Unit - 4

Chapter - 11 Advanced Knowledge Representation Techniques

Introduction; Conceptual Dependency Theory (Conceptual Primitive Actions, Conceptual Category, Rules for Conceptualization Blocks in CD, Generation of CD representation, Conceptual Parsing, inferences associated with primitive act). Script structure. CYC Theory; Case Grammars; Semantic Web (Resource Description framework, ontology).

• Introduction:

KR is an area of artificial intelligence whose fundamental goal is to represent knowledge in a manner that helps drawing conclusions from that knowledge. KR system should not only hold knowledge but also set of basic inference rules. Inference Rules are syntatic procedures or functions that operate on knowledge and derive information. Syntatic information of rules is also used by the production system to decide which rule is applicable, to be fired. Predicate logic & production rules are syntatic in nature. Syntatic structure based knowledge representation methods are weak methods but at the same time are adequate for general problem solving.

Semantically oriented approaches for knowledge representation are quite useful to guide searches more efficiently. Semantic nets capture semantic semantic relationship among concepts (entities) and are used with set of inference rules, which interpret the specific arcs showing relationship. The frame system is found to be more structured than semantic net & contains larger set of inference rules with the capacity of integrating other knowledge structures (such as predicate rules, semantic nets, production rules etc..) within frames in order to make it more powerful.

The inheritance capability is much faster than resolution-based theorem proving in predicate logic. The hybrid structure can be created that combines the advantages of slot-&-filler structure of semantic net with the advantages of predicate logic. Extended semantic network (ESNet), CYC, Ontology are examples of such structures. The ESNet incorporates clausual rules in semantic net, thus enhancing the capabilities of Semantic nets using advantages of predicate logic. There is another system called KRYPTON in which knowledge is divided into two distinct

repositories < TBox (slot-and-filler structure containing concept information)
ABox (contains logical assertions)

/* The atomic predicates used in ABox assertions refers to concept defined in TBox */

These representations are inadequate for representing Knowledge required for core Natural Language understanding applications. He require structures to hold deep sense & meaning of the sentences. For capturing indented semantics of the knowledge, there are various approaches, viz Conceptual Dependency, Scripts & Case Frames.

Conceptual Dependency is a semantic representation rather than a syntatic representation. It provides abstract structure with actions & the dependency relationship. Script structure is similar to frames ~~ex~~ except that slots in script keep information by using conceptual dependency primitives that are useful for reasoning about situations. The CYC uses both frames & logic to encode specific types of knowledge & inferences for commonsense reasoning. Ontology is a structure holding detailed semantic knowledge & can be viewed as an extension of semantic net.

• Conceptual Dependency Theory:

Conceptual Dependency (CD) is a theory of deep semantics for concept used for natual language understanding. It mainly focuses on the concept and rather than on syntax or structure. Conceptual Dependency uses the basic hypothesis, that the ACTION is the basis of any proposition. All propositions that describe events are made up conceptualizations that comprise an actor, an action, & a set of cases that depends on that action. The main import -ant concept of the CD theory is that there must be a canonical form for meaning representations, i.e different Words & structures having same meaning should also have the same representation. The type of roles. conceptual roles in this canonical form do not correspond syntatic roles. rather the Words ~~do not~~ are broken down into their conceptual parts & are then placed in a meaning representation with respect to their conceptual role instead of the syntatic role. It should be noted that the words do not appear in conceptualizations. Similarties & overlaps in meaning of Words are handled by the concept of the PRIMITIVE ACTION. The primitives are not category names but rather elements that can be used in varied combinations to express the underlying meaning of a given world. Conceptual Dependency representations use eleven primitive acts as the basis for most activities. These acts were designed by Schank by observing the structural similarities in the sentences represented in actor - action - object framework. A large set of states and a set of conceptual roles can be expressed using this minimal set of primitive actions.

* Conceptual Primitive Actions:

Actions in natural languages are generally specified by the verbs. Most of the verbs have been categorized under the following eleven primitive actions. Sometimes one verbs may fall into two categories & in that case the most relevant in the content might be choosen at the time of interpretting sentences.

