Intelligent Systems: Reasoning and Recognition

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Structured Knowledge Representation

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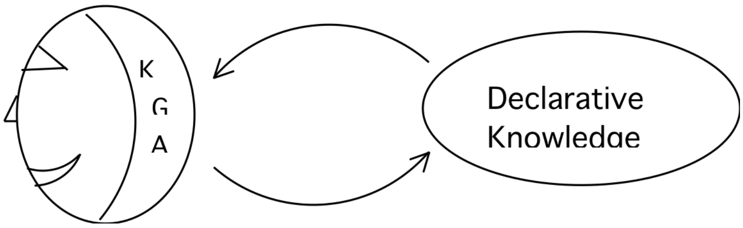
Physical Symbol System Hypothesis (PSSH)

Origins - Linguistic view of intelligence: B. Russel, L Wittegenstein, AJ Ayer, and many others. The analytical philosophy movement of the late 19th and early 20th century concentrated on symbolic logic as the foundation of knowledge.

In the 1940's, Boolean logic emerged as a fundamental tool for the design and programming of computing machines. Thus much of Computer Science was based on Boolean Logic and other tools from analytic philosophy.



In 1976 Allen Newell announced the Physical Symbol System hypothesis (PSSH):
A physical symbol system has the necessary and sufficient means for general intelligent action

Allen Newell, H. A. Simon, (1976), "Computer Science as Empirical Inquiry: Symbols and Search", Communications of the ACM, 19

PSSH became central dogma of Artificial Intelligence in the 1980's. As a result Logic Programming, based on resolution theorem proving, was thought to be the future of computer Science (Feigenbaum 1980).

After some initial success, problems soon emerged. For example:
1) The difficulty of applying logic programming for many practical problems.
2) The algorithm complexity of resolution theorem proving

Over the last 10 years, artificial intelligence has learned that linguistic expressions of knowledge is a useful tool, but is not sufficient for intelligence.

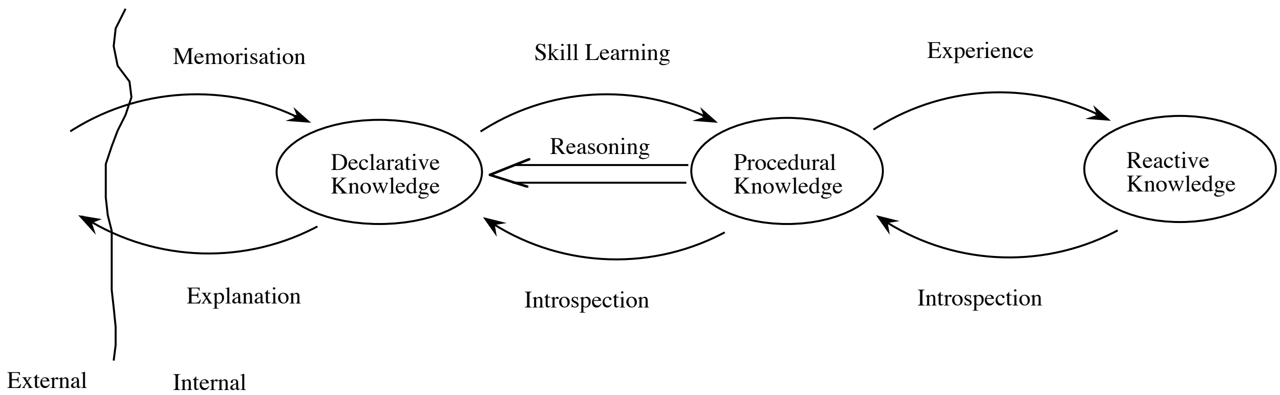
Kinds of Knowledge

Cognitive Psychologists identify different categories of knowledge:

Declarative: A symbolic expression of competence.
Declarative knowledge is abstract
Declarative knowledge is used to communicate and to reason.

Procedural: A series of steps to solve a problem.
A compiled expression of knowledge

Reactive: stimulus - response.



Declarative Knowledge is useful for Communication and for reasoning about knowledge (meta-knowledge).

Structure Knowledge Representations were explored as a general representation for symbolic representation of declarative knowledge. One of the results was a theory for Schema Systems

Schema Systems

Schema systems are symbolic structures for encoding "declarative" knowledge. Declarative knowledge is appropriate for communication and for reasoning about knowledge. Schema systems provide a general theory for declarative representation of structured knowledge.

Schema system can be used to build explanation systems. Schema system can also be used to reason about phenomena to generate new knowledge.

The concept for Schema dates back to I. Kant (In Critique of Pure Reason (Kritik der reinen Vernunft) 1781.

Kant proposed that knowledge was grounded (based) on perception. He proposed the use of "schemata" as a means of organizing and interpreting perceptual phenomena.

