Modelling and Simulation of Dynamic Systems

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Lecture - 04
Introduction to Simulation

In this lecture on introduction to simulation and this lecture is part of our course through which you are going through that is modeling and simulation of dynamic systems. Now simulation basically, as the name indicates that we want to do something numerically. But, many times simulation also means trying to find out the behavior of something when it is not actually happening that is, what is the literal meaning of it and this simulation we could do using hardware as well as software also.

Hardware for example, if you have a huge mechanical system is there consisting of large amount of mass spring having very high stiffness likewise, damper. So, we can see if you want to do certain parametric study for this type of system then what we have to do is that it will be difficult to make any variations there.

So, what simulation through hardware what do I mean that what people used to do is that they find out a electrical equivalent of this mechanical system where is consist of resistor inductor and capacitor and then they do the manipulation in equivalent electrical system, in order to do the parametric study but, here the lecture which I am going to talk to you other than experimental simulation what you would like to be doing is that, we will be talking about the numerical simulation.

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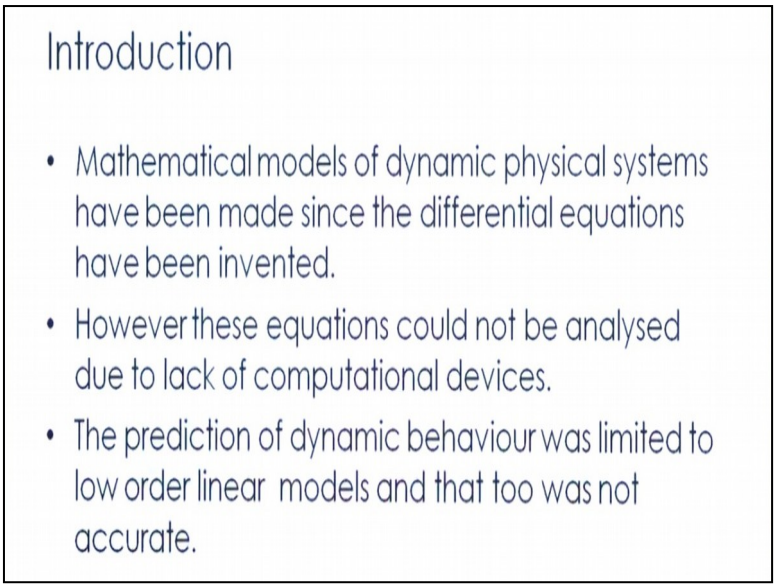

So, mathematical models of dynamic physical systems have been made. Since the differential equations have been invented actually a great boon for the dynamic modeling or mathematical modeling of the dynamic system. Now, earlier these equations could not be analyzed due to lack of computational devices already computers was not that powerful. So, it was difficult to analyze these equations using the existing computational devices that time.

The prediction of dynamic behavior was limited to low order linear models and that too was not accurate. Because, when you create a linear model naturally you make many assumptions in order to convert the real physical problem into real physical problem which is always a non linear problem, and when you want to convert non linear problem into the linear problem you make many assumptions and because as that these models were not very accurate.

Now, coming back to the definition of simulation, simulation basically refers to the procedure of solving the equations that resulted from the model development.

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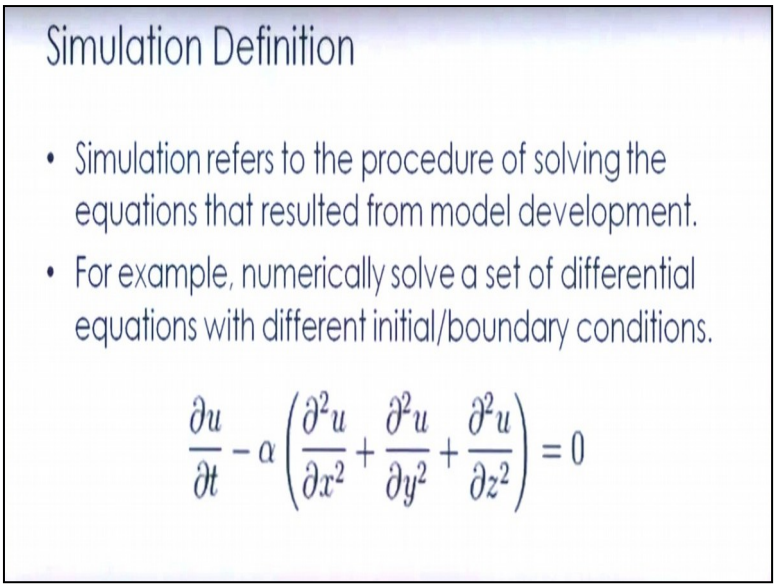

So when we have physical model or mathematical model of the physical system then we tried to solve the equations, which have come after creating a model of the system. Now the question is how we solve those equations are mathematical models. So simulation basically refers to the procedure of solving the equations that resulted from the model development. I can just cite one example numerically solve a set of differential equations with different initial and boundary conditions.

