Biomedical Signal Processing
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Lecture - 61
Tutorial - IV (Contd.)

Now, we will look at the 5th problem of the 4th tutorial. Here we have to go for a that Envelogram.

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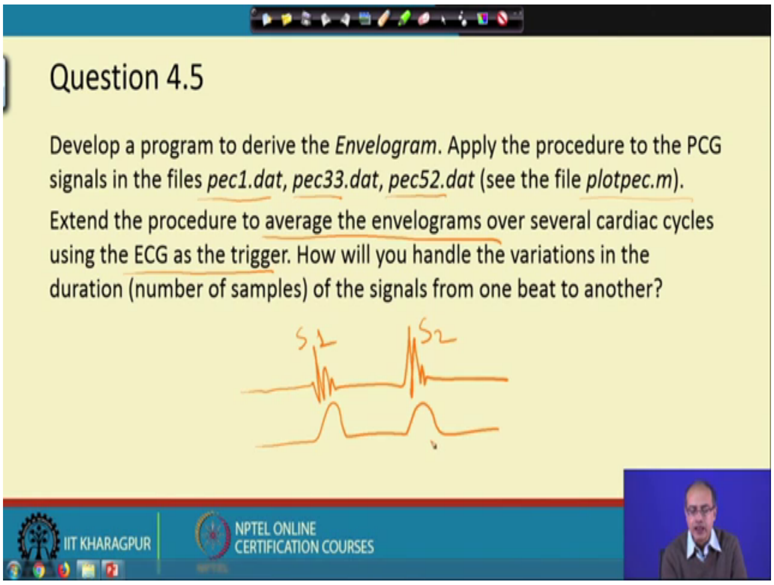

Question 4.5

Develop a program to derive the *Envelogram*. Apply the procedure to the PCG signals in the files *pec1.dat*, *pec33.dat*, *pec52.dat* (see the file *plotpec.m*). Extend the procedure to average the envelograms over several cardiac cycles using the ECG as the trigger. How will you handle the variations in the duration (number of samples) of the signals from one beat to another?

And in this case of Envelogram that we are given three data files pec1, pec33 and pec52 ok. And to read that file and as well as plot we are given a MATLAB file. Now, these three that PCG files, phonocardiogram files that we have to produce the averaged envelogram over the several cardiac cycles using ECG as a trigger.

And another question we have that because the cycles would vary how do we handle that variation in the length of the signal from one bit to the other bit. Now, why average envelogram is actually requested? If you look at that the PCG signal we have two variations that one is S1 and S2.

These two signals are there in the phonocardiogram. Now, out of these two that both of them they are random in nature. So the envelope what we create out of it, it has some amount of variation. And that if we use the average envelogram we can get a get a better rendition of that or better actually estimate of that S1 and S2. Because if we take the cycles one after another we can assume that the condition of heart has not changed from one beat to the other ok. Specially for the consecutive several beats ok.

And as we are doing the averaging and that if you look at that nature that envelogram will be like, it will be one peak could be here and another peak could be here. It would be very much dependent on the position of these ok.

So, for the averaging just like synchronous averaging we need to have a reference to actually align them. And in that case that another challenge is there that as the, the beats are not exactly equal. Because ECG is a (Refer Time: 03:03) that it is not a exactly periodic signal, but nearly periodic or pseudo periodic signal. So, that there would be some variation in the length of the signal ok. So, in that case that how do we take care of that ok. So, that is the challenge we face here in this case.

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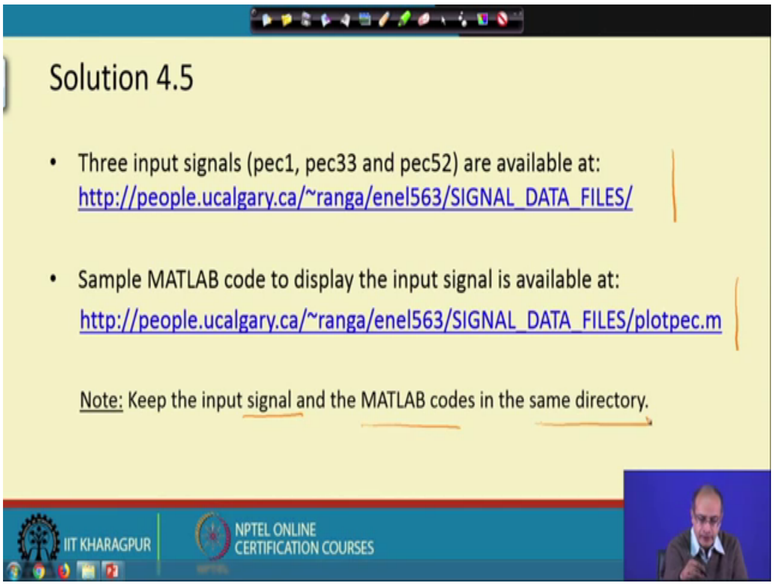

