Artificial Intelligence
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Lecture – 07
Logic In AI: Different Knowledge Representation Systems, Part - 1

So, in this set of lecture, we are going to talk about 1 of the most important topics in traditional AI. And I am using my words carefully, because now if you talk to an AI modern AI researcher, they will not go gaga about logic. 10 years ago, they would have gone Gaga about probability or probabilistic models. And these days they will gaga about neural networks. And we will study both of them. But logic was considered 1 of the most fundamental and important topics in AI, since the beginning of the field of AI.

And we have talked about situations where, you know our founding fathers were trying to prove theorems in logic, trying to solve everything through logic, all of 80s, all of 70s, a lot of 60s and 50s. What about logic and different kinds of logic and modeling a problem and logic and showing it in twice settings it gets you what you want to get, etcetera. Logic was the medium of conversation within AI system.

We are in the world of representation right now we have been trying to define representations that allow us to explain the problem to the problem solving agent. There is another way we need to represent things, which is knowledge.

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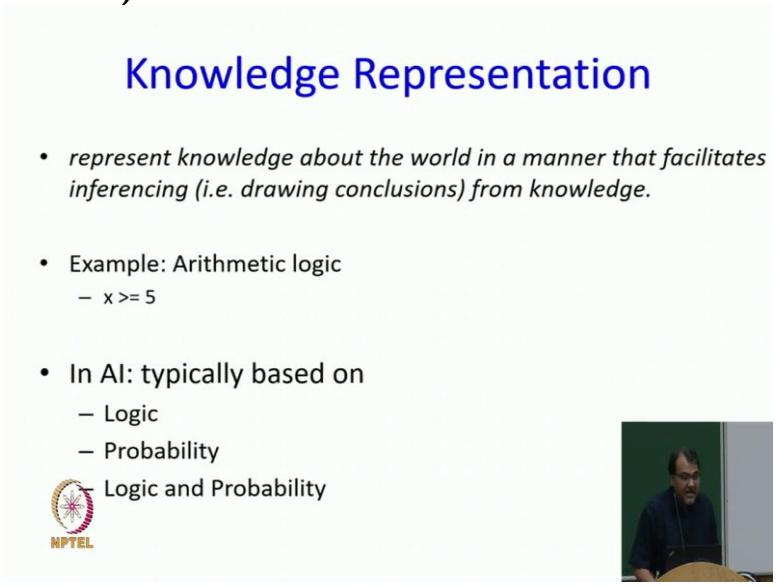

Knowledge representation is 1 of the fundamental tenants of AI. Represent knowledge about the world in a manner that it facilitates inferencing. Like I tell you x > = 5. You sort of know that it cannot be 4 it cannot be 2, it cannot be -3. If you do not know what it is? Maybe it is 5, maybe it is 25. Maybe it is 2000, but by expressing an assertion about the world, I reduced my space of models that I was considering. I have some variables; let us say in this case, I have a variable x.

And let us say I also have a variable y, for now. They can take any integer s value. I have many models of the possible worlds, I have many possible worlds. And these worlds each world is called a model. For whatever reason, this is just the jargon in logic, so each possible world like x = 7, y = -3 is the world, x = 25. y = -1000 is a world. These are possible worlds of my problem. If I make an assertion, like x > = 5, I reduced my space of models.

Now I know that any model in which x was -3 and y + 25 is no longer valid. Any model where x was -7 is not valid, any model x + 4 is not valid. So, we have some knowledge about the world. This is how we specify the problem to any agent we tell them some knowledge of the world. Which language to be tell that in we tell that in typically some language of logic at least if you are in the 70s or 80s.