So, we may have the different initial and different boundary conditions and for those differential boundary conditions my intention could be solving of this model this is what is called simulation.

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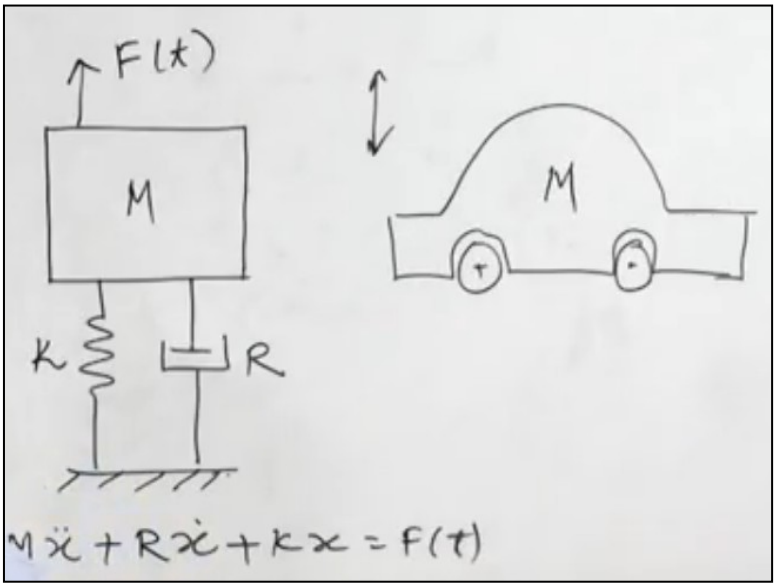

Now, before I move for this we will be talking a lot in this lecture by taking a simple example of spring mass damper system and of course this model represents the many physical systems.

For example, I have taken in my earlier lectures I talked about modeling of this water tank and we could always make this type of model for a system that, if I have got a simple car and I want to mathematically model it then the equivalent suspension system whatever suspension system this system has I can represent that suspension system using spring and damper and the model of mass of the car I can represent by a lumped mass.

So, from here I can try to simulate this is the equation or if I am interested in knowing the behavior of this car for the vertical motion this way so this is the m and we have the suspension system been represented by the spring and damper system.

So, the expression for this is supposed is subjected to certain excitation ft then the system equation could be m x double dot + k the let me derived system. Later so plus I can write r x dot + k x is equal to f t. So the simulation here basically means that I want to solve this equation this differential equation and when it is subjected to different type of initial or boundary conditions.

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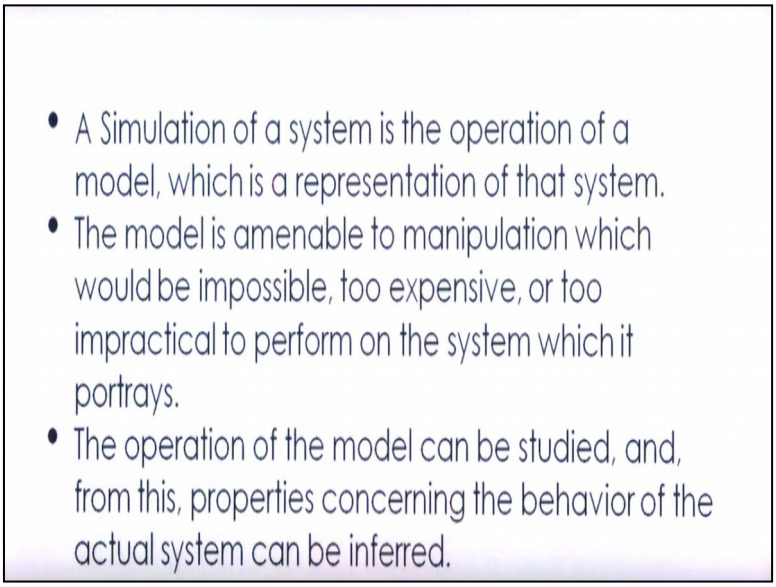

Now a simulation of a system is the operation of a model which is representation of that system. So, we are basically operating on the model and that model actually represents your

physical system. Now the model is amendable to manipulation which would be impossible too expensive or too impractical to perform on the system which it portrays.

So for example, I want to see the performance of the different stiffness's on the vertical motion of the car here then virtually if I am doing it on the real physical system I need to replace the suspension system and then I want to see the vertical motion. here and again apart from those hardware I also, request some device measurement devices measuring the vertical motion.

But, in mathematical modeling and simulation we can change this stiffness and damping values and we can see the behavior. So this is what I mean by the model is amendable to manipulation. The operation of the model can be studied from these properties concerning the behavior of the actual system can be inferred.

Now, let see the simulation technique has such now as I was telling you for a giving mathematical model sometimes it is possible to derive information about the system by analytical means. Now, as we will be seeing the difference between analytical way of solving the problem and simulating the problem. So, but this analytical method or analytical way of solving the problem is always not possible.

