ECS602U Digital Signal Processing Lab 1

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Contents

1 Preface

This is the report after the first lab of ECS602U. We had a choice from two exercises and I decided to solve the first one: *Moving Average of Time-Series.* The exercises requires to analyse data from a provided file[1]. This contains measurements taken from an ocean buoy positioned off the coast of Oceanside, California, in March 2006.
After extracting all the data [2] and plotting the magnitudes of Peak Period and Significant Wave Height[3] , a matlab function to compute the M-Order Moving Average[4] is utilised to generate subplots for the 5th, 21st and 51st order moving average of the plotted measurements [5].
An improvement on the M-Order Moving Average function is implemented, in order to remove the delay generated by converting it into a non-causal system [6] and the Moving Average graphs are the plotted again [7].

[1] 045200603.txt
[2] relevant code 2.1
[3] relevant code 2.2
[4] relevant code 2.3
[5] code 2.4 , 2.6
[6] relevant code 2.8
[7] relevant code 2.9

2 Moving Averages of Time-Series

2.1 Retrieve measurements

The function receives as an input the file name and returns a data struct and the total number of elements held by the struct.

```
function [data, count] = readbuoydata(datafile)
%open filename for read returning a scalar file identifier
fid = fopen(datafile,'r');
% stores content of first line in tline var, moves fptr forward
tline = fgetl(fid)
% stores content of second line in tline var, moves fptr forward
tline = fgetl(fid)
%fills up a matrix of 10 columns and
%as many rows (inf) are required until EOF is reached
[A,count] = fscanf(fid,'%d %d %d %d %d %f %f %d %f %f',[10 inf]);
%fill data struct
%converts an array of 6 elements [YMDHMS]',
%where M,S=0 into a serial date number
data.date = datenum([A(1:5,:); zeros(1,size(A,2))]')';
 % significant wave height, 6th element per row
data.Hs = A(6,:);
% peak period, 7th element per row
data.Tp = A(7,:);
% peak period direction, 8th element per row
data.Dp = A(8,:);
% average period 9th element per row
data.Ta = A(9,:);
% sea surface temperature, 10th element per row
data.SST = A(10,:);
%closes file
fclose(fid);
```

2.2 Plotting Peak Period and Significant Wave Height

Figure 1 shows the plot of peak period and significant wave height.

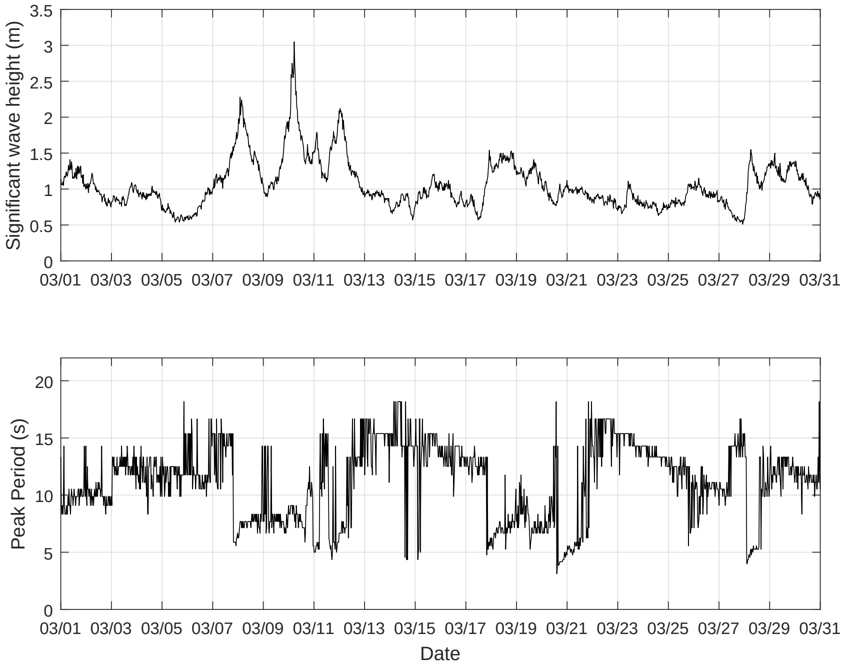

Figure 1: Significant wave height(top) and peak wave period (bottom) of the Oceanside offshore buoy for the month of March 2006.

