Digital Signal Processing & Its Applications

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Lecture 01

Introduction to Digital Signal Processing

So, good morning and a warm welcome to this course on Digital Signal Processing and its applications. This course is treated as a basic course, by enlarge a basic course, at the graduate level however. That means for students who pursue a master's or a doctoral program. Typically, it's a core course for many specializations or at least a course which occupies the status of an introductory or first-level course on Digital Signal Processing.

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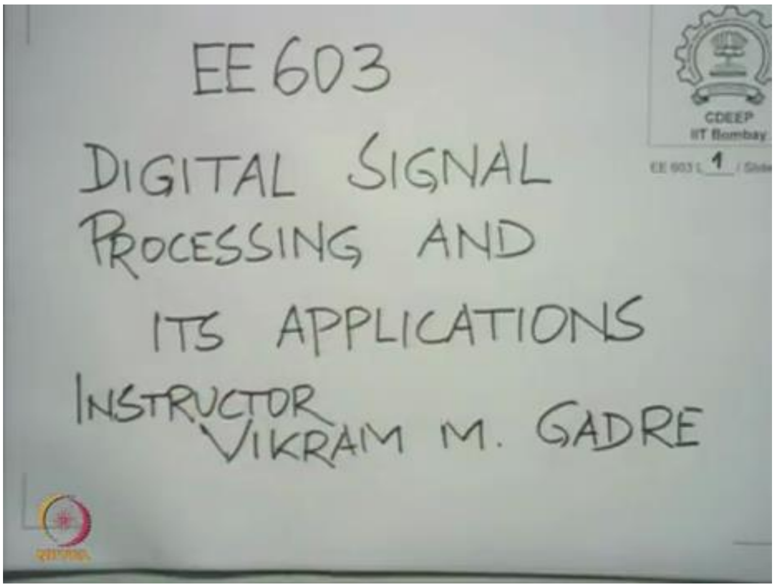

The course is entitled Digital Signal Processing and its applications. And before we proceed, let me introduce myself. My name is Vikram M. Gadre. I am a faculty member in the Department of Electrical Engineering, IIT Bombay. I have been instructing this course before; a number of times.

And what I intend to do right now is to first give you a feel of what we intend to do in this course. What is the aim? What is the objective of this course? What does the title mean? What lies behind the title, not so obvious? And how we are going to conduct this course?

Well, if you ask me to summarize the aims and objectives of this course in a few sentences, the first objective is to move from continuous-independent variable to discrete-independent variable. What that means is, if we take the example of an audio signal. In audio signal, the independent variable is time.

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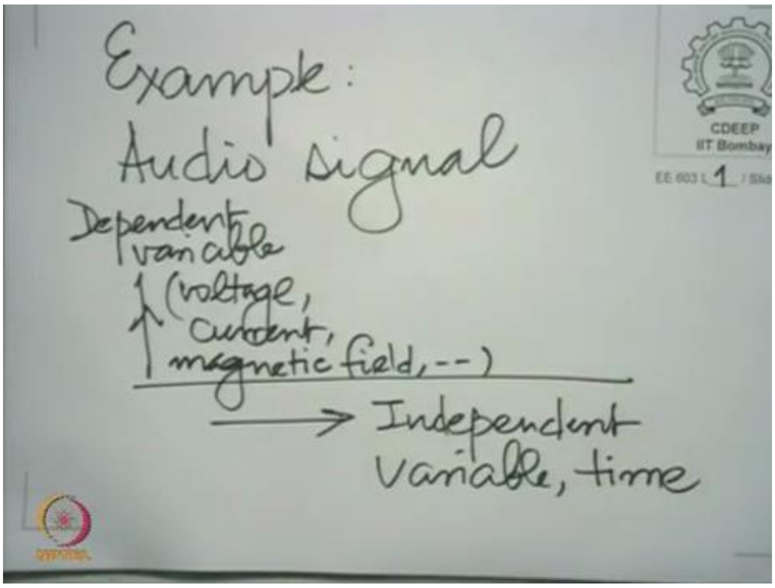

So, let us make it a practice to write down. Let us take an audio signal as an example. Independent variable is time and the dependent variable could be the nature of; could be depending on the nature of the recording. So, it could be for example, a magnetic signal if it is an audio magnetic recording or it could be a voltage signal, whatever. So, it could be voltage, current, magnetic field, whatever. It depends on the nature of the record. Isn't it?