So, whenever it is possible of course we tried to go for the analytical method. Because, it gives us the general solution where as the numerical method gives us the solution for the specific case that is for the specific set of values and that too, for the specific set of initial conditions.

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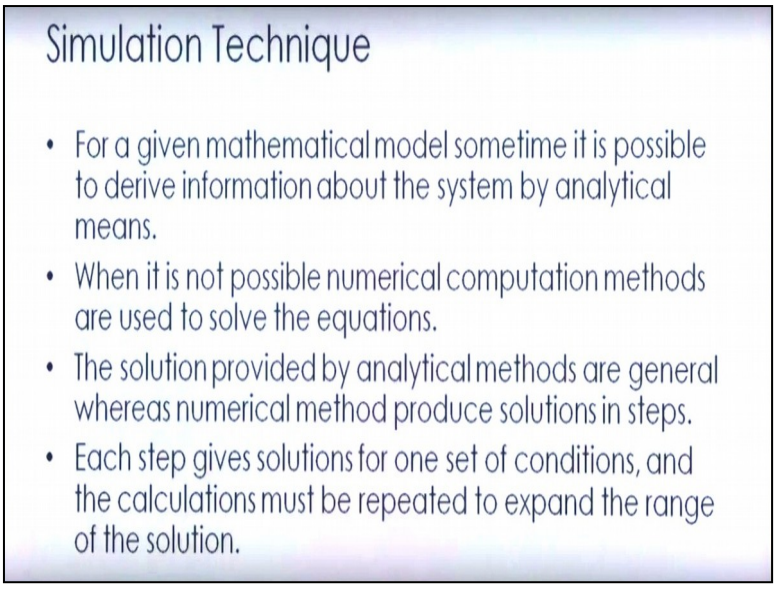

So when it is not possible, numerical computation methods are used to solve the equations. So as I said if your systems system becomes complicated and it is not possible to derive the analytical expression and analytical solution for the given system then we resolve to the numerical computational technique. In order to simulate or solve the equation, the solution provided by the analytical methods are general.

I just explained you, whereas the numerical method produce simulate solution in steps. So, the analytical method gives you the general solution where as simulation numerical methods produce the solution in the step. Each step gives solutions for one set of conditions and the calculations must be repeated to expand the range of the solution. So this is what asked to be done in case of the numerical method.

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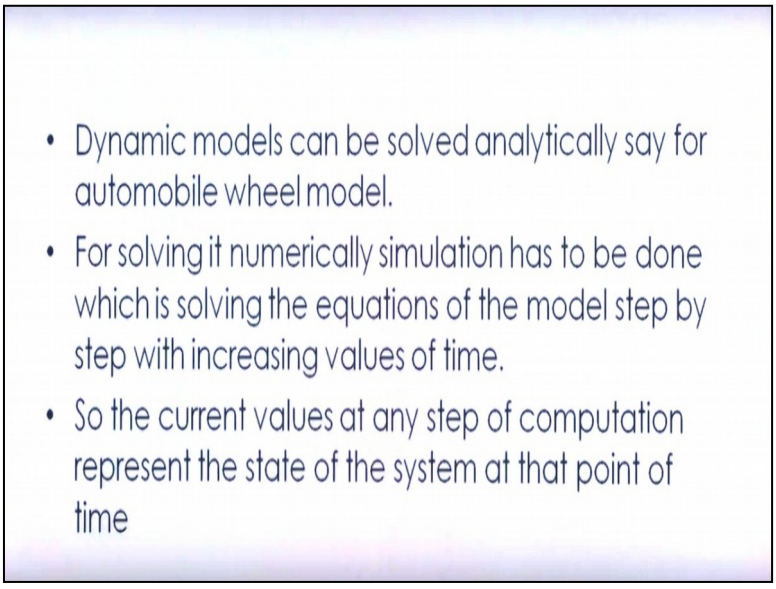

Dynamic models which of course are our principal component of our course here so, the dynamic model can be solved analytically for the automobile wheel models. So, this model which I just talk to you on this model we can solve is simplified model. The simply model of it this can be solved analytically and of course if, I want to solve this model numerically the simulation has to be done which is solving the equation of the model step by step with increasing values of time.

So, we solve the model step by step with increasing value of time and this is what we call it as simulation. Now, so the current values at any step of computation represent the state of the system at that point of time, so this is what we mean by the current value it basically states the state of that system at that particular instant of time. Now, there is the term it find it literature and that term is the system simulation.