It is acheived using the following Matlab code.

```
[data, count] = readbuoydata('045200603.txt');

x = data.date;
y = data.Hs;

figure;
subplot(2,1,1);
plot(x,y,'k');
axis([x(1) x(end) 0 3.5]);
set(gca,'XTick',[x(1):(x(end) - x(1))/15:x(end)]);
datetick('x',6,'keepticks','keeplimits');
grid on;
ylabel('Significant wave height (m)');

y = data.Tp;
subplot(2,1,2);
plot(x,y,'k');
axis([data.date(1) data.date(end) 0 22]);
set(gca,'XTick',[x(1):(x(end) - x(1))/15:x(end)]);
datetick('x',6,'keepticks','keeplimits');
grid on;
xlabel('Date');
ylabel('Peak Period (s)');

print(gcf,'-depsc2','ex22.eps');
```

2.3 M-Order Moving Average

The finite difference equation that allows to implement a M-Order moving average is displayed.

$$y[n] = \frac{1}{M} \sum_{k=0}^{M-1} x[n-k] \tag{1}$$

The following Matlab script is used throughout the lab to perform a M-Order Moving average of any 1-dimensional input data. The input therefore are the data vector and the M-Order of Moving Average to be performed.

```
function y=ex23(x,m)

x=x(:);
x=[zeros(m-1,1);x];

for mm=1:length(x)-m+1
    y(mm)=sum(x(mm:mm+m-1));
end
y=y/m;
y=y(:);
end
```

2.4 M-Order Moving Average for Peak Period

Figure 2 displays plots of Peak Period data smoothed by the M-Order Moving Average, where M = 5, 21, 51.

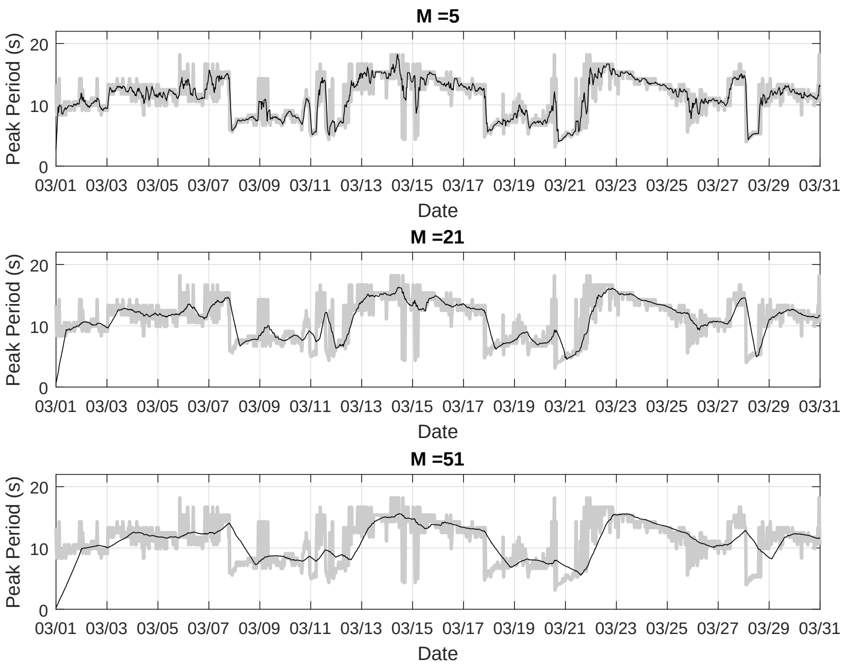

Figure 2: Moving average of peak period data with different M-Orders.

It is acheived using the following Matlab code

```
[data, count] = readbuoydata('045200603.txt');

x = data.date;
y = data.Tp;
M = [5 21 51];
figure;

for mm = 1:length(M)

    subplot(3,1,mm);
    plot(x,y,'Color',[0.8 0.8 0.8],'Linewidth',2);
    hold on;
    avg = ex23(y,M(mm));
    plot(x,avg,'k');
    axis([x(1) x(end) 0 22]);
    set(gca,'XTick',[x(1):(x(end) - x(1))/15:x(end)]);
    grid on;
    ylabel('Peak Period (s)');
    datetick('x',6,'keepticks','keeplimits');
    xlabel('Date');
    ylabel('Peak Period (s)');
    title(['M=' num2str(M(mm))]);
end

print(gcf,'-depsc2','ex24.eps');
```

2.5 Observations on averaged Peak Period data

With increasing values of M, the waveform smoothens, as more values are averaged. Given the moving average's initial value is 0, the beginning of the averaged dataset displays a gradual build up, as the sum reaches the actual average of the first samples. By similar reasoning, when the peak period suddenly drops the averaged data, decreases the slower the greater the M-Order. A general trend is much more visible with the averaged data, hence the wave trains result being more visible.

2.6 M-Order Moving Average for Significant Wave Height

Figure3 displays plots of Significant Wave Height data smoothed by the M-Order Moving Average, where M = 5, 21, 51.

