Networks and Systems
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Lecture-5
Representation and classification of systems

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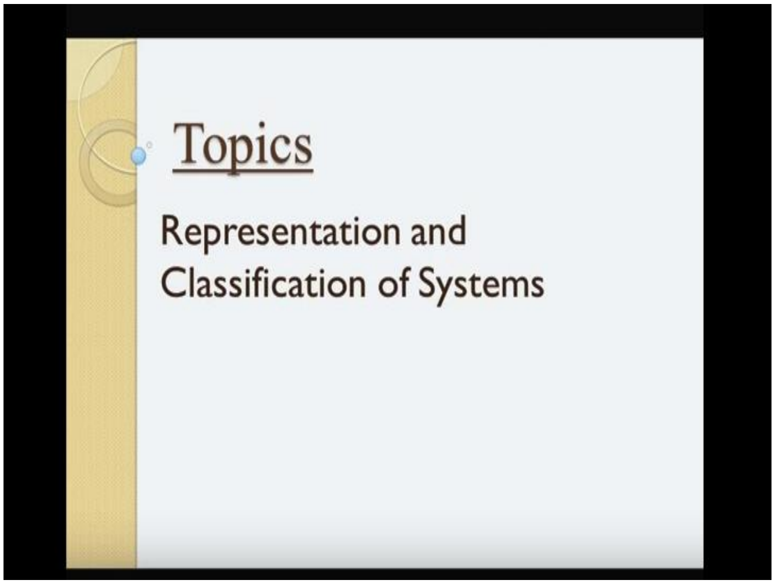

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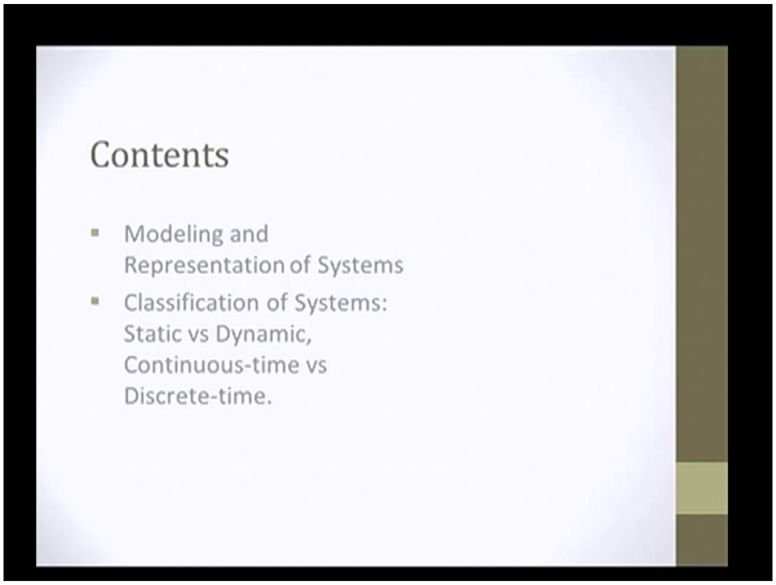

Then after having discussed what a system means and have and what a model means and how this a analysis such as various models are facilitated by a common body of tools coming under the names system analysis, system theory. Let us now look up see how we represent a system.

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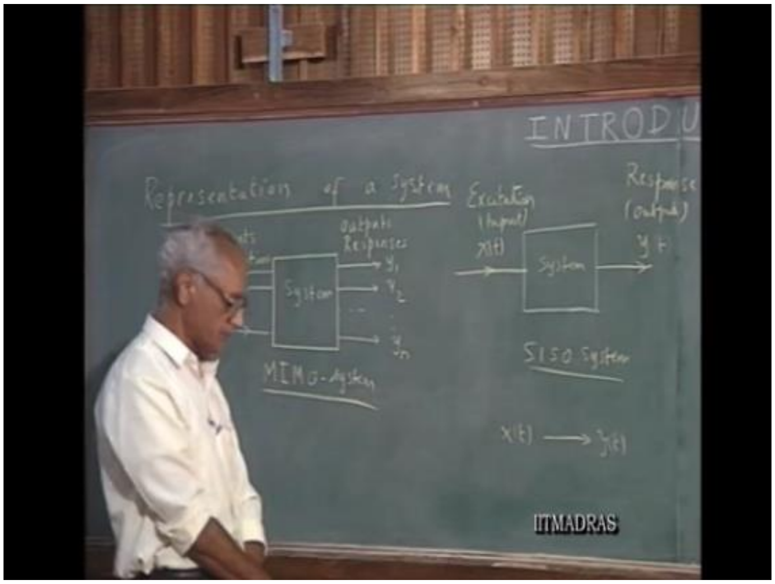

Very often we are interested finding out the response of a system under the influence of a particular input. We are not too much bothered about the various variable the various signals internal to the system. In this event we represent a system as a black box and the various inputs that are given to the system are represented in a manner may be called as x1, x2 write up to xm. And under the influence of the various inputs there are certain responses in the system which we were interested in these are called the outputs or responses.