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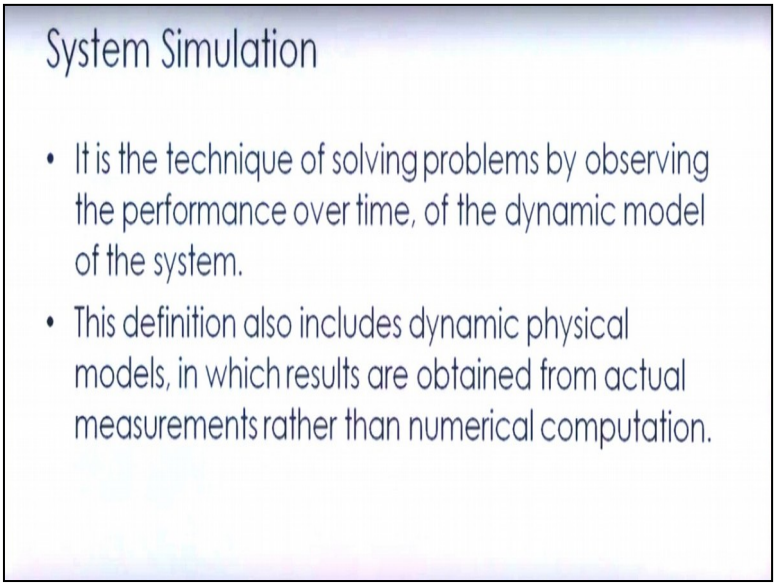

System simulation basically it is a technique of solving problems by observing the performance over time of the dynamic model of the system. So, if we want to solve a certain problem then we observe the performance of over the time of the system of the dynamic model of the system and that is how we solve that problem. Now, this definition also includes dynamic physical model in which results are obtained from the tactical actual measurements rather than numerical computation.

This I talk to you about this during my introduction for this particular lecture. Where I talk to you about the actual physical measurements from the dynamic physical model. So, that is there. Now, let see oh what is the how do we compare, or how do we see the advantage and

disadvantages of the simulation and the analytical methods. So, as I said the analytical method gives us the general solution.

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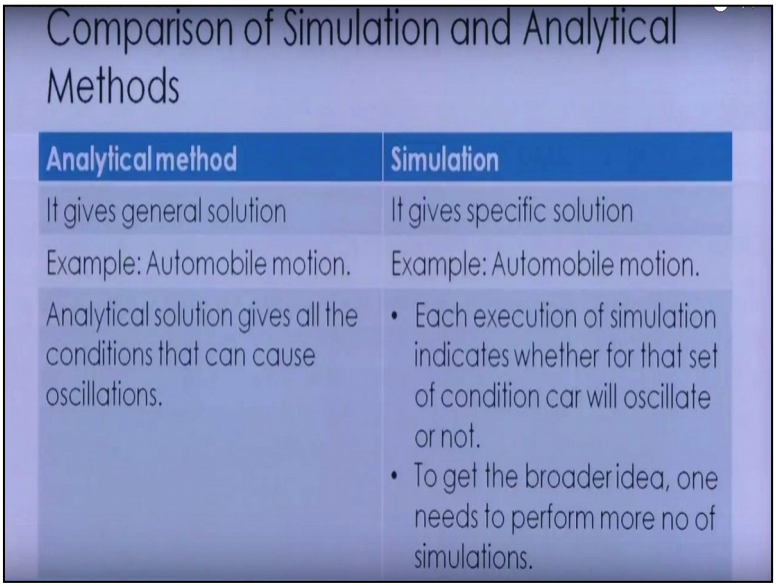

So, from the general solution we can infer about the behavior of the systems whereas, the simulation results gives us the if specific solution for a if specific set of input parameters and the initial conditions. So, if I take the example of the same automobile motion which I just discussed an analytical solution gives all the conditions that can cause oscillations.

So, we can if I talked about oscillatory behavior of this particular equation then the analytical solution gives all the condition that can cause the oscillations. Now, if I talk about the same example solving the same example that is the automobile motion through simulation then here we see that each execution of simulation indicates whether for that set of condition the car will oscillate or not.

So, whatever numerical values you have chosen and whatever your conditions are their inputs where are their input parameters are there so that for each execution of simulation you will get to know whether the car will oscillate or not, and of course if, you want to have a broader idea about the behavior of the automobile motion naturally you need to perform the number of simulations. So you need to go through more number of simulations and that is what minute times we call it as the numerical experimentation.

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Analytical method	Simulation
• This is preferable when solution is sought for some maximising condition. • A single mathematical solution can give such a condition.	• Here many simulations runs are needed to find a maximum value. • However, we cannot tell whether it is local or global maximum.
Analytical results may have complex series or integrals which needs extensive evaluation.	Simulation is quicker and easy way of deriving results.

Carrying all the simulations many times and that is what we call it as the numerical experimentation. These analytical methods are preferable when solution is sought for some maximizing condition so if I want solutions for some maximizing conditions then we prefer this analytical method. But, but here and this maximizing condition we can get by a single mathematical solution give can give as such maximizing condition.

But, if I talk about simulation here you require the many simulation runs are needed to find a maximum value, and here we cannot tell whether it is local or global maximum. What do you mean by local and global maximum? I hope all of you know that, if some behavior is like this you have some parameter and some time your behavior is like this and some behavior is like this.

