MODULE - III

KNOWLEDGE REPRESENTATION

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Knowledge

Knowledge is awareness or familiarity gained by experiences of facts, data, and situations. knowledge can be acquired in many different ways and from many sources, including but not limited to perception, reason, memory, testimony, scientific inquiry, education, and practice. The philosophical study of knowledge is called epistemology.

Knowledge in AI

Different kinds of knowledge which need to be represented in AI systems:

Object:

All the facts about objects in our world domain.

E.g., Guitars contains strings, trumpets are brass instruments.

Events:

Events are the actions which occur in our world.

Performance:

It describe behavior which involves knowledge about how to do things.

Meta-knowledge:

It is knowledge about what we know.

Facts:

Facts are the truths about the real world and what we represent.

Knowledge base:

It is the totality of information, structured or unstructured, stored in a system.

Different types of knowledge

1. Declarative Knowledge:

- Declarative knowledge is to know about something.
- It includes concepts, facts, and objects.
- It is also called descriptive knowledge and expressed in declarative sentences.
- It is simpler than procedural language.

2. Procedural Knowledge

- It is also known as imperative knowledge.
- Procedural knowledge is a type of knowledge which is responsible for knowing how to do something.
- It can be directly applied to any task.
- It includes rules, strategies, procedures, agendas, etc.
- Procedural knowledge depends on the task on which it can be applied.

3. Meta-knowledge:

- Knowledge about the other types of knowledge is called Meta-knowledge.

Different types of knowledge

4. Heuristic knowledge:

- Heuristic knowledge is representing knowledge of some experts in a field or subject.
- Heuristic knowledge is rules of thumb based on previous experiences, awareness of approaches, and which are good to work but not guaranteed.

5. Structural knowledge:

- Structural knowledge is basic knowledge to problem-solving.
- It describes relationships between various concepts such as kind of, part of, and grouping of something.
- It describes the relationship that exists between concepts or objects.

THE RELATION BETWEEN KNOWLEDGE AND INTELLIGENCE:

Knowledge of real-worlds plays a vital role in intelligence and same for creating artificial intelligence. Knowledge plays an important role in demonstrating intelligent behavior in AI agents. An agent is only able to accurately act on some input when he has some knowledge or experience about that input.

Let's suppose if you met some person who is speaking in a language which you don't know, then how you will able to act on that. The same thing applies to the intelligent behavior of the agents.

A knowledge representation structure (or, knowledge representation system) is a particular set of definitions, rules and procedures for setting up a representation that captures information and knowledge about the world.

REQUIREMENTS / DESIRABLE PROPERTIES FOR KNOWLEDGE REPRESENTATION SYSTEM

A good knowledge representation system must possess the following properties.

1. **Representational Accuracy:**
   KR system should have the ability to represent all kind of required knowledge.
2. **Inferential Adequacy:**
   KR system should have ability to manipulate the representational structures to produce new knowledge corresponding to existing structure.
3. **Inferential Efficiency:**
   The ability to direct the inferential knowledge mechanism into the most productive directions by storing appropriate guides.
4. **Acquisition efficiency:**
   The ability to acquire the new knowledge easily using automatic methods.

SOME KNOWLEDGE REPRESENTATION SYSTEMS

There are several knowledge representation systems such as the following.

- Semantic networks
- Frames
- Conceptual dependencies
- System based on logic

SEMANTIC NETWORKS

A network is an interconnected group or system. The word “semantic” means “related to meaning, especially meaning in language”. Thus a “semantic network” is an interconnected system or group related to meaning. Such a system can be represented by a directed labeled graph. Semantic networks are a logic-based formalism for knowledge representation.

Definition

A semantic network is a graph constructed from a set of vertices (or nodes) and a set of directed and labeled edges. The vertices or nodes represent concepts or objects, and the edges represent relations between the nodes.

EXAMPLES

Example 1

Consider the knowledge contained in the following sentence:

S1: “Sparrow is a bird.”

There are two concepts in the sentence, namely, “Sparrow” and “Bird”. The relation between these concepts is indicated by “is a”. We represent the two concepts by two nodes in a graph and the relation between them by a directed edge with the label “is-a”. The knowledge contained in S1 can now be represented by the graph shown in Figure 1.1. This is the semantic network representation of the knowledge contained in S1.

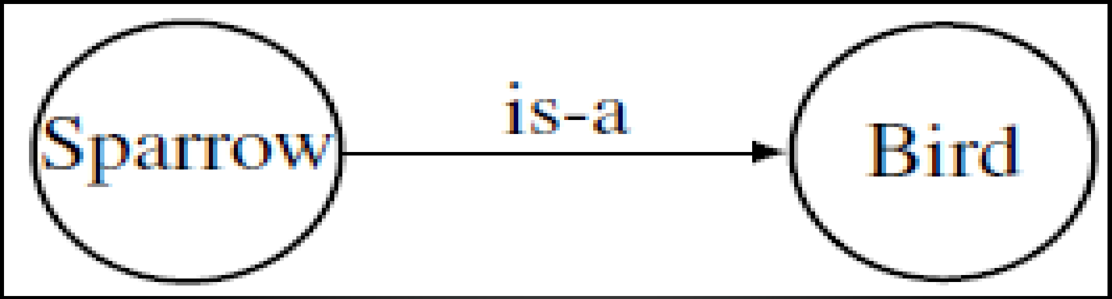


Figure 1.1 : Semantic network representation of “Sparrow is a bird”

EXAMPLES

Example 2

Consider the knowledge contained in the following sentences:

S2: "Tweety is a bird.", "Birds are animals."

The sentences has three objects "Tweety", "Birds" and "Animals". Tweety is the name of a particular bird. So the sentence "Tweety is a bird" means that the bird Tweety is an instance of the class of things indicated by the word "Birds". The sentence "Birds are animals" means that all members of the class of things indicated by "Birds" are also members of the class of things indicated by "Animals". To represent the knowledge contained in S2 by a semantic network, we need three vertices to denote the three objects. These vertices are to be connected by directed edges with appropriate labels. The knowledge contained in S2 is represented by the graph exhibited in Figure 1.2.

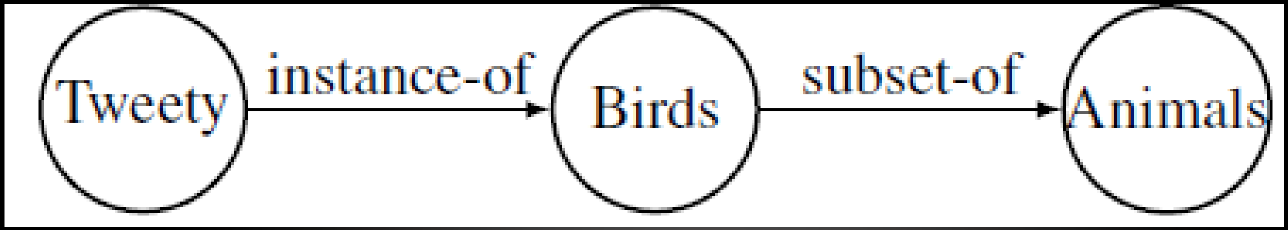


Figure 1.2 : Semantic network representation of S2

EXAMPLES

Example 3

Consider the sentence:

S3: “A bird has feathers.”

