Artificial Intelligence

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Lecture - 18
Semantic Net

In the last lectures we looked into different one particular knowledge representation scheme namely the rule based system. Our objective for the entire course is to look into different ways in which a system can demonstrate intelligent behavior. And one of the major components of demonstrating intelligent behavior is acquiring and using knowledge. In the last lecture we saw one such way of representation that is the rules. And we also concluded the lecture with one very important and popular application of such rules in the form of some of the expert systems which are rule based systems. Besides rules there are other methods and modes of representing knowledge.

Today we will start discussing on a few of those other modes of representation of knowledge. So we will be looking at other knowledge representation formalisms and we will be starting with our discussion on semantic nets. Now, as you know the word semantic means meaning. So we are familiar with two words syntax which is essentially the grammar of a language and semantics is the meaning of any sentence for example. I may form the sentence correctly which may be grammatically correct that means it may be syntactically correct but it must be meaningful. In order to be meaningful it should be semantically correct.

When do you say a particular sentence or statement is meaningful?
A sentence is meaningful when we can really understand it and map it to some of the known concepts of the real world in which we live or see or can visualize or realize. So the essence of knowledge in one form is built around the different concepts that are spread around us. Whatever we look at for example, if I look at this room then I will be looking at different chairs, tables etc. now each of these are different concepts. And the chair for example is made up of wood usually. There can be chairs which are not made of wood that may be made of iron, steel or some other material. So whenever we talk of chair we can think of some other association with the material by which the chair is made of.

Whenever we talk of chair another pertinent question can be what is the size of the chair? What is the weight of the chair?
Whenever I use a word say a boy then obviously with that usage of the word boy it certainly maps into a particular concept within me because along with the boy I have got so many other associations. a boy will be at most if I call him a boy will be at most of say 18 years old, whenever he is more than 18 years usually I call him a man or whatever. A boy will be having height, will be having weight, and usually may be going to school so there are so many other associations that come up. If I talk of tiger then immediately some concepts, the tiger is a concept and along with that I can associate how many legs does the tiger have and the immediate answer is four, what is the color of the tiger? There

may be two possible answers white or yellow. So whenever we use any particular word we are actually referring to some concept and along with that concept we immediately associate some other related concepts. And this association of the different concepts builds up our knowledge system, our conception, our knowledge base. So this is another view of looking at knowledge that knowledge can be represented as a network as a connection interconnection of different concepts.

Now, in semantic nets that is what has been explored how we can represent a domain specific knowledge using the different concepts. In today's lecture we will see how we can represent the concepts and how we can represent the knowledge using these concepts. And also as it has been mentioned earlier that I cannot call any collection of facts or information to be knowledge unless I can use it use it for inferring some new facts. So, if I have to call this semantic net as a knowledge representation method or scheme then I must also have some particular inference mechanism by which I can utilize this representation to infer new things to answer different questions all these things we will have to look into and that is what we will try to see in today's discussion.

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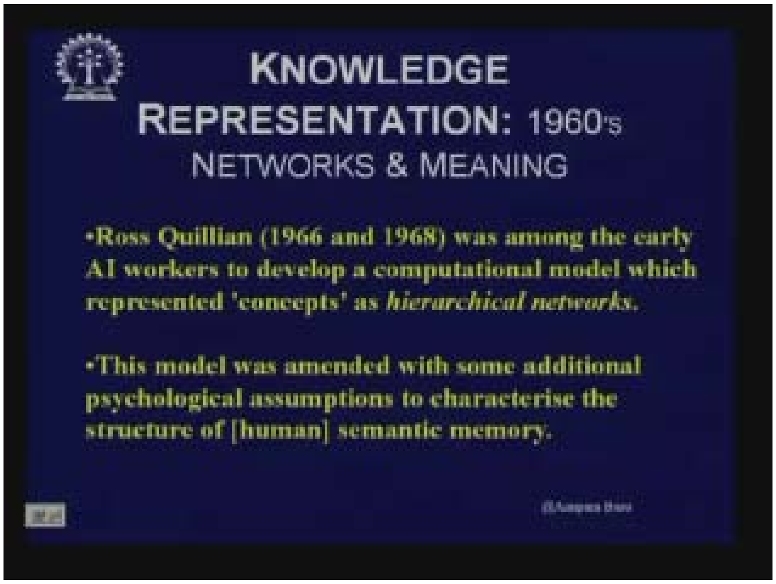

Now, the idea of semantic nets dates back to 1966 and in two very important papers that were written by Ross Quillian who was one of the early workers of AI and who tried to develop a representation of meaning. This slide has been titled as the thoughts about knowledge representation as it were in the 1960s. And also the subtitle is networks and meaning. That means that here we try to represent the different concepts in the form of network and also try to capture the meaning of the concepts in the network structure. But what Quillian tried to do is to represent different concepts as a hierarchical network, that is very important because if I just say, he is a boy or he is a man then immediately I also know that man is a concept but man is a mammal and I also know the concept mammal and there are many properties we share in common between man and mammals.

And when I say Tom is a man and John is a man then both these other entities tom and John are also examples of man and they share some of the properties in common because of the relationship with the common concept man. Tom and John also share some properties of the concept mammal because all of them are connected to the concept mammal because John and Tom are man and man is a mammal. As a collection of different concepts organized in a network this is organized in a hierarchy or layer.

Now this model was later on amended with some psychological assumptions because the original objective of all these exercises all these research was to try to understand how we the human beings think, how we represent our concepts in our mind. So there has to be some correlation with the structure of human semantic memory not that everything is known about it but a lot of research has gone in into this aspect by psychologists and whatever is learnt from them can also be utilized in our computer representation of knowledge semantics and meaning. In this approach of representing meaning as networks concepts can be represented as hierarchies of interconnected concept nodes.