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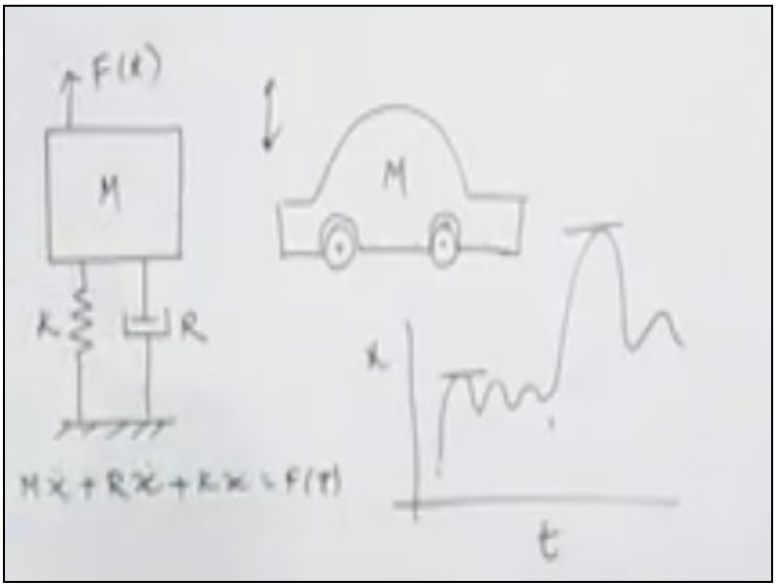

So, something is in this range this we call it as local maximum in this range this is the locally maximum value where here this is the global maximum so that thing we cannot tell we cannot find out we cannot tell whether it is a local are global maximum using the numerical simulation. Analytical results may have complex series of integrals which needs extensive evaluation.

In fact, this is, one of the big drawback of analytical results that, it may have complex series are integrals and those integral are complex series needs extensive evaluation. But, you can see that we get the simulation results is specially with powerful computation tools and the powerful software which carry out the numerical integrations very easily as well as they are many vitalizing tools such as animation tools.

This simulations have become one of the preferred method of finding out are looking at the behavior of the system. So, experimental nature of simulation so as I was talking to you the numerical experimentation which is we call it that if, we go for the many number of runs. we go for the many number of runs of simulation.

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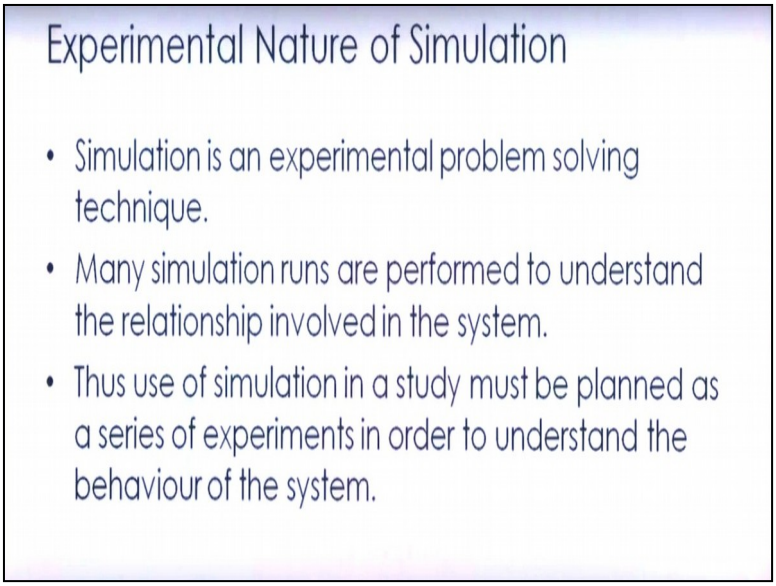

So, this simulation is an experimental problem solving technique basically so this is what we call it as the numerical experimentation many simulation runs are performed to understand the relationship involved in the system. We need to perform the many number of simulations in under to understand the relationship in the system. Thus, use of simulation in a is study must be planned, as a series of experiments in order to understand the behavior of the system.

If, you are not going to plan, or if you are not planned your simulation study then you will be randomly doing something, and you may not be able to the reach to any conclusions out of the simulation results which you are getting. So, one need to understand and one need to plan about the simulation study.

As I use the series of experiment in order to understand the behavior of the system, there are principally two types of simulation which we usually come across one is the continuous simulation and another is the discrete even simulation, will discuss details of this type of system simulation method so that continuous simulation basically is used for continuous system.

