DSP Lab 4
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1a.Specification
Detect the R wave from your recorded ECG signals.

1b. Implement

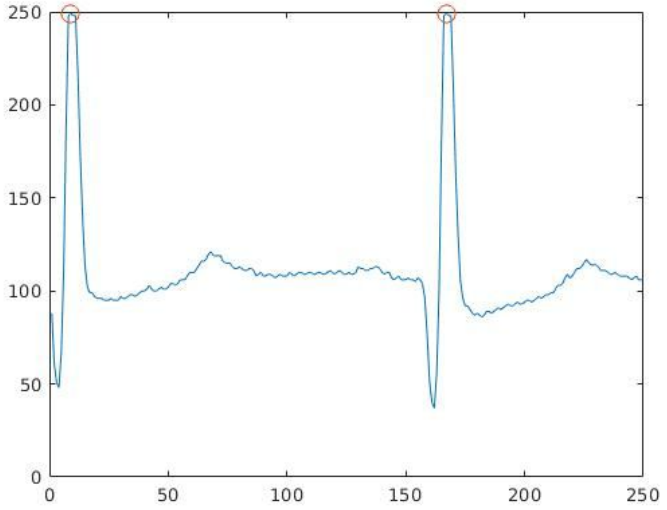


Figure 1.a

1c.Discussion

作法如下，先通過moving average filter將60hz的雜訊濾掉，再通過high pass filter [1,-1]，可以粗略知道峰值就在通過[1,-1]濾波器之後的波形，值由負轉正的那個點，以老師上課的作法是希望直接平方，但我認為平方後，負端也會被翻成正值，對於找尋真正的峰值實在是有所不易，所以我先把訊號內所有負的值變成0，做歸一化，方容易我之後取門檻值，再做平方，如此一來，在通過設定的threshold，方可以找到我要的peak點，對於訊號處理上就變得容易。實作過程中，我使用conv的函式，所以我有處理group delay的問題，根據conv的形式去shift訊號，讓訊號對到我所希望找到的峰值。

2a.Specification
Find the R-peaks in MIT-BIH database.

2b.implement

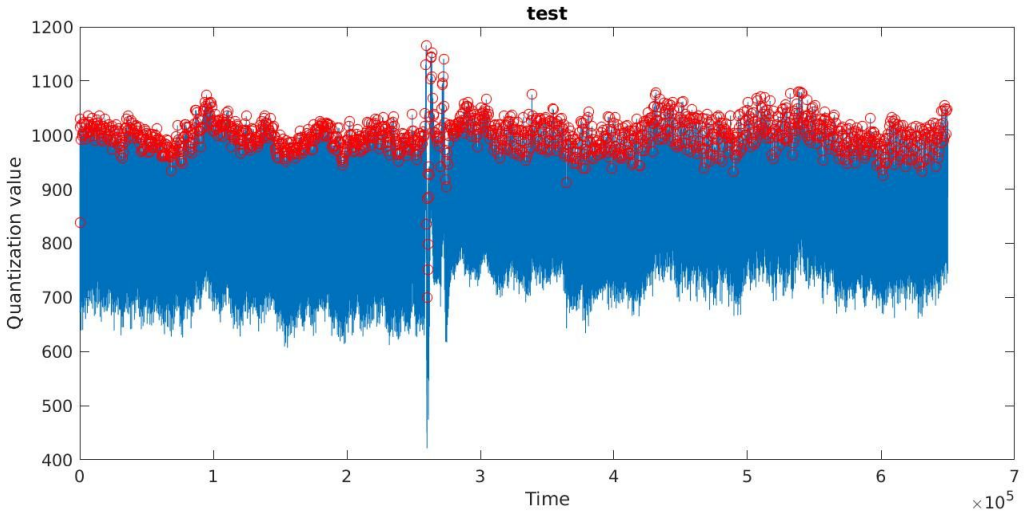


Fig 117m.mat

		TP	FN	FP	Precision
2	100.m_first_row:	2271	1	1	99.96%
3	103.m_first_row:	2079	5	0	100.0%
4	112.m_first_row:	2539	0	0	100.0%
5	117.m_first_row:	1508	26	27	98.24%
6	122.m_first_row:	2476	0	0	100.0%
7					
8	107.m_first_row:	2080	57	47	97.79%
9	114.m_first_row:	935	943	514	64.53%
10	119.m_first_row:	1986	1	1	99.95%
11	205.m_first_row:	2583	73	63	97.62%
12	219.m_first_row:	2095	59	0	100.0%
13					
14	108.m_first_row:	960	802	565	62.95%
15	203.m_first_row:	1092	1877	273	80.0%
16	210.m_first_row:	2344	305	33	98.61%
17	222.m_first_row:	2252	231	3	99.87%
18	230.m_first_row:	2255	1	3	99.87%

