Artificial Intelligence:

Conceptual Dependency (CD) Theory

Prof. Deepak Khemani

Department of Computer Science and Engineering

Indian Institute of Technology, Madras

Module – 05

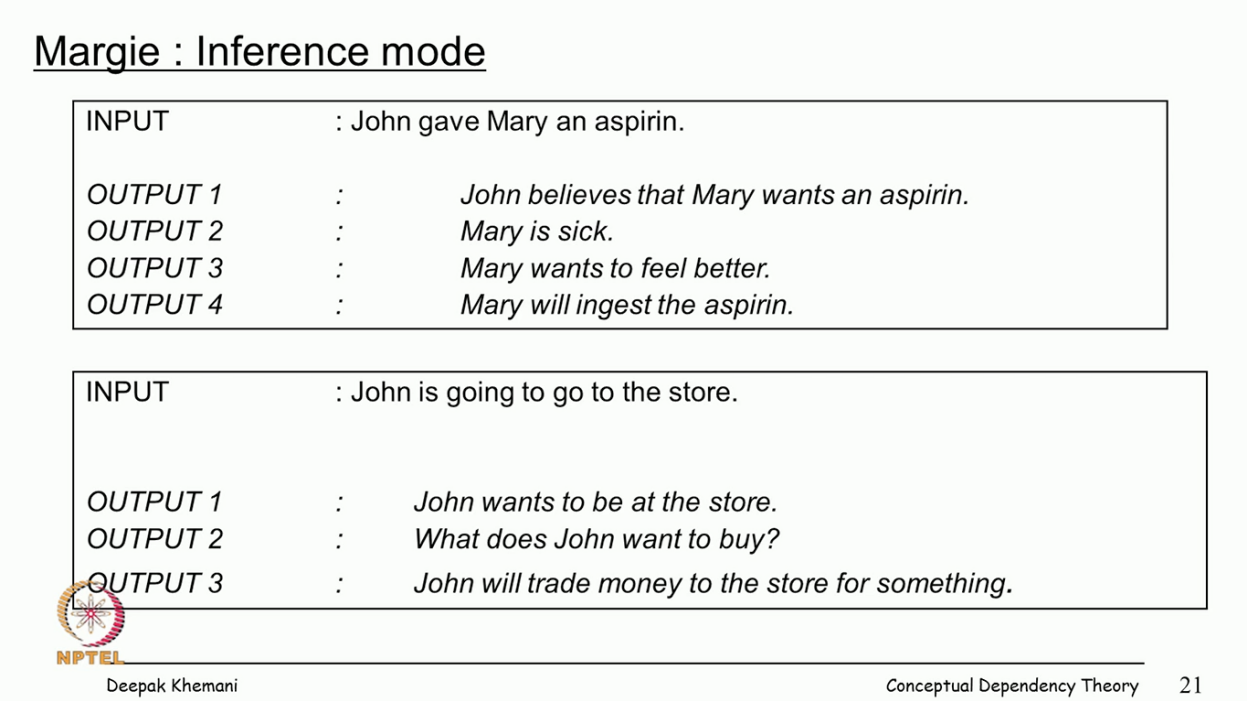
Lecture - 02

So In the last class we were looking at some of the basic programs developed by Yale group based on conceptual dependency and this particular program is called Margie and this particular program was designed for sentence level understanding. You could just understand one or two sentences. Later on they designed more program which tried to understand complete stories because they required more context knowledge or you may say as some linguists call it Pragmatics, you should what really is happening out there in the world to make sense of what you are seeing. But we will come to this later. Lets look at a few more examples of Margie in the inference mode.

So here is a sentence John gave Mary an aspirin and all these inferences Margie makes, that John believes that Mary wants an aspirin, Mary is sick, Mary wants to feel better, Mary will ingest the aspirin. Now you can see that these are not deduction, they are not deductive inferences they are not guaranteed to be true. But we don't often make inferences which are guaranteed to be true. So this is focused more on non logical inference making which is based on what really often happens in the world.

John is going to the store. So one thing is he wants to be at the store. Other thing is he may want to buy something. And if you are really knowledgeable about the world you will say he will take some money and buy something from the store.

(Refer Slide Time: 01:52)



You can also work in the paraphrase mode where once you have generated the conceptual dependency representation of a sentence you can generate a natural language sentence from that. So for example John advised Mary to drink the wine. The program has paraphrased it saying John told Mary that drinking wine would benefit her. And later on at some point we will see how is the word advise represented in conceptual dependency. That's the key to understanding this sentence. Or this sentence which says John killed Mary by choking Mary. A paraphrase could be John strangled Mary because somehow the system is able to understand that strangle means killing by choking. And John choked Mary and she died because she could not breathe. All these must be represented in the meaning of the world strangle.

Reading the book reminded Rita to loan the book to Bill. Rita remembered to give the book to Bill and she expects him to return it because of the word loan because someone read the book. In this sentence its not figured out that it was Rita herself who read the book. These small inferences can sometimes be hard to make in natural language. So John prevented Bill from giving a banana to Rita by selling a banana to Rita. So its just paraphrasing what you are reading here. Bill was unable to give a banana to Mary because Rita traded John some money for a banana. So we all know that buying, selling, they all involve trading of money on one side and getting some entity on the other side. Mary could not get a banana from Bill because Rita bought a banana from John. So just stating it in different way essentially.

So the basic axioms we will look at in conceptual dependency representation is that for two sentences with identical meaning or as close to meaning as possible

regardless of the language so its not that this is a English language based representation or Hindi language based representation or Tamil or Marathi or whatever. It's a language independent form and you should be able to represent whatever you are saying by parsing any language. They should have the same representation and at some point some of their work showed that they could read a story in English and paraphrase it into Spanish for example. May be in one of the example that we will see after a week or two we will see such examples. That is possible because once you have a canonical representation which is language independent you can generate output in any language that you desire.