Solution 4.5

- Three input signals (pec1, pec33 and pec52) are available at: http://people.ucalgary.ca/~ranga/enel563/SIGNAL_DATA_FILES/
- Sample MATLAB code to display the input signal is available at: http://people.ucalgary.ca/~ranga/enel563/SIGNAL_DATA_FILES/plotpec.m

Note: Keep the input signal and the MATLAB codes in the same directory.

So, first job like all the that assignment that first we need to collect the data and the MATLAB file to read them and we need to first keep the signal as well as the MATLAB code in the working directory of the MATLAB. And then we start the exercise.

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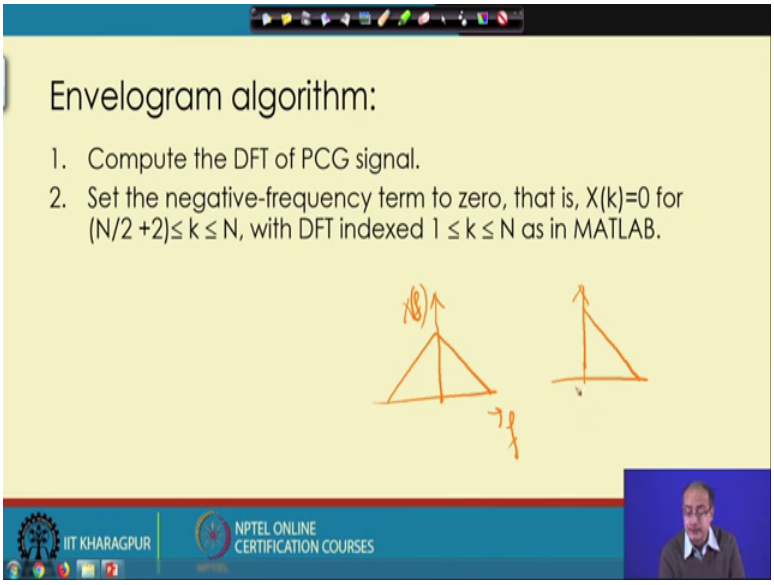

Envelogram algorithm:

1. Compute the DFT of PCG signal.
2. Set the negative-frequency term to zero, that is, X(k)=0 for (N/2 +2)≤ k ≤ N, with DFT indexed 1 ≤ k ≤ N as in MATLAB.

So first let us remember that how do we create an Envelogram. In case of envelogram that what we are trying to do is that we have to that, if you look at that theory what we are trying to get? We are looking for the that analytic signal and the amplitude of the analytic signal is providing us the that envelop or Envelogram.

So, first we need to find out the analytic signal and we know that some characteristics of the analytic signal unlike our real signal, that analytic signal has only the that presents in the right side of the that the frequency axis ok. That means, if we have a real signal that say we have a spectrum like this. Here is the that amplitude and this is the frequency if this is say x x f. Now corresponding analytic signal the spectrum would be like this that analytic signal does not have this actually any value in the negative side ok.

Now, we are exploiting that fact to construct the analytic signal and from there we find out the envelogram ok. So, the first step towards it is that we go for the that the DFT of the PCG signal. We can also imply fft if we want first computation. Now, DFT we have mentioned here because it is more generic. And what we have to do that we have to put all the coefficients which are in the negative side.

After taking the DFT for a signal starting from length 1 to N, we know that the number of coefficients we get is also 1 to N and in that scenario the negative frequencies are there from nearly half to the N. That is N by 2 plus 2 to N ok. So that means, that if you look at that sequence if the here is a middle, we are just starting from little after that and to the end.