Kant's philosophical system was grounded in Cognitive Abilities.
Kant wanted to show that not all truths are grounded in empirical observation.

Kant distinguished "Phenomena" from "Noumena". Noumena is the underlying unknowable reality of the universe. Noumena can never be completely known, but only partially observed through the senses.

Phenomena are perceptions of Noumena. Phenomena provide partial, possibily flawed, observation of Noumena.

Kant proposed that schemata are constructed to represent "typical" phenomena. These schemata become "prototypes" for interpreting and organizing perceptions.

Some popular manifestations were
Computer Vision: Frames
Story Understanding: Scripts
Context Aware Systems: Situation Models,
Language translation and understanding: Semantic Nets

These tools can be unified under the term "Schema Systems".

Frames

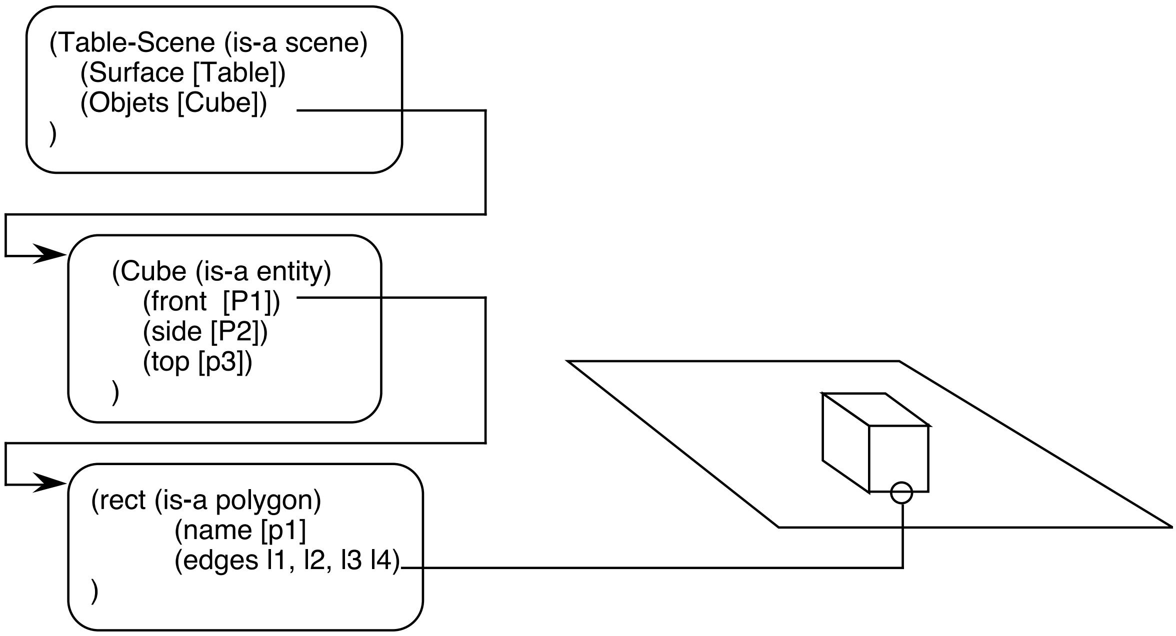
Marvin Minsky, A Framework for Representing Knowledge, in: Patrick Henry Winston (ed.), The Psychology of Computer Vision. McGraw-Hill, New York (U.S.A.), 1975.

A Structured Representation to provide context for focusing visual interpretation of scenes.

M. Minsky proposed Frames as a structure to guide scene interpretation in computer vision. A frame guided interpretation in a top down manner, telling the system where to look and what to look for. Minsky's insight was that it is much easier to see if you know what to look for.

Frames provide visual context to guide scene interpretation.

A Frame tells the program what to look for and where to look for it.



A Frame is composed of a set of "slots" and "methods".

A slot is a named place-holder for a pointer. The slots point to other frames that represent entities that are described (or interpreted) by the frame. Ultimately, some slots point to raw perceptions.

When a slot points to an entity it is said to play a "role" in the frame. Frames typically come with methods (procedures) for searching for the entities that can plays roles in the frame.

Frames can be formalized as a set of relations between entities having certain properties.

Relations as N-Ary Predicates

Definition: Relation : a significant association between or among things.

Relations are a key concept in Structured knowledge representations.
Relations capture configurations of entities. Examples include temporal relations, spatial relations, Family relations, Social structures, Corporate organization, markets, etc.

Relations are formalized as N-Ary Predicates.

The valence or Arity of a relation is the number of entities that it associates.

Unary or Monadic: Man(Bob)
Binary or dyadique: Brother(Charlie, Bob)
Ternary or triadique: Action(Jim, Talks-To, Bob)

Unary relations represent properties for entities
Binary relations associate entities.

