TALE – 2 Course Design and Instruction of Engineering Courses
Prof. N. J. Rao
Department of Electronic Systems Engineering
Indian Institute of Science, Bengaluru

Lecture – 32
Simulation Approach to Instruction

Greetings and welcome to Module 3 Unit 14, which is on Simulation Approach to Instruction.

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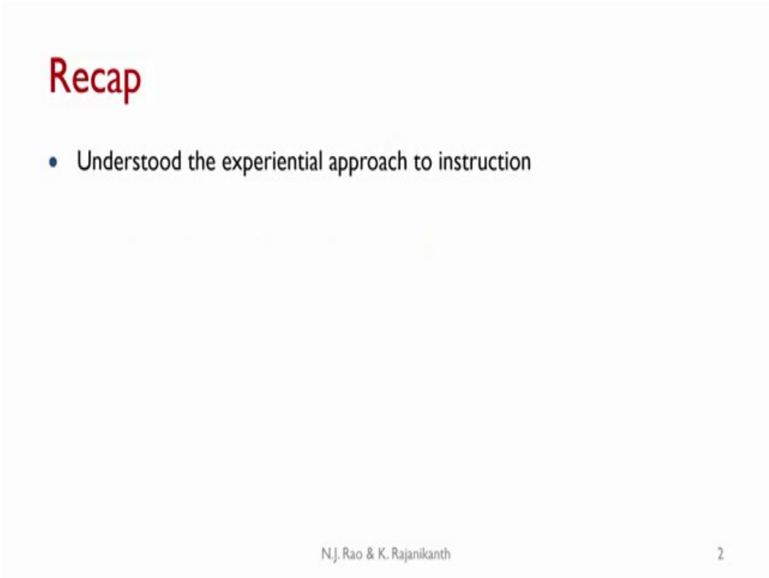

In the earlier unit, we understood the experiential approach to instruction.

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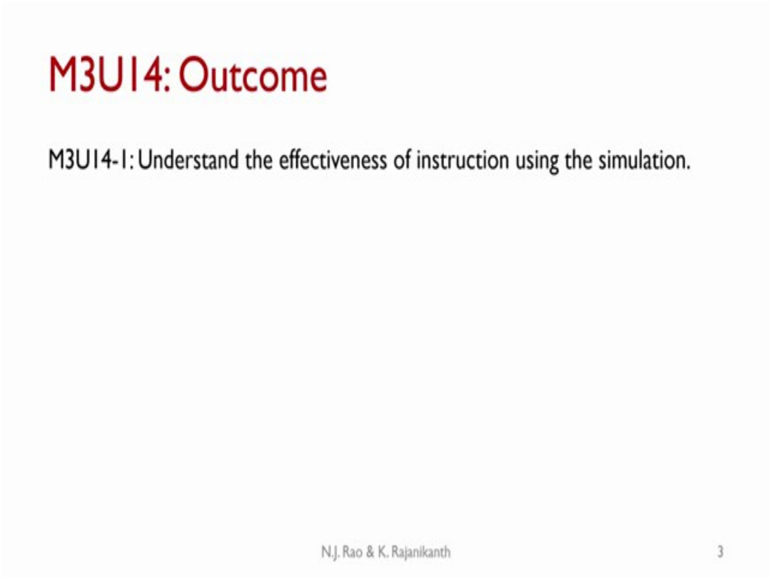

The goal of this unit is to understand the effectiveness of instruction using simulation. How do I use the simulation as a method or a mechanism by which I can make my instruction more effective?

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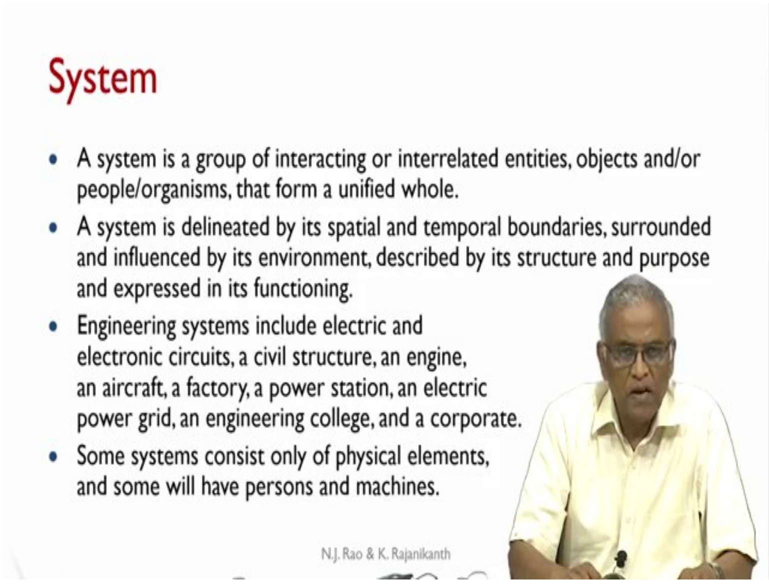

Before we talk about simulation, we need to introduce the word 'system' with which all of you are familiar. But we formally define it here; a system is a group of interacting or interrelated entities, objects, and/or people or organisms that form a unified whole. There are endless definitions of a system, and most of them do capture all the features. What are these features? There are a set of some objects or entities.

An entity can be some physical object. Persons and/or organisms can also be entities involved (if we are talking ecological system; obviously, organisms will also come into the picture.) They are not a mere collection of entities, but they are interrelated for a purpose. For example, four people that are associated with this recording are briefly interrelated to one another other, because one is making notes about what is happening, another operating the camera the other one is combining the inputs that come from two streams and recording. This is a kind of system where all the elements, namely the four persons, are interrelated, and the purpose is to record. This explains one definition of system.

