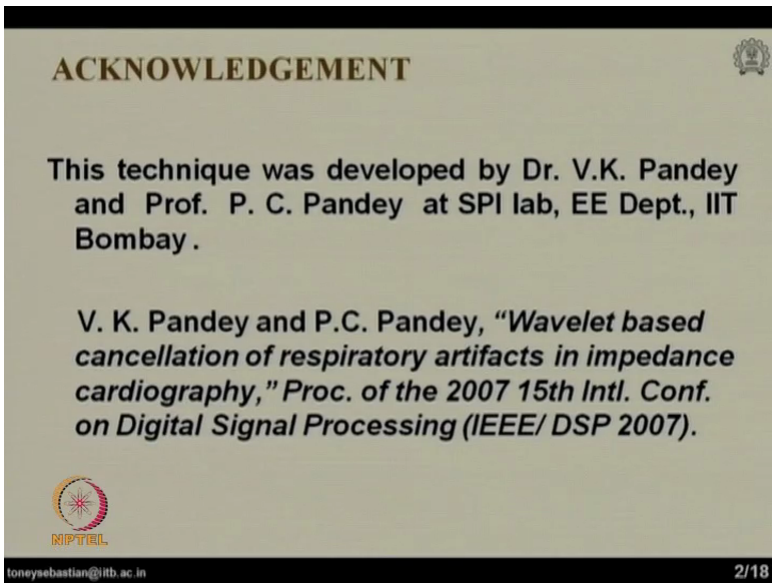
Fundamentals of Wavelets, Filter Banks and Time Frequency Analysis.
Professor Vikram M. Gadre.
Department Of Electrical Engineering.
Indian Institute of Technology Bombay.
Student's Presentation.

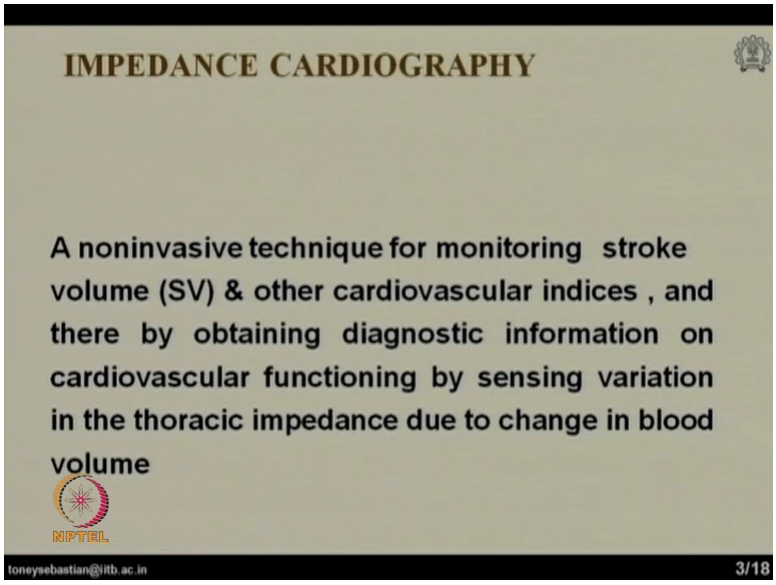
Today I am going to request one of the students who has attended this course, namely Tony Sebastian to make a presentation on the excellent application presentation that he worked upon in this course. I shall not take away from him the Thunder of explaining what he did, save to give an introduction in a few lines. I shall just introduce the broad theme of his application. And the broad theme relates to what is called that denoising.

Now denoising as the name suggests means an operation of separation of wanted and unwanted in the mixture of signal and noise. As expected, normally the noise or the perturbation is unwanted and it is often the case that when one goes into the wavelet domain, particularly in the context of biomedical signals, it is easier to separate the wanted signal from the unwanted noise.

We could have several instances of this but what we have today is essentially a suppression of respiratory artifacts which Tony would explain to you on his own. So now I introduce Tony Sebastian and I request him to make a presentation on his work related to the suppression of these kinds of artifacts and wavelet-based denoising.

(Refer Slide Time: 2:37)

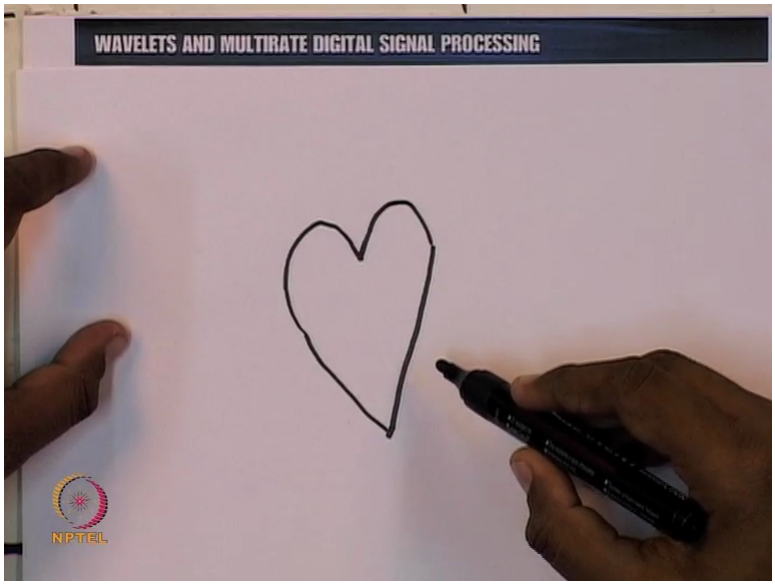


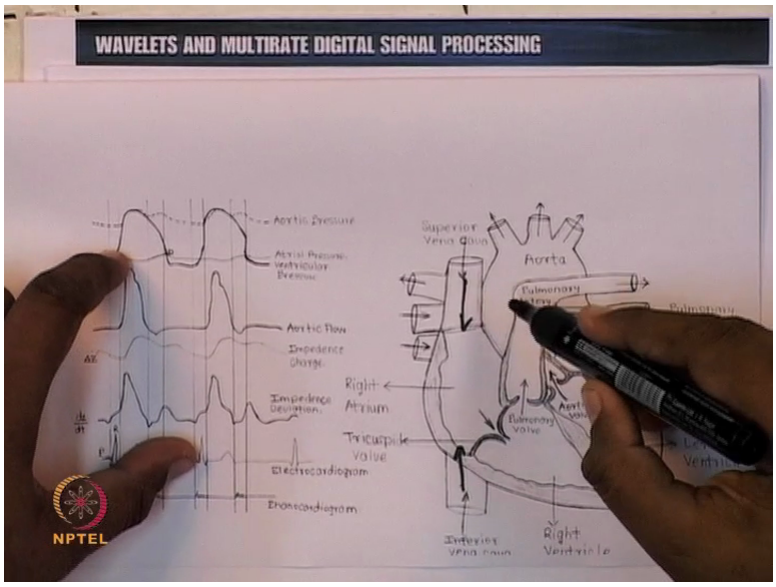


Hello everybody, myself Tony Sebastian of Second-year M Tech student, M Tech student of biomedical department IIT Bombay. Welcome to my application assignment presentation on wavelet-based denoising for the separation of respiratory artifacts in impedance cardio gram signal. Now the technique I am going to present here was originally developed by Dr Vinod K Pandey and Prof PC Pandey of EE Department, IIT Bombay. Now what is impedance cardiography?

Impedance cardiography is a non-invasive technique for monitoring stroke volume and other cardiovascular indices. And thereby obtaining diagnostic information on cardiovascular functioning by sensing the variations in thoracic impedance due to the change in blood volume. Now since most of you are from engineering background, many of the technical terms in this destination are not familiar for you.

(Refer Slide Time: 3:31)





So it is better to have some basic understanding of the heart's structure for getting into this definition and hence for the better understanding of the project. Now, let us look into the structure of the heart. Now, this is the structure of the heart, most of you may be familiar with, but this is not how the heart looks like. Let us look into the actual structure of the heart. Now, this is how the structure of the heart looks like. Thanks to my friend Ajay Tijori for drawing such a wonderful diagram for this presentation.

And now let us look into the structure of the heart with an engineer's perspective. We can visualize heart as a combination of 4 chambers, here you can see one chamber, that is the right atrium, here you can see the second chamber, that is the left atrium, now here is the right ventricle and here is the left ventricle. Now the right side of the heart, that means the left-

hand side of the picture deals with the deoxygenated blood and the left side of the heart, that is the right side of the picture deals with the oxygenated blood.