So it could be a mechanism for language translation as well so this would be as some people would call it deep translation. You go down to the meaning level and generate the new sentences in the new language as opposed to most translation systems are more superficial they don't really create a conceptual representation of what is being translated. Any information which is implicit in the sentence must be made explicit in the representation because representation is all that you will be working with. In some sentence its something like eager evaluation the moment you figure out what the sentence is saying you create its representation. As opposed to lazy evaluation which you would say that I will make the inferences when I need to make the inferences. The meaning propositions underlying language are called conceptualizations. Two kinds of conceptualizations active or stative.

Active basically states that an actor does an action which may have an object and a direction and may have an instrument but the basic diagram that you will use is an arrow with two lines, double arrow with two lines two sided arrow with two lines. And the stative representation says an object is in a state and we will represent as three line double sided arrow. That we have already seen.

What are the kind of inferences that Margie can make. So this is how people have programmed it. These are kind of common sense inferences you might say John picked up a rock he hit Bill. So it's a specification inference John hit Bill with the rock. It doesn't say anywhere in the sentence that he hit Bill with the rock but that's a plausible inference you can make. That John hit Bill with the rock. Then John and Bill were alone on a desert island. John was tapped on the shoulder. Now if you can figure out that only John and Bill were there then you can figure out that John was the one who tapped Bill.

Now causative inferences, John hit Mary with a rock then it's a plausible inference again that John was probably mad at Mary. Now resultative inferences, Mary gave John a car and you can infer that John has the car. Then you can have motivational inferences, John hit Mary then you can infer that he probably wanted Mary to be hurt. Enablement inferences Pete went to Europe where did he get the money to travel? Function inferences John wants the book then he probably wants to read it. These are all inferences we are making different types of inferences we are talking about. Enablement prediction inference Dick looked in his cook book to find out how to make roux. So he will probably now make that particular dish.

Missing enablement inferences. So Mary couldn't see the horses finish. She cursed the man in front of her. Why did she cursed him? Because he blocked her vision. So

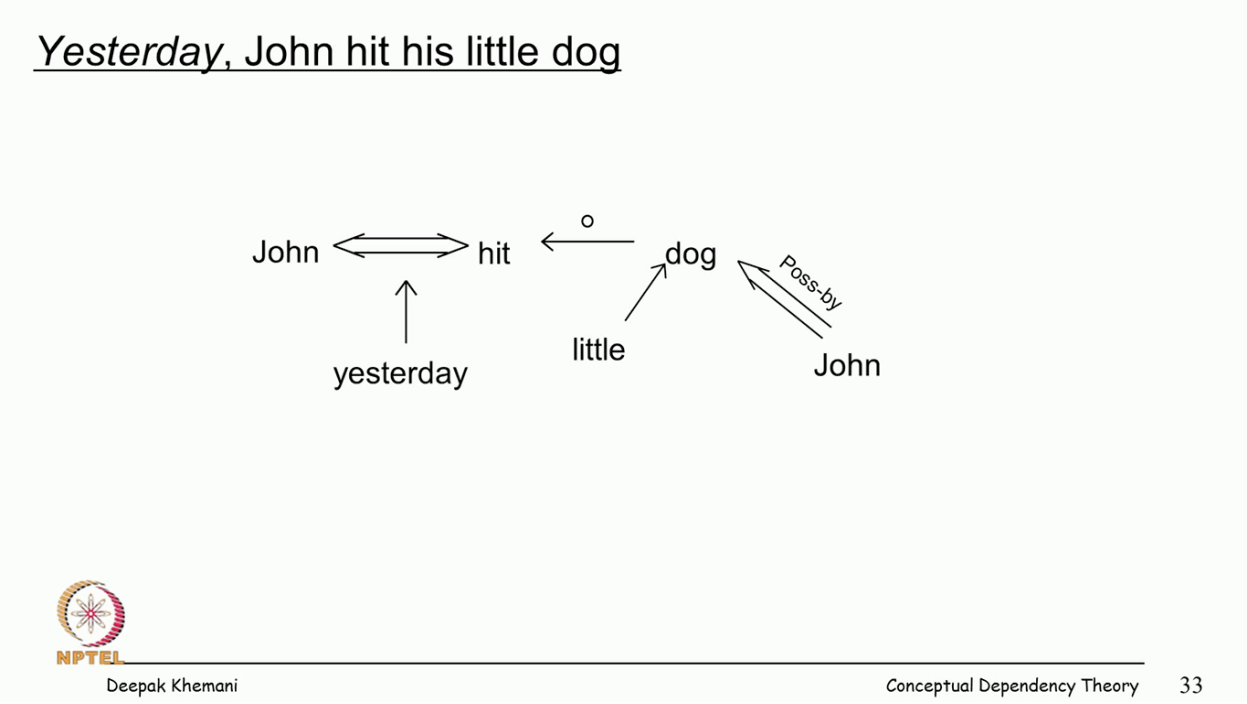
that's an inference we can make. Trying to explain what is the connection between sentences. So as we will see as we go along the whole idea of understanding story is to somehow establish connection between the different sentences. So if you can establish the connection and if the story is coherent to start with then you can say that you have understood the sentences

Intervention inferences. Baby ran into the street Mary ran after him why? Because she doesn't want the baby to get hurt. Action prediction inferences. John wanted some nails. He went to the hardware store. Knowledge propagation inference. Pete told Bill that Mary hit John with a bat. So Bill knows that John has been hit by bat. Towards the later part of the course we will try to see if we have time we will look at this kind of epistemic reasoning that if you tell somebody something then the person knows it.

Normative inferences. Does Pete have a gall bladder? Its very likely. John saw Mary at the beach Tuesday morning. Why wasn't she at work? So it's a question but it's a question which is based on the the inference that she should have been at work Tuesday morning what is she doing at the beach.

