Fuzzy Sets, Logic and Systems & Applications

Prof. Nishchal K. Verma
Department of Electrical Engineering
Indian Institute of Technology, Kanpur

Lecture - 01
Introduction: Fuzzy Sets, Logic and Systems & Applications

So, welcome to the first lecture of the course on Fuzzy Sets Logic and Systems and Applications. This lecture is based on the Introduction of Fuzzy Logic and then the little bit of introduction to artificial intelligence and I will try here to relate fuzzy logic with Artificial Intelligence. So, before I move to that part, I would like to tell you that fuzzy logic is a multi valued logic and of course, as I have mentioned already that there is a linkage of fuzzy system with artificial intelligence.

So, or in other words I would like to tell you that the fuzzy systems is one of the very key agents of artificial intelligence. So, when we talk of artificial intelligence, or machine intelligence in other words let me briefly define what is artificial intelligence.

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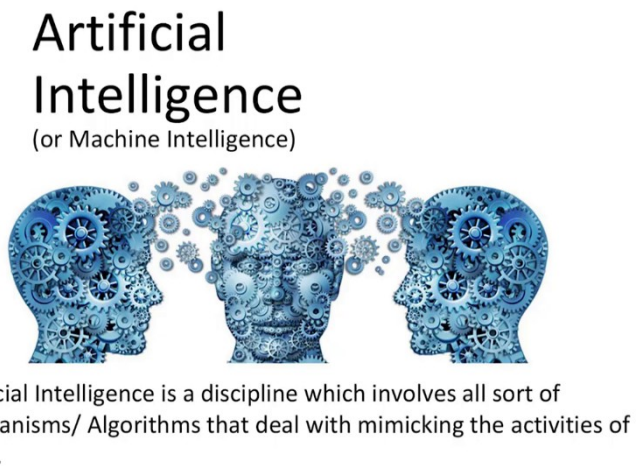

So, artificial intelligence is nothing but it is a discipline which involves all sort of mechanisms, algorithms that deal with mimicking the activities of our brain.

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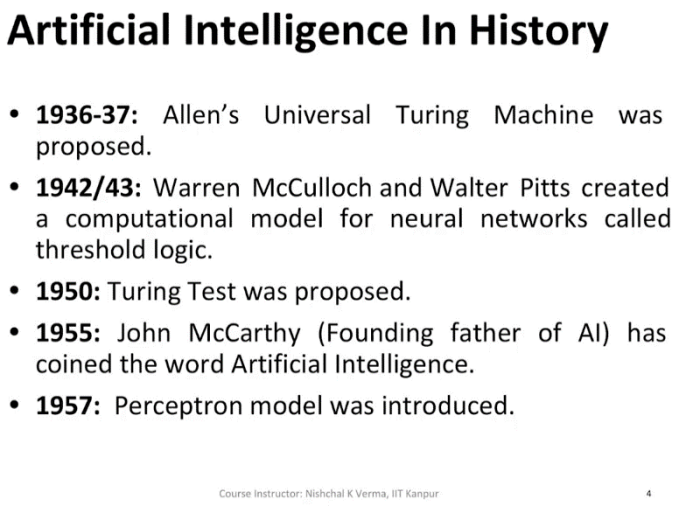

I would like to go to brief history of artificial intelligence, since we are going finally, to study fuzzy systems and as I mentioned that there is a linkage of fuzzy systems with the artificial intelligence. So, it is necessary to have our brief history of artificial intelligence. So, artificial intelligence starts with the Allen's Universal Turing Machine it is here and it was the time in 1936 - 37. So, around that it was proposed and with this the beginning of artificial intelligence is seen here and then in 1942 - 43 Warren McCulloch and Walter Pitts created a computational model for neural networks and that was also called threshold logic.

So, this was the time when artificial neural network started. So, here it was basically a preposition of the ANN model and it was based on the biological neuron and then in 1950 a Turing Test was proposed, in 1955 the formal name artificial intelligence has come up and this name was given by John McCarthy. As it's written here that in 1955 the John McCarthy founding father of artificial intelligence has coined the word artificial intelligence.

In 1957 a perceptron model was introduced. So, a perceptron model is nothing, but it is again artificial neuron model, the difference here is just the activation function. So, perceptron model is ANN model with activation function as binary linear.

