Intelligent Systems: Reasoning and Recognition

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Structured Knowledge Representations: Situation Models, Frames, Scripts, Semantic Nets

Bibliography:

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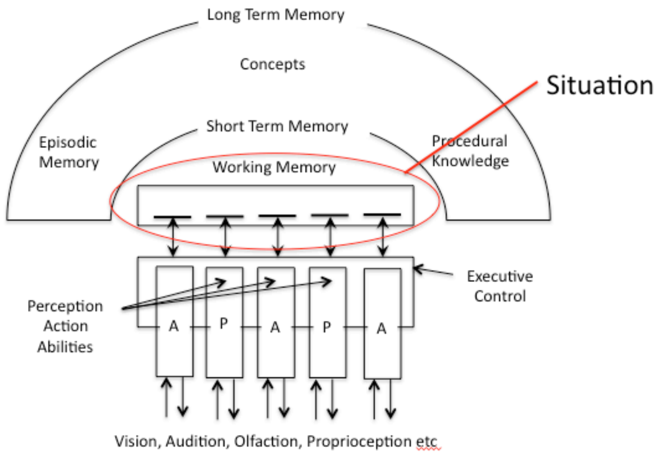
Situation Models

Situations models (P. Johnson-Laird 1983 - Mental Models.) are used in cognitive psychology to describe the mental models that people use to understand and reason.

A situation model captures the activity of working memory. Working memory elements are called "entities". Entities are instances of concepts. The structure (the set of associations) for an entity are defined by its concept.

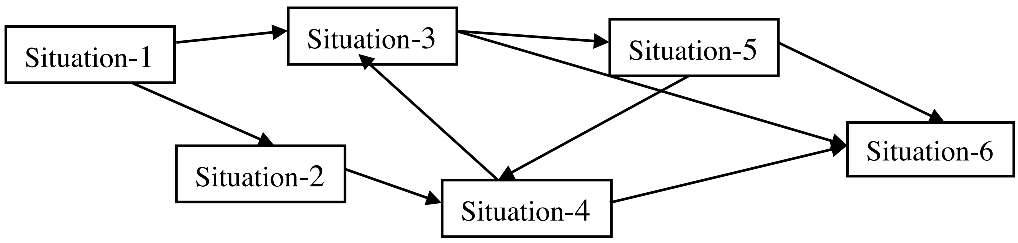


A situation is as set of relations between entities (a state).
A Situation model is composed of a set of entities (defined as instance of concepts with properties), a set of relations between entities, a set of behavior (event-condition-action rules) that can be associated to situations, and set of state transitions that organize the situations as a graph.

Entities:	Anything that can be named or designated; People, things, etc. (entitles are defined using schema or frames)
Properties:	Descriptions of entities such as position, size, color, etc
Relations:	N-ary predicates (N=1,2,3 …) that relate entities. (relations are defined as tests on the properties of entities).
Situation:	A set of relations between entities

Situations can be organized into a state space referred to as a situation network.
Each situation (or state) corresponds to a specific configuration of relations between entities. A change in relation results in a change in situation (or state).

Structured Knowledge: Situations Models, Frames, Scripts and Semantic Nets.



The situation graph, along with the set of entities and relations is called a Context.

Each situation can prescribe and proscribe behaviors.
1) Behaviors: List of actions and reactions that are allowed or forbidden for each situation. Behaviors are commonly encoded as Condition-Action rules.
2) Attention: entities and relations for the system to observe, with methods to observe the entities
3) Default values: Expectations for entities, relations, and properties
4) Possible situations: Adjacent neighbors in the situation graph.