This sentence means that the object “Feather” is part of the object “Bird”. In a semantic network representation of the sentence, the edge joining the nodes is labeled “HAS-A” (or “HASA”, or “PART-OF”) as in Figure 1.3. Such a relation is referred to as a part-whole relation. The link or edge is from whole to part.

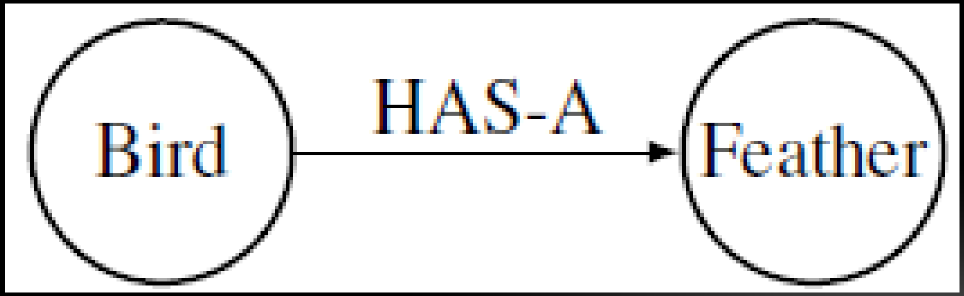


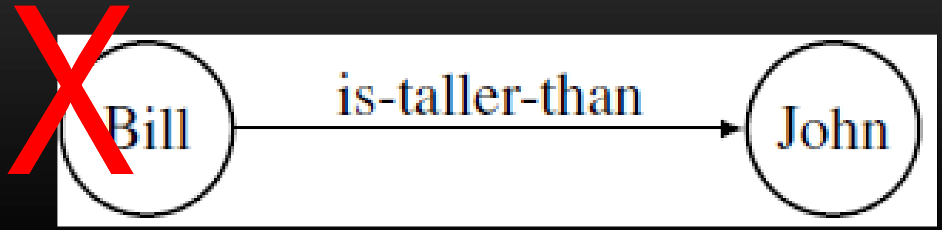
Figure 1.3 : Semantic network representation of S3

EXAMPLES

Example 4

Consider the sentence:

S4: “Bill is taller than John.”



Inappropriate semantic network representation of S4

This representation of the sentence does not represent the knowledge expressed by the sentence because the relation “is-taller-than” cannot be taken as a basic relation. What the sentence actually means is that the height of Bill is greater than the height of John.

Thus the proper semantic representation of the sentence “Bill is taller than John” is the one given Figure 1.4. In this figure we have used the basic relation “is-greater-than” and also the relation “height”.

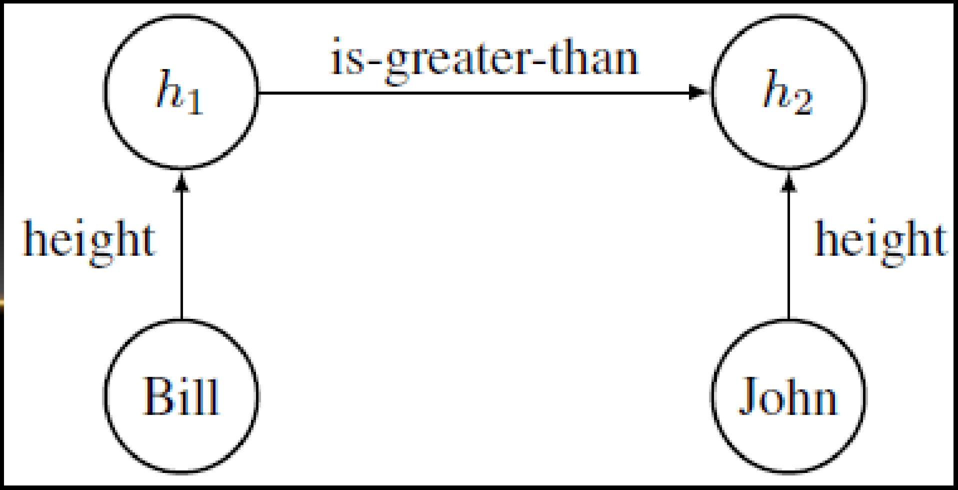


Figure 1.4 : Semantic network representation of S4

EXAMPLES

Example 5

Consider the sentence:

S5: "Sara has brown eyes."

This sentence has three concepts "Sara", "Brown" and "Eyes". "Brown" is a property of "Eyes" and, in a semantic representation of the sentence, the property can be denoted by the label "Property" or more specifically by the label "Colour". The semantic network is shown in Figure 1.5.

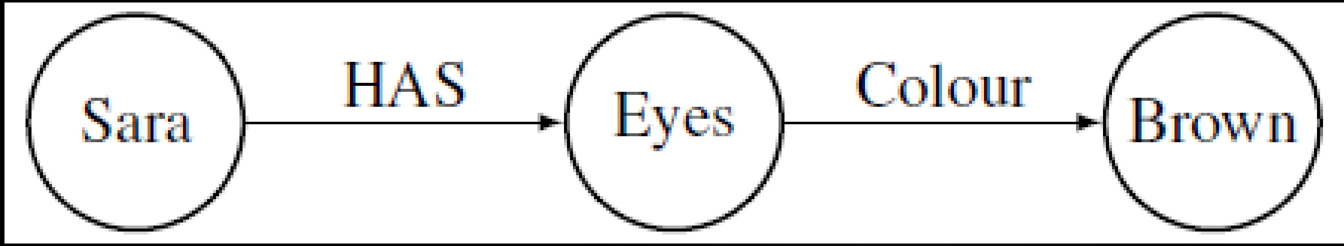


Figure 1.5 : Semantic network representation of S5

EXAMPLES

Example 6

Consider the knowledge represented by the following sentences:

- Tweety and Sweety are birds.
- Tweety has a red beak.
- Sweety is Tweety's child.
- A crow is a bird.
- Birds can fly.

The semantic network representation of the sentences is given in Figure 1.6.

Note the use of the labels "Property", "Child-of" and "Color" in the network.

