Knowledge Modelling and Representation
Semantic networks and Conceptual Graphs
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Logical model: Difficult to represent the knowledge
  - Propositional logics: Decidable system but requires a lot of time to make the decision
  - Other logics (predicate logic, non-classical logic): more expressive but less decidable, sometimes undecidable

How to make the inferences efficient?
  - Restraine the logics
  - Abandon the complete semantic formalization required by the logics (completeness)

Some solution(?): Make the manipulation of representations easier
The first networks

- Issued from the first works in cognitive psychology in 60s-70s
- Study if the memory functioning is based on proximity between the concepts?
- Experiments
  - Measure the time necessary to answer some questions
  - Listen a set of words and then measure the time necessary to remember them
Semantic networks

The first networks: experiments

- Present the target object, and then enumerate a set of words and ask the participant to link these words with the object if relevant.
- Measure: errors and answer time according to the relation existing between the words and the object.

Example:

man, adult male, person, individual, someone, mortal, human, soul, living thing, life form, organism, being entity, causal agent, cause, causal agency, blackman, bachelor, dandy, boyfriend, adult male body

(excerpt from the WordNet)
The first networks: experiments

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(excerpt from the WordNet)
The first networks: experiments

Conclusions

- Associative memory
- Notion of the typical object
  - Some hyponyms belong more strongly to the category than other hyponyms
  - Influence of this feature on the time needed to answer
  - It is considered that the typical object is associated to its category more rapidly than less typical objects
- Principle of economy
  - interesting for Computer science
  - less relevant for humans which memory seems to have unlimited capacity
Semantic networks

The first networks

- From the psychological point of view, these works are rather abandoned today
- AI experts programme using this structure of networks
Semantic networks

Definition

- Semantic network is an oriented and labelled graph.
- This graph is formed with nodes - which represent the concepts - related by the arcs.
- The concept acquires its meaning only through the relations it has with other concepts.
- The relation R between two nodes, labelled A and B, has the property to link these nodes: R(A,B)
Definition

- The arcs of the graph represent the relations (usually binary) between the concepts.
- The nodes and the arcs are labelled.
- Example:

  ![Diagram](image-url)
Semantic networks

General presentation

- Elementary graphs
- Heritage of properties $\Rightarrow$ Notion of inference
- Table of composition of relations
  - If the concepts $C_1$ and $C_2$ are linked by the relation $R_1$
  - and if $C_2$ and $C_3$ are linked by the relation $R_2$,
  - Then $C_1$ and $C_3$ are implicitly linked by the relation $R_3$
    - if $R_1(C_1, C_2)$ and $R_2(C_2, C_3)$ then $R_3(C_1, C_3)$
- Use in information retrieval
General presentation

- Artificial ambiguity in the network
- Binary relation/action with several agents
- Predicative concepts: the nodes represent not only the objects but also the actions and situations
- The state is encoded by the node and not by the link
- Notions of expectation and the default value for some attributes of predicative nodes
Semantic networks

Problems

- Confusion between individuals and classes
- Distinction between the assertions for all the members of the class and the assertions on this class
- General recorded properties for one class are not valid for the sub-class
Solutions

- Distinguish the nodes representing the class from the nodes representing the occurrences
- Introduce different links which permit to take into consideration all these aspects
Semantic networks

Types of links in the networks

- Epistemic links
- Logical links
- Conceptual links
- Links specific to the domain
Types of links in the networks

- **Epistemic links**
  - **kind-of:**
    - Between the general concept and the concept which is more general
    - Mechanism of classification and categorization
    - Inclusion

    ![Diagram](mammal \(\text{kind-of}\) animal)

- **is-a (instance-of):**
  - Between the individual concept and the general concept
  - Mechanism of identification and of recognition
  - Membership, belonging

    ![Diagram](Socrates \(\text{is-a}\) philosopher)
Semantic networks

Example

Animal

Mammal

Dog

Cat

Bird

Ostrich

Canary

kind-of

kind-of

kind-of

kind-of

is-a/instance-of

is-a/instance-of
Types of links in the networks

- Logical links
  - logical connectors
    - negation
    - and
    - or

- Modalities
  - it is possible that
  - it is necessary that
  - think/believe that
  - it is allowed that
Semantic networks

Types of links in the networks

- **Conceptual links**
  - Inspired by the Fillmore's case grammar
  - Identification of general relations

- **General links**
  - **agent** (of the action)
  - **object** (of the action)
  - **receiver** (of the action)
  - **date**...

