Artificial Intelligence
Prof. Anupam Basu
Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur
Lecture - 40
Natural Language Processing - II

This will be last lecture of this course Artificial Intelligence and in this lecture we will be dealing with some of the issues of natural language processing. In the previous lecture on we were trying to bring out some of the issues. Let us discuss issues on machine translation and discuss the remaining part of natural language processing.

To start with let us have a look at the issues involved in machine translation because we have seen that machine translation is a very important aspect of many natural language applications like speech to speech, text to speech, even for text to speech from another language, information retrieval, cross language information retrieval.

Right now in India which is a multilingual country a lot of effort has been extended towards development of machine translators. IIT Kanpur has developed Anglabharti a machine translator from English to Hindi and there are other efforts at different IITs like IIT Kharagpur and C-DAC where machine translation activities have been carried out and also at IIIT Hyderabad Sakthi a machine translator has been developed.

When we talk about machine translation it can be text to text machine translation. That means say a text is given in Hindi and that has been translated in Bengali or it can be from speech to speech so speech to text and then machine translation at the text level and then again converting that to speech. Now most of the work that has been done has addressed pairs of widely spread languages like English French, English Chinese, English German, English Hindi etc. We are working on English to Bengali and this sort of activities are gone in. Right now works are also been carried out from Hindi to English, Hindi to Bengali and government of India has taken a lot of initiate in these activities.

How to translate a text?
There are different approaches. Example, base translations where we have got some templates and given a particular sentence we try to fit it to a template and that template will tell us the best way to translate it. But the most commonly used approach is statistical where we learn again from the previously translate data.
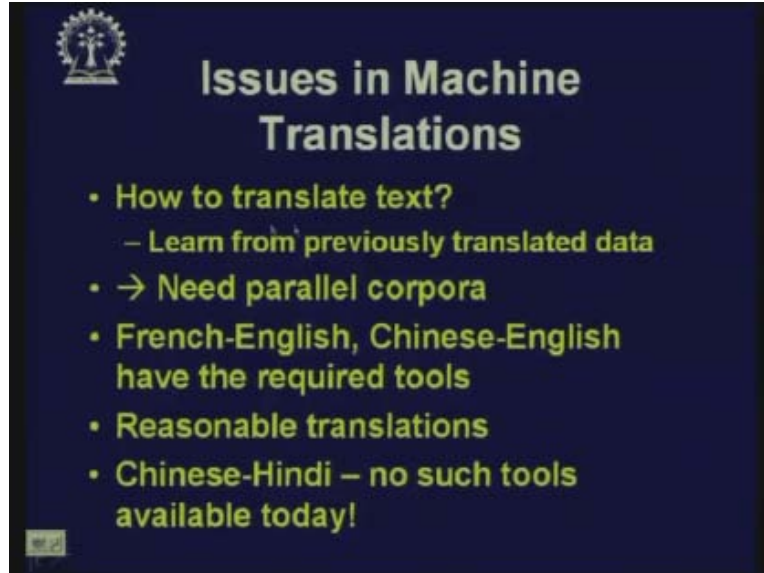
Where from can we get translated data?
For that we need parallel corpora. What is a parallel corpora? A parallel corpora is a collection of the pair-wise sentences. For example, there is a English sentence and the corresponding Hindi translation of that which is sentence wise and also word level. Every word having its translated form so it may appear to be very simple then but it is not so because of the several reasons that there are so many issues of resolving ambiguities and other things.

For French and English and from Chinese to English there are required tools and there has been reasonable translations. When a translation is being done by a machine we are not expecting perfect translation, we are not also right now thinking of translating literature keeping the flavor which the human beings also cannot do most often. But if we just restrict ourselves to some routine day-to-day sentences without special levels then we get reasonably good translations here. Chinese to Hindi for example there are no such tools there are efforts going on for translating for building parallel corpora for English Hindi, Bengali Hindi etc.

Now a major laborious task is how to obtain the parallel texts? Can you get it from the web? In the web most of the contents are in English so how do we get the same contents in Hindi? That is difficult but there are some cases where we get parallel corpora in many government records where those are stored both in Hindi and English so that may be one approach. Once we have the text how to get the most out of them? We have to do the word alignments. We have to really align the Hindi word with the corresponding English word. We have to obtain the proper lexicon and also we will have to input some knowledge from well studied language. In spite of all these techniques the domain knowledge will be required and very helpful for better performance. From machine translation which is a very important activity we now move on to another respect of natural language processing that is natural language understanding.

Understanding natural language is very important. You have seen the dialog in MYCIN. In a very strict sense that was not a natural language understanding program but in a restricted sense yes because for the small domain it interpreted in particular way in a very restricted format. But if we want to make a dialog system for example I type in some query and the system will understand, it is not the sort of query we give in Google, I can type in natural language query like for example what would be the best for possible train if I would like to go to Delhi may be through Agra or may be through Allahabad? It is this sort of construct. Now, if we type that thing in or modify the sentence a little bit, what will be the best way to go from Delhi to Bombay possibly through Allahabad or possible through some other place at a low cost?

Now we would like to have the system, process this query understanding what exactly I want and respond back to me. Natural language understanding can often be very difficult. Now our objective is to make the computers react intelligently to human speech, speech is the ultimate but as an intermediate we can assume that we are typing in text. This is the most natural interface to computers. For example, in database query now we type in standard SQL query in the SQL language but the ultimate aim could be that I am just asking for the query, I am just giving the speech query and I am getting the answer or I am writing the query in a free format of English and I want the answer.

(Refer Slide Time: 09:12)

(Refer Slide Time: 09:40)

Now the research that is involved in that belongs to two disciplines; one is AI who are focusing on programs that will react to language and linguistics is the discipline studying the human language used. Both these disciplines must collaborate hand in hand in order to get a good result. Verbal speech recognition is related but it also requires some digital signal processing and other things where we have to extract the speech signals.

(Refer Slide Time: 07:07)

The point to remember is all natural languages are as complex as the other. There cannot be any language which is very simple and the other is very complex. And no natural language is best suited towards modeling or easier to process. And the vocabulary of the

different languages is different and that is because of the different social factors. Now relatively easy to derive natural language parsers are grammar for constrained English but not for general English however because in natural language we get a lot of flexibility and we can use some dictionary or lexicon of words and their grammatical usage. Grammar can both recognize and generate sentences, we can use grammar to do that.

(Refer Slide Time: 11:24)
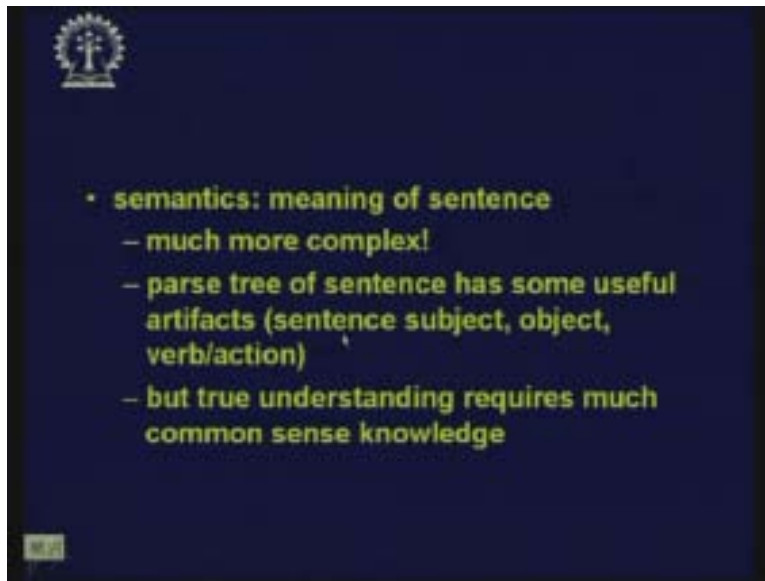
Another very important issue is to understand the meaning of the sentence, semantics. That is much more complex. As we have shown earlier that parsing a sentence helps in some way to understand which part is the subject of the sentence, which part is the object and which part is the verb etc. As in the earlier example, from the sentence I went to the bank to enjoy sunset. We could buy syntactic method we could eliminate the possibility of bank from being a verb like depend that was eliminated but true understanding requires much more common sense knowledge, the relation, the context and all these issues. If I just take this simple sentence Mary ate spaghetti with George and if I write Mary ate spaghetti with chopstick now what is the difference between these two sentences? The structure is same, x ate y with z is the structure. But since George is a person and basically it means Mary and George ate spaghetti together whereas in the other case Mary ate spaghetti using a chopstick.