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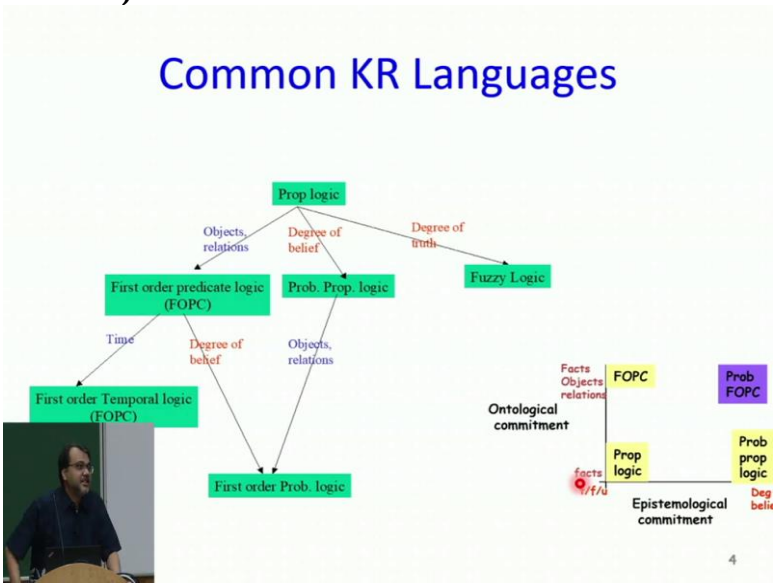

There are many kinds of common knowledge representation languages. These are called knowledge representation languages, propositional logic is 1, first order logic is another, first order temporal logic is first order logic with the an element of time in it. Probabilistic

propositional logic we will study that Bayesian networks is 1 example of that. We are saying that we do not know whether it is true or not, but it may be true with probability something.

Fuzzy logic we are saying something else. All of these logics are making different kinds of ontological commitments and different kinds of epistemological commitments. These are big words. Let us understand that ontological commitment says what am I modeling? What are the atomic units? What are the elements of my sentence? The elements of English would be words. What would be equivalent elements of propositional logic they will be?

Can you guess, you know propositional logic, Boolean logic, the elements would be propositions? A, B they are the atomic units, then you can say A and B, not A, not A or not B or C, but A is a basic proposition and they are why it is called a proposition logic fact. So, my basic unit is a fact in a propositional logic setting. And what do I know about them, I know that a fact is either true, or the fact is false, or suppose I tell you, x > = 5.

What can you say about x = 6? It could be true. It could be false. I do not know. And so in our world, I would either know something to be true. Or I would know something to be false. Or I would not know something to be true or false. Let us say unknown. So if we think about propositional logic, my basic elements through which I make assertions and everything are propositions are facts. They are what I model in my ontological commitment.

Propositional logic sits where my ontological commitment is my ontology only maintains facts and what do I know about it? They are my epistemological commitment. Epistemological thing means what I know about it. So what do I know about it? I know that it is either true or false or I do not know unknown. Now, let us talk about slightly different logic settings like first order logic. In first order logic, my element basic unit by which things get joined is not a fact.

How many of you have studied first order logic? How many you at least know what is first order logic, basics of first order logic? Then you have not done any logical, you have not done this for every x, there exists y such that r x y, you have never studied this? Where have you studied discrete maths? So, you have studied first order logic. So, I defined objects, I define relations on the objects and relations on the objects make facts. Let us think about it again, we have been talking about atomic agent for a very long time.

Let us take the example of our class. So, earlier we gave the example that if Parth is sitting in chair 25, Vishwajith is sitting in chair 37, Kiran is sitting on chair 49 etc, etc, etc. This whole state I am going to give a number. They are where we started from the very beginning of the class. And then we said they are ridiculous. Let us say we make assertions of the fine, we did not say that but we can say that we will make facts, each fact would be true or false.

So 1 fact could be Parth in chair 25, another fact would be Parth in the chair 26 another factor to be Parth in the chair 37. And then specific facts would be true in our state and specific facts will be false in our state. And that would be which logic, propositional logic, because each fact is my unit. Now somebody can say this is ridiculous again, why are you saying Parth is in 25 is 1 fact, second Parth is 26 is 1 disconnected fact. It should be connected to the fact that they are both facts about Parth.

So let me say Parth is a person and chair is a chair. So 1 kind of object is the person another kind of object is the chair. I have 100 students in my class. Those become my 100 person objects. I have 150 chairs in my class those become my 150 chair objects. And then I have a relation sitting in and this relation takes first argument as a person and second argument as a chair. So, this relation is also called predicate, by the way, predicate fluent, these are all words of the same feather.