Now these 4 chambers can be visualised as a combination of as 4 pumps. Now, it is very similar to the mechanical pumps, the function is just to pump the blood. Now blood from different parts of the body will enter into the heart through the right atrium. Now here you can see the 2 major vessels, this one and this one, these are the superior vena cava and the inferior vena cava.

Superior vena cava will be bringing blood from the upper part of the body to the heart and inferior vena cava will be bringing blood from the lower part of the body to the heart. Now the name superior and inferior is not because of the functioning, it is just because of the position. Now as soon as this right atrium is filled with blood, this blood will be, right atrium will pump the blood to the right ventricle, there is a valve separating the right atrium and the right ventricle, that is known as, that is this one, that is the tricuspid valve.

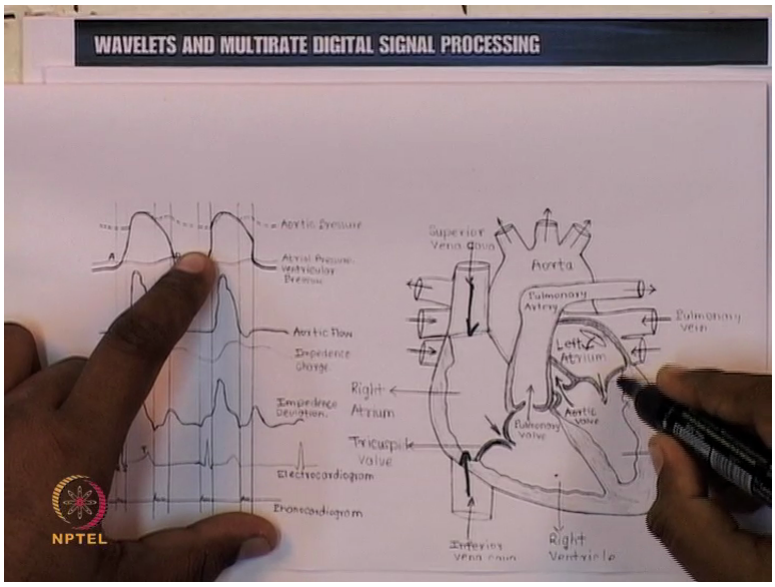
Now, from this right ventricle, this right ventricle will pump blood to the lungs for getting oxygenated. As you know, blood which is coming from different part of the body to the heart has carbon dioxide in it and we need oxygen in the blood for the body functioning. Now in the lungs this blood will exchange carbon dioxide and oxygen, for that this right ventricle will be pumping blood to the lungs through the pulmonary artery.

This is the pulmonary artery, so right ventricle will be contracting in this direction and by that time this tricuspid valve will be closing and this particular valve will be opening. This particular valve is known as semi-lunar valve because it is opening to the pulmonary artery, it is known as pulmonary semi-lunar valve. So blood from this right ventricle will pump to the pulmonary artery and it will go to the lungs and from the lungs blood will come back to the heart to the left atrium.

So blood will come back from the lungs to the heart through this pulmonary vein to the left atrium, left atrium is on the top side. From this left atrium blood will be pumping into the left ventricle. There is a valve separating left atrium and the left ventricle, that is known as the Mitral valve or the bicuspid valve. Now, comes the most important part of the heart, left ventricle out of these 4 chambers I say left ventricle is the most important part because left ventricle will be pumping blood to the different part of the body.

As you know, since our body parts are far away from the heart, it has to do a lot of work for pumping blood to the different parts. So this left ventricle will be contracting with maximum force and when it is contracting, this particular valve will be opening, this valve is again a semilunar one which is the iotic semilunar one because it is opening to the iota. And from this left ventricle, the blood will be pumping to the iota, iota will be taking away his blood to the different parts of the body, here you can see different branches of this iota.

(Refer Slide Time: 8:15)



Now, here comes, here again see the beauty of this cardiac design, I say the beauty because, see compared to all the other chambers, left ventricle has to do maximum work, for that this particular muscle has maximum thickness compared to other ones, other chambers. Now, another important factor here is, why left ventricle is important as, even if these atrial muscles have problems or even if these atrial pumps are not working, because of the gravitational force and because of the weight, this tricuspid valve and bicuspid valve will automatically open and 70 percentage of the blood will automatically fall into the ventricle even if these atrial pumps are not contracting.

So, we can say disorders relating atrium are not comparatively that much danger compared to the disorders related to ventricle. Now, let us look into some of the waveforms related to heart. This upper dotted line indicates the iotic blood pressure, that is when we are measuring our blood pressure by using normal pressure meter, we will be getting this iotic blood pressure. That is when we are going to hospital, the doctor is measuring our iotic blood pressure by using his normal pressure sensors.

And this blood pressure what we are normally getting for a healthy man, 80 to 120, that is the systolic and diastolic pressure of the iota, here is the iota you can see. Because normally our doctors are measuring blood pressure in the hand, this blood pressure is slightly whatever pressure we are measuring a slightly lesser than the iotic pressure but it gives an approximate measure of iotic blood pressure. Now the 2nd waveform is the ventricular blood pressure and the 3rd one is the iotic pressure.

Now, at the initial phase you can see iotic pressure is little bit higher than particular blood pressure. Now, when this iotic pressure as higher than particular pressure, this tricuspid valve as well as the bicuspid valves are open and at this time this left atrium and the right atrium are contracting and blood will be falling to the ventricles. Now, as soon as these ventricles start contracting, pressure inside ventricle will increase, start rising, at some particular point it will overcome iotic blood pressure.

At that particular moment this iotic valves, this tricuspid valve and the semilunar valve will be closing because the pressure inside the ventricle is higher. This valve will be closing and it prevents the backflow and pressure inside ventricles will be start again and again and building. At some particular point it will overcome the pressure inside the iota and at that particular moment this semilunar valve will be opening and ventricle will be pumping blood into the iota.

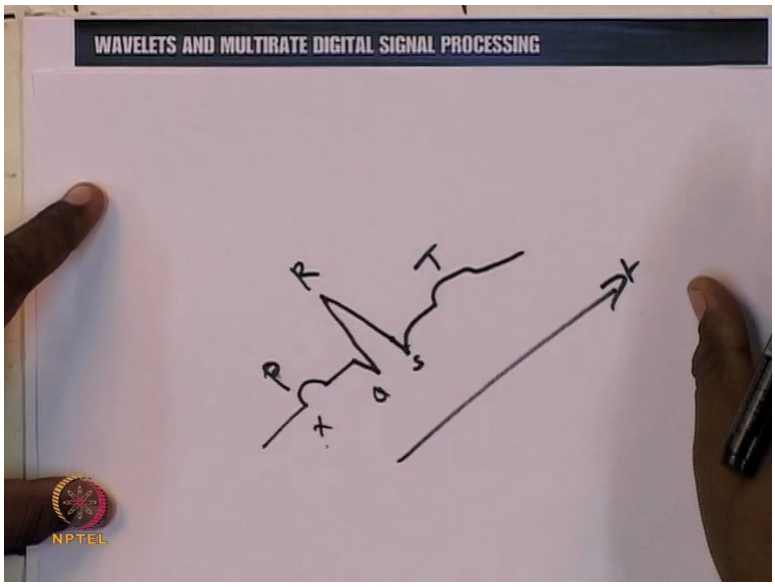
This will be continued for a moment, when this ventricle starts relaxing, the pressure inside the ventricles start reducing. When this ventricular pressure becomes lower than the iotic pressure, this iotic valve will be again closing and ventricle starts relaxing, the blood flow stops. Now this ventricular pressure will again come down and when it comes down below the iotic, the atrial blood pressure, this tricuspid valve will again, tricuspid valve and bicuspid valve again will open and blood will again come to ventricle and this cycle will be continuing.

Now, the next waveform is iotic flow, as you can see, this particular point is the point at which the iotic valves are opening, the semilunar valves are opening and at this particular moment, blood flow to the iota starts and it will be a pulsatile flow, you can see, if you tight our radial artery or some particular points, you can see the pulsatile flow, you can feel the pulsatile flow of the blood.

So this will be pulsatile and when this particular valve is opening, blood flow will be , a sudden blood flow will happen and it will continue for a moment and once the valve closes, flow against stops, again in the next cycle it will be continuing. The next 2 waveform will be looking a bit later. In the next waveform, this particular waveform is the most common bio signal and most of you might be familiar with this particular waveform, this is electrocardiography waveform.

In most of the films, the climax scene will be some ECG waveforms will be coming, some ECG waveform will be coming and one of the waveforms from will be stooping, that will be the end of the story. So this waveform, particular waveform, this electrocardiography signal gives the measure of the electrical activities of the heart. This particular waveform I will draw once again and I will explain.