A system is delineated by its spatial and temporal boundaries, surrounded and influenced by its environment, described by its structure and purpose and expressed in its functioning. All these elements apply to the example that was given above. It is delineated by spatial and temporal boundaries. The spatial boundary is the room where it is being presented, and the other one is the control room, and the temporal boundary is the whole thing that is organized to happen within a specific time period, about 30 to 45 minutes. Whatever we do is surrounded and influenced by its environment, the kind of room, the lighting, kind of furniture, how we have access to the computer and so on.

There are a structure and purpose expressed in its functioning; that means all the concerned people agree to a particular relationship among them about the role, and everyone shares the same purpose. The purpose is to record a lecture on a particular topic and to make it a part of a course. That is how one can consider the system.

When it comes to engineering systems, they include any kind of units like electric or electronics circuits, a civil structure, an engine, an aircraft, a factory, a power station, an electric power grid, an engineering college and a corporate are all engineering systems.) Some systems consist only of physical elements, while some will have persons and machines also.

For example. I can look at an electronic circuit - the role of a person is to understand or analyze it, but he is not part of this system. Whereas, if you talk about an engineering college - an engineering college has a whole lot of technology, rooms, computers, some rules and so on. Then the people in that include administrators, the faculty, the students all interact with each other. So, if you want one can consider engineering college as an engineering system its needs to be modeled accordingly. There are different modeling methods available for such systems.

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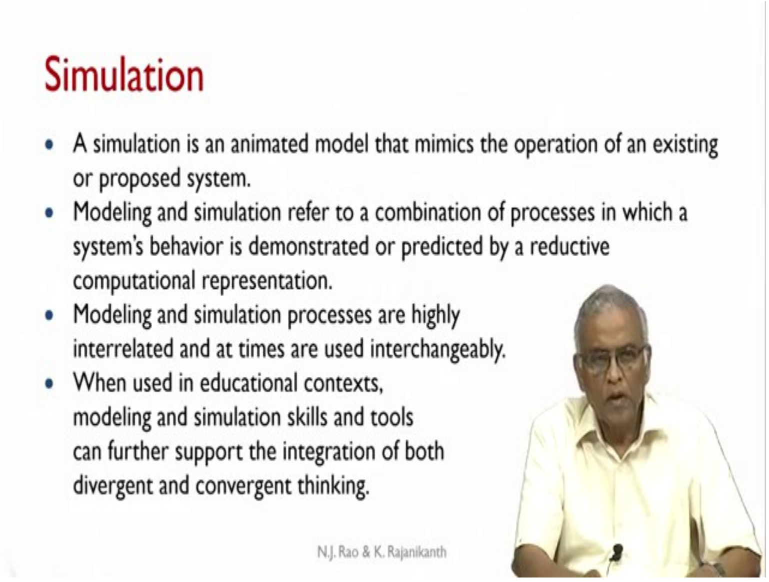

Simulation: A simulation is an animated model that mimics the operation of an existing or proposed system. I need to create a model, and then I will make the model simulate it so that the operation of an existing system is mimicked. If you want to demonstrate how an electronic circuit. I mimic the operation of an existing circuit, for that I require a model of the elements of the circuit. Another example, I want to create a new building, and it is a proposed system rather than an existing system.

Modeling and simulation refer to a combination of processes in which a system's behavior is demonstrated or predicted by a reductive computational representation. When I want to simulate something I need to model - I need to model all the elements and their interconnections.

We have to agree with the kind of modeling that done, and then only we simulate it. When we simulate it, we may or may not be satisfied with the kind of output that we get, and when we review the models that we used for some of the components or elements, we may find them unsatisfactory; we go back and readjust their models. The modeling and simulation processes are highly interrelated and at times, are used interchangeably.

I can refer to the entire simulation as a way of modeling systems. When we use it in an educational context - modeling and simulation skills and tools can further support the integration of both what we call divergent and convergent thinking, which we have explored earlier. That is when we are trying to come to a solution that is convergent thinking, and when we want to explore possibilities, we use simulation for divergent thinking.

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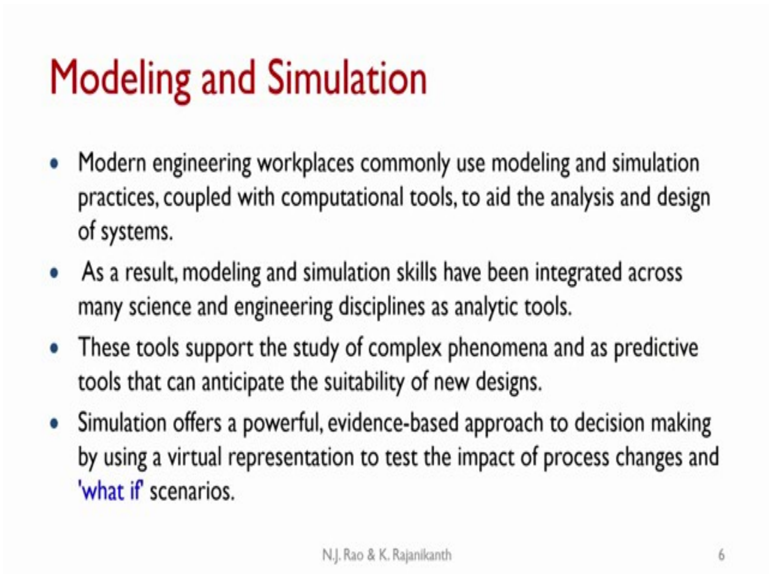

Modern engineering workplaces, where graduates are going to work, use modeling and simulation practices coupled with computational tools to aid the analysis and design of systems.