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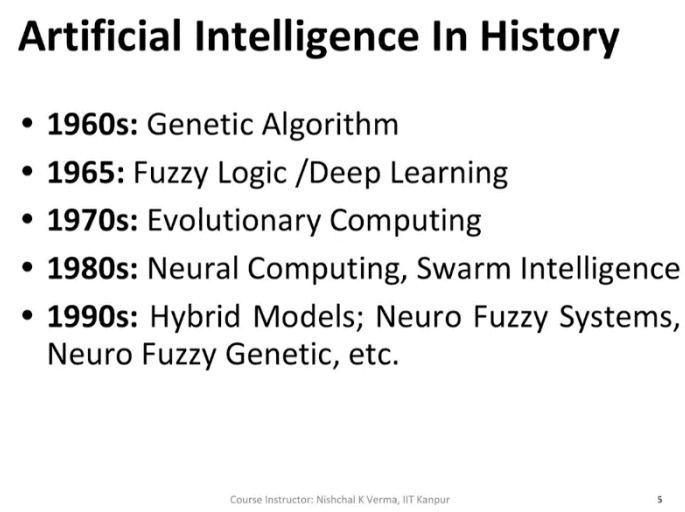

And then in 1960's the genetic algorithm was proposed, in 1965 it is very important to note here that in 1965 fuzzy logic was proposed by professor Lotfi A Zadeh. And this is a time when the deep learning term which is very very relevant, very very popular term being used nowadays, it was coined in 1965 by Evancho and Lapa. So, I would say here that this year there were two main concepts were proposed, first concept was fuzzy logic and then the deep learning. And these two have a very high correlation.

In 1970's evolutionary computing was proposed. So, various algorithms of evolutionary computing were proposed and then 1980's witnessed neural computing swarm intelligence and then 1990's hybrid models of these like neuro fuzzy systems, neuro fuzzy genetic, fuzzy genetic like that the models were proposed. So, in nutshell I would say the fuzzy neuro genetic all these were used together to give a better model performance and these were proposed when studied.

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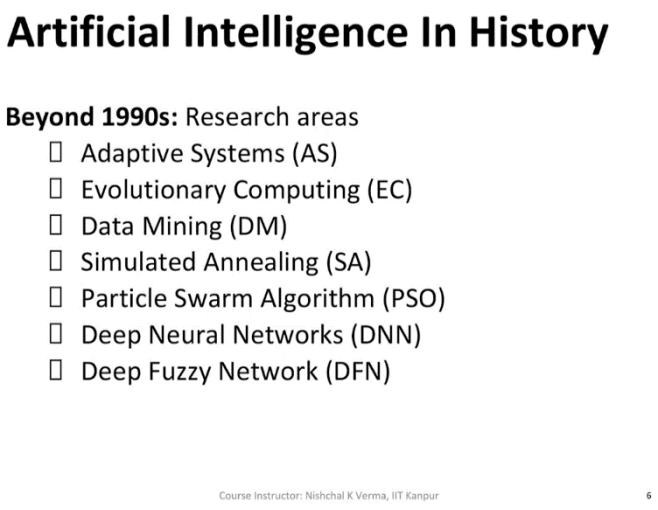

Beyond 90's the research areas based on all of these agents were helpful in giving rise to various models, various systems. For example, if systems, evolutionary computing, data mining, simulated annealing, particle swarm algorithm, deep neural networks, deep fuzzy networks etcetera.

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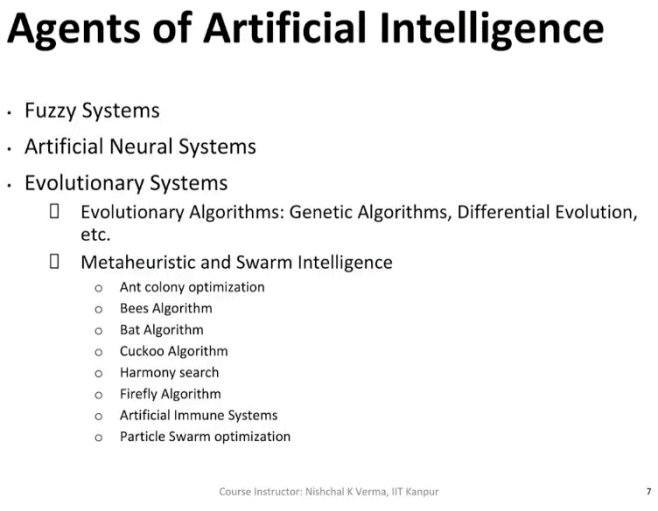

So, the artificial intelligence which started which was seen right from, I would say the birth of artificial intelligence is seen around 1936 – 37, and it you know with the advent of all these agents for example, fuzzy systems, neural network, genetic algorithm and many more

which I am I will be describing in due course of time. So, we can call these are the agents of artificial intelligence, like fuzzy systems, artificial neural systems, evolutionary systems.