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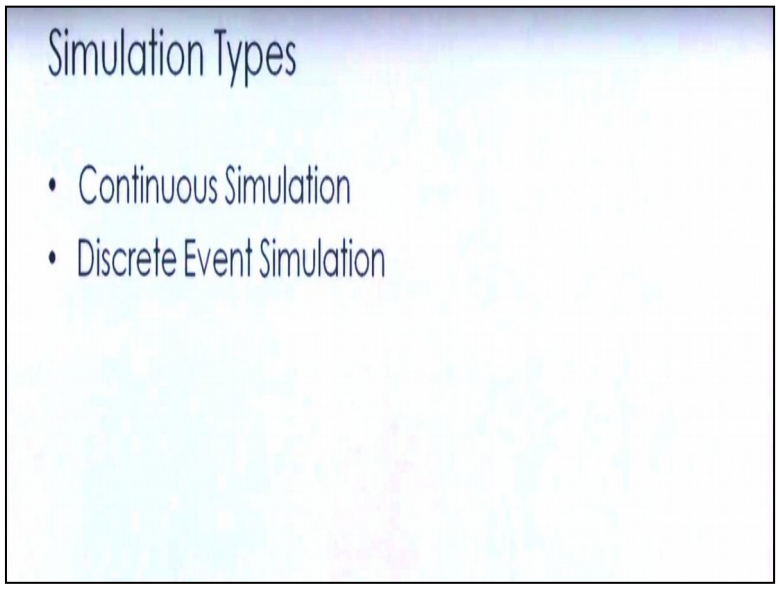

So, if you are modeling a continuous system then we used the continuous simulation I have discussed these things some of these things in my earlier lectures where we talked about the models.

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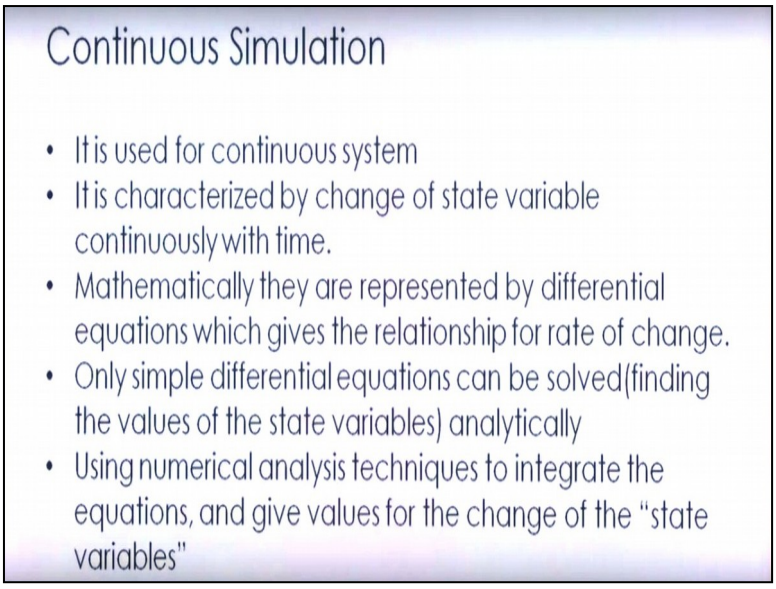

Now, it is characterized by change of state variable continuously with time. there are some details available about state variable in fact, one of my lecture is only on the state variable formulation where you would be finding out the details what all the state variable formulation but, for the moment you just understand that all state variables or basically variables through which you can study the behavior of the system.

So, that is mathematically they are represented by differential equations that is the continuous system. They are represented by the differential equations, which gives the relationship for the rate of change, and all the simple differential equation can be solved finding the values of the state variable analytically. So, that is what I said using numerical analysis techniques to integrate the equation and give values of the change of the state of variable.

So, we can use the numerical analysis technique to integrate the equations and give the values for the change of state of the variable. So, that can be done. Now, coming back to the discrete event simulation; this simulation method is used for the discrete systems.

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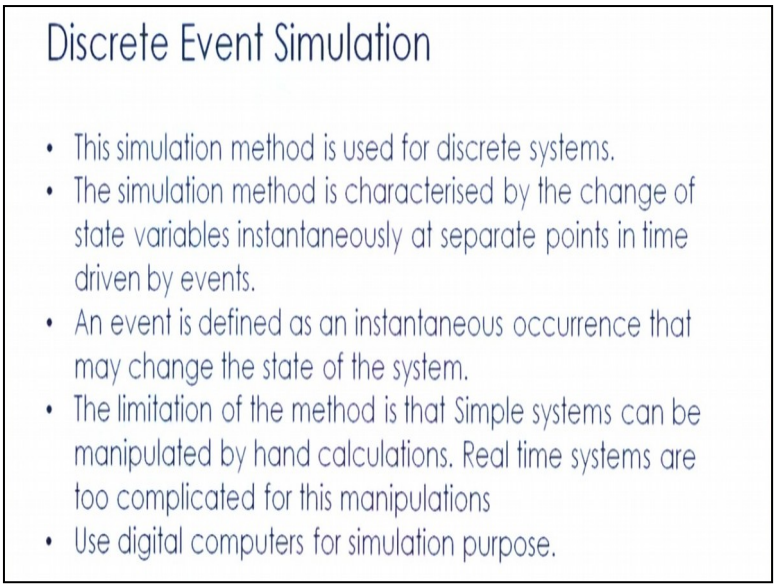

This simulation method is characterized by the change of is state variables instantly instantaneously at separate points in time driven by events, and an event is different defined as an instantaneous occurrence that may change the state of the system. The limitation of the method is that, simple systems can be manipulated by hand calculations. Real time systems are too complicated for this manipulations. Of course, we can use the digital computers for the simulation purpose.