For example, if engineering graduates from electronics discipline work in a company that is supposed to design a chip (IC - integrated circuit), then they model electronically, (there is nothing like breadboarding these days) and do the simulation. A whole bunch of models of components used in a circuit is available in the component library. Depending on the function that is required, draw the components from the library and put them on the screen and then start interconnecting them using something similar to a Spice program.

The kind of model that you choose depends on the kind of functionality that you want. Sometimes the circuits are so complicated; one simulation run might take a half a day even with the powerful computer. The primary method of designing an integrated circuit is through simulation. Different people may be responsible for different parts of the circuit, as well. It has to be pieced all together.

As a result of modeling and simulation skills have been integrated across many science and engineering disciplines as analytical tools; that means, the way you use those models to put elements together and simulate is now a required skill for all graduates. These tools support the study of complex phenomena, and as predictive tools, they can anticipate the suitability of a new design. For example, if I need to design a circuit, before the first prototype fabrication, investigate the suitability of the design through simulation.

So, simulation today is the most effective, offers a convincing evidence-based approach to decision making, and using virtual representation to test the impact of process changes and mainly 'what if' scenario. If I change this parameter this way, what happens? Am I too close to some critical values? How far should I go? All that can be investigated through simulation and the more number of parameters that you have, the more time you have to spend in simulation; collect all the results and interpret which is the best set of parameters that you need to implement.

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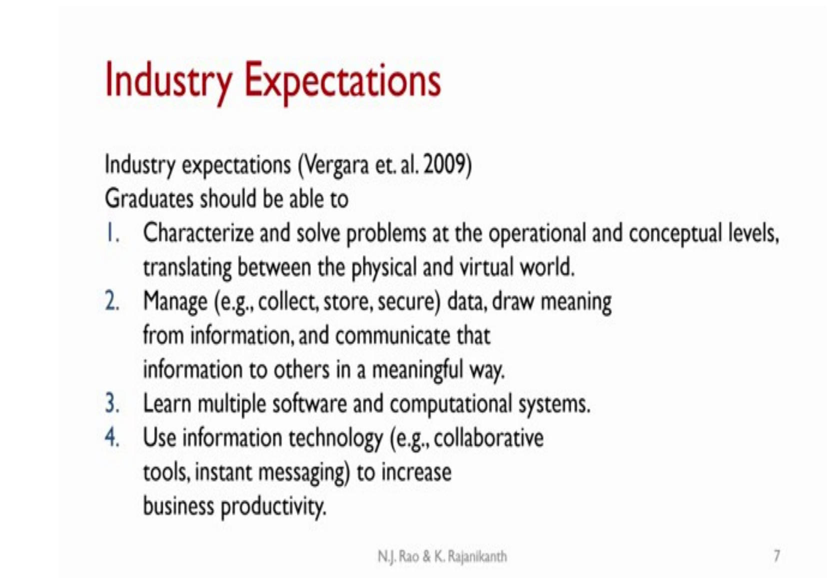

A study was conducted on what the industry is expecting from graduates with regard to modeling and simulation. These are the words used by that committee, "the graduate should be able to characterize and solve problems at the operational and conceptual level.” Please note that it is operational as well as conceptual levels - translating between the physical and virtual worlds.

I should be able to create a virtual world; if I am designing a circuit, my circuit is now a Spice program, and the physical world will be the final circuit when I get the prototype made from an agency that puts the circuit together.

When I simulate, I will collect the data; the data may be available in several forms, I should be able to draw meaning from that information. and communicate that information to others in a meaningful way. This is one of the requirements of the industry.

Learn multiple software and computational systems. A graduate should know to deal with different software tools that are used for different kinds of elements or products. Use information technology - there are collaborative tools with instant messaging to increase business productivity. These are the statements made by industry experts. But how do I translate into what I need to do during the 4 years of engineering program?

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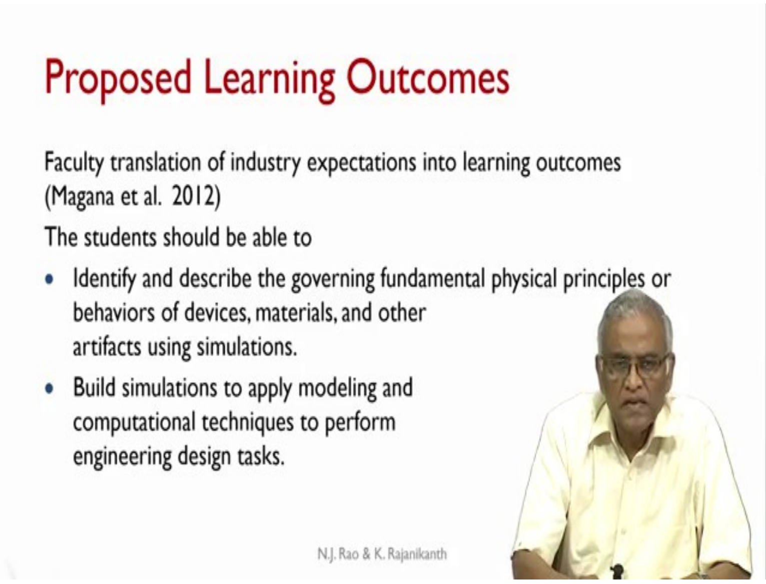

A large number of faculties were asked on how do they translate the industry expectations into learning outcomes (because we are all talking about the outcome based education so, they have to be translated into learning outcomes?) A few people got together and they said the student should be able to identify and describe governing fundamental physical principles or behaviors of devices materials and other artifacts using simulations. (I think all the words do make direct sense to teachers of any engineering course)

Build simulations to apply modeling and computational techniques to perform engineering design tasks. One should be able to describe the principles and behaviors of devices and then using simulation, interconnect them, and using computational techniques to perform actually engineering design. These are translated into learning outcomes by the faculty. You can slightly re-word them to suit your convenience, but this is the aim of the simulation approach to instruction.