For example, verbs – push, throw, kick require physical force to be applied to an object may fall under PROREL Act. But MOVE and GRASP primitives are more specific where verb kick falls under MOVE & verb throw falls under GRASP. These primitive ACTIONS are listed as follows

1. ATRANS : Transfer of an abstract relationship such as possession, control, or ownership. It requires an actor, object, & recipient.
   Eg: verb - give, take, purchase
2. PTRANS: Transfer of the physical location of an object (or actor) that requires an actor, object & direction.
   Eg: verb – go or walk, fly...,
3. PROPEL: Application of physical force to an object (push, pull).
   Eg: verb – push, pull, throw
4. MOVE: Movement of a body part by its owner (kick, throw, hit)
   Eg: verb - kick
5. GRASP: Grasping of an object by an actor. (catch, clutch)
   Eg: catch → GRASP of an object of an actor. The object was PROPEL before GRASP.
6. INGEST: Ingesting of an object by an animal (eat, drink, smoke). It requires an actor, object, and direction.
   Eg: eat or drink (a), smoke (from), breathe (into)
7. MTRANS: Transfer of mental information thru animals within an animal itself. (tell, read, speak, sing). In MTRANS action, the various sense organs serve as the origins. Recipient, object, & actor are required, although here these cases refer to the above mental locations as recipient & mental information as possible objects.
   Eg: tell, speak, sing; read; remember...,
8. MBUILD: The construction of new information from old information within an actor, ie to create/combine through internally. It takes place within IM and receives its inputs from the CP (the conscious processor) and from IM. It transforms them into a new idea & places that idea in the CP.
   Eg: decide, describe, imagine, consider, answer.
9. EXPEL: Expulsion of something from the body of an animal.
   Eg: weep, cry, sweat..,
10. SPEAK: Producing sounds.
    Eg: say, tell, sing...,
11. ATTEND: Focusing of a sense organ towards a stimulus
    Eg: listen, watch, see, look...,

All these primitives are grouped & classified in the broad categories as

GROUPING OF PRIMITIVES

Category	Primitive Acts
state change Primitives	ATRANS and PTRANS
Mental Action Primitives	MTRANS and MBUILD
Senses (often instruments for other Acts) such as eyes, ears, tongue etc;	ATTEND and SPEAK
Physical Action Primitives	INGEST, MOVE, GRASP, PROPEL, EXPEL

* Conceptual Category:

CD provides specific set of building blocks from which representations can be made rather than only a structure in which knowledge can be represented. Building blocks are set of allowable dependencies among the conceptualizations for different events. There are four primitive conceptual categories from which dependency structures can be built.

- ACT — Actions {one of the CD primitives representing verb}
- PP — Object {picture produceas or noun/pronoun}
- AA — Modifies of actions {action aiders or adverb}
- PA — Modifiers of PP's {picture aiders or adjective}

The relationships between concept are called dependencies. The main conceptualization of a clause is a two-way dependency between a PP (the actor) and an action. It is important to note that actions are broken down into sequence of primitive ACT's.

A set of rules describe the syntax of the conceptual level, & these rules specify which type of concepts can depend on which other type, as well as the different kinds of dependency relationships b/w concepts.

Specific concepts depending on other concepts based on the particular meaning of these concept is determined by semantics of the conceptual level. There exists a dictionary of ACT's which specifies different meanings with its conceptual structure for each verb.

Conceptual relations, at a higher level, indicate dependencies between conceptualizations, annotated with conceptual tenses such as past, future and conditional. Other types of conceptual relations are the time & locations of a conceptualization. The set of conceptual tenses includes

- p – Past
- f – Future
- t – Transition
- ts – Start Transition
- tf – Finished Transition
- k – Continuing
- c – Conditional

* Rules for Conceptualization Blocks in CD :

Dependency structures are themselves conceptualization & therefore can serve as components for larger dependency structures. The dependencies among conceptua-lization correspond to a semantic relations among the underlying concepts. Most important allowable structures / the rules are:

Rule 1 Rule representing relationship b/w an actor & the event caused by him/her is called a two-way dependency, as neither actor nor event can be considered primary. The letter p in the dependency link indicates that the event occured in the past.