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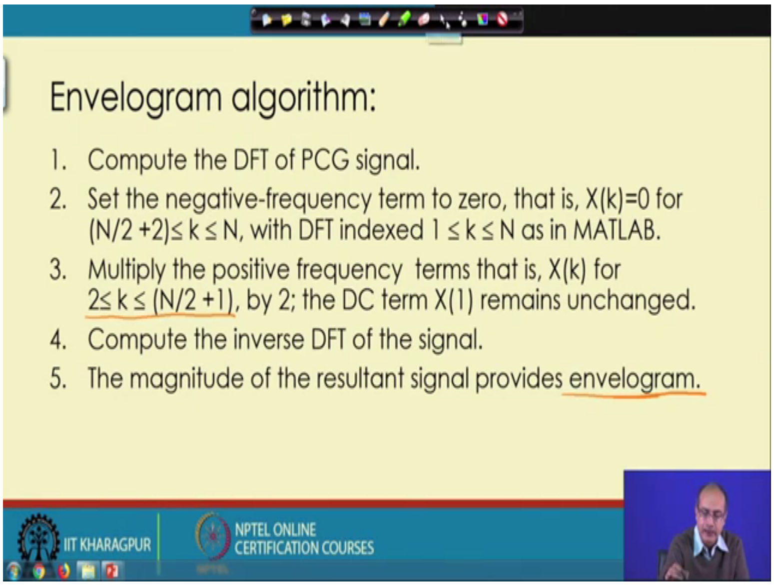

Envelogram algorithm:

1. Compute the DFT of PCG signal.
2. Set the negative-frequency term to zero, that is, $X(k)=0$ for $(N/2+2) \leq k \leq N$, with DFT indexed $1 \leq k \leq N$ as in MATLAB.
3. Multiply the positive frequency terms that is, $X(k)$ for $\underline{2 \leq k \leq (N/2+1)}$, by 2; the DC term $X(1)$ remains unchanged.
4. Compute the inverse DFT of the signal.
5. The magnitude of the resultant signal provides envelogram.

So, that part all the coefficients we are forcing to zero and the positive part of it that this part that what we are doing that from that part we are that we have to increase the value ok. And the first one this is the DC value that will remain to be the same ok. So, that is what we are doing actually step by step here. The next is the positive frequency terms which are starting from index 2 to N by 2 plus 1.

They are multiplied by 2 and the DC term 1 remains unchanged ok. So, that is the way we get now the spectrum of the analytic signal ok. The next is we go for the inverse DFT of the signal. That means we started with a real signal. In this case it is PCG, which is our signal of interest and we have created the that analytic signal in between in the frequency domain. And when we take the inverse DFT, we get the analytic signal in the time domain.

And next point is that we have to look for the magnitude of the resultant signal. That will provide us the this envelogram ok, that the analytic signal what we got the amplitude will give us the Envelogram. So, for that what we have to do we have to take actually the that absolute value of that because this one would be a complex signal. So, if we take the absolute value of it we will get the that magnitude and that is what we are looking at. That is provides us the Envelogram.

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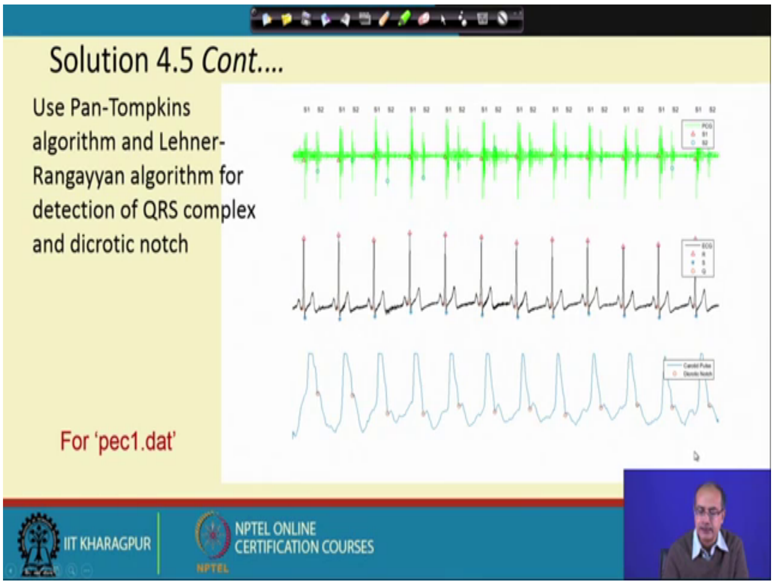

Solution 4.5 Cont....

Use Pan-Tompkins algorithm and Lehner-Rangayyan algorithm for detection of QRS complex and dicrotic notch

For 'pec1.dat'

Now, let us proceed. We first go for the Pan-Tompkin algorithm for the and the Lehner-Rangayyan algorithm for detection of the QRS complex and dicrotic notch. Now why we are doing that we know that the beat location where is from actually cycle to cycle. So, in this case that S1 and S raise 2 these two signals of the PCG their location also will vary.

