Intelligent Systems: Reasoning and Recognition

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Structured Knowledge Representation

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Intelligence : The ability to Know and to Understand

In the first lessons we saw that Knowledge can be understood as competence.
What does it meant to understand?

A modern view is that understanding is "the ability to predict and explain"
Our problem is how to program a system that can "understand".

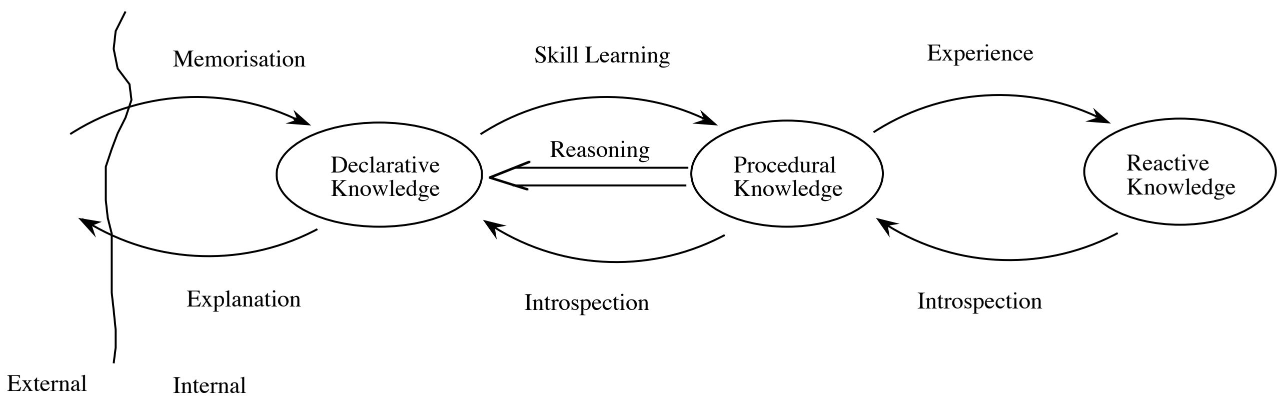
Kinds of Knowledge

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

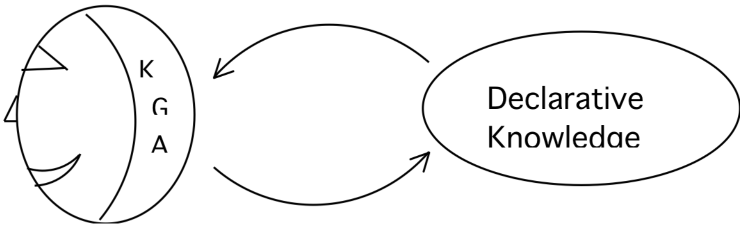
Reactive: stimulus - response.



Physical Symbol System Hypothesis (PSSH)

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

Origins - Linguistic view of intelligence: B. Russel, L Wittegenstein, AJ Ayer, and many others.



PSSH: A physical symbol system has the necessary and sufficient means for general intelligent action

PSSH became dogma in the 1980's and was severely criticized in the 90's and rejected in the 2000's

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 system provide a general theory for declarative representation of structured knowledge.

Explanation is a form of communication. Schema system can be used to build explanation systems.

Prediction is a form of reasoning. Schema system can be used to reason about phenomena to generate new knowledge.

Three popular manifestations were
Computer Vision: Frames
Language translation and understanding: Semantic Nets
Story Understanding: Scripts