Now, any meaningful signal, most of the signals in fact that we deal with in real life, have a continuous-independent variable and a continuous-dependent variable. By continuous I mean, if you take any 2 values of the independent variable, you can always find the possible value in between them, no matter how close they are.

So, for example, if you take the values of time equal to 1 and 1.00001. I can still find the value 1.000005 which is in between these. So, now no matter how close I have my two independent variables, I am always able to find another value of the independent variable in between them. That is what continuity means. That is what is meant by a continuum. So, we introduce this idea of a continuum, formerly the idea of a continuum.

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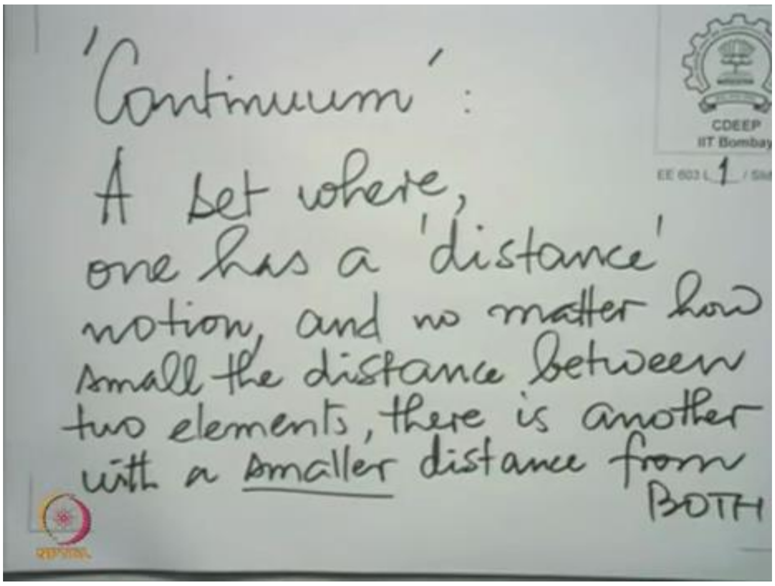

A set where, one has a ‘distance’ notion, and no matter how small the distance between two elements, there is another with a smaller distance from both. I told you this is an introductory course at the graduate level. Isn't it?

So, when we introduce idea at a graduate level, at the level of masters and doctorate, we are a little more formal or we are a little more in depth than we are in an undergraduate level. So, we proceed from intuition to a reasonable level of completeness. Not, not very rigid; not very rigorous but a reasonable level of completeness. That shall be our practice.

So, even here if you notice, we have not confined ourselves only to one-dimensional signals. In a one-dimensional signal like audio of course, the independent variable is time. So, in the real axis is what can be used to index time. And therefore, the idea of distance is very clear.

On the real axis pick any 2 points. The difference between them; the modulus of the difference between them is the distance. And in that context this definition becomes very clear: no matter how small the distance between 2 points, I can always find another point which is at a smaller distance from both of them; both of them.

Both of them is critical. Okay? But you must remember that you can also have a two-dimensional independent variable. For example, you can have a picture. So, we should make a note of that.