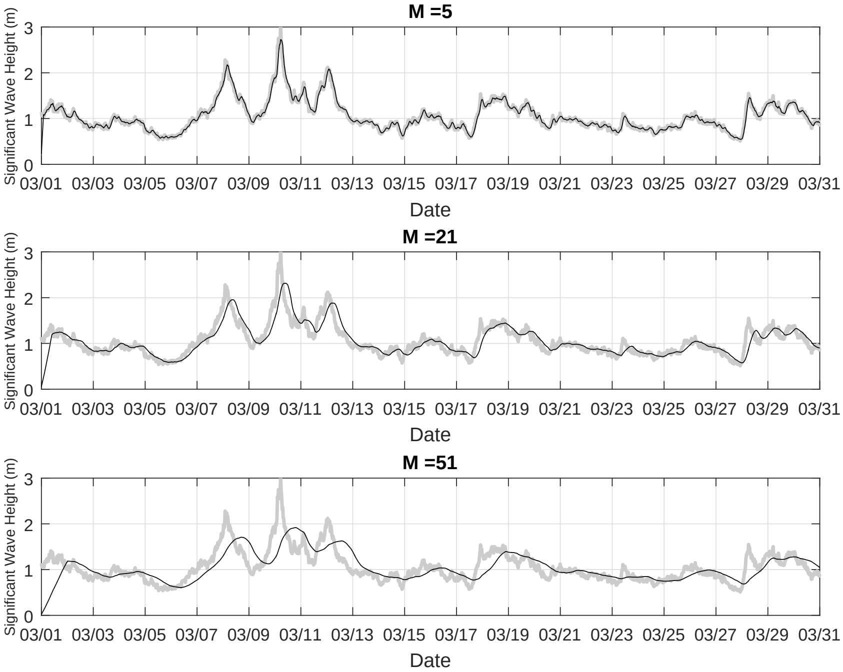

Figure 3: Moving average of Significant Wave Height data with different M-Orders.

It is acheived using the following Matlab code

```
[data, count] = readbuoydata('045200603.txt');

x = data.date;
y = data.Hs;
M = [5 21 51];
figure;

for mm = 1:length(M)

    subplot(3,1,mm);
    plot(x,y,'Color',[0.8 0.8 0.8],'Linewidth',2);
    hold on;
    avg = ex23(y,M(mm));
    plot(x,avg,'k');
    axis([x(1) x(end) 0 3]);
    set(gca,'XTick',[x(1):(x(end) - x(1))/15:x(end)]);
    grid on;
    ylabel('Peak Period (s)');
    datetick('x',6,'keepticks','keeplimits');
    xlabel('Date');
    ylabel('Significant Wave Height (m)','FontSize',8);
    title(['M =' num2str(M(mm))]);
end

print(gcf,'-depsc2','ex26.eps');
```

2.7 Observations on averaged Significant Wave Height data

The averaged data seems delayed compared to the original. The delay increases with M, as the average is done over x[n] and M-1 samples prior to it. Hence the output y[n] has moved (M-1)/2 positions forward when equation 1 is evaluating a peak mid point for the x[n-k].

2.8 Removing delay: non-causal system

Equation 2.8 represents the finite difference equation that allows us to remove the delay caused when avareging with 1

$$y[n] = \frac{1}{M} \sum_{k=\frac{(M-1)}{2}}^{\frac{(M+1)}{2}} x[n-k]$$

(2)

Below the code to convert 2.1 into a non-causal system.

```
function y=ex23(x,m)

x=x(:);
x=[zeros((m-1)/2,1);x;zeros((m-1)/2,1)];

for mm=1:length(x)-m+1
    y(mm)=sum(x(mm:mm+m-1));
end
y=y/m;
y=y(:);
end
```

2.9 Non-causal moving average of Significant Wave Height and Peak Period with different M-Orders.

Applying the non-causal system to evaluate the moving average of the data set it is possible to plot figures 4 and 5. It is visible how the moving average isn't delayed.