(Refer Slide Time: 12:42)
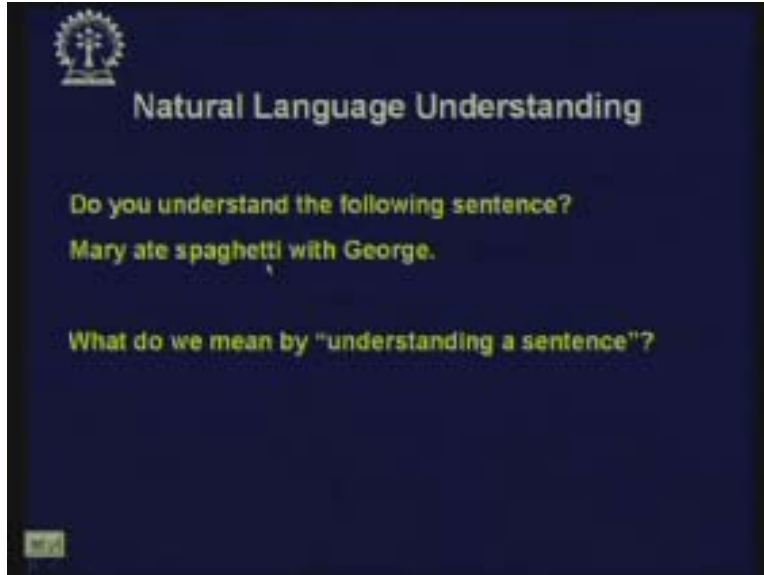
So what we really mean by understanding a sentence?
One way we can say that when we listen to a sentence we probably make a picturization make a perception of that. May be if we think of a large semantic net describing the world in our mind some of the nodes of those semantic net gets activated and we get some sub tree model. But still it is an open question that what we really mean by understanding a sentence? And an indirect way might be that if I really understand a sentence properly then I can reply to that or respond to that properly.

Now we look at another sentence: When the balloon touched the light bulb it broke. What broke? A balloon touched the light bulb and the light bulb broke. Or is it when the balloon touched the light bulb the balloon broke? Explore it because it touched the hot light bulb. Now how do you understand that? How the machine understands that? We immediately assume that the light bulb cannot be broken by the touch of a balloon but it is the balloon that got broken. But in order to understand this we need so much of domain specific knowledge that are related that a balloon is a light object and a balloon cannot break a light bulb which is a stronger object etc.

So how do you go about it?
When the balloon touched the light bulb it broke. Now we are going to a discourse that is a set of sentences. This caused the baby to cry. Now what is this and this? The balloon caused or the event of the balloon getting broken caused the baby to cry? Obviously as a human being we know that the balloon got broken and that made the baby cry. But how do you know that? We know that because we have got a domain knowledge which has got the information that a baby likes the balloon. And if any thing that is light is broken then the person feels sad. That may be stored in semantic net or may be in some other form or may be in the form of rules.

Another point is, when the balloon touched the light bulb it broke. Now if there was some ambiguity to which my system was a little hesitant to really decide on what broke probably the second sentence actually helps to resolve this ambiguity in this case. But in some cases it can create further ambiguities as well. Mary gave John a dirty look and picked up the baby. Probably you can picturize that John is the father who led the balloon go and it touched the light bulb and it broke. So Mary the mother was really annoyed with John and John shrugged and picked the balloon. Now what does it mean?

With this sentence there is so many scope of interpretation but we are interpreting it so naturally because of the deep knowledge of the domain or the world that we have with us. Now let us see how the system will react to some questions.

Which one got broken? Suppose the system says balloon then who cried? The answer is baby, was anyone angry? Now by reasoning where I expected the background knowledge to be there I can get the answers and these keywords are directly in this sentence. But was anyone? ==Nowhere written that Mary was angry or John== was angry. But that is subject to interpretation because Mary gave John a dirty look. The deeper knowledge or the more complicated scenario we are going in that giving a dirty look implies that someone is angry.

Now the issue is, in the real world there are so many possibilities. In a rule based system if you thing of can you really store all these possibilities? How much will you store? And can you ever make it complete? So that makes the entire scenario very difficult and this is one side. Another side is that natural language gradually evolves, new words are coming in, new phrases are coming in, new expressions are coming in so how to deal with that? That is why there is an attempt to go towards statistical reasoning, statistical method, statistical learning and translation which is helping to have a quick fit solution though not always very correct but mostly it works fine. Did John care? John shrugged and picked the balloon. So, John probably cared more for the balloon and not for the baby but that has to be inferred and this inference is quite complex.

(Refer Slide Time: 18:40)
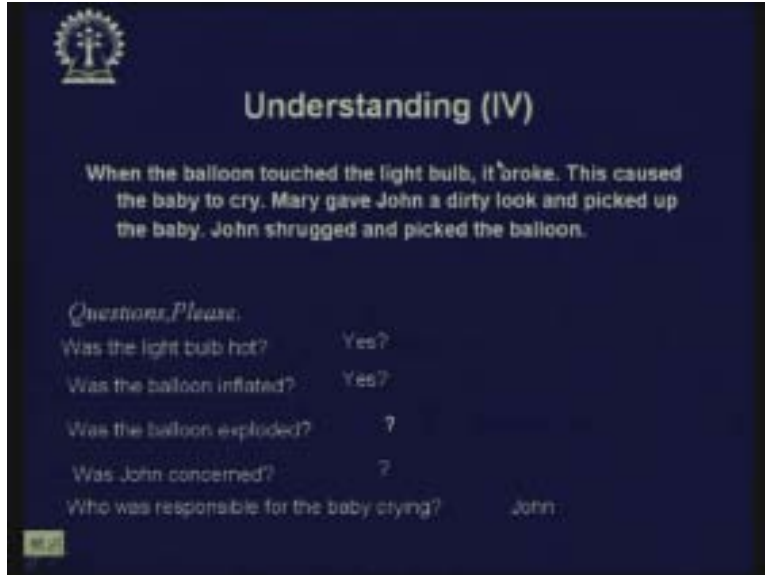
The next thing is the same thing; was the light bulb hot? The answer is yes. Now how did you get it as yes? Now here it is also subject to interpretation and inference because it is coming from the domain of physics or domain of the real world that when a balloon touches the light bulb the light bulb if it was kept on then it is hot then only a balloon can break. If the light bulb was off then obviously it will not break. But here weather the light bulb was on or not is not the issue since it broke we infer that the light bulb must be hot.

Was the balloon inflated?
Yes and how did you get that otherwise if it is not inflated how do you say that it broke? Was the balloon exploded? This is another question. Was John concerned? Questions as such are all subject to interpretation and complicated inference. Who was responsible for the baby crying? John? In a way yes but actually the balloon was responsible but since Mary gave John a dirty look it tells us that obviously John had something to do with the balloon going of and touching the light bulb.

