Biomedical Signal Processing
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Lecture - 56
Tutorial – III (Contd)

We start now the fourth question of tutorial 3.

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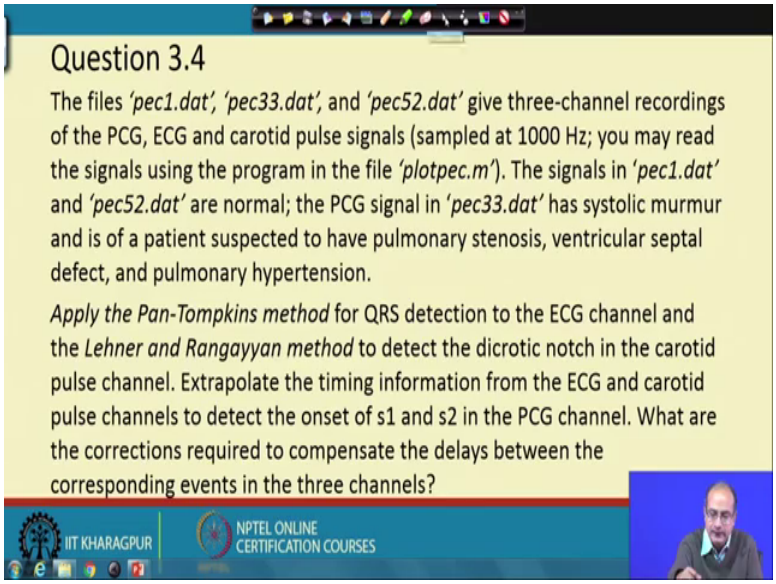

Here, we deal with the PCG signal or Phonocardiogram. 3 recordings of ECG signals are given and each of them they are 3 channel recordings. And they are sampled at thousand hertz. Out of these, the first 2 a normal, the third one is suffering from systolic murmur and systolic murmur means there is sound of that heart or murmur that is found in the PCG signal. And the patient is suspected of having pulmonary stenosis; that means, narrowing of the artery that living to that the right ventricular to the lung and ventricular septal defect; that means there is some opening in that the layer which is separating the left and the right ventricle.

So, there is some whole in that. So, that is also causing turbulence. And pulmonary hypertension maybe there; that means, the pressure is higher than the normal. So, all these things can call actually more turbulence giving rise to that murmur which is recorded in the pec33 dot dat. Now, to get actually that the PCG signal, we need to take the help of 2 other signals; the QRS in the ECG and we use the Pan-Tompkin algorithm

to detect that. And for that that carotid pulse, we need to find that dicrotic notch, for that the Lehner and Rangayyans method is used. And these to helps to find out the onset of S 1 and S 2 in the PCG channel and there will be some delay in this process.

So, how do we compensate for the delay, so, that is the exercise given to us.

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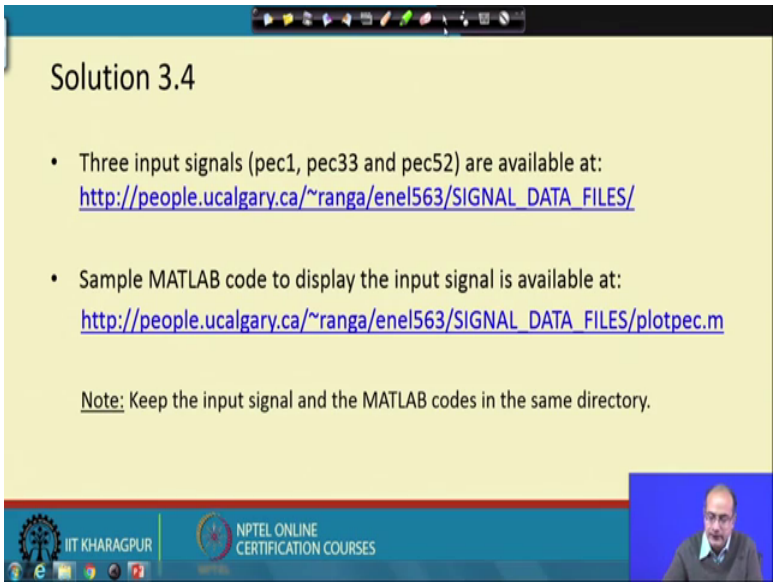

So, first we start with downloading that the data and that MATLAB file to read those data. And we need to keep them in the working directory of the MATLAB ok. We need to put them in the same directory because that is the way the path is given in the whole.

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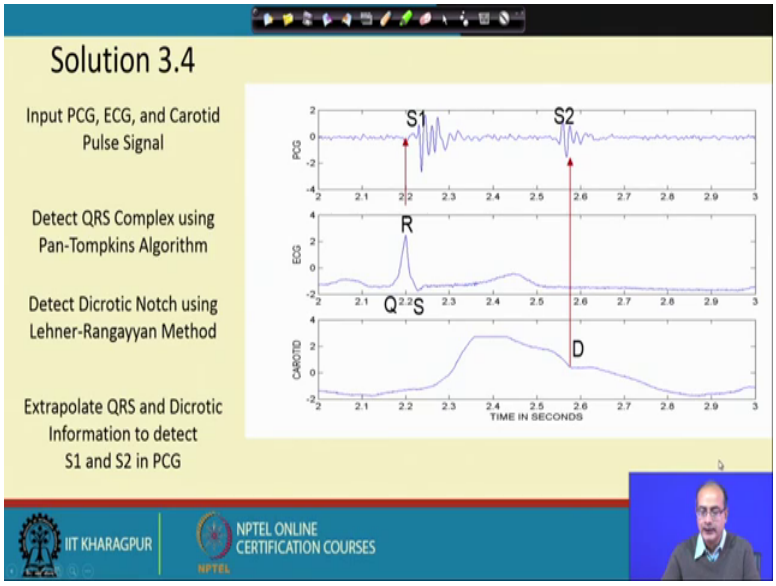

So, here we see the 3 signal side by side, that at the top we get the PCG signal here, then ECG, then carotid pulse that in the PCG signal unless there is murmur, the S 1 and S 2 this 2 that that waves these 2 are not that prominent and there will be lot of noise.

So, S 1 and S 2 may get actually worried in noise. So, we need to take the help of the other signals that is ECG, that QRS complex of the ECG and the dicrotic notch for this deep, these 2 to help to detect S 1 and S 2. Now, how that happens that when the QRS complex comes then the ventricles get they get compressed and gives rise to that starts the flow of the blood in the arteries and that gives rise to the murmur, if there is any construction or if any other defect is there. So, that gives rise to the first signal S 1 in the PCG. Then, at the end of that does the compression of the ventricle that when it is starting to relax then to hold that pressure, the valve in between the ventricles and the arteries they close.