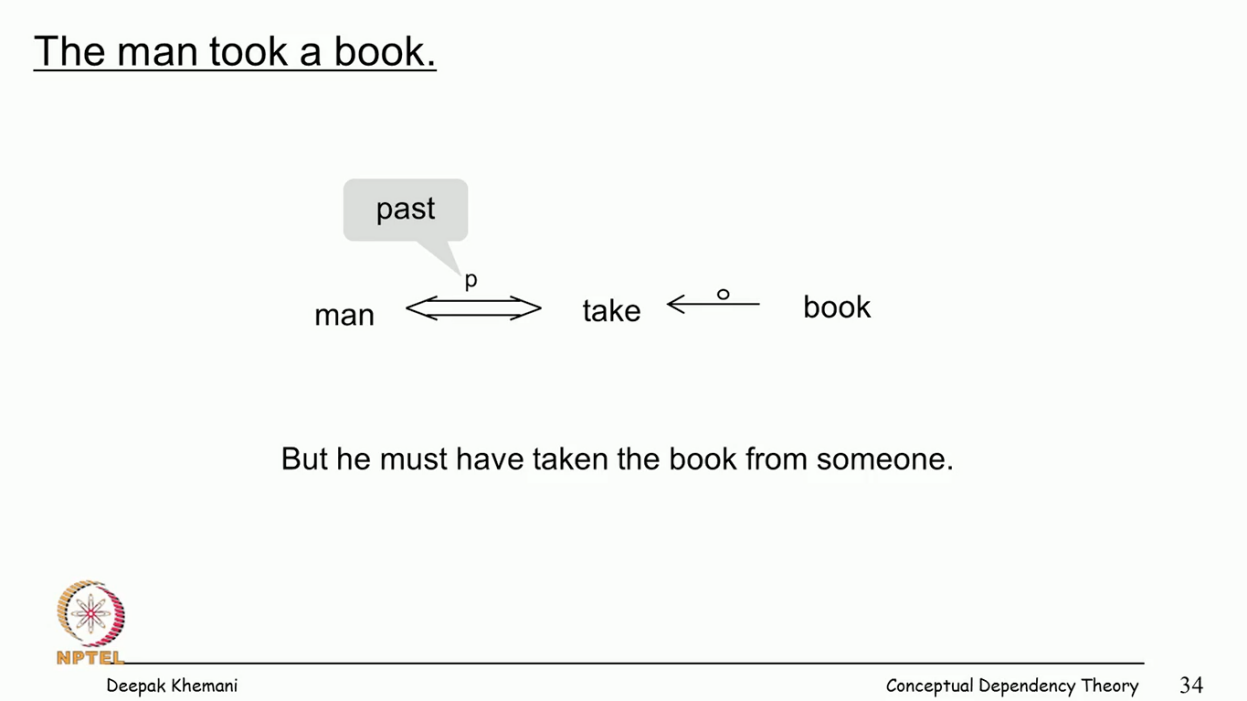
State duration inferences. John handed a book to Mary yesterday. Is Mary still holding it? Probably not. So you need some world knowledge to say that you don't keep holding a book all the time. Then there are some heuristics. Mary went to work. What is the time of this common action likely to be? So most probably people go to work in the morning so it must be morning so you can make this inference unless ofcourse she happens to work at the call center in India servicing someone in the USA. John went to Paris. Predict the likely instrumentality fly.

(Refer Slide Time: 10:00)



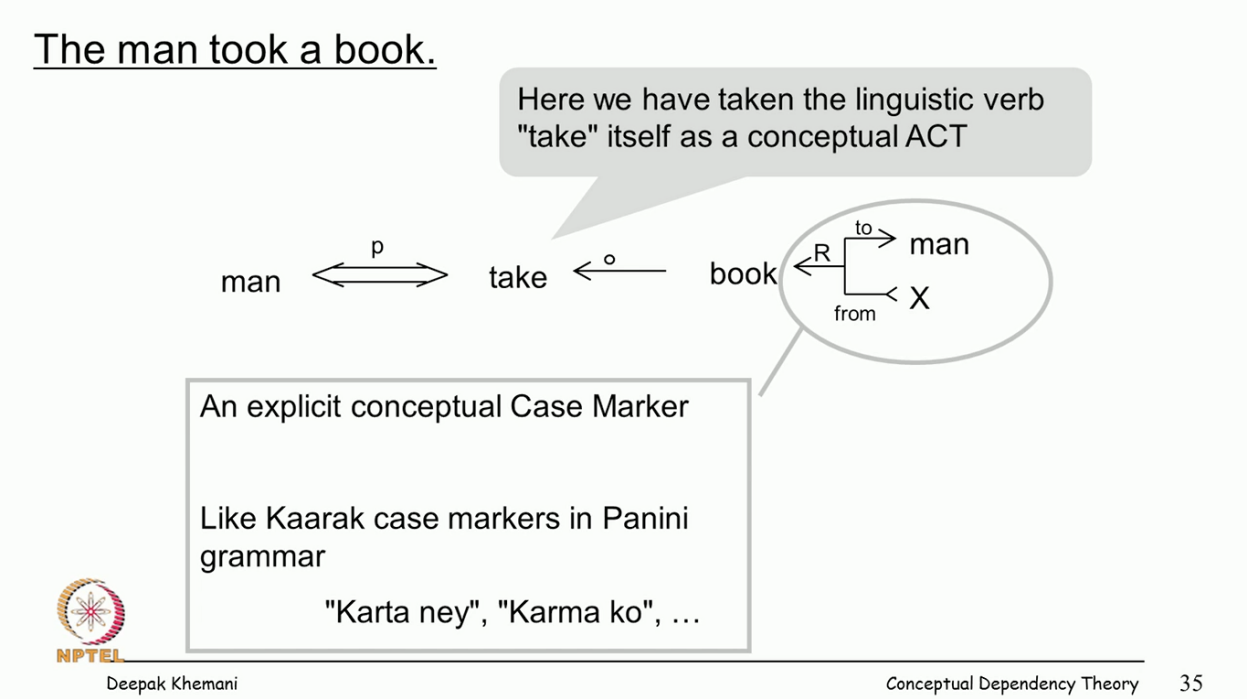
So this is the first sentence that we saw. John hits his little dog. If we add the word yesterday to that, yesterday John hit his little dog then the same conceptualization we were looking at except that the fact that the timestamp in some sense has been put on the conceptualization and that is yesterday. So far we have been choosing these words in adhoc fashion. So now we really want to come to conceptual dependency theory which is this small set of predicates that they use for describing any event. So if we want to say something like man took a book we might represent it something like

(Refer Slide Time: 10:43)



The man did the action take and the object of the action was book. And since he must have taken it from someone we can add this recipient case to that which says from someone to the man the book was. So these are called case markers.