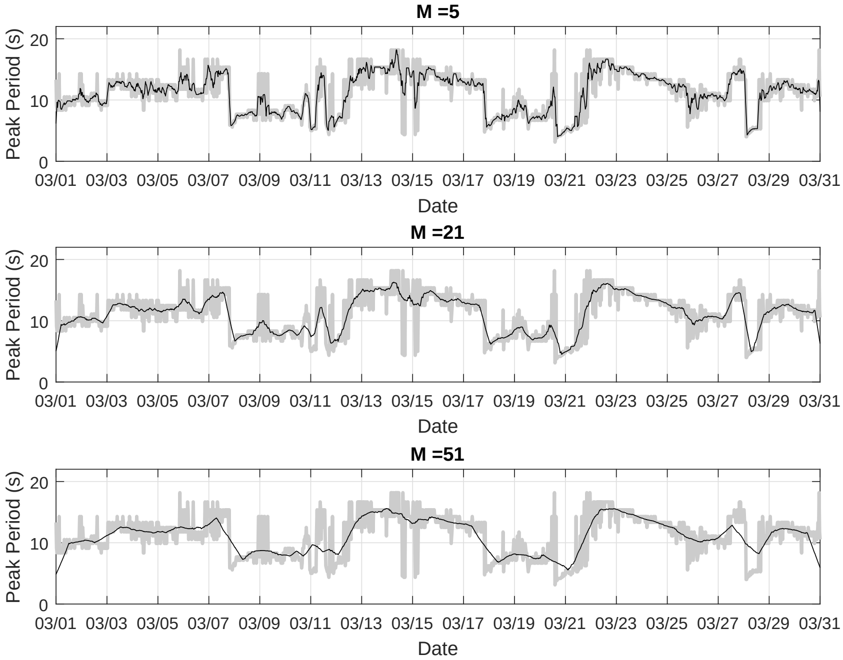

Figure 4: Moving average of Peak Period with different M-Orders.

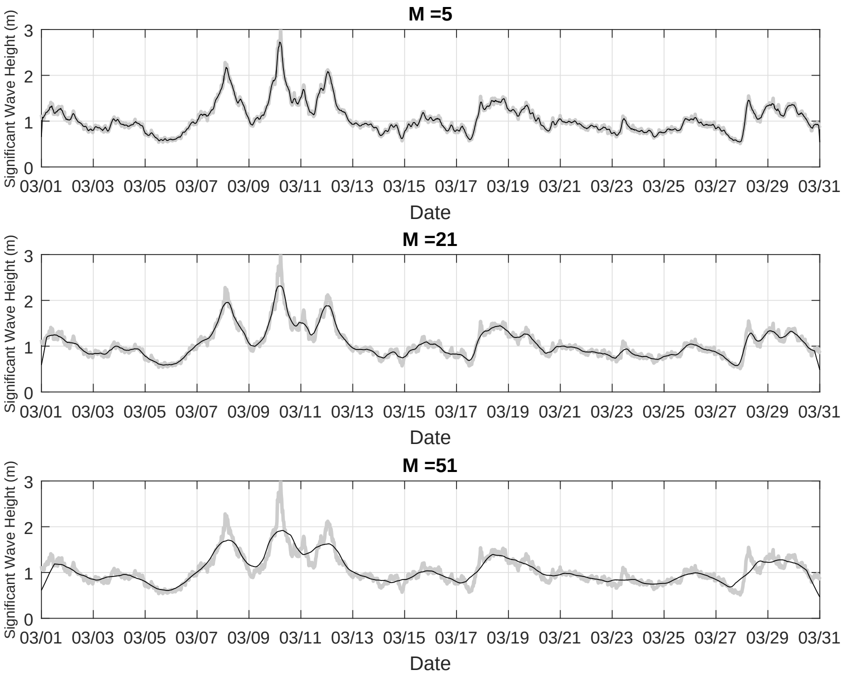

Figure 5: Moving average of Significant Wave Height with different M-Orders.

The figures are achieved with the following script.

```
[data, count] = readbuoydata('045200603.txt');

```

```
x = data.date;
y = data.Tp;
M = [5 21 51];
figure;

for mm = 1:length(M)

    subplot(3,1,mm);
    plot(x,y,'Color',[0.8 0.8 0.8],'Linewidth',2);
    hold on;
    avg = ex27(y,M(mm));
    plot(x,avg,'k');
    axis([x(1) x(end) 0 22]);
    set(gca,'XTick',[x(1):(x(end) - x(1))/15:x(end)]);
    grid on;
    ylabel('Peak Period (s)');
    datetick('x',6,'keepticks','keeplimits');
    xlabel('Date');
    ylabel('Peak Period (s)');
    title(['M=' num2str(M(mm))]);
end

print(gcf,'-depsc2','ex28b.eps');

y = data.Hs;
figure;
for mm = 1:length(M)

    subplot(3,1,mm);
    plot(x,y,'Color',[0.8 0.8 0.8],'Linewidth',2);
    hold on;
    avg = ex27(y,M(mm));
    plot(x,avg,'k');
    axis([x(1) x(end) 0 3]);
    set(gca,'XTick',[x(1):(x(end) - x(1))/15:x(end)]);
    grid on;
    ylabel('Significant Wave Height (m)','FontSize',8);
    datetick('x',6,'keepticks','keeplimits');
    xlabel('Date');
    title(['M=' num2str(M(mm))]);
end

print(gcf,'-depsc2','ex28b.eps');
```