So, that the pressure is maintained and that gives rise to actually a small deep in the carotid pulse signal that is the pressure at the carotid pulse. And at that time also there is some turbulence because of the change of pressure and that reflects as the second wave or S 2 wave. So, here in this picture, we are showing that that QRS complex if we use the pentagon algorithm, we can find it out easily and that helps to give us the S 1 and that the dicrotic notch, we can get using the Lehner and Rangayyan algorithm which helps to find out that S 2. So, that is the task we are assigned to. And let us look at that how we proceed.

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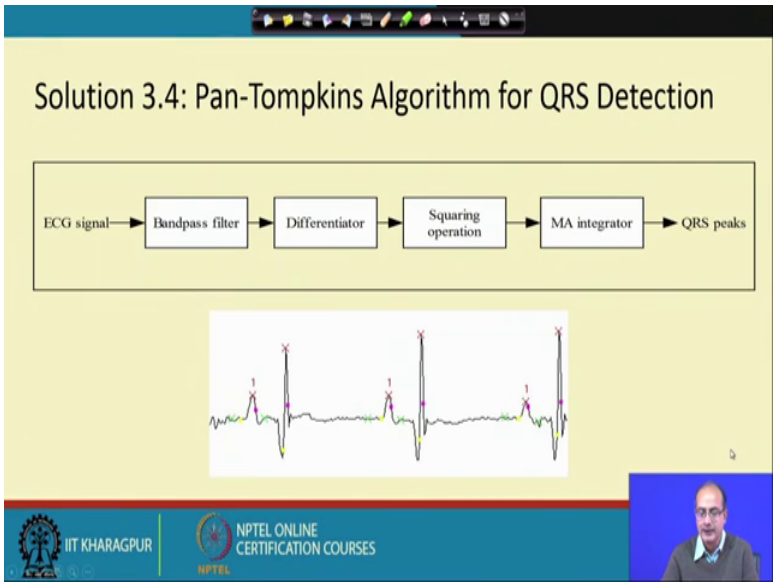

So, what we have taken here? We are explaining the block diagram of the pentagon algorithm where the band pass filter is there, followed by Differentiator, Squaring Operation and the Ma filter.

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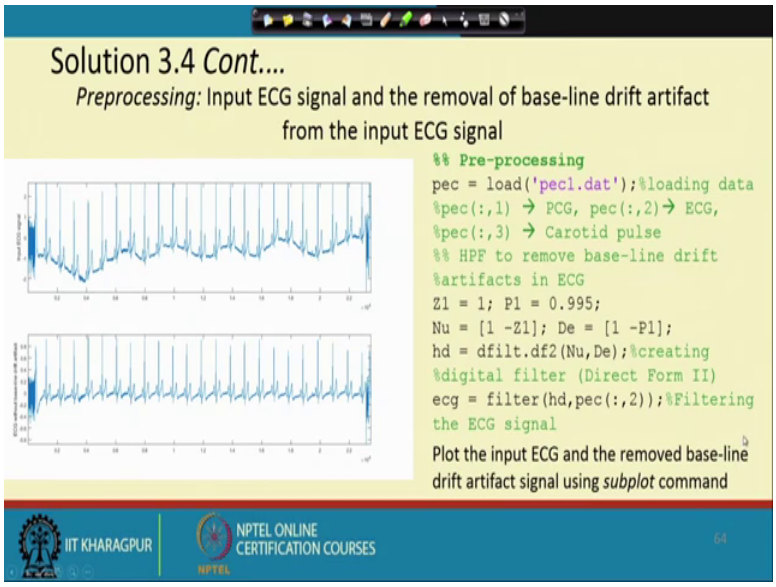

And before that before we take up the things, we pre process that ECG signal, we try to remove the baseline drift. Here, in the left we see the ECG signal is suffering from the baseline drift and that is removed by a filter with putting a 0 at the DC frequency and

followed by a actually along with a pole is also there to make that the signal in such a way that other low frequency components are not actually affected that much.

So, we are able to remove the baseline wandering.

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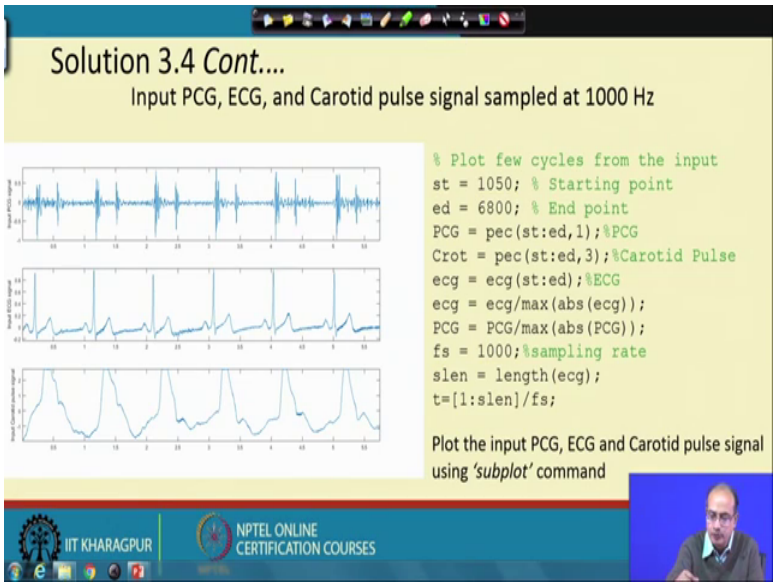

So, once the pre processing is done, let us look at that how we need to proceed. So, as a first part, we show all the 3 signals together. We did the PCG signal and we plot them in the left hand side. Here, that we are taking a small part of it that a small part of the signal we have taken for actually the purpose of plot that starting point and endpoint is given, we have taken only that part. So that, we can have a better plot and sampling frequency we know that it is 1000 hertz. So, we have used this information to make a good plot here.

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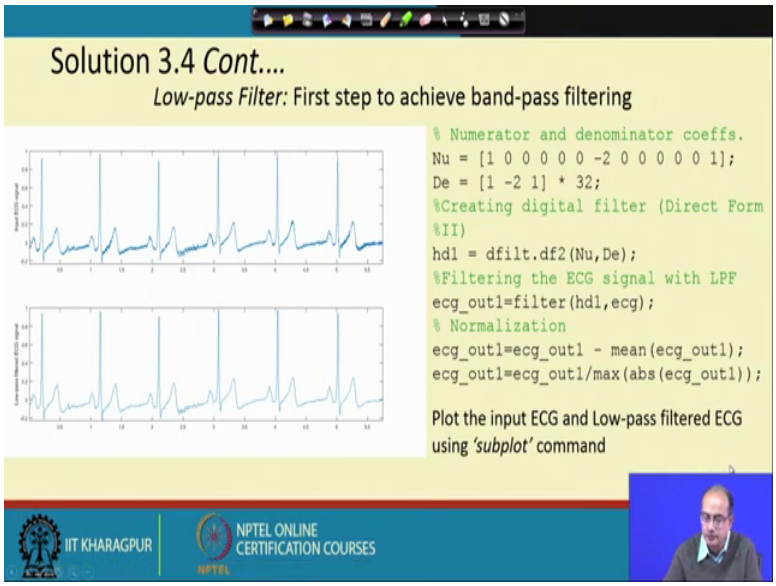

So that, first thing is that we need to go for that our Pan-Tompkins algorithm is to have a band pass filter which is actually prepared with the help of a low pass filter and a high pass filter. That low pass filter here that in this case we get that the output, we are getting that high frequency, the noises are subdued, the power frequency hammond and high frequency noise they are subbed here and for that that Pan-Tompkin has given the numerator and the denominator.

