Fundamentals Of Artificial Intelligence
Shyamanta M.Hazarika
Department of Mechanical Engineering
Indian Institute of Technology – Guwahati

Lecture – 10
Introduction to Knowledge Representation

Welcome to fundamentals of artificial intelligence. Today we will review knowledge representation and reasoning particularly to motivate the introduction of formal logics as knowledge representation formalism for Artificial Intelligence. Knowledge representation in reasoning forms the backbone of any intelligent behaviour through computational means. Infact human intelligence is also driven through knowledge.

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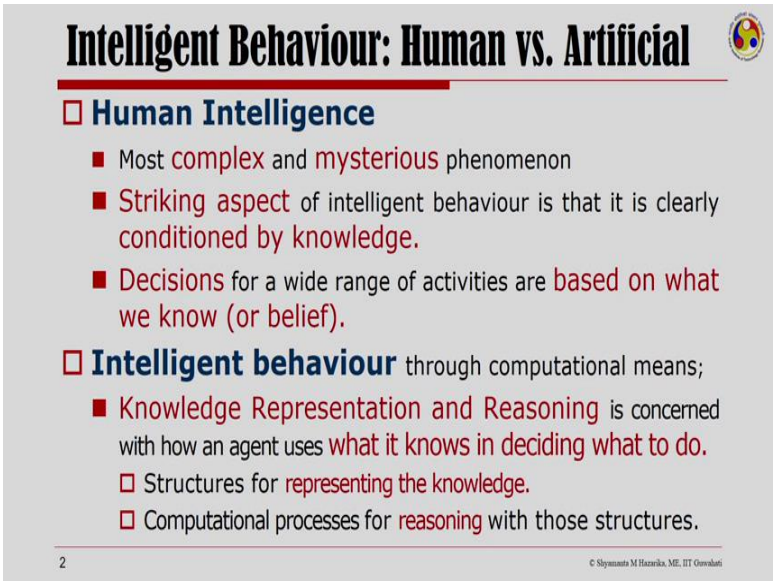

Most complex and mysterious phenomena is intelligence that human exhibit. But the striking aspect of intelligent behaviour is that it is clearly condition by knowledge. Decisions for a wide range of activities are based on what we know or belief. Intelligent behaviour that we arrived through computational means knowledge representation and reasoning allows an agent to decide what to do based on what it knows.

What is important for such a system to be in place is to have structures for representing the knowledge and then certain computational processes for reasoning with those structures. This is what we will look at today and try to motivate how formal logic forms a very interesting choice to be taken up for representation of knowledge in AI. But then what is knowledge in order to understand knowledge. We start with the basic definition of what we mean by data.

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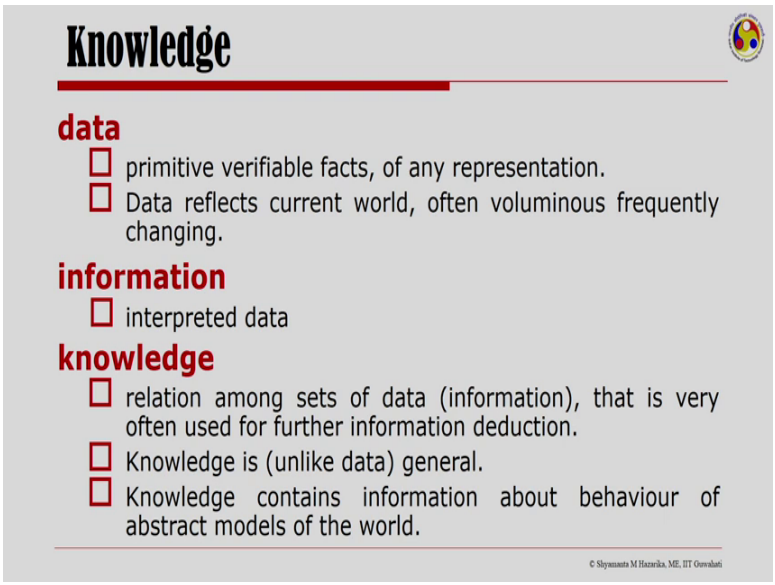

Data is primitive verifiable facts of any representation and data reflects the current wall data is often voluminous and it is frequently changing. As you process data you get information. So any interpreter data is information. Knowledge is one step ahead of this. It is about the relation among sets of data that is very often used for further information deduction. Knowledge is unlike data general knowledge contains information about behaviour of abstract models of the world.

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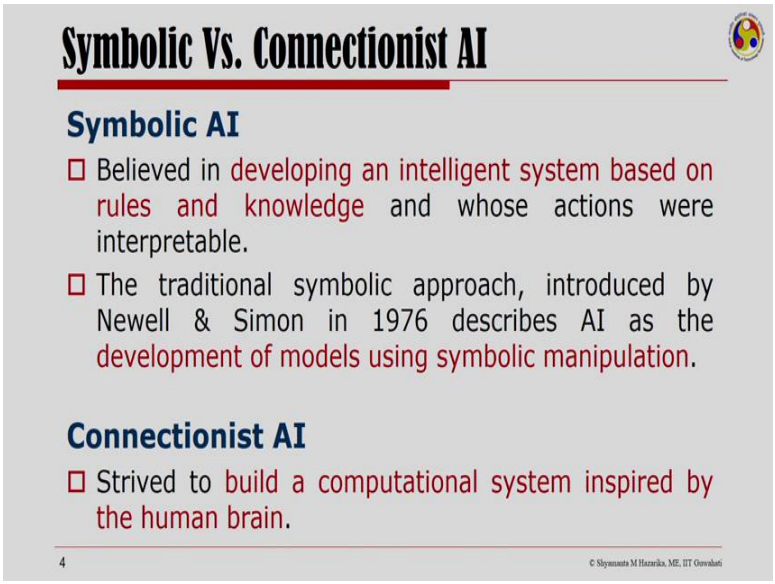

Now from the very beginning of a there is been two approaches to look at artificial intelligence. One believed that developing an intelligent system was to be based on rules and knowledge and any intelligent behaviour is actually manipulation of symbols. This approach to AI is called the symbolic AI. So, the traditional symbolic approach was introduced by

Newell and Simon in 1976. And describes the development of models using symbolic manipulation then there is the other approach to AI.

Which is call connectionist AI, the connectionist AI is trying to build a computational system inspired by the intricacies of the human brain we will not going to the details of whether or symbolic AI or connectionist AI is going to win the race of creating an intelligent system, but then we like to point out that there is a realisation that their needs to be some convergence of both the approaches to really have an interesting intelligence system in place. We will talk of that convergence here and only focus our attention on symbolic AI.