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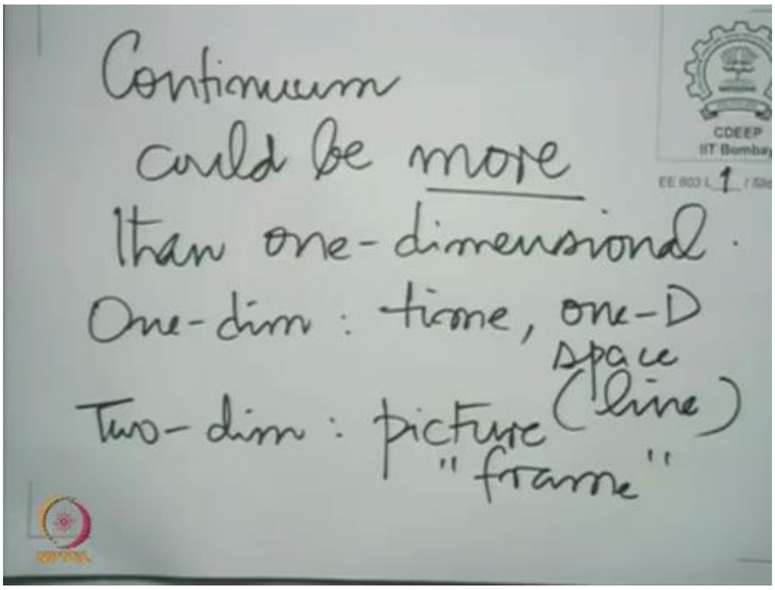

Continuum could be more than one-dimension. One-dimensional, an example is time; one-D space that is a line and so on. It could be two-dimensional. So, for example you can have a picture. Picture frame you can call it, if you like. So, the space on what you put a picture, on which you put a picture is a two-dimensional continuum.

In fact, it can be three-dimensional. So, all of us exist in three-dimensional space. In fact, now it is better known that we have more than three dimensions. But that is a different issue. We definitely know that we are at least 3 dimensional.

So, continua can be more than two; more than one-dimension. Could be two-dimension, three dimensions. In fact, that multi-dimension. And what is important is that in most cases of real-life situations both the independent variable and the dependent variable are continua. That is what we must take into account.

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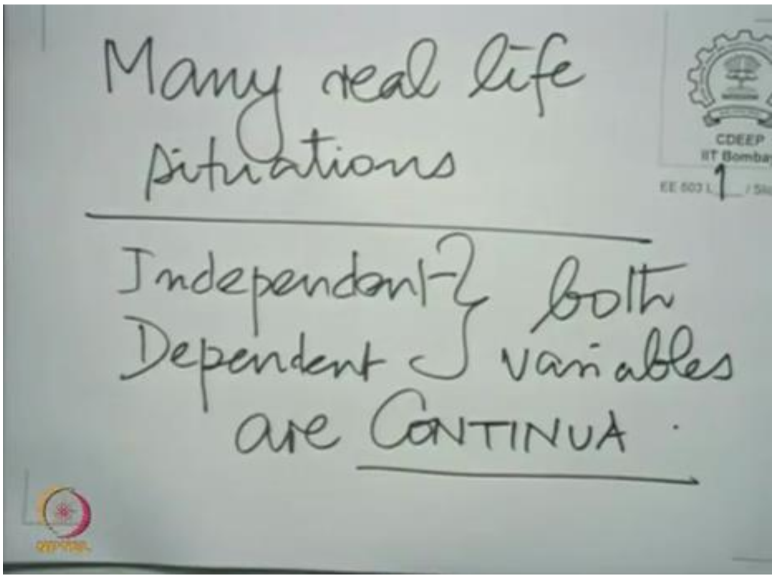

Many real-life situations. Independent variable. Dependent variable. Both variables are continua's. Now, if you wish to capture the essence of what we are going to do in this course, we wish to be able to develop the ability to take such a real-life signal; to take an equivalent signal or an equivalent entity where the independent variable has been discretized. But the dependent variable still remains continuous. So, let us summarize that.