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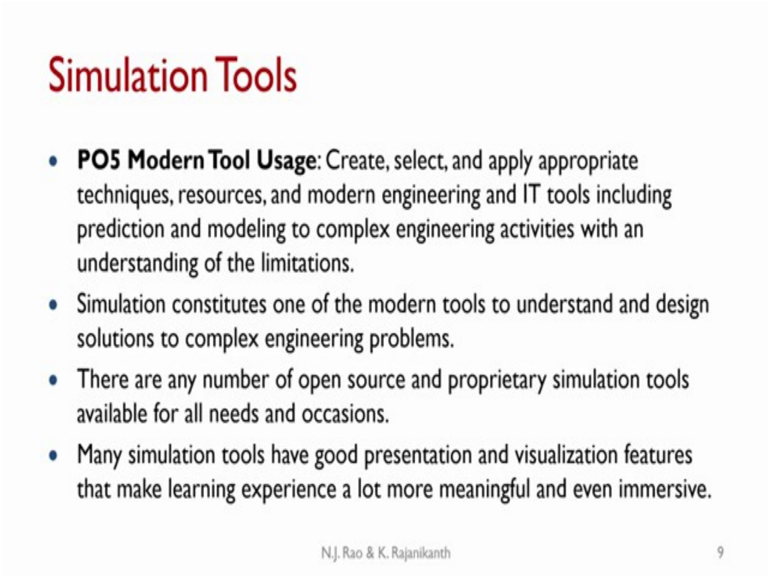

If you look at the program outcome 5 as given by NBA (which is similar to what even ABET says) regarding modern tool usage: Create, Select and Apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations. There are many elements in this; obviously, every activity cannot address all the elements.

Here we are neither creating nor selecting, but you are just applying an appropriate technique, a simulation tool that is used to model and predict the behavior of some engineering system.

To that extent, simulation constitutes one of the modern tools to understand and design solutions to complex engineering problems. The solution may be by trial and error, replacement of one component by another, or re-create the models of the elements, and so on.

There is any number of open source and proprietary simulation tools available for all needs and occasions. I am sure that presently, many of the engineering colleges do use some simulation tools, MATLAB, SPICE, and so on. Many simulation tools have excellent presentation and visualization features, as well. Some of the early ones did not have this, but present-day available simulation tools have excellent visualization features; that means, the final output can be presented in a very user-friendly way so that what is happening in this system is made more explicit.

The simulation can make the learning experience a lot more meaningful and even immersive in the sense that you are part of the virtual world that is created.

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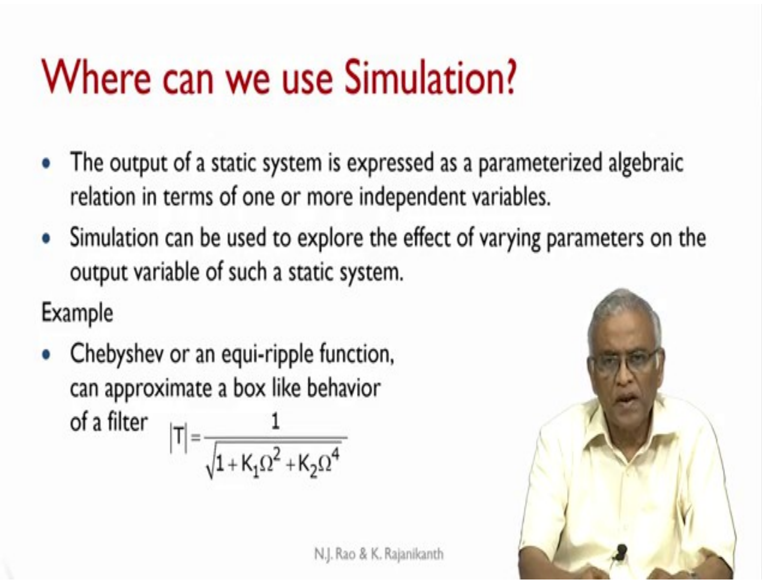

Where can we use simulation? Let us say the output of a static system, which is expressed as a parameterized algebraic relation in terms of one or more independent variables. If you consider system is a kind of a box, you have some inputs and one output, and the relationship is tractable. Sometimes you can have a closed-form solution. But what we want to do is to keep changing the parameters and see what happens; how does it look like; unless I get in some kind of a graphic output I may not be able to appreciate the effect of changing parameters.

Let us take a simple example; a Chebyshev or equi-ripple function can approximate a box-like behavior of a filter. A filter rejects components of the input signal which belong to a specific range of frequencies and accepts only the signal that is part of an identified band. The magnitude of the output is presented in this as a simple equation. It is a second-order function because you have the square root, omega is the input variable. and K1 and K2 are two parameters.

