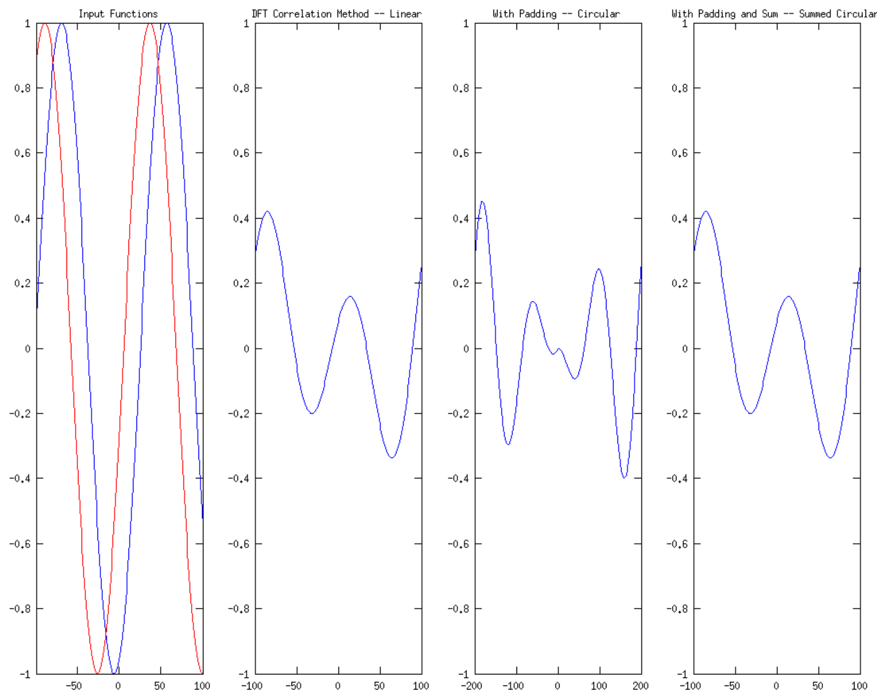

Input Functions
Cross-correlation Function

5 Problem 3

```
%Problem 3
% Write a program to linearly correlate two time sequences using the DFT.
% Perform the circular computation and then repeat with correct zero
% supplementation. Comment on the differences between the output sequences
% obtained.

clear all; close all;

N = 200;
% sin-shaped signal -- slowly varying
x(1:N) = sin((1:N)/20);
x_f = fft(fftshift(x));
y(1:N) = sin(((1:N)+20) / 20);
y_f = fft(fftshift(y));

% Correlation without Padding
% Do the multiplication in frequency space
psi_f = x_f .* conj(y_f);
psi_1 = (ifft(psi_f))/N;

% Correlation with Zero Padding
% Pad arrays to size N >= N_1 + N_2 - 1
pad_size = size(x,2) + size(y,2) - 1;
x_padded = zeros(1,pad_size); x_padded(size(x,2):end) = x(1:end);
y_padded = zeros(1,pad_size); y_padded(1:size(y,2)) = y(1:end);
x_padded_f = fft(fftshift(x_padded));
y_padded_f = fft(fftshift(y_padded));

y_save = x_padded_f .* conj(y_padded_f);
y_save = ifftshift(ifft(y_save));

psi_2 = y_save / N;
psi_2_sum = (y_save(1:N) + y_save(N:end)) / N;


h = figure
subplot(1,4,1)
plot(-floor(N/2)+1:floor(N/2),x,'b');
```

```
title('Input Functions');
axis([-floor(N/2)+1 floor(N/2) -1 1]);
hold on;
plot(-floor(N/2)+1:floor(N/2),y,'r');
subplot(1,4,2)
plot(-N/2:N/2-1,psi_1);
title('DFT Correlation Method -- Linear');
axis([-N/2 N/2 -1 1])
subplot(1,4,3)
plot(-N+1:N-1,psi_2); hold on;
title('With Padding -- Circular')
axis([-N N -1 1])
subplot(1,4,4)
plot(-N/2:N/2-1,psi_2_sum);
title('With Padding and Sum -- Summed Circular')
axis([-N/2 N/2 -1 1])
```

Graph 1 shows the input functions, Graph 2 shows the linear correlation, Graph 3 shows the circular correlation, Graph 4 shows the summed version of Graph 3 to show that it is the same as Graph 2. The differences between Graphs 2 3 are due to the circular correlation producing a periodic output.



6 Problem 4

```matlab
% Problem 4
% Write a program to design an IIR high-pass digital filter based on a Butterworth analogue prototype.
%The user should be able to specify the filter with: the -3 dB cut-off frequency; and the frequency at
%an X dB attenuation point of the filter; and the sampling rate. (From these specifications the program
%should automatically determine the required filter order).
% Plot the magnitude of the frequency response of the filter.

point_1_f = input('Enter desired -3dB cut-off frequency : ')
point_2 = input('Enter next attenuation point (dB): ')
point_2_f = input('Enter desired frequency at the next attenuation point : ')
sample_rate = input('Enter sampling rate : ')

T = 1/sample_rate;
w = 0:sample_rate;
w_ac = (2/T) * tan(2*pi * point_1_f * T / 2);
w_att = (2/T) * tan(2*pi * T * point_2_f/2);

filter_order = round(log10(10^(point_2/10) - 1) / (2*log10(w_ac/w_att)));
disp(['Filter has order: ', num2str(filter_order)]);

z = exp(1i*w*T);
% High-pass filter:
G = (z-1) ./ (2 + w_ac * (T/2)).*z + (w_ac*(T/2) - 1);

% Plot up until operating range of filter at z=-1
h = figure;
plot(w,abs(G).^2);
xlabel('Frequency');
ylabel('G(f)');
title('Frequency Response of Filter')
```

Using the bilinear transform method for IIR filter design.
The following were derived for use in the program:

$$\text{Substitution for s in the high-pass filter case} : \ s = \frac{\omega_a}{s} \tag{1}$$

$$\text{Substitution for bilinear transform} : \ s = \frac{2}{T}\frac{z-1}{z+1} \tag{2}$$

$$G(z) = \frac{z-1}{(z-1) + w_{ac}\frac{T}{2}(z+1)} \tag{3}$$

$$G(z) = \frac{z-1}{(1 + w_{ac}\frac{T}{2})z + (w_{ac}\frac{T}{2} - 1)} \tag{4}$$

$$\tag{5}$$

Graph of the frequency response of the filter. With a -3dB cut-off frequency of 1 kHz, attenuation of 10 dB at 350 Hz, and a sampling frequency of 5 KHz.