So, first we have to find out those location and for that we need to find out the location of the ECG signal and for that we need the Pan-Tompkin algorithm and Lehner and Rangayyan algorithm will help us to get the that dicrotic notch and from there we can get the location of S2. We have already discussed these points in the previous assignments. So, here what we show at the top? That we have the PCG signal given; we have marked S1 and S2 location.

And how do we get that? We get the S1 location that is given by the R point in the ECG signal which we could recover using the Pan-Tompkin algorithm and for the dicrotic notch we have used the Lehner and Rangayyan algorithm which is given below that here. So, that from there dicrotic notch that we are getting the location of the dicrotic notch and that gives us the that S2 ok. So, these two part we have actually collected from this signals and once we get that we know the span of importance of the PCG signal. Now if you look at in between that this part for example, this is there is no actually activity.

So, there is actually that whatever the signal is there it is noise ok. So, these portions it is better that we throw it away and we will consider for getting the envelop because that is the noise flow ok. And here another thing we notice here neither the S1 and S2 they are looking exactly the same if you look at this one. That is 1 the next cycle 1 nor they are exactly periodic the difference between the two beats they are not exactly the same.

So, that gives rise to the challenge and it needs that we need to always take the help of the ECG signal and find out the R location to find out the location of S1 and that for that for the S2 also for each cycle. Now, let us proceed that this is for the first signal that PC1 let us see that what happens for the other signal and how do we first find out that location.

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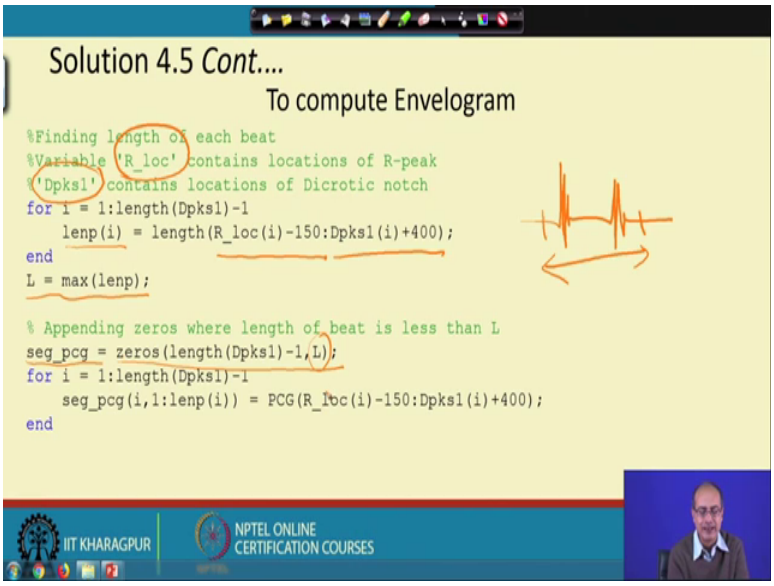

Solution 4.5 *Cont….*

To compute Envelogram

```
%Finding length of each beat
%Variable 'R_loc' contains locations of R-peak
%'Dpks1' contains locations of Dicrotic notch
for i = 1:length(Dpks1)-1
    lenp(i) = length(R_loc(i)-150:Dpks1(i)+400);
end
L = max(lenp);

% Appending zeros where length of beat is less than L
seg_pcg = zeros(length(Dpks1)-1,L);
for i = 1:length(Dpks1)-1
    seg_pcg(i,1:lenp(i)) = PCG(R_loc(i)-150:Dpks1(i)+400);
end
```

Now, what we do that here we are assuming that we already know that that Pan-Tompkin algorithm and from there we have the R location already found ok. And the location of the dicrotic notch is also found as we have done the assignments earlier. So, those codes are with us we have found this two.

Now, using that what essentially we are trying to do? We are trying to take if say this is that S1, this is S2. We are trying to take a segment like this, somewhat starting before S1 and going after S2. So, for that what we are doing we are taking R location minus 150 samples and we are going that dicrotic notch location plus 400 samples ok.

So, that way we are taking actually somewhat more than the that the exact S1 to S2 because there would be some spread of the signal. So, we are trying to make sure that we are not losing out anywhere because of the measurement error ok. So, we are taking this Pan and that part of that signal PCG signal, we are actually taking cycle by cycle ok.

This for loop is to actually store those locations, that multiple beats or multiple cycles of the that PCG signal. And at the end of it we take the maximum length of actually this signal segments. Now, what it gives to us it gives us that what could be the maximum length. So, first we provide a container that segmented PCG fill it with zeros ok.