So, I will say that now the sitting in part 25 is my fact and not sitting in part 26 that is also a fact. And when I define my language this way, this is called first order predicate logic makes sense.

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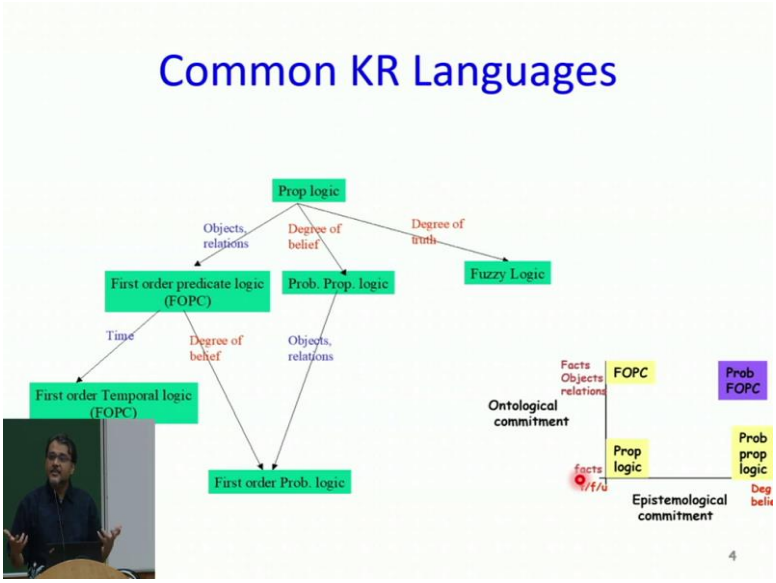

So, in this world of first order calculus, first order predicate logic, my ontological commitment, what does my ontological elements? Objects, relations between the objects and facts are formed when relations are applied on objects. In the language of AI atomic agent was a state propositional definition of a state variables and a specific assignment to all propositional variables gave me a state.

So, a state specific assignment complete assignment of state variables makes us state. And in first order logic I have even 1 level of indirection objects relations. Then I apply or relations on objects and that give me my state variables and I numerate all the state variables that gives me my state. So, notice what I am doing, I am reducing the amount of effort it takes for me to specify a problem by incorporating more and more structures are the real world into my representation?

And what is my epistemological commitment and first order logic was the same. Each fact can either be true or false or unknown Parth is sitting in C 25. I know to be true participating in C 26. I know to be false. The Vyansh is sitting in C 28. I do not know. Because I do not know how what did you answer looks like, where is the Vyansh by there? He looks like that. So he is not sitting in chair 28.

Now I know. So by asking a question and getting the answer, I reduced my model of the world. I asked for some information. I got that information. By using that information I got rid of all those models where the Bianchi was sitting in seats 28, 29, 30, 35, I know he is sitting in chair 77. And only those models remain, and so on and so on and so on. So do you

now understand the difference between ontological commitment and epistemological commitment?

You are learning these terms for the first time, you have some intuition now. Let us look at some other examples. For example, probabilistic logic, you know, when I have probabilities over facts, so my ontological commitment stays the same. I know, in my logic, I have facts. We can have the same fact, Vyansh is sitting in C 26. You can have the same fact. Now, what do I know about it? Let us think about it. Either, I know it to be true. I know it to be false. And when I do not know, I might say that I do not know where the Vyansh is sitting.

But most likely the person sitting in the chair 26, he is not Bianchu. Because I have vague memory of what Bianchu looks like. Now it is possible that you are Bianchu I do not know for sure. But I believe that you are not. So therefore I will say the Bianchu sitting in chair 26 is probably point 1, or something like that. And if I do not know anything, what it looks like, I can just say that, you know, the probability they are sitting in every chair is 1 over 150.

I am just being uniform, ignorant. So the point is, what am I modeling in logic, I am only modeling true false and nothing else. I do not know in the middle. But now I am modeling my degree of belief. I know it to be true, I know it to be false, but in the middle, if I do not know it to be true or false, I may have preference of most likely whether it is true or most likely whether it is false. Now there are other examples.