Rule: PP ⟺ ACT

Eg: John ran → CD Representation → $\overset{p}{\text{John}} \Longleftrightarrow \text{PTRANS}$

Rule 2 Rule representing relationship b/w an ACT and PP (object) of the ACT is shown by the direction of an arrow towards the ACT, since the content of the specific ACT determines the meaning of the object relation.

Rule: ACT ← PP

Eg: John gave book to mary → CD Representation → John ⟺ PTRANS ← book

Rule 3 This rule shows relationship both ways b/w two PPs. Once PP belongs to the set defined by the other PP.

Rule: PP ↔ PP

Eg: john is a doctor → CD Representation → john ⟷ doctor

Rule 4 It shows a relationship b/w two PPs. One of the PP provides a particular kind of information about the other PP. The most common types of information to be encoded in this ways are possession (shown as 'poss-by') and location (shown as 'loc'). The direction of the arrow is again toward the concept being described.

Rule: PP ← PP

Eg: john's car → CD Representation → car ←(poss-by)— john

Rule 5 It shows a relationship b/w a PP & a PA that is asscated to describe it. In this case PA represents the states of PP such as height, weight, health, ectc., on numeric scales & has both ways arrows.

Rule: PP ⟺ PA

Eg: John is fat → CD Representation → john ⟺ Height (>50)

Rule 6 It shows a relationship between a PP & an attribute that already has been predicated of it. The direction of the arrow is toward the PP being described.

Rule: PP ↔ PA

Eg: Smart John → CD Representation → john ← smart

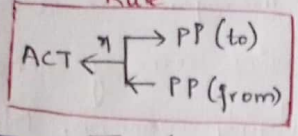
Rule 7 It shows a relationship b/w an ACT and its physical source & destination locations of ACT. Here 'd' indicates the source & destination case relation, as this representation is also used for recipient case relation later. We can use 'V' for vehicle which can be single object (or full conceptualization)

Rule: ACT ← PP(destination), ACT ← PP(source)

Eg: John went to school from home → CD Representation → $\text{John} \overset{p}{\Longleftrightarrow} \text{PTRANS} \leftarrow$ School, Home

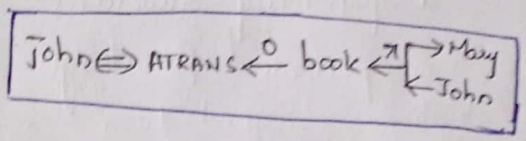
Rule 8 It shows a relationship between an ACT & its source and the recipient of ACT. The letter 'r' indicates source & recipient case relation.

Rule



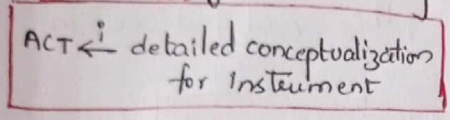
Eg: John gave a book to Mary

CD Representation



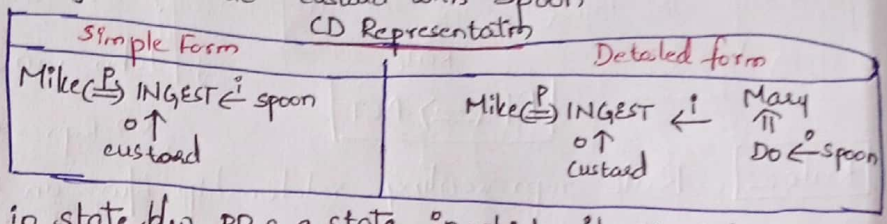
Rule 9 It shows a relationship b/w an ACT and the instrument using which it is performed. In the simplest form, instrument can be represented by just a single physical object (or) must be expanded to a full conceptualization. Here DO represents some act done by actor using instrument. The letter 'i' represent instrument

Rule



Eg: Mike ate custard with spoon

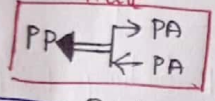
CD Representation



Rule 10 It shows a relationship that describes the change in state b/w PP & a state in which it started & another state in which it ended. Here states of objects are described using numerical values.