So, we have made use of that numerators coefficient and denominator coefficient and created the filter here and we have passed that actually that was the filtered is made we converged that with the ECG signal to get the output and then we have removed that mean as well as we have normalize that signal to make it actually win between minus 1 to plus 1 ok.

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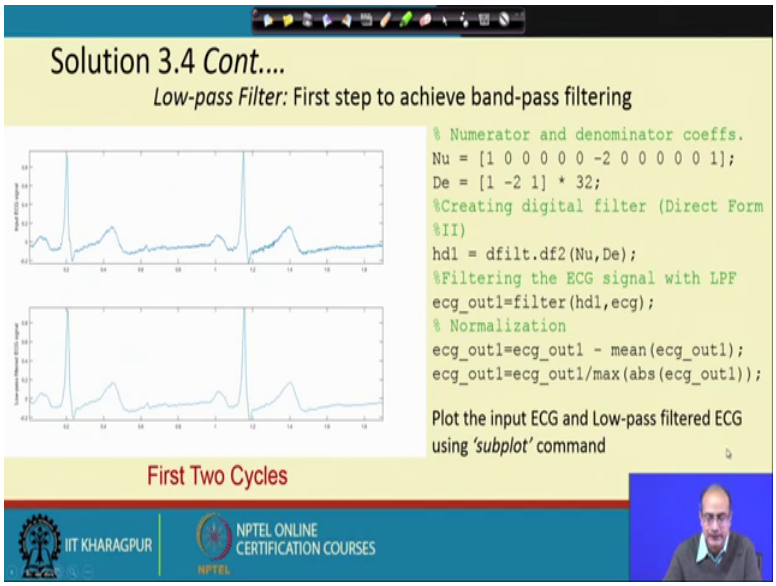

So, we have shown the plot and now let us proceed for the next step of that it before that, we just show that more carefully we have shown only the first 2 cycle so that, we can appreciate the change better.

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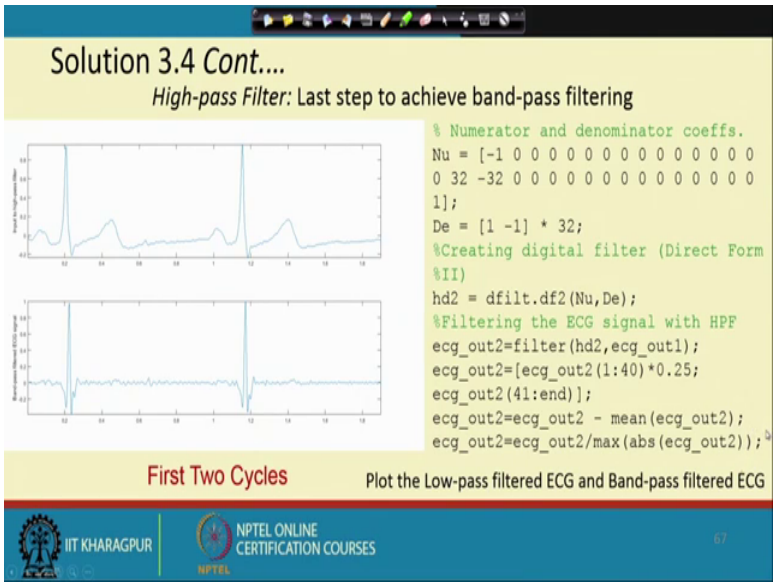

And let us now proceed for the last step of the band-pass filter.

Again, we have another filter that after the low pass filter, we have a high pass filter here and the denominator and the numerator are given here. Numerator coefficient numerator coefficients and denominator coefficients, we have created that the filtered direct from 2

structure and we convolve it with the output of the low pass filter and then, we are actually we are finding that there is some transient at the beginning. So, we are deemphasizing them. We are making them actually one fourth of the amplitude for the first 40 coefficients and rest of it remains the same. And then, we are subtracting the mean and we are again normalizing it de-normalizing, I would rather say.

So,. So, that is what we have done. So, here is the plot we get that first, we have the plot that we see that in this case, that the p and the t wave they are subdued and the QRS complex that remains to be prominent, but the shape is changed after the this band-pass filter.

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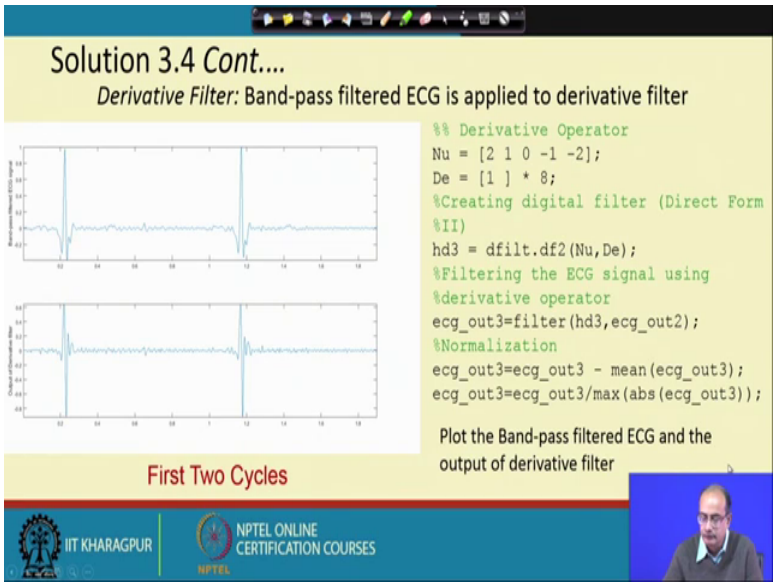

So, now, let us go for the next step that is the derivative filter which is applied on the band pass filter ECG. So, the derivative filter is also provided by Pan-Tompkins. They have told what should be the form. So, we have created a filter that out of it that direct form 2 filter and passes that band-pass filter output through this new filter convert with this new filter and again that same step of baseline removal and the normalization or renormalization is done.