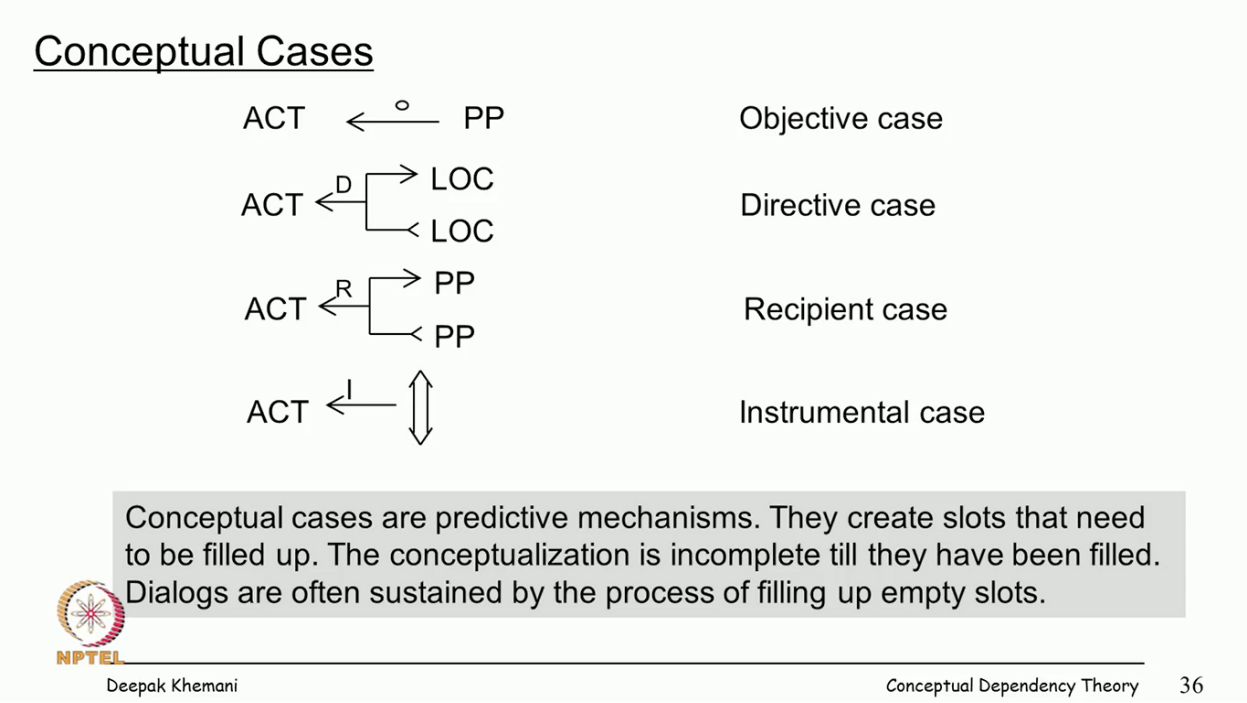
(Refer Slide Time: 11:04)



And in some languages like many indian languages the case markers are explicit so there are specific markers for describing the different cases that can occur in understanding a sentence. So you must have heard things like Karta ney Karm ko if you have studied Sanskrit or may be even Hindi whereas if you observe English language doesn't have explicit case markers. So you say John gave Mary the book nowhere it says that John is the agent and Mary is the recipient whereas in indian languages these things are explicit, in most indian languages, in some of them they are mixed up with the words so they are inflection on the words in some they are separate words for example in hindi they are separate words.

So what are the conceptual cases we are talking about. The Objective case what are the objectives of a sentence. The directive case which direction did a person go to. Recipient case what was being transferred or the instrumental case as to what was the instrumental action. Conceptual cases are predictive mechanisms. They create slots that we need to fill up. The conceptualization is incomplete till we have filled up all the slots.

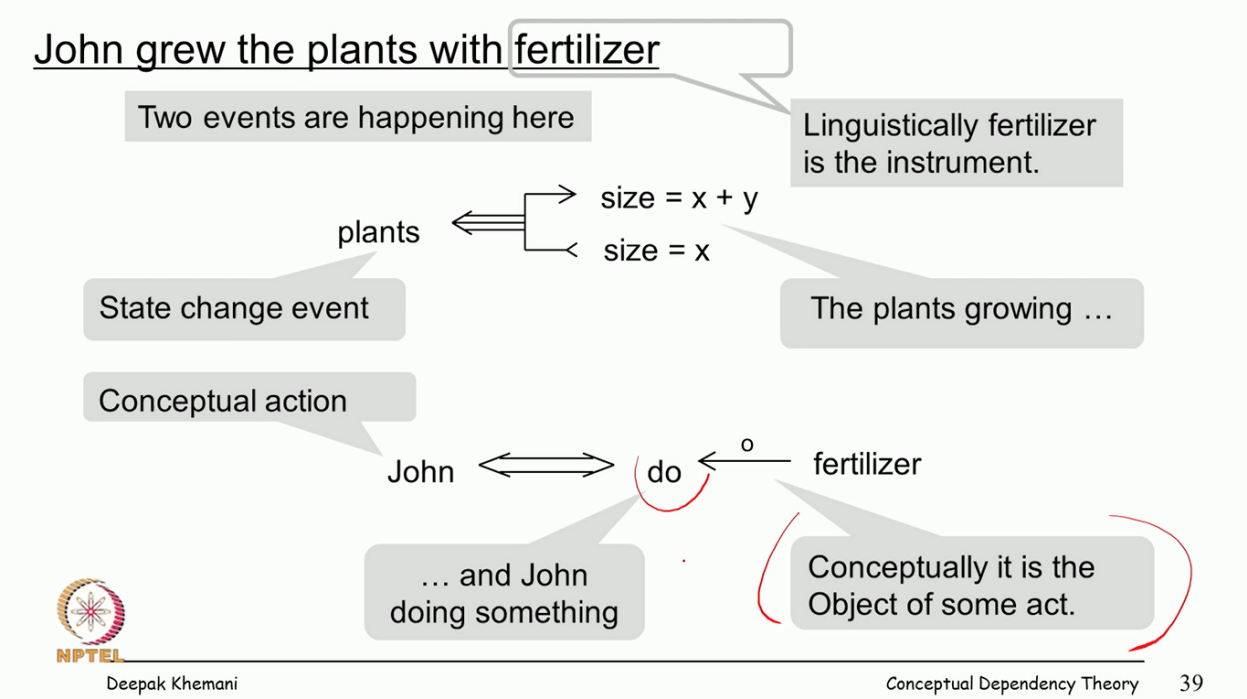
(Refer Slide Time: 12:18)