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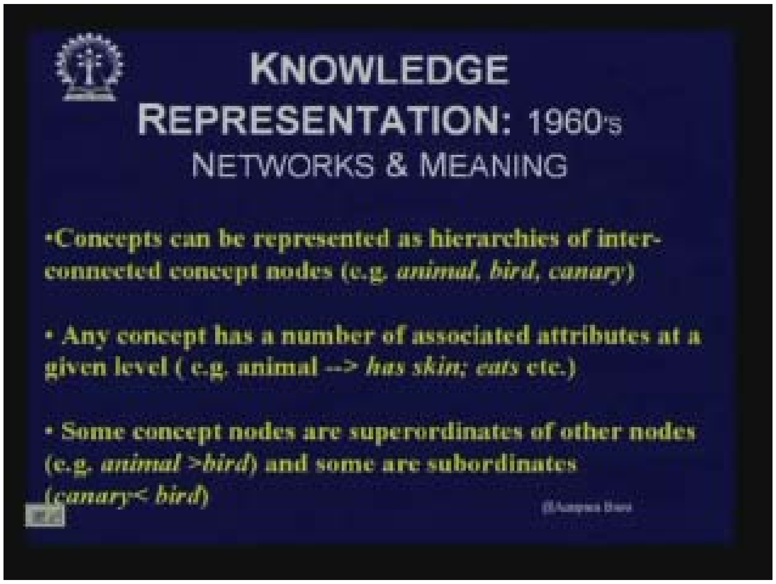

If I assume that one concept will be one node, for example, animal is a concept, bird is a concept, canary is a particular type of bird, stalk is another type of bird all these are birds and they are related to the concept bird therefore. But canary is another class of bird, sparrow is another class of bird but all of them share some things in common with bird and bird again being connected to animal will have some common properties with animal. So we can say that any concept has a number of associated attributes at a particular given level. We can say that the concept animal immediately tells us it has got skin, it eats, it runs, etc. All these properties are related to the concept animal. Similarly, we will have some attributes related to the concept bird.

Now some concept nodes are super ordinates of other nodes. For example, animal is at a higher level than bird because a bird is an animal, a tiger can be an animal, a lion can be an animal, a crocodile can be an animal so animal is more of a super class or super ordinate of all these sub classes or subordinates like bird, tiger etc. Again if we go one level down the hierarchy from here we will see that bird is again a super ordinate of canary. Canary can be a bird, stalk can be a bird, peacock can be a bird, ostrich can be a bird all these are different types of birds but all of them are birds and all birds are animals.

So in this example we can see clearly a three level of hierarchy at the top level as we have shown is animal. After that there is bird and bird is at one level lower than animal, more specific than animal. And tiger, lion all these things may be in the same level as bird. Now individual categories of birds like canary, peacock, and penguin come one level down that hierarchy. So in this example we have seen a three level of hierarchy but there can be multiple levels of hierarch. So the essence of this idea is that we can organize the different concepts at different levels and all these concepts may have some relationship from one level to another. That is the basic idea and each of these concepts will have some attributes specified at that level. Like animal we will have attributes, bird we will some additional attributes etc.

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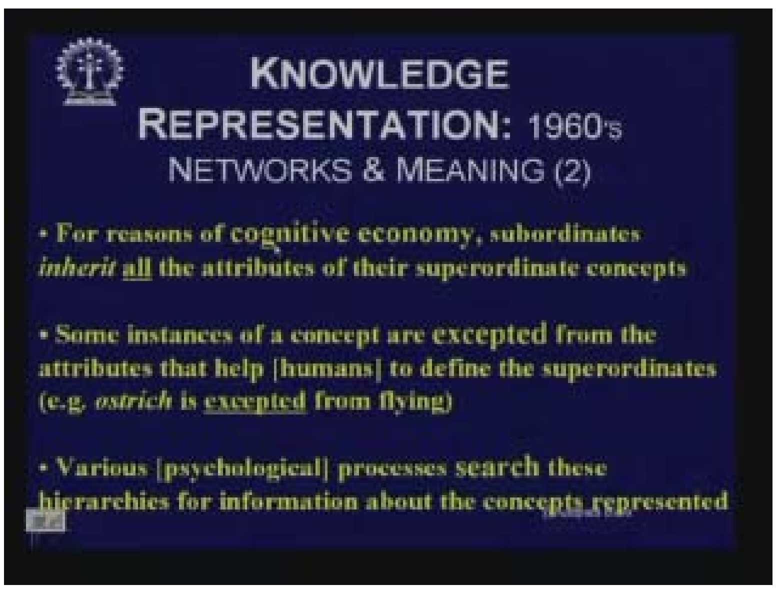

However, we cannot store in a computer or might be in our human mind also we do not explicitly store everything. So we often talk of cognitive economy. That means how much we store. So, for reasons of cognitive economy subordinates inherit all the attributes of their super ordinate concepts. So what does it mean? It means that if I had specified something about bird then those attributes will be inherited by whoever are the descendants in that hierarchy. Here is an example, I can say that mammal is a category so here I can say human and I can say might be some animals and they are related. This is at the top level L0 and this is at level L1. Now human beings can have some attribute, this is an attribute link which says has and I write down another concept hands. Now, if I draw another level down here can be man and here can be woman. Now man is linked to human it is down this level L2.

Now man can have some additional properties, woman can have additional properties over human but whatever is there as a property of human will also be there for both man and woman. If it was not the case if I just go on adding properties at the human level like color of blood the color of blood is red, now if I had to store everything here then I had to store has, hands, color of blood, red etc. But this part is not required to be stored explicitly. I would have to store it here as well as for woman and everything so I do not need to store this here because it is already stored at the upper level so I do not need to store this part here and it is sufficient to store at the parent level or the higher level. This is what is meant by cognitive economy.