So, with that, we get the cycles of that output of the derivative filter. And derivative filter output, we can get that the signal waveform is much more actually changed; however, now the QRS complex that it has become more prominent and we have more symmetric than the previous one ok. And when we look at the first 2 cycles, we can get the change

clearly and it has actually become like 2 sets of the ripples near the q QRS complex, both positive and negative sides are there to it and let us proceed for the next step.

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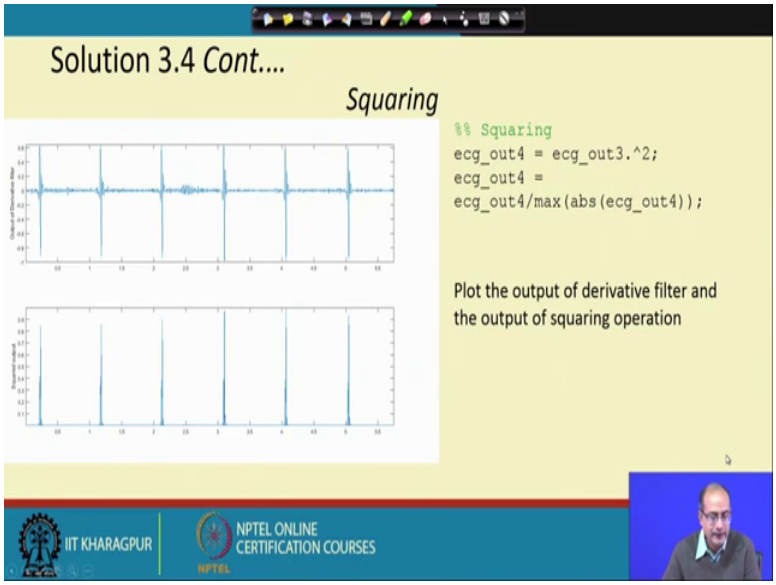

The Squaring Operation is the next step. We take that point wise square and we normalize it again and that with that what we get, we get post like structure, then everything becomes positive and it becomes a little jagged which will be more clear when we look at only the first 2 cycles that we get the peak, but it is a big jagged multiple peaks are there.

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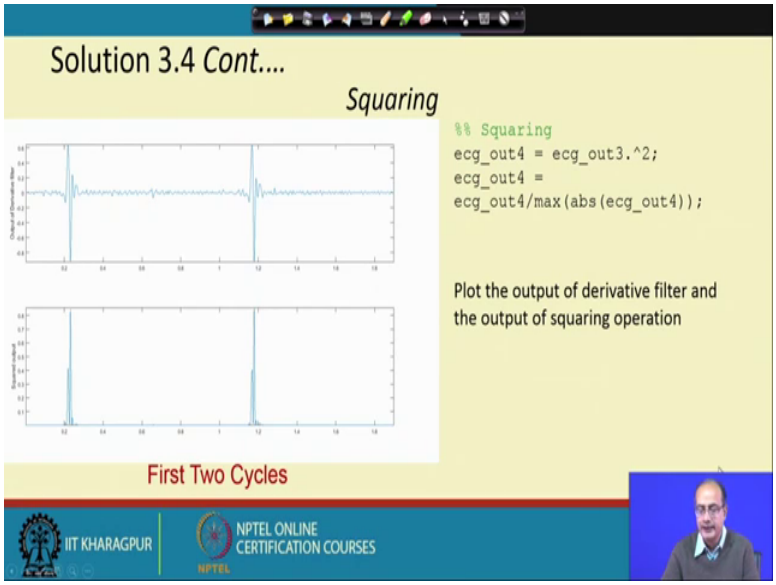

So, the question remains that which one need to take we need to take as the real represented in of the QRS complex or rather though we are sure that QRS complex is there which would indicate as the location we get into the dilemma.

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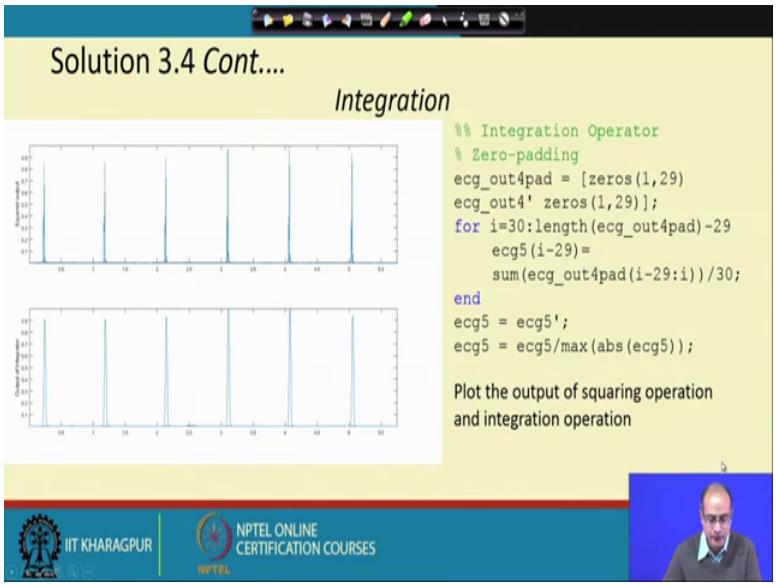

So, we go to the next step that does the integration. Here, that that we have actually that 30 that point Ma filter is applied and to apply that, we need to actually pad 29 0 at the beginning and at the end of the signal and then, we have the 30 point Ma filter here. And again, it is normalize to keep the signal within that 0 to 1.

So, that we get the signal as shown in the left hand side. Now, what we get these signal what was that jagged peaks. Now, they have merged and giving a clean single peak for each QRS complex. So, that was what we are looking at that we can get the unambiguously the location of the QRS complex and that is the actually we get by using that Ma filter.

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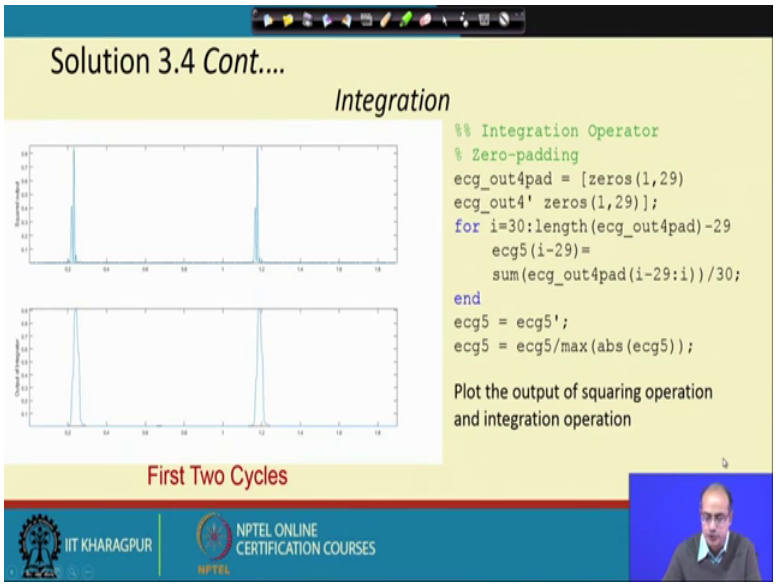

And when we look at the first 2 cycle, we get it more clearly that we can see the jagged peaks clearly and that helps us to see that after the integration how they much together to a post.