So as we will see the whole way of processing is to hypothesize the conceptual structure which may have empty slots and your whole story understanding process would be motivated by trying to fill up those slots. So we will see after we have gone through the basics of CD theory. So we said man took a book but you could also say I gave the man a book. Now you can see that only difference between giving and taking is the actor or the agent is different. So when you say he took a book, he becomes the actor. If I say I gave the book to him I become to agent. The action doesn't change the doer of the action changes. So one thing they want to do is to separate these facts, you don't need a separate word for take and separate word for give. Instead you can use something like Trans which is short for transfer. So when you say man took the book you can say man transferred the book from someone to the man. When I say I gave the man a book then I did the transfer. So the agent or the actor changes the action remains the same.

So if you say John grew plants with fertilizer then there are two things which are happening here. One is that the plants are growing and we will approximate that by saying that they are growing from a size x to size x plus y. very naïve way of representing growth but we will assume that its like that. And then john is doing something we don't know what john is doing but he is doing something with the fertilizer. Now fertilizer linguistically is an instrument. Plants with fertilizer but conceptually as you can see here fertilizer is an object of an action we have not specified what the action is. So we will just used do for that to stand for he did something.

(Refer Slide Time: 14:30)



So there are two things which are happening. A state change event that is the plants are growing and a conceptual action that john is doing something and the object of this action is the fertilizer. So there is a causal connection we talked about the causal connection. This is one example of that. So john did something with the fertilizer which caused the plants to increase in size. So again it is very some people call it a very folk psychology way of representing things we don't really represent things like that in our heads x and x plus y but lets assume we are doing something like that. And there are certain markers like I stands for intentional he did this intentionally and the simplest way of parsing this sentence that john grew the plans with fertilizer is so say that he did something as a result of which the plans grew. But if you are a more knowledgeable person if you know what fertilizers, what you do with fertilizer and so on you may create a different conceptual structure based on this.

So this is the representation of the sentence john grew the plants with fertilizers but you may create a different structure. You may create a structure like this which says he transferred the fertilizer from the direction of the bag to the ground where the plans are growing and as a result of which the plants grew in size from x to x plus y. so you see it depends upon the worldview of the reader or the listener if you don't know what you did with the fertilizer then you wont know.

So what are the CD actions that we will talk about. So this is the place where we cut down on the possible actions. We say for take or give we will use some common form and in effect what this proof showed us was with 11 to 14 actions you can represent almost most of the everyday activity in terms of just the small set of predicate. So one action we will call as Atrans. Transfer of an abstract relationship

such as possession, ownership or control. So if I give you a book then I am physically giving you a book but I am also transferring possession of the book to you. So that transferring possession part would be captured by the action Atrans. So give take buy will all involve atrans so when you buy something you transfer possession of some money to someone and that person transfers the possession of that object to you. But the underlying act would be atrans.

As opposed to it is Ptrans, physical transfer. If I give you a book I am doing ptrans as well as atrans. So I must model it like that. So when I say I gifted you the book then I physically gave you the book as well as transferred possession. But ptrans will also be used for people going somewhere that john went to the canteen so he ptransed himself to the canteen. Or you put something into the basket you ptrans something into the basket.

Then Propel application of physical force to an object. Anything which is talking about application of force irrespective of whether that object moves or doesn't move. I mean you will go and push the wall, you are still applying force but the wall is not going to move. So any action of force like push pull throw kick will have propel as the way of describing them. Then Move is used to talk about an animate agent moving a body part and is often an instrumental act for Ptrans. So if you say john went to the canteen you can say john went to the canteen by doing the instrumental act of moving his legs which you can break down further saying moving left leg right leg and so on which is trying to describe what you mean by walking. So move foot is an instrument in kick so if you say Beckham kicked the ball then he moves his leg in such a manner that it resulted in his foot and ball coming into a state of contact as a result of which the ball went flying into the air. And it totally went into the goal right.

Grasping is to grasp and object by an actor. Anything is talking about picking up or grabbing or letting go will be to not grasp anymore and so on will involve grasp. Ingest all kinds of input to our system. Expel all kinds of outputs from the system will be modeled as either ingest or expel. Mtrans is a third kind of transfer which is mental transfer. The transfer or mental information between animals or within an animal. So memory will be modeled again this is folk psychology this is not congnitive science or neuro science. This is just a way of trying to model how we represent and process things. So we can think of memory as a long term memory short term memory conscious processor immediate memory that kind of stuff and this is what this group did.