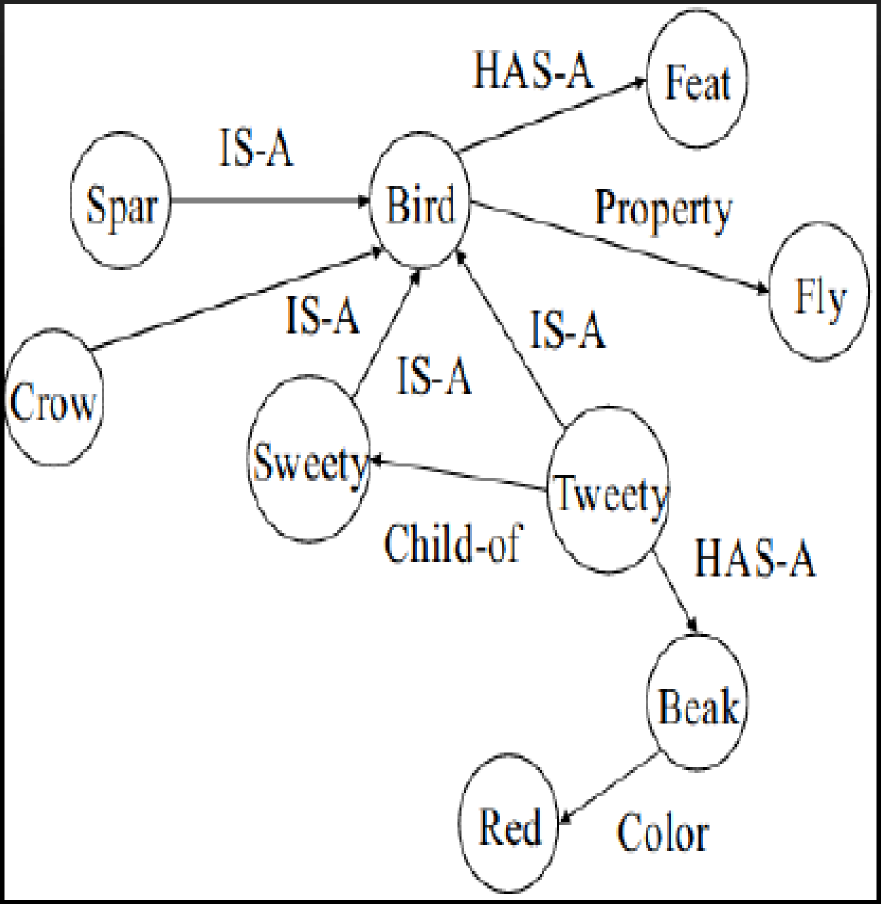


Figure 1.6 : Semantic network

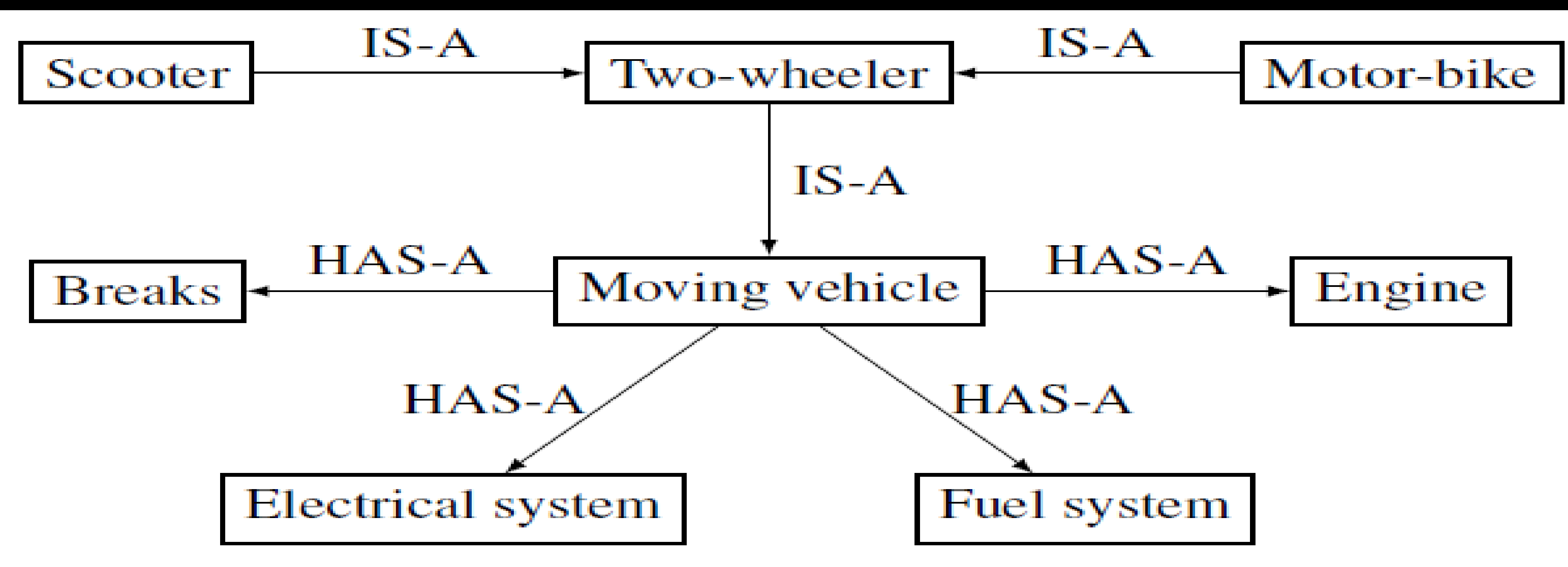
Example 7

EXAMPLES

Consider the following sentences:

- Motor bike is a two wheeler.
- Scooter is a two wheeler.
- Two wheeler is a moving vehicle.
- Moving vehicle has a brake.
- Moving vehicle has a engine.
- Moving vehicle has electrical system.
- Moving vehicle has fuel system.

Figure 1.7 : Semantic network



EXAMPLES

Example 8

Figure 1.8 shows another simple semantic network. Note the use of the label "is" instead of "IS-A". This is perfectly permitted as there are no standardization of the notations for labels. Also note the labels "lives in" and "works in".