And in evolutionary algorithms we mainly cover genetic algorithms differential evolution and then in evolutionary systems we have meta heuristic and swarm intelligence. Under these we have ant colony optimization, Bees Algorithm, Bat Algorithm, Cuckoo Algorithm, Harmony search, Firefly Algorithm, Artificial Immune Systems, Particle Swarm Optimization.

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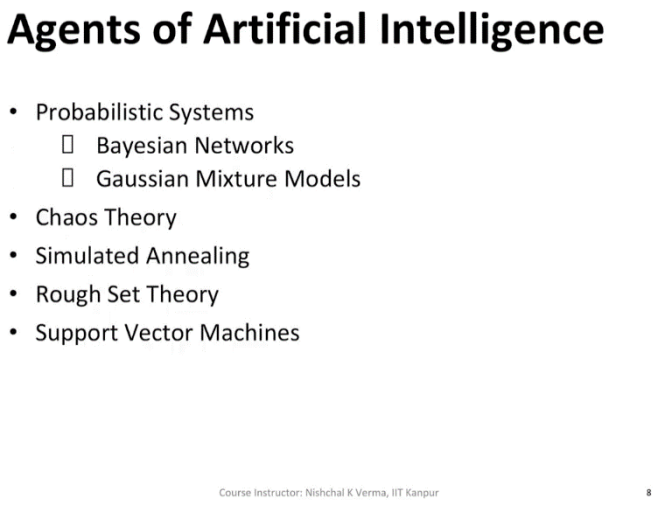

And then as agents of artificial intelligence again we have probabilistic systems, for example, Bayesian networks, Gaussian mixture models, hidden Marco models which is not mentioned here and then we have as agent of AI, we have chaos theory simulated annealing, rough set theory, support vector machines and there are many more agents which I have not been mentioned here.

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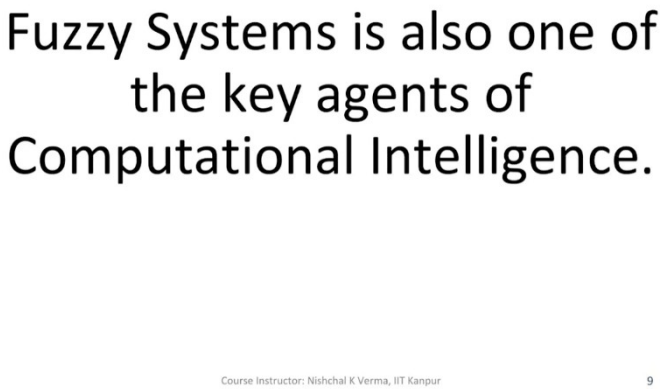

So, fuzzy system is also one of the key agents of computational intelligence. So, computational intelligence is an equivalent name of artificial intelligence, these two names go hand in hand and I would like to just briefly tell you the definition of a computational intelligence.

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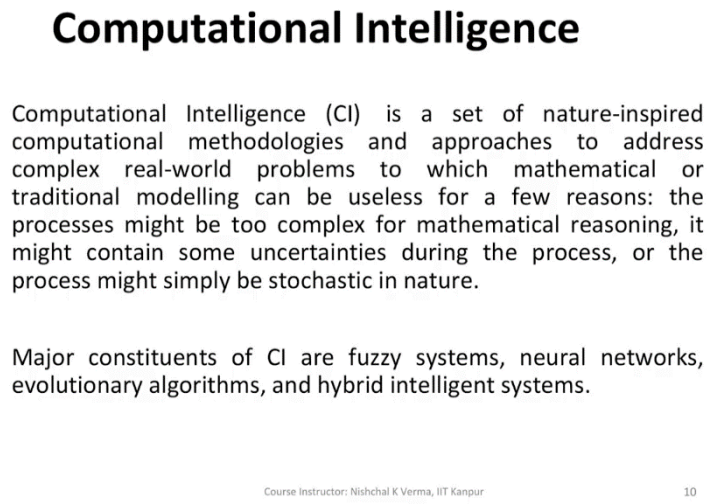

So, Computational Intelligence basically a set of nature inspired computational methodologies and approaches to address complex real world problems to which conventional mathematical or traditional modelling can be useless.