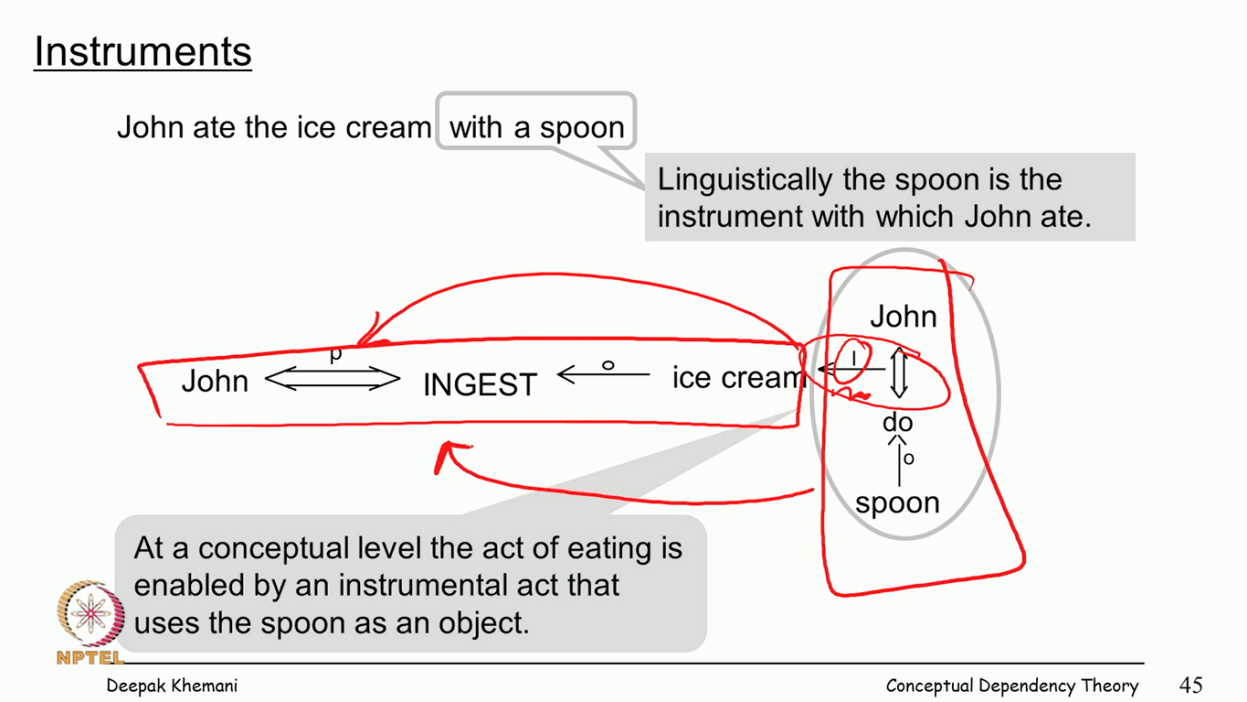
So memory was partitioned into conscious processor, long term memory and so on and so forth. So if you are talking something like telling somebody then you are Mtransing between people, when you are seeing something then you are Mtransing something from your eyes to your conscious processor. If you remember something then you are mtransing something from the long term memory to the conscious processor. These are just wanys of modeling things but instrumental to all these kind of things is Mtrans which Is mental transfer.

Then Mbuild is the construction of the new formula from the old information. So you might say that he decided, concluded, imagines, considered, any kind of inference would involve mbuild. Speak is an action of producing sound. It doesn't necessarily mean speak in a language. Anything which produces sound we will model by using speak. So if you want to talk about saying or playing music or cat purring or somebody screaming everything will involve speak. Attend, the action of attending or focusing a sense organ towards a stimulus. Also an instrument to Mtrans. So if you want to say he is seeing something he is mtransing something from his eyes to the conscious processor the instrumental act was that he attended his eye towards the object or something like that. If you are listening you are using your ears so you are attending your ears to that.

So lets look at this notion of instrument when you say John ate the icecream with a spoon linguistically the spoon is the instrument with which John ate. Conceptually the action that we are going to talk about is that John ingested icecream and we will think of an instrumental act in which John is doing something with the spoon and spoon is the object of that act.

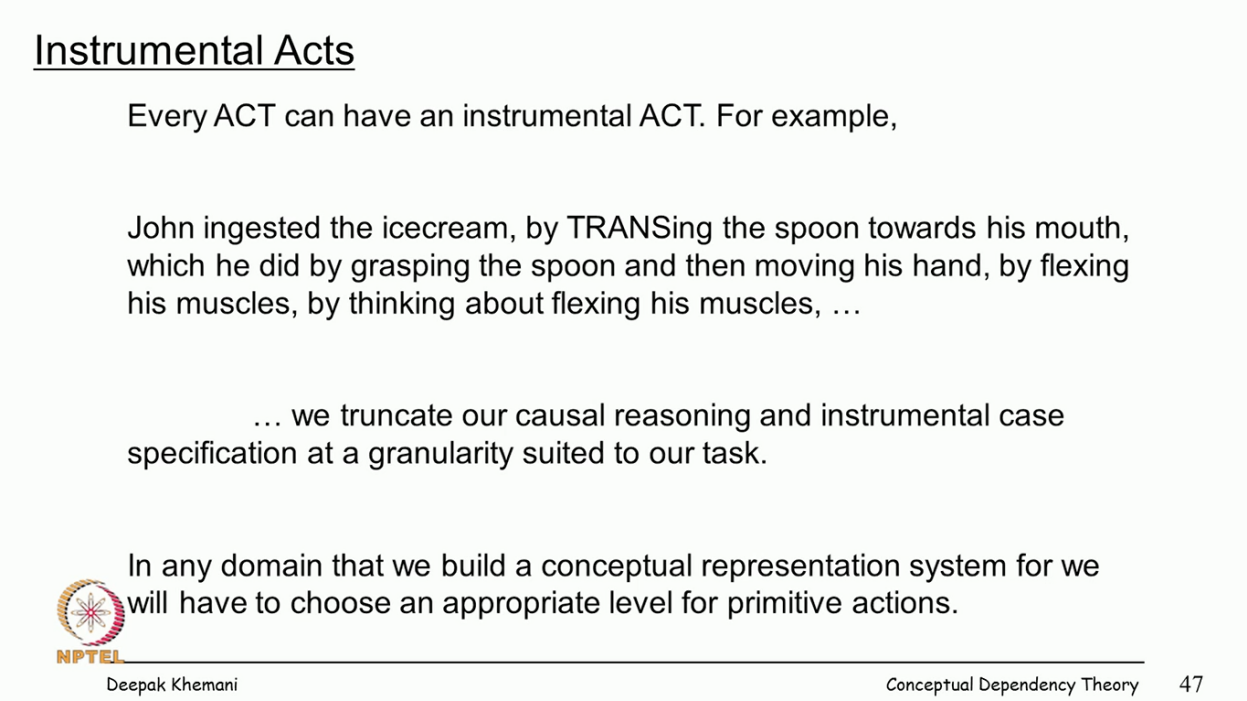
So this arrow that you see here this arrow with this letter I, stands for instrumental act. So this whole act which includes this whole thing is actually an instrument to this. The arrow should really be pointing to the other act but it is convenient to write it at the end of the conceptualization. But you must imagine that this thing is one act, this thing is another act and this is instrumental in doing this.