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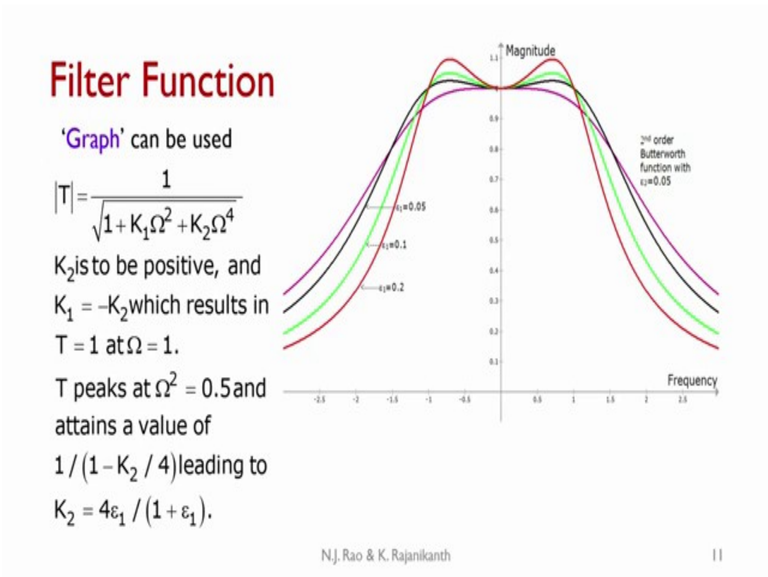

Let us assume K2 is to be positive and K1 = - K2; that means, you need to look at only one parameter and which should result in T equal to 1, at ω equal to 1. and T peaks at specific values within the passband. The relationship is expressed in terms of ε. ε1 is the maximum magnitude in the passband. I specify what should be this maximum. That is stated as epsilon, and I compute what K2 is for different epsilons. Once I compute K2, K1 is automatically decided.

I have a situation where K2 is equal to -K1. If you take a simple open-source tool called 'Graph' which can plot the output for different epsilons. I can see the characteristic I am interested, which is the rate at which the output falls from 1. As you can see, the faster it falls higher the ripple in the passband. Like this, I can make sense when I look at the output in this graphical form. This is the most elementary type of simulation that we can think of. This function I can replace it with anything and plot.

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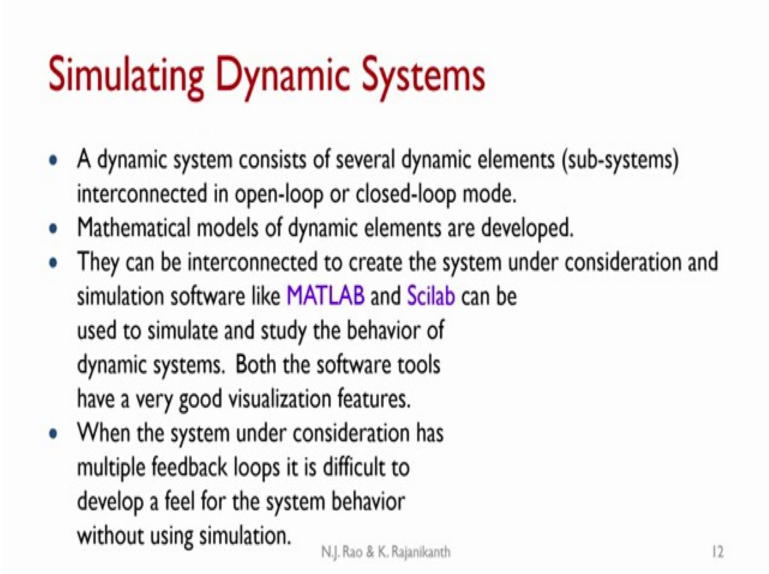

Let us look at the next level, and practically all engineering systems are dynamic in nature. A dynamic system consists of several dynamic elements or subsystems interconnected in open-loop or closed-loop mode. That means I can consider several boxes that are interconnected, and each box is an element, sometimes a static element or a dynamic element. Mathematical models of all the dynamic elements are developed first.

Usually, a dynamic element can be described as a differential equation. To start with, we will call it linear ordinary differential equations; sometimes, we have more complex elements. These elements need to be modeled as non-linear differential equations or as partial differential equations.

The first thing is the elements that I am looking at are dynamic in nature, and their models need to be developed. I can give it in the form of a differential equation or as a transfer function. They can be interconnected to create the system under consideration, and simulation software like MATLAB or Scilab can be used to simulate and study the behavior of dynamic systems. I am sure this is what is being used extensively in many of the colleges. In fact, this should be brought to the classroom. In an interactive way ask the students to explore the behavior of the system when you start changing interconnections or the parameters of the system.

Both tools have excellent visualization features. The output behavior can be plotted as surfaces or curves and so on. When the system under consideration has multiple feedback loops, simulation really comes to your aid, and it is difficult to develop a feel for the system behavior without using simulation. You should note that somehow human beings are not very good at predicting the behavior of a system that has several feedback loops.

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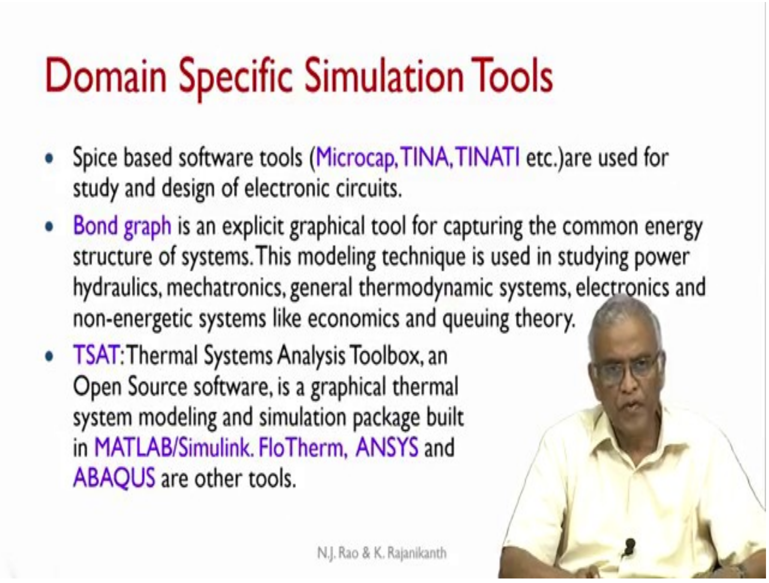

