**Modeling & Simulation of Discrete Event Systems**

**Dr. Pradeep K Jha**
**Department of Mechanical and Industrial Engineering**
**Indian Institute of Technology, Roorkee**

**Lecture - 34**
**Verification of Simulation Models**

Welcome to the lecture on Verification of Simulation Models. So, in this lecture we will talk about the introduction about the validation, verification and credibility of the simulation models. And also, we will discuss about the verification of simulation models in detail; that what needs to be done for verification of simulation models. Now why this verification or validation is important? So, one of the important and difficult task for a developer is to ensure that simulation model is accurate representation of actual system being studied. So, what is what we do in simulation so far? We have studied that whenever we talk about simulation means; we try to gather the data, we try to see that what kind of data you have.

Then further you write computer programs. Basically, your job is to imitate any process. So, how good you are imitating the process? Now in most of the cases in normal circumstances the processes are quite complex. So, you basically get the data, and then try to assume to make it somewhat simple. Because it is very difficult to completely represent the actual system. In the actual system there are lot of factors which are active, at many stages the randomness is there. Then one or other may be correlated or not. Then there are many issues which cannot be implemented.

Now, the thing is that whenever a person is given, the task of simulation he is expected that the prediction of the parameters the performance measures will be very much close to what actually could have happened. So, it is a very tedious task it is a challenge for the model developer; that he will always be questioned whatever you have modelled, whatever you have given the results. So, the thing is that he has to see that you he has to build some model, which should be true representation of the actual system. And also, that it should be credible; means the persons who are going to be to use that they should say okay; that yes, it is we can trust this. So, it is must be trustworthy.

And it will be credible if when designing the system while modelling the system, the proper consideration or opinions of the persons have been taken. If the experts in that

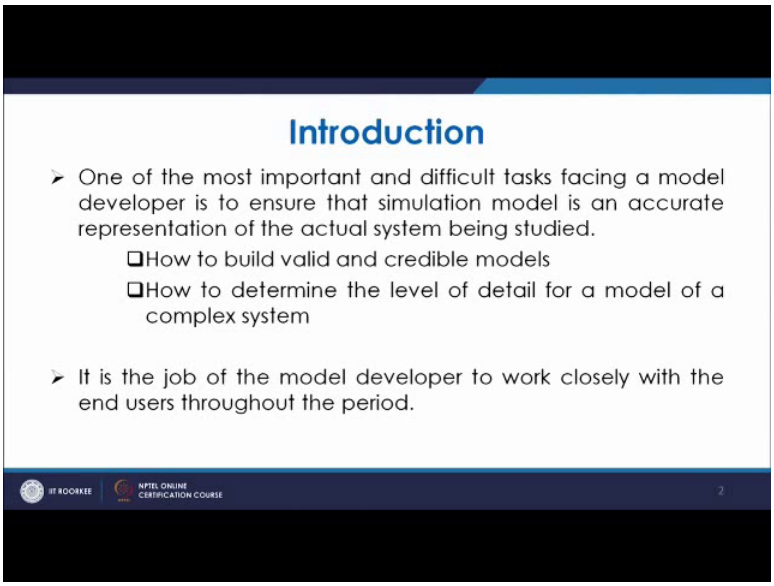
area they feel that yes, every constitution has been taken, no important assumptions have been missed out. And the results which are coming up they are looking realistic. If that being the case basically they are the stakeholders they have to see that for which ever process you are giving them the simulation, because the person who is at the shop floor he looks at that results everyday realistically he faces the task he faces the challenge, he comes across the output parameters. So, he has all the ideas and they have maximum faith in the actual results.

Now the simulation which is done by the analyst, they also are normally the expert they have certainly the knowledge of the system they have to. So, they have to make those people convinced; that the model which has been made it is quite trustworthy. So, for that it is required that the person should be contacted he should be kept in the loop for most of the time. He should be made aware of the assumptions the conditions, those all those algorithms which you are mean the principles on which this algorithm are developed they are taken into account.

Now, you have when you have a very complex system, then you have to determine the level of detail what you mean to have. So, the simple is if it is simple it is very clear, but then for the complex system there should be group of persons who should say that yes, this is what is required to be incorporated. These conditions are required to be incorporated. So, how to determine the level of details for a complex system model? These are the challenges. Because ultimately it is the developer who will be asked to clarify (Refer Time: 06:14) that whatever he has modelled, because it if at any stage he use a certain input values, and these input values are not trustworthy. He has got certain input values which are basically very, very unrealistic.