Now, so if you want to simulate something what should be our sequence of events?. So, the simulation process basically consist of first, what you do is that you have to describe the problem then, after you describe problem, you have to give the definition of the problems by definition of the model.

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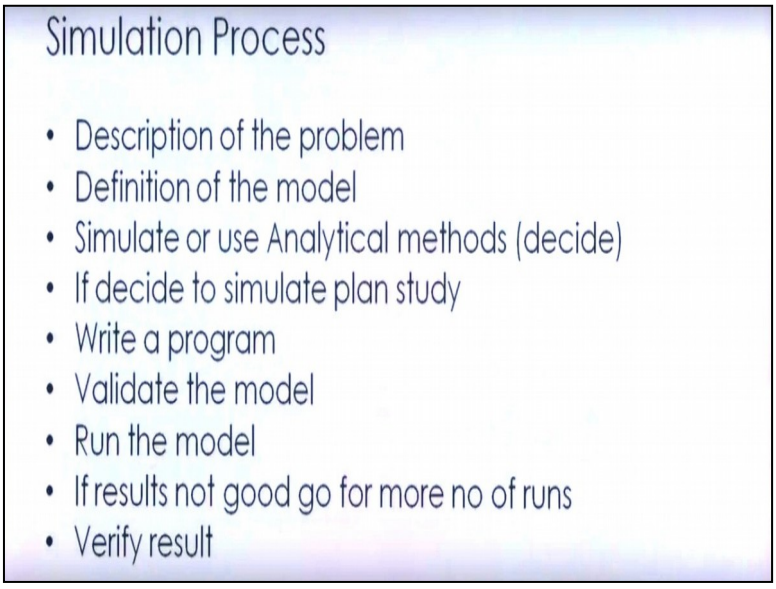

So, from description of the problem actually you are formulating your model and you give the definition of the model and once your model is ready then you desire whether you want go for simulation, or you go for the analytical methods what method you want to solve your model that decision you have to take. Then, if you desire to simulate, you have to plan your study. What all simulation study you are going to do, after you have plan these things then you write a program.

Now, these days you can write this program in any of the language c plus mat lab or mathematical any language you can, then you have to well develop that model. You have to run the model, and if the result is not good then you have to go for more number of runs and then finally verify the results. So this is how the simulation process consists of. Now, there are different simulation software's available in the market which you can take help in your simulation exercise.

So, there could there is a classification of simulation software it could be a general purpose of software or, it could be an application oriented software and the modeling approaches could be event scheduling approach or the process approach.

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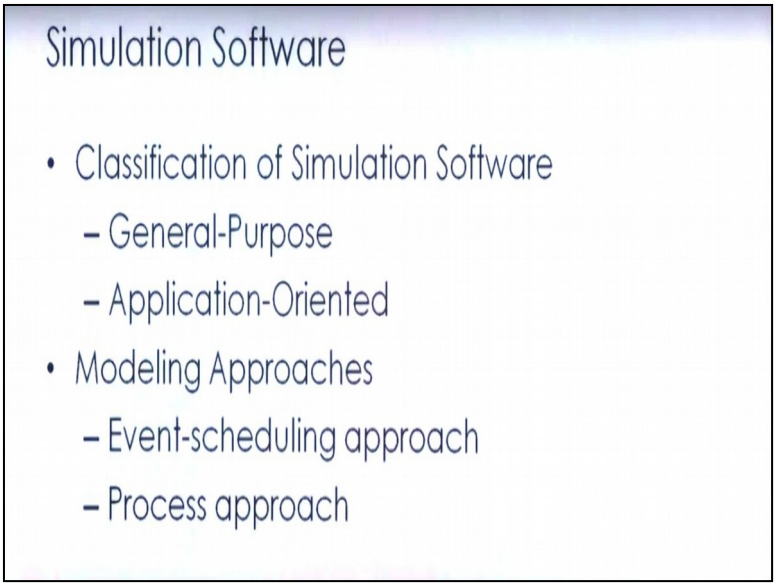

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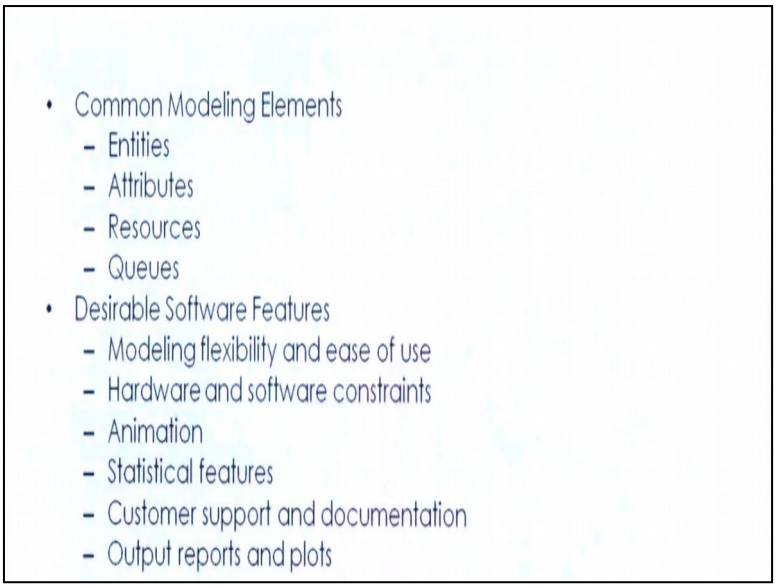