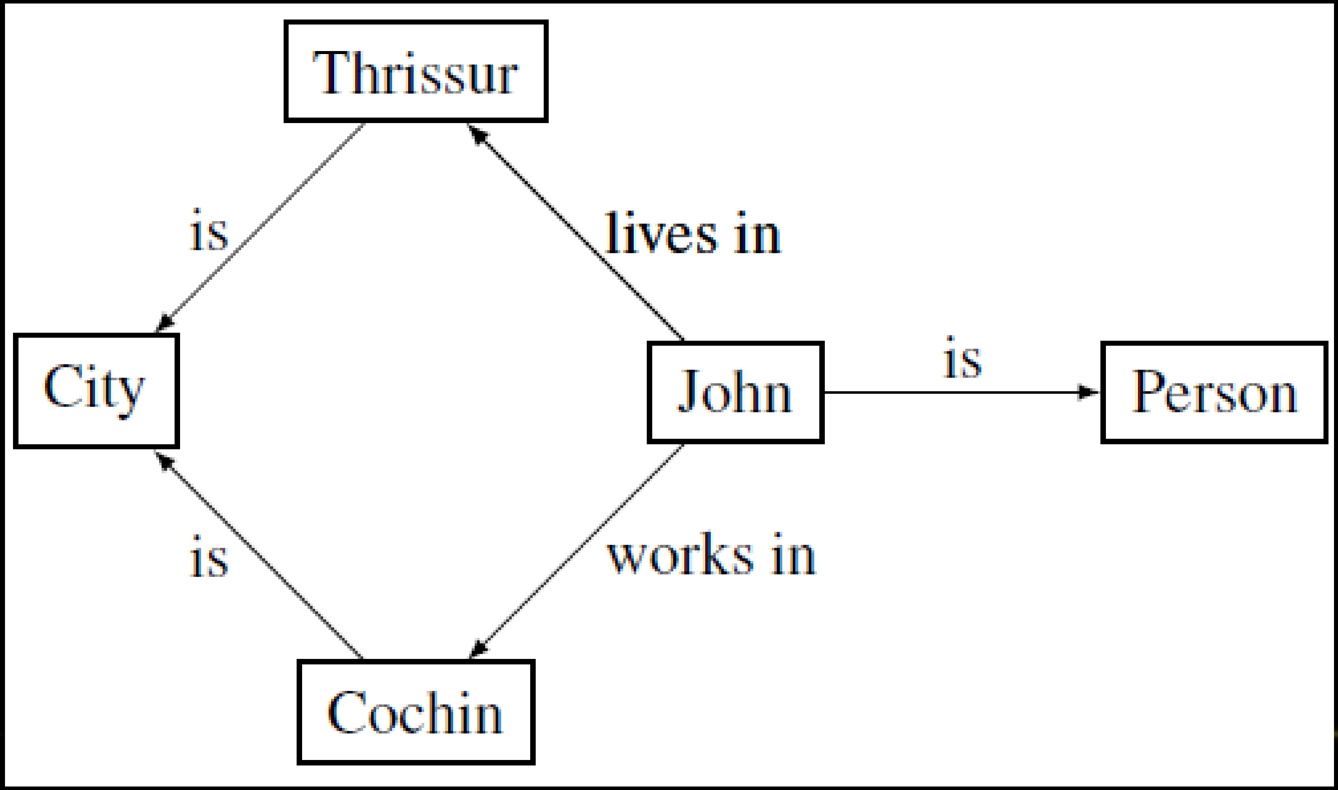


Figure 1.8 : A simple Semantic network

EXAMPLES

Example 9

Figure 1.9 shows a semantic network with several objects and categories.

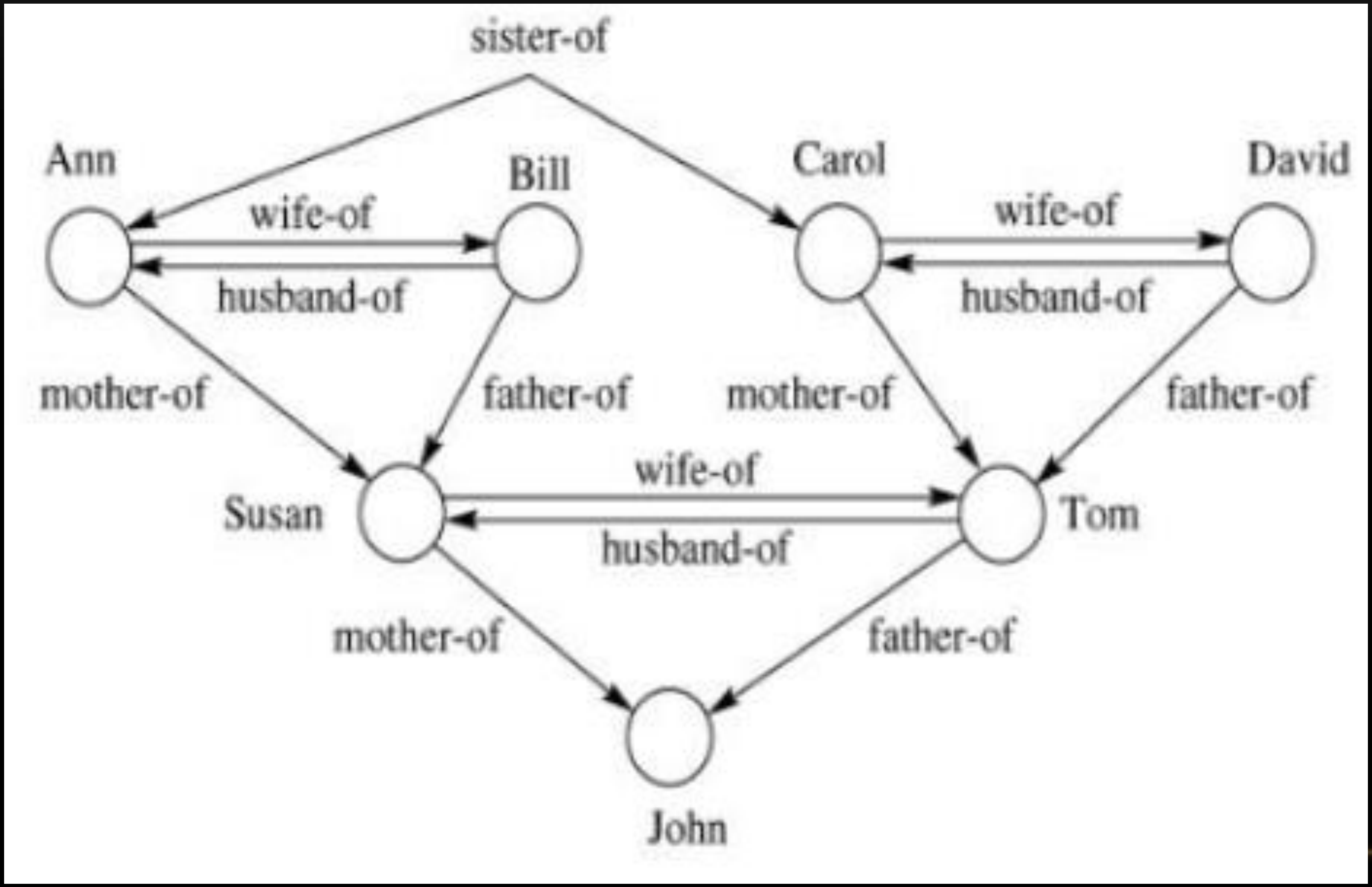


Figure 1.9 : A Semantic network

EXAMPLES

Example 10

Figure 1.10 shows a semantic network with two objects (John and Mary) and four categories (Mammals, Persons, FemalePersons and MalePersons).