(Refer Slide Time: 14:13)

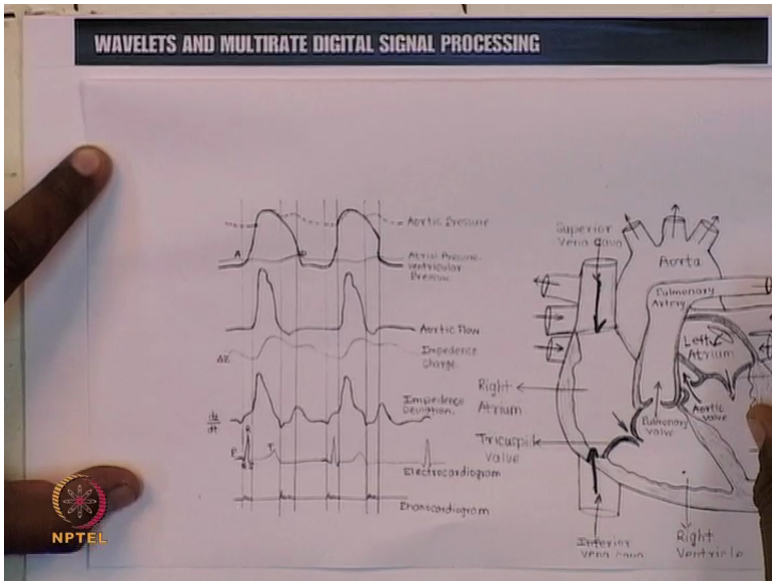


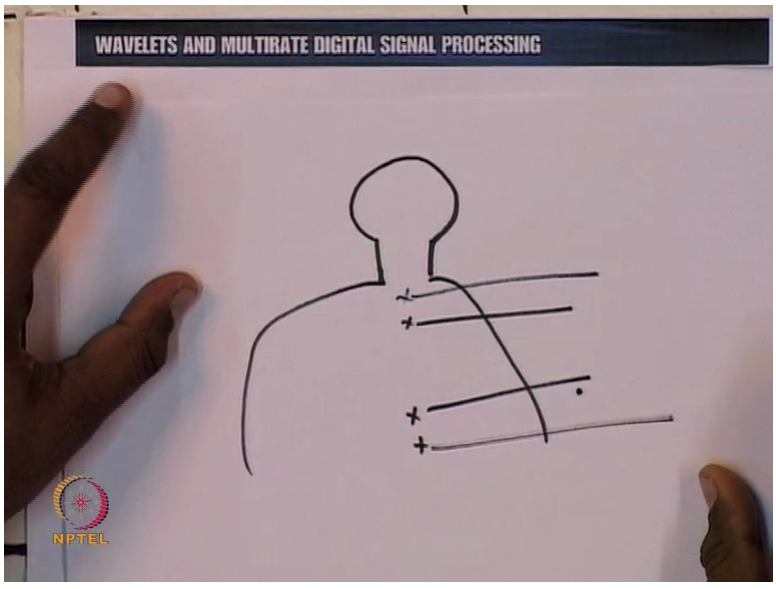
Now, a basic electrocardiography signal will be looking something like this. So this is the P wave, then Q, R, S and a T wave. This P wave indicates the beginning of contraction of the atrial pumps, so as I showed, as I showed in the previous picture the atrial pumps will be start contracting, and this axis is the time axis. So, in each cardiac cycle, at this particular moment, the atrial pumps will be start contracting and this Q RS complex indicates the contradiction of ventricles.

So atrial contracted, at this particular moment, the ventricular pumps start contracting, when the medical pumps are start contracting, the upper pumps again start relaxing. At T wave, the ventricular pumps are relaxing. So, by looking at the electrocardiography signal, a

cardiologist can tell how good a heart is working or how, what are the major disadvantages, disorders of a heart (())(15:24).

(Refer Slide Time: 15:38)



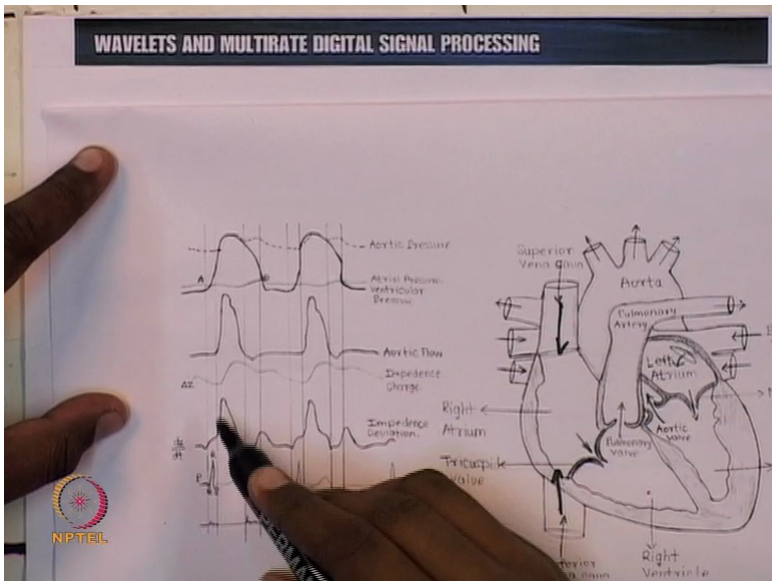


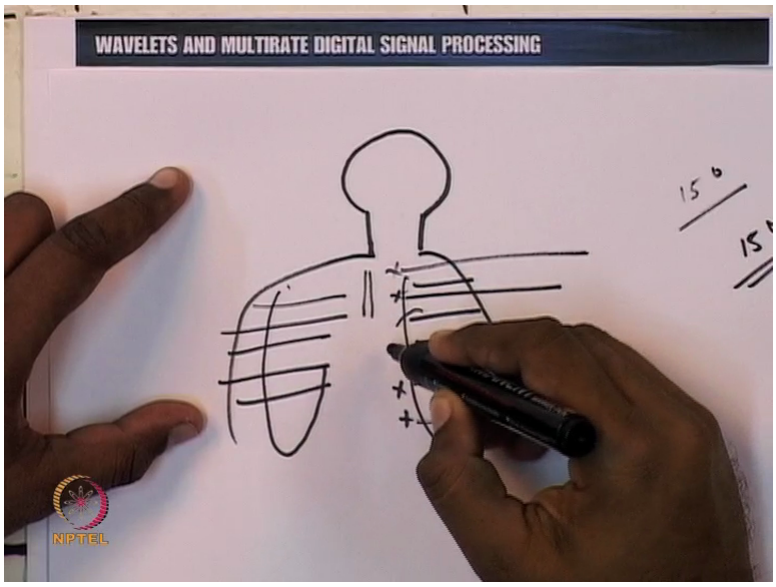
Now, coming back to the previous picture, so this gives a measure of electrical activities of the heart. Now the last one is the phonocardiogram that actually gives the cardiac sounds, cardiac sounds means, our doctors basically by the stethoscope they are hearing these sounds. These sounds are actually closing of these valves. 1st sound is the closing of this iotic valve and 2nd is the closing of these semilunar ones. Now we will go back to impedance cardiography technique.

Now, for impedance cardiography we will place 4 electrodes like this in the body and we will be injecting current through the upper 2 electrodes, that means we will be basically injecting

a high-frequency current of very low amplitude and we will be measuring the potential voltage difference between these 2 particular moments and we will find out the impedance variations across these 2 particular points, this area is the thoracic region. Now we will go back to the previous picture and understand the 2 waveforms which we kept aside.