That means I do not want to store all the attributes at all the levels instead whatever is there at the top level say mammal I can certainly say it drinks milk or born from mother whatever it is. Then all the concepts which are children of this level will inherit these properties that are there at the top level. That is the basic concept of this sentence that is for reasons of cognitive economy subordinates that means whichever are down the hierarchy inherit all the attributes of the super ordinate concepts. Now for some instances of the concepts there are exceptions from the attributes that help us to define the super ordinates.

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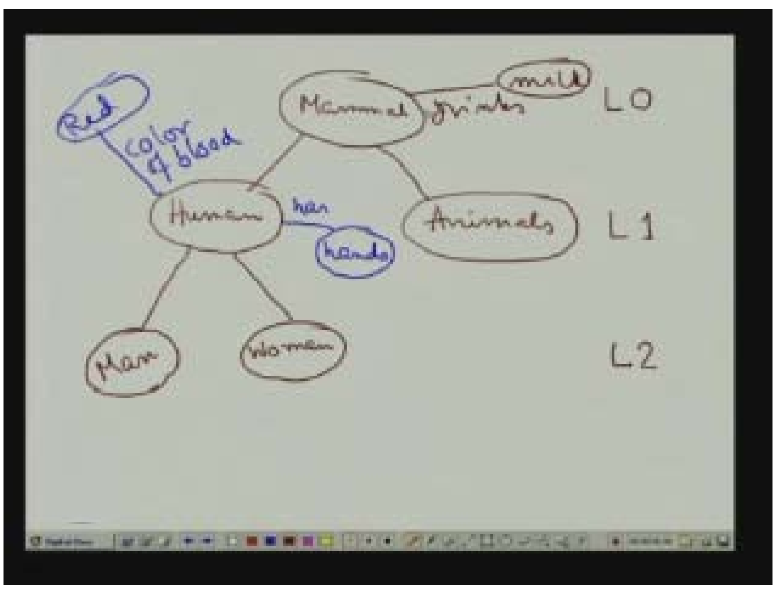

Let us take one example, a typical classical example is, when we say bird, bird is a concept then birds can fly, what is the locomotion of birds? It is flying, how do they move? They move by flying so if it is a sparrow it is a type of bird then obviously it will be automatically inferred that sparrow is a bird and I know birds can fly so sparrows can fly. This is what we can inherit from the parent category. But ostrich is an exception ostrich cannot fly but ostrich is a bird. It has got all other attributes that a bird has such as feathers, wings, two legs, has a beak all those things but only the locomotion is an exception. Therefore at the subordinate level I may need to modify some of the attributes in special cases which are exceptions. So the general rule we that we can think of is, usually we will inherit all the attributes of the parent but at the lower level we can modify them in special cases as required. Various processes search these hierarchies for information. Here is a hierarchical network that we are talking about.

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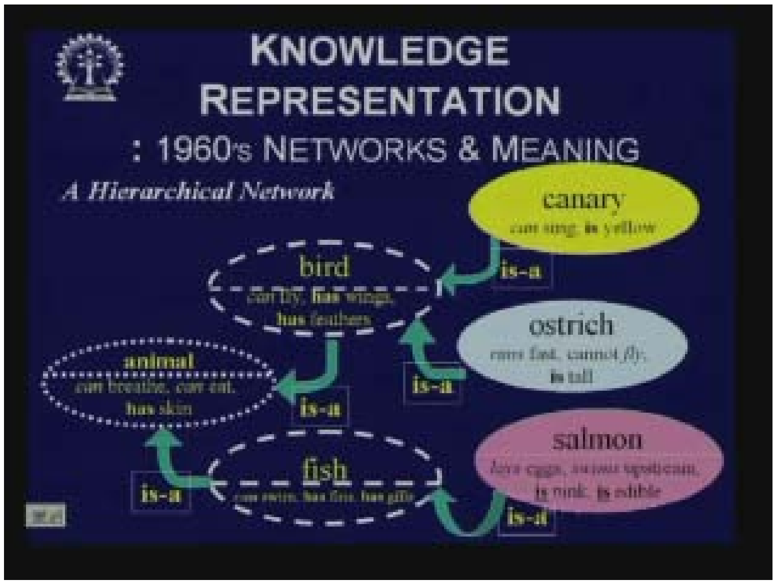

What is the super ordinate in this hierarchy? We have got animal, this is the super class the top level. Now we have got bird, we have got fish. Now these are related to this concept animal. Each of these ovals represent one concept. this oval represents bird and look at this green link the name of this green link or this green link is leveled with is-a that means bird is a animal, in proper English it should be is an animal but we are not making a distinction, so here is-a means bird is a subordinate of this super ordinate. Similarly fish is a subordinate of this animal. Now look at these parts; this concept animal is associated with some properties like can breathe, can eat, has skin etc. Now this can and has are different attributes of this concept animal.

Similarly, bird has got some additional attributes like can fly, has wings etc. I cannot say that animals have wings because all animals will not have wings. But bird can fly, has wings, and has feathers. Similarly, if we look at this concept fish we have got some additional attributes like can swim, has fins, has gills etc and fish is a animal. Now, if we go one level down the hierarchy we will see that these colored ones are even more a further specialization of birds.

Canary is a bird, ostrich is a bird, and salmon is a fish. now note a couple of things here that if I look at this concept bird the bird as is written over here has got these three attributes can fly, has wings, has feathers. But just because it is a type of animal it is a subordinate of an animal the property of animal are also inherited, can breathe, can eat, and has skin. So, if anybody asks the question can a bird eat the answer will be yes because though I do not find that the attribute can eat is here in a bird I know that a bird is an animal and therefore whatever property is there in the case of animal will also hold here. Therefore I can say bird can eat.