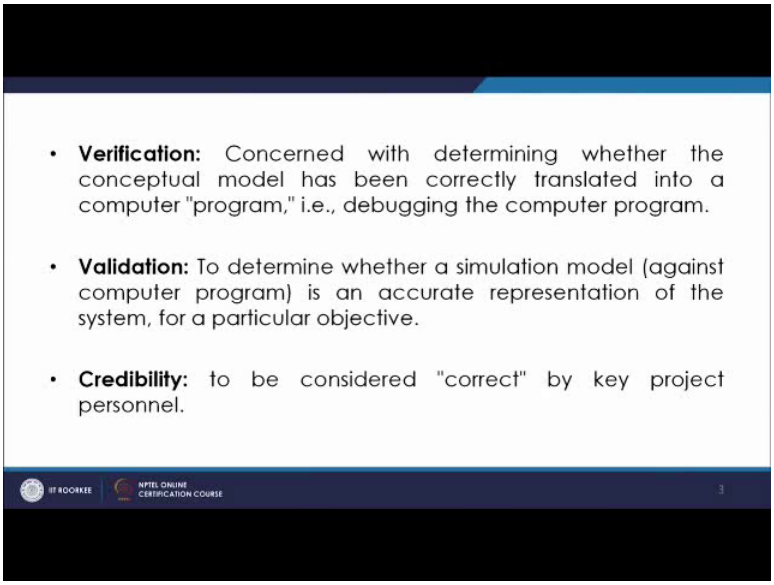
In those senses when you have the unrealistic results, it is bound to give you the unrealistic outputs. And when this is basically faced when this is been challenged by the experts or key personnel managers, when they see the results they can only say, that no, this data which you have been taken we have taken this is not a realistic data. So, for the model to be credible you have to have their opinion they should be there in the system so that your model is credible. They only we will say that what you want what they need to get it from the model. Typically, in a complex system the person who is involved he will be only in a position to say, that what level of detail is required and how to determine that. So, they will be helping in that.

(Refer Slide Time: 07:48)




So, it is a job of the model developer to work closely with the end users throughout the period. Means periodically he has to be sitting together, he has to apprise the results or the programs they are making and the results is getting in between intermediate results, he has basically to make that aware he has to work closely with the end users throughout the period.

(Refer Slide Time: 08:23)




So, what is verification? Verification is concerned with determining whether the conceptual model has been correctly translated into a computer program; that is

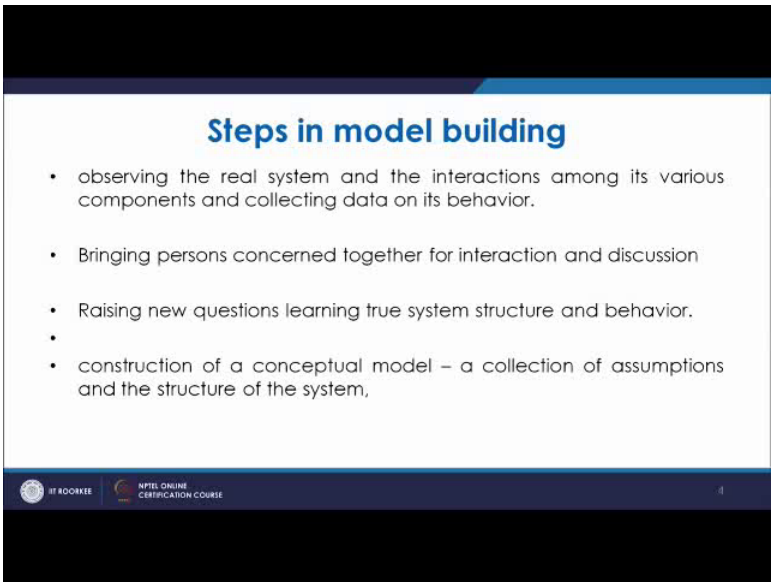
debugging the program. So, once you start making a program. So, in that there are lot of steps. And the verification process means you have to debug the program. You have to see that there is the program runs all right, all the sub routines which are attached they are working quite fine.