Each situation indicates:
Transition probabilities for next situations
The appropriateness or inappropriateness of behaviors

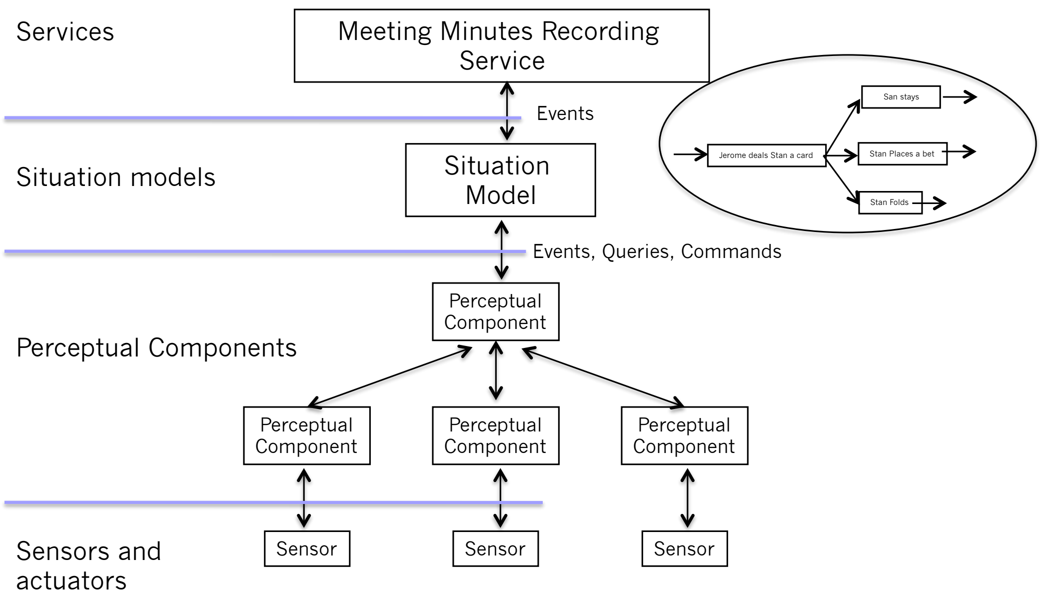
Behaviors include
1) methods for sensing and perception, and
2) appropriateness of actions
3) changes in state in reaction to events.

The sets of entities, relations, behaviors, and situations are sometimes said to defina a "Context" model. Situation models are used to construct context aware systems.

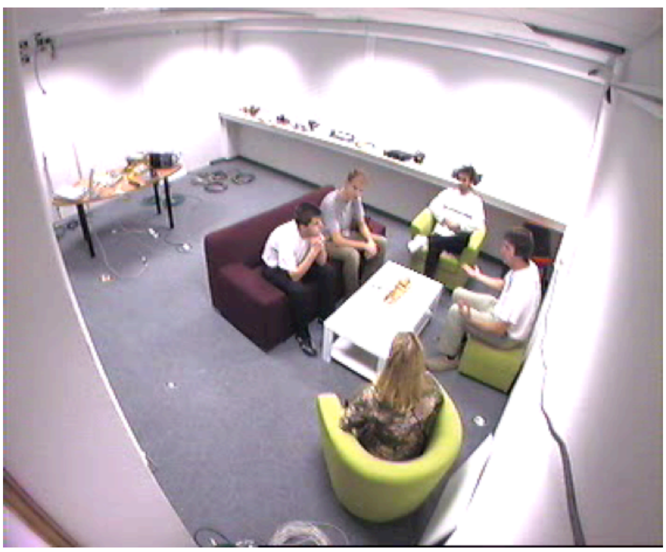
A "Context" is defined as
1) A set of entities, with their properties.
2) A set of relations between entities
3) A network of situations, such that each situation specifies
- A list of adjacent situations, possibly with transition probabilities.
-A list of system behaviors that are allowed or forbidden, possibly with preferences (appropriateness) for the situation.

Structured Knowledge: Situations Models, Frames, Scripts and Semantic Nets.

Example: Meeting Recording System



Entities:
Patrick, Jerome, Sonia and Stan, agenda
Roles:
Moderator, Speaker, Participant, current-agenda-item, etc
Relations:
Moderator(Patrick) speaks-to participants(…)
Participant(Jerome) talks-to Participant(Stan)
Participant(Sonia) looks-at Participant(Patrick)



Situations models can be constructed using Frames.