(Refer Slide Time: 17:27)





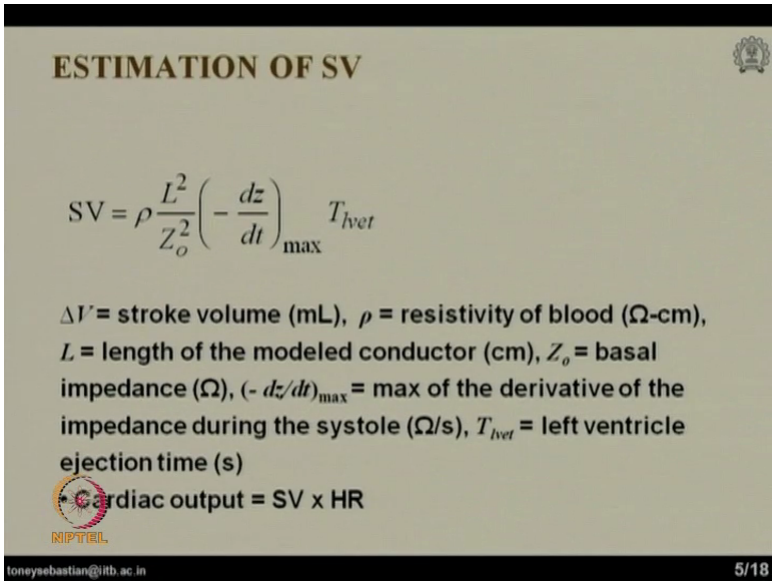
Now, these are the 2 waveforms we kept, this one is the Delta, that means the impedance variations because of the blood flow, because in every body part, in every body part , in the thoracic region there are basically 3 types of conductive tissues. That is, 1st one is the, in this area basically we can see 3 different types of tissues. One is the rib cage, you can see something like this, we have ribs, this side and this side, rib cage bones, these are bones, these are basically nonconductive.

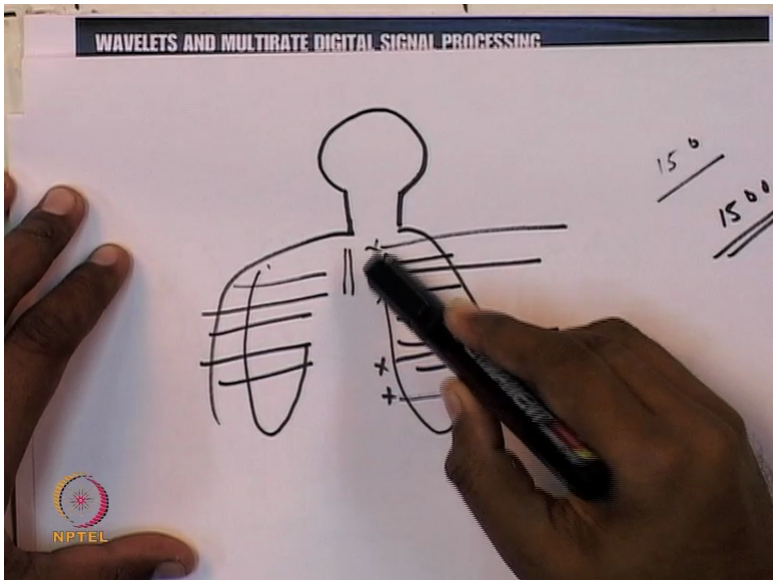
Then here we will be having the lungs, lungs are muscle tissues, soft tissues, they are conductive but not that much conductive compared to blood. Then next one will be the vena cava and the thoracic iota, vena cava will be somewhere here and iota will be here. And compared to all the other body fluids or body parts, blood is more conductive. If, for example if you say conductivity of blood is 150, then conductivity of lungs and other muscles are 1500 or 10 times lower compared to blood.

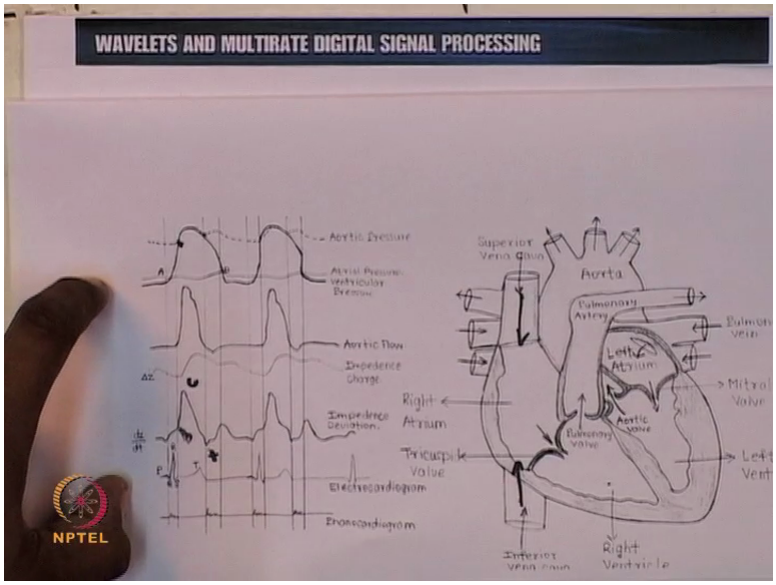
So whenever the heart's pumping, what will be happening, this iota will be changing its dimensions. Now, because of that the voltage we are measuring changes and we can sense, we can find out the impedance variation from that. Now, this is how the impedance variation looks like. Whenever the iota is opened, that means blood is pumping to the iota, its dimensions changes in the impedance goes down, resistance goes down.

So, here you can see a fast change in the impedance and it will again come down, again in the next cycle the same variation will happen and the time derivative of this particular waveform is known as the impedance cardiograph, cardio gram signal. By using certain parameters measured from this impedance cardio gram signal we can find out stroke volume and as we told other cardiovascular parameters. The 3 major points in this particular waveform are the B point, the C point and the X point. These 3 points are the major points in this particular waveform.

(Refer Slide Time: 20:21)







And this is the time derivative of this impedance waveform and this is known as the impedance cardio gram signal. Now coming back to the slides for finding out how, how to estimate the stroke volume. Now, for estimating the stroke volume, we have a special formula developed by Kubisec et al. That formula is stroke volume here in the slide you can see, stroke volume is equal to rho into L square divided by Z0 square into negative of dz by dt Max into Tlvet.

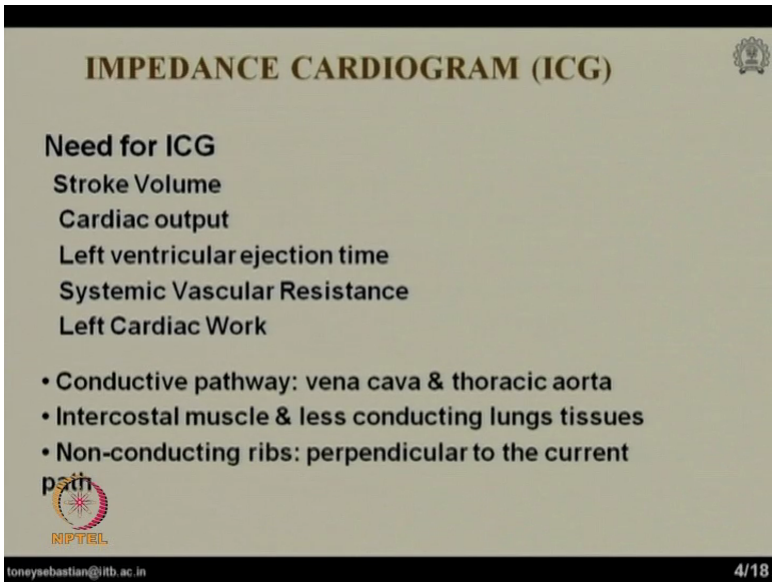
Let us spend a minute in understanding this formula. Rho is the resistivity of the blood, that is a constant, that is somewhere around 150, then L is the distance between the electrodes as we showed in the previous picture. The distance between these 2 electrodes are L, that is the, we are, we are actually modelling this thorax as a conductor. So the distance between these 2

points is L, now the next parameter is Z0, that from the previous picture, this Delta Z will be about a particular base value.

So that particular base value is Z0, normally it is around 25 but it varies from patient to patient. And next parameter is dz by dt Max. dz by dt Max, this is the dz by dt waveform, dz by dt is not the difference between the C point and X0, X point, but it is actually the difference between B point and C point. Now B point, what is the significance of B point and X point. Here comes the significance of the other waveform. B point indicates this particular point, this particular point is a point at which ventricular pressure is above the iotic pressure.

That means this is the particular moment at which the iotic valves are opening and the blood is pumping into the iota. And X point as this particular point and at this particular point, ventricular pressure will be again come down below the iotic blood pressure and at this particular moment, this valve will be closing. So during this period, that means the time period from which B point to X point, iotic valve is open and this is the particular moment in which iotic valves are opening and this is the direction in which ventricles are pumping back into the iota.