![Diagram showing types of links in semantic networks](image-url)
Semantic networks

Types of links in the networks

- Links specific to the domain
  - Interoperability between computer systems
  - Terminologies and ontologies as shared conceptual representations
    over 100 relations grouped in:
      - physically related to
      - spatially related to
      - temporary related to
      - functionally related to
Types of links: detailed observations

- Hierarchy
- Particularization
- Equivalence
- Contrast
Semantic networks

Types of links

- Part
- Spatial relations
- Inheritance
- Function
Semantic networks

Example (next)

![Semantic network diagram]

- Animal
  - Mammal
    - Dog
      - Hector
    - Cat
      - Silvester
  - Bird
    - Ostrich
    - Canary
      - Tweety
- Action
- Watch
- Granny

Relationships:
- Kind-of
- Is-a/instance-of
- Owns
- Agent
- Object
Comments

- No formal definition
- The associated reasoning depends on the implementation strategies
- Evolution: logical definition
  ⇒ this requires to differentiate the nodes which represent the classes, and the nodes which represent the instances (cf KL-One [Brachman 1977-1985]).
Critics

- Absence of the methodology which provides precision on general principles about the foundation of these representations
- Vague definition of nodes and of links between them
- Brachman (1979): KL-ONE
- Distinction of three axes
  - The hierarchy of concepts in classes and sub-classes
  - Explicitation of other links between the concepts through the attributive links
  - Finite number of primitive links
Semantic resources

The best known:

- WordNet (semantic network)
- FrameNet (schemas and scripts)

Other resources can be used as semantic networks:

- The UMLS in the medical domain  
- Verbnet  
  (http://verbs.colorado.edu/~mpalmer/projects/verbnet.html)
- BabelNet (http://babelnet.org/)
Semantic resources

WordNet
https://wordnet.princeton.edu/

- Lexical network in English (≈ 150,000 words – nouns, verbs, adjectives, adverbs)
- Initially based on psycholinguistic approach (started in 1985, first version in 1993)
- Open and free resource
- Lexicon and meaning organized with the synsets (sets of synonyms)
- Hierarchical organization
  The main semantic relation: hyperonymy
- Semantic relations between the synsets
Entry: man (adult male)

- hyperonyms:
  - person, individual, someone, mortal, human, soul
  - living thing, life form, organism, being
  - entity
  - causal agent, cause, causal agency
  - entity

- hyponyms: blackman, bachelor, dandy, boyfriend...

- meronym: adult male body
11 senses of man

Sense 1
man, adult male

=> male, male person
   => person, individual, someone, somebody, mortal, soul
      => organism, being
         => living thing, animate thing
            => whole, unit
               => object, physical object
                  => physical entity
                     => entity

=> causal agent, cause, causal agency
   => physical entity
      => entity

=> adult, grownup
   => person, individual, someone, somebody, mortal, soul
      => organism, being
         => living thing, animate thing
            => whole, unit
               => object, physical object
                  => physical entity
                     => entity

=> causal agent, cause, causal agency
   => physical entity
      => entity
Semantic resources

WordNet

Example 2

Sense 1
patient
  => case
    => person, individual, someone, somebody, mortal, soul
    => organism, being
      => living thing, animate thing
        => whole, unit
          => object, physical object
            => physical entity
              => entity
    => causal agent, cause, causal agency
      => physical entity
        => entity
    => sick person, diseased person, sufferer
      => unfortunate, unfortunate person
        => person, individual, someone, somebody, mortal, soul

Sense 2
affected role, patient role, patient
  => semantic role, participant role
    => grammatical category, syntactic category
      => class, category, family
        => collection, aggregation, accumulation, assemblage
          => group, grouping
            => abstraction, abstract entity
              => entity
Semantic networks: Conclusion

- **Benefits**
  - The notion of proximity
  - Some readability, visual aspect
  - Quite a good level of declarativity

- **Drawbacks**
  - Little theoretical foundations
  - Poor reasoning mechanisms
  - No formal semantics
Semantic networks: Conclusion

- Types of applications
- Organization of lexicon
  - Terminology
  - Lexical networks (WordNet)
  - Ontologies
- Information retrieval
- Helps the navigation in the hypertext (Web)
- Portals of companies (Intranet)
- NLP
- Knowledge management (KM, memory in companies)
- E-learning
Conceptual graphs