(Refer Slide Time: 19:07)

Therefore it is a much deeper inference that gives this answer John. So if we say that we were trying to parse a paragraph then all sentences we find are related to one another to different degrees. And we have to denote the relationship among the components that we are getting after parsing the individual sentences.

(Refer Slide Time: 20:22)

First of all we are getting the components as words and we try to find the partnerships. But when these words get embedded in a sentence then also there are some ambiguities and we have to resolve them. Now there is a paragraph so now we will have to discuss about inter sentence relationship and may be when we are going for discourse consisting
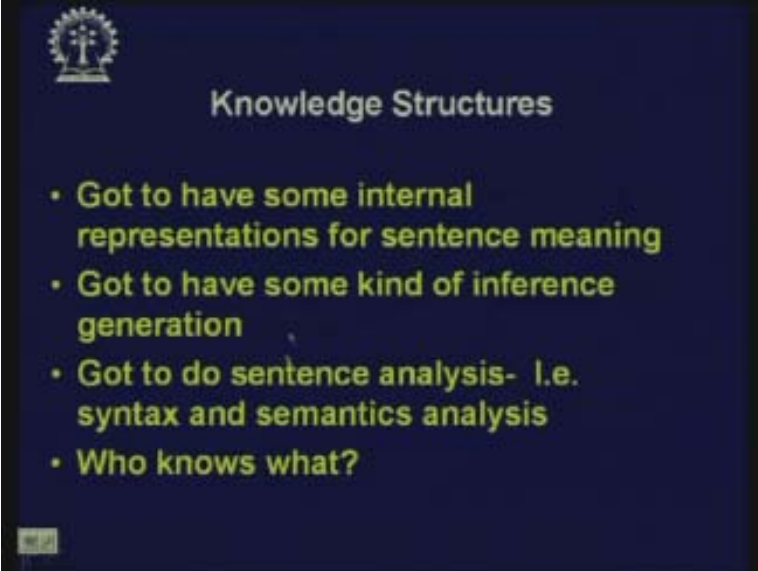
of a number of paragraphs we will have to establish inter paragraph relationships and in that way it gets more complicated. There are some implicit knowledge about the universe and thus knowledge representation is very crucial about the whole thing. Natural language systems like early toy systems were attempted for a long time. One of the well known systems is Eliza. It pretends to be a psychologist and talks to the user. What does it do? It parses a sentence and looks for keywords and phrases. The user for example says I feel angry today.

(Refer Slide Time: 22:22)
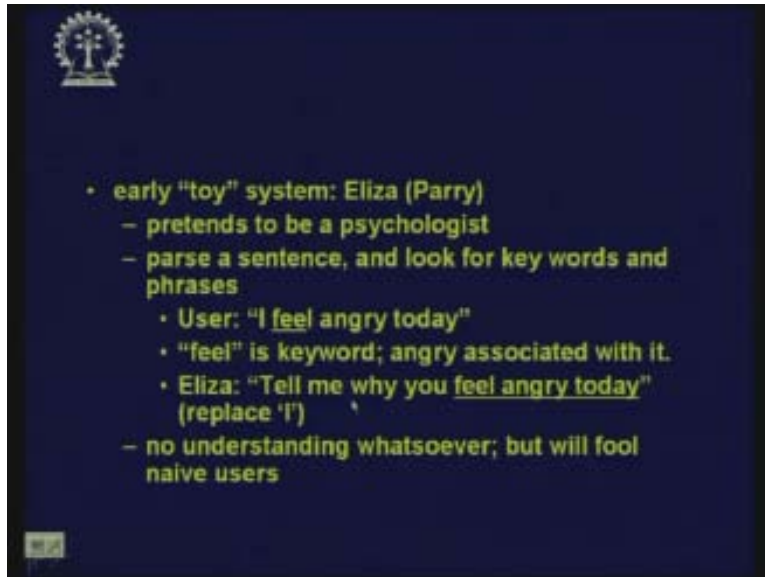
Now, feel is the keyword that Eliza knows so Eliza can therefore respond as, tell me why you feel angry today? So it takes this entire component this entire part of the sentence feel angry today and just replaces I with u so you feel angry today and this is a very routine mechanical way of forming a question. Tell me why you feel angry today? Actually it is not deep understanding but in a way it can fool the naïve users and the naïve users can find it very interesting that Eliza is conversing to that.

(Refer Slide Time: 23:22)

Now, in order to really build a good knowledge understanding system we require knowledge representation and we require knowledge structures. We have to have some internal representations for representing the meanings of these sentences. We have to have some kind of inference generation, we have to do some syntax and semantic analysis. So if we look at sentence analysis here is a serial flow of control we need many things but here only a few things are enlisted.

(Refer Slide Time: 23:52)
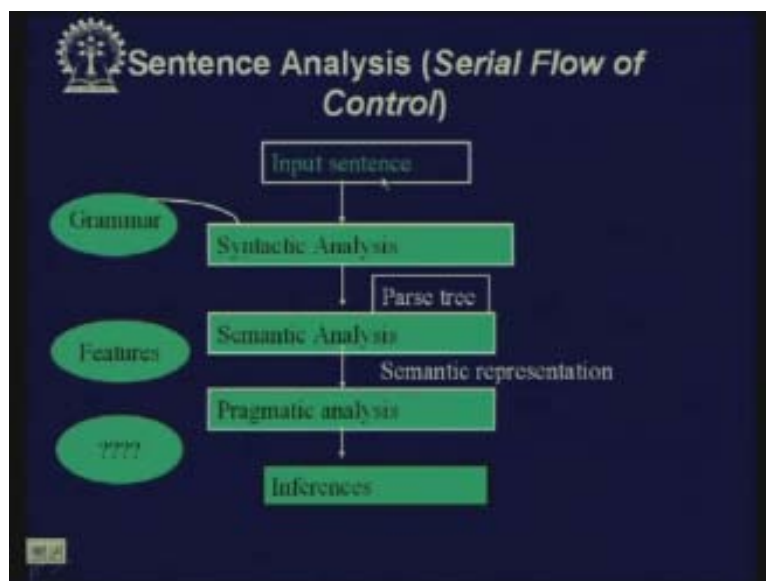
We have got an input sentence here and that is undergoing syntactic analysis and for that we are using the grammar, this grammar is being used and consequently we are getting

the parse tree as the out put of this syntactic analysis. And this is followed, this parse tree at the syntactic level after doing some part of speech tagging we can handle or we can deal with some of the semantic issues. But there are many more semantic issues which cannot be handled at this level. This is followed by semantic analysis. And this is a complex problem where we will be needing features of the domain. And after that we need some pragmatic analysis.

Some things are really not possible to be uttered in a particular context those are pragmatic considerations and also we have to carry out inferences in order to discover the meanings. In the previous example of the balloon breaking issue we have already seen that we often need deep semantic understanding or we need a deeper inference to be carried out in order to understand because many of the things are implicit and need to be inferred and often these inferences are quite complicated.

Now the point is that here we have shown a serial flow of control. Is this serial flow of control enough? I will first do syntactic analysis then I will do semantic analysis then pragmatic analysis then I will do inference but possibly not always.