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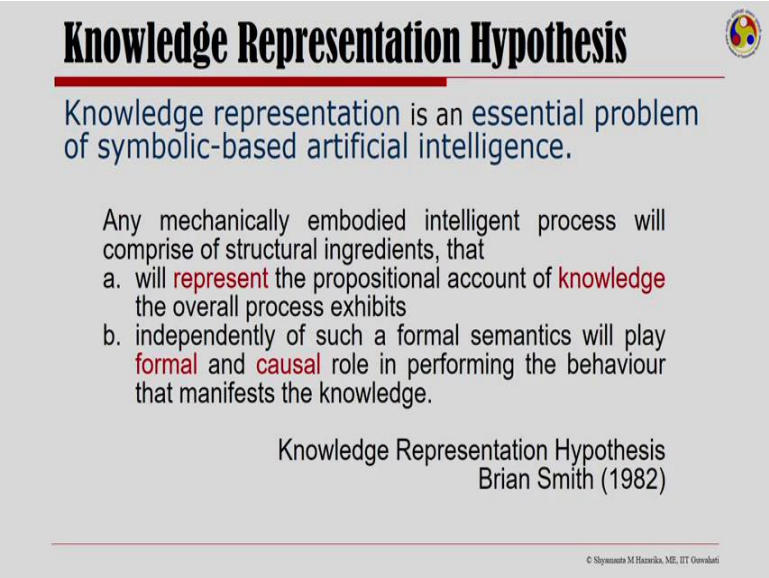

So, knowledge representation that is based on the knowledge representation hypothesis is an essential problem of symbolic based artificial intelligence. The knowledge representation hypothesis put forward by Brain Smith in 1982 states that any mechanical embodied intelligent process will comprise of structural ingredients that will represent some of the prepositional account of knowledge.

An independently of such a formal semantics will play formal and causal role in performing the behaviour manifests the knowledge.

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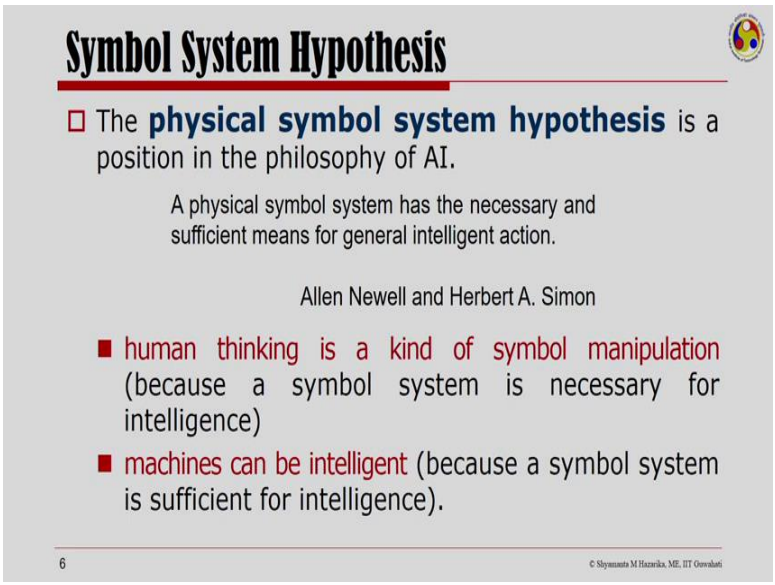

The symbol system hypothesis is a position in the philosophy of AI which was put forward by Allen Newell and Herbert Simon, the physical symbol system hypothesis states that the necessary and sufficient means for general intelligent action is a physical symbol system. Now there are 2 things to observe from this statement. One that human thinking is a kind of symbol manipulation because a symbol system is necessary for intelligence that is what they have stated.

Therefore we can say that human thinking is a kind of symbol manipulation. And the other is that because a symbol system is sufficient for intelligence we could have machines that can be intelligent.

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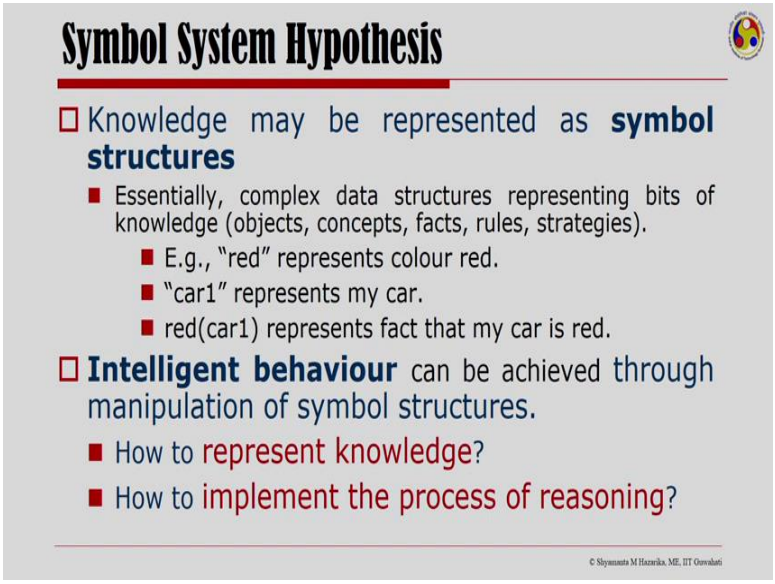

According to the symbol system hypothesis knowledge may be represented as symbol structures. Essentially we would have complex data structures representing bits of knowledge. Like I would be talking of objects, concepts, facts, rules, strategies and we could use different representations to show what we mean by these different things. For example I could use a string like red to represent colour red or I could use a string like car1 to represent my car.

And then if I write a very simple statement like red car 1. I would then be able to immediately see that these represent the fact that my car is red. Intelligent behaviour thereafter can be achieved through manipulation of do symbol structures. Therefore it is important for us to answer two questions. 1, how do we represent this knowledge in form of structures? And how do we implement the process of reasoning?

In order to understand this letters first try to understand what we mean by representation. As I was telling you I could use a string like a red to mean the colour red or a string like car 1 to mean that, that is my car.

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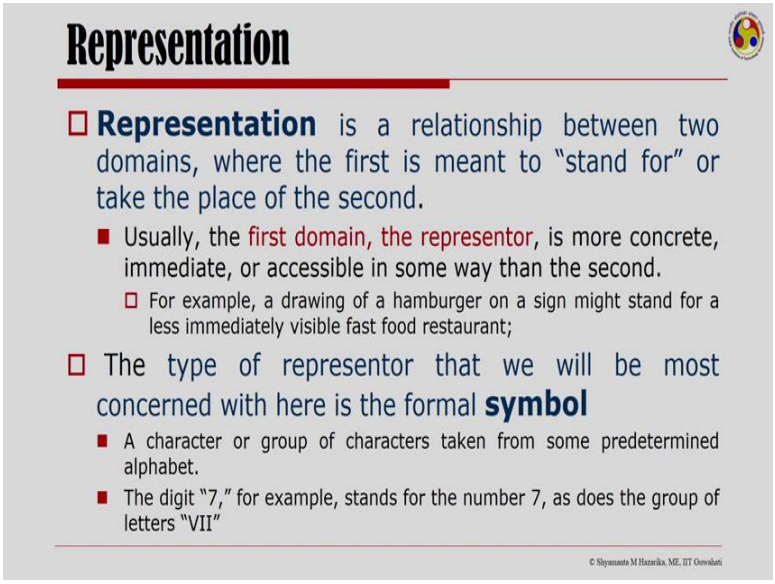

So, representation is a relationship between two domains. The first is meant to stand for or take the place of the second. In the example that I was illustrating red is standing for the red colour. Usually the first domain the represented is more concrete immediate and accessible in some way then the second. It is like you are driving on a highway and you see on a sign post a hamburger. Now immediately, you know that some fast food restaurant is nearby.