If I say on 23rd May 1975, did it rain in Delhi? We had a question. Now, do you know it the answer? Somebody knows the answer. Most probably No. What is your name? Kashika says, it may. So it is most probably not, but do you know the answer? You do not know the answer. You are only making an educated guess. You have some belief degree of belief that it could have rained who knows what happened?

What was the weather condition in 1975 they say it has become hotter, maybe the seasons have shifted, whatever it is. But based on your current knowledge of the world you believe most likely did not rain, it is may must have been extremely hot. So but I can ask a similar question that on 1 December 1975 did it rain in Seattle? And for people who know Seattle will say, I do not know, but most likely, yes. Because in Seattle, it only rains from August to July.

You guys are slow in identifying jokes. You know, once they asked in a when does it not rain in Seattle? And the person is founded, I do not know, I am only 4 years old. So, I mean, that is the joke about Seattle. Anyway. So what is my epistemological commitment, my epistemological commitment is I know, to be true, I know to be false, but when I do not know I still have a degree of belief. And therefore it is much more expressive than you know, logic because logic only says unknown.

Then there is something called fuzzy logic, in the middle, you can also do probabilistic first order logic. You have facts, objects, relations, and then the abilities on top of it. And believe it or not in the late 90s, and all of 2000s this was the range, or at least 1 of the most important ranges in the field of AI. And 1 of the leaders of this area in India is our close collaborator, Parasingla who was a student of Pedro Domingos who started this very beautiful famous model called Markov logic networks.

And notice the word Markov and logic. It is logic. And it is also Markov, which was referring to probability. And there are many other models that came out probabilistic relational models came out of Daphne koehlers group. You know Daphne Koller? Daphne Koller was 1 of the first founders of Coursera she was at Stanford at the time as a professor, very, very famous and well known AI researcher.

These are people you should definitely check out you should know what they stand for. In fact, ever if you do a course on probabilistic graphical models, a course that sometimes gets offered in our department, and in many other IITs and in areas in the world. And universities in the world, you will most likely be referring to the book by Daphne Koller. So, she and others at the time define this whole area of statistical relational learning.

Again statistical is a term for probability and relation is a term for first order. Very important stuff at the time again, it might come back into in prominence, who knows in the next few years. So this is about combining probability and logic. But what is this fuzzy logic business? Is it the same or is it different? The fuzzy logic says something very interesting. It says that earlier facts could only be true or false or unknown. But now the truth itself is fuzzy.

Like I asked you the question, what is your name? Harkeerath. Is harkeerath tall? Now this notion of height and tall, specifically, it can you specifically say that this is true or false? Well, if he goes to China, he might be tall. And if he goes to the US or Australia, it might not be considered tall. But notice that the concept itself is a fuzzy concept. You know, here is another beautiful example. You know, you take 2 puppies.

1 of them who is red and another who is brown and you close your eyes, you put them in a box, you close your eyes, you take out a puppy, and you do not know whether this puppy is red or brown, is this fuzzy logic or probabilistic logic? Probabilistic logic, I do not know whether it is true or false. I do not know whether it is brown or red, but it is either brown or red. Now they allow them to mate, let us say they are of opposite genders, and lots of puppies come out.

Then, I take this puppy out and look at the puppy and ask the question, is this puppy red or brown? Now is this propositional logic, fuzzy logic or probabilistic logic? This is fuzzy logic. This is not neither red nor Brown, it is somewhere in the middle it is probably 0.7 red and 0.3 Brown. When your truth becomes non binary and a number, then you get into fuzzy logic. But you can still not know it.

You can still close your eyes and take a puppy out and ask the question is this puppy that red or brown and in this case it will be probabilistic fuzzy logic. So now you are able to see that difference in your commitments. Now, I shall point out that fuzzy logic has gone sort of out of circulation; it was the big deal in the 80s. You must have or at least your parents have heard about washing machines which have fuzzy logic in them.