Similarly, if I ask the question can canary fly or does canary have feathers? When I described canary I just specified some specific attributes that are special to the category class canary can sing and is yellow, the color is yellow. But just looking at this I cannot say whether canary has wings. But yet I can say that canary has wings because I also know there is a link between the concept canary and the bird, the relationship between them is easy. So canary is a bird and I know that birds has wings therefore canary has wings. Similarly look at salmon, salmon is a fish and a fish can swim, has fins, and has gills. But salmon has got some additional specific attributes like lays eggs, swims upstream, is pink, is edible etc.

Now straight away if I say does salmon lays eggs?
The answer is yes because I can see that attribute right here. But if I ask the question can salmon swim? The answer is not here but if I follow this link I can see that salmon is a fish and fish can swim that means all fish can swim unless specified otherwise so I can infer that salmon can swim. If I ask can salmon breathe then the answer is not here so I go up this link the answer is not here as well but the answer is here you can see. Since fish is a animal it can breathe. But now let us look at ostrich. Now here I have written ostrich has got the attributes runs fast, cannot fly and is tall.

Suppose this attribute cannot fly is not written over here in that case if I ask can ostrich fly?
I will first look at the answer here and since this cannot fly is erased from here I will look over here and find well I do not find an answer here but let me try because ostrich is a bird therefore here is written can fly so the attribute of bird is can fly therefore ostrich can fly that would be my inference. But here in this case we have got specific information that ostrich cannot fly. So this attribute locomotion cannot fly or locomotion might be walks but it cannot fly that will have overriding precedence over whatever I know from the parents. So as I go down the hierarchy in this direction I come from the more general to the more specific. That is what we just now discussed that usually we take the properties from the parents but we go down as we go down we can be more specific and we can at times override the property at a lower level. So this is an example of a hierarchical network which demonstrates the different levels of hierarchy such as animal is in the top level L0, bird and fish is at lower level and canary ostrich salmon is at even lower level.

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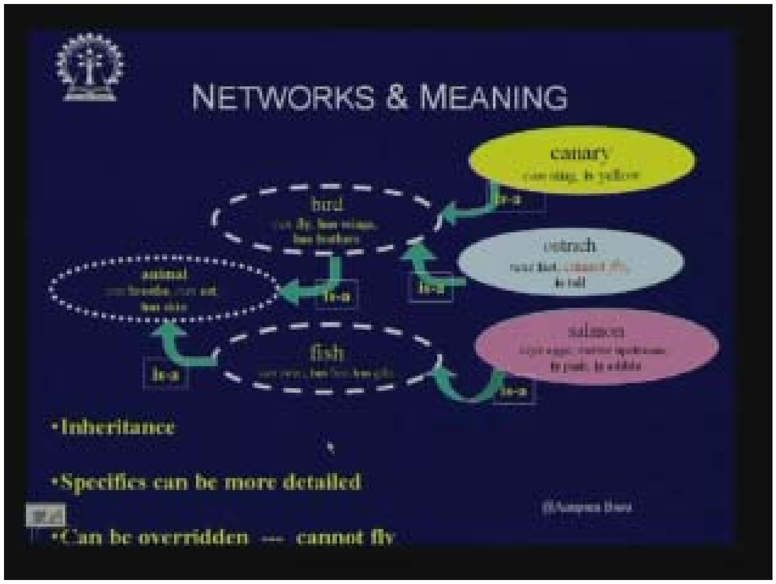

The same hierarchy here has been shown in red that ostrich cannot fly to show that it is an exception at the lower level. Now there are three things we have just now shown, the first one is called inheritance. Inheritance means any child concept. We will inherit all the properties of the parent concept. So canary, ostrich will inherit all the properties of bird, salmon will inherit all the properties of fish and in turn bird and fish will inherit all the properties of animal that is the first thing it is inherited with some exceptions. Specifics can be more detailed. Think of a human species, we inherit many of the genetic characteristics from our parents and that is exactly is what is happening here. It is the parent child relationship so in general the child inherits some of the properties of parents and the child can have its own properties which were not exhibited in the parent. Similarly here specifics can be more detailed and can be something that is inherited from the parent that can be overridden.

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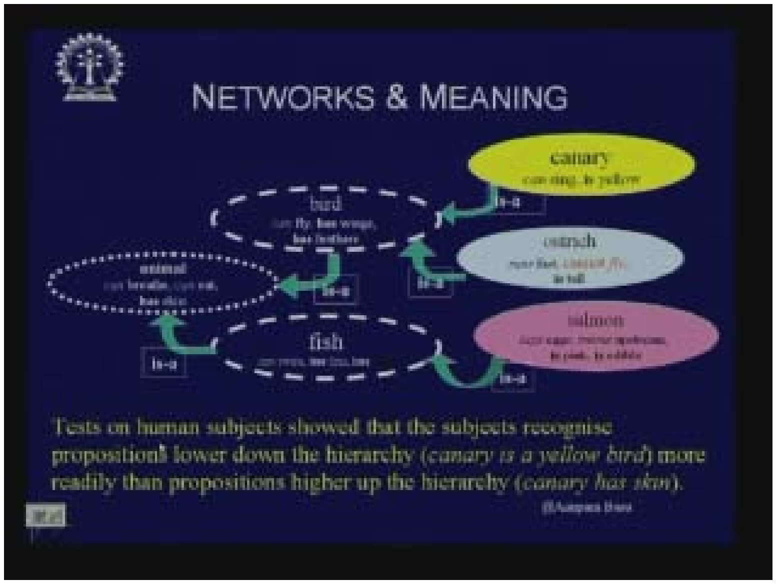

Through some psychological experiments that has been carried out and when the tests were tried on human subjects it was evident that the human subjects recognize propositions or statements which have lowered down the hierarchy much faster much readily than the propositions which are higher up.