Common modeling elements should be a entities attributes resources. Queues and here are all the desirable software features, these are which most people are interested in that, if you should have the modeling flexibility and ease of use hardware and software constraints. Animation, I talk to a little idea animation basically, gives us the actual behavior actually the depicting as if the real system is working and these animation results are usually prepared through the simulation that which is available.

So, this animation is basically the virtualization of your results what you can that better way of virtualization of the results then, if some statistical features are there in your software it is very good customer support and documentation and output reports and the plots. So, these are some of the desirable software features we should be available with the simulation software, there are again certain advantage and disadvantages of simulation.

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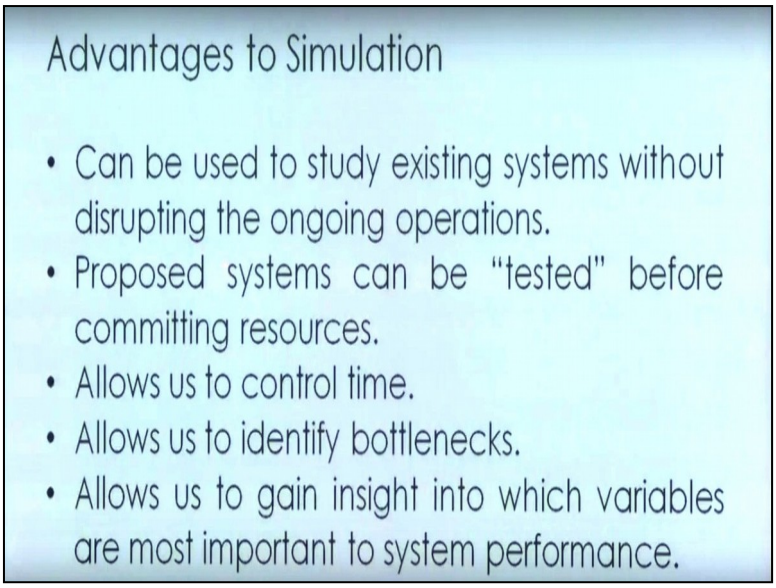

Advantage, if I look at it can be used to study existing systems without disrupting the ongoing operations. The proposed systems can be tested before committing resources allows us to control time, allows us to identify the bottlenecks. You can identify to go inside the model, which variables are most important to the system performance and if, you look at the disadvantage of simulation or see the building of model it is a art, as well as science.

So, first of all you must be comfortable in creating the model of the system.

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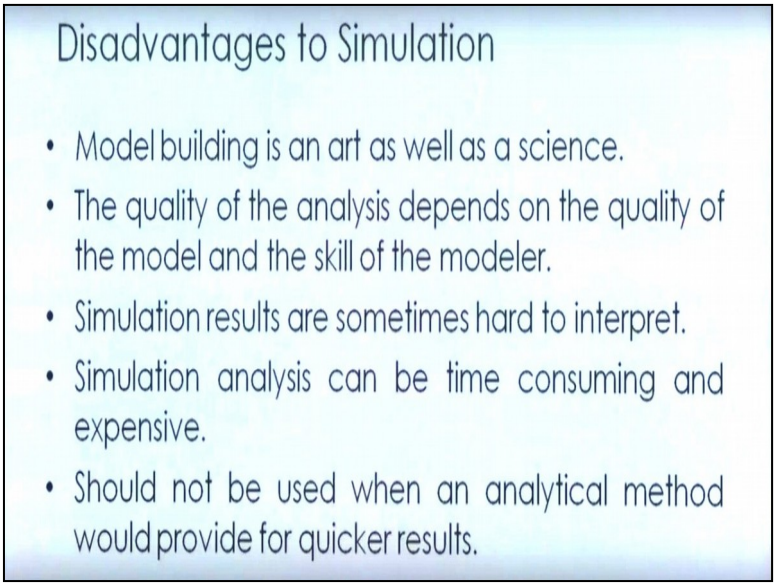

The quality of analysis depends on the quality of the model and the skill of the modeler. Simulation results are sometimes hard to interpret that is also, one should have the understanding of the actual behavior of the system. Then, from that understanding you can interpret the system simulation analysis; can be time consuming and expensive also, and it

should not be used when an analytical method would provide the quicker results. So that is what we should do.

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If, you want to further read about this chapter you can refer the system simulation book by Garden. Thank you.