(Refer Slide Time: 25:53)
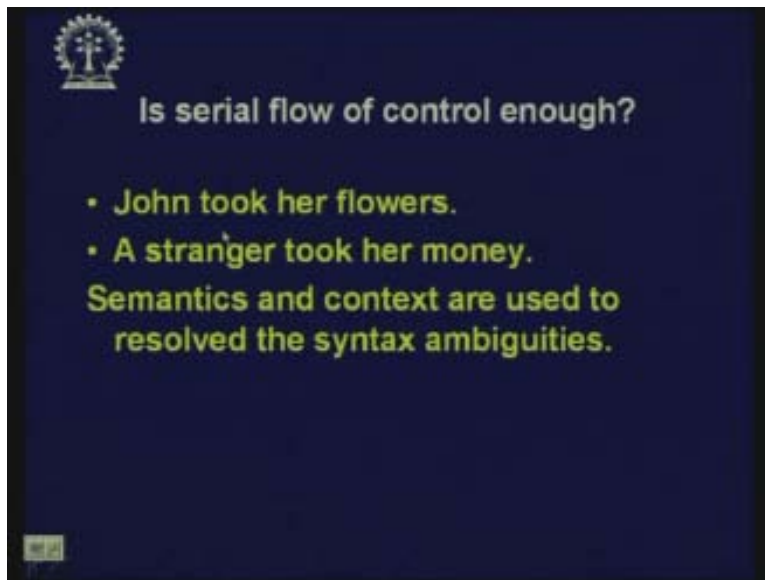
For example, if we look at these two sentences; John took her flowers, what it means? So somebody brought some flowers and John took that.

A stranger took her money.
Now these two takes are different, this is accepted and this is stealing. A stranger stole her money. Now semantics and context are used to resolve the syntactic ambiguities because here this is subject to interpretation. And here when the balloon touched the light bulb it broke this caused the baby to cry. Mary gave John a dirty look and picked up the baby.

John shrugged and picked the balloon. Now we can observe that seven explicit information is given like:
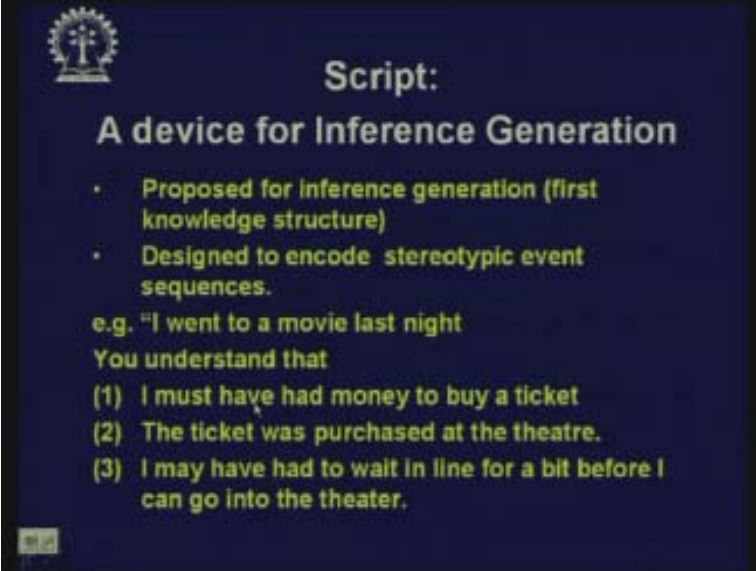
The balloon was originally inflated, the light bulb was hot these are also not very explicit they have got some little bit of inferences required but that is quite straightforward, the balloon exploded that is straight away stated over here but there also it broke means what broke? Whether it is the bulb or the balloon? The anaphora reservation was required to find the proper reference.

The explosion made a loud noise this is inferred nowhere it is said that there was a noise but this caused the baby to cry might be the noise. The baby was scared but that is relatively direct, crying may have direct relationship with being scared, the loud noise scared the baby, Mary picked the baby to comfort it. Here none of them are actually so much explicit they require some sort of inference.

(Refer Slide Time: 28:22)

There have been different methods which has been proposed to carryout an inference for natural language understanding. One way of doing that is the script language which is very helpful to encode stereotypic event sequences. I went to a movie last night. Going to a movie is a very stereotype scenario because all of us know that there are some routine things that we must do in order to go to a movie hall and see the movie.

We must have money, we must go to the movie hall, we must get the ticket, and in order to get the ticket we must have enough money so that we can pay for the ticket and after we get the ticket we proceed towards the movie hall, we have to show the ticket to the usher and then we need to go and sit in the movie hall and watch the movie. I also know that the amount of money I had when I went in the movie hall and when I come out of the movie hall the amount will be less because I had to pay for the ticket. This is a very stereotypic situation.

Another very popular stereotypic situation is going to a restaurant. Before I go to a restaurant I must have money, I must go to the restaurant, I must find the seat in the restaurant, I will have to order food and I have to order food so that the cost of the food is less than the money that I have, after eating I have to pay for the food and when I come out then I will have less amount of money. These are various stereotype situations as if drama script has been written. And whether I go to a restaurant or you go to a restaurant or your friend goes to a movie the steps that will be executed are very similar and that is why this is called a script and as if we are following a script.

If I describe a stereotypic situation using the script language then as soon as I write that I went to a movie last night you understand that I must have had money to buy the ticket. That is possible to infer very easily. The ticket was purchased at the theatre or in the movie hall; I may have had to wait in the movie line for a bit before I can go in to the theatre.

(Refer Slide Time: 31:37)
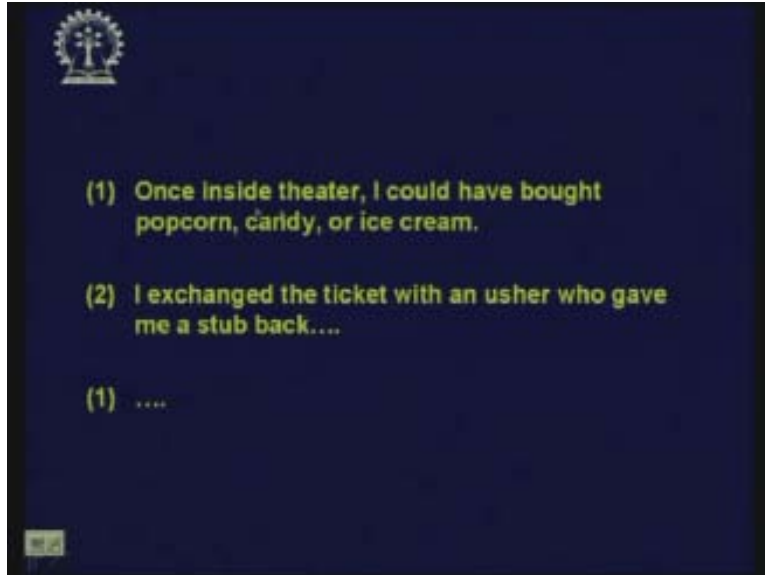
That is a typical movie hall scenario there is a queue and you may have to wait, you can further infer more and once inside the theater I could have bought popcorn, candy or ice cream which are the typical things that are possible, and obviously you will not assume that inside the movie hall you will buy a chicken dish. I exchanged the ticket with an usher who gave me a stub back etc and I can go on. Therefore this is the script language. Now, using this sort of script, if we look at this balloon script here is a partial description of the balloon script.