RECALL has shown below :

100.m 99.95%
103.m 99.76%
112.m 100.00%
117.m 98.30%
122.m 100.00%

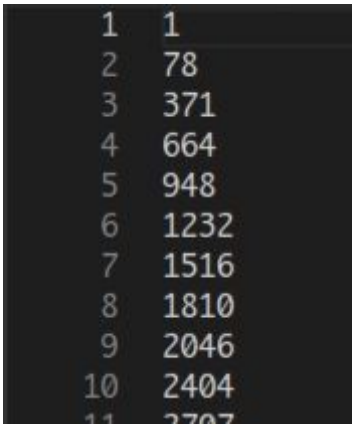
107.m 97.33%
114.m 49.78%
119.m 99.94%
205.m 97.17%
219.m 94.19%

108.m 54.48%
203.m 36.78%
210.m 99.48%
222.m 90.69%
230.m 99.95%

2c. Discussion

Precision，recall的概念在專題時就已經碰過，比較好奇的是recall的值竟然不用紀錄？！，所以我也例外的紀錄了一下recall值，precision指的是你選的資料內有多少是正確的，recall是所有正確的資料內，你選中多少比例，而TP,FP個別指的是你選的資料內正確的與錯誤的資料數，而FN 指的是正確的資料內你有多少沒選到，首先,我會先記住每一個rpeak的index，並且在之後輸出成txt檔案，再透過python處理去比對資料。在比對完資料後，再將那些資料紀錄在我的result.txt內，做成表格輸出如上。而下圖分別為matlab輸出資料code碼與輸出的資料格式

```
fileID = fopen('Desktop/4up/DSP_LAB/hw4/predict/117_1.txt','w');
fprintf(fileID,'%d\n',rpeak);
```



再者，我使用自己寫的python code去做資料比對，首先會先把每一筆資料的時間load進變數內，誤差範圍我選擇的是+-10點，大概為0.05秒左右，然後透過index先把index轉換成時間，在誤差範圍之內的差距，那個點就視為選中，然後是以一個範圍一個範圍做資料比對的。

3a.Specification

Implement the pre-processing of the ECG signals (Lab 3) and R-peak detection in real time ,and display the processed ECG signals and the R-peaks in real time.

3b.Implement

附壓縮檔內有

3c Discussion

後來real_time的寫法，我將normalize寫成一個function，high_pass也寫成一個function，moving_average也寫成一個function，找尋peak也寫成一個function，模

組化方便自己管理，每紀錄30個點，我就會去find peak尋找rpeak 點做標注index的動作，並透過index的vector，計算出heart_beat_rate。

Extra Question
1a.Specification
Please modualize your signal processing flow. That is, please make each block as a function and then perform function calls.
In your report, please specify the block diagram of your signal processing, and the corresponding function of each block.
If you're implementing real-time R-peak detection, please also justify your approach. Note that you can implement your signal processing modules in PC or in Arduino. Note that you have to hand in your codes along with your report, and please provide the average of the elapsed time for 100 loops of your signal processing via MATLAB function "tic" and "toc" (see ShortIntro2MatlabProfile.pdf)

1b.Implement:

lab4_3>low_pass (Calls: 99, Time: 0.022 s)
Generated 14-Oct-2018 21:17:46 using performance time.
subfunction in file /home/pohan/Desktop/4up/DSP_LAB/hw4/lab4_3.m
Copy to new window for comparing multiple runs