For a few reasons, like the processes might be too complex, the processes for which we are developing the model that could be too complex for mathematical reasoning. It might contain some uncertainties during the process or the process might simply be stochastic in nature. So, the major constituents of computational intelligence are fuzzy systems, neural networks evolutionary algorithms and other hybrid intelligent systems.

So, we can clearly see here fuzzy system which is also a key agents of computational intelligence. So, what I mean here is that that artificial intelligence and computational intelligence although these two go hand in hand are being interchangeably being used, the fuzzy system is a key component of these two.

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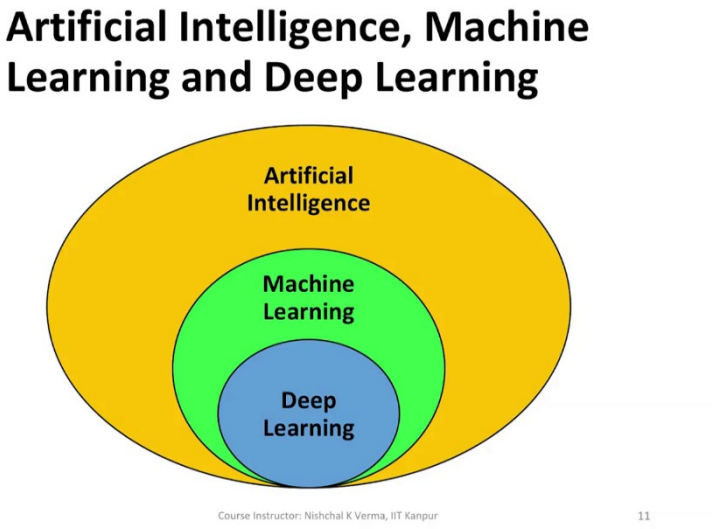

Let us now just look at the artificial intelligence, Machine Learning and Deep Learning. So, at this stage let us now understand as to how the artificial intelligence which we have just discussed and then machine learning and deep learning how are these three terms related.

So, we see here that the artificial intelligence is a very broad term; what do I mean by broad term here is that the artificial intelligence is a bigger set and machine learning is the is actually part of artificial intelligence because the agents of artificial intelligence like a fuzzy systems, neural network, artificial neural network, genetic algorithm and all other which we have already mentioned. So, they help us in managing the machine learning process or machine learning activities.

And then comes the deep learning which is again you see is a very smaller set than the machine learning. So, it means that machine learning is a bigger set and deep learning is smaller set and deep learning is contained in the machine learning and artificial intelligence.

It means that the deep learning is part of artificial intelligence, deep learning is part of machine learning and deep learning here would mean that it's a part of machine learning and in machine learning when there is an intense learning process or repetitive learning hierarchically, so, this is termed as deep learning. In nutshell I would say the deep learning is also part of artificial intelligence as machine learning.

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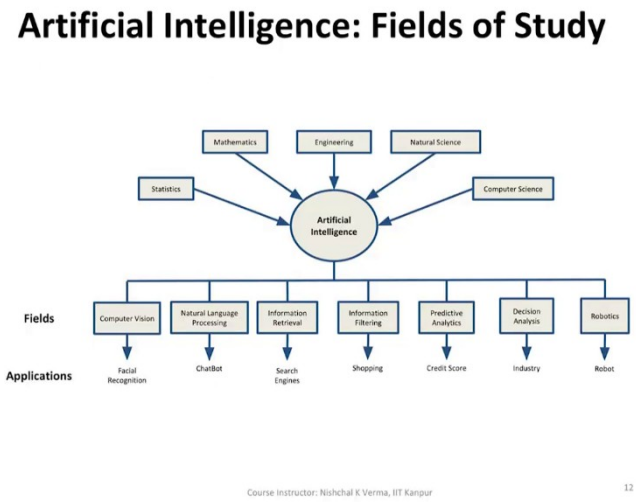

So, let me just briefly describe to how artificial intelligence the theory getting developed through various the research experts of from various fields for example, the statistics, mathematics, engineering, natural sciences, computer science. So, the artificial intelligence is an interdisciplinary area and experts from these areas, but not limited to these areas, they are contributing to the theory development of artificial intelligence.