Similarly, the inputs are called excitation also other name is excitation. So we may say the system responses under the influence of an excitation or the system gives an output under the influence of an input and there may be n such responses we are interested in. So in this particular system we possibly have n inputs and n outputs and then the representation like this is refer to as a multiple input, multiple output system.

So let us consider an electrical network in have several sources voltages and currents and would like these are the various inputs in the electrical network, current sources and voltage sources. We are interest in finding out the voltages and currents at different points. We are interest in finding out all those responses so we can model this as a multiple input or multiple output system. On the other hand very often we might be interested in finding out the influence of one particular input and we like to find out the response at a particular location.

Then we have x of t may be the input signal y of t is the output signal. So we may call this again as input or excitation and this can be called a response output and this will be called single input, single output. But the class of system which will talk about later linear time invariant systems if we have a complete knowledge how a system behaviors behaves with a single input and a single output and a particular output.

Then we can use that information to get the a particular response whether variety of inputs simultaneously occur by the principle of super position and this is something which can always do for a particular class of system that we are talking about. So our concentration may be for most of the time and a singe input and a single output system but that does not in any case take away from the generality of the tools that we employ.

To simplify this notation this is a block diagram representation of a system. I mentioned this is as a black box because we are not particularly interest in what is inside therefore we have we assumed that we have two terminals where the input is fed and 2 terminals where the output is fed taking the electrical circuit as an example and this whole concept of a particular input giving rise to an output can also be very succinctly and compactly indicated as xt and arrow yt that means in a particular system once we know what the system is we can say then the system input xt gives us a output yt this is the excitation and this is the response.

So very often we use this type of notation when we have to deal with a particular system and would like to have a variety of inputs and what are the output that to get we use this kind of compact representation to indicate input and output relations of a system. As I said systems are quite diverse in nature and naturally the properties also diverse in nature. We would like to classify the systems depending upon the particular property or characteristic that we have in mind.

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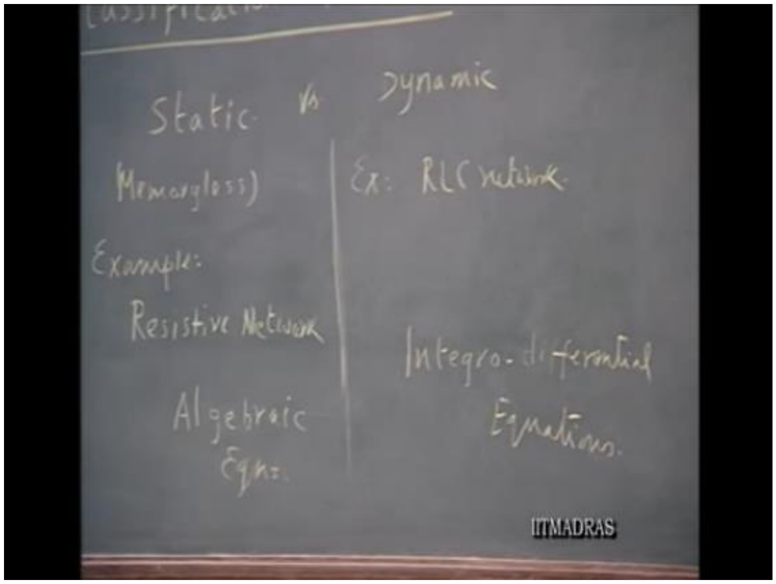

So let us now talk about classification of the systems. One can call classify system as either a statistic system or dynamic system. A static system is 1 which the output depends upon the input at the time and nothing else it does not depend upon what happened in the past.

The past history of the system is immaterial so if you give a particular input the output is dictated by that input nothing else is required. Take for example an electrical resistor the current in that resistor is depends only on the voltage at the particular point of time not that how that voltage is come about not about its rate of change etc but it is depend just on the voltage at the particular time that dictate the current in the resistor.

So if I resist to network is there a one port resist two network then the input voltage is given the current is immediately reduced by magnitude of the voltage at a particular point of time. So static networks are also sometimes called memory less networks or memory less systems example a resistive network where as a dynamic network it is not enough if you know the values of the instantaneous values of the inputs at that time.