That the number of the length we know that how many cycles are there? That is one variable and another is that maximum length and now first attempt in the for loop we have calculated only the length of that range. In the next one we are actually collecting that part after we know that what is the maximum length required. We are just picking up that part from the PCG signal and storing it in segmented PCG.

And each of these row this i variable it is given actually the index of the the cycle ok. We are collecting the data of over multiple cycles. So, that is what actually we are storing it for them because we would need them to calculate the that Envelogram. And once we have the envelogram of each of these cases then we can actually average them to get the average envelogram.

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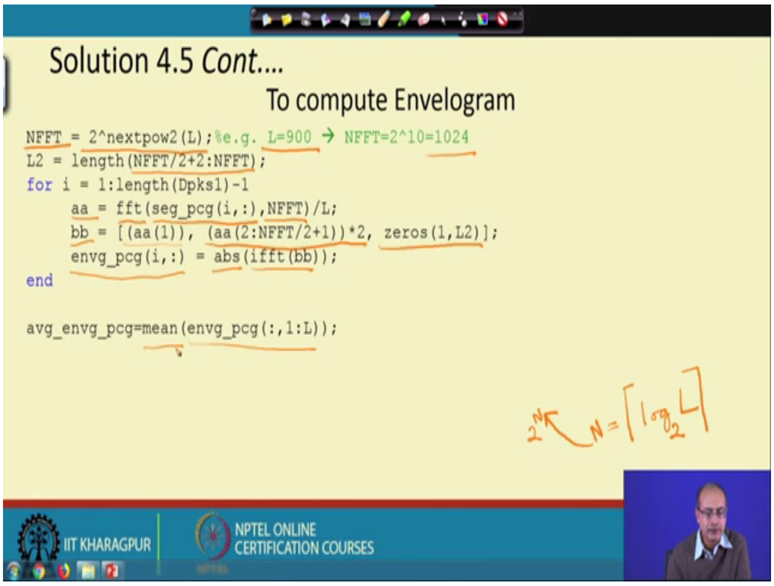

Solution 4.5 *Cont….*

To compute Envelogram

```
NFFT = 2^nextpow2(L);%e.g. L=900 → NFFT=2^10=1024
L2 = length(NFFT/2+2:NFFT);
for i = 1:length(Dpks1)-1
    aa = fft(seg_pcg(i,:),NFFT)/L;
    bb = [(aa(1)), (aa(2:NFFT/2+1))*2, zeros(1,L2)];
    envg_pcg(i,:) = abs(ifft(bb));
end

avg_envg_pcg=mean(envg_pcg(:,1:L));
```

$2^N \leftarrow N = \lceil \log_2 L \rceil$

So, let us proceed for that and we see that first that once we have the length of the beat then we have to find out that how do we take the Fourier transform and invariably that we are looking for that fft for that purpose. And we know for fft that power should be of 2 to the power N, the length should be of 2 to the power N. So, we are trying to find out that what is the length of it. For example, in this case the length is the maximum length is L that is 900.

So, next value which is 2 to the power N is actually 1024. How do we find it out? We can take the log to the base 2 l and we can take actually sealing of that to give us n and that N we can take that to compute the, 2 to the power N. So, this whole operation is done by actually this line that next power 2 L. This is actually computing this part that sealing of log of L to the base 2 and then we take 2 to the power of that quantity.

So, we are computing that 2 to the power N here and we are get that number of coefficients or length of samples for fft ok. We are storing in that variable in FFT. Then we are computing some variable L2 which will require for the computation for ease of actually remembering that we have that something we have taken that length by 2 plus 2. So, that and from there to the end. So, we are taking actually that length as L2 ok, that will help us to do some bookkeeping.

Now, the first job is that we need to take the Fourier transform of each of these that PCG segments or each of the cycle of the PCG that which are padded to some extent if they are less than L. And beyond that also it could be actually padded and we are taking NFFT point fft.

In fact, if we have decided about it that we are using NFFT then we could actually compute NFFT and we can directly take actually that NFFT as the L in the previous case and that both the jobs could be done together itself ok. That here, when computing the fft that first actually this subroutine fft it pads it further if it is less than actually NFFT. That means, from 901 to 1024 it will pad with 0 and then compute the fft ok.

And that once that is done in the that segment that in the that variable b what we are keeping? We are actually keeping the coefficient. These are the aa is the coefficient of the Fourier transform of the PCG signal, that is the real signal; Now, the corresponding analytic signal that in the frequency domain is bb. So, we are taking the DC coefficient that is not changed. That positive coefficients it should be actually multiplied with 2 that is starting from 2 to NFFT by 2 plus 1 and then we need to have the remaining part should be zeros.