(Refer Slide Time: 23:17)



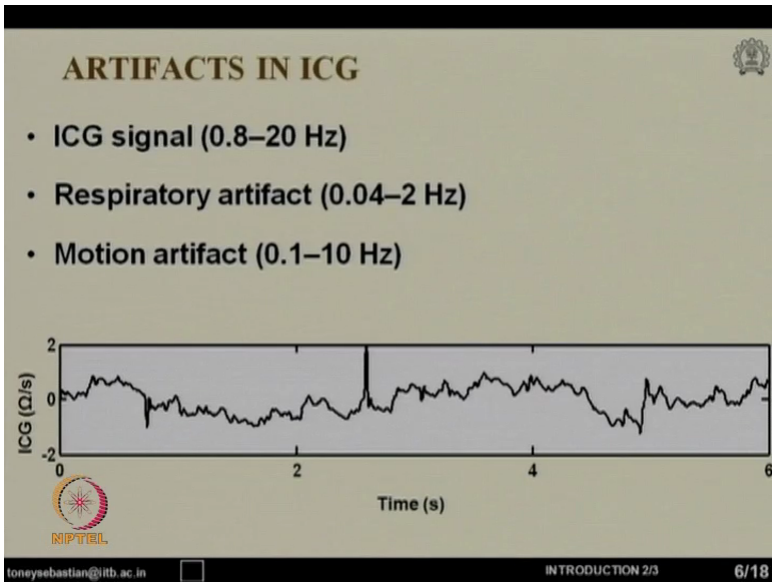
So Tlvet is basically the time difference, the point, difference the time duration between B point and X point. So from this waveform, impedance cardiography waveform, we will be basically taking dz by dt Max as well as Tlvet. Now the other major parameters related to heart, they are stroke volume, stroke volume is basically the amount of blood pumped by

heart during one heartbeat. That is during which this iotic valve is open, what is the amount of blood pumped by the heart in one cardiac cycle.

And the 2nd parameter is cardiac output. Now the cardiac output is the amount of blood pumped by hard in one-minute, that is basically in stroke volume multiplied by heartbeat. That is we can see by counting, just by counting number of C points or, C points will be very easy to detect and by counting the number of C points or by counting the QRS complex in the ECG diagram we can get the heart rate. And then by multiplying stroke volume into that particular value, you will get the cardiac output.

And next parameter is left ventricular ejection time, that is basically the time difference between B point and X point. Next parameter of interest is systemic vascular resistance, that is the resistance offered by iota to the blood flow and the next cardiovascular indices is left cardiac work, that is as I told you we are basically, among all the cardiac parameters, we are basically interested in this part of the heart, that is left ventricle.

(Refer Slide Time: 24:48)



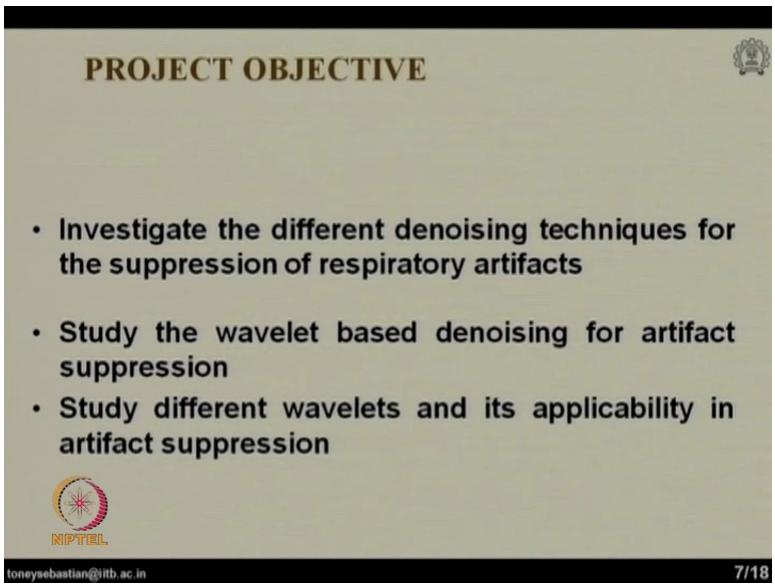
The work done by this part of the heart for pumping blood into different part of the body, that is the left cardiac work. Now coming back into the artifacts, impedance cardiography signal, basically have few types of artifacts. What are artifacts? Artifacts are actually man-made signals which are not necessary, which are unnecessary impedance cardiography point of view. Now we have 2 types of artifacts, major artifacts are the respiratory artifacts and the motion artifacts.

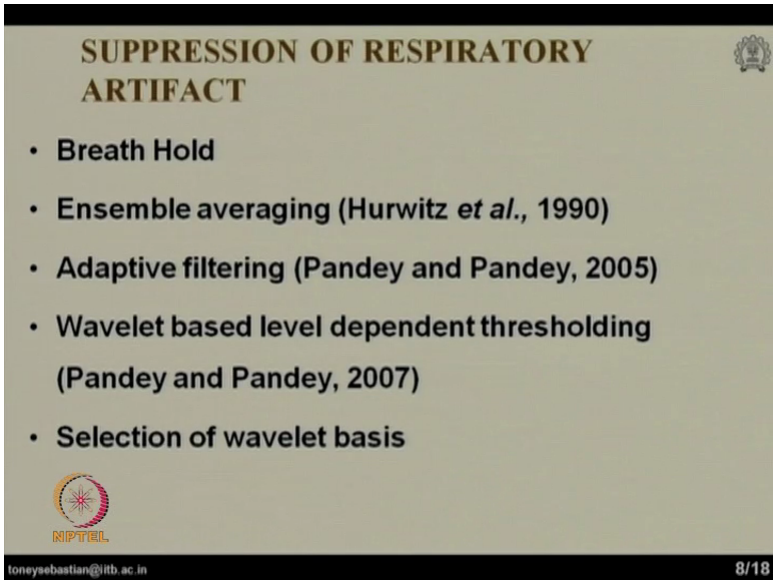
Now the respiratory artifacts are very low in frequency, that is basically from 0.04 hertz up to 2 towards and motion artifacts are up to 10 hertz. Now if we analyse the impedance cardiography spectrum, we have signals of interest from 0.1 hertz, sorry 0.8 hertz up to 20 hertz. Now here again you can see that these motion artifacts and respiratory artifacts has signal components of, components in the same band.

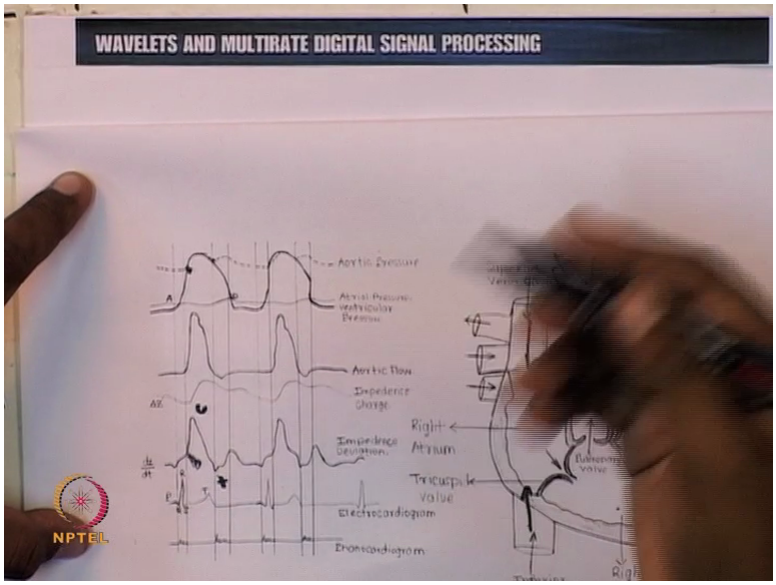
Now, we are actually looking into, here in this particular presentation we are looking into respiratory artifacts suppression. Now in this particular picture you can see a signal, and impedance cardiography signal recorded during exercise. So this is an ICG waveform recorded from a healthy subject during exercise, this particular signal has both respiratory and motion artifacts. Now this particular peak, high peaks are because of motion and this slow varying baseline is because of respiration.

Now, what is the disadvantage of this artifacts, here you can see when we are finding out dz by dt Max, these particular points will be coming into picture and they will be introducing severe errors and because in the formula we are using dz by dt Max, this will introduce severe errors for calculating stroke volume. Also this baseline drift also introduce errors in the dz by dt Max, also in Tlvet calculation. So it is very important to suppress these artifacts for the proper estimation of stroke volume and other cardiovascular indices.

(Refer Slide Time: 27:17)







Now the project objective is to investigate different denoising techniques for the suppression of these artifacts and study in detail the wavelet-based denoising techniques for the respiratory artifacts suppression and investigate few different wavelets and see how these wavelets are useful in these denoising applications. Now there are different methods of artifacts suppression. The 1st technique is breath hold, now again see, the respiratory artifacts is because of respiration, so the easiest way or the simplest way of respiratory artifacts Cancellation is holding the breath.