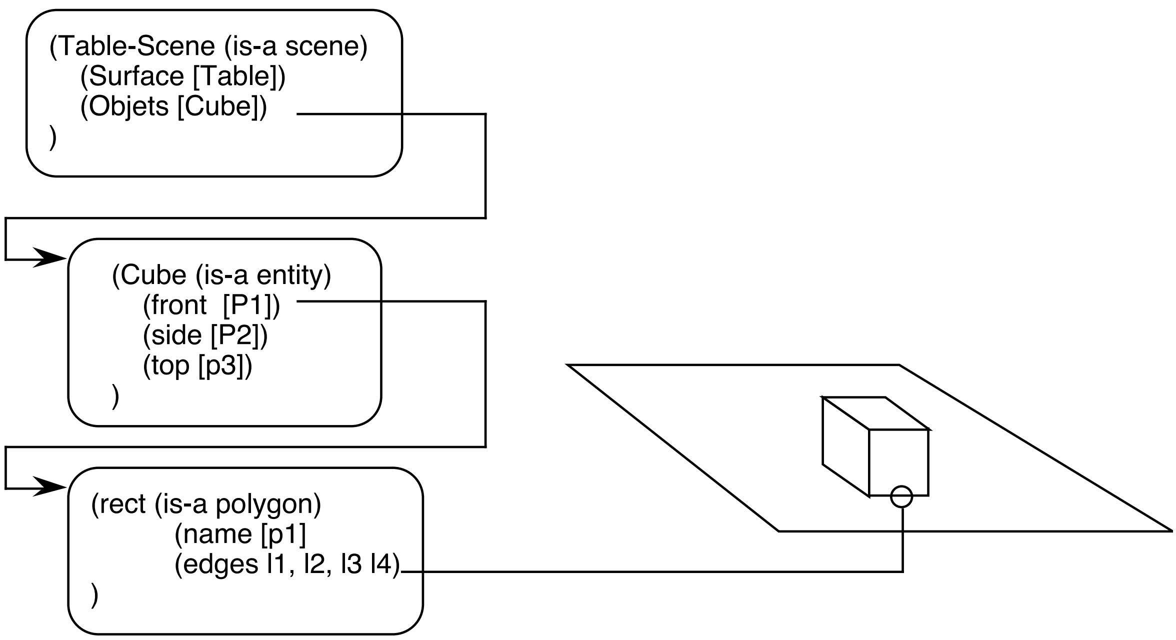
Eventually these three tools were unified under the term "Schema Systems" .

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



Fundamental Problems:

Frame acquisition is long, tedious, and ad hoc
Recognizing the proper frame to apply to a new scene.

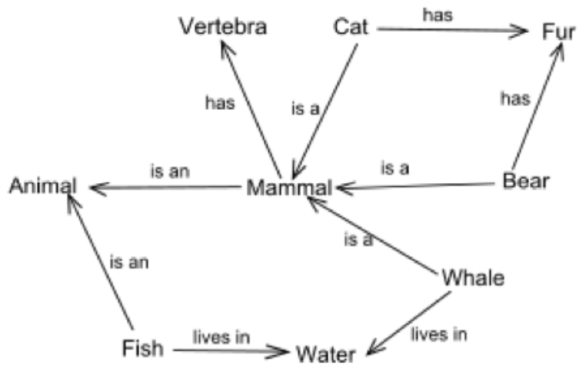
Semantic Nets

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



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:

Relations as N-Ary Predicates

Rlations 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.

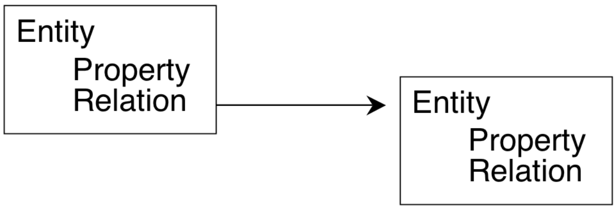
A symbol is a triadic relation between a sign, a thing and a agent. The agent interprets the sign to represent the thing.

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

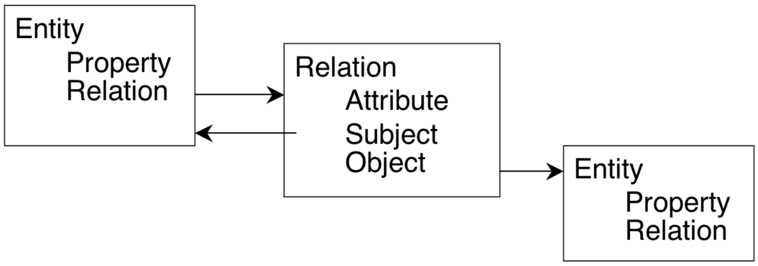
Relations can be represented "implicitly" or "explicitly".

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

Implicit:



Explicit:



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. 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

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.