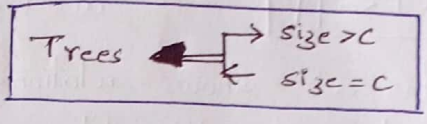
Eg: Health range could be −10 to 10 {(dead, −10), (seriously ill, −9), (sick, [−1, −5]), (alright, 0), (fine, 5), (perfect health +10)}.

Rule



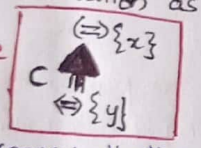
Eg: The Trees grow

CD Representation



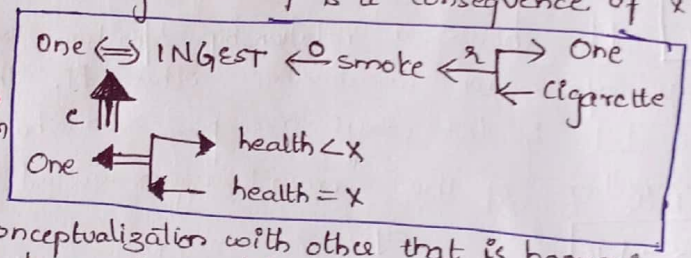
Rule 11 Relationship b/w one conceptualization & other conceptualization that causes it. Here {x} & {y} represent two full conceptualizations where {y} is caused by {x}. It is conditional representation as 'if x then y'. Alternatively, we can say that 'y' is a consequence of 'x'.

Rule



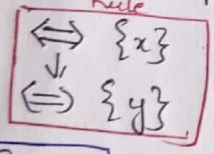
⟺ conceptualization of x & y

Eg: ~~Terrorist~~ Smoking is harmful to health CD Representation



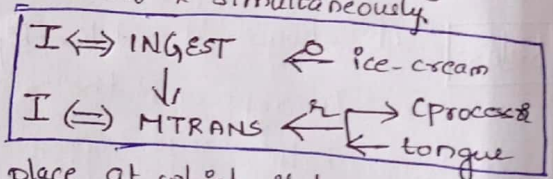
Rule 12 It shows a relationship b/w one conceptualization with other that is happening at the time of the first. Here event 'y' is happening while event 'x' simultaneously.

Rule



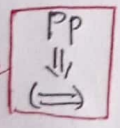
Eg: I enjoyed while eating ice-cream

CD Representation



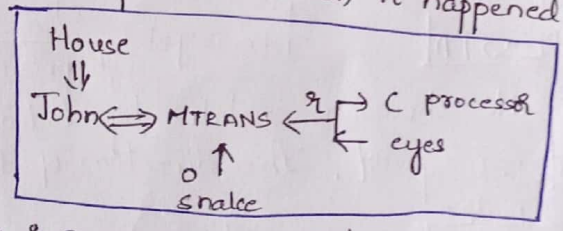
Rule 13 It shows a relationship b/w conceptualization & the place at which it happened.