(Refer Slide Time: 32:12)
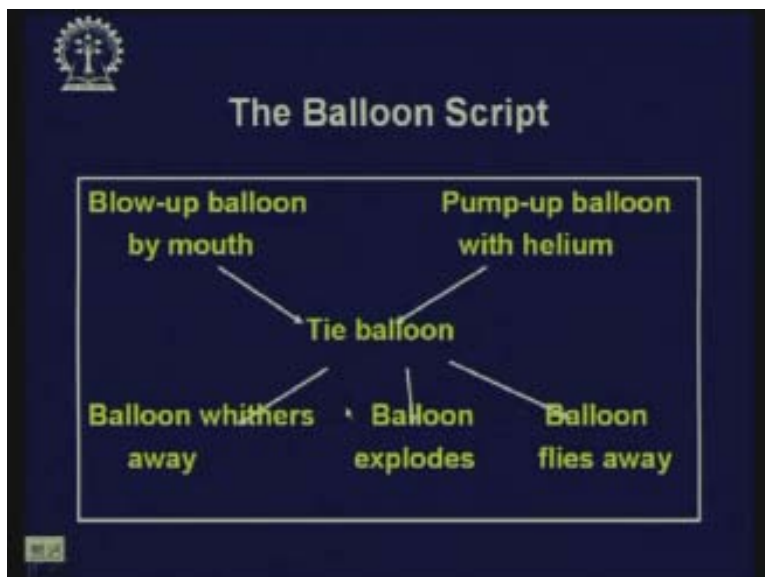
It is possible that I blow up the balloon by mouth and tied the balloon or I could have bumped the balloon with helium and then tied the balloon. After tying the balloon a couple of things can happen. Either the balloon wither away the balloon explodes or the balloon flies away. In that way we can describe the entire scenario this is very small part of balloon. And we can go on keep building a complete screen of the drama. If we consider what happened with the child, Mary, John and the balloon exploded as a drama we can write down a script in the form of some specific language as is provided by the script language. But there are a couple of problems in this approach. First of all the script that you write will be very complicated and often very difficult to handle. Another issue is that the only script that we find is often not enough. In order to understand the scenario we have to have some basic idea of where we are trying to reach.

(Refer Slide Time: 33:36)
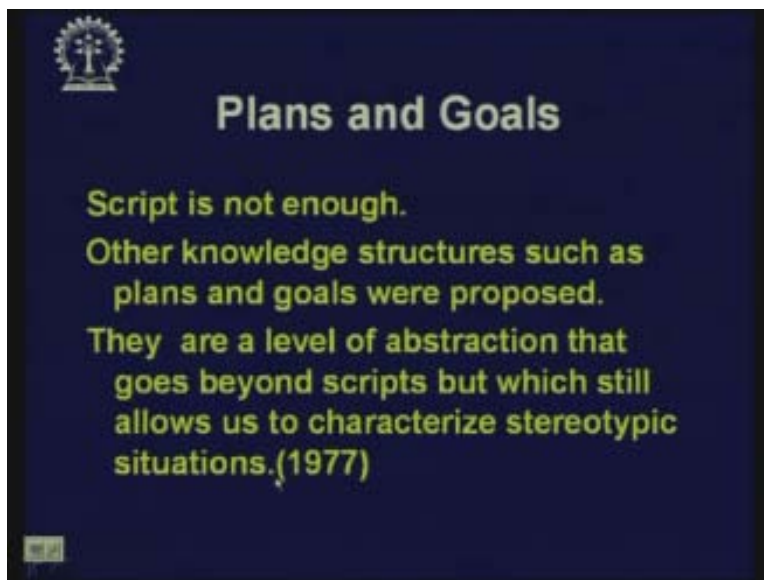
Some sort of goal based planning is required. But there are different levels of planning which are often found useful to carry out stereotype situations because if I go to a movie hall I have got a complicated script over there but my objective is to see the movie and get a seat. And out of the possible script actions that I may possibility take I will take the best one that will satisfy my goal faster.

For example, just you want to go to the movie hall and you have got different ways of going. Now, in order to understand suppose a statement is there I went to the movie hall yesterday night, I started from my home in the evening I reached the movie hall for the night show just five minutes before the show started and you go on saying different things.

Now if somebody asks why were you late?
Will the system be able to infer that he must have gone to the movie hall not by taking a taxi or a cab but probably went by bicycle or by a slower vehicle or taken a longer route, and why would a person choose a longer route, must be he did not have enough money

and he wanted to save money. If you have taken a cab the amount of money that you would be left with would not be sufficient to buy a ticket. So these are all inferences and these inferences might be you can write everything out in the script but that becomes very cumbersome instead if we have got a plan and you apply the planning knowledge also over here you will be in a better situation to handle it. So the moral of the story is, in order to build an effective system script is one thing the domain knowledge is another thing may be the semantics nets and all those things are required, we need the lexicon and may be we need the planning structure and in that way there can be numerous things which will have to be used together in order to be an effective system.

(Refer Slide Time: 36:22)
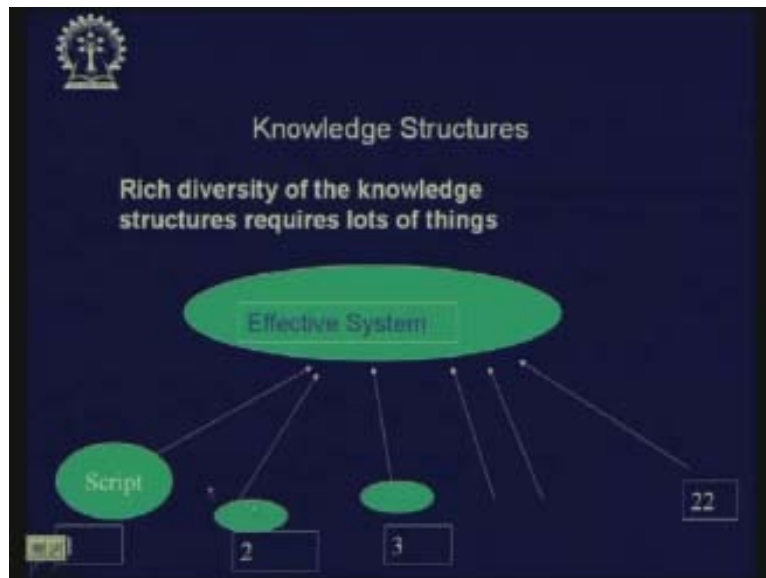
Here is a particular approach to be discussed. It is not a unique approach but that is one of the approaches that are found to be very useful in natural language understanding known as case frames or semantic frames. Now you are exposed to the frame structure. A frame is a data structure like a frame boy will consist of different slots like age, height, weight, name etc these are the slots and boy is a and this is human etc, and in age since I am saying a boy I can also have some constraint that the age can be any value between 5 to 15 beyond which I will not call him a boy.