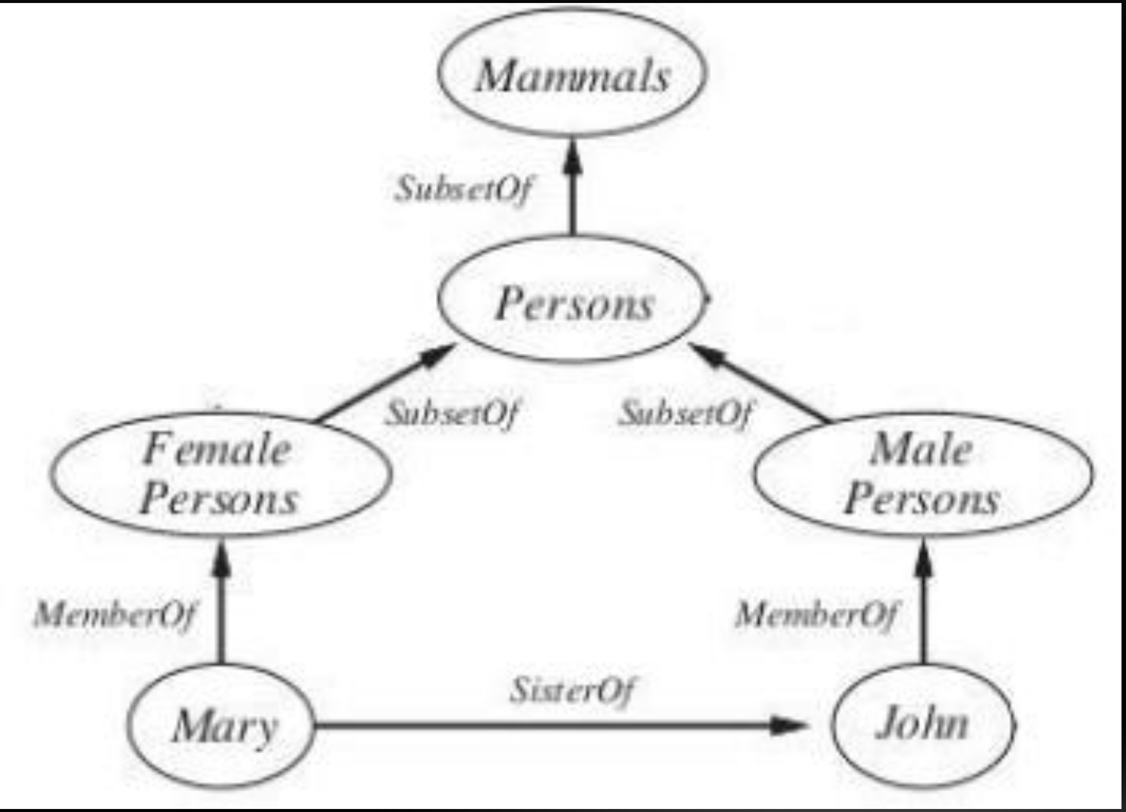


Figure 1.10 : A Semantic network

NOTE

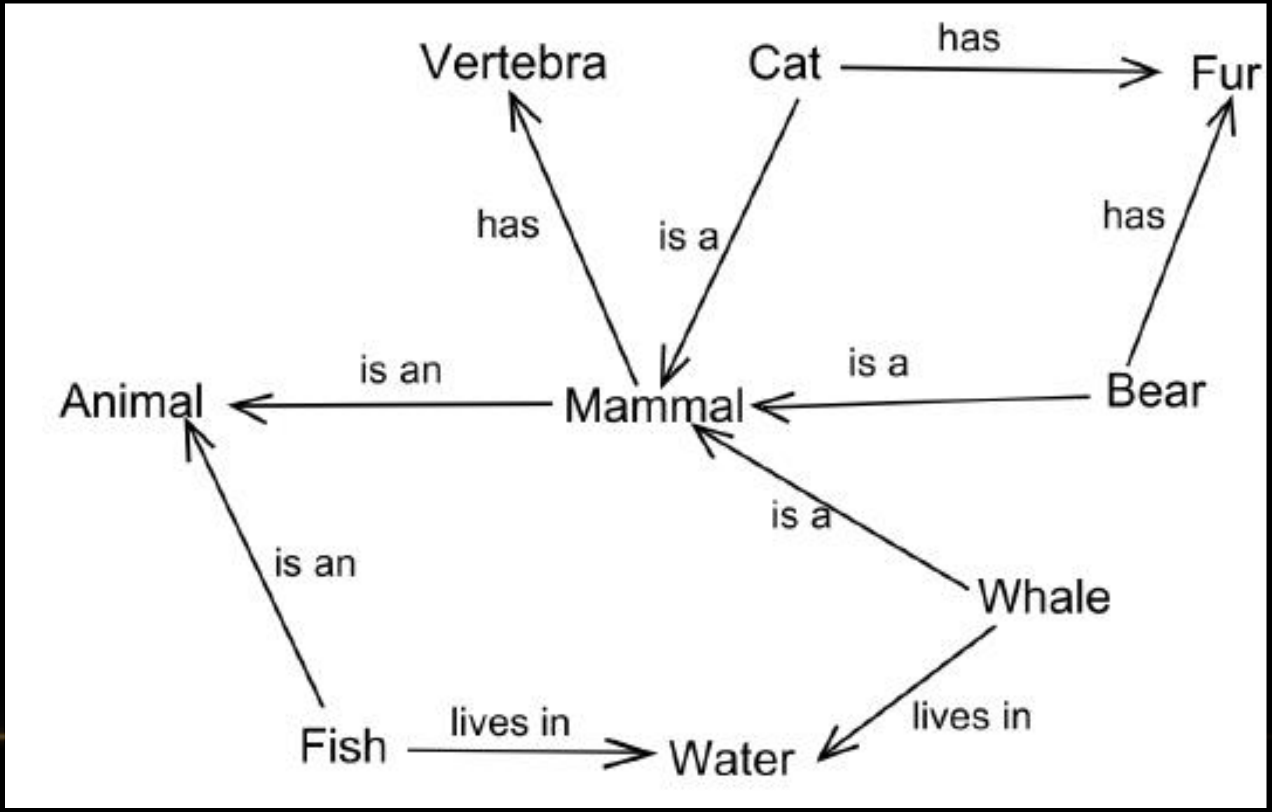
It appears that there are no universally agreed conventions on the use of geometrical shapes to represent nodes. Ovals, circles and rectangles are all used to represent nodes. Also, there is no complete set of standard terminology to label the edges in semantic graphs. However, the following are some of the most common semantic relations used in semantic networks.

- IS-A (ISA)
- IS-PART-OF
- IS-SUBSET-OF
- A-KIND-OF (AKO)

DIFFERENT KINDS OF SEMANTIC NETWORKS

1. Definitional networks

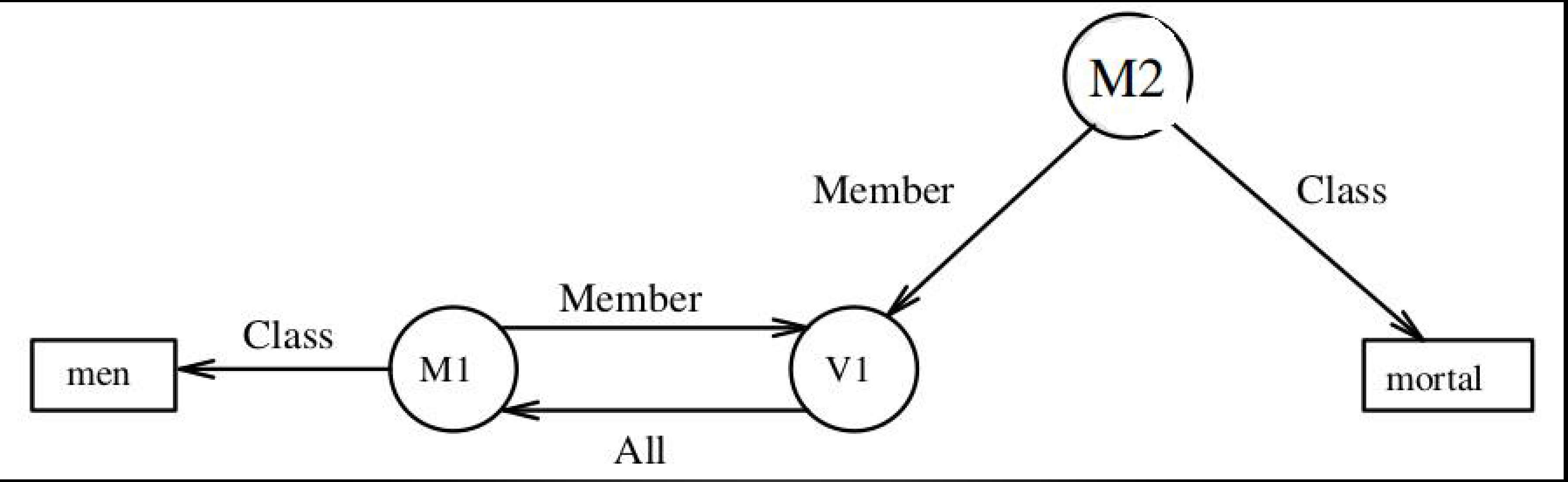
- These emphasize the subtype relation between a concept type and a newly defined subtype.