(Refer Slide Time: 22:51)



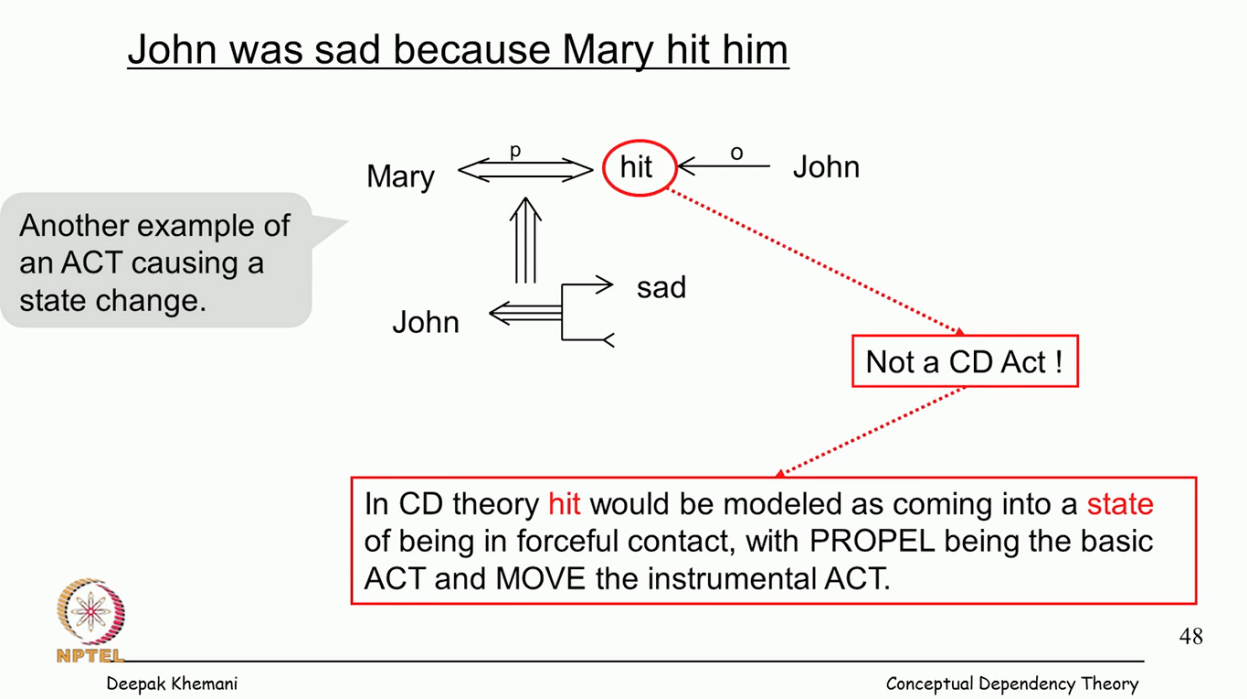
He ate icecream and the instrumental thing was he did something with the spoon. Again if your worldview if more informed you will know what he did with the spoon. Okay just what I was saying arrow is meant for the act. And not for icecream essentially even though it appears to point to icecream. So if you know more about something that what you do with spoon then you say that the act was that he transferred the spoon which contained icecream from the icecream to the mouth which was his mouth. So every act can have instrumental acts, for example

(Refer Slide Time: 23:36)



John ingested the icecream by Trasferring the spoon towards his mouth which he did by grasping the spoon and then moving his hand by flexing his muscles by thinking about flexing his muscles and so on and so forth. You can always break it down into smaller instruments but we when you talk about representation we will always truncate this whole chain at some level we are comfortable with. That's the whole idea of modelling when you are modeling something you are abstracting away from the level of detail at which the thing is happening into some level of detail which is useful for you and you are comfortable to handle. So lets look at more sentences so John was sad because Mary hit him. So we will model this as a state change. Some action is causing a state change. What is the change which is happening? That john has gone from some state to being sad. And Mary did the action of hitting.

(Refer Slide Time: 24:36)



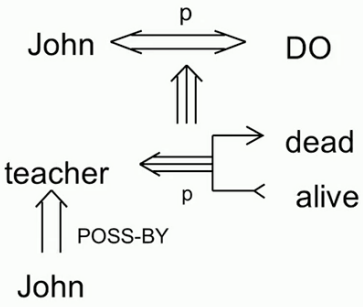
Now hitting is not a CD act. We want to restrict ourselves to a small set of acts. What we would really do is we would as described here that in CD theory it would be modeled as coming into a state of being in forceful contact with Propel being the basic act and Move the instrumental act. We will see an example. But basically we want to represent this as a causal relation that Mary hit John however we represent this and that caused John to go from a state not sad to sad. So events can cause other events as we saw. So when Fred gave Mary a peach she ate it. So fred transferred the peach from Fred to Mary as a result of which Mary ingested the peach.

So certain words in English language and other languages which are treated as verbs do not necessarily have a direct correspondence to what we would call as actions. Now in English killed is a verb so for some dubious creature like john he went and killed his teacher. John killed his teacher. In English language it's a verb so he did I mean if you try to imagine what John did what is the action John did then it is difficult for you to imagine simply by reading this sentence that John killed his teacher. You don't know how he killed him he could have shot him he could have drowned him all kinds of things. So conceptually a verb like kill in the language will be treated as state change causal event in conceptual dependency. So we will model this as saying that John did something and P stands for past as a result of which the teacher who was John's teacher went from a state of being alive to a state of being dead.