So when I instantiate the frame Tom is a boy then we create an instance of this frame where that we talk about a particular boy Tom whose age will be 10 the exact data of Tom maybe 5 ft and weight may be 60 kgs, name is Tom etc that is a frame. And we have also seen that a frame can be used for and these are the constraints that we can associate to the different slots and we have also seen how the frame based inference is done.
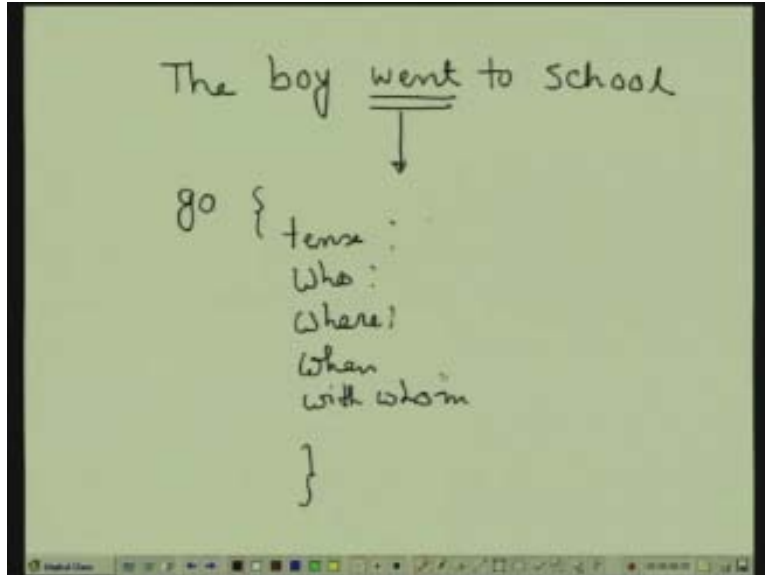
(Refer Slide Time: 38:22)
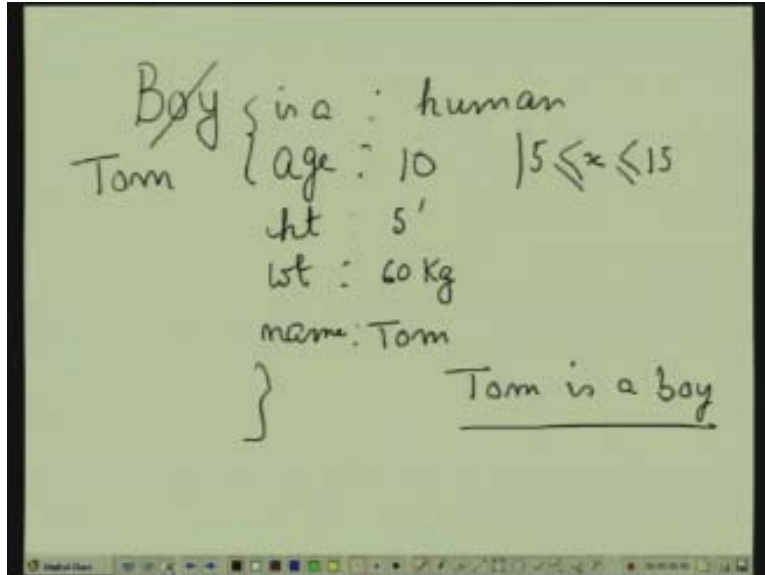
In the case of natural language understanding whenever I make any sentence the boy went to school now if we take the verb and went is a past tense of go we can create a frame go which will be any verb and any verb will have different slots and what these slots will be? One thing is that in this case it can have different tenses so in this case went will be an instance of go with past. But the action of going will require or can generate the question who went? I can ask the questions relevant to going.

What are the possible questions I can ask?
I can ask who went. Where did he go? When? With whom etc, these are possible questions I can ask. Similarly, if I consider the verb give then associated with give I can have a number of queries like, who gives? Gives what? To whom? Where? How etc similarly if I take the verb eat then also I can have queries like who eats? Eats what? Where? With what?

Tom ate spaghetti with chopstick, with what etc are some very relevant queries associated with a particular verb.
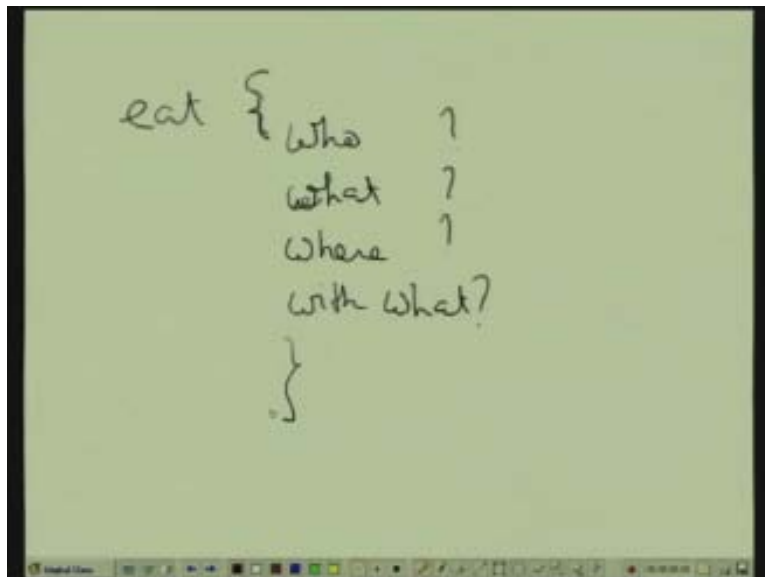
Karaka: In Indian languages we got six karakas and basically karaka is determined by the relationship that a word has got with a verb. Like Tom went to school, who went to school?

The answer is Tom. That answer is a nominative case in Indian languages <mark>katrikara</mark>42:12.

Therefore who, what are different roles or in English grammar we also say these are different cases so karaka and case is the same thing. So these sorts of frames like the frame for eat starts with who eats? What etc are different cases and such frames are called case frames or they are also called semantic frames because in some way whenever we identify the karaka we can answer some of the questions like Mary ate spaghetti with chopstick. And if I have got a verb eat then this particular verb will be an instance of eat where the tense will be passed, who will be Mary? What will be spaghetti? With what will be chopstick?

When we have got this case frame instantiated then obviously if I ask the questions how did Mary eat spaghetti? The answer will be here and so we can say that Mary ate spaghetti with chopstick. If we ask what did Mary eat? The answer will come directly from the slot of this frame. That is why such case frames find a lot of applications in natural language understanding.

(Refer Slide Time: 44:29)
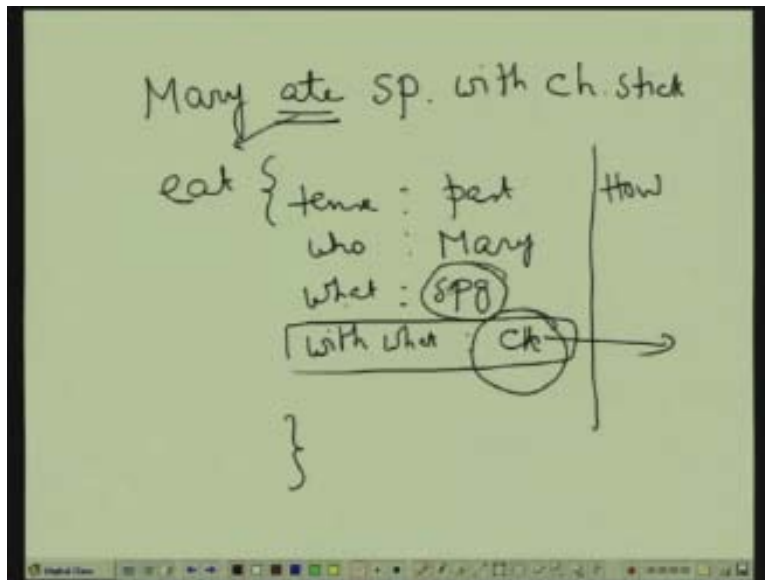
(Refer Slide Time: 47:22)
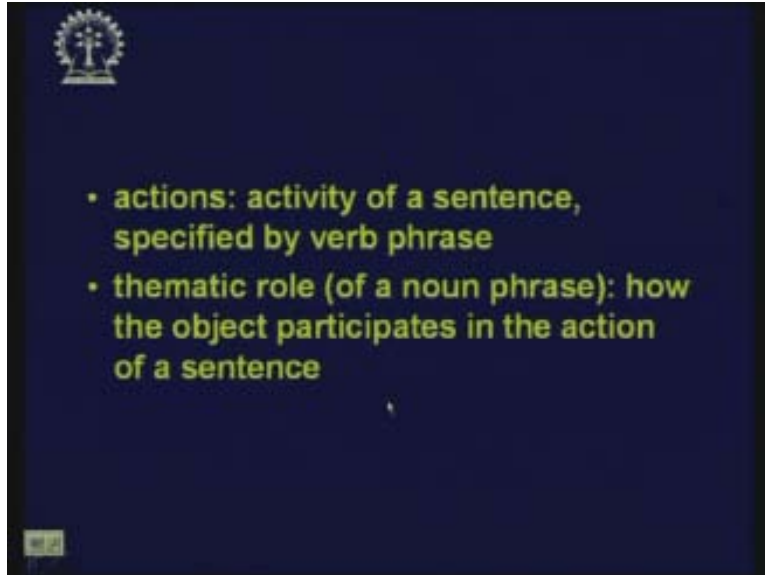
Frame knowledge representation is a good way to represent some common sense and we can define some stereotypical aspects of using frames and sentences about that domain can be parsed and the meaning can be extracted in terms of what the frames expect. What is important here is to know what the frames expect.