Rule



Eg: John saw a snake in the house

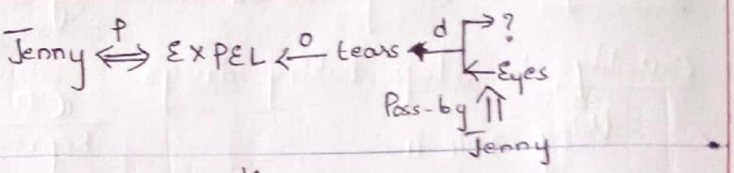
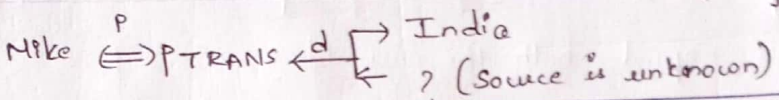
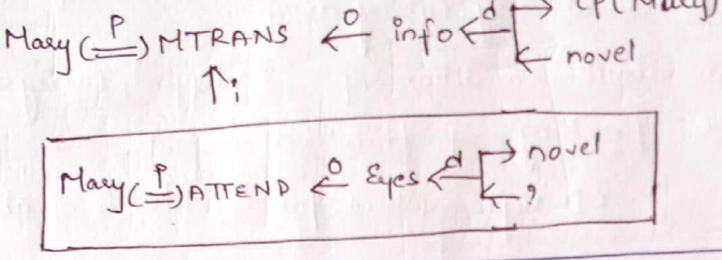
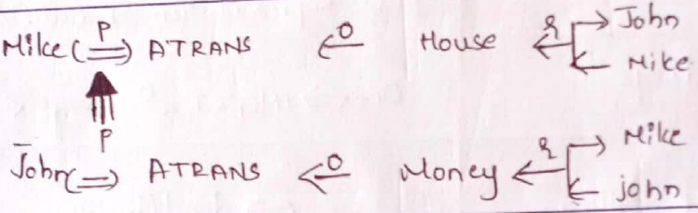
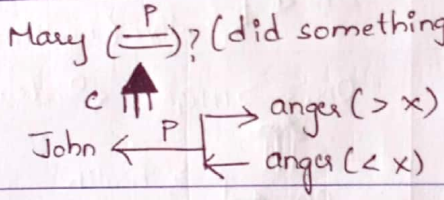
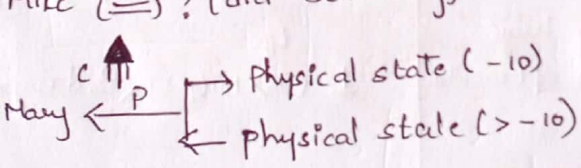
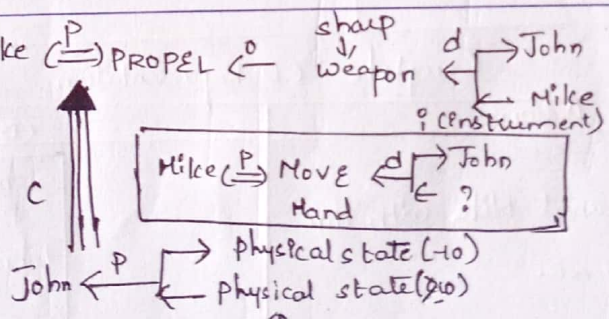
CD Representation



These rules of CD representation help in drawing inferences & are independent of the language, as it is built using conceptual primitives which give the intended meaning of the words. There should be only unique representations of meaning conveyed by two or more sentences. Sentences are represented as series of diagrams depicting actions using both abstract & real physical situations. The actions are built up from a set of primitive acts which can be modified by tense. CD provide a structure that contains node representing information using a specific set of primitive acts. It is basically an Interlingua representation in which sentences in different language having same meaning will have same CD representation.

* Generation of CD representation:

- **CD Representations for simple sentences** – Some english sentences having simple but deep intended meanings are as below

Examples	CD Representation
Jenny Cried	
Mike went to India	
Mary read a novel	
John purchased House from Mike	
Mary ~~John~~ annoyed John	
Mike killed Mary	
Mike threw sharp weapon & killed John OR Mike killed John by throwing sharp weapon ↑ • CD Representation for more sentences	

- **CD Representation for Deep Meaning Sentences & Text:**

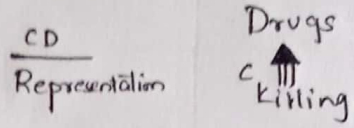
Let us consider systematic way of constructing CD representations for the sentence having inherent meaning, by considering the following examples.

Eg: Since drugs can kill, I stopped.

The intended meaning of sentence is that drugs are harmful & can kill a person. Because of this, I stopped taking drugs. Clearly there are two causalities where one is caused by other. These two causalities are represented in CD form as follows.

Causality 1 : killing can be caused by drugs:

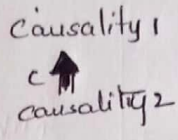
CD Representation



Causality 2 : stop taking drugs

Using rule 11

CD Representation

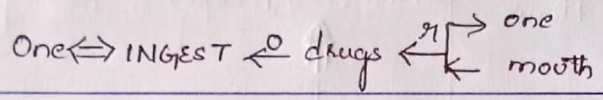
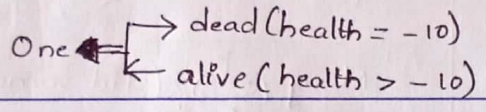
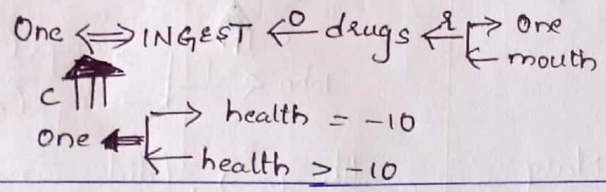
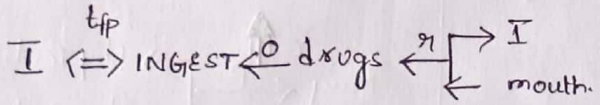