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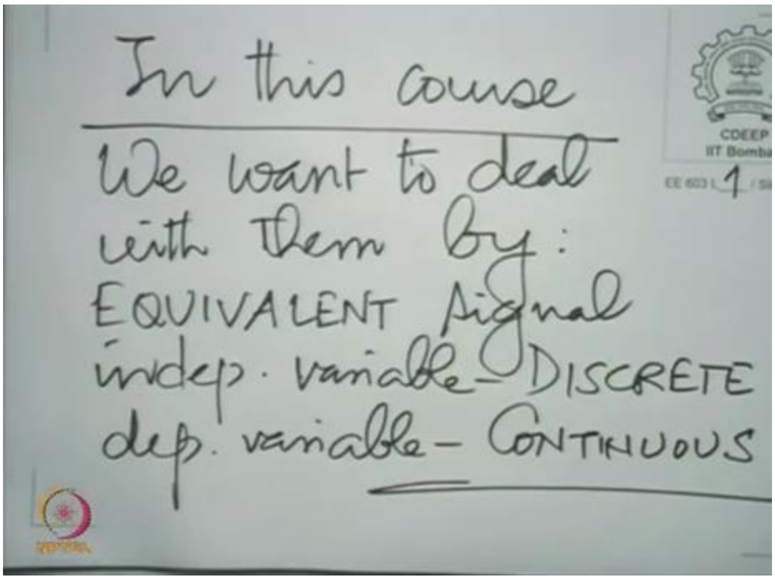

In this course, we want to deal with them by an equivalent signal where the independent variable is discrete but the dependent variable is continuous. That is a deep idea. You see, we are not sacrificing the continuity of the dependent variable. We are only sacrificing the continuity of the independent way.

For example, if I have an audio signal. What I am saying is, I will understand as if I am going to deal with values of the audio signal taken at certain chosen instants of time. And when I say equivalent what I mean is that I should choose my instance of time.

I should choose the points at which I record the values carefully and strategically so that I have no loss of information. I have nothing to lose by working only with those values and not the whole signal as it is.

But I am not compromising in principle or in thought on the continuity of the dependent variable. So, suppose the audio signal has been recorded in the form of a voltage waveform or if it is a magnetic field variation. I am assuming that variation will be continuous. I am assuming that voltage waveform will be continuous. Right?

Although, I agree that in practice, that may not be true. In practice that may also get discretized. That may also acquire only a finite set of values because you may have finite precision. Right,but we will ignore that. And there is a good reason why we are going to ignore it.

If we were studying this subject about 20 years ago, we would have been very concerned about how we are going to record continuous values. But today with the advent of very superior memories and very superior recording devices, that is almost a non-issue. One can record values very, very accurately to such a precision that one need not even worry about the fact that it is discrete. That is exactly what we are going to do. Ok? At least to simplify matters, to begin with.

Now, of course, what do you mean by a variable being discrete? It means it disobeys that property of continuous or continuum. That means it is possible to find 2 values that you have chosen for the variable between which there is none. And in fact, all, when you say discrete actually, it means, this is true for every such value that you can find; for every value that you take which you are accepting of the independent variable.

That means, for example, if you have sampled in time, then for every value of time that you have taken there are several values, in fact, you will not be able to find values less than a certain distance from that point. That is something like the nearest sample from there. Isn’t it? The nearest point in time close to that point and therefore, we will not be able to find values at a distance less than that from that point.

Anyway, now naturally why do we want to do this? The reason is very simple. That is exactly what you need to do if you want to deal with signals on modern computing devices. So, what do we want to do ultimately you see we want to deal with signals. We want to make sense out of them. We want to modify them. So, let us put down what we mean by signal processing.

We understand what we mean by a signal. In fact, if you ask me, a signal is hardly different from any function of an independent variable. The variation of a dependent variable against an independent variable is a signal as simple as that.

It could be the variation of a voltage waveform against time. It could be the variation of a current waveform against time. It could be the variation of temperature across space. It could be the variation of intensity on a two-dimensional frame as the picture does. It could be three different colour variations giving you a colour picture. So, the variation of the dependent variable against the independent variable is a signal.

As we have seen, the dependent variable and the independent variable could either be discrete or continuous. We shall be dealing with potentially continuous independent variables but which have been discretized. And now we will explain what we want to do? What do you mean by signal processing?