Many of the tools for simulation are domain specific. For example, spice based software tools like MICROCAP, TINA, and TINATI are used for study and design of electronic circuits. The bond graph is an explicit graphic tool for capturing the common energy structure of the systems. This modeling technique is used in studying power hydraulics, mechatronics, general thermodynamic systems, electronics, and non-energetic systems like economics and queuing theory as well.

TSAT - Thermal Systems Analysis Toolbox, an open source system, is a graphical thermal system modeling and simulation package built into MATLAB or Simulink. It is a kind of built on top of MATLAB and Simulink, but specifically for thermal systems. There are other specialized systems like Flo Therm, ANSYS and ABAQUS are other tools for modeling thermal systems.

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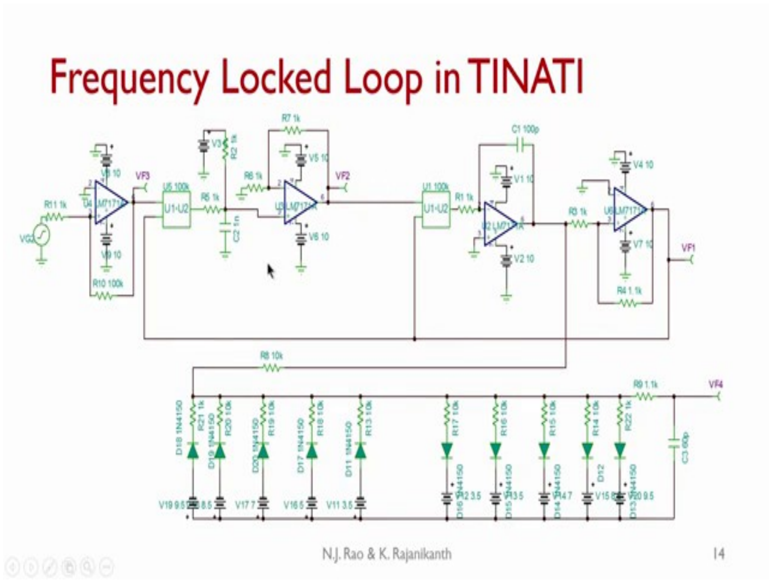

Let us look at how simulation in TINATIit can look. For example, here we are trying to study the frequency locked loop, The FLL will have a VCO, voltage-controlled oscillator, and a phase detector which are non-linear. Here we have an input signal, which is a square wave connected to the phase detector. The output voltage is proportional to the phase between the two input signals.

The FLL presented above operates with square wave signals. If the input is a sine wave you convert it into a square wave, and the output is again converted into a sine wave using a diode function generator. There are so many parameters that influence its behavior, and in addition the devices used (the operational amplifiers) have their own limitations.

You have to investigate whether the whole circuit works in the frequency range that you are interested in; otherwise you have to change the Op Amps or change some other parameters. The quality of the sine wave will depend on the number of segments and the diodes used in creating this diode function generator.

There are a whole bunch of parameters to explore. This is purely mathematical, and the final relationships are so complicated that you can explore this function of this circuit through simulation only. We provided an example how a circuit of this nature can only be explored through simulation. Fortunately this kind of software will work on a laptop or a PC.

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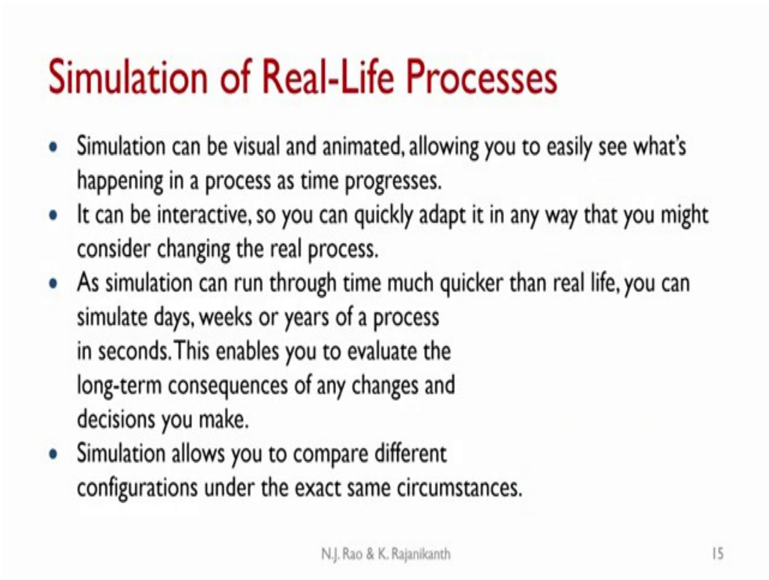

Let us consider the simulation of some real-life processes. Simulation can be visual and animated allowing you to easily see what is happening in the process as time progresses, and it can be interactive. So, you can quickly adapt in a way that you might consider changing the real process. As simulation can run through time much quicker than in real life, you can simulate days/weeks/years of a process in seconds. This enables you to evaluate the long term consequences of any changes and decisions that you make.