So, here is, the hamburger representing the fast food restaurant the type of represented that will be most concerned with here would be formal symbols. So these are characters or group of characters taken from some predetermined alphabet. Like for example the digit 7 stands for the number 7 as the group of letters V 11.

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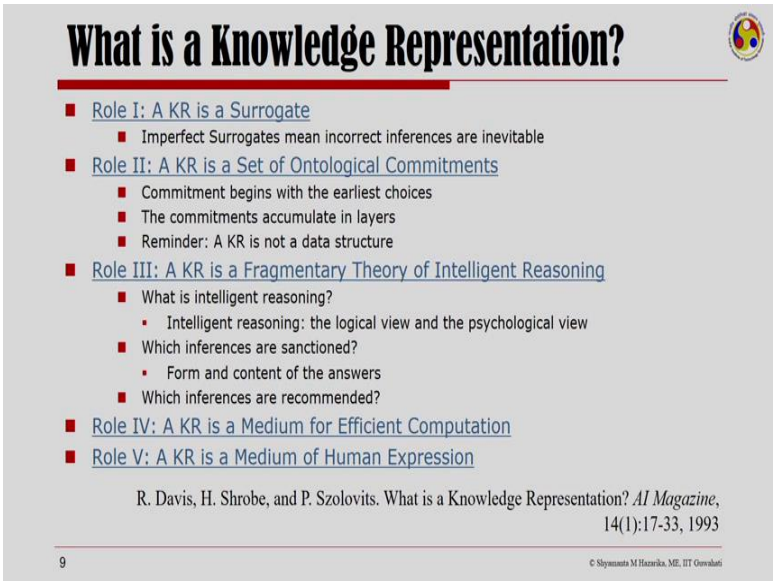

What is knowledge representation? to answer this question what is knowledge representation? The best reference that we can think of is the paper by Devish, Shrobe and Szolovits on what is knowledge representation? According to them a knowledge representation has the role of a surrogate that is why I should look at the representation is a surrogate of what is being represented. And it would be a set of ontological commitments that I make.

Now, one needs to remember at this point that a knowledge representation is not a data structure. It is a set of ontological commitments about what is there that I am representing? The third role of knowledge representation is that of a fragmentary Theory of Intelligence reasoning? Now this brings us to the question of what is intelligent reasoning. Intelligent reasoning I could take the logical view as well as the psychological view.

But then here we keep ourselves restricted to the logical view and we will look at which inferences are sanctioned which influences are recommended. The fourth rule of knowledge representation is as a medium for efficient computation. And then they have listed fifth and the final role of knowledge representation as a medium of human expression. We will look at each of them one by one in the next couple of slides.

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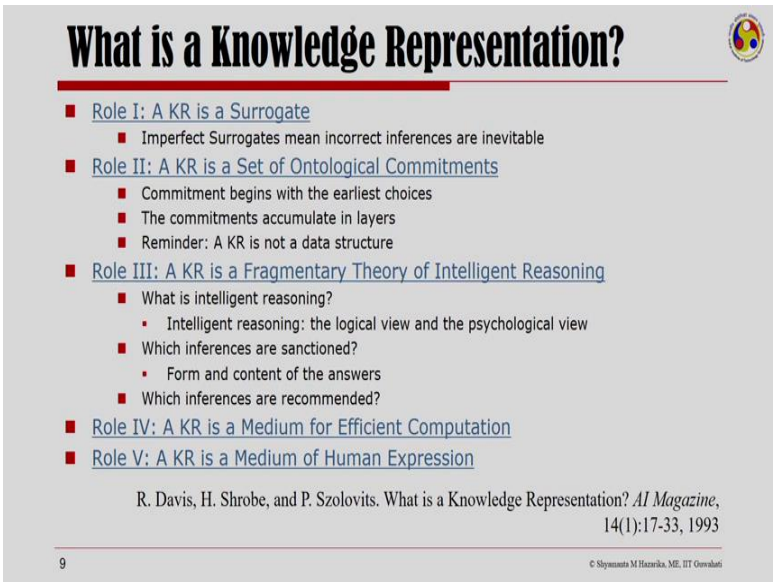

Let us look at what we mean by knowledge representation as a surrogate when we say knowledge representation is a surrogate we need it is a substitute for the thing itself. So it is used to enable an entity to determine consequences by reasoning about the world. Next it is a set of ontological commitments that means having a knowledge representation. I am now able to answer a question like in what term should I think about the world.

Now this is one important aspect that we need to understand that ontology means the wall as we see it. In what terms should I think about the world the knowledge representation give me an answer to that question.

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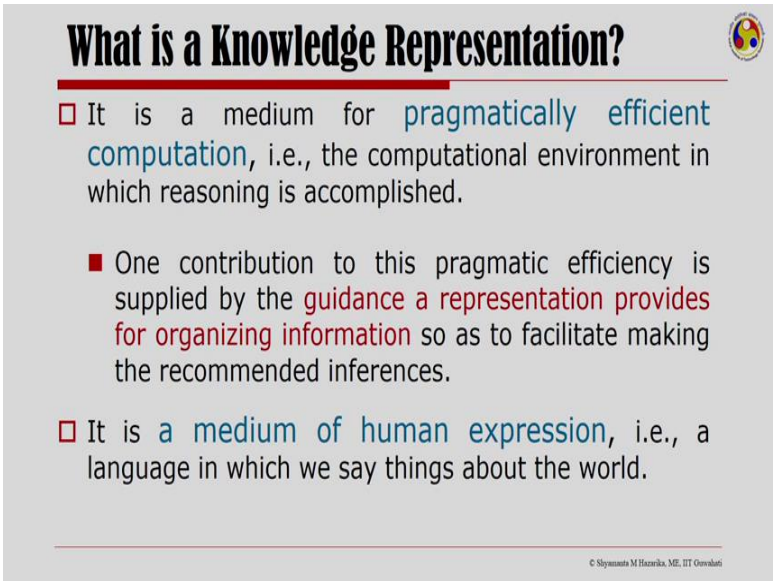

As a fragmentary Theory of Intelligence reasoning it could be expressed in three components one the representations fundamental conception of intelligent reasoning, two the set of inferences the Representation sanctions and three the set of inferences it recommends. Finally knowledge representation is a medium for pragmatically efficient computation that is it provides a computational environment in which region is accomplished. Now one contribution today's pragmatic efficiency is supplied by the guidance representation provides for organising information.

Representation allows you to organise information in the most efficient way. So, as to be able to make the recommended inferences from it, it is a medium of human expression that is, it is a form of language in which we see or say things about the world.