Let us expand both the causalities

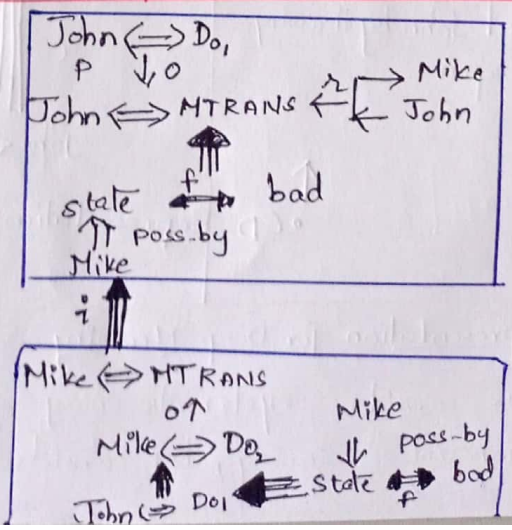
The CD representation of causality 1 is developed using actions, namely, taking drugs & killing can be caused by taking drugs

Causality 2 is about an action of "I stopped taking drugs". The conceptual tense tfp means the finishing of transition in past.

CD representations for constituents of above example

Actions	CD Representation of causality 1 & Causality 2
Taking drugs	
Action of killing	
Killing is caused because of taking drugs	
I stopped taking drugs Here tfp : is a finish of transition in the past	

Complete CD Representation

Actions	CD Representation
John warned Mike with dire consequence.	

* Conceptual Parsing:

Conceptual parsing is required for generating CD representation from source sentences in natural language. The main steps involved in CD parsing are as follows:

- Syntactic processor extracts main verb & noun along with syntactic category of the verb (transitive | intransitive) from the sentence.
- Conceptual processor then makes use of verb-ACT dictionary. Once the correct entry from dictionary is choosen, CD processor analyses the rest of sentence looking for arguments for empty slots of the verb. CD processor examines possible interpretation in a well defined order.

Let us consider following cases to handle with 'PP' phrase & formulate steategies to disambiguate the meaning. If CD processor finds 'with PP' phrase (PP is picture producing) it indicates one of the following cases showing relationship b/w PP & the conceptualization of which it is a part.

Case1: The sentences having 'with PP' phrase with non-animate PP is one sentence & animate PP in other sentence as given in the following sentences.

(1). John broke the door with hammer — Type1
(2). John broke the door with Mike — Type2

- Rule1: If PP in 'with PP' is non animate & CD Act requires instrument then the sentence is of Type1, where PP(hammer) is resolved to instrument.
- Rule2: If PP in 'with PP' phrase is animate & CD Act requires instrument then the sentence is of Type2, where PP(Mike) is resolved as co-actor.

Case2: In the sentences having 'with PP' phrase, if PPs in both the sentences are non-animate, then they have to be resolved using semantic lexicon. Consider.

(1). John went to garden with flowers — Type3
(2). John went to garden with bag — Type4.

In Type3, non-animate noun 'flowers' is part of garden, whereas in Type4, non-animate 'bag' is some object not related to garden. Such association of word senses could be found in WordNet & then disambiguation is possible. Here noun 'bag' is treated as possession by John.

Case3: In the sentences having 'with PP' phrase, if PPs in the sentences are animate, then they have to be resolved using semantic lexicon & context. Consider

(1). John went to the garden with Mike — Type5
(2). John went to the garden with butterflies — Type6
(3). John went to the garden with dog — Type7

In these sentences, Mike, butterflies & dogs are animate PPs & can be be resolved as

- Mike is easily resolved to co-actor of John as both are human & have similar characteristics
- WordNet can be used to check if butterfly and garden has some common sense.
- Dog is still ambiguous as it may be treated as possession of actor or may be a part of garden as animals many wonder in garden. Such situations can be further resolved by considering the content of sentences.