You should something more you should know perhaps a **a** kind of summary of what happened in the past in the form. Suppose let us take an RLC network for example if you want to know the response of an RLC network impressed excitation the driving force you should also know what is initial charge in the capacitor, what is the current in the inductor and this is what has come about because the past system the network how whatever excitation it has been applied with and whatever remnants it has left in the system.

So in a dynamic system the response depends not only on the instantaneous values of the inputs but perhaps on the derivatives of the inputs and also the integrals of the input quantities and so on. So it is it doesn't merely depend upon the instantaneous values the rate of change and the inputs the integrals values of the inputs the past history of the input as summarized by the initial conditions are all important in the case of dynamic systems for example an RLC network.

So if you are having an RLC network with given excitation functions its not enough you know the complete solution problems you should also know the initial currents in the inductor and initial charges in the capacitor. So it turns out that when you want to describe a static system the equations govern in the performance are turns out in the algebraic character. Where as since in a dynamic situation you need to take stock of the derivatives the time variation of the various quantities we have integro differentially or an integro differential equations can always be reduce the differential equation but let in general we can say integro differential equation.
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So you have on one hand some differential equations and also you have differential derivative as well as integration of the integral with various quantities and so in general integro differential equation that govern the performs of a dynamic system. A second method of classification of systems to categorize the MAS as a continuous time system or a discrete time system alternatively discrete time.
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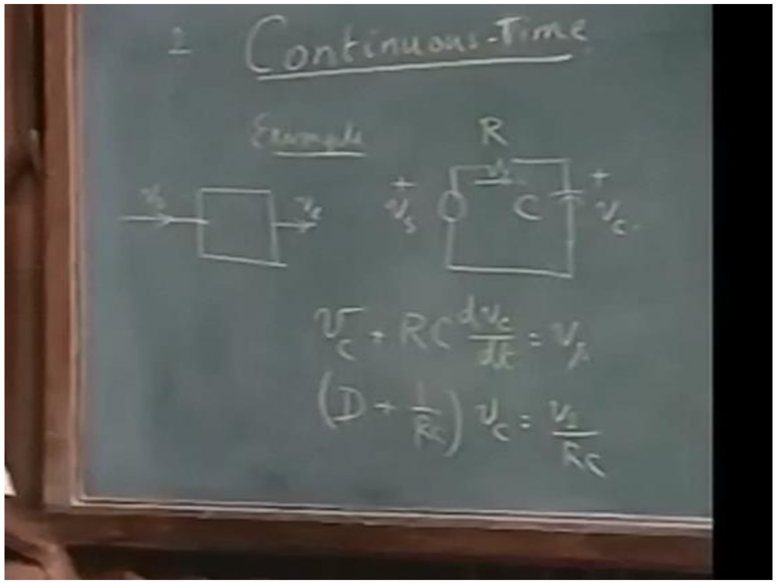

In a continuous time system the input output relations are described are defined for every instant of time on a continuous basis. In other words were interested or we can calculate in principle the variables at every single point of time on the time axis on a continuous basis. Where as in a discrete time system you have this input output relation discrete time system you would have a input and output relation defined at particular discrete points along the time axis not necessarily at every point of time.

We will see the meaning of this more clear fashion as we go along. So, let us talk about a continuous time system an example of continuous time system as an example let us take this RC network. So, we have a source Vs a voltage source we have resistance and capacitance and this is the voltage across the capacitor Vc. So we would like to view this as a system in which Vs is the input quantity and the voltage across the capacity V0 or Vc as the output quantity.

So the input output relation in this case is defined by the following relation after all Vs equals Vc plus the the voltage across the resistance and the voltage across the resistance is r times the current to the resistance and the current to the resistance is CDV and CDT. So R times C dvc by dt is the voltage Vs. So Vc is the output and Vs is the input the there is differential equation governing the input quantity with the output quantity.

So you can put this in a compact fashion as D plus 1 over RC times Vc equals Vs over RC where D is the derivative operator you can instead of D Vc by dt you can write as DVc as a more compact notation which you I am sure you are familiar with this notation. D dividing this entire all terms by RC this what you get D plus 1 over RC Vc equals Vs over RC.

So this is a first order differential equation and this is the input output relation for this. So this is you can solve for this depending upon the Vs that you are having and you can get values of Vc at every instant of time and equations itself is define for every instant of time this is an example of a continuous time system.