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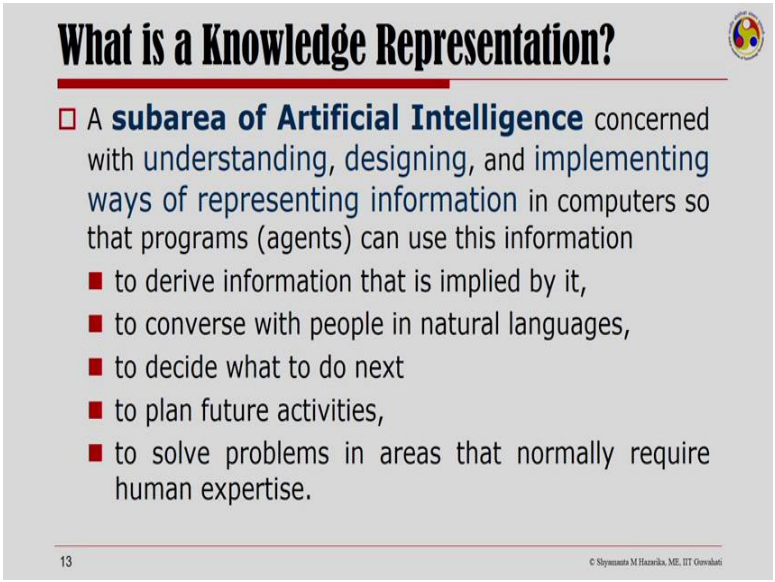

So, now it is representation as I have been emphasizing from the beginning is an important sub area of artificial intelligence which is concerned with understanding designing implementing ways of representing information in computer, so that programs are particularly intelligent agents use this information. Now that information would be used to derive new information to converse with people in natural languages.

To decide what to do next that is to take decisions, to plan future activities and to solve problems in areas that normally required human expertise.

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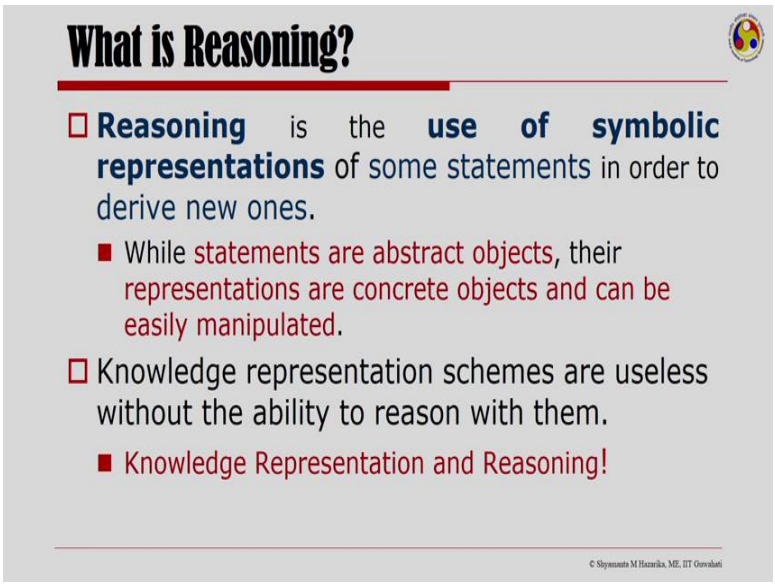

Let us now focus on what we mean by reasoning. Now, having said that representation is about getting to some symbols, reasoning is the use of the symbolic representation of some statements in order to derive new ones from them. One must realise that statements are abstract objects. Their representations are the concrete objects that we have created. And we can easily manipulate.

The knowledge representation schemes would be useless without the ability to reason with them and that is why we say knowledge representation and reasoning together with not only look at the representation part reasoning is an integral part of knowledge representation. And that is why the term is knowledge representation and reasoning.

Now how does the knowledge representation and reasoning work one realisation that one needs to have even before you start working with knowledge representation and reasoning is that any form of Intelligence requires knowledge.

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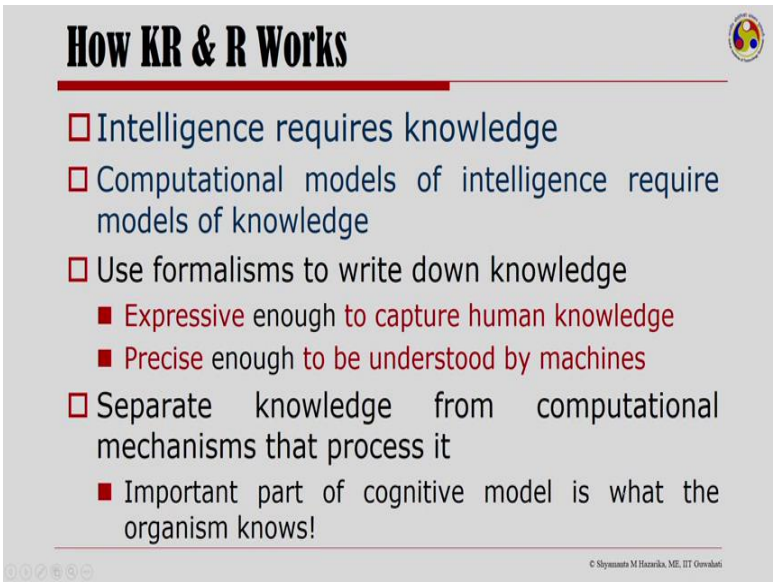

And a computational model of Intelligence requires models of knowledge on which to work on to get or infer the knowledge. Use formalisms to write the knowledge and then this formalism must be expressive enough to capture human knowledge. They must be precise enough to be understood by machines. So this is something that I would love to emphasize one more time that when we are trying to use formalisms to write down the knowledge for a given problem.

We would definitely want them to be expressive so as we can capture as much human knowledge as possible. But then it needs to be precise as well to be understood by the machines. Separate knowledge from computational mechanism said processor it is very, very important. We need to understand that the knowledge and the computational mechanism that process that need to be separate.

And that is why I am precise in the beginning that knowledge representation is not about having a data structure. So there is a important part of cognitive model in what the organism knows but then we should not mix both the knowledge and the computational mechanism of a system when we are trying to create an intelligent system with the knowledge representation reasoning.

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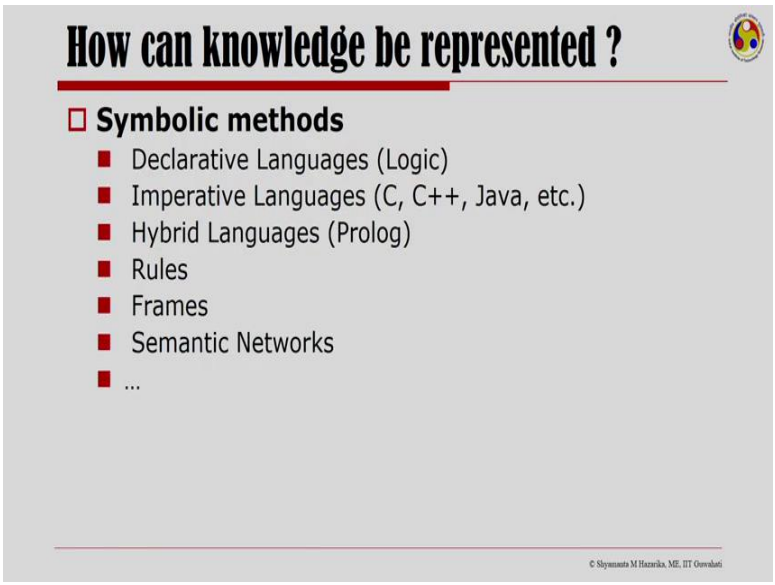

So, the next question arises is how can knowledge be represented? In the very beginning I have pointed out that there are two approaches to AI. One, the symbolic AI which is about creating intelligence to manipulation of symbols the other approach is the connection is there which is about creating the computational model of the human brain depending on which approach to take.

