**The lecture 2**

**Systems modeling**

Why is modeling required? Because … modeling may be quite useful:

1. To find the height of a tower, say the *Kutub Minar* of Delhi or the Leaning Tower at

Pisa without actually climbing it

2. To measure the width of a river without actually crossing it

3. To gauge the mass of the Earth, not using any balance

4. To find the temperature at the surface or at the centre of the sun

5. To estimate the yield of wheat in India from the standing crop

6. To quantify the amount of blood inside a living human body

7. To predict the population of China for the year 2050

8. To determine the time required by a satellite to complete one orbit around the

earth, say at the height of about 10,000 km above the ground

9. To assess the impact of 30% reduction in income tax over the national economy

10. To ascertain the optimally efficient gun whose performance depends on 10 parameters,

each of which can take 10 different values, without actually manufacturing

1010 guns

11. To determine the mean time between failures (MTBF) or average life span of an electric bulb

12. To forecast the total amount of insurance claims a company has to pay next year

Similarly, for a given physical, biological, or social problem, we may fi rst develop a mathematical model for it, and then solve the model, and interpret its solution with respect to

the problem statement.

Man has been modeling and simulating ever since his brain developed power to image.

Children start modeling from birth. We are all simulating—like a child with a doll, an

architect with a model, and a business man with a business plan, etc.

What is modeling?

Modeling is a process of abstraction of a real system. A model portrays a conceptual framework to describe a system and can be viewed as an abstraction (essence) of an actual system or a physical replica of a system or a situation. It is a factual representation of reality.

The word model is derived from Latin and its meaning is pattern (physical model).

The abstracted model may be logical or mathematical. A mathematical model is a mathematical description of properties and interactions in the system. The development of a mathematical model depends on the system boundary, system components, and their interactions. It also depends upon the type of analysis that we want to perform, like steady state or transient analysis and the assumptions that we will consider while model development.

If assumptions are more then the model will be simpler, but the accuracy of the response of the model would be less. If there are fewer assumptions, the model will be complex and the accuracy will be better. Hence, during model development, it is necessary to optimize two things:

1. Simplicity of the model

2. Accuracy of the model or faithfulness of model

**Need of system modeling**

Models are used to mimic the behavior of systems under different operating conditions. This

may also be done with the help of experimentation on the system. But, sometimes it is inappropriate or impossible to do experiments on real systems due to the following reasons.

1. ***Too expensive***: Experimenting with a real system is an extremely costly affair. For example, the physical experimentation of a complex system like the satellite system is quite expensive and time consuming.

2. ***Risky***: Risk involved in experimentation is another factor. In some systems there is a risk of damaging the system, or a risk of life. For example, training a person for operating the nuclear plant in a dangerous situation would be inappropriate and life threatening.

Modeling is an essential requirement in certain situations, such as the following:

1. ***Abstract specifications of the essential features of a system***: When a system does not exist and a designer wants to design a new system like a missile or an airplane. The model will help in knowing, prior to the development of the system, how that system will work for different environmental conditions and inputs.

2. ***Modeling forces us to think clearly before making a physical model***: One has to be clear

about the structure and the essentials of the situation.

3. ***To guide the thought process***: It helps in refining ideas or decisions before implementing

it in the real world.

4. It is a tool that improves the understanding about a system, and allows us to demonstrate

and interact with what we design, and not just describe it.

5. ***To improve system performance***: Models will help in changing the system structure

to improve its performance.

6. ***To explore the multiple solutions economically***: It also allows us to find many alternate

solutions for the improvement in system performance.

7. To create virtual environments for training purpose or entertainment purposes.

**Modeling methods for complex systems**

It is possible to acquire an almost white-box model of a fighter jet, by modeling it with every mechanical part of such a jet embedded into the model. However, the computational cost of adding such a huge amount of detail would effectively inhibit the usage of such a model. Additionally, the uncertainty would increase due to an overly complex system, because each separate part induces some amount of variance into the model. It is therefore usually appropriate to make some approximations to reduce the model to a sensible size. Engineers often can accept some approximations in order to get a more robust and simple model. For example, Newton’s classical mechanics is only an approximated model of the real world. Still, Newton’s model is quite sufficient for most ordinary-life situations, that is, as long as particle speeds are well below the speed of light, and as long as we study macroparticles only.

Mathematical models of such systems are most accurate and precise, but can handle the system complexity only up to certain limit. Simple systems are easy to model mathematically.

As the system’s complexity increases, mathematical model development becomes quite cumbersome. At the same time, it is also difficult and time consuming to simulate complex system models. In such situations, ANN models are better in comparison to mathematical models. As it is evident from literature that for good ANN model development, it is necessary to have accurate and sufficient training data, and this is really difficult for real-life problems. Most of the real-life problems have qualitative information, which is either difficult or impossible to translate into quantitative form. Hence, fuzzy modeling is the only option for such circumstances. The modeling using fuzzy logic is quite useful for highly complex systems as shown



**Classification models**

Models have been widely accepted as a means for studying complex phenomena for experimental investigations at a lower cost and in less time, than trying changes in actual systems.

Knowledge can be obtained more quickly, and for conditions not observable in real life. Models tell us about our ignorance and give better insights into the system.

**Physical vs abstract model**

To most people, the word “model” evokes images of clay cars in wind tunnels, cockpits disconnected from their airplanes to be used in pilot training, or miniature supertankers scurrying about in a swimming pool. These are examples of physical models (also called iconic models), and are not typical of the kinds of models that are of interest in operations research and system analysis. Physical models are most easily understood. They are usually physical replicas, often on a reduced scale. Dynamic physical models are used as in wind tunnels to show the aerodynamic characteristics of proposed aircraft designs. Occasionally, however, it has been found useful to build physical models to study engineering or management systems; examples include tabletop scale models of material-handling systems, and in at least one case a full-scale physical model of a fast food restaurant inside a warehouse, complete with full-scale, and, presumably hungry humans. But the vast majority of models built for such purposes are abstracted, representing a system in terms of logical or quantitative relationships that are then manipulated and changed to see how the model reacts, and thus, how the system would react— if the abstract model is a valid one. An abstract model is one in which symbols, rather than physical devices, constitute the model. The abstract model is more common but less recognized. The symbolism used can be a written language or a thought process.

**Mathematical vs descriptive model**

A mathematical model is a special subdivision of abstract models. The mathematical model

is written in the language of mathematical symbols. Perhaps the simplest example of an abstracted mathematical model is the familiar relation

Distance = Acceleration × Time

*d* = *a* \* *t*

This might provide a valid model in one instance (e.g., a space probe to another planet after

it has attained its flight velocity) but a very poor model for other purposes (e.g., rush-hour

commuting on congested urban freeways).

