Mathematical Methods and Techniques in Signal Processing - I
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Lecture – 01
Introduction to signal processing

Welcome all of you to the course on Mathematical Methods and Techniques in Signal Processing.

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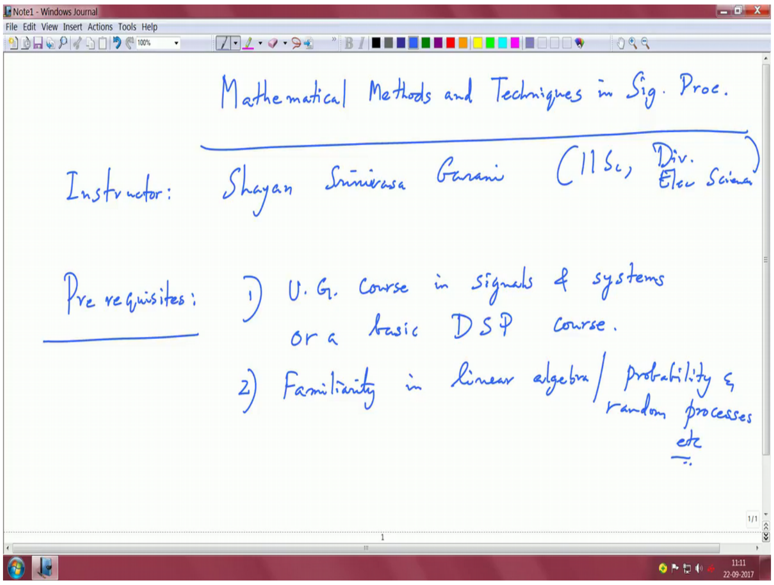

So, let me give you a brief introduction I am Shayan Srinivasa Garani, I am a faculty at the Indian Institute of Science within the division of the electrical sciences. And this course is basically an introduction to the foundations of signal processing, I mean introducing to you the mathematical aspects for signal processing that are required for you to pursue your research I mean read is a foundational course essentially which gives you a footing to do other courses and get a better grip of understanding of signal processing. And those of you who would be joining the industry still you would be able to appreciate what is the underlying, what are the underlying principles behind signal processing. So, that when you build an engineer systems you would you would really appreciate the theory behind this. So, this is the intent of this course.

This is a graduate level course and those of you who have a good undergraduate background in signals and systems or digital signal processing at the undergraduate level you can credit this course. So, I would say prerequisites undergraduate course in signals and systems or a basic digital signal processing course. There are no co requisites and I would expect some familiarity in linear algebra probability and random processes etcetera. So, these are some basic math at the undergraduate level you should be comfortable with and the prerequisites are basically undergraduate course in signals and systems.

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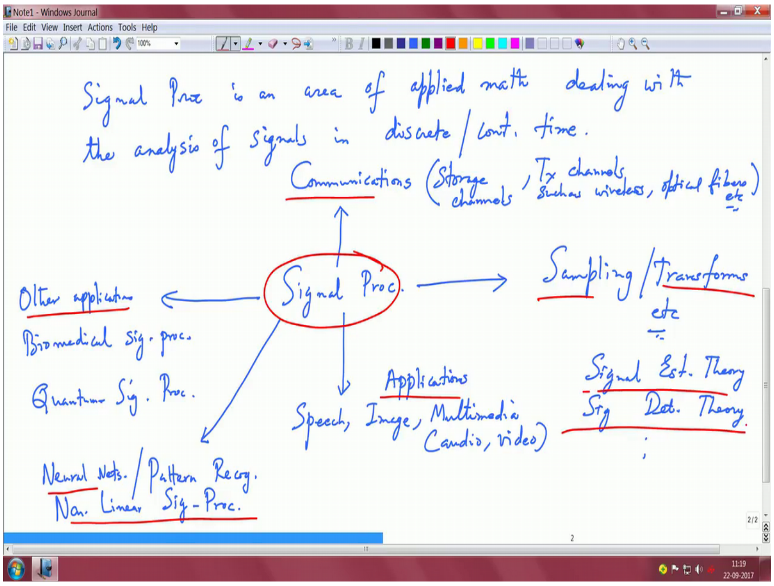

Now, one might wonder what is the signal processing about, I mean this is one of the major streams in electrical sciences. So, signal processing is an area of applied math dealing with the analysis of signals in discrete or continuous time. So, we can have analog signal processing, we can also have digital signal processing. And if you look at the foundations of signal processing it basically comes from control systems, control theory continuous or discrete time control systems. And if you look at the foundations of control it again comes from mathematics right it is basically systems theory or mathematical system mathematical system science.

So, therefore, signal processing is an area of applied math and it has been very popularly adopted in the electrical engineering community because it is useful for us for solving a variety of problems we encounter in engineering. So, if you see the spread of signal processing I think you will be really intrigued how many areas it touches upon. The DSP foundations start from sampling, transforms etcetera right. I mean we want to represent a signal, how best can we represent a signal, what is the choice of basis functions to represent the signal, how optimal is this representation in what sense, its lot of these questions. Then sampling, how should I go about sampling right, if I take an analog signal and I sample, can I reconstruct it, what is the reconstruction error, can I do regular sampling, can I do irregular sampling, so on and so forth right. I mean these questions are basic fundamental questions that gets into our mind and all of which is really research that has been pursued over several decades.