Examples From Blocks world
Arity 0 : (HandEmpty)
Unary : (OnTable A)
Binary: (On A B)
Ternary: (Over A B C) ;; Block A is a bridge over B et C.

A symbol is a triadic relation between a sign, a thing and a agent. The agent interprets the sign to represent the thing.

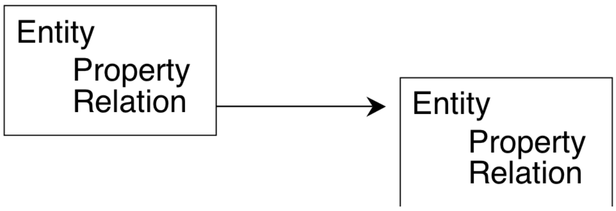
```
(defclass symbol (is-a USER)
   (slot signe)
   (slot chose)
   (slot agent)
```

)

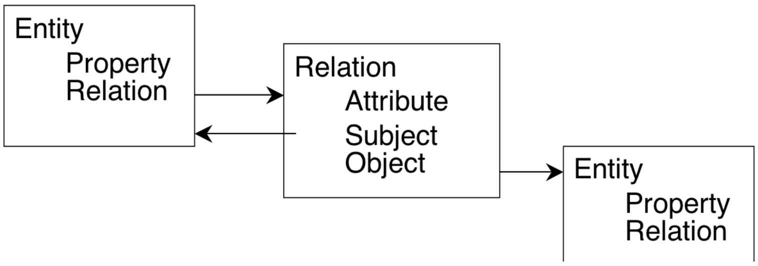
Relations can be represented "implicitly" or "explicitly".

In an implicit representation, the thing is represented as a value of a slot.
In an explicit representation, the ternary structure is expressed as a schema.

Implicit:



Explicit:



Implicit representations are simpler and slightly more efficient in computing and memory.

Explicit representations allows a system to reason about relations.

This is yet another example of the power of representing program as data.

Scripts

Schank and Abelson Scripts, Plans, Goals and Understanding, Erlbaum, 1977.

A script is a data structure used to represent a sequence of events. Scripts are used for interpreting stories. Popular examples have been script driven systems that can interpret and extract facts from Newspaper Stories.

Scripts have been used to
1) Interpret, understand and reason about stories,
2) Understand and reason about observed events
3) Reason about observed actions
4) Plan actions to accomplish tasks.

A script is composed of
1) A scene
2) Props (objects manipulated in the script)
3) The actors (agents that can change the state of the world).
4) Events
5) Acts: A set of actions by the actors.

In each scene, one or more actors perform actions. The actors act with the props. The script can be represented as a tree or network of states, driven by events.

As with Frames, scripts drive interpretation by telling the system what to look for and where to look next. The script can predict events.

Example of a script

The classic example is the restaurant script:

Scene: A restaurant with an entrance and tables.
Actors: The diners, servers, chef and Maitre d'Hotel.
Props: The table setting, menu, table, chair.
Acts: Entry, Seating, Ordering a meal, Serving a meal, Eating the meal, requesting the check, paying, leaving.

Schema systems capture Frames, Scripts, and semantic network as networks of schema. Typically, schema represent relations between entities playing roles:

Situation Models

P. Johnson-Laird 1983 - Mental Models.

Situations models are used in cognitive psychology to express the mental models that people use to understand.

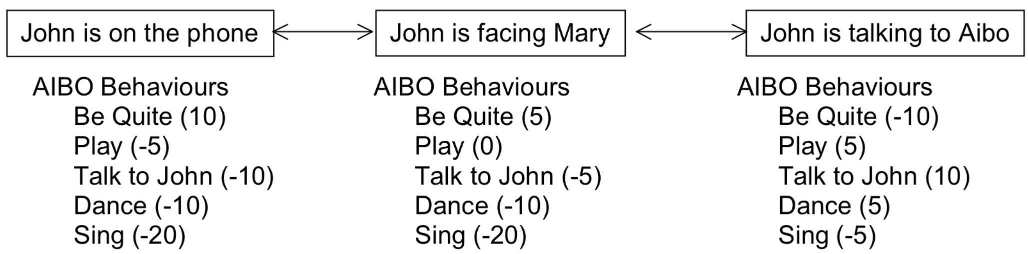
Situation: Relations between entities
Entities: People and things;
Relations: An N-ary predicate (N=1,2,3 …)
Example: John is facing Mary. John is talking to Mary.

Situation models can be easily expressed as schema.
A situation graph describes a state space of situations

A Situation determines:

System Attention: entities and relations for the system to observe
System Behaviours: List of actions that are allowed or forbidden
Default Values: Expectations for entities, relations, and properties

Behaviours include methods for perception, and methods for interaction with the external world



Each situation indicates:
Transition probabilities for accessible situations
The appropriateness or inappropriateness of actions.