What are the propositions?
If I say canary can sing that proposition is some how stored here. How is the proposition stored? Proposition is stored in terms of the attribute and the object relationship. Canary is an object having the attribute can sing so that is at this lower level. Usually human beings very quickly recognize the specifics when they look at a canary the first thing well a canary is yellow, a canary can sing, and ostrich? It cannot fly it runs very fast. But the thing in order to state the proposition is, canary has wings, canary can breathe they automatically do not come in because what you are looking or what you are perceiving is at this lower level and so whatever is very much evident in front of you at the lower level will have more precedence more importance and human beings quickly recognize that.

But for recognizing, not that they cannot understand the other things they can also understand that canary can breathe but somehow the reason that canary is a bird and bird is an animal so all animals can breathe therefore the assumption is that canary can also breathe. One thing is ready acknowledgement another thing is acknowledgement through reasoning. It has been found through psychological tests that the facts which are at a lower level have got more ready acceptance to human subjects and that justifies that validates this model of knowledge representation. Till now what we have been discussing is, how concepts can be represented as hierarchical network. Now we can define semantic networks and semantic network is a structure for representing knowledge as a pattern of interconnected nodes and arcs.

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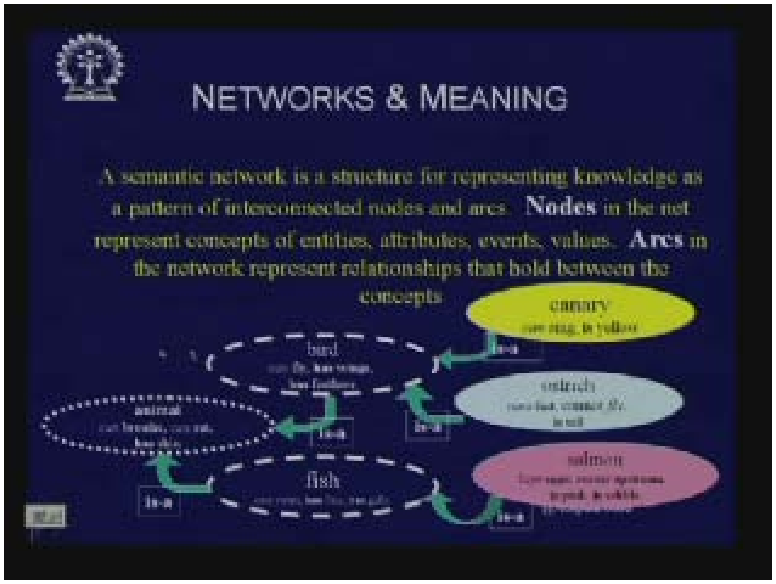

Nodes in the semantic net represent concepts of entities, attributes, events, values etc. Arcs in the network represent relationships that hold between concepts. Therefore arcs are denoting relationships, till now we have shown only one type of relationship that is easy. But priory this part requires a little bit of explanation. Nodes in the net represent concepts of entities, attributes, events, values etc because I can also draw a semantic net in this way. Man is a concept and man is a mammal and man has got different attributes I can say number of legs, I can draw another type of node two that will be there in the mammal. Man, number of legs, number of hands etc or number of eyes can be two but there can be other attributes also like height. Now this height is less than 7 feet which is rather common. In that way I can have different types of nodes. This is one type of node that is representing a concept.

There can be nodes which are representing values as well like these are representing values. All these together are giving me some statements; Man has hair and hair is a type of skin. Now all these things are concepts, has hair, we saw birds has feathers but man has hair and what is hair? Hair is a type of skin so here this is another concept, this is another concept, this is another concept and they are different entities and there can be also values so it is not necessary that only concepts will be nodes.

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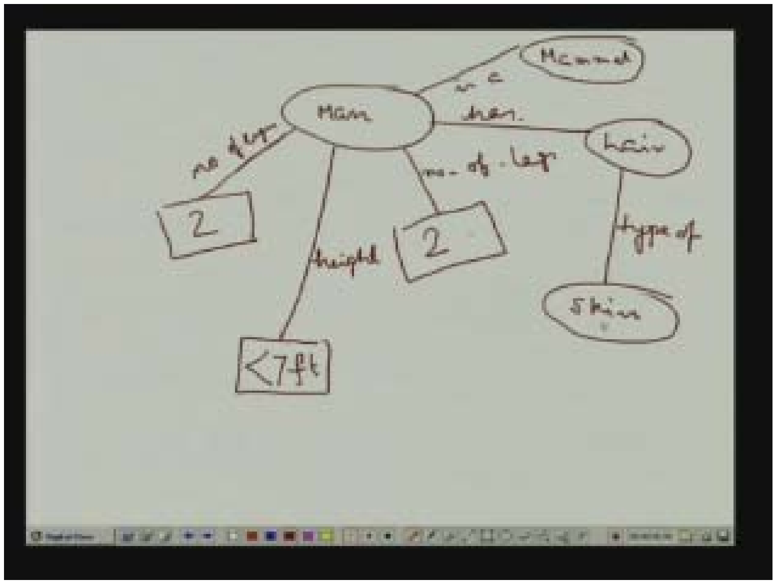

In a semantic network we can have different types of nodes. Nodes in the net represent concepts of entities, attributes, events, values etc. Arcs in the network represent relationships that hold between the concepts. Here I have got so many other concepts. Now, when I store that in a computer I will store that with some particular type of coding. Now I will level the concepts and might be in a table where I will have C1, C2 etc I will have to encode each of those concepts and each of those concepts can have some attributes as well so I have to store them. Now here what we are showing is that C1 is the top level concept and I store C1s attributes. The next level is C1 1 and all the child concepts are leveled as C1 1 1 C1 1 2 so C1 has got two children C1 1 and C1 2 a sort of subscript notation that we use.