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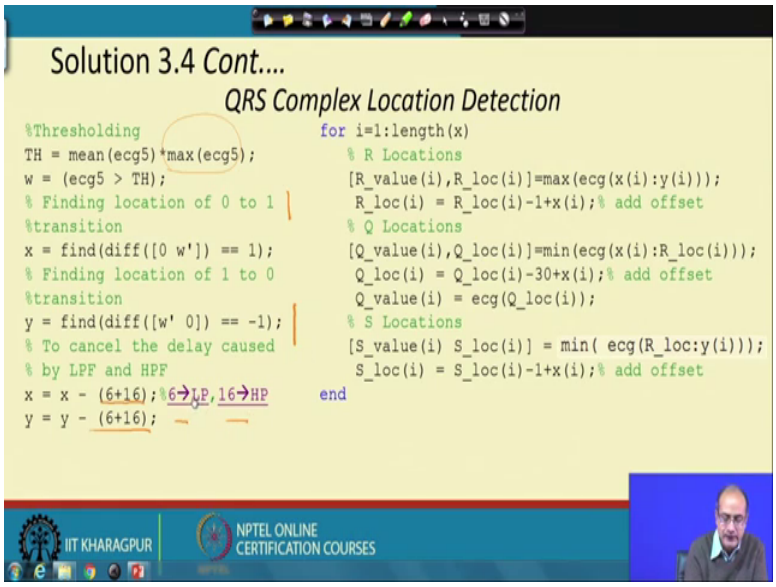

Next is that QRS Complex Localization. We have to take some threshold and we need to find out that what is going above the threshold and when it is coming down and then that is what we are doing here that that is what we are doing here that it is above the threshold, the threshold is nothing but the mean of that ECG signal and that again a scale

is given ok. So, we have taken the max; that means, the 50 percent of that ECG signal should come because we have already taken these as a one ok. So, we are just taking a threshold. I think it is better to tell in that way and we take that differentiation to find out that when we are getting 0 to 1 transition and 1 to 0 transition ok. And these 2 transition gives us that whenever actually QRS complex is starting and ending ok.

So, in between these 2, we have the R wave. And next what we do? We need to do some compensation of these 2 and we see that we have taken a actually offset 6 plus 16 out of which, the Da 6 is coming because of the low pass filter and 16 is coming of out of the high pass filter. Now, how do we get it if we want to know? We need to look at that this low pass filter and high pass filter again.

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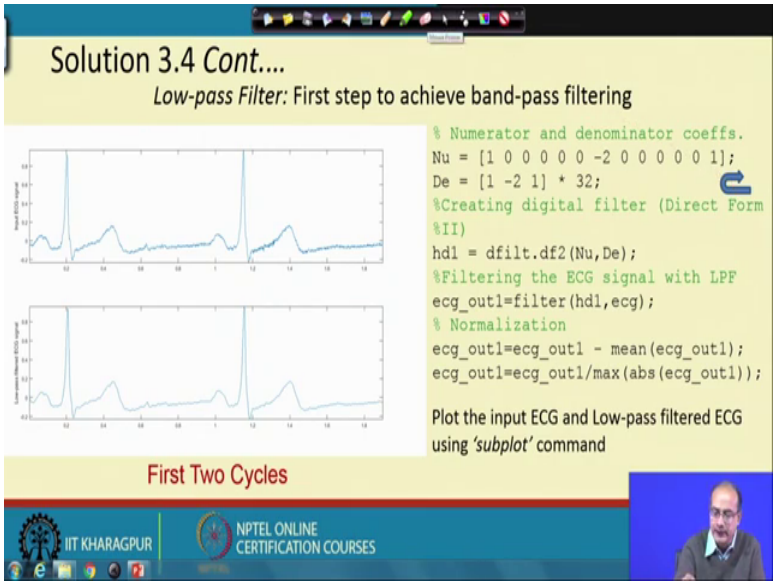

We need to find it out that the low pass filter what we have taken earlier, that it is giving us that this signal which is giving a delay of 6 here and that is the reason that we need to given offset to actually remove that.

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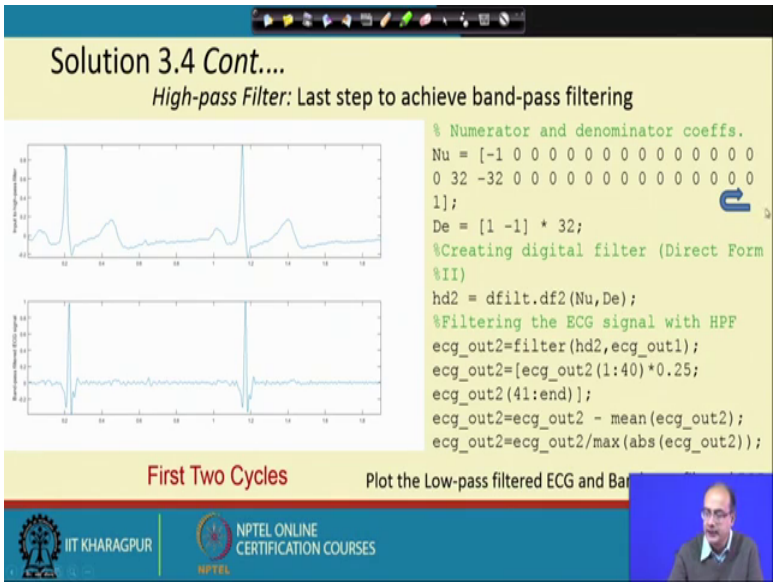

Next, if we look at the high pass filter, again we see here is a 16 point delay. Look at the numerator structure that it has that that need the numerator 33 coefficients are their which is giving a delay of 16. So, that also caused the delay in the output. Now, if you want to find out the location, we need to compensate for that. So, that will help us to go to the real place where the QRS complex was there. And next, we look for the maximum point between the 2 points of X and Y which gives us R. If we go a little backward from that ECG or rather R point look at that that the location of the R and that the minimum point where it is started that is xi. So, we get the Q point and if you look at one to look at the Y position rather that S location. We need to look at that in between that here that R and the Y.

So, these 3 we need to look at. And here, we are having a offset that each of these case as our inter values in between X I and Y I. We are looking at that the point that will be exact the value what we get here it is within this range. So, we need to take care of the fact that it has X I minus 1. So, many actually points before that. So, we need to add that offset to adjust that point.