Sowa 84

- *a priori* not conceived for a particular application
- General idea: Any representation can be re-written as conceptual graph
- Origin of the idea: psychology of vision
  The perception is the elaboration of the model from partial images (percepts) which are combined.
Conceptual graphs

- Concrete concepts are distinguished from abstract concepts because they are associated to percepts.
- Abstract concepts receive the meaning through a large semantic network which purpose is to link them to concrete concepts.
- The meaning of the concept is related to its position relative to other concepts.
Conceptual graphs: definition

- Conceptual graph: bipartite and oriented graph
  - 2 kinds of nodes: concepts and relations
  - The nodes are linked by oriented arcs
  - The arc always links the concept to the relation
  - The concept node can be isolated (non-related)

Exemple:

\[
\text{Isaac} \rightarrow \text{agent} \rightarrow \text{eat} \leftarrow \text{object} \leftarrow \text{apple}
\]

[Isaac] -> (agent) -> [eat] <- (object) <- [apple]
Notion of support

- Conformity of the graph to the support: $S$-graph
- Any conceptual graph is related to the support
  The support specifies the syntactic constraints which permit
to describe the application domain
A set of name of two types of concepts
- “universal” type: above all the elements (⊤)
- “absurde” type: below all the elements (⊥)

For each pair of concepts, we define
- a minimal-common-sup-type
- a minimal-common-sub-type

Intensional definition: lattice
Example

Conceptual Graphs

Human ⊤ Fruit

Apple ⊤ Peach
To each concept is associated
- A word or a symbol
- A representative in the world

A set of objects is associated to each name of concept. These objects are possible references to the concept.

Then we define a concept a tuple \((t, \text{ref})\) where \(t\) is a type, \(\text{ref}\) the reference to the concept
We make a distinction between
- the generic concepts (*)
- the individual concepts (#followed by a number)
- the concepts referring to a measure: @

Examples:
- [Man : *]: a man (anyone - generique concept)
- [Man : #42]: a man in particular (individual concept)
- [Man : John]: a man named John (individual concept)
- [hauteur : @170]: a concept measure (1.70m)
- [Man : {*}@4]: 4 men
Conceptual graphs: the relations

- simple Graph
  - a set of concepts and a set of relations such as
    - Each concept is related to at least one relation
    - Each relation is related to any number of concepts

Isaac ➔ agent ➔ eat ➔ object ➔ apple
Peter thinks to the painting. The painting represents a boat in the see. A fish is drawn on the sail. A person on the boat is catching a fish in the sea.
Example of graphs of rule

If

Cat

---
on

Carpet

Then

family pet

attribute

Happy
Conceptual graphs: modifications

- Creation of new graphs by the operations
  - of deleting
  - of insertion
  - of join

  on the sub-graphs or on the relations
Representations of the CG

- **Graphical form**
  - DF – Display Form
  - concepts are represented by rectangles
  - relations are represented by ellipses
  - If the relations have more than two parameters, the edges are numbered

- **Linear Form**
  - LF – Linear Form
  - concepts are represented between []
  - relations are represented between ()

- **Logical format for exchange**
  - CGIF – Conceptual Graph Interchange Format
    - ISO/IEC24707
    - www.jfsource.com/cg/cgif.htm
  - Proposed Form for the formal exchanges between soft agents
  - *x is a tag related to a concept which then allows to associate various relations thanks to the ?x
Example

*Archimedes in the bath*

- Graphical form

```
Archimedes -> (in) -> bath
```

- Linear form

```
[Archimedes] -> (in) -> [bath]
```

- Logical format for the exchange

```
[Archimedes: *x]  [bath: *y] (in ?x, ?y)
```
Conceptual graphs: Summary

**Benefits:**
- General representation model is very clear
- Intermediary representation level between the language and the formal logics
- Integration of large general culture and knowledge
- Logical strength of the representation related to the semantics

**Drawbacks:**
Problems with
- disjunction
- negation
- imbrication of quantifiers
Tools and platforms for conceptual graphs

- Platforms created depending on the needs in representation and computing
- [http://conceptualgraphs.org/](http://conceptualgraphs.org/)
- French platform developed at LIRMM (Montpellier)
- Semantic web search engine
  - CORESE
  - [http://wimmics.inria.fr/node/33](http://wimmics.inria.fr/node/33)
Conclusion

- Two models of representation:
  - Semantic networks
  - Conceptual graphs
- Graphical representation of knowledge
  - better readability
  - but
    - poor formalism in semantic networks
    - difficult implementation of logical operations