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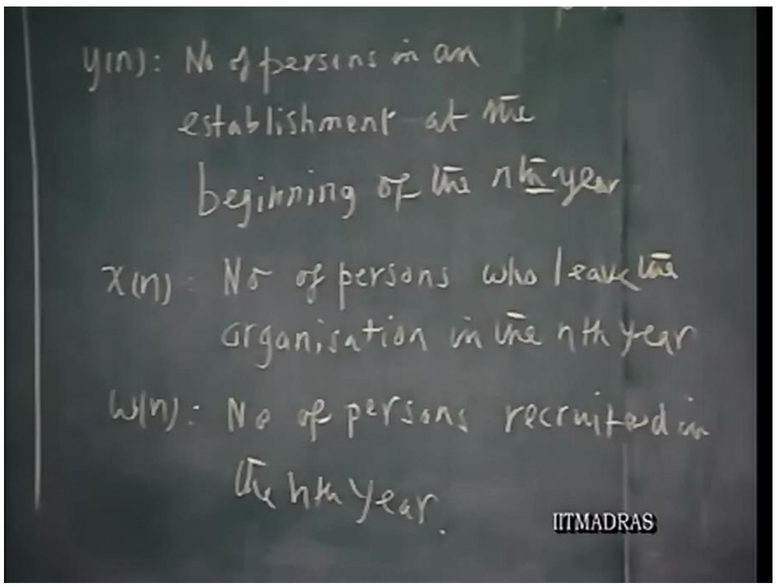

As a discrete time system you would like you have this input output relations described for discrete values along the time axis. So if this is the time axis you might be having equation which are valid only at certain points.

So the time axis may be define in a units of seconds, micro seconds, months, years and the case may be for example I may take this t in years in which case suppose I calculate this 0 1 2 3 4 etc so this is break this up say n n plus 1 etc. I am interested I will have a equation which describes the operation of the system at particular points on the time axis not we don’t care what happen in between 2 and 3 so that is called discrete time system.

As an example let us consider an organization in which yn is the number of persons in the organization in establishment number of person in an establishment at the beginning of the nth year that is ym. Let me take xn as a number of persons who leave the organization in the nth year who left the organization either a retired or left for other jobs or died whatever the reason might be xn is the number of the persons who leave the organization in the nth year.

Let wn is the number of persons recruited you recruits in the nth year then you can clearly see that given these variables which describe the operation of the system the system now we are concern the variables are these we are interested in the number of people employed in the organization.

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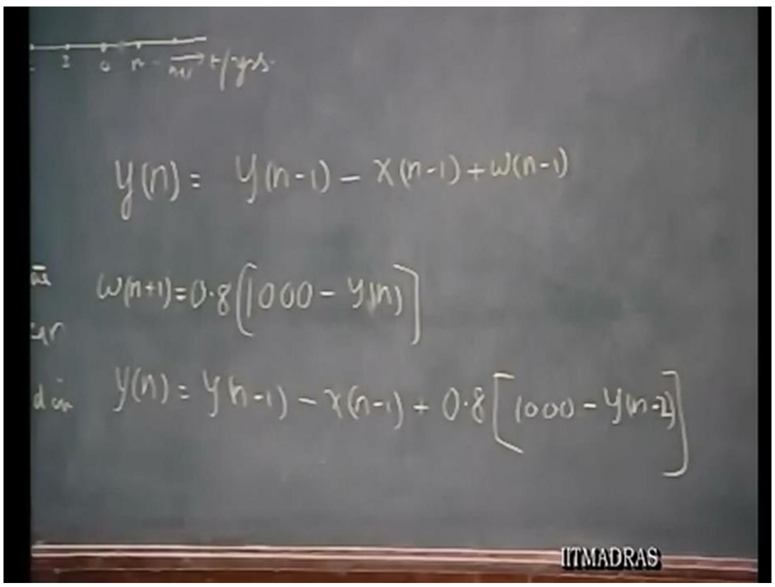

y of n is the number of person at the beginning of the nth year these are the number of persons at the beginning of the previous year and out of these x people x n minus 1 persons have left the organization during that year.

Therefore, so might less by that amount but so many people might have been recruited therefore plus wn minus 1 this is the equation which gives us the number of person in the organization at the beginning of nth year in terms of y n minus 1 x n minus 1 and w n minus 1. Let me further assume that the requirement policy of the organization such that at the beginning of each year they would like to find the vacancies the sanctioned strength let us say thousand therefore thousand minus y n is the number of the vacancies at the beginning of the nth year.

And then they put out an advertisement recruit people and then the recruitment policy is such that it takes about an a year to recruit people and therefore whatever recruitments steps have been taken in the nth year we will take effect only in the next year. So the number of people recruited in the n plus 1nth year is let us say this is the target but all the people who have been recruited may not join or may be their may not be suitable candidate so let us say eighty percent of this target amount is recruited.