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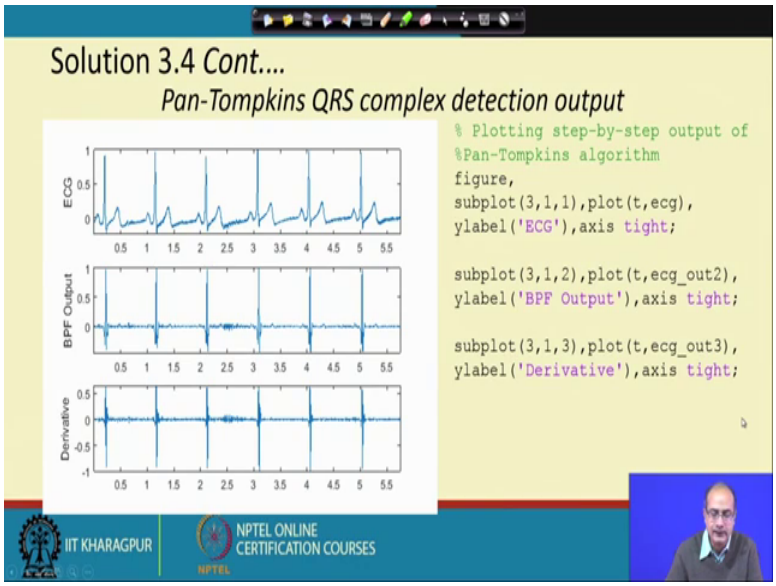

And here, we are showing that step by step that how we are getting that output.

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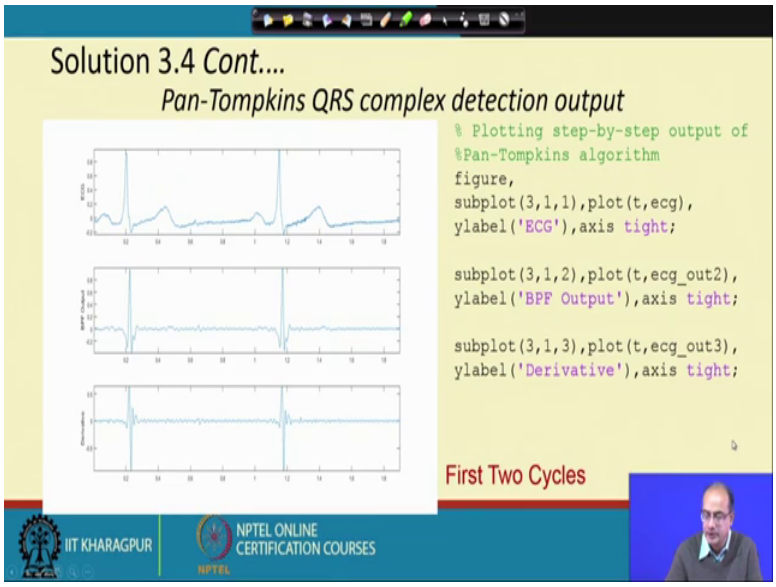

We are showing the first 2 cycles that to make it better that we get the ECG band-pass output, the derivative one.

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Then, we have that the squared output of the integrator and at the end the QRS the complex that Q R and S, all the 3 points they are marked on the ECG.

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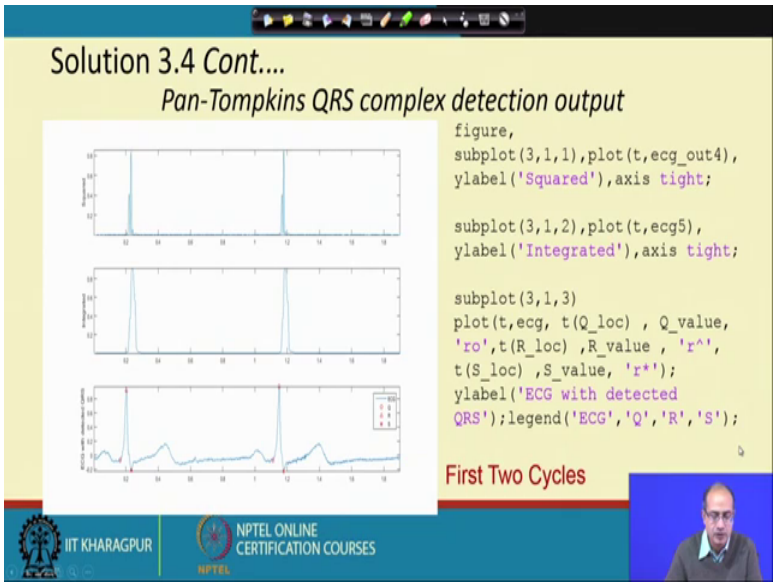

So, the first 2 cycles they make it more prominent.

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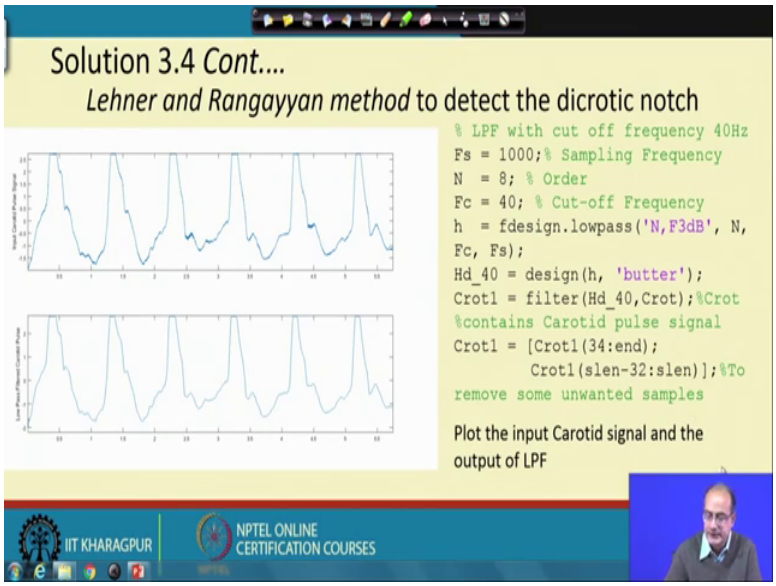

Next, we go for the Lehner and Langayyans method to detect the dicrotic notch. So, first we remember that what are the inputs we are given. That sampling frequency, it is 1000

that we have that a filter which is 8 point filter, that order is 8 and cutoff frequency is 40. So, that it is a low pass filter with cutoff frequency 40 and we design that filter using that 3dB that bandwidth and the model order that of the Butterworth filter that, we create that first the design, then we create the Butterworth filter out of that 840.