Line Number	Code	Calls	Total Time	% Time	Time Plot
66	temp=conv(data,one_filter/n,'s...	99	0.011 s	47.5%	
65	one_filter = ones(n,1);	99	0.009 s	38.3%	
67	output=temp(n-1:(length(temp)-...	99	0.001 s	5.4%	
69	end	99	0.000 s	0.7%	
64	n=8;	99	0.000 s	0.1%	
All other lines			0.002 s	8.0%	
Totals			0.022 s	100%	

Figure 1.a

lab4_3>high_pass (Calls: 99, Time: 0.010 s)
Generated 14-Oct-2018 21:13:39 using performance time.
subfunction in file /home/pohan/Desktop/4up/DSP_LAB/hw4/lab4_3.m
Copy to new window for comparing multiple runs

Line Number	Code	Calls	Total Time	% Time	Time Plot
74	output =conv(data,h1);	99	0.007 s	75.8%	
75	output = output(2:(length(outp...	99	0.001 s	10.9%	
76	end	99	0.000 s	1.0%	
73	h1 = [1 -1];	99	0.000 s	0.5%	
All other lines			0.001 s	11.8%	
Totals			0.010 s	100%	

Figure 1.b

lab4_3>hbr (Calls: 99, Time: 0.063 s)

Generated 14-Oct-2018 21:14:50 using performance time.
subfunction in file /home/pohan/Desktop/4up/DSP_LAB/hw4/lab4_3.m
Copy to new window for comparing multiple runs

Line Number	Code	Calls	Total Time	% Time	Time Plot
111	for i = 2:(length(rpeakvector)...	99	0.030 s	48.4%	
118	output = mean(temp);	99	0.022 s	34.4%	
114	temp(i-1)= (1/(sum((rpeakvecto...	268	0.006 s	9.3%	
116	end	268	0.002 s	3.7%	
120	end	99	0.000 s	0.3%	
All other lines			0.002 s	4.0%	
Totals			0.063 s	100%	

Figure 1.c

lab4_3>normalize (Calls: 99, Time: 0.007 s)

Generated 14-Oct-2018 21:14:20 using performance time.
subfunction in file /home/pohan/Desktop/4up/DSP_LAB/hw4/lab4_3.m
Copy to new window for comparing multiple runs

Line Number	Code	Calls	Total Time	% Time	Time Plot
80	data(data<0)=0;	99	0.004 s	54.7%	
81	norm =data(:) ./ max(da...	99	0.001 s	14.8%	
83	end	99	0.000 s	2.0%	
All other lines			0.002 s	28.4%	
Totals			0.007 s	100%	

Figure 1.d

lab4_3>findrpeak (Calls: 99, Time: 0.053 s)

Generated 14-Oct-2018 21:15:10 using performance time.
subfunction in file /home/pohan/Desktop/4up/DSP_LAB/hw4/lab4_3.m
Copy to new window for comparing multiple runs

Line Number	Code	Calls	Total Time	% Time	Time Plot
100	end	83726	0.014 s	26.1%	
92	if data(i)>0.5	83726	0.012 s	23.5%	
98	i=i+1;	83726	0.012 s	22.2%	
93	[value ,index]=max(disbuff(i:i...	460	0.009 s	16.2%	
94	temp=[temp index+i-1];	460	0.004 s	6.6%	
All other lines			0.003 s	5.4%	
Totals			0.053 s	100%	

Figure 1.e

```
< 0.001      1   27 while i<3000
  0.025   2999   28     tic
  8.110   2999   29     data=fscanf(s1);%read sensor
  0.414   2999   30     y(i) = str2double(data);
                 31
  0.004   2999   32     if i<=1000
  0.003   1000   33         disbuff(i)=y(i);
< 0.001   1999   34     else
  0.073   1999   35         disbuff=[disbuff(2:end) y(i)];
< 0.001   2999   36     end
                 37
  0.006   2999   38     if i>1 & mod(i,30) == 0     %update every 30 point
                 39
  0.025     99   40         out   =  low pass(disbuff);  %lowpass
  0.012     99   41         output= high pass(out);         %high pass
  0.012     99   42         norm  = normalize(output);      %normalize
< 0.001     99   43         norm2 = norm .^ 2;              %square
  0.057     99   44         rpeak = findrpeak(norm2,disbuff);   %rpeak index get
  0.066     99   45         heartbeatrate = hbr(rpeak);     %heart beat rate
                 46
  0.072     99   47         set(h_plot,'xdata',time,'ydata',disbuff)  %draw
  0.863     99   48         title(['Heart Beat rate is ',num2str(heartbeatrate),'Hz']);
  0.368     99   49         xlabel('Time');
  0.784     99   50         ylabel('Quantization value');
                 51
  0.001     99   52         if length(rpeak)>=1
  0.043     99   53             set(d_plot,'xdata',rpeak,'ydata',disbuff(rpeak));
  2.166     99   54             drawnow;
< 0.001     99   55         end
                 56
< 0.001     99   57     end
< 0.001   2999   58     i=i+1;
  0.311   2999   59     disp(i);
  0.002   2999   60 end
```