You could have symbolic methods of representing knowledge which would involve things like declarative languages, imperative languages, hybrid languages like Prolog, rules, frames semantic networks so on and so forth.

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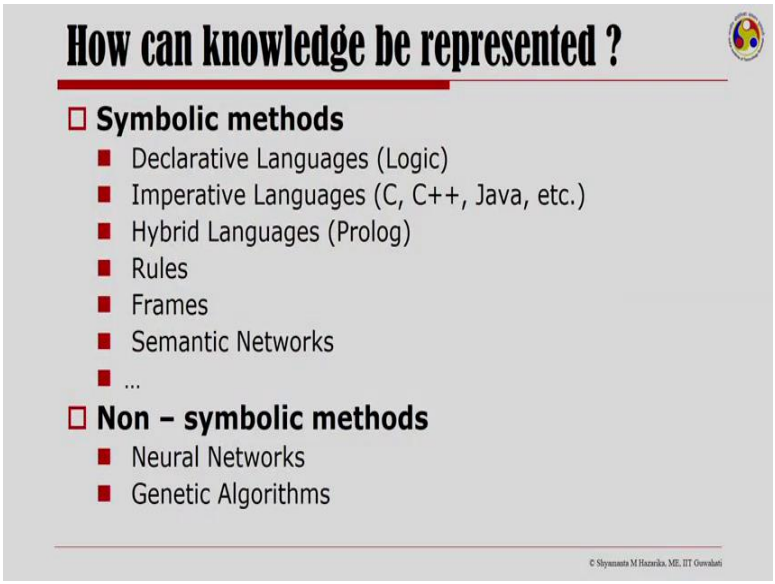

We could have non symbolic methods of knowledge representation the popular among them being neural networks and genetic algorithms. Now let us quickly focus on what we mean by knowledge representation languages.

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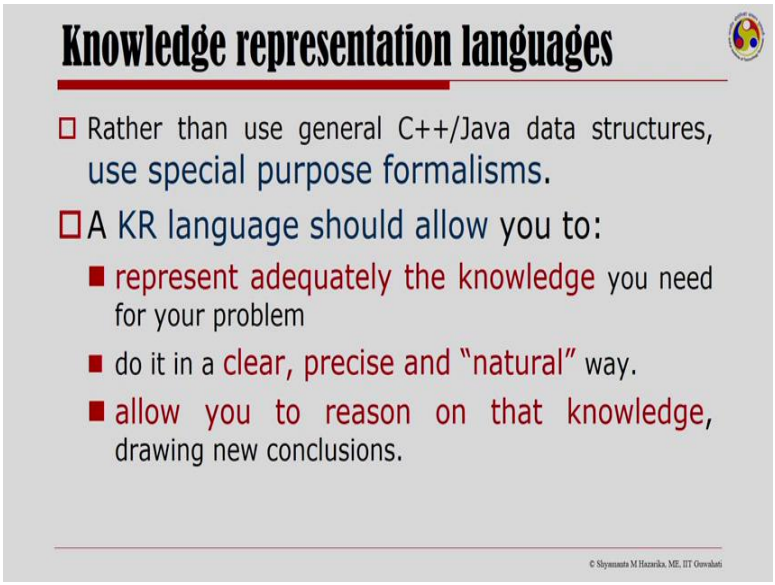

Now rather than general purpose languages like C++, Java knowledge representation requires use of special purpose formalisms. In knowledge representation language should allow one to represent adequately the knowledge you need for the problem. Two do it in clear precise and natural way three allow you to reason on that knowledge drawing new conclusions. We will look at each of them one by one.

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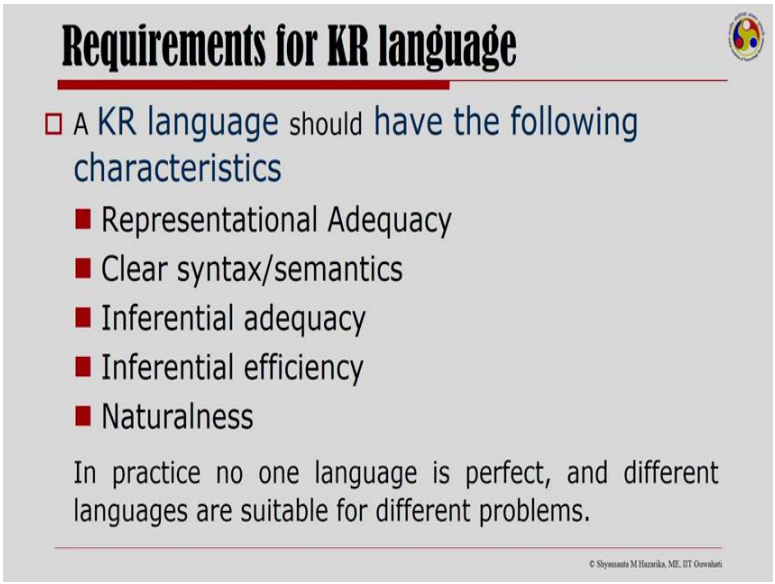

What are the requirements for a knowledge representation language? Knowledge representation language should have the following characteristics. One, it should have

representational adequacy. It should be good enough to represent the problem that I am thinking of representing. So it must be expressive enough. To cover all the ideas that needs to be represented.

It must have clear syntax and semantics. How to write a particular proposition in that language and what is the meaning associated with that proposition it needs to be very clear. Third, it must have what is call inferential adequacy? One needs to have the ability to derive new knowledge from the given set of statements in the knowledge representation. That is one would love to another or what we say the KR language should have inferential adequacy.

It must be that when I am deriving new knowledge from existing statements in the knowledge representation, it should do it efficiently and that is what is call inferential efficiency. And finally the knowledge representation that I have should have some naturalness in the sense that a human being should be able to make out what is being represented by actually looking at it and trying to get the essence of the thing.

We will come back to this when we will be talking of what we mean by KR language be natural. Now improve this no one languages perfect and different languages are suitable for different problems.

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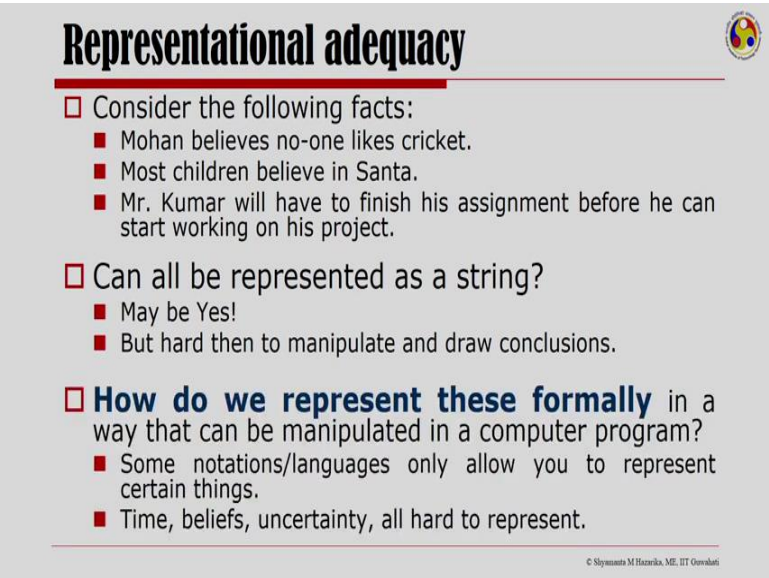

Let us first try to understand what we mean by representational adequacy. Consider the following facts here. The first statement says Mohan believes no one likes cricket. Second, statements says most children believe in Santa and the third statement says Mr Kumar will

have to finish his assignment before he can start working on his project. Now could have use the language like C and represent these statements as strings.