And we apply that on the carotid pulse here ok. Filtering the carotid pulse with that low pass Butterworth filter and at the end of it that we get the signal that we removes the some unwanted portion that, we are keeping that 34 to m that part. So, we are removing some initial part that which is having the transient and then you go for the plot of the signal ok. So, after the Butterworth low pass filter, me get the noise is present earlier which were visible here they are removed. So, that is a good thing that we could get rid of those noises.

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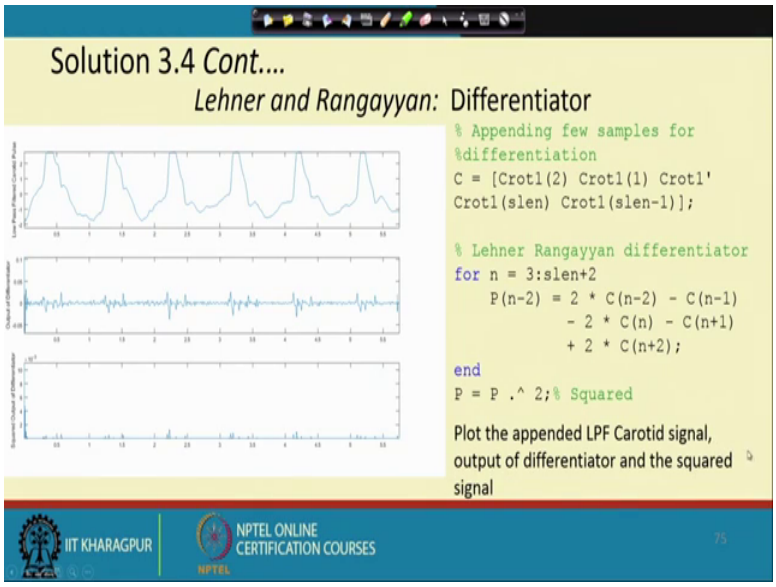

So, that the first task next is that we are going for Differentiator and in fact, that it is necessary before applying a differentiator, we need to do that low pass filter otherwise those noises could be magnified and have an impact on the accuracy of the technique.

So, in this case, a second order filter or second derivative is suggested by Lehner and Rangayyan. And for that, we do some padding. How the padding is done? Our signal is starting from say x 1 two x 1 than x 2 going up to say x n minus 1 and x n with that, we are using the reflection to pad both, we are having again x 1 and x 2 and at the end after this, if you look at that after this what we are having x n plus first x n and then followed

by x n minus 1. So, you get it here. So, that is the way we have increased that length that to give it the maximum smoothness they are because if you pad with 0 it will unnecessarily give rise to some high frequency at that point.

So, we have that output here of the Differentiator followed by the squaring operation point wise squaring operation and then, we plot that signal ok. What we get that we get all the signal has gone because of the differentiator, we get some pulses here and after squaring operation that becomes positive, we get some small pulses there.

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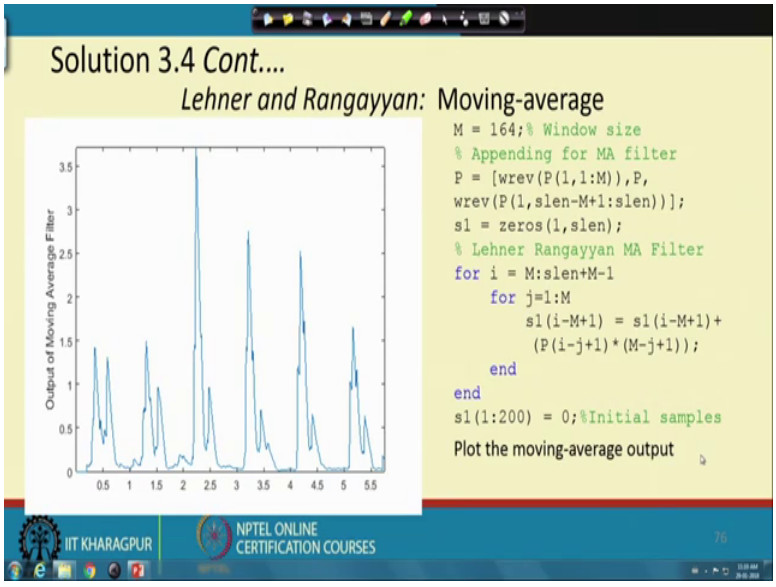

And next, we apply a moving average a in a filter is applied and that moving average it makes it makes it more easy to get this peaks and to get that, we have to again plot this to the scale properly. And what we get 2 peaks are there for each one of them. Out of these 2 peaks, the second peak is important to us in each case that second peak we have to look at ok.

So, that the plot of the moving average, we have actually given here that after the Ma filter.

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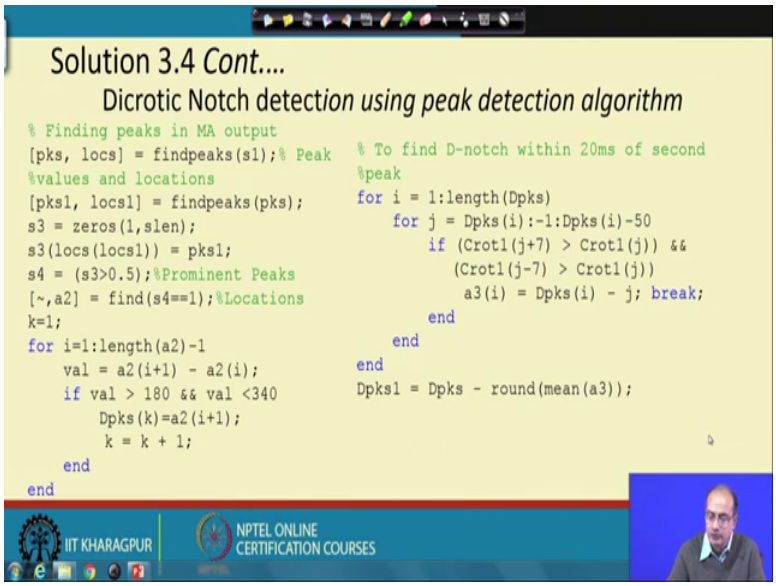

That we are seeing it and we use the peak detection algorithm, find peak which is above that the threshold, we are looking at and that with that that we are finding out the dicrotic notch which is within 20 milliseconds of the peak. Now, after finding out the second peak what we are doing, we are going into that the dicrotic notch know that is the carotid pulse signal, we are looking into that and trying to find out a prominent deep that is; the pixels which are that that plus minus 7 that they are above these actually point. So, we are trying to find out the point that both the side there is a actually at least 7 points they are actually above that point. So, that way we would get not a local peak, but we will get a prominent one ok.