Let us take real-life process: in particular, a sizeable departmental store (it can be where you buy your provisions and your daily needs or maybe a weekly needs) user will collect whatever he wants to buy and comes for billing. If you have only one or two counters through which you are billed, then customers would experience significant delay. But if there are more counters, the billing will be faster, bút it can cost more. But what is the level at which you need to operate? How many counters should you have, or should you make these counters time-dependent, depending on when you have a peak requirement?

Such real-life processes are best simulated. Because each user is different - he may be coming with a different set of items or products he is buying. All such variations can be simulated and practically create precisely the same circumstances that you encounter in a shop.

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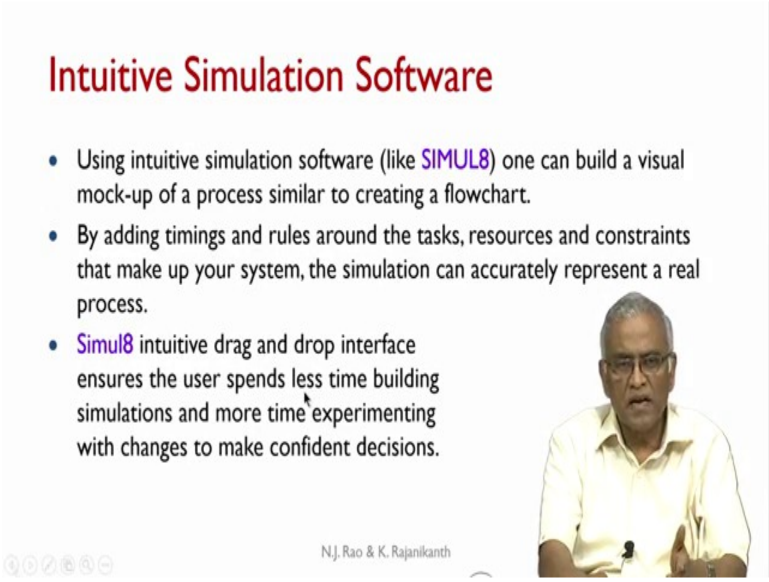

The software tool SIMUL8 uses intuitive simulation. Using drag and drop approach you can build a system and even keep modifying it and see how it behaves. A real-life process can be simulated, but here we are concerned with only time delays and queuing systems. You do not have use too many complex dynamic elements.

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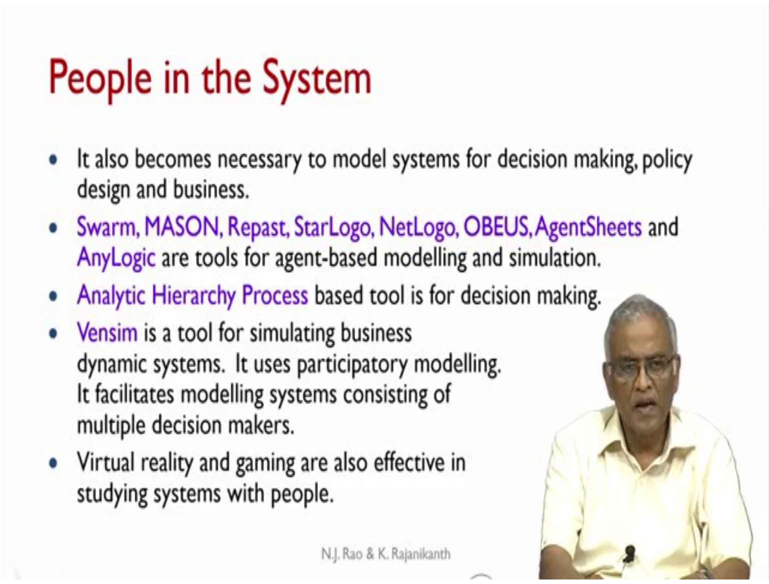

Then you can consider the next level of complex systems where people are parts of the system; that means they are making decisions, and the way they behave will have to be modeled as a part of the system. In these systems, we explore decision making, policy design, and business where people are integral parts of the systems. To do this you have different kinds of scenarios. One method is to use agent-based modeling - an agent is making a decision.

In that case, one can use relatively well-established Softwares like Swarm, MASON, Repast, StarLogo, NetLogo, OBEUS, AgentSheets, and AnyLogic are tools for agent-based modeling and simulation.

The analytic hierarchy process is another tool to model decision making. If there are multiple players who are part of decision making and each person participating in that have different criteria for their choices, then to explore such systems there is a methodology called analytic hierarchy process, and you can use that software tool to model that behavior.

There is another tool called Vensim, or several equivalents of that tool for simulating business dynamic systems. It uses participatory modeling; that means, all the key players in that will sit together and model the system. It facilitates modeling systems and simulating, where it consists of multiple decision-makers. Virtual reality and gaming is also an effective way of studying systems with people. As you can see one has a wide variety of simulation tools for different purposes.