DIFFERENT KINDS OF SEMANTIC NETWORKS

2. Assertional networks

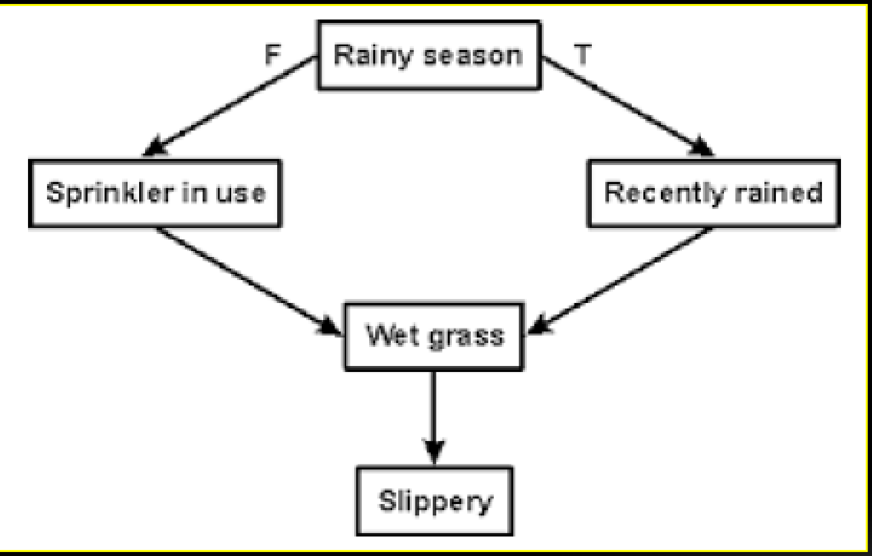
- Assertional semantic networks, also known as propositional semantic networks are designed to represent assertions or propositions. Figure shows a semantic network representation of the proposition “All men are mortal”.



DIFFERENT KINDS OF SEMANTIC NETWORKS

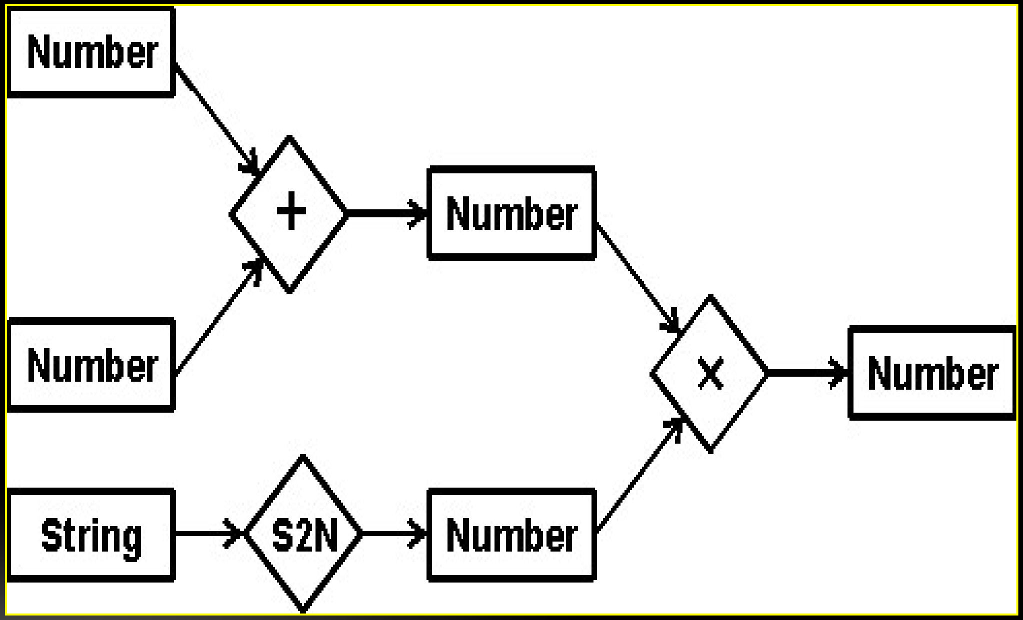
3. Implicational networks

- These use implication as the primary relation for connecting nodes.



4. Executable networks

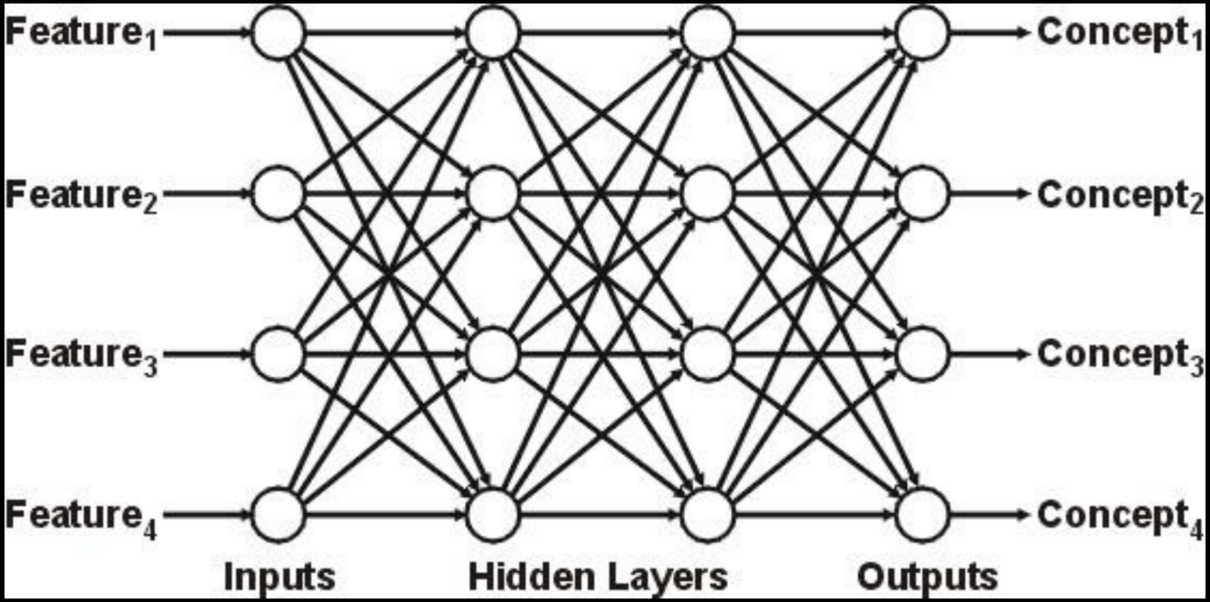
These include some mechanism which can perform inferences, pass messages, or search for patterns and associations.



DIFFERENT KINDS OF SEMANTIC NETWORKS

5. Learning networks

- These build or extend their representations by acquiring knowledge from examples



6. Hybrid networks

These combine two or more of the previous techniques.