Then I represent all these are strings. Maybe yes, but then the question is if I want to manipulate and draw conclusions I will have a lot of a problem. So how do we represent things formally in a way that can be manipulated in a computer program? That is what is answered by the idea of representational adequacy.

Some notations all languages only allow you to represent certain things. That is fine. But if it represents it should be manipulable. Now concept like time believe uncertainty all are hard to represent. Infact in this course, we will look and how to represent uncertainty and also will talk of how to represent believes and time and some point of a discussion.

A representation need to have when defined syntax and semantics. So, knowledge representation languages should a precise syntax and semantics. One must know exactly what an expression means in terms of objects in the real world. This is because one needs to understand. That I am doing knowledge representation and reasoning I am actually mapping the real world to representation of facts in the computer.

And then this is where inferences are being drawn and new conclusions are being gathered. Now, after new conclusions are being gathered. It is important that I can map back to the real world. If I do not have clear semantics on what is the meaning of each of the symbols that I am using here this mapping back to the real world will be either ambiguous or would not be possible at all. So, one needs to have precise Syntax and semantics for a knowledge representation language.

This is something that one needs to understand very, very clearly. This is precisely because I bring from the real world into the computer the facts of the world in terms of a representation that I myself define and use and that representation must therefore have precise meaning associated with every symbol that I am using. So, we should exactly know what an expression means in terms of objects in the real world.

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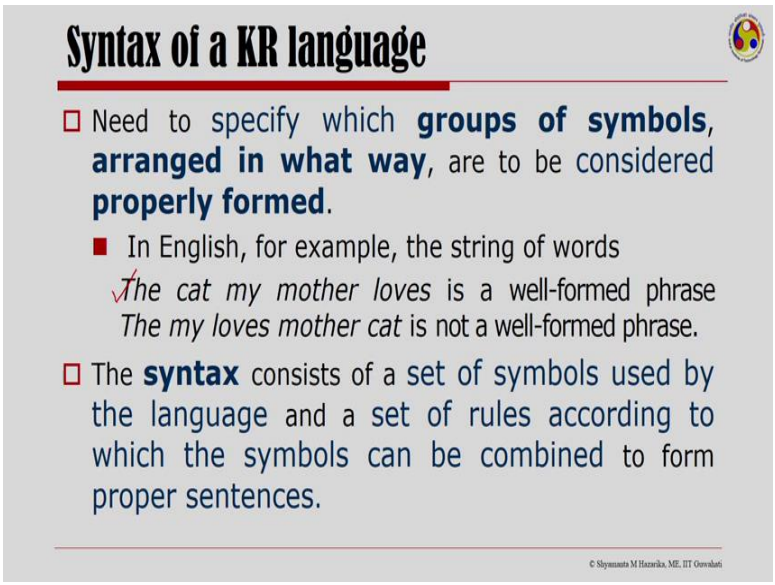

Now will take a moment to understand what we mean by Syntax of a query language. In any knowledge representation that would be a group of symbols arrange in some way. But then what should be considered properly formed. And what would not be considered properly formed is defined by the syntax of that knowledge representation language. So in English, for example if I take two strings now, the first string the cat my mother loves actually is a well formed phrase.

Where is if you take the next one the, my loves mother cat is, is not a well formed phrase. And therefore the first pass is the syntax of English second does not the syntax consists of a set of symbols used by the language another set of rules according to which the symbol can be combined to form proper sentences. So, we need to understand that for a knowledge representation language we must have precise Syntax defined.

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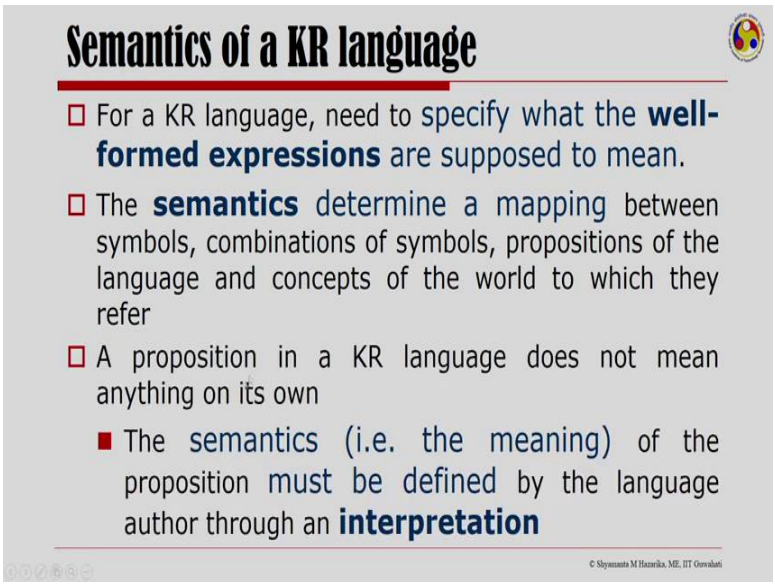

The semantics on the other hand specifies what the well formed of expressions of a knowledge representation language are supposed to mean. The semantics actually is a mapping between the symbols combination of symbols preposition of languages and concepts of the world to which they refer. So, a proposition in a knowledge representation language does not mean anything on its own.

The semantics that is the meaning of the proposition must be defined by the language author through something call the interpretation. So that is very important that I have a precise Syntax and approaches semantics.

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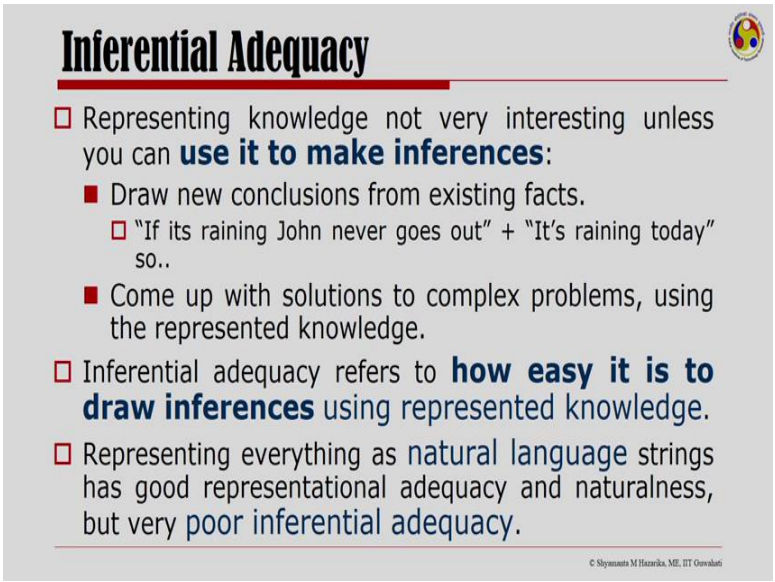

Now let us focus on the next requirement of a knowledge representation language which is inferential adequacy. Representing knowledge would be really not interesting unless you can use it to make inferences. We should be able to draw new conclusion from existing facts. If I say a statement like if it is raining John never goes out and I say it is raining today then one can immediately draw a conclusion that John is not going to go out today.