We can use Semantic lexicon, dictionary to resolve some of the ambiguities. WordNet is a semantic lexicon for the English language. It groups English words into sets of synonyms called synsets, provides short, general definitions, records various semantic relations b/w these synonym sets. The purpose of WordNet is to produce a communication of dictionary & thesaurus.

* Inferences Associated With primitive act:

General inferences are stored with each primitive act & reduce the number of inferences that need to be stored explicitly. The meaning of the concept consists of the meaning of the primitive itself & its associated inferences. Basically, inference is a conceptualization that is inferred by another conceptualization.

For example, from a sentence "John killed Mike", we can infer that 'Mike is dead'. So conceptualization for inferences is embedded in CD representation for primitive Act of killing. Let us take another example of primitive Act INGEST. The following inferences can be associated with it.

- The object ingested is no longer available in its original form.
- If object is eatable, then actor has less hunger.
- If object is toxic, then actor's health is bad.
- The physical position of object has changed. So PTRANS is inferred.

For a sentence "John took drug yesterday", we can infer that John's health is bad whereas for the sentence "John ate food", we can infer that John has less hunger.

The Word in the dictionary are maintained with following information

- Syntatic category with all possible attributes & properties.
- The verbs with all possible senses & primitive Acts.
- With each primitive Act, inference rules are stored.

* Usefulness of CD Representation:

CD representation proves to be of greater use for storing implicit & explicit knowledge in the sentence / text in natural language in a more compact way.

- It is easier to describe inference rules that are represented once for each primitive action

For example, inference rule with ATRANS (transfer of ownership of an object) can be used to know who has an object after the action & who had it earlier, & also what is the object involved in this transfer. Similarly inference rule with INGEST can be used to know what has been ingested by whom.

- Implicit information is deduced & stored as a part of CD representation for future use.
- CD representation is good model for representing simple events.
- Unspecified element of representation of one piece of information can be used as a focus for the understanding of later events as they are encountered.

CD representation developed by number of programs such as MARGIE (Meaning Analysis, Response Generation and Inference on English) as a model of Natural language understanding, & SAM & PAM (Script/plan Applier Mechanism) to understand stories.

Problems with CD representation:

- Difficult to construct original sentence from its corresponding CD representation
- It is difficult to use CD representation as a general model for knowledge representation because this theory is based on representation of events as well as all the information related events.
- Rules are to be carefully designed for each primitive action in order to obtain Semantically correct interpretation.
- Many Verbs may fall under different primitive ACTs, & it becomes difficult to find correct primitive in the given context.
- CD representation becomes complex requiring lots of storage for many simple actions.

• Script Structure:

- Schank & Abelson introduced the concept of scripts in 1997 that were build upon CD framework to handle story understanding by organizing episodes in a sequence(or) a chain of situations which could be anticipated using personal experiences rather than Semantic categories.
- Scripts are structures representing procedural knowledge by describing a set of stereotyped events in a particular situation (or) context which could be expected to be followed from one to another event.
- It consist of set of slots which may contain default values along with some information about the type of values they might contain. It looks similar to frames, except that the values of the slots must be ordered & have more specialized roles.
- Script structure allows individual to make inferences needed for understanding by filling in missing information

- In real world situations, we see that event tends to occur in known patterns because of causal relationship to the occurrence of events. A number of computer programs have been developed to demonstrate the theory.
- Schank applied his theoritical framework to story telling & the development of intelligent tutors. The classic example of Schank's theory is restaurant script.

Each script contains the following main components:

Entry Conditions ⟶ must be satisfied before events in the script can occur
Results ⟶ Conditions that will be true after events in script occur.
Props ⟶ Slots representing objects involved in the events.
Roles ⟶ Persons involved in the events.
Track ⟶ Specific variation on more general pattern in the script. Different tracks may share many components of the same script but not all.
Scenes ⟶ The sequence of events that occur. Events are represented in conceptual dependency form.

- The scripts are useful in describing certain stereotyped situations such as going to theater or cinema hall, going to market, robbery in the bank etc.