My Module function:

```
function output=low_pass(data)

    n=8;
    one_filter = ones(n,1);
    temp=conv(data,one_filter/n,'same');
    output=temp(n-1:(length(temp)-(n-1)));
end
```

Figure 1.g

```
function output=high_pass(data)

    h1 = [1 -1];
    output =conv(data,h1);
    output = output(2:(length(output)-1));
end
```

Figure 1.h

```
function norm  = normalize(data)

    data(data<0)=0;
    norm        =data(:) ./ max(data);
end
```

Figure 1.i

```
function rpeak = findrpeak(data,disbuff)
    temp=[1];
    i=1;
    while i<(length(disbuff)-90)
        if data(i)>0.1
            [value ,index]=max(disbuff(i:i+90));
            temp=[temp index+i-1];
            i=i+90;
        end
        i = i+1;
    end
    rpeak=temp;
end
```

Figure 1.j

1c Discussion

我這邊以real_time跑3000次(每三十個點找peak)為例，我發現我花最多時間的是在draw跟fscanf這兩個function內，倒是自己做的function速度蠻快的，自己做的函式又以heart beat rate跟find peak是所有自己定義的function裡面花最久的。以紀錄來說我是使用profile on這個built-in 函式去做測時。

2a.Specification

Please draw a table in your report. The first column is the name of the data set, the 2nd column is TP, the 3rd column is FN, and the 4th column is FP. Please justify how you estimate your TP, FN, and FP and the precision when matching your results with the ground truth.

2b Implement

	TP	FN	FP	Precision
100.m_first_row:	2271	1	1	99.96%
103.m_first_row:	2079	5	0	100.0%
112.m_first_row:	2539	0	0	100.0%
117.m_first_row:	1508	26	27	98.24%
122.m_first_row:	2476	0	0	100.0%
107.m_first_row:	2080	57	47	97.79%
114.m_first_row:	935	943	514	64.53%
119.m_first_row:	1986	1	1	99.95%
205.m_first_row:	2583	73	63	97.62%
219.m_first_row:	2095	59	0	100.0%
108.m_first_row:	960	802	565	62.95%
203.m_first_row:	1092	1877	273	80.0%
210.m_first_row:	2344	305	33	98.61%
222.m_first_row:	2252	231	3	99.87%
230.m_first_row:	2255	1	3	99.87%

FIG 2A

As shown above

2c.Discussion
前面第二小題

3a.Specification
Note that you have to take care "the delay" (from linear phase FIR filter) introduced by your signal processing (e.g., FIR filtering) in order to obtain the same R-peak time as provided in the *.txt file when you find R-peak

3b.implement
[

```
function output=low_pass(data)

    n=8;
    one_filter = ones(n,1);
    temp=conv(data,one_filter/n,'same');
    output=temp(n-1:(length(temp)-(n-1)));
end

function output=high_pass(data)

    h1 = [1 -1];
    output =conv(data,h1);
    output = output(2:(length(output)-1));
```

```
End
]
```
(以上為function code)(以下為main的一小部份）

```
if length(rpeak)>=1
   set(d_plot,'xdata',(rpeak-1),'ydata',disbuff(rpeak));
   %drawnow;
end
```

3c.Discussion
由上可以看到，因為有delay的關係，所以必須微調將點的位置微調回來

4a Specification
Real time filtering can be simply implemented according to the "structures" of the discrete-time FIR or IIR system (see at 5:53).
In your report, please "elaborate" how you implement your real time filtering and provide your codes in your report and explain your codes.
(from this you should know the "structure" of a system (or a transfer function, H(z) = Y(z)/X(z), Y(z): output, X(z): input) can be used for real-time implementation of a digital signal processing system)