Frames

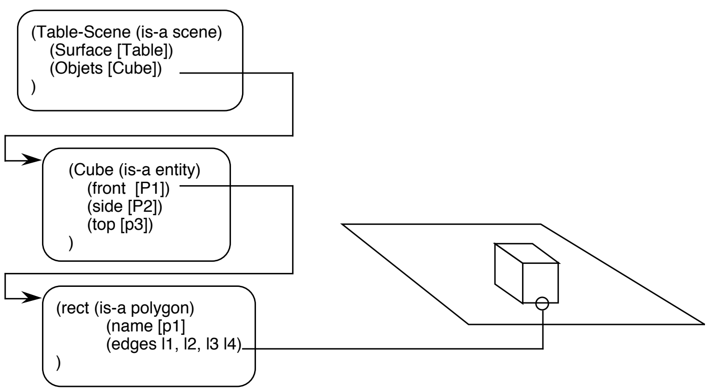
Frames are data structures that can be used to represent concepts and guide reasoning. Frames represent perceived entities as examples of concepts. Frames are used to organize perceptions in Computer Vision, Linguistics and Cognitive Systems.

Frames were made popular by Marvin Minsky (1976). Minsky proposed Frames as a structure to guide visual interpretation in a top down manner, telling a vision 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.

A frame describes a perceived entity with a set of properties and relations, represented by slots, and a collection of procedures for perceiving, reasoning and acting with the concept. The key insights are:

1) To provide procedures or operations to detect entities, either as perceived entities or as other frames.
2) To provide default values for properties when perception is not possible or fails.

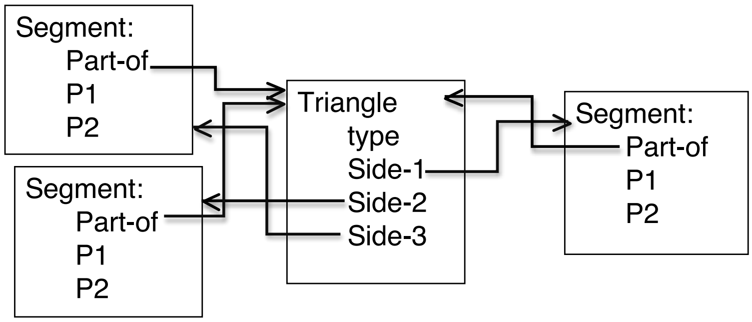
Frames represent concepts and can be composed hierarchically to describe complex entities.



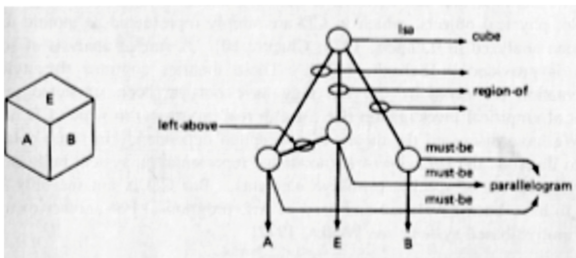
Frames provide visual context to guide scene interpretation. A Frame tells the program what to look for and where to look for it. They ask allow a system to ask questions about objects, such as what and where

Frames are composed using relations, represented by slots that contain pointers to other frames. Relations represents information about the object, such as part relations (composed of, part-of), Position relations (above, below, beside, inside, contains), Time relations (before, after, during), as well as specific properties of the entity (size, position, color, orientation).

For example, the concept Triangle has the part relation "composed of" with three segments. The triangle can also have an is-a relation (category membership) with different triangle types such as equilateral, isosceles, right angle, etc.



Ultimately, some slots point to raw perceptions (phenomena).



A Frame for a Cube
(from E. Rich "Artificial Intelligence", Fig 7-13, p231

When a slot points to an entity, the entity 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. Typically a slot-filling procedure will apply a set of acceptance tests to an entity to see if it satisfies the requirements for the role

Frames generally include typical examples (prototypes) that can