To understand this concept better, let us consider another example of developing a script for going to theater to see a play. This might involve the following scenes:

- Going to theater
- Buying ticket.
- Going inside hall & sitting on a seat
- Watching play
- Exiting from theater.

Various components of script for going to theater are described as follows:

Entry conditions:

- P wants to see a play
- P has money

Results:

- P saw play
- P has less money

Props

- Ticket; Seat; play

Roles:

- Person
- Ticket distributor
- Ticket checker.

Complete Script for Event-Going to theatre

Script: Play in theatre	Various Scenes
Track: Play in Theatre Props: • Ticket • Seat • play Roles: • Person(who wants to see a play) - P • Ticket distributor - TD • Ticket checker - TC Entry conditions: • P wants to see a play • P has a money. Results: • P saw a play • P has less memory • P is happy (optional if he liked the play)	Scene 1: Going to theatre • P PTRANS P into theatre • P ATTEND eyes to ticket counter Scene 2: Buying ticket • P PTRANS P to ticket counter • P MTRANS(need a ticket) to TD • TD ATRANS ticket to P Scene 3: Going inside hall of theatre & sitting on a seat • P PTRANS P into hall of theatre • TC ATTEND eyes on ticket Poss-by P • TC MTRANS (showed seat) to P • P PTRANS P to seat • P MOVES P to sitting position Scene 4: Watching a play • P ATTEND eyes on play • P MBUILD (good moments) from play Scene 5: Exiting • P PTRANS P out of Hall & theatre

If a particular script is to be applied, it must be activated based on its significance. If the topic is important, then the script should be opened. If a topic is just mentioned, then a pointer to that script. For example, given "John enjoyed the play in theatre", a script "Play in theatre" suggested above is invoked and all implicit questions can be answered correctly. Here the significance of this script is high.

- Did john go to theatre?
- Did he buy ticket?
- Did he have money?

If we have a sentence like "John went to theatre to pick his daughter", then invoking this scripts will lead to many wrong answers. Here significance of the script theatre is less. Getting significance from the story is not straightforward. Some heuristic can be applied to get the value.

If events follow a known track, we can use scripts to answer implicit/explicit questions. Different tracks may allow different outcomes.

The main advantages of script structures are that they are capable of predicting implicit events & that a single coherent interpretation may be build up from a collection of observations.

The disadvantage of script structure is that they are capable more specific & less general than frames. It is not suitable to represent all kinds of knowledge, because scripts are inflexible. To deal with inflexibility, smaller modules called memory organization (MOP) can be combined in a way that is appropriate for the situation.

∘ CYC Theory:

- CYC is a theory designed for describing the World knowledge (commonscense knowledge) to be useful in AI application & more specifically in natural language understanding similar to CD theory.
- It is more comprehensive, & was conceived by Lenat & Guha for capturing common scence Knowledge from the project to capture a knowledge from 100 random-ly selected articles in ENCYCLopedia Britannica in 1990. So CYC theory name came from this project.
- CYC structure contains representations of events, objects, attitudes, space, time, motion etc., & tends to be huge in structure. It is required to store special implicit knowledge (or) commonscense.
- It is particularly concerned with issues of scale.

∘ Reasons for building large KBs:

* Brittleness - Specialized KB are brittle. Hard to encode new situations & degradation in performance. Commonsense based KBs should have firmer foundation.
* Form & Content - Main focus of KR should be on comprehension. Commonsence strategies could point out where (~~main focus (is compreher)~~) difficulties in content may affect form & temporarily focus on content of KBs rather than on their form.
* Shared Knowledge — Small KB system should allow greater communication among themselves with common bases & assumptions.

It is a huge task to build such a large KB. Starting CYC was to encode 10 millions of facts that make common sense knowledge, & then make itself a learning system.

- There are some methods & languages in AI which can be used for acquiring this Knowledge automatically. machine learning methods can be employed.
- Special language based framework system is called CYCL using which CYC Knowledge is encoded. CYCL generalizes the notion of inheritance so that properties can be inherited along any link rather than only "isa" and "instance" links.
- In addition to frames, CYCL contains a constraint language that allows the expression of arbitrary first order logical expressions.