And if we see here that the artificial intelligence is used by various fields for example, computer vision and we see here the natural language processing, information, retrieval information filtering, predictive analysis, decision analysis, robotics, but not limited to these, again these are the few fields that are mentioned and there are many more where artificial intelligence is contributing.

And then if we see they are separate applications again, I would say these applications are the applications that are mentioned here are only a few applications, but there are so many applications in respective fields which are being practiced which are being carried out by the with the help of artificial intelligence.

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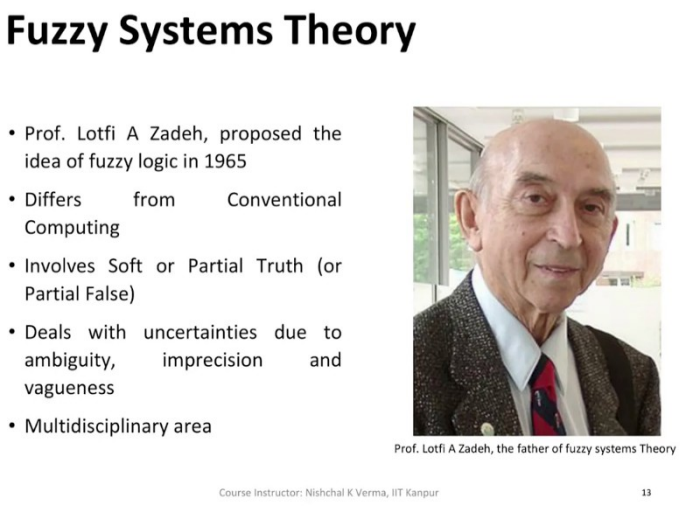

So, now coming to the fuzzy systems theory which is based on fuzzy logic, professor Lotfi A Zadeh which is who is also known as the father of fuzzy systems theory. So, he proposed the idea of fuzzy logic in 1965. Fuzzy systems theory differs from conventional computing because the conventional computing is based on bivalent logic or the Boolean logic whereas, fuzzy logic is based on the multi valued logic. So, we can also say that the conventional computing is based on one of the cases of or we can also say that the conventional computing that we have done. So, far is one of the cases of fuzzy logic or the mathematics based on the fuzzy logic.

Fuzzy systems theory involves soft or partial truth or partial false; soft because the truth if it is soft it means that it is true, but not 100 percent true or somewhere in between 0 to 100 percent or false in between 0 to 10 percent. So, if it is 100 percent true the truth is hard or the false is 100 percent it means the false is hard, but if there is a truth or the false which is not 100 percent or somewhere in between 0 and 100 percent it is termed as soft.

Fuzzy systems theory also deals with the uncertainties due to ambiguity, imprecision and vagueness. So, these are the uncertainties which are very special kinds of uncertainties

because these uncertainties cannot be dealt by any other artificial intelligent agents, so far what we have done mainly about uncertainties due to randomness and which is which can be dealt or which are dealt by probability theory because the uncertainty here is due to a randomness, but this is different from the uncertainties due to randomness. So, that is why fuzzy system theory is very well suited for tackling these uncertainties.

And let me make it very clear here that these uncertainties cannot be dealt by the probability theory very well. So, another thing is that fuzzy system theory is a multidisciplinary area, multidisciplinary area here would mean that the concepts of fuzzy systems theory can be very well utilized by many disciplines.

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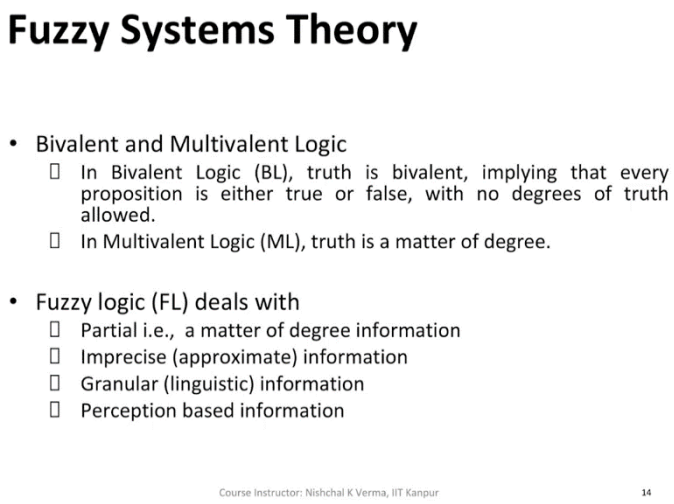

For example, the engineering science, humanities and so on and so forth. As I already mentioned that fuzzy systems theory is based on fuzzy logic and fuzzy logic is multivalent logic.