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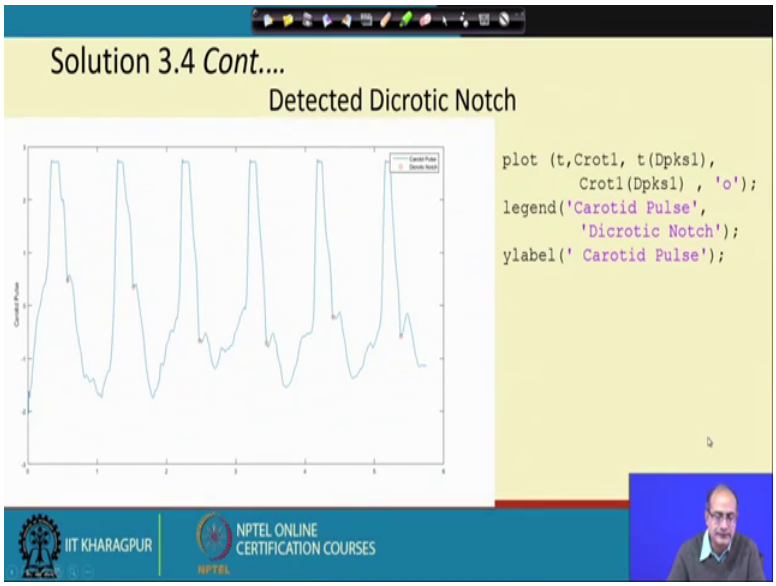

So, that is how the peak we get and then, once we have the carotid pulse detected, we marked that here in this plot.

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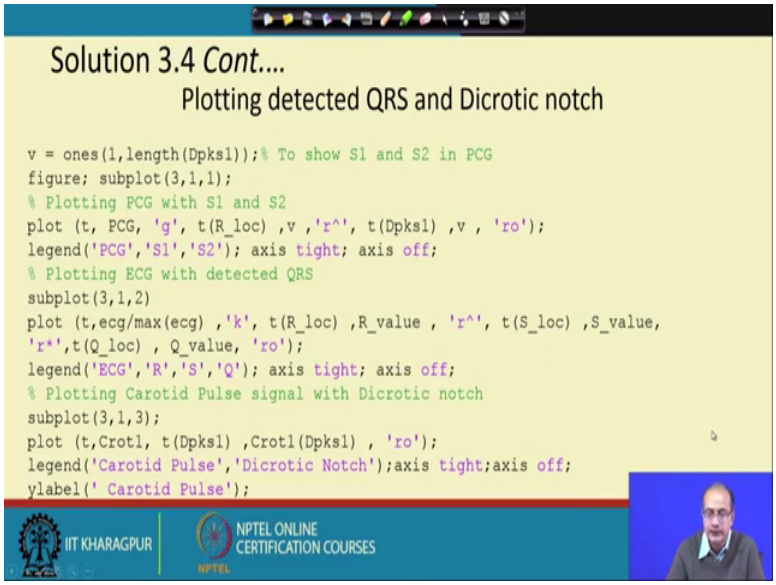

Now, we are plotting the QRS and the dicrotic notch which are required to do this job.

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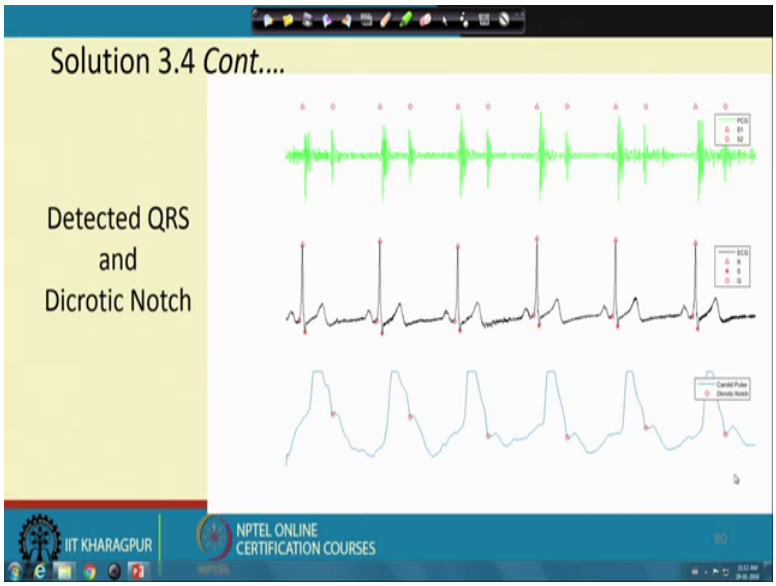

Here, we are showing that that at the top, we have the PCG signal. The PCG signal, we are showing that we are showing the location of the R, which can give us the S that R wave is here and the carotid pulse signal is marked here, that we are marking here. So, that is giving the location of that the S 2 point ok. So, that is the way we find out the location of s 1.

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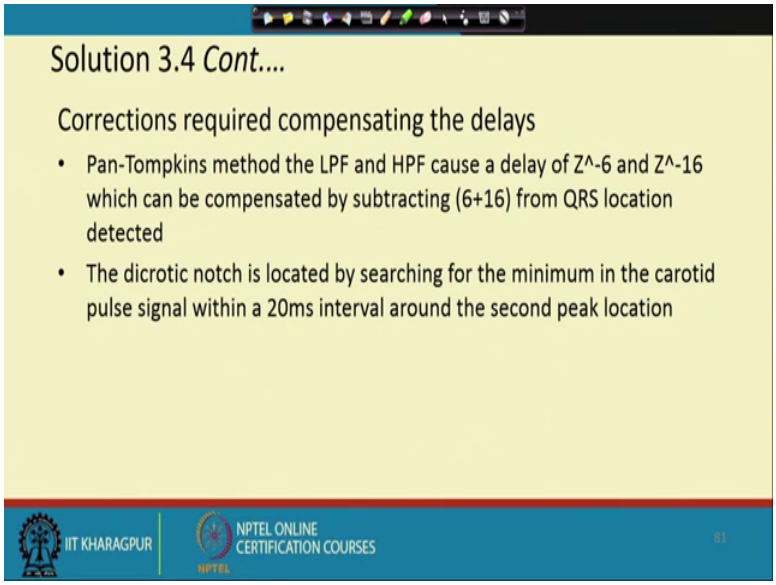

And S 2 and so, what we get that we need corrections for compensating for the delays used for the 2 techniques. Pan-Tompkin algorithm, we have to fill thus which are giving

rise to sufficient amount of delay that is the low pass and the high pass filter they are giving the delay of 6 and the 16 delays respectively.

So, that 6 plus 16 22 delays, we need to subtract to adjust the QRS location in along with the signal. Again, for the dicrotic notch is it is located by that finding out the minimum in the carotid pulse within 20 millisecond interval around the second peak. So, they are also it is not exactly allying, we need to such for it and find it out and then only, we can find the carotid pulse signal and both of these carotid pulse that the dicrotic notch and our that location of the R wave they help us to find out S 2 and S 1 respectively.

Thank you.