So, in that particular way we can represent all these concepts. Now where is the meaning? We are calling it semantic network we have seen that it is a structure of nodes and arcs. The nodes are representing different concepts. Now, do the concepts by themselves express the meaning? No, the concepts do not express the meaning by themselves. In order to understand meaning of the semantics it lies in the structure as well as the relations that are there. For example, the meaning will quickly change when I look at this network and compare it with the earlier network.

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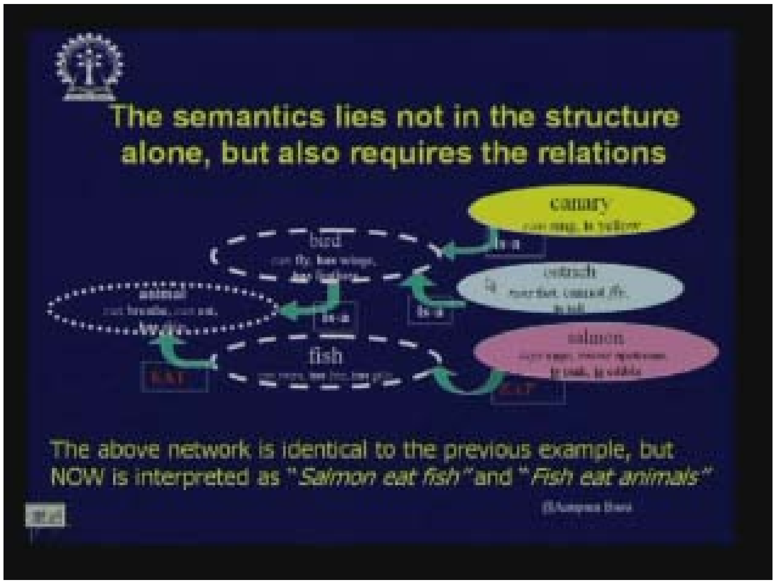

This network has got two links salmon fish and animal are connected by is-a links and I just change at this level these two links from is-a to it. If I just withdraw these levels the other structures the concepts and the linkages are remaining the same but only thing that i have changed is the relation. Now, immediately the meanings have changed. Now what this structure means is, salmon eats fish and fish eat animals. Now I can no longer answer questions which I was doing earlier.

Does salmon has fins?
I look here and find salmon lays eggs, salmon swims upstream, salmon is pink, salmon is edible and I do not know whether it has fins or not and because I cannot now recognize that salmon is a fish that link that connection is lost. If I had another link over here is-a link then it would have been all right and I could have traversed through that is-a link and could have arrived at that answer salmon has fins. But as the structure lies now I can only say salmon eats something called fish which has fins. But whether salmon has fins or not is what I do not know.

In fact it has become really a meaningless thing that fish eat animal and it is not always the case but you see how by changing the relations the total meaning changes and whatever I was able to do earlier in this case I cannot do any further because of the missing link here. So the important thing to state is that, whether we can represent the meanings and concepts in the form of semantic networks, the answer is yes we can do it but the meaning lies in the structure as well as the levels of the arcs and those are the relations we are giving now.

We are talking of concepts, we just mentioned about propositions salmon eats fish that is a proposition, ostrich cannot fly that is a proposition. If you recall we encountered proposition earlier while discussing logic. So, is there any relationship or they are absolutely two different things? Can we represent whatever we are stating in semantic nets through logic? And whatever we are stating through logical propositions can they be represented in semantic nets? All these are very natural questions. Let us look at this example.

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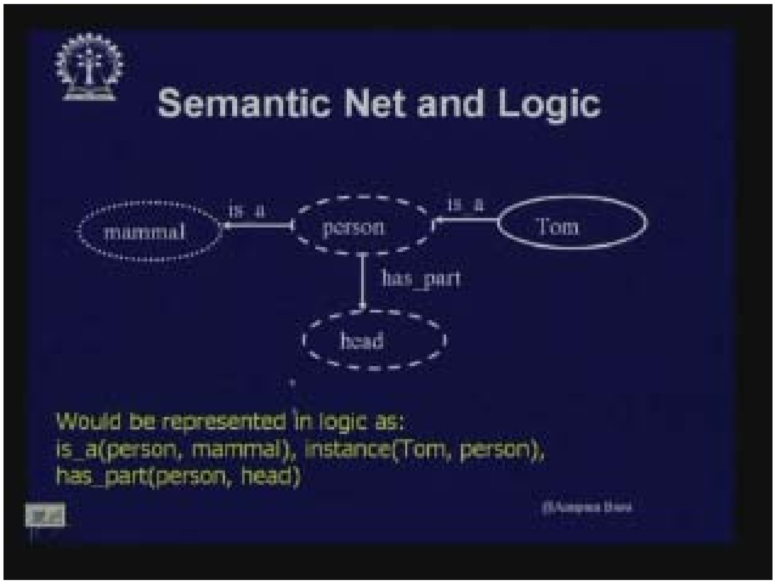

Suppose this semantic net where we have got four concept nodes person is a mammal, person has part head, and Tom is a person. Now, here you see Tom is a specific person. So till now person is a category or class. Those of you who are familiar with object oriented systems, the concepts of objects, classes, sub classes will find a similarity here with the concept nodes we are discussing. But let me state here that the concepts of objects and object based design, object oriented systems came much later and has been systemized much later. These network concept of representation of meaning dates back to 1960s as we have said so this is a predecessor. And it has been certainly much systemized later.

Here if we talked about object oriented terminology then Tom is an instance of the class person. If I have added a node here man is a person, woman is a person then man woman are still classes I am not talking of a particular man or particular woman but Tom is a particular person and through this is-a links in semantic nets I cannot make this distinction between whether it is an instance or a class. Here Tom is a person, person is a mammal and person has part head. So, if we just look at this part I can answer some questions.