ADVANTAGES AND DISADVANTAGES OF SEMANTIC NETWORKS

Advantages

1. They give an adaptable method of representing knowledge because many different types of object can be included in the network.
2. The network is graphical and therefore relatively easy to understand.
3. Can be used as a common communication tool between the knowledge engineer and the human expert.
4. Efficient in space requirement.
5. Easily clusters related knowledge.

Disadvantages

1. There is no standard definition of link names.
2. Semantic networks are not intelligent, dependent on creator.
3. Links are not all alike in function or form.
4. Links on objects represent only binary options.
5. Undistinguished nodes that represent classes and that represent individual objects.
6. Processing is inefficient for large networks.
7. Do not represent performances effectively.
8. It is difficult to express some properties using semantic networks, like negation, disjunction,

FRAMES

A frame is a collection of attributes and possible values that describe some entity in the world. A frame system is a collection of frames that are connected to each other by the fact that the value of an attribute in one frame may be another frame.

1. The basic characteristic of a frame is that it represents related knowledge about a narrow subject.
2. A frame system is a good choice for describing a mechanical device, for example a car.
3. Just as with semantic nets, there are no standards for defining frame-based systems.
4. A frame is analogous to a record structure, corresponding to the fields and values of a record are the slots and slot fillers of a frame.
5. A frame is basically a group of slots and fillers that defines a stereotypical object.
6. A frame is also known as slot-filter knowledge representation in artificial intelligence.

FRAME STRUCTURE

The frame contains information on how to use the frame, what to expect next, and what to do when these expectations are not met. Some information in the frame is generally unchanged while other information, stored in “terminals”, usually change. Terminals can be considered as variables. Each piece of information about a particular frame is held in a slot. The information can contain:

- Facts or data
  - Values (called facets)
- Procedures (also called procedural attachments)
  - IF-NEEDED: deferred evaluation
  - IF-ADDED: updates linked information
- Default values
  - For data
  - For procedures
- Other frames or subframes

EXAMPLES

Example 1

A frame for a book.

Slot	Value
Title	Artificial Intelligence
Genre	Computer Science
Author	Peter Norvig
Edition	Third Edition
Year	1996
Page	1152

Example 2

The frame representation of the statement: "Peter is a 25 year unmarried doctor with bodyweight 78"

Slot	Value
Name	Peter
Profession	Doctor
Age	25
Marital status	Single
Weight	78

EXAMPLES

Example 3

In this frame, he car is the object, the slot name is the attribute, and the filler is the value.

Slots	Fillers
Manufacturer	General Motors
Model	Chevrolet Caprice
Year	1979
Transmission	Automatic
Tyres	4
Colour	Blue
engine	Petrol

EXAMPLES

Example 4

Table below defines a frame with name ALEX. The various slots in the frame, their names, their values and their types are all specified in the table.

Slot	Value	Type
ALEX	-	(This Frame)
NAME	Alex	(key value)
ISA	BOY	(parent frame)
SEX	Male	(inheritance value)
AGE	IF-NEEDED: Subtract(current,BIRTHDATE);	(procedural attachment)
HOME	100 Main St.	(instance value)
BIRTHDATE	8/4/2000	(instance value)
FAVORITE_FOOD	Spaghetti	(instance value)
CLIMBS	Trees	(instance value)
BODY_TYPE	Wiry	(instance value)
NUM_LEGS	1	(exception)

FRAME LANGUAGES

Frame language is a technology used for knowledge representation in artificial intelligence. The earliest Frame based languages were custom developed for specific research projects and were not packaged as tools to be re-used by other researchers. One of the first general purpose frame languages was KRL (Knowledge Representation Language).

CONCEPTUAL DEPENDENCY

Conceptual dependency (CD) is a theory of knowledge representation developed by Roger Schank and his teammates at Yale University in the 1970’s.

It is a theory to represent natural language sentences in such way that:

- It is independent of the language in which the sentences are stated.
- It facilitates drawing inferences from sentences.

SIMPLE EXAMPLES OF REPRESENTATIONS OF SENTENCES IN CD THEORY

Example 1

Consider the English sentence:
“John ran”.

This sentence has two words “John” and “ran”. The first word refers to a particular person or a particular object. The second word is a verb and hence denotes an action. The action is running, that is, moving from one place to another. In the terminology of CD theory, we say that it is an example of a physical transfer of an object from one place to another. We also say that it is an action of the PTRANS type. (PTRANS stands for physical transfer.) In the sentence, “ran” depends on “John” and “John” depends on “ran”. There is a mutual dependency.

SIMPLE EXAMPLES OF REPRESENTATIONS OF SENTENCES IN CD THEORY

In the notations and terminology of CD theory, we represent the sentence "John ran." in the form:

$$\text{John} \overset{p}{\Longleftrightarrow} \text{PTRANS}$$

Here, the two-sided double-line arrow indicates mutual dependency and the letter "p" above the arrow indicates that the action is in the past tense. Further, in CD theory, we think of "John" as a member of the category of "real world objects" which is denoted by "PP" which is an abbreviation for "picture provider". Also, PTRANS is a member of the category of real world actions which is denoted by "ACT".

The representation of the sentence "John ran." given above can be thought of as obtained by an application of the following rule of dependency in CD theory:

$$\text{PP} \Longleftrightarrow \text{ACT}$$

SIMPLE EXAMPLES OF REPRESENTATIONS OF SENTENCES IN CD THEORY

Example 2

Consider the English sentence:

"John gave Mary a book."

There are four concepts in the sentence: "John", ”gave", ”Mary", ”book". In the sentence the actor is "John", the action is "gave" and the object of the action is ”book". The actor and the action are mutually dependent, but the action and object are not. Action depends on the object, but the object does not depend on the action. So, the sentence ”John gave a book" is represented as:

$$\text{John} \overset{P}{\Longleftrightarrow} \text{gave} \overset{O}{\longleftarrow} \text{book}$$

Now, consider the action "gave". It has two meanings: simply a physical transfer, or an ownership transfer. In the former case it is an example of PTRANS. In the latter case it is an abstract transfer which in CD theory is indicated by ATRANS. Assuming that it is the latter, we may represent "John gave a book." as

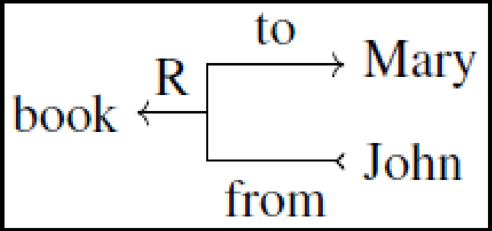
$$\text{John} \overset{P}{\Longleftrightarrow} \text{ATRANS} \overset{O}{\longleftarrow} \text{book}$$

SIMPLE EXAMPLES OF REPRESENTATIONS OF SENTENCES IN CD THEORY

Example 2

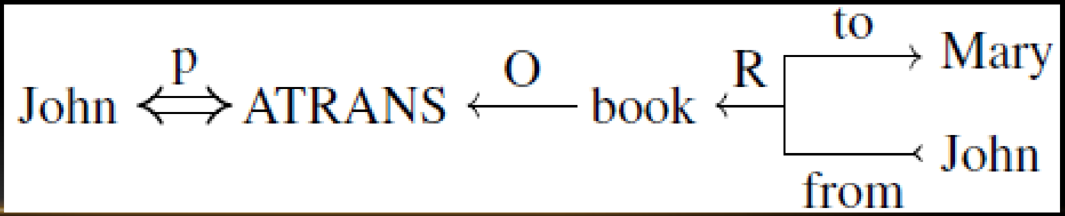
"John gave Mary a book."