Now, one can think about some applications of signal processing in the area of speech, image, multimedia which can include audio, video so on and so forth and these are all really application, applications. So, there are other applications one can think about such as in biology or I would say biomedical signal processing. You can also think about it, think about apply applications of signal processing in maybe within quantum right. Then there are other application domains I mean communications for example, though it is a an area, a discipline in itself one can think about signal processing for communications and when you think about the applications in communications it can be for storage channels or it could be in transmission channels such as wireless you know optical etcetera, optical fibers etcetera right. There are lot of applied areas.

And of course, I should also mention some important theoretic areas for example, in signal estimation theory, this itself is an area, signal detection theory so on and so forth. I mean number trans; number theoretic transforms all these come under this transforms. So, one side is applications, other side is theoretic foundations right. So, I would give you one example of how one can think about applications perhaps in the communications side.

So, imagine you are taking your data bits and then you are modulating these data bits and then transmitting them over say a wireless channel you are transmitting them over air. So, it is basically analog and then you have to do some filtering when you receive the signal and once you do the filtering and you know removing noise and canceling some of these non-linear effects you will have to basically do some sampling right. And once you sample you have the signal in the digital or the discrete time domain and once you have the signal in the discrete time domain you have to do many things post that. I mean you will have to equalize, you will have to do timing recovery, you may have to do detection many things that you will have to consider right. This is all part of signal processing.

This is one example where you can clearly see how signal processing is playing a significant role towards recovering of your of your data. Now, one can think about you know another applied I would say applied plus theoretical foundations together here would be in neural nets, pattern recognition etcetera and all of this I think is essentially non-linear signal processing. So, questions of question such as how can I learn the data samples that are given to me, how can I generalize, can I build classifiers if you given my data sets, can I cluster, many of these questions right I mean clustering, classifications, recognition, recall all these type of problems which are dealt in conventional neural networks in pattern recognition and you know soft computing type of areas I think the foundations to those are essentially from non-linear signal processing.

So, I mean and then if you say where is the signal processing coming from and this is basically an applied math area because you require a lot of mathematical topics to have a firm footing of signal processing. So, let us look at what kind of background, not background I would say what kind of mathematical topics and tools we will encounter when we learn signal processing right.

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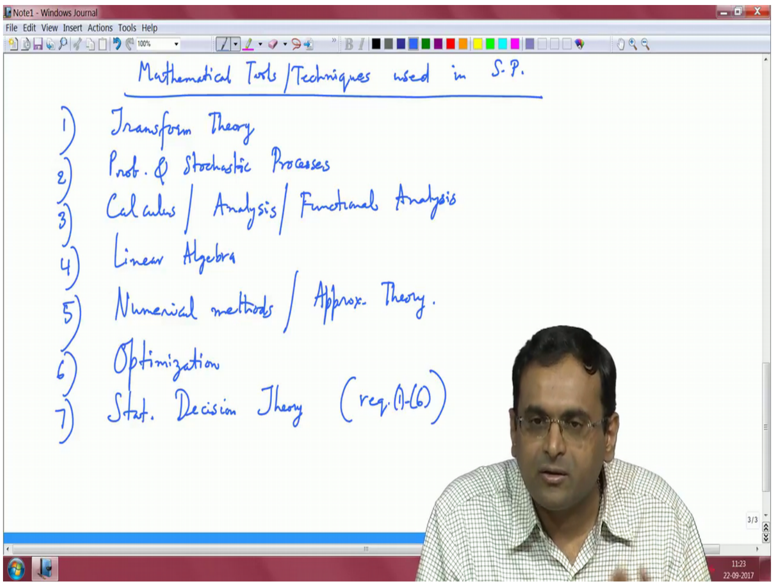

Mathematical tools or techniques used in signal processing. These are heavy math that we will need, but it is all fun. We will need transform theory and this is for signal representation purposes, then we will need probability and stochastic processes because often we have to deal with signal with noise and most communication systems are most communication channels are noisy right and then when there is noise this is buried in the channel I mean it is inherently noise is inherently part of any channel. So, therefore, overcoming the limitations of noise is a very important step. So, therefore, we need a lot of probability and random processes.

Then you will deal with calculus or I would say analysis topics you will need a firm footing in linear algebra because once you understand how you can convert a signal to a vector in a vector space right. Then it is basically very very easy for you to think about invoking techniques in linear algebra or matrices etcetera, towards building algorithms and having to and studying systems.

We will need numerical methods and I would say very broadly we will need techniques and tools in approximation theory and I would say we will need functional analysis often when we have to drive things we have to set up optimal, you know we want optimize on something that something has to be a functional and we have to set up a functional. And therefore, you know studying the techniques, properties building, these functional studying the properties etcetera we will need function an analysis optimization is another branch which is heavily required in signal processing. And last I would mention about statistical decision theory. Of course, this is a this will possibly require optimization and all these from 1 through 6, but it is still an area in itself, no it is a derived sub area from 1 through 6 right. And we want to often make decisions from uncertainty.

So, as you see you require a lot of, I would not say require as you study signal processing you will encounter a lot of tools either you study all these mathematical topics and then sit through signal processing or maybe you sit through and understand how signals and systems work. And then as you start developing your feel for the topic you see that you will need these tools in mathematics and then you can go deeper into each of the topics and then learn whatever is required and then bring in those tools to signal processing. So, therefore it is an applied math.