Does tom have a head?
Yes I can answer Tom is a person and person has part head so Tom has head. And whatever were the attributes of the mammal I could have also talked about those attributes to be valid for Tom. Now the same structure can be represented in logic where I just use these relations as the predicates. Is a person mammal is a person mammal so it is a binary predicate with two attributes. Now, in logic I can say instance Tom person that

Tom is a instance of a person, has part person head. If you take any two partitions and the relation connecting them I can represent them as propositions as we do in logic.

We started with the point that we want to represent the concepts and the meaning because that is essential to represent knowledge. And we have seen that concepts can be restored or represented in a form of a hierarchical network and using this idea the semantic net representation came into being where it consists of nodes and arcs and the nodes represent concepts, entities, events, values and the arcs represent different attributes. That is how we can represent different facts that we want to state or model about the real world. Now let us see how we can represent some more facts in semantic nets. Suppose there is a game being played between two teams Norwich and Spurs. Now one team is a winner and another is a loser.

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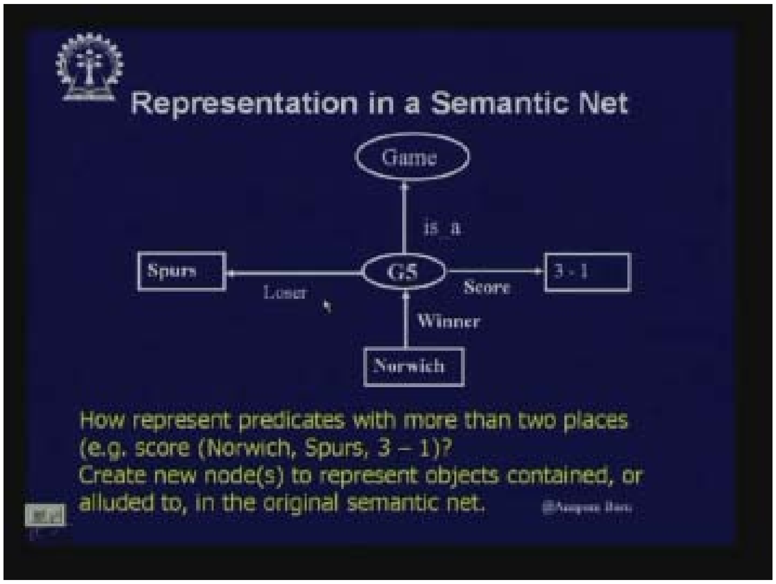

Now how do you represent that fact that Norwich defeated Spurs? I just want to say Norwich was the winner spurs is loser. Norwich is a winner of what? So winner of a particular game which I have just named here G5 and what is G5? G5 is a game and any game will have a winner and loser so Norwich is the winner and Spurs is loser. Now, if I want to state it was a football match and Norwich defeated Spurs with a score 3 for 1 then I have to add another attribute score 3 and 1. Let us forget about what is written below and look at this white thing.

Now what can we say about this?
We can say G5 was a game that was played in some particular ground, I could have even stated G5 played at, I could have added a particular arc over here saying that it was played at some particular football ground and the attribute G5 is a game and it has got a winner and loser so I can say that in the game G5 Norwich was the winner and Spurs is the loser. And if I look at this I can also say that the result of game G5 was 3 1.

Typically earlier what we have seen is, when we take these two nodes and look at the relation between them what we represent is a two place predicate a predicate is-a which can take two parameters. But often we may need to represent facts with more than two parameters. For example, Norwich Spurs, Norwich defeated Spurs with a score 3 1 or the score of Norwich over Spurs was 3 1. Now this is a three place predicate, now how do you do this? In order to do this if I had just taken these two I would have said Spurs was the loser in game G5. If I had just taken these two I would have said Norwich was the winner in game G5. If I had said what is G5 then I would have looked into these two nodes and would have said G5 is a game. If I had taken these two I would have asked what is the score of G5? The score of G5 is 3 1. All these were two place predicates.

But whenever we need to represent three place predicates I need to create a new node this new node has to be created otherwise I could have just said game in this game there is a winner and loser I could have said spurs and Norwich. But the score of different games will differ so I may need to create a particular node which will specify the additional fact. We will see some more examples from here. For example, if we look at this point we see that it is a more complicated example which we are trying to show: John gave Mary the book; John gave the book to Mary. Now how do you represent this? We have shown that gave is an action, giving this book to Mary is a particular event and this event of giving has got an agent as somebody who gives and somebody who receives. Any giving will have two requirements. Somebody will have to give and somebody has to receive. The person who is giving is an agent and the person who is receiving is a recipient. Therefore for an event of giving the action is giving, it has an agent John and a recipient Mary.

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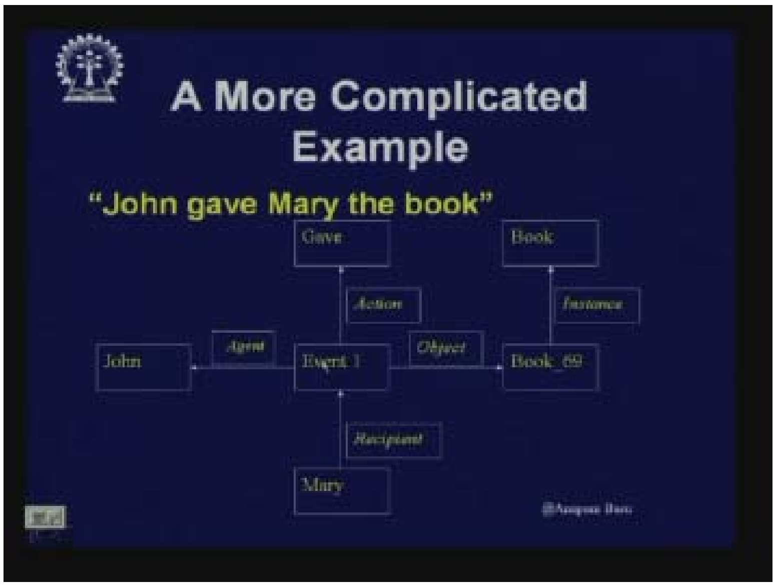

Now what is being given?
The object that is being given is a book.
What is that?