So, that process is verification. Verification means it will verify the program, the logic on which the program has been written whether it will give the same results. So, for that there is a team normally a team is there who will talk about all the aspects and they will discuss about it. So, this this process is known as verifications. So, whenever any computer program has been made it required to be verified.

Then comes validation. Now validation is that to determine whether a simulation model or the computer program is the accurate representation of the system for a particular objective. Now the objective varies. So, for particular set of objective the model which you has been made whether it will truly represent the system. That is basically known as validation. So, that again for that you have class; I mean quite a good number of steps how to have the validation done.

Similarly, credibility weather your program is credible. Whether it can be said to be correct by the key project personnel, whether they can say that yes, the results which we are getting it is all realistic and it is all very much true if they are compared to the real-world results. So, these are the three points which are required to be kept in mind when you are making a simulation program. And we will see that how this verification is done in this lecture.

(Refer Slide Time: 11:19)




So, as we know that you have certain steps in the model building. When we start building the model there are some steps which are to be followed.

So, first is that observing the real system; and the interactions among it is various components, collecting data on it is behaviour. The thing is that first of all whenever you are to make a model, you have to see you have to observe the real system. How the real system works, because after looking at the real system, you will be able to have the visualisation you have to you have to see that what are the basically different components and how they interact, what are the parameters which are interlinked. Many a times some values depend on certain other parameters. So, you have to link them. You have to see what kind of data you are having whether you are having proper data. So, all this is required.

So, for that you need to have a proper person who is known to the system, who is in continuous interaction with the system. He knows that what should be the input parameter many a times you have one input parameter which may work for one or 2 cases or 3 cases. And many a times 3 data is required for one input parameter. So, this will be given only by the person who is working in that. Then bringing persons concerned together for interaction in discussion.

This is important that when you have to formulate the assumptions, when you have to bring the objectives out you need the persons together. They should be talking discussing

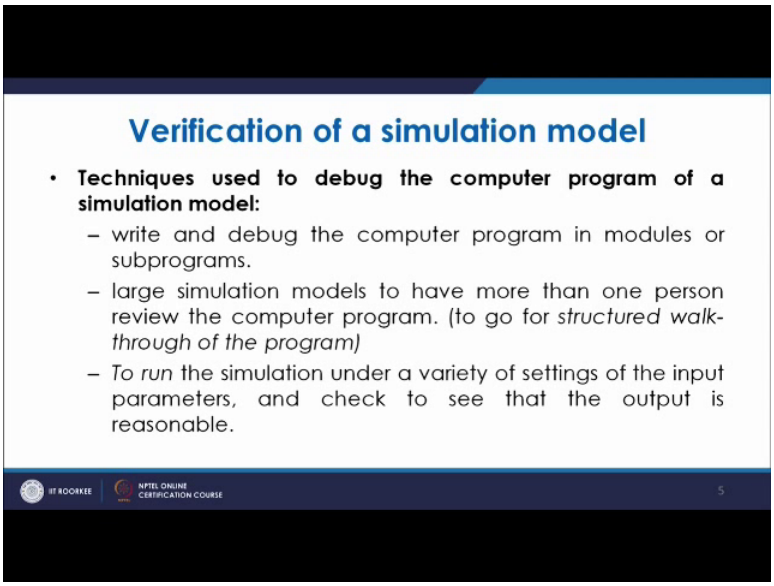
on every assumption. They should be discussing among themselves, discuss upon the points. That why this assumption has been taken, what way the assumptions are going to help you in realistically simulating the event.

So, while doing the discussions new questions will be raised. So, the new questions will basically talk about the system structure, behaviour, how that system will respond. So, once you have that meeting of all these persons who are involved, and they will be questioning about the systems structure and behaviour. Then more and more things will be clear. And it will tell you that whether you are model building is going in the right direction or it needs certain attention in certain ways.

Construction of a conceptual model: so basically whatever you are assuming and whatever you are making the model, depending upon the input parameters and then assumptions. If they are better you are going to better simulate the system. So, basically this only is reflected ultimately as an output. So, you must have a proper model, proper assumptions collection all time assumptions which we have taken it should be assumptions document should be there.