Now the problem with breath hold is, when we are holding the breath, cardiac activity will always go down. Another problem is, when we are recording the impedance cardio gram after exercise, it is difficult to hold the breath, because after the exercise, cardiac activity will be

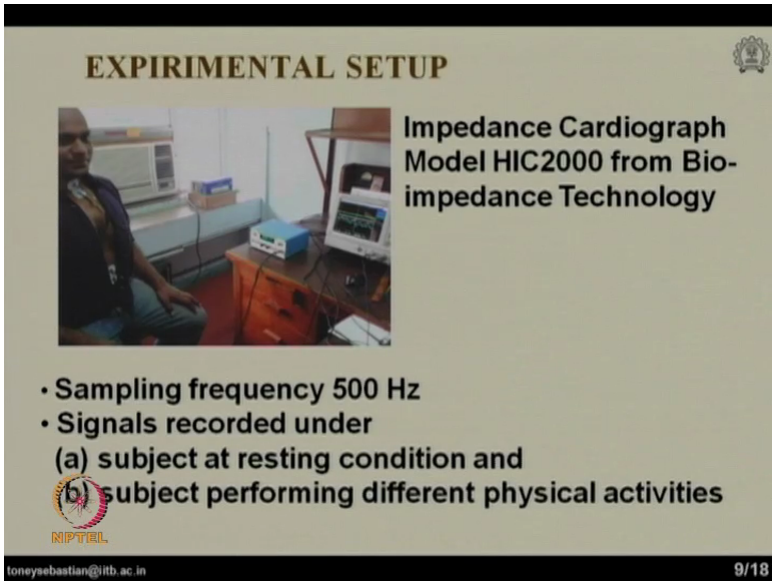
more, so it is difficult to hold the breath. The 2nd established technique is ensemble averaging, the problem related to ensemble averaging was proposed by Hurwitz et al in 1990.

The problem related to ensemble averaging is it will distort the waveform or it will remove the base, remove the beat to beat variability in the impedance cardio gram. Actually we are interested in stroke volume as well as the variation in the stroke volume, in each beat how much the, how much variation is coming in the blood, that gives, that makes the sensing diagnosis. Now, when we are doing ensemble averaging, it may blur this B point, X point and so we will not get after ensemble averaging, we will not get this clear B point and X point and hence it will introduce distortion or errors in calculating the stroke volume.

Next technique is adaptive filtering which is developed by Prof PC Pandey and Vinod K Pandey, again in 2005 in IIT Bombay. The problem with adaptive filtering is, adaptive filtering is always good in bio signal denoising if we have a reference signal. But for adaptive filtering, we need to have a reference signal, for that we have to keep a pressure sensor in the nostril, so this has again problem of patients complains, that is how adaptive filtering works.

Then the next technique is the one which we have (())(29:51) is wavelet-based denoising, which is known as the level Dependent thresholding, which is again developed by Pandey and Pandey in 2007. Now in wavelet-based denoising, selection of wavelet-base is very important. Why selection of wavelet-base is very important? In denoising applications, it is observed that basically, whether it is in ECG denoising or in ICG denoising, it is observed that if the wavelet and waveform has some similar shape, then the denoising is better, always better.

(Refer Slide Time: 30:43)

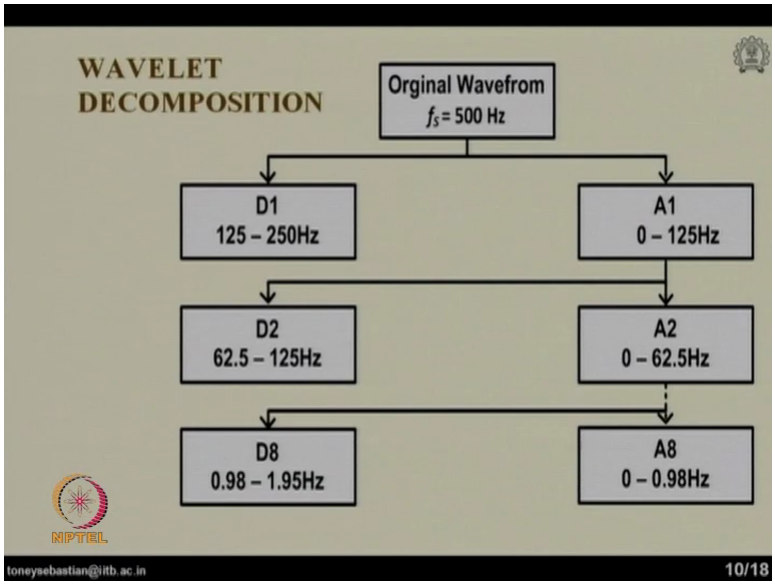


So in ECG denoising or in ICG denoising there are some particular wavelets which has shape similarity with bio signal, those wavelets will be giving better denoising, better suppression of noise in the signal. Now let us see some waveforms. This is the experimental setup of impedance cardiography, here you can see the recording of impedance cardio gram, 4 electrodes are placed over here, 2 in the upper part and 2 in the lower part.

This is the impedance cardiograph and through the upper 2 electrodes, current will be injecting, high-frequency current of low magnitude will be injecting and this will be measuring, these lower 2 electrodes will be used for measuring the voltage and hence will be calculating the impedance variation. Now this impedance cardiography, this particular impedance cardiography is HIC 2000 cardiograph from bio impedance technology.

Now we have acquired the signal at sampling rate of 500 hertz, signals are recorded both in resting condition as well as signals are recorded by performing different activities, one signal which we, so before is while performing some activity.

(Refer Slide Time: 31:49)

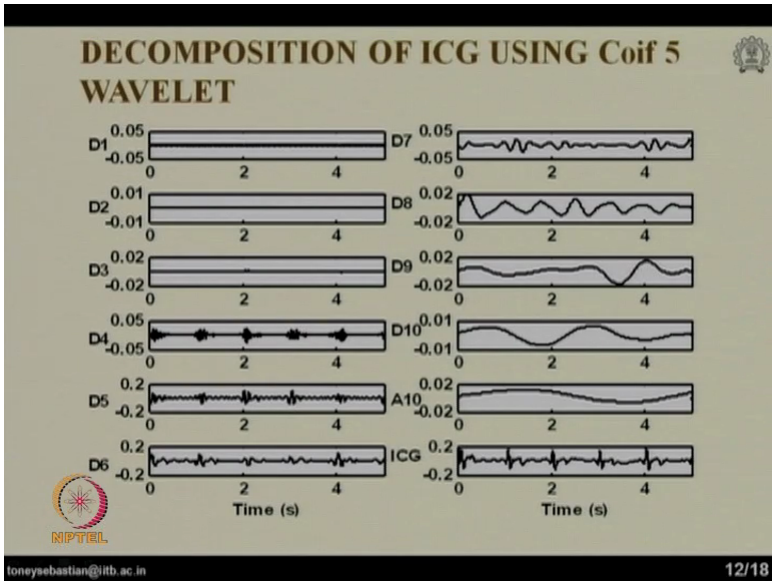


Now, this is the basic wavelet decomposition. The original waveform is sampled at 500 hertz, now each detail gives a bandpass signal and each approximation gives a lowpass signal. Now when we are decomposing the signals into different levels, for example if you are decomposing the signal into 8 levels or 9 levels, the 1st decomposition, if the sampling rate is 500, it will be having signal components up to 250 hertz because of Nyquist criterion.

So the 1st detail will be having component from 125 hertz to 250 hertz and the approximation will be having signals from 0 hertz to 125 hertz. 2nd detail will be having component from 60 to 5 hertz, 62.5 hertz to 125 hertz and 2nd approximation will be having components up to 62.5 hertz. Similarly in 8th level, it will be having component from 0.98 hertz to 1.95 hertz and approximation will be having components from 0 to 0.98 hertz.

Now in this particular method, what we are doing is, we are decomposing the signal into different levels and we are also decomposing the artifacts into different components. And we are seeing up to what level the signals are present and up to what level the artifacts are present.