Next, consider the dependency of "Mary" on the other concepts in the sentence. The dependency of "Mary" on "John" is one of a "recipient-donor" relationship and the "book" is dependent on this relation. So the dependency can be represented as :



R indicates a recipient-donor relationship.

Putting all the components together, we obtain the CD representation



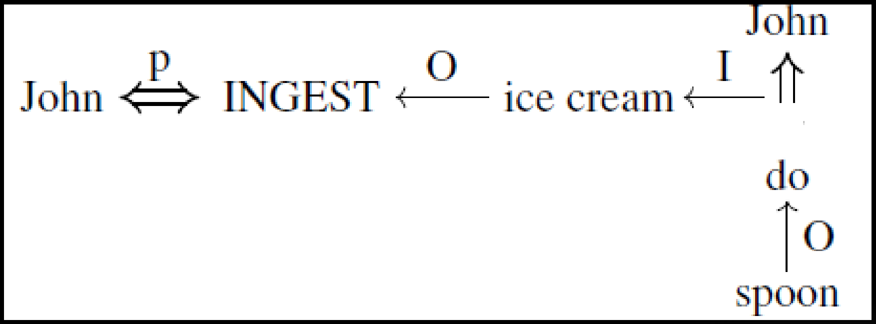
SIMPLE EXAMPLES OF REPRESENTATIONS OF SENTENCES IN CD THEORY

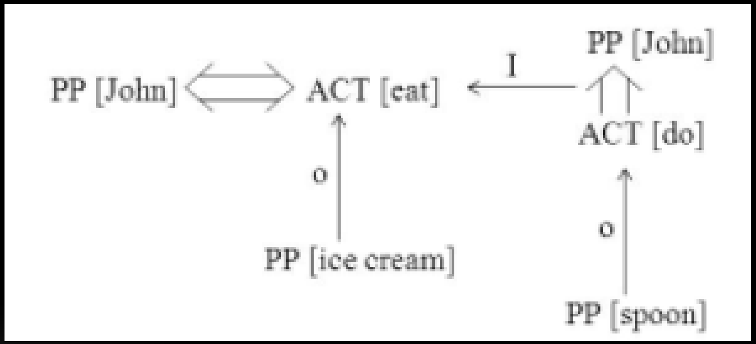
Example 3

Consider the English sentence:

"John ate the ice cream with a spoon."

The verb "ate" which is the past tense of "eat" is conceptualized as "ingesting" or "taking in" and is indicated by the primitive action INGEST. In the sentence, the spoon is the instrument of the action. In CD theory, an instrument of action is indicated by the letter "I". The sentence can be represented in the following form.





THE BUILDING BLOCKS OF CONCEPTUAL DEPENDENCY

1. Primitives conceptual categories

The primitive conceptual categories available in the CD theory are given.

Primitive	Meaning
ACT	**Real world actions.** There are only eleven of these ACTs
PP	**Real world objects (Picture Producers).** Only physical objects are PPs.
AA	**Modifiers of actions (Action Aiders**) (Attributes of actions)
PA	**Attributes of an object (Picture Aiders).** PAs take the form: STATE(VALUE). That is, a PA is an attribute characteristic (like color or size) plus a value for that characteristic (red or 10 cm).
T	**Times**
LOC	**Location**

THE BUILDING BLOCKS OF CONCEPTUAL DEPENDENCY

2. The primitive acts of CD

The CD theory recognizes 11 primitive acts. Table gives these primitive acts, their meanings and examples.

Primitive	Meaning	Example
ATRANS	Transfer of an abstract relationship (Abstract TRANSfer)	give
PTRANS	Transfer of the physical location of an object (Physical TRANSfer)	go
PROPEL	Application of physical force to an object (PROPELling an object by applying physical force)	push
MOVE	Movement of a body part by it's owner (MOVEment)	kick
GRASP	Grasping of an object by an actor (GRASPing)	throw
INGEST	Ingesting of an object by an animal (INGESTing)	eat
EXPEL	Expulsion of something from the body of an animal (EXPElling)	cry
MTRANS	Transfer of mental information (Mental TRANSfer)	tell
MBUILD	Building new information out of old (Mentally BUILDing)	decide
SPEAK	Production of sounds (SPEAKing by producing sounds)	say
ATTEND	Focusing of sense organ toward a stimulus (ATTENDing to a stimulus)	listen

3. Conceptual tenses

There are definite symbols in CD theory to indicate the tenses of verbs like, for example, “p” for past tense. The available symbols are given in Table

Symbol	Tense	Symbol	Tense
p	Past	?	Interrogative
f	Future	/	Negative
t	Transition	nil	Present
t_s	Start transition	delta	Timeless
t_f	Finished transition	c	Conditional
k	Continuing		

4. Indicators of dependencies (arrows)

Arrow type	Meaning
$\longrightarrow, \longleftarrow$	Direction of dependency
$\Longrightarrow$	Two-way links between the actor (PP) and the action (ACT)
$\Rrightarrow$	Dependency between PP and PA

THE BUILDING BLOCKS OF CONCEPTUAL DEPENDENCY

5. Symbols for conceptual cases

Symbol	Meaning
o	Objective case
R	Recipient case
I	Instrumental case (e.g., eat with a spoon)
D	Directive case (e.g., going home)

6. States

States of objects are described by scales which have numerical values.

For example, the state of health of a person is represented by a numerical value which goes from -10, +10, "-10" indicating "dead" and "+10" indicating "perfect health". The intermediate values may represent various states of health as indicated below:

State of health	Numerical value
dead	−10
gravely ill	−9
sick	−9 to −1
all right	0
tip top	+7
perfect health	+10

Various other states like the states of "fear", "anger", "mental state" (sad, happy, etc.), hunger, etc. have also been defined the CD theory with appropriate numerical values. There are also states that have absolute measures like, "length", "mass", "weight", "speed", "size", etc. Further, there are also states which indicate relationships between objects like "possession" indicated by "POSS" in CD theory.

ADVANTAGES AND DISADVANTAGES OF THE CD THEORY

Advantages

1. CD theory gives a representation of sentences which is independent of the words used in the statement.
2. CD can facilitate translation from one language to another based on the idea of the statement and not just translation of the words used in the statement.
3. We can fill missing pieces in the fixed structures by fetching them from the context.

Disadvantages

1. It is only a theory of representation of events.
2. CD theory requires that all knowledge be decomposed into low-level primitives. This may be impossible in certain situations.
3. The CD representation is sometimes very inefficient. To represent a sentence it may take several pages of CD diagrams.
4. Complex representations require a lot of storage.
5. There are no representations of relationships which can help us make inferences from the links.
6. The set of 11 primitive acts is incomplete. All knowledge should be expressed into these acts which is sometimes inefficient and even impossible.
7. Many concepts are not recognized in CD.
8. In the generalized representation, the finer meaning is lost. For example there is a difference between giving and gifting something which is not captured by CD.
9. It is difficult to construct the original sentence from its CD representation.