I already explained difference between bivalent logic which is nothing, but the Boolean logic and the multivalent logic. So, let us now understand in bivalent logic truth is bivalent means every proposition is either true or false with no degree of truth allowed. Means that truth is truth and the false is hard. In multivalent logic as I already explained this also truth is a matter of degree or I would say here as I mentioned just before the slide the truth or false is soft.

A Multivalent logic can take in multivalent logic the values of truth or false they can take any value in between 0 and 1. So, that is why if we talk of the degree, so degree can be can be infinite in number, the number of values that can be assigned can be infinite. So, fuzzy logic deals with partial which is a matter of degree.

So, partial information, imprecise information fuzzy logic deals with the granular information granular here would mean that if we have linguistic information the fuzzy logic can deal with this kind of information and manage to understand, manage to quantify from the linguistic information and then fuzzy logic can also help in perception based information. In other worse words perception based information can be quantified by fuzzy logic.

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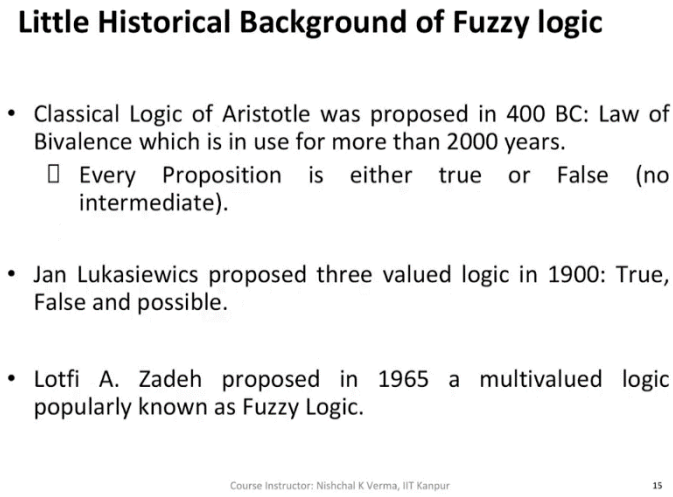

So, let me go through little historical background of fuzzy logic, classical logic of Aristotle was proposed in 400 BC, 400 Before Christ. So, it is now very clear here that the bivalent logic or the Boolean logic was proposed by Aristotle, in 400 BC, the law of bivalence which is in use for more than 2000 years. So, it means every proposition is either true or false, it means here true is hard and false is also hard it means 100 percent true or a 100 percent false. So, there is no intermediate value of true or false.

So, another logic here is was proposed by Jan Lukasiewics who proposed three valued logic in 1900 AD, this logic is a three valued logic it means that we have true, false and possible. And then Lotfi A Zadeh proposed a fuzzy logic in 1965 which is bivalued logic and this is again this is very popularly known as fuzzy logic.

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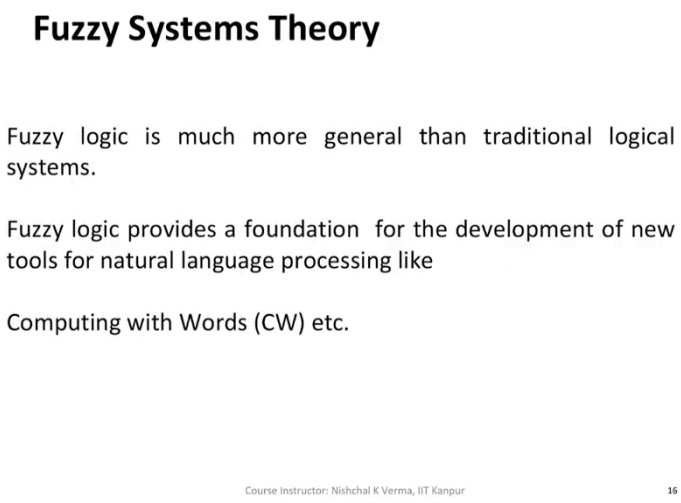

So fuzzy logic is much more general as I already mentioned, than the traditional logic or conventional logic these systems based on the traditional logic system. So, I can say here the traditional logical systems. So, this statement goes like this the fuzzy logic is much more general than traditional logical system, fuzzy logic provides a foundation for the development of new tools for natural language processing like computing with words. So, this is a very important area where fuzzy logic is very very helpful.