It is a particular book. I am not saying John gave Mary a book but I am saying John gave Mary the book so I am talking of a particular book so I can say John gave Mary this giving event has got an object I can give you the pen, I can give you the money so giving is an action which has got a giver, which has got a recipient and also some object that is being given. There is more of it like how it is being given, when it is being given etc. John gave Mary the book. So the object that is being given I could have said book but why I did not say it is a book because book is a general class and we are talking of a particular book that is book 69 and what is this book 69? It is an instance of book.

So you see how this English statement John gave Mary the book simply translates to this nice semantic net form. Now here we have got these where all these are entities, event John Mary book 69, book is a class, giving is a class, these are concepts of giving. I could have written over here given also but this particular node is gave because its tense is past which is a type of giving where the tense is past and I can make it more detailed therefore this is one example.

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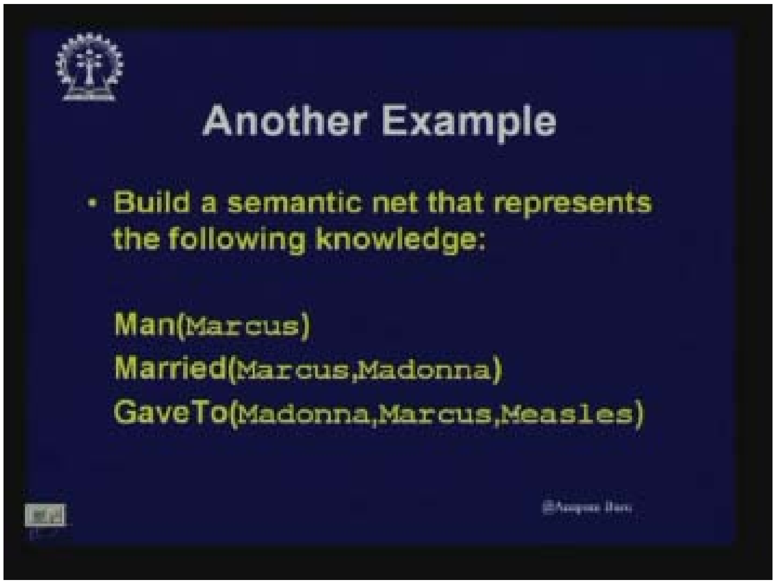

Let us look at another example; suppose we are asked to build a semantic net hat represents the following knowledge. We have just now shown that given a particular semantic net how that can be represented in the form of logic. Now what we are showing in this example is, given some logical statements can we draw a semantic net with that? So let us look at these statements; Man Marcus that means Marcus is a man, married Marcus Madonna so Marcus is married to Madonna so these are propositions. Gave to Madonna Marcus Measles that means Marcus was infected by the disease measles because Madonna had it so Marcus got it from Madonna. So this infection we are explaining through this gave to Madonna, Madonna gave to Marcus measles. These are three place predicates. So these three statements is a story.

Marcus is a man, Marcus married Madonna and what happened was Marcus was infected with measles by Madonna. Now how do I represent this story in the form of a semantic net? Marcus is an instance of man so I take this sentence man Marcus, Marcus is an instance of man which is a concept, Madonna is another instance, Marcus is married to Madonna so the second statement is also covered and third thing is giving. Now Marcus and Madonna married and they probably gave so many gifts to each other may be so many other things were there but this giving measles is a particular instance of giving. So I cannot directly relate it to the concept giving it is a particular giving therefore I can denote it with a particular giving G17 is an instance of give action.

Madonna also gave a book to Marcus so I cannot just say all the give actions are connected to this. This is a particular give action. Now what was given? Measles was given but of course it is a disease but here we are simplifying it. And who gave? Madonna gave and who got? Marcus got. Now I can look at the earlier presentation here and I can understand many things from these three logical statements and the same thing I can understand from this semantic net structure show here.

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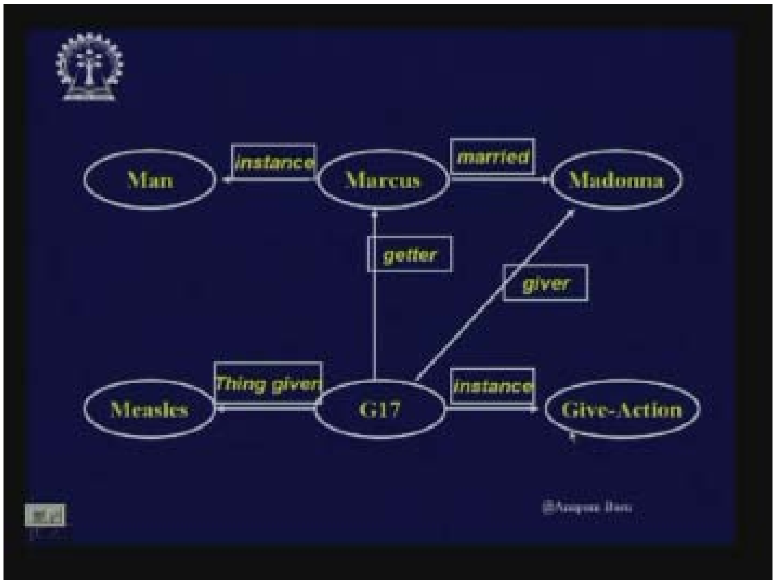

Later on let us see some more representation of semantic nets, how semantic nets can be used to represent more complex concepts and how we can infer using semantic nets and that will be followed by other knowledge representation schemes.