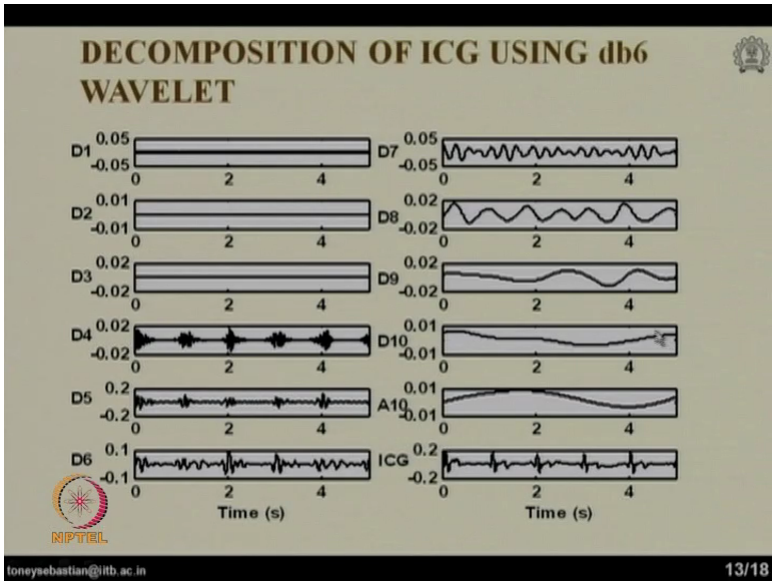
(Refer Slide Time: 33:21)



Now we use different wavelets for the decomposition. And this is the 10 level decomposition of an ICG signal which is shown here by using the Coif 5 wavelet. Here you can see the detail 1 and detail 2, they do not have much component, detail 3, they do not have much components because we do have components only up to 20 hertz, these are high-frequency components, we do not have any signal or artifacts in this area.

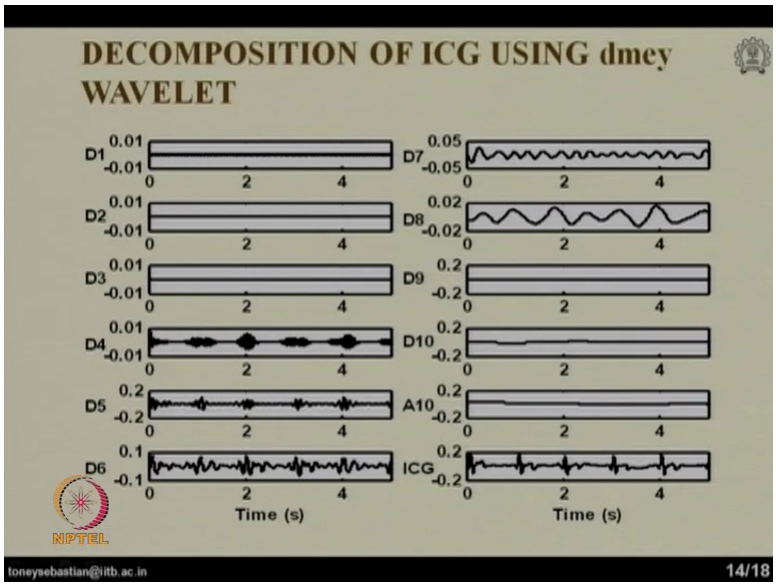
And from the 4^{th} approximation, post detail onwards, we have signal components, 5^{th}, 6^{th}, 7^{th}, to 10^{th}, all the approximation, all the detail and approximation, this is an ICG recorded under breath hold condition, so it is not having any artifact, it is having only purely signal components. So all the 10 details and approximation has signal components, so we cannot use this particular wavelet for the separation because it is not capturing signal components in any particular detail because see a a level detail or 9^{th} level detail are very low frequency components.

(Refer Slide Time: 34:46)



So this will be having, even if the signal is supposed to have a respiratory artifacts, this will be having signal as well as D9 will be having, D9 and D10 will be having signal as well as artifacts. Now, this particular waveform is the 10 level decomposition of same ICG using the Y6 wavelet. Again you can see all the 10 details and the approximation has signal component, components in it. Now here comes the one which we are interested in.

(Refer Slide Time: 35:00)

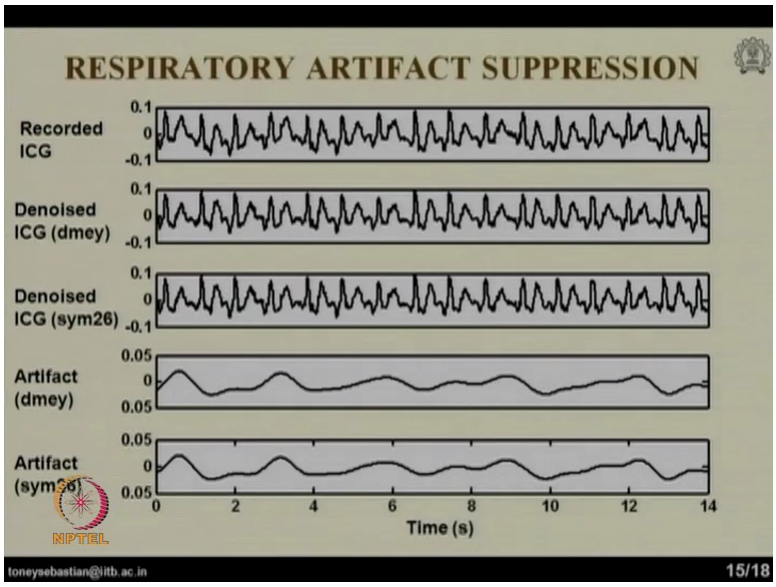


This is the 10 level decomposition of the same ICG by using dmey wavelet, that is the discrete meyer wavelet. Now here you can see D1 and D2, D3 are such they are high, high-frequency components, they do not have, we do not have any components in them but D4, D5, D6, D7 and D8 has signals in it. But in D9, D10 and A10 we do not have any component,

any signal component. So this is basically, D9 is the low-frequency area, that is from 0 to 0.98 hertz.

So here is basically, in this frequency band the respiratory artifacts are coming and in this particular section we do not have any signal component, so this particular wavelet will be very useful for separating the signal and the artifacts. So in our denoising techniques, we will be basically adding this 1st 8 details and we will be removing D9, D10 and A 10 for the artifacts suppression. So the artifacts free ICG signal is obtained by adding D1, D2, D3, D5, D6, D7 and D8.

(Refer Slide Time: 36:12)



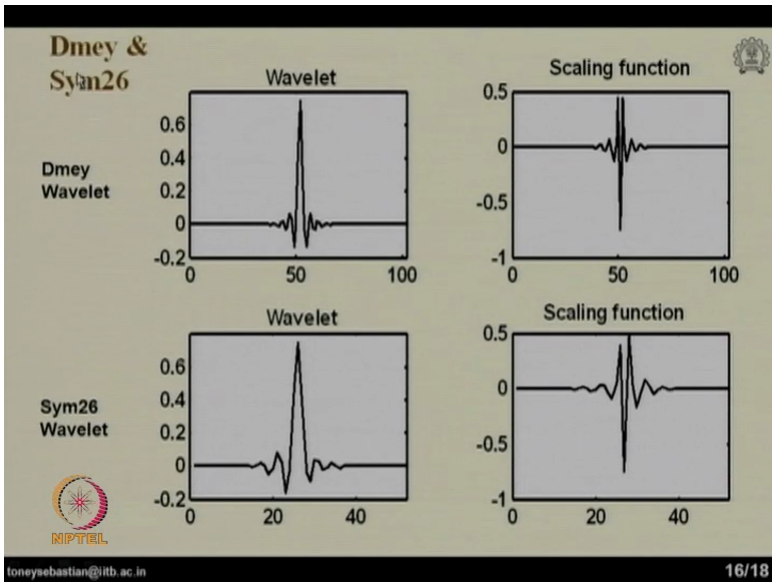
Now further studies at SPLR showed that similar results, this obtained by dmey wavelet can be achieved by using one more wavelet that is similar 26 wave also gives similar results as obtained by dmey wavelet. Here you can see one ICG waveform recorded under resting, under resting condition but with respiration. This 1st waveform is the ICG recorded with the respiratory artifacts. The slow varying, the slow varying oscillations are because of this respiration sinusoidal oscillations are because of the respiration.

Now the 2nd wave is denoised ICG waveform by using dmey wavelet, that is we are, we have decomposed the signal into 10 levels by using dmey wavelet and reconstructed the signal by using 1st 8 details. And the 3rd one is same procedure followed by using similar 26 wavelet, by visually we can see both the wavelets are giving same performance. Now the 4th one is the artifacts which is extracted from the ICG waveform by using dmey wavelet, this is basically

1st waveform minus the 2nd waveform, that is 1st waveform which has artifacts and the 2nd one is the denoised waveform, the difference is basically the artifacts signal.