(Refer Slide Time: 47:40)
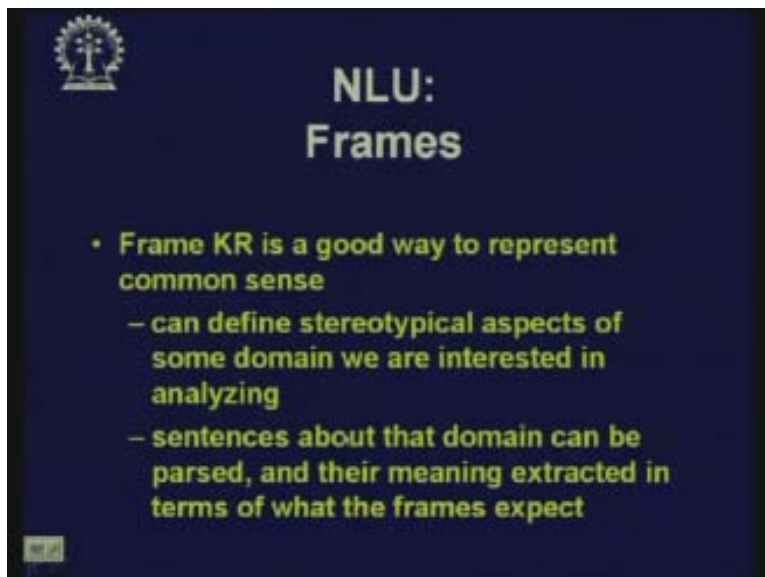
I am in a scenario where again I take the case eat, I have got all the possible slots what, who, with what, where etc. now each of these slots have got an expectation so whatever value fills up this part who eats has to be an animate object. So I cannot just say the spaghetti ate Mary because spaghetti is an inanimate object, what eating this must be an

inanimate object so we know what is expected over here and this helps in dissolving some of the ambiguities where we expect a place here so that should be some sort of a proper noun so we expect some noun phrase here. And with what, we expect some instrument or some inanimate object here or it can be also if it is an animate object in that case that will relate to whom? Mary ate spaghetti with John and now since John is animate then obviously the relationship will be with whom, that means this will no longer be an instrument but will be a co-agent. The agent of eating is Mary and John was with her so that is a co-agent. In that way by looking at these possible constraints and the types of value filling up these blanks we can approach towards better understanding of the sentence.

Therefore these case frames are being built around the verb phrase. So we start with actions that are the activity of the sentence by the verb phrase and the thematic role of all these cases that I was showing are also mentioned as thematic roles. The different words in a sentence have got a role to play in that entire sentence which could be any sentence. Any sentence that I state builds up a picture. You can think of different ways, I make a sentence and there was an expert artist probably he would have drawn that on the canvas immediately so that instead of listing to the sentence I can look at the picture and understand the same thing.
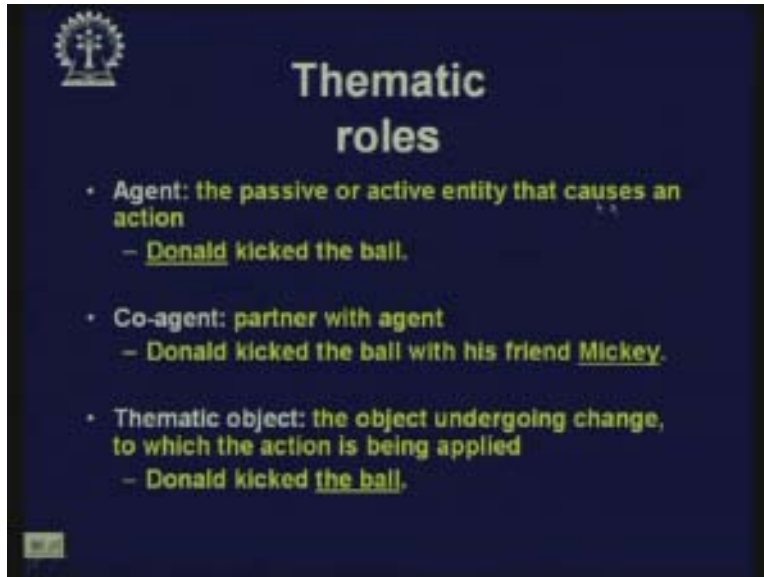
The other thing is whenever I state a sentence since I have got a good semantic net type of structure and if I understand that sentence the proper nodes of that semantic net will be activated, so this is another way of looking at it. I am just saying in a different way. whenever I say a sentence that can always can be enacted and I always talk about a theme and any theme will have different roles in it, every component every word of the sentence plays a particular role in that drama that the sentence picturizes. Whatever slots are being shown are different thematic roles and these are to be filled by a sentence and the task is to determine the thematic roles of noun phrases.

(Refer Slide Time: 49:39)
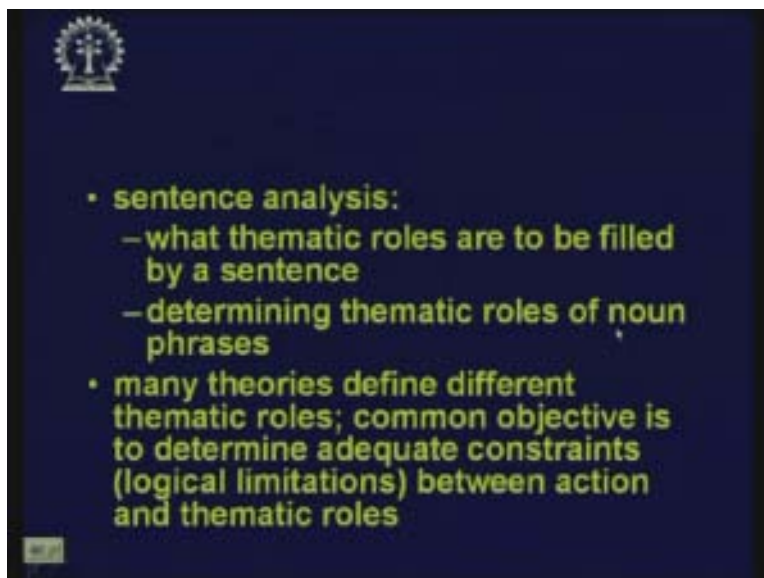
There are many theories that define different semantic thematic roles. However, the common objective is to understand the sentence although is not complete. In Indian languages when we work then we may have a different structure and a little bit of extension of the thematic roles but these are more or less standard agent.
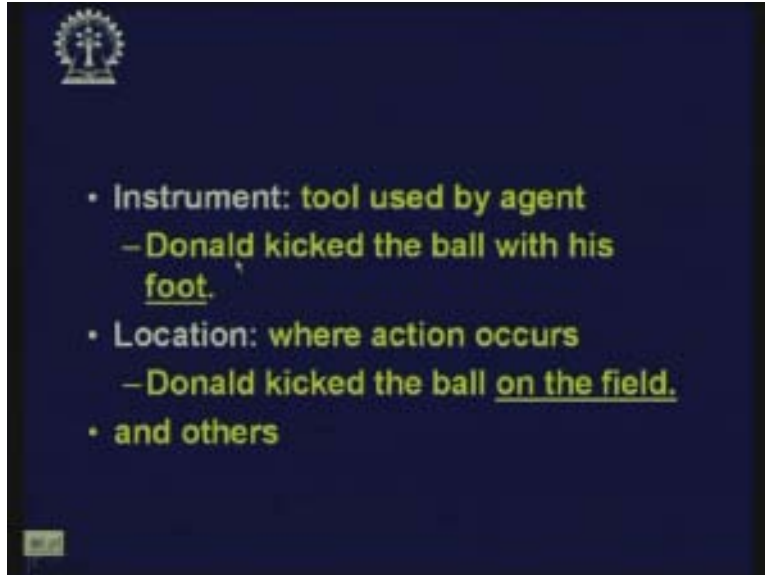
(Refer Slide Time: 50:16)