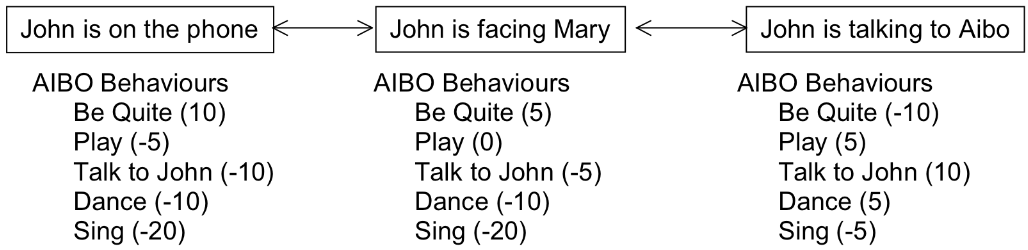
Situation models are easily expressed as schema.
Social common sense can be represented as a script for social interaction.
Situated social common sense is obtained when the situation model is used to determine behaviour that is expected in a situation.

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.)

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

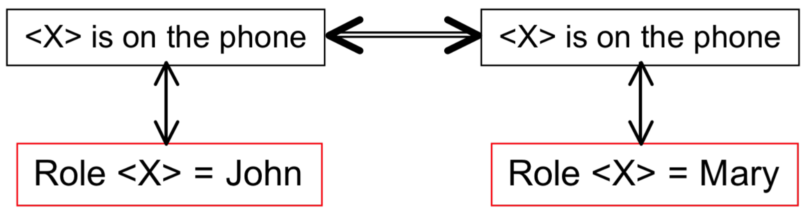


Each situation indicates:
Transition probabilities for accessible situations
The appropriateness or inappropriateness of actions.

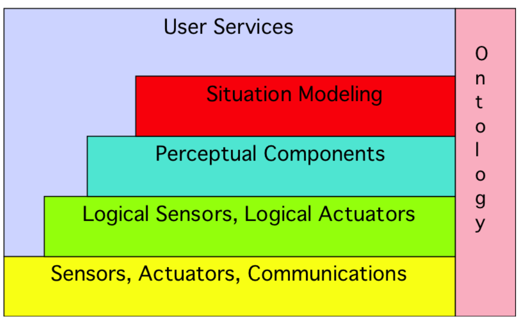
Role: An abstract person or thing

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.



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:



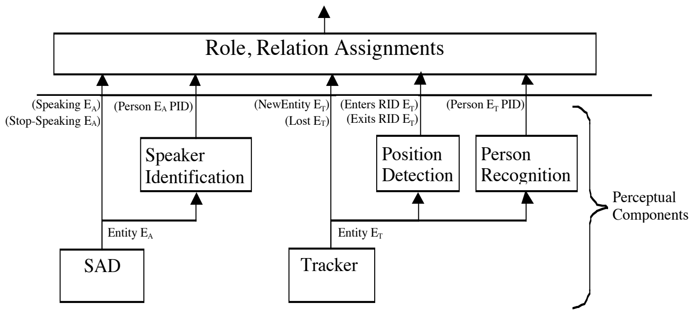
A <u>role</u> is a "variable" for entities.

Roles allow generalizations of situations.
Roles enable <u>learning by analogy</u>

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

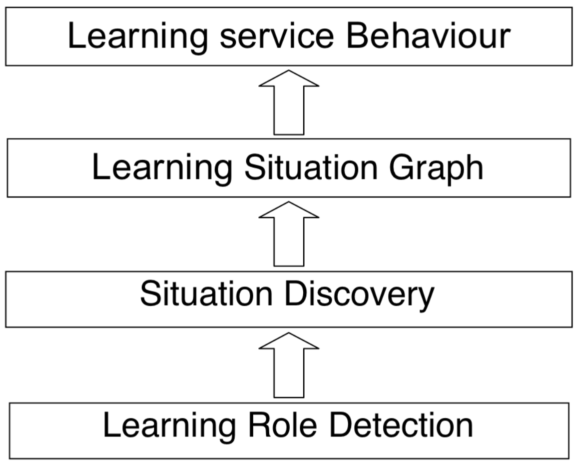
The situation model is a state graph of situations, where each situation is a set of predicates expressing relations between entities playing roles.

The roles act as filters for observed entities.



Situation models raise a number of challenging machine learning problems.

<u>Four Learning Problems</u>
Learning Service Behaviour
⇒ Supervised on-line Learning
Learning Situations Graphs
⇒ Supervised off-line Learning
Situation Discovery
⇒ Unsupervised off-line Learning
Role Detection
⇒ Off-line Statistical Learning



For this we will need Probabilistic techniques for learning and recognition.