(Refer Slide Time: 27:03)

State change "verbs"

John killed his teacher.



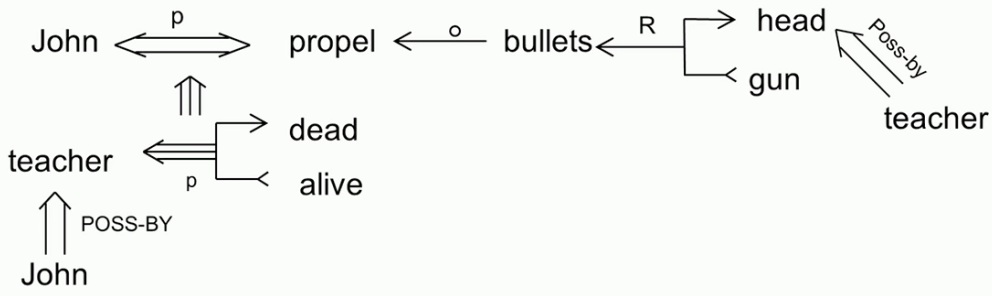
In state change verbs the linguistic verbs often focus on the state change while ignoring the action.

So conceptually killed is not an action. Killed is a causal relation between some action and some effect. So that's one distinction one has to make. Now if you had said that John killed his teacher by shooting him in the head then you would have said that John propelled bullets from the gun to the head of the teacher as a result of which the teacher went from a state alive to dead.

(Refer Slide Time: 27:34)

Being more specific

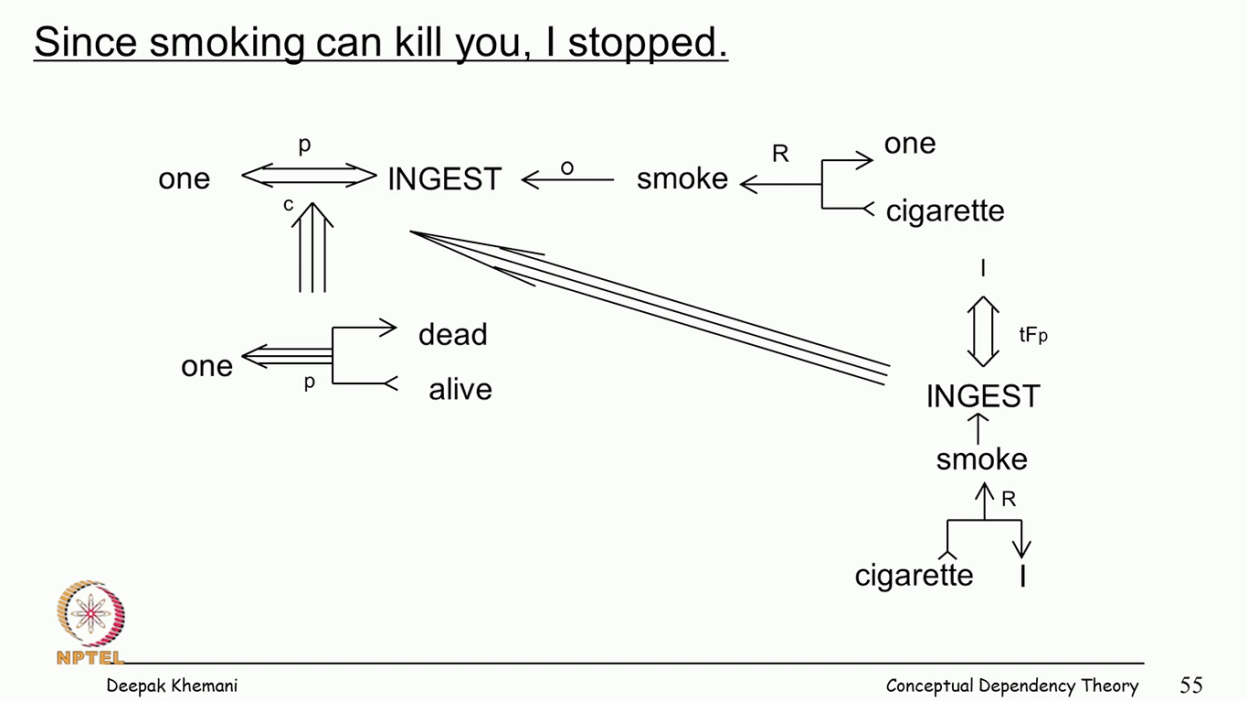
John killed his teacher by shooting him in the head.



When you say Flying, if you say Sam flew his plane to San Francisco. Then flying is again a English language verb but we will model it as a state change or state causative effect. That Sam did something to his plane as a result of which his plane flew from somewhere into San Francisco. If you want to say Comforting then John comforted Mary so John did something as a result of which Mary went into a state of being comfortable.

He is a more complex sentence that since smoking can kill you I stopped smoking. Now this is a slightly more complex thing. Now if you want to model this you can see that the first the relation between the act of smoking and the state change event of dying.

(Refer Slide Time: 28:51)



So the first part of this if you watch this carefully. First part is the relation between smoking and dying and then this whole thing causes you to stop smoking. So there is one conceptualization which relates ingesting to dying. If you ingest smoke then you can die. So this c stands for can. It can kill you. It doesn't mean you will die if you smoke a cigarette or something like that. Now this whole thing was a reason for which I did this act of stopping to smoke. Now this the stopping is captured here. So sometime in the past I stopped doing this so the label basically captures that but conceptualization is I ingest smoke from the cigarette to me but sometime in the past I stopped doing that. And I did this because smoking can kill you which is in the larger concept.

Then something like while going home I saw a frog. So one conceptualization is a timestamp for another conceptualization. So the top one says that I was going home, so house possessed by me. And the second one says that I saw a frog and

the first one is a timestamp when I saw the second one. Okay so I will stop here. In the next class we will continue looking at representations of conceptual dependencies.