In other words if fuzzy logic has the ability to deal with to understand the linguistic information and to quantify it in such a way that linguistic information is properly understood and processed and a suitable output is created.

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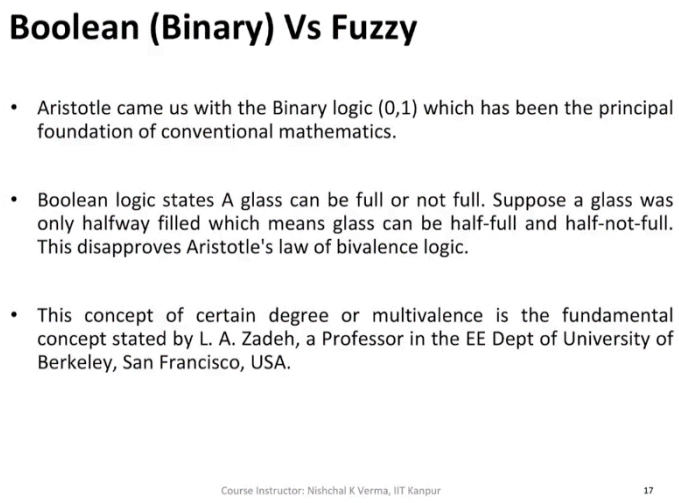

The Aristotle came us with the binary logic which has been the principle foundation of conventional mathematics. Boolean logic states a glass can be full or not full. So, if we have a case for example, that a glass is either half way filled. So, by using the Boolean logic we cannot manage to define the half full glass of water or anything.

So, this disapproves the Aristotle's low of bivalent logic or in other words we can say that the Boolean logic is not sufficient to manage to take up this kind of situation. This concept of certain degree or multivalence is the fundamental concept is stated by Lotfi A Zadeh this helps us in defining such situations very well.

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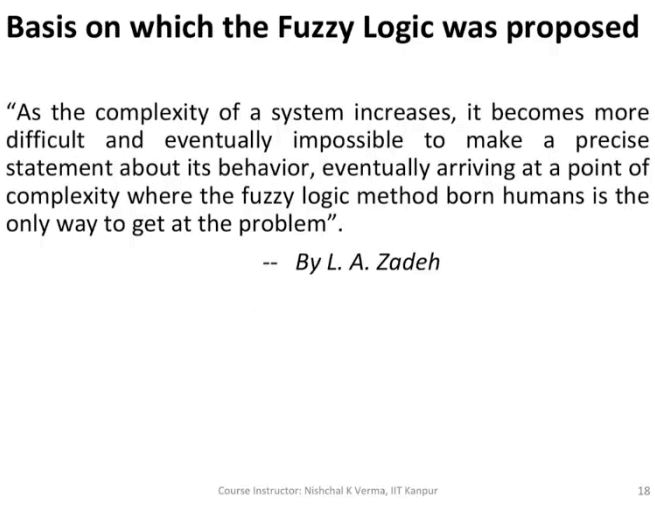

So, basis on which the fuzzy logic was proposed is here as the complexity of a system increases it becomes more difficult and eventually impossible to make a precise statement about its behavior, eventually arriving at a point of complexity where the fuzzy logic method born humans is the only way to get at the problems. So, this statement was made by professor Lotfi A Zadeh.

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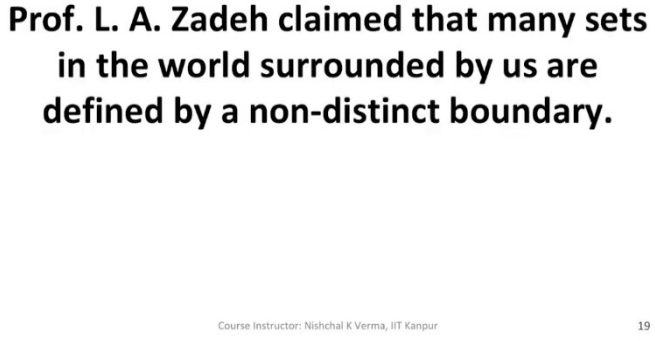

A professor Lotfi A Zadeh claimed that many sets in the world surrounded by us are defined by a non distinct boundary. So, we will have few examples later and then we will see that the

claim of professor Lotfi A Zadeh is true. Let us also understand and let us also know that why should we use fuzzy logic or fuzzy systems theory.