And then once we have that that we have to take the ifft of that to get the that time domain signal and absolute value of it. We give us the magnitude and these part is very necessary because as this is a analytic signal, in the time domain it will give us a complex signal not a real one.

So, if we want to know the magnitude we need to take the absolute value of it because the number should be the complex number. And once we have that this envelogram for each of this cycle them together and compute the average by using the command mean ok. So, that is the simple algorithm here and there is a way we calculate the average Envelogram. Let us see that how the result we get.

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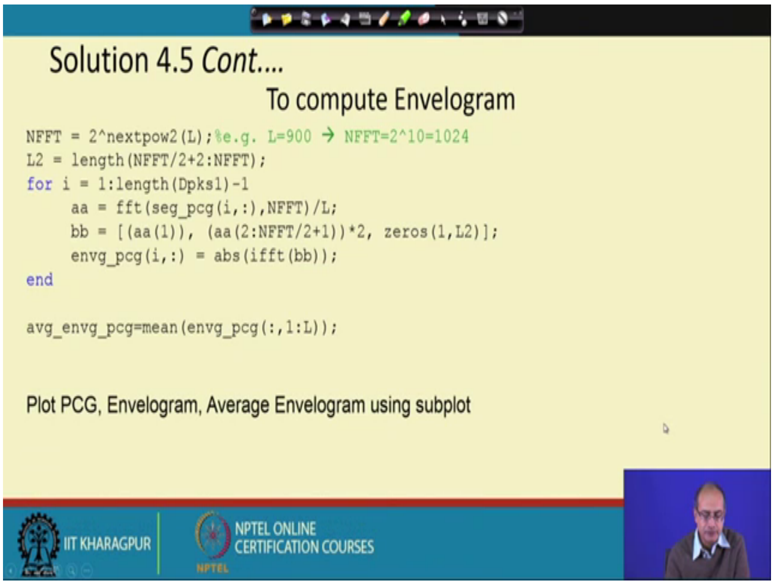

Solution 4.5 *Cont....*

To compute Envelogram

```
NFFT = 2^nextpow2(L);%e.g. L=900 → NFFT=2^10=1024
L2 = length(NFFT/2+2:NFFT);
for i = 1:length(Dpks1)-1
     aa = fft(seg_pcg(i,:),NFFT)/L;
     bb = [(aa(1)), (aa(2:NFFT/2+1))*2, zeros(1,L2)];
     envg_pcg(i,:) = abs(ifft(bb));
end

avg_envg_pcg=mean(envg_pcg(:,1:L));
```

Plot PCG, Envelogram, Average Envelogram using subplot

We for that we plot the envelogram and the average envelogram using the sub plot command.

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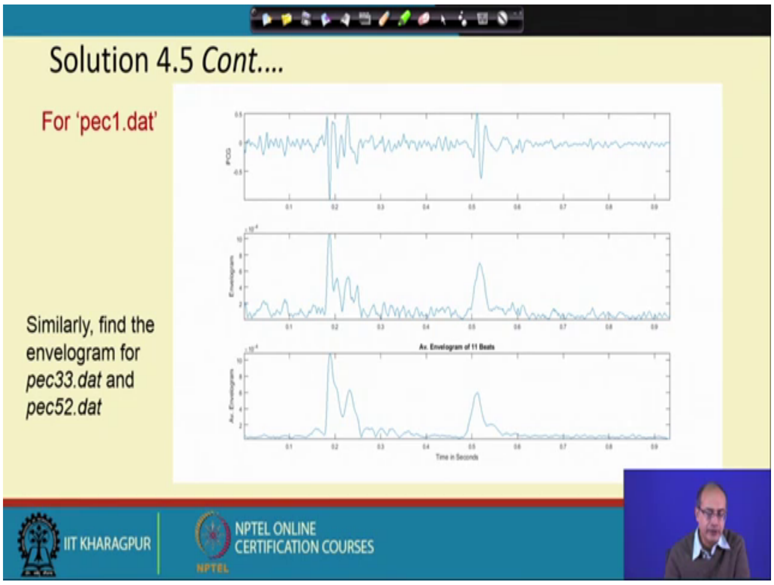

Solution 4.5 *Cont....*

For 'pec1.dat'

Similarly, find the envelogram for *pec33.dat* and *pec52.dat*

So, first we take the that first PCG signal pec1.dat and here we have taken just one single cycle to give a better rendition. If we take all the cycles that we get the whole signal, but none of these cycles with clear. So, in this case we get that this is the S1 and this is the S2 but corresponding envelogram we get here. Now, out of it if we look at that S1 that it has lots of variation here this part specially.