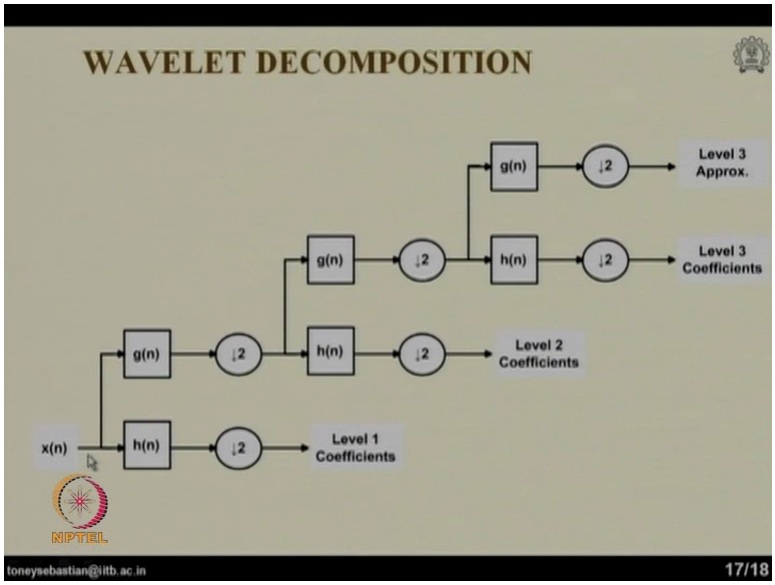
And the last one is the respiratory artifacts removed by using similar 26 waveform. Here you can see both the waveforms, both the wavelets are capturing exactly same artifacts and exactly the same signals. Now, why this happens?

(Refer Slide Time: 37:59)



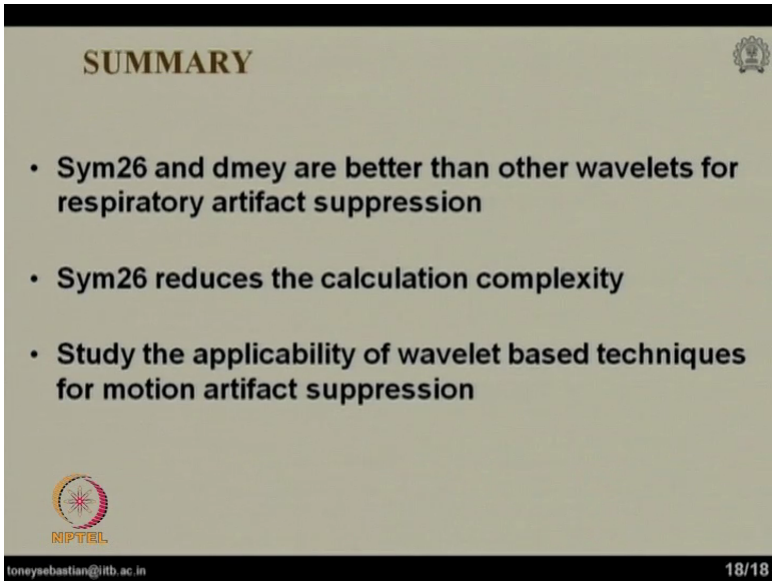
See, here we can see the wavelet and scaling function of dmey wavelet and similar 26 wavelet. Here dmey wavelet has one or 2 samples in a wavelets compared to similar 26 wavelet has 52 in it. Now here you can see it almost has same shape, we can see the shape similarity in dmey wavelet and similar wavelet, both the mother wavelet and the scaling function has similar shape for dmey wavelet and similar 26 wavelet. Because of this shape similarity we are getting same result for both the wavelets.

(Refer Slide Time: 38:48)



Now, this is a basic block diagram of wavelet decomposition by using filter bank. Here you can see we are using, we will be having filters, lowpass filter, decomposition filter and again here after this here we will be getting wavelet coefficients. And for getting the details back, we have to use the reconstruction filters of same length again. Here you can see the advantage of using similar 26 wavelet because similar 26 wavelet is having only 52 coefficients compared to dmey wavelet having one or 2.

(Refer Slide Time: 39:33)



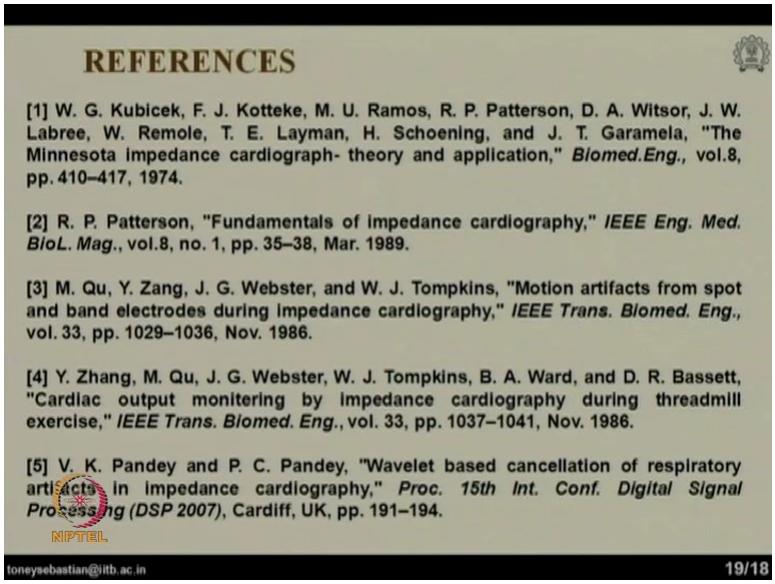
So, since we are using 10 level decomposition, if we use similar 26 wavelet, the calculation complexity will be comparatively very less compared to dmey wavelet. Now, coming back to the summary of the presentation. We can see that both similar 26 wavelet and dmey wavelets

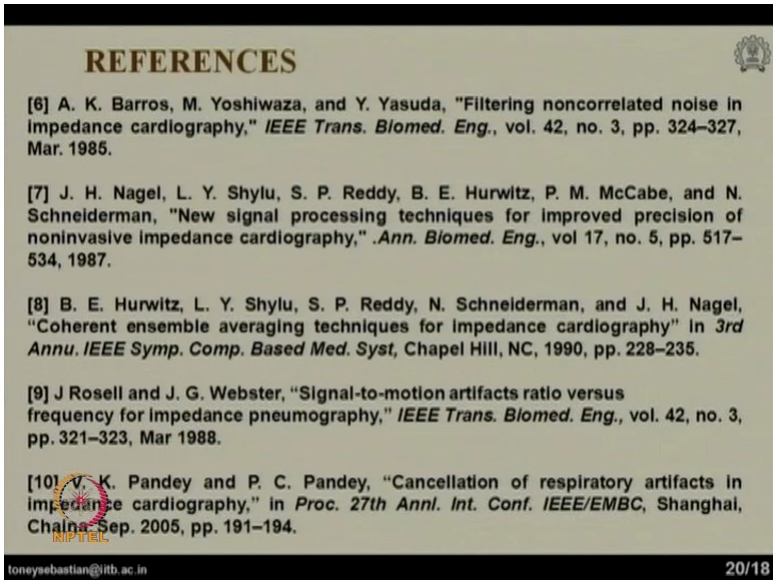
are giving better performance in artifacts suppression and they are giving almost similar performance compared to other wavelet and we studied different wavelets like coif wavelet and the Y6 wavelet.

They were not comparatively that much good compared to the wavelets. And similar 26, advantage of similar 26 wavelet is it reduces the calculation complicity because of it is having low number of filter coefficients. Now the future work will be a, we have, we can study the applicability of wavelet in denoising motion artifacts. And also we can investigate whether any other wavelets are giving denoising application.

What you can try is, you can use this technique or similar technique for the denoising of, ECG denoising because ECG data files are available in MITB database, you can download some ECG database, ECG data signals from MITB database and you can try similar kind of technique in denoising of ECG signal. ICG signals, till now it is not that much popular compared to city signals, so we do not have any open database compared to ECG signal, so we can download some ECG signals from MITB database and I hope you all will try some of the denoising techniques, maybe these techniques may not be applicable but some modification of this may help in denoising, ECG signal denoising also.

(Refer Slide Time: 41:20)





So you can try that kind of denoising. And these are few reference papers we have referred, the 1st paper is Kubicek et al's paper. They proposed the impedance cardiography technique itself and a few other reference papers are, denoising techniques and signal processing techniques. If you are interested in further studies, you can refer to these papers and get more information on this denoising technique and more about impedance cardiography technique. That is all about the presentation, thank you.