That whatever assumptions have you taken how much they are required, whether they are required or they are not required to study the system or whether you need any extra assumption to be added into the system. So, that list should always be there whenever there is any discussion with the key personnel with the management personals, then that becomes important.

(Refer Slide Time: 16:09)




So, the next step is that- what are the techniques which are used for debugging the computer program; that is the verification of the simulation model. So, as we know that the normal process of writing the computer program, because you are always dealing with very complex systems. So, your programs are normally very, very large. And it is always advisable to write and debug the computer program in modules or subprograms. So, that is the way if he is an expert programmer they always write the programs in small sections, and then they basically attach one to other with the main program. So, that it has some advantages.

If you write one program a very large program and if there is any I mean debugging problem anywhere, it is very difficult to write to completely check the program it is very difficult to it becomes very combustion to locate the place where it has been. So, for making good computer programs you must have the modules or subprograms you have different kinds of subroutines, like you have the queen program you will have another extra subroutine. Like, for one for arrival, one for service, one will be for the numbers. Suppose required in case of other kind of programs you will have one as random generators.

So, you will have different kinds of sub programs, and these programs are basically used to write these. So, how overall you will have the flexibility to check. So, whenever if suppose the program does not run, the separate subunits or sub programs can be checked.

And ensure that whether there is any defect in that portion. So, that will be you know making the task easier for the programmer.

Large simulation models to have one or more person review the computer program. So, what happens that once you have the computer program large programs? Then it is better that you be on a round table, and go for structured walk through. Means every person will talk about every point, and then it will be discussed that whether the particular assumption which has been taken whether it is required. What is the logic? (Refer Time: 19:16) to get the data and how these data will be useful.

So, structure walkthrough; means you have the experts sitting together programmers analyst, and they will be discussing on every point. So, in that case the things become more clear any new assumption which is required, or any assumption which has to be deleted, any condition which has to be removed. These are basically coming out very effectively when there is a structured walkthrough of the program.

So, this is very important step, and whenever this is done many a times you see that it comes to the person that some very important assumption have been left out. Or in some very important objective has been left out. So, new assumptions may come because of these structured walkthrough. So, they will talk about the different algorithms they will see that whether this portion is running all right what kind of results are coming. So, this way you have the reviewing of the computer program going on.

Then you have to run the simulation under a variety of setting of the input parameters. So, you have different types of input parameters. Now you have to see that you run it and see that how this output is coming, how much reasonable the output is. Because many a times among the data which is taken input data which is taken. Many a times some of the data is superfluous. So, that may lead to some very awkward results. So, when you are basically periodically if you get the results and getting the outputs.

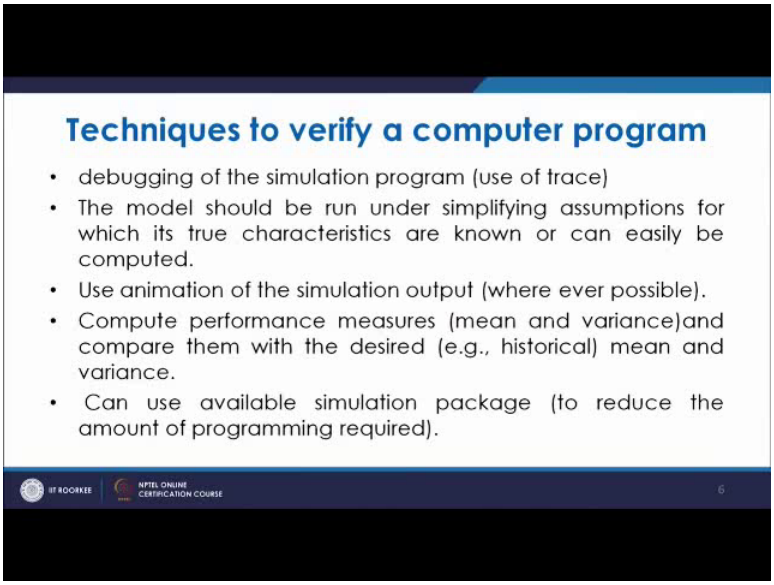
And periodically you are checking the output parameters under the certain set off input parameters. And you are analysing the output using suppose statistical means. You go on checking the output parameters have the confidence intervals; see that whatever you are getting whether it is in the realistic boundaries. So, you have to do all that under the variety of the setting of input parameters, you have different kind of input parameters.