So, that once we average it over number of cycles we get that it becomes much more smooth and we get actually much better, actually an envelope. And correspondingly the perturbations outside actually that S1 and S2 they are also reduced to a good extent ok. So, that that makes a that envelop more actually that that appropriate for representing the seat. Now, let us look at the next actually point that in a similar way we find out for the that pec33 and pec52.dat.

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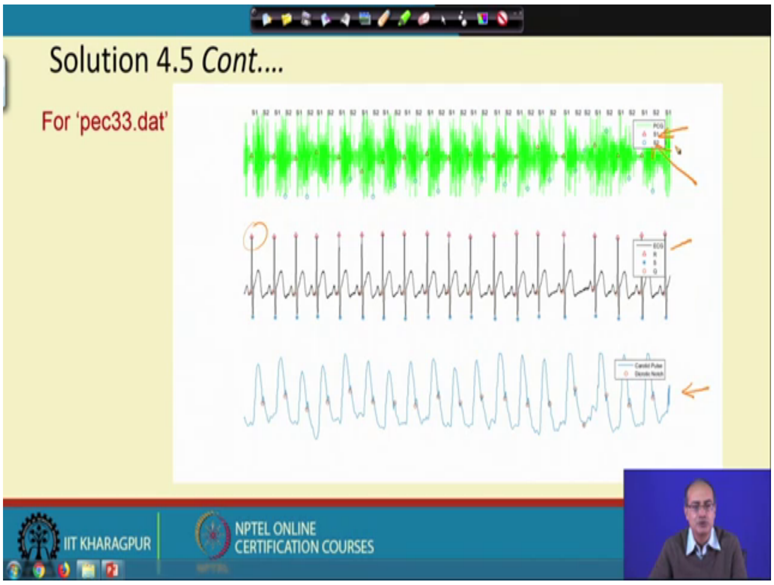

Solution 4.5 Cont....

For 'pec33.dat'

So, for the pec33.dat again we start from the beginning that we need to find out the that R wave from the ECG signal. So, we are mark that with the triangle and from there we have taken here that the location of the S point, we have mark that. And for that next we have taking the carotid pulse and we got the location of the dicrotic notch from there we got the S2.

And you see in this case that S1 and S2 that a lot of I think murmurs are there; that signal seems to be merged actually to some extent ok. So, in any case that that way we could find actually the span of the that each cycle of the PCG and from there we could actually get the envelop.

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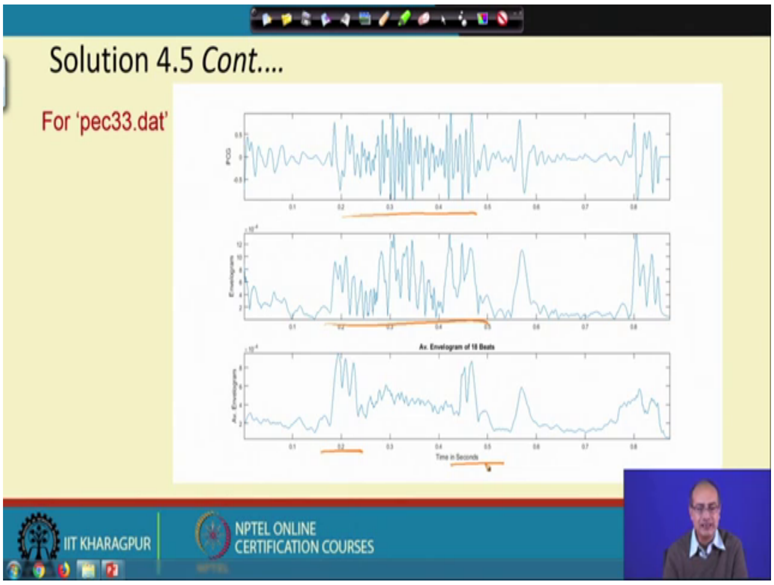

Solution 4.5 Cont....

For 'pec33.dat'

In this case as the variations are more or S1 and S2 are more jiggered, as we can see it here that it is much more jiggered. We have the envelope also like that ok. In fact, in intermediate portions also you see that lot of peaks are there.

However, when you go for the average periodogram that S1 and S2 they are coming much more prominent way ok. So, that is the benefit of I would say that going for the envelop, envelogram to average Envelogram.