4b.Implement

```
%%%%%setup%%%%%%

clear all;
fclose('all');
serialobj=instrfind;
if ~isempty(serialobj)
   delete(serialobj)
end
clc;clear all;close all;
s1 = serial('/dev/ttyACM0');  %define serial port
s1.BaudRate=115200;     %define baud rate

disbuff=nan(1,1000);

fopen(s1);
clear data;
N_point = 1000;
fs=250;   %sample rate
```

```
time=[1:1:1000];
Figure

h_plot=plot(nan,nan);
hold on;
d_plot=plot(nan,nan,'ro');hold off;
tic
%%%%%%set up%%%%%%

i=1;
%%%%%%%%infinite loop%%%%%%%%%%
while 1

   data=fscanf(s1);%read sensor
   y(i) = str2double(data);

   if i<=1000
      disbuff(i)=y(i);
   else
      disbuff=[disbuff(2:end) y(i)];
   end

   if i>1 & mod(i,30) == 0     %update every 30 point

      out   =  low_pass(disbuff);  %lowpass
      output= high_pass(out);         %high pass
      norm  = normalize(output);      %normalize
      norm2 = norm .^ 2;              %square
      rpeak = findrpeak(norm2,disbuff);   %rpeak index get
      heartbeatrate = hbr(rpeak);     %heart beat rate

      set(h_plot,'xdata',time,'ydata',disbuff)  %draw
      title(['Heart Beat rate is ',num2str(heartbeatrate),'Hz']);
      xlabel('Time');
      ylabel('Quantization value');

      if length(rpeak)>=1
         set(d_plot,'xdata',rpeak,'ydata',disbuff(rpeak));
         drawnow;
      end

   end
```

```
    i=i+1;
end
%%%%%%%%infinite loop%%%%%%%%%%

%%%%%%%%lowpass%%%%%%%%%%
function output=low_pass(data)      %low pass

    n=8;
    one_filter = ones(n,1);
    temp=conv(data,one_filter/n,'same');
    output=temp(n-1:(length(temp)-(n-1)));

end
%%%%%%%%lowpass%%%%%%%%%%

%%%%%%%%highpass%%%%%%%%%%
function output=high_pass(data)     %high pass

    h1 = [1 -1];
    output =conv(data,h1);
    output = output(2:(length(output)-1));
end
%%%%%%%%highpass%%%%%%%%%%

%%%%%%%%normalize%%%%%%%%
function norm  = normalize(data)    %normalize

    data(data<0)=0;
    norm        =data(:) ./ max(data);

end
%%%%%%%%normalize%%%%%%%%

%%%%%%%%rpeak%%%%%%%%%%
function rpeak = findrpeak(data,disbuff)    %find peak

    temp=[];
    i=1;

    while i <(length(data)-25)

        if data(i)>0.5
```

```
        [value ,index]=max(disbuff(i:i+25));%period=25
        temp=[temp index+i-1];
        i=i+25;
    end

    i=i+1;

  end

  rpeak=temp;

End
%%%%%%%%rpeak%%%%%%%%%%

%%%%%%%% heart-beat calculate %%%%%%%%%%
function output = hbr(rpeakvector) %heart beat rate

  interval = [-1 1];
  temp=[];

  for i = 2:(length(rpeakvector)-1)

    disp((sum((rpeakvector(i:i+1) .* interval))/250.0))
    temp(i-1)= (1/(sum((rpeakvector(i:i+1) .* interval))/250.0));

  end

  output = mean(temp);

end
%%%%%%%%heart beat calculate%%%%%%%%%%
```

4c.Discussion

code中，每三十個點，會找peak點一次，並畫出來，每一個function都有模組化管理寫清楚，在real time把圖秀出來

4.Conclusion

這次作業除了算心跳圖，還有用python做資料的比對，以及學到了觀看程式效率的函式，precision,recall也算是幫我複習到不少觀念與想法。

5.Reference

Wiki
Python

壓縮檔會附上python code做資料比對