Many a times you assume that this is for this particular distribution with that parameter and the result you which you get may not be so; I mean realistic. So, you will have to change the input parameters settings, and then ultimately your job is to have the performance measures; that is output. So, every stage you will have to see that the output which you are getting. It is not going into any unrealistic horizon or unrealistic domain. This is important.

Now, the next is that you debug the program, and use of trace is very much advocated. Now while debugging the program what we discussed that we are basically very much concerned that what is the output coming after every stage. So, we are comparing this output performance measures, and see that you are getting the realistic results, as compared to what you could have expected from the real system. So, this trace use of trace is very much common in debugging of the program, where you see that you have the event list you have everything on the front.

And when you get the outputs you are able to compare from that event list, or you have other input parameters assumptions are there. So, you are basically able to trace it; that whatever you are getting with respect to certain event list or the input values whether you are getting the results I mean which is in the line with those values.

(Refer Slide Time: 24:49)




So, use of trace is very much you know in practice for the debuggers debugging operations in the case of this verification of programs.

The model should be run under simplifying assumptions for which it is true characteristics are known, or easily can be computed. So, this is important; that you must have the assumptions which should simplify, but then the true characteristics should be maintained. It is not advisable to go for a very complex assumptions. So, that you are thinking of more accurately you know, simulating the system, and you have taken the complex assumptions. Basically, that takes large amount of time, and many a times that does not improve the output performances, reliabilities.

So, you should be running the model under simplifying assumptions. So, that you know that what is going to be it is effect, and how it is going to, because once you take the simplifying assumptions which will make the model simple. Then the model can run and get the results easily. Further once you get the results and if you want to further incorporate few points you can think of doing some necessary changes, but if you start from very complex assumptions. Then many a times you are stuck in between. So, that is important that you must have those assumptions which should simplify, and you should you should help you in seeing that your simulation progresses in even manner.

Use animation of the simulation output wherever possible. This animation is very important, nowadays you have good softwares good programs, simulation programs and animation basically gives a very good idea about the correct presentation, correct you know understanding of the problem. Many a times many assumptions which you have taken they get clear by looking at the animation. So, you should be using the animation, whenever you have the possibility you should show the results using animation.

Computer performance; so, computing the performance measures and compare them with the desired mean and variance. So, once you are getting the performance measures the results, now you get it is mean and variance. And then you can see that how much it is comparable with the historical mean and variance. So, we have seen that we have the techniques of comparing the means or variances. And you can say that yes, this mean is very. So, whatever this system you are getting result it looks similar to the actual system. So, you have we have already studied about the comparison of systems in which we compare the parameters by making the confidence intervals.

So, that basically gives you an idea that the predicted model or the simulation model which is developed, which is basically which predict certain results whether these results

are considered to be similar to the results which is the standard one. So, we have discussed that we can have the difference and then you find the confidence interval see that interval contains 0 means if the interval contains 0; means there is possibility that there is no difference many a times.

So, this is required to ensure; that yes, the model is all right, the assumptions which has been taken and based on that you have got certain results, they look all right. The program is all right. So, that it has run and give the meaningful results.

Now, there are many kinds of many available softwares, nowadays which are quite efficient. So, you can do your own programming, but then own programming takes a lot of time many a times. So, you have open source codes available. You have simulation packages available where that is advisable, because it has the inbuilt many things like animation you have, you can put the data it will talk about the suitability of data, what type of fit applies to that data. So, the simulation packages are basically advisable in such cases, because the systems are normally very complex large amount of data is to be dealt large amount of randomness is there in many kind of data.

So, in those cases you have you have to use this simulation package which will reduce large amount of programming time or so. So, many a times we should prefer to go for the simulation package.

So, these are the techniques which are used to verify a computer program. And once you feel that the program is verified, then half way you are true because ultimately the program which runs gives you the results, and if it is verified by the personal if it tells that yes, all the assumptions. All the linking all this is right, the results which you are getting look realistic. Then that is basically most of the work is done.

So, then we will further see in our next lecture that how we ensure the validity and credibility of the model, so that we will see later.

Thank you very much.