Agent is the passive or active entity that causes an action. For example, in the sentence Donald kicked the ball Donald is the agent, co-agent is the partner with the agent. For example, Donald kicked the ball with friend Mickey. So here Mickey is the co-agent. There is a thematic object, what? Donald kicked what? Kicked the ball and this is the object undergoing change. Often another way of looking at it is that any sentence if I enact it that will create a state change. Donald kicked the ball so the ball moved from one place to another so the over all state changed. That is also a very interesting way of looking at the whole thing. So the object that is undergoing change is the thematic object. The instrument is the tool used by the agent like Donald kicked the ball with his foot.
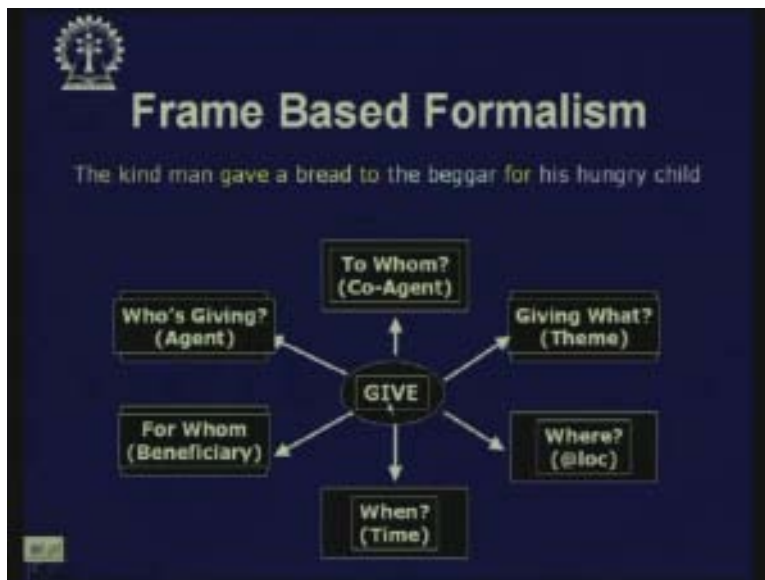
Location is another thematic role that is the place where the action occurred. Donald kicked the ball on the field. And in this way we can go on adding thematic rules. Now let us look at this dialogue.

Again here the verb is give, who is giving? The kind man gave bread to the beggar for his hungry child. So, I start with giving that is the past tense, who gives? The kind man, hence the agent slot the agent role is filled with the kind man, to whom? Who is participating in the action? The beggar that fills up the co-agent or the beneficiary it is not exactly a co-agent but it is a beneficiary the beggar, gave what? That is the theme so

bread fills up here the beggar comes up here or sometimes we may like to put the beggar gave the bread to the beggar that is the co-agent and for his hungry child who will be ultimately benefited, the hungry child will fill up here and when means the time, time is not specified. Now if we fill up this frame, this sentence has not filled up all the possible frames. So a partial instantiation of the frame is possible and different verbs can have different frames. The domain of a role is dependent on the verb.

(Refer Slide Time: 53:00)
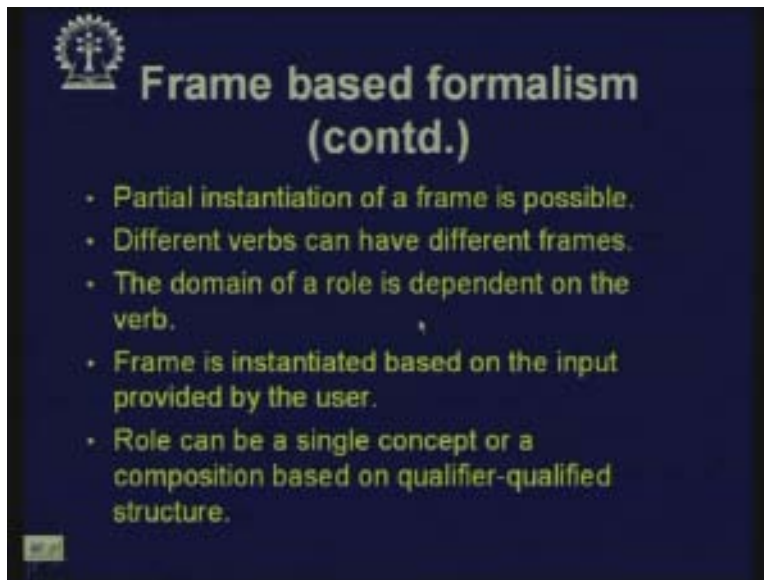
A role can be a single concept or composition based on a qualifier qualified structure like here:
The kind man the agent part is being filled up with this entire structure the kind man. It is not only the man but it is qualified so it is not a word but a structure. It is not a single concept but a composition. Once this is filled up, it is partially filled up because this sentence does not talk about time. So, if we look at this frame then we can answer a couple of questions like who gave the bread. Obviously the answer is agent.

Now I am asking a difficult question, why did the kind man give the bread to the beggar? The answer will be the beneficiary, who is the beneficiary for his hungry child. So at least to a particular level we can answer some of the queries corresponding to this. Here is another sentence: Robbie made coffee for Suzie with a percolator, you can make case frame structure, now this is made.

(Refer Slide Time: 54:39)
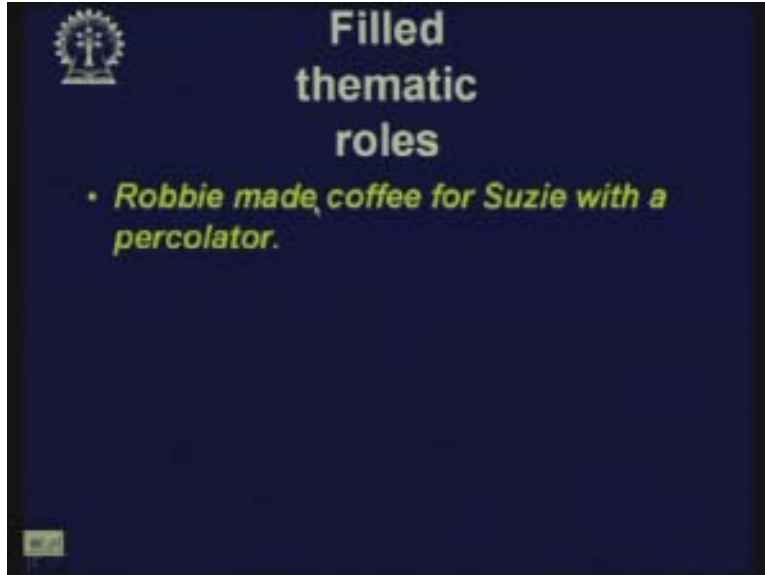
Make means making a thing, He made a toy and make coffee that means prepare coffee. So the verb make can have multiple frames making coffee and making a machine, making a noise, the child made noise in that case the frame of make will change. So you have to make an appropriate frame for the particular semantics of the verb and then parse this sentence and fill up the thematic roles manually and you will see that you will be able to answer some of the questions. Now this is just the tip of the iceberg. Natural language understanding is a very interesting and very deep issue and subject and area of research.