ECE-497/BME-491: Applied Biomedical Signal Processing

Homework #2
Due at the beginning of class, December 15, 2006

In this assignment we will explore using the autocorrelation as a method for detecting beats during a regular rhythm, such as sinus rhythm or ventricular tachycardia. We will also continue to look at signal averaging.

1) In this problem we are going to combine results from your completed *laptop1.m* and *laptop2.m* to use an autocorrelation to locate beats (determine trigger points). We will be using the data files *pt8 vt.pa* and *pt9 vt.bi*, just as we did for the Laptop assignment. It will probably be easiest if you read through the whole problem before starting, so you know what you will have to do.

a) Copy your code that computes the normalized autocorrelation (using the direct method) to laptop2.m (or some variation of it). Modify your estimate of the normalized autocorrelation so it works for lags from 1 to N-1, where there are N points in the data file. Modify your code so than instead of triggering when the absolute value of the data x exceeds a threshold, trigger when the normalized autocorrelation exceeds a threshold. *Turn in your code.*

b) Produce a plot that shows the original signal and the locations of the trigger points, shown by '+', or some other visible marker.

c) For each of the data files, plot the original signal with the trigger points using at least three different thresholds. Try to vary the thresholds by as much as possible, but be sure your choice of threshold detects all of the beats (except for maybe the first and last beats) and does not detect a beat where there is none. Is the beat detected in the same place each time? *Turn in your plots.*

d) For each of the data files, choose a good set of triggering points (as much as possible these should be at the same location on the beat), then construct a template that is similar to that used during the Laptop day. Note that you can choose the left and right edges of the template to be negative distances from the trigger point. For *pt8 vt.pa* your template should be about 160 ms wide, while for *pt9 vt.bi* your template should be about 125 ms wide. The actual beats for these signals are the parts of the beats with the highest frequencies (i.e., the fastest moving parts of the signals).

e) Compute signal averaged electrograms for both signals. Set your threshold initially at 0.9 and compute the signal averaged electrogram using as many beats as you can. Turn in your plots. Then reduce the threshold as much as you need to to get at least 14 beats in the signal averaged electrogram. *Turn in your plots.*

f) One of the things you will have probably noticed is that as you signal average, the average signal seems to look less and less like the original template (beat). This should not be surprising, since in order to get enough beats we are having to signal average with beats that have a very low correlation coefficient with the original beat. Although the signals look alike, the problem we are having is with what is called *trigger jitter*, which means the trigger point is not at the same location for all of the signals. One (computationally expensive) way around this is to slide the template across the beat we want to average with, and then assume the trigger point is where the *best fit* occurs. We assume the original trigger point is close, and really only slide a bit to the left and right from the original trigger point. The program *signal_average_remove_jitter.m* does this for you. The arguments to this file are the same as for *signal_average.m*, except there is one extra argument at the end which indicates how much (in terms of sample points) we are to slide to the left or right of the original trigger point to try and get a good fit. Rerun your signal average attempts using this new program, set the threshold as high as you can to get at least and 14 beats for *pt9 vi.bt*. *Turn in your plots for each signal averaged signal, and compare these to your results from part* **e**.

2) In this problem we will do the same thing as in problem 1, except we will be using surface electrograms during sinus rhythm. For this part you will use the file *ecg_hfn.dat*. This data file is larger than we want, so examine the signals from sample 1 to sample 8000. Note that the sampling rate for this data is 1000 Hz, so you may have to change the sampling rates in the programs you have been using.

- Determine a threshold and dead time that will work at detecting all of the beats (except possibly the first and the last). Turn in your plot showing the signal and the detected beat locations. It may be useful here to also plot the autocorrelation versus time to help determine a good threshold. Is the beat detected in the same place each time?
- Select a template. Be sure to include the *p*, *QRS*, and *T* waves in your template. *Turn in your plot of the template.*
- Attempt to signal average this template. Set your threshold as needed to signal average at least 4 beats, then at least 8 beats. *Turn in your plots.*
- Does this seem to work very well? Signal average accounting for trigger jitter using at least 8 beats with a threshold as high as possible and compare your results. *Turn in your plot.*

3) We have been using the piece of code (or something very similar to)

```
  tt = (x >= max(abs(x))*threshold);
  index = find(tt)
%
%  Now start at the back and eliminate a point if it is
%  is adjacent to the one next to it. Also eliminate any points
%  at the beginning or end
%
  beat_index = [];
  ii = length(index)-1;
  while (ii > 1)
      if ((abs(index(ii)-index(ii-1)) ~= 1)   ...
```

```
          && (N-index(ii) > dead)              ...
           && (index(ii) > dead))
        beat_index = [index(ii) beat_index];
    end;
    ii = ii-1;
end;
```

Explain, line by line, what this piece of code is doing. (You don't have to explain the comments!)