You may not hear this term anymore, because those things are passed away. But when I was a kid, it was a big thing, washing machines has fuzzy logic in it, Japanese. Fuzzy logic was considered 1 of the ways in which the problems of logic can be solved and we will talk about the problems of logic when we come to probabilistic models. But over time, this has gone out of circulation, because people found some technical inconsistencies in fuzzy logic and other kinds of things came up, which became important.

I would point out, that while when I was growing up as an AI researcher, as a student and so on, nobody used to talk about fuzzy logic where I was. Some of the ideas of fuzzy logic are

starting to become useful in neural networks. So in our world comes full circle. When I was a student, nobody used to talk about neural networks. Now everything is in neural networks. Nobody used to talk about fuzzy logic, they still do not, but some ideas have been taken.

For example, if I have a variable with truth point 7, and another variable with truth point 5, what is the truth of the conjunction of these 2 variables A and B? This is a question that fuzzy logic has to deal with, because my truth is always fuzzy and so now if we talk about output of A and B, A or B, not A and so on, so forth and you have to have a real valued answer for everything. And all of those ideas have become extremely important in neural networks. And we would not go there.

I should also point out there is 1 other thing is you will not study which became a big thing but is no longer that bigger thing called non-monotonic logic. So up, until now, I have been telling you, you give me a new fact. And I reduce my space of models. But can it ever happen that you give me a new fact and I increase my space of models? If that happens, it is called non monotonic logic. For example, I tell you that I have a bird and animals.

Let us say I tell you, I have a living being raised here, it could be the people tree, it could be a human, it could be an eagle, whatever, right? I have lots of models. And I tell you, this living thing is a bird. So now suddenly, you have reduced your space of models and you say, I know if it is a bird that it flies. So therefore, I have reduced my space gotten rid of the people tree and a human and I have it do is just a space of models. And I can sort of say that it flies.

Because I know that if it is a bird, it flies, but then I tell you, it is a penguin. And as soon as I tell you, it is a penguin, you say, it no longer flies. What did I do? Basically, I told you something that if it is a bird that flies but then I gave you an exception. This happens mostly except when it is a penguin or an ostrich or something. So when you do this logical reasoning, then every time you get a new fact, you start making assertions.

But then as soon as you get a new fact, which is an exception fact, then you go back on your session, if you have this kind of phenomenon, then this is called non monotonic logic. So in your brain, you must be thinking that there may be other ways of dealing with it. And we are not getting into the details. I am just giving you the term non monotonic logic just for your high level understanding.

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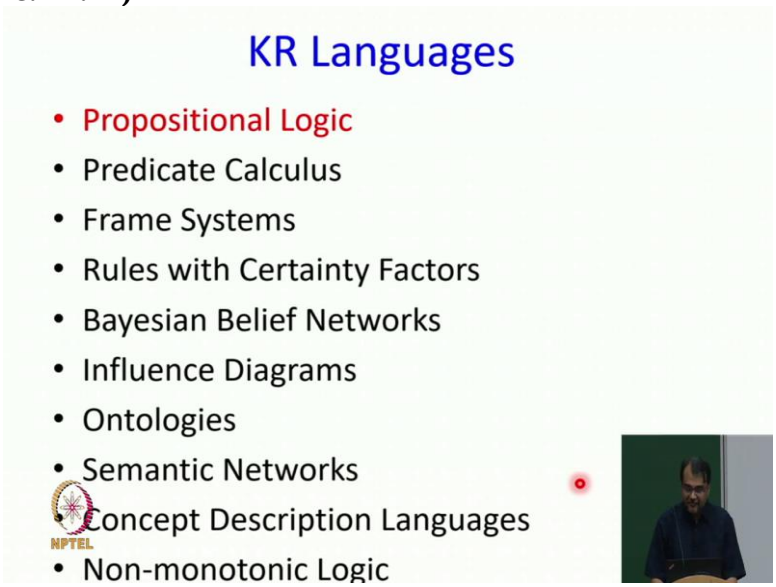

And there are many different kinds of knowledge representation languages propositional logic predicate calculus, frame systems certainty factors Bayesian networks influence diagrams ontologies semantic networks, concept description languages non monotonic logic, fuzzy logic, description logic there are just too many of them. Okay. And of course in our class we will only be studying propositional logic and then probabilistic propositional logic, we will be Bayesian networks.