The ability to derive this new information that John is not going out today based on two bits of information that I have specified. One if it is raining John never goes out, two it is raining today that ability that I can get and new inference is drawn is called inferential adequacy. So we should come up with solutions to complex problem using the represented knowledge and that can only happen if the knowledge has enough inferential adequacy.

Inferential adequacy refers to how easy it is to draw inferences using the represented knowledge. Representing everything as natural language strings would really have good representation and adequacy and naturaless but very poor inferential adequacy. Now let us take a minute to understand what we mean by this. This is because natural language strings if I used to represent a certain problem.

I can represent anything and everything using natural language strings. Given a group of natural language strings it would be very difficult for a computational mechanism to draw a new group of natural language strings. Now, this is something we must take note that this is not that this is impossible. But then we are talking of the level of difficulty. The difficulty on working with just natural Language strings would be far more than the difficulty of working with a group of symbols that I would used to refer to the natural language strings.

And therefore if I am doing something in natural language strings, I would have very good representational adequacy. But I would have very poor inferential adequacy.

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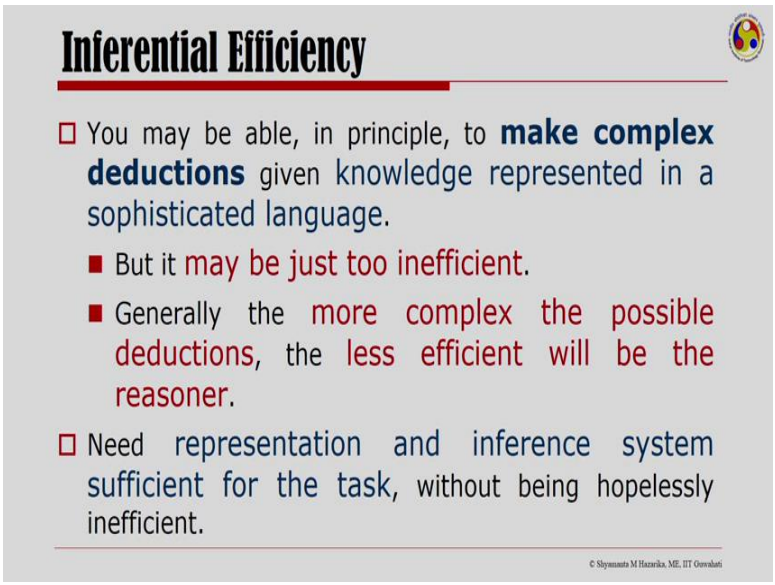

Next requirement is about inferential efficiency. I should be able to make in principle complex deductions given the knowledge representation in a sophisticated language. Now the more complex the possible deductions are the less efficient will be the reason. But then I must have the ability to make complex deductions. So, we need representation and inference systems which sufficient for the task without being hopelessly inefficient.

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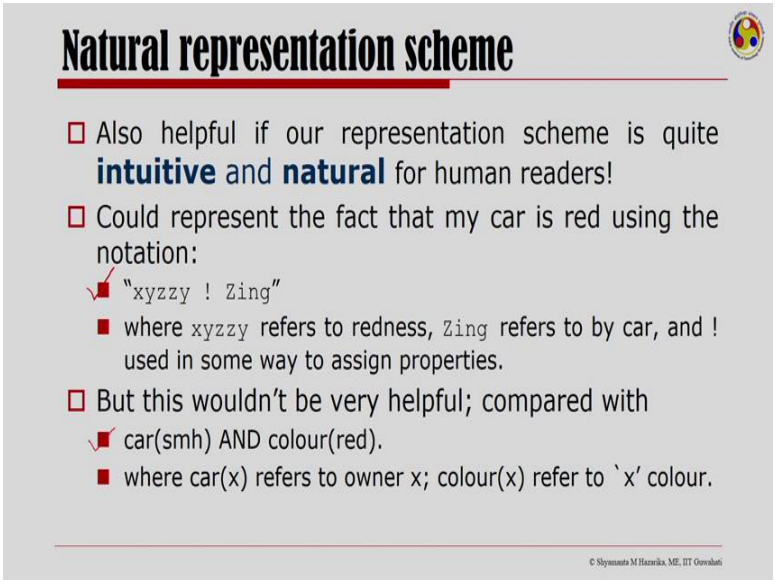

Let us now look back on what we have introduced in one of the characteristics of KR language. That is the natureless if a representation schema is quite intuitive and natural for the human reader it would help both the representation and the reasoning. So could represent the fact that my car is red using the notation something like x y z z y bank zing where x y z z

y could referred to redness refers to my car and bang your is used in some way to assign properties.

But then for human reader this statement here would really be not comprehensible contrast this with the following. Let us write something like car smh and colour red. Where car x refer to the owner x and colour x can refer to the x colour. Now the second group of statements that I have written is more understandable on natural in some way then the first one. In knowledge representation language needs to be something along the second line then along the first which is very incomprehensible.

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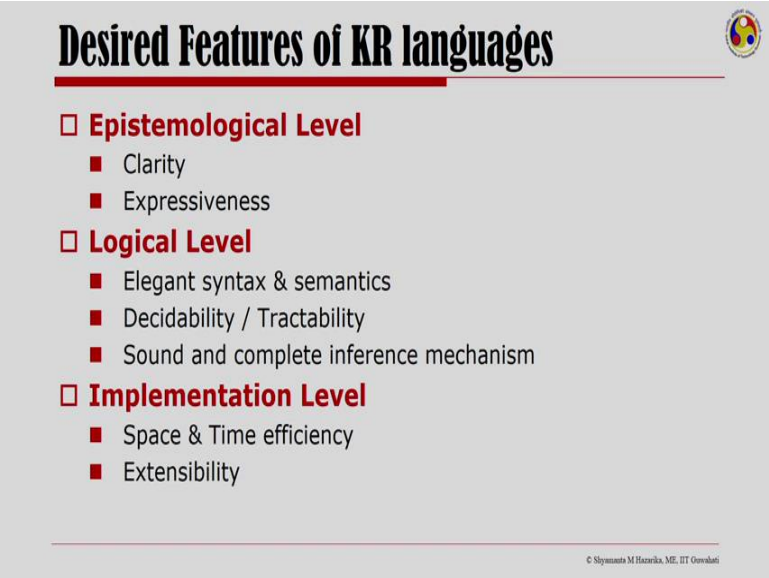

The design features of a knowledge representation language therefore would be at the epistemological level. We need to have clarity and expressiveness. At the logical level one needs to have elegant Syntax and semantics. It needs to be decidable attractable. It needs to be sound and complete in terms of inference. And in terms of implementation we need have space and time efficiency and it must be extensible.