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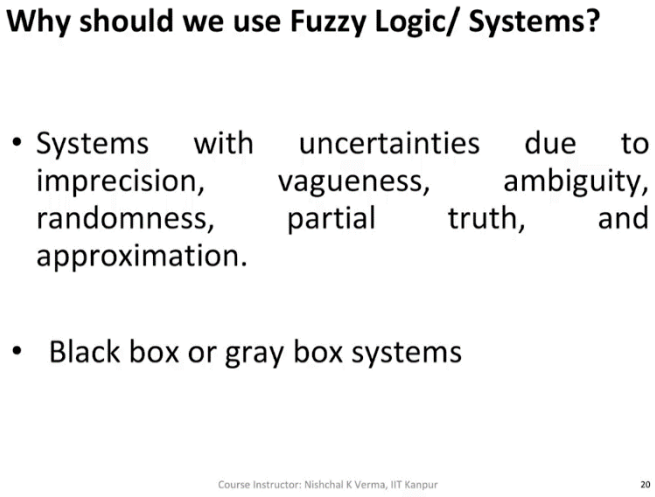

So, we use fuzzy logic when we have systems with uncertainties due to imprecision. I mean the systems which suffers from the uncertainty is due to imprecision, vagueness ambiguity, randomness, partial truth and approximation. Fuzzy logic can be very very helpful in managing with the black box model or gray box model of a system, many times we do not have the idea of the exact physical laws of the system, defining the defining the system and are many times the system which is which we are studying are trying to model that is not accessible to us.

So, we do not have all the physical laws which are governing the system in order to model the system mathematically. So, we cannot get the exact mathematical equations. So, when these situations occur we take the help of black box modeling where fuzzy system is also one of the tools, one of the agents, one of the methods we can manage we can we can model the system using black box modeling approach or the gray box modeling approach.

So, when we say gray box gray box means that a part of the system part of the system's mathematical equations are known or either known or can be known and that is how you know the gray box kind of system can be can also use the fuzzy logic or fuzzy systems theory in order to get the final model.

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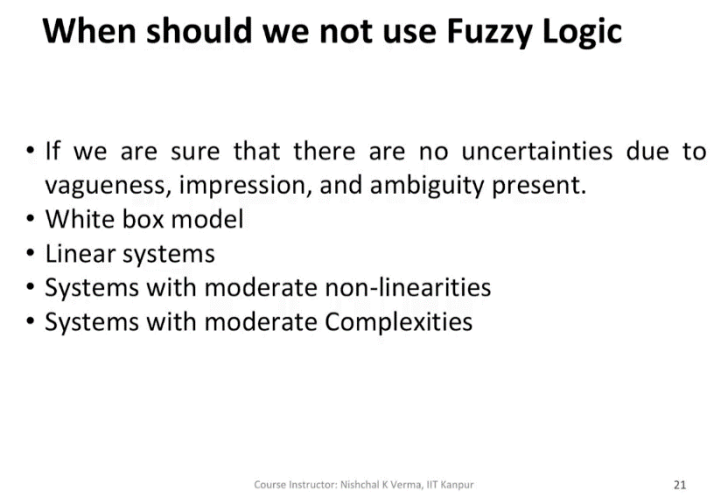

We should also know that when should we do not use the fuzzy logic like whenever we already have the physics of the model known; obviously, we can have the mathematical equations known, it means we have the model available mathematical model available. And when we have mathematical model available then of course, this kind of model is also termed as white box means the mathematical all the mathematical equations governing the model is known. So, we do not require any such agents like fuzzy systems theory or fuzzy based theory to go for this black box modeling approach.

So, in this case when the model is completely known then fuzzy logic is not needed and then here when we have a system which is a linear system, then also we do not need to use fuzzy systems theory for understanding the behavior or the getting the model and then systems with moderate nonlinearities we can use simple models and fuzzy logic is not needed. Also the systems with moderate complexities, so unless we have a very high complexity we should not use fuzzy systems theory for studying such models. So, with this now I would like to stop here and in the next lecture I will discuss some real time applications of fuzzy system.