So this whole, like the most traditional AI courses will go at depth about first order logic. But I am taking this executive decision that we do not have to cover it because in the modern world, those ideas are not the most important ideas that we need to worry about. But still, you have to have some high level understanding.

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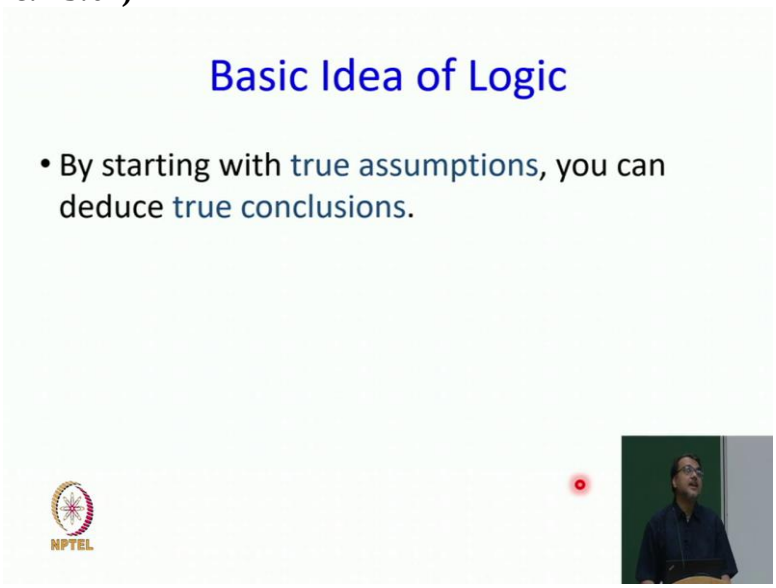

And what is what are you going to study? Well, basically what you are going to study is I will give you some true assumptions, and then you have to deduce true conclusions and that is the basic idea of logic.

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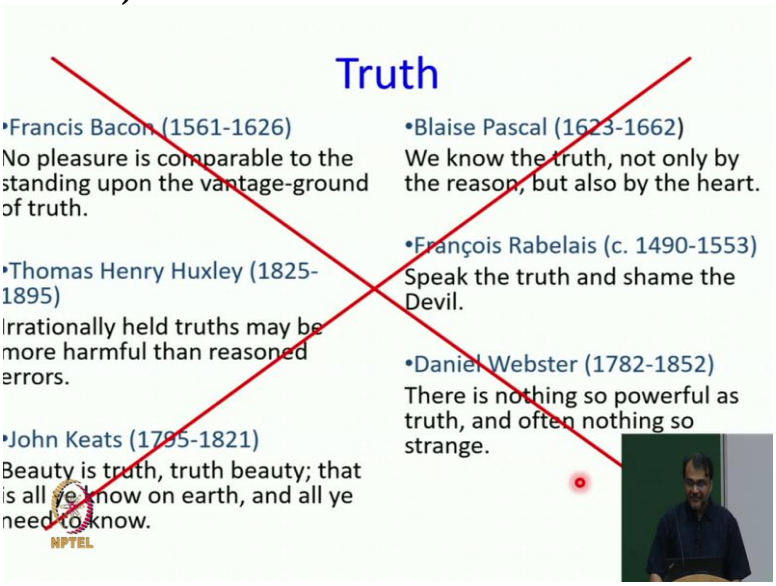

And what is true. This is a filler topical question and we will never talk about it through means 1, and false means 0. And they are sort of what we are going to talk about. We are computer scientists, at 1 step up, you can become a philosopher and then you can say that you know, truth is, we know truth only by reason. Sometimes, you know truth by heart, nothing more powerful than the truth and you can start debating about what is truth and what is not.

For us it is just value 1 is truth. I think this is a good point to stop. In the next class, we will start talking about different components of a knowledge representation system, as they are studied in that logical framework. Thank you.