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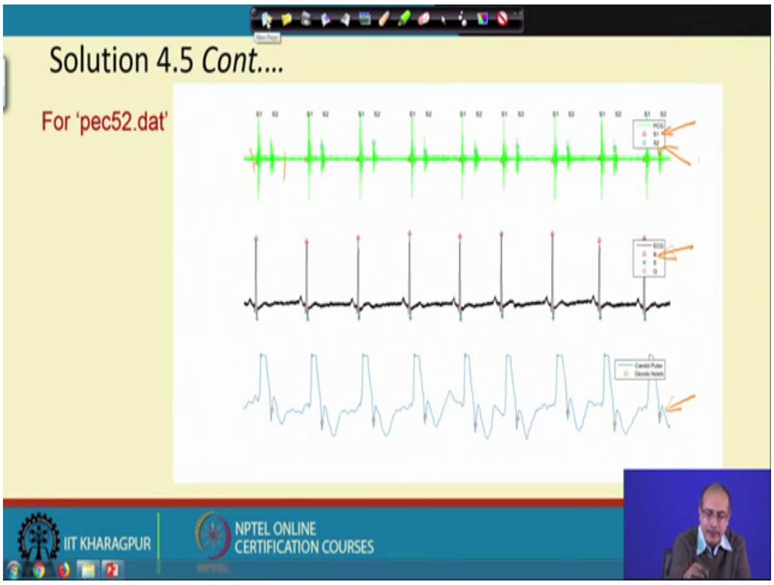

Solution 4.5 Cont....

For 'pec52.dat'

Now, let us look at the third one which seems to be again a better signal where S1 and S2 they are limited in time and again we follow the same procedure that first we look at the ECG signal and we get the R wave from where the location which gives us the location of S1.

And from the carotid pulse we get the location of the that dicrotic notch which gives us the location of S2. We have mark them, we find out that each cycle and from that that we could compute the the envelogram and the that average envelogram ok.

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Solution 4.5 *Cont....*

For 'pec52.dat'

And again what we notice that the things what we had for example, here those things are actually minimized in average periodogram ok. So, here the that dips were there they have become actually minimized. We get a much more stable shape in case of average periodogram ok. So, that is the wave we have successful in computing them.

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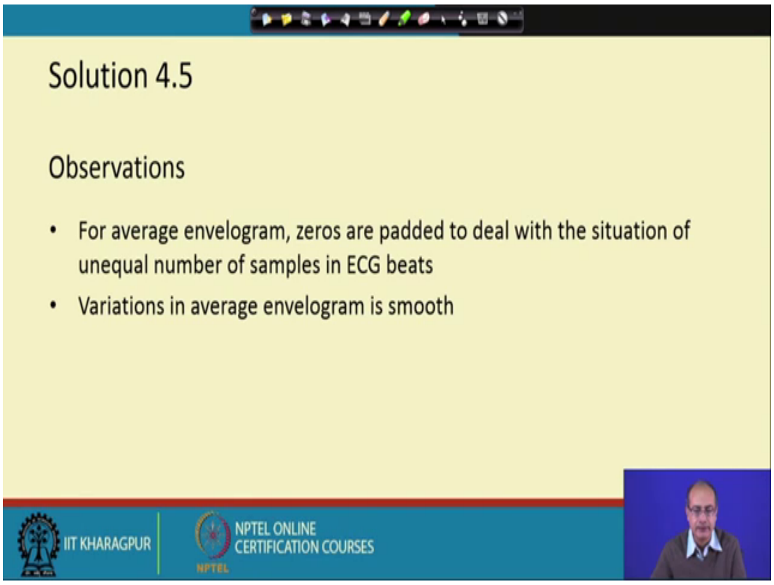

Solution 4.5

Observations

- For average envelogram, zeros are padded to deal with the situation of unequal number of samples in ECG beats
- Variations in average envelogram is smooth

And at the end of it we need to have some observation that what we learn out of this assignment. The first thing that for average envelogram the zeros are padded to deal with the situation of unequal number of samples in the ECG beats. Each cycles are different in length and that to avoid the numerical problem in averaging the cycles which are of unequal length, what we do? We add zeros at the end. What we called as padding and make them of equal length and that makes it easy for us to take the average ok.

So, there is the first part. In fact, that was one of the question we are ask you answer. The next point is that the variation in average envelogram is moved that average are actually averaging is actually helping us to that (Refer Time: 28:26) the variation and that has a positive wave effect in the getting the envelop of the signal ok. So, that is the benefit we get out of the average envelogram.

Thank you.