Role: An abstract person o**Error! No index entries found.**r thing

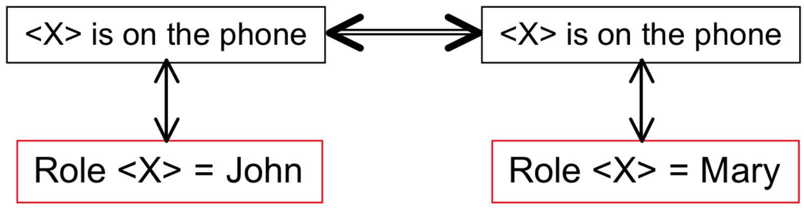
A role predicts the actions that might be taken by an actor or the actions enabled by an object.

Entity: A correlated set of observed properties.

Two kinds of entities:

Actor: An entity that can spontaneously act to change a situation.

Prop: An entity that can not spontaneously act.



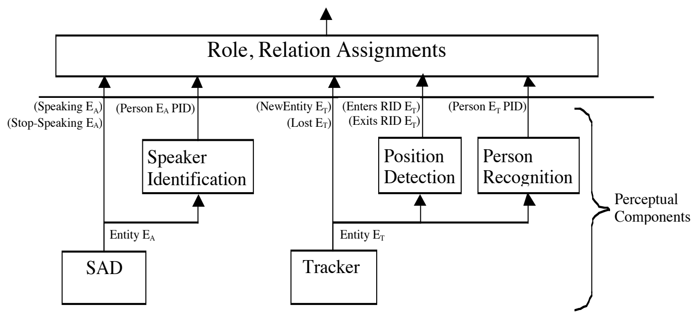
A role is a "variable" for entities.

Roles allow generalizations of situations.
Roles enable learning by analogy

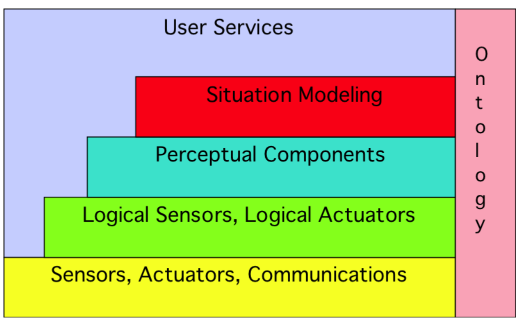
A Role is a Unary predicate that acts a filter on the entities.

The situation model is a state graph of situations, where each situation is a set of predicates expressing relations between entities playing roles.

The roles act as filters for observed entities.



Situation models rely on perception to provide information about the world.
The following is a layered architecture used for context aware services driven by a situation model:



An important form of situation models are models for social situation.

Common sense: The collection of shared concepts and ideas that are accepted as correct by a community of people.

Social Common Sense: shared rules for polite, social interaction that govern behavior within a group

Situated Social Common Sense: Social common sense that is appropriate for the situation

Social common sense can be represented as a script for social interaction.
Situated social common sense is obtained when the situation model is used to determine behaviour that is expected in a situation.

In human activity people play roles in shared interaction contexts
Roles define appropriate and inappropriate actions

Social interaction is modeled as a Situation Graph
Social interaction is not linear but includes alternatives and loops.
(A network rather than a sequence.)

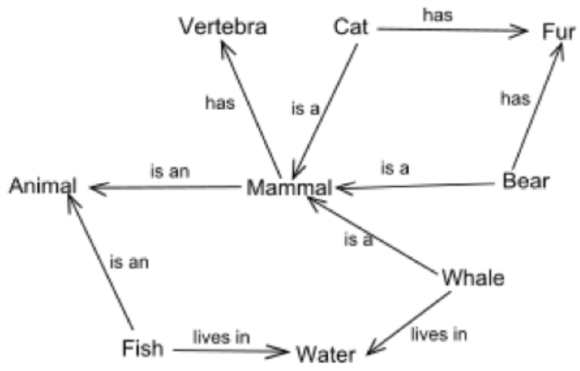
Semantic Nets

M.Quillian, (1968). Semantic Memory, in M. Minsky (ed.), Semantic Information Processing, pp 227-270, MIT Press

J. F. Sowa (1987). "Semantic Networks". in Stuart C Shapiro. Encyclopedia of Artificial Intelligence. Retrieved 2008-04-29.

Network of semantic relations between concepts.

Used as a form of knowledge representation for language understanding and translation



Fundamental problems

Some Fundamental Problem with all schema systems.

1) Knowledge acquisition: Learning a schema system is long, tedious, and ad hoc process.
2) Context Recognition (The Frame problem): Many problems are easily solved when the context is known. Recognizing the correct context can be very difficult.

Solution to both of these can be obtained from Probabilistic techniques for learning and recognition.