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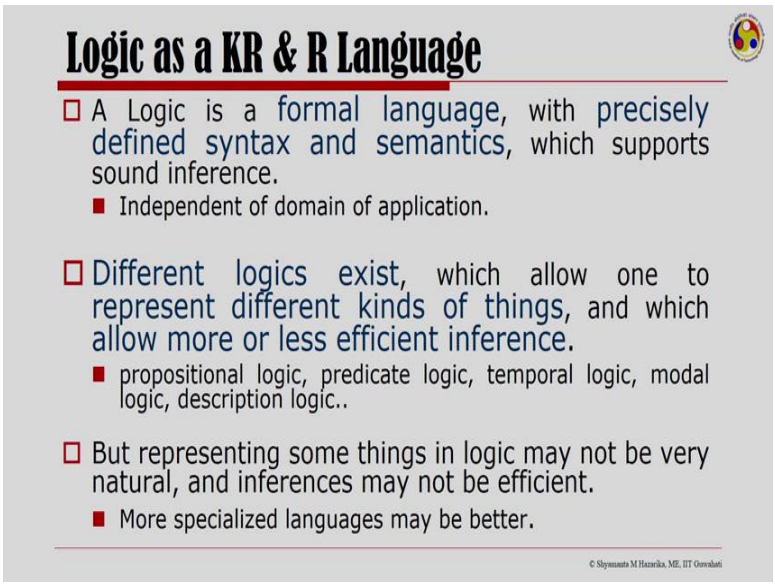

This is where we will see that for knowledge representation and reasoning formal logic is the first choice. Why is logic? The first choice for in knowledge representation language is precisely for the region logic is a formal language with precisely define syntax and semantics and it supports sounds inference, the language is independent of domino of application. And their exits different logics which allows one to represent different kinds of things with more or less efficient inference like we have prepositional logic, predicate logic, temporal logic, modal logic, description logic so on and so forth.

Representing something's in logic cannot be very natural but then inferences would be very good. At times inferences may not be efficient as well under such circumstances more specialised languages may be better. But here in this course will focus on formal logic for knowledge representation and reasoning.

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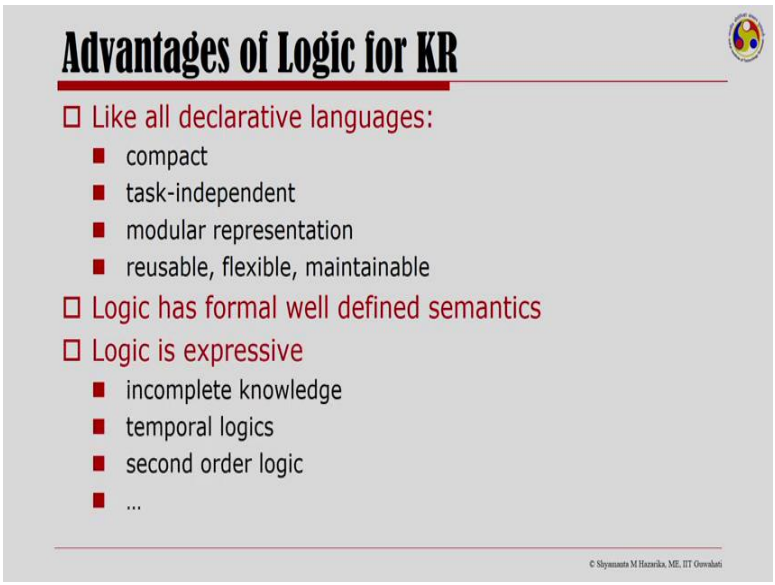

So, what are the advantages of logic for knowledge representation like all declarative languages logic is compact, task independent, modular reusable, flexible and maintainable. Logic as formal well defined semantics and logic is expressive.

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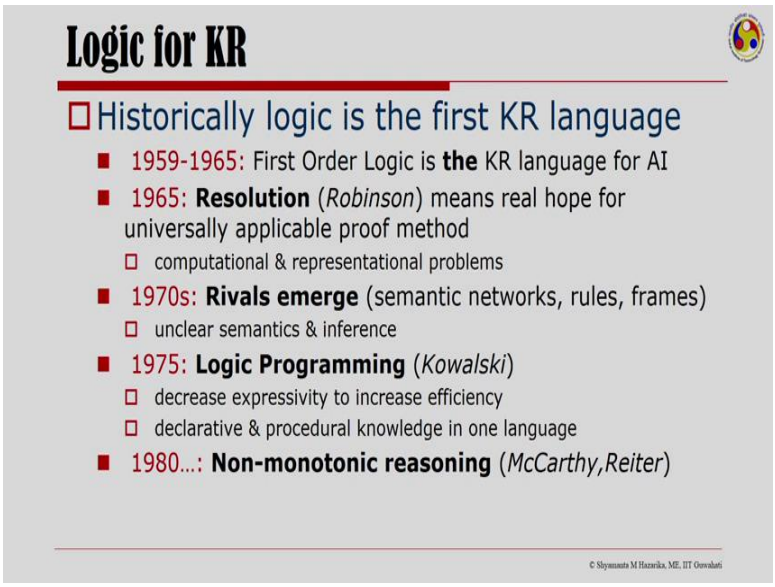

Historically Logic is the first knowledge representation language. First order logic has been the knowledge representation language for Artificial Intelligence from around late 50's. Around 65 we have same Robinson come up with resolution which meant real hope for universally applicable proof method. We will look at resolution as part of our discussion on first order logic.

Along 70's number of rivals the logic emerged like semantic networks, rules, frames. However they have unclear semantics an inference. And around 75 with logic programming with decrease expressivity, but there was a huge increase in efficiency. Logic regains its place in AI in knowledge representation language. Around 1980's is there was non-monotonic reasoning introduced which good deal with common sense knowledge.

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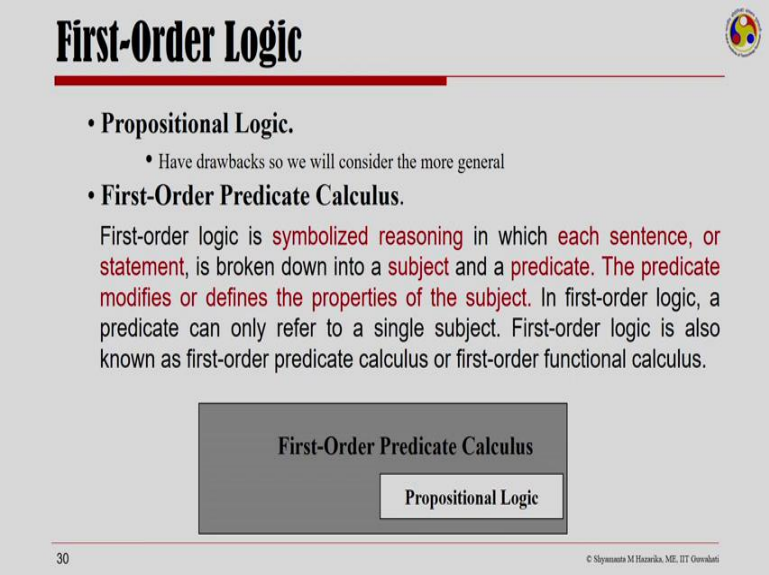

So as part of introduction to knowledge representation and reasoning will start with propositional logic will see propositional logic has drawbacks. So we will consider the more general first order predicate calculus. First order logic of first order predicate calculus is symbolised reasoning in which is sentence is broken into a subject and predicate. The predicate modifies or defines the properties of the subject.

First order logic provides a well-defined language for us to express knowledge. And this is what we will take up for discussion, in our next class, thank you.