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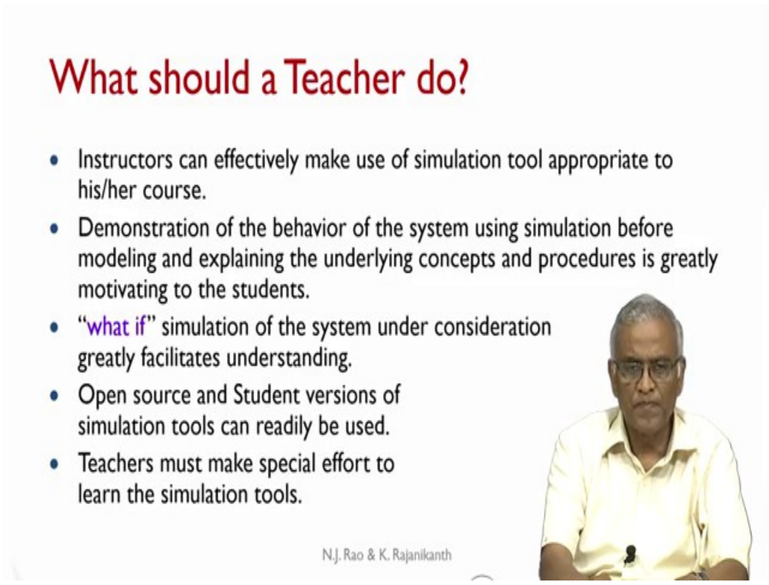

What should a teacher do in such a case; instructors can effectively make use of a simulation tool appropriate to his or her course. Using the simulation tool requires an LCD projector in the classroom. The teacher should be able to dynamically simulate systems in the classroom while interacting with the students. That kind of facility is handy, and if the facilities are not there the college should create such mechanisms where teacher can demonstrate right in the classroom to explore.

If you are exploring some equations in a course, simulation can demonstrate how the system behaves as you keep changing some parameters.

Demonstration of the behavior of the system using simulation before modeling and explaining the underlying concepts and procedures is highly motivating to the students. Let us take the example of an FLL. That is before I talk about FLL in terms of all its elements, their modeling, and what kind of devices that I use, I can first simulate an FLL and explain its function, and what exactly happens. If an FLL has the output frequency the same as the input frequency, which looks very simple, but it can also act as a filter.

For example, if there is a lot of noise associated with the input frequency when I take the output from an FLL, it gives you a pure signal. It locks to the input frequency; then I can explore the effect of changing the input frequency. Once I fully understand the functions of an FLL then only I go to its modeling and design. Students are already motivated and are excited about what an FLL does. Then as a teacher you are going to the details and not the other way. One can reverse the process

The simulation of the system under consideration greatly facilitates understanding. If you take an FLL, what happens if I add more segments to the diode function generator. 'What if the simulation can be done to understand the system under consideration.

Open source and student versions of simulation tools can readily be used. Some of the simulation tools can be quite expensive, but open source and student versions are available, which are adequate to handle smaller systems that we usually deal with in our courses.

In a project mode, if you want to simulate, you have to have access to more elaborate simulation tools. We strongly recommend teacher must make special effort to learn the simulation tools and use them in the class. It is a very powerful method of instruction.

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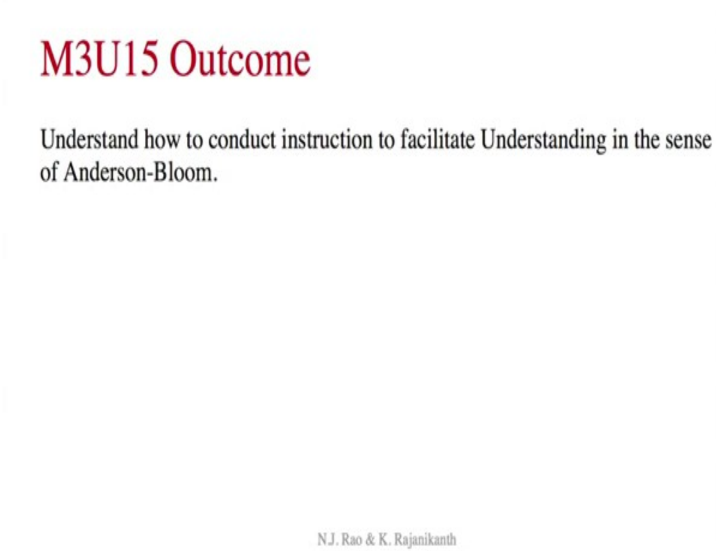

Hopefully, the teachers would select an open-source tool appropriate to his course and start using it in classroom instruction.

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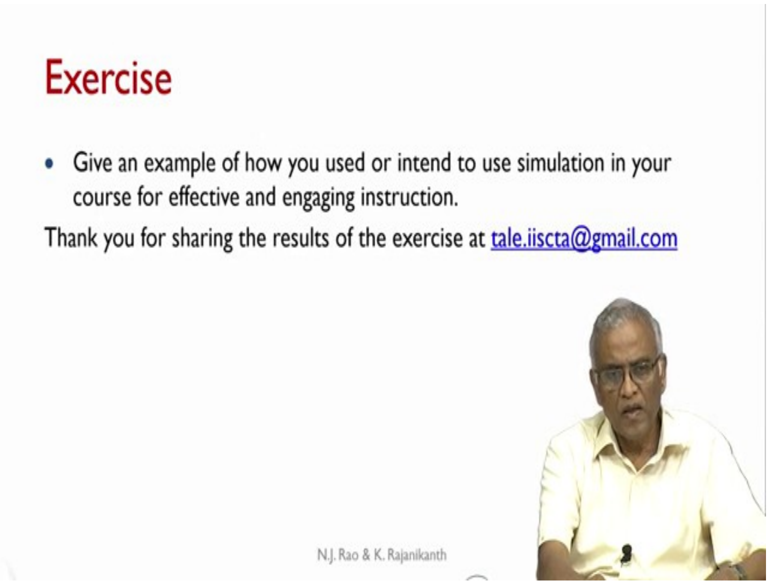

Exercise: Give an example of how you used or intend to use simulation in your course for effective and engaging instruction. That means students are directly engaged with the activity. How do you use simulation as a tool for any of the course outcomes or a competency? Thank you for sharing the result of the exercise at this particular address.

Thank you for your attention.