So w n plus 1 is point eight and thousand minus yn. So if you substitute now this expression into this you can now write yn equals yn minus 1 minus xn minus 1 plus point eight times wn plus 1 is this so wn minus 1 is point eight times thousand minus yn minus 2 because wn minus 1 this index now is n plus 1 has gone down by 2 steps. Therefore this must also go down by 2 steps that means the person recruited in the n minus 1th year will be based upon the number of people in position at the beginning of n minus 2 second year.

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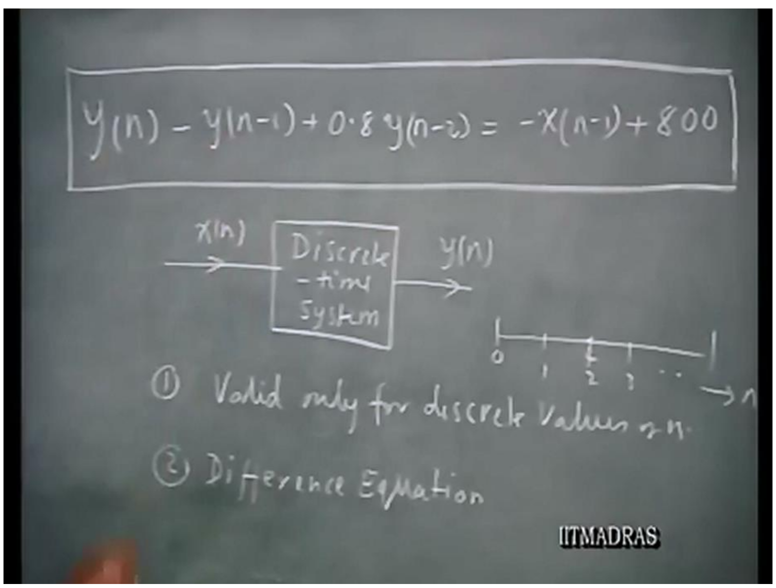

So if you substitute all this you have now an equation which will be the previous equation then leads to yn minus yn minus 1 plus point eight yn minus 2 equals minus of xn minus 1 plus 800 so this is an equation which will enable us to calculate the number of persons in the organization at any year n in the terms of the values of yn at the previous years, at the previous 2 years and also the number of people leaving the organization in the n minus 1th year.

So this can be thought of as discrete time system in which you have the input xn the number of people leaving the organization that is some thing which is unpredictable that is the kind of input that you have for the system. So under the influence of the input we would like to calculate the output of the resultant in the number of people in the organization in the nth year yn. So it can represented by means of a discrete time system which as got xn as the input and yn as the output.

Now we have to keep in mind that these two quantities the input and the output xn yn the have mean in only for integral values of n so n is the number of years in our case 0 1 2 3 and so on and so forth. We cant read any mean in that for non integral values of n this has mean only for n is equals 1 2 3 so on and so on. The distance between successive units in our case happen to be years but in general it could be seconds, minutes or whatever you are having. It is also conventional the most of the cases we take these intervals at regular points along the time axis.

So it could be seconds it could be months it could be days it could be years and so on in our case it happens in the years. So the point to observe is this is valid only for discrete values of n and usually the integral values of n in the appropriate set of units. Now secondly this kind of equation is called a difference equation. In contrast to the differential equation that you come across in the continuous time system.

In discrete time system the equation will be the independent variable takes in discrete values and the equation of the this type is called the difference equation in contrast to differential equation that we come across for continuous time system. So that is the major difference between a continuous time system and a discrete time system and a continuous time system you have at the differential equation coming into operation in the discrete time system you have a difference equation that is important.

Secondly what we would like to know is the order of the differential equation it is the difference between the highest index and the lowest index. So n and n minus 2 these are the this is the dependent variable the difference between these 2 is 2. So in our case is the second order difference equation in this case it could be higher order in the general case. So in the discrete time system the points to note are that the equation is valid for specific integral value of the independent variable m and the independent variable usually is time that's why this is called discrete time system.

But the same methodology is applicable even to situations where the time may not be independent variable for example if you have got a along a line you will like to point out you will like to graduate this at you will like to have an equation which specify the values of some kind of independent variable at along discrete points along the line. The space coordinate can also be an independent variable. Even though systems are refer to a discrete time system because this is a more common type of system you can say discrete system but we call it discrete time system even in that case.

So the two important differences between continuous time system and discrete time system are continuous time system the differential equation well easy comes into play here the difference equation comes into play and the continuous time system the variables are described at a every point and time along the continuous and basis in the discrete time system they are defined only by the discrete values of the independent variable which is usually time and that's why is called t a discrete time system.