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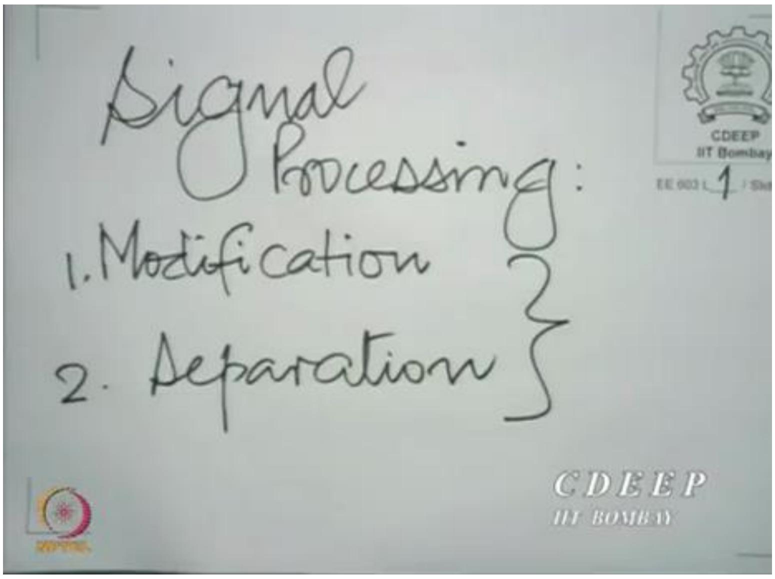

So, you understand what is a signal. What is meant by signal processing? Again, to cut a long story short signal processing means 2 things. Essentially- modification and separation. At least from our point of view it means 2 things.

So, modification means, I have one signal with certain characteristics. I wish to modify it into another signal with some different characteristics. What are those characteristics let us take us some time to understand. Now, I again give you an example and we shall build on that example in the next lecture. Not only in the next lecture; in many subsequent lectures after. It will take us quite some time to build on this example.

In the audio domain going taking again the context of audio. Let us say we have a mixture of male and female voices recorded in an audience. Typically, male voices are likely to have what is called a lower pitch. They seem to sound slightly deeper. And female voices are slightly likely to have a higher pitch. It is likely to sound a little more shirring than the male ones. Is that right?

Now, this is how we understand it intuitively. This is how we describe the two components of that signal, recorded signal as we understand it or as we perceive it with our senses. But we need to go to a different way of description when we want to do something with the audio signal. This description is not going to help us process that audio signal.

What do you mean by processing? We either want to modify it. That means I want to take that recorded signal which has both male and female components. I want to suppress the male component and enhance the female component. Or I may want to suppress the female component and enhance the male component of recording. That is an example of modification.

Or I might want to separate. So, I might want to have one signal essentially only of the male component or largely only of the male component so you cannot get exactly that. And the other signal essentially only of the female component or largely only of the female component. So, I may want to separate or I may want to modify.

Now, it is easy to put down this description in common language as we have done. But to achieve this requires many steps. And as I told you, we are going to spend many steps in going there. We first need to translate what we have said into language that will help us build a system which will do what we want to.

So, if you want to build a system, which will do this, it first requires translation of this requirement or of this description into a language which that system can understand. And that will take us several lectures. In fact, in a way it will take us half this course. So, it is a fairly heavy price that we pay if we wish to automate. But it is a price worthwhile to be paid. Because once we automate, we get several powers through the process of automation.

It is worth paying that price to evolve a language, to evolve a platform where we can translate this common parlance into something that a system that does what we want to can understand. Now what do we need for that?

We need to first build certain notions of systems themselves, to build certain different ways of describing signals or to identify certain typical signals. And then to build certain domains in which we can characterize that system. And finally, to put down certain properties of a class of systems that we wish to deal with. All this we need to do.

And of course, we will need several lectures for that. Is that right? So, in the subsequent lectures from now, we shall be carrying out this task step by step. Is that right? So with that then we shall conclude the lecture today.

And we shall proceed in the next lecture to put down in little more detail how we are going to move towards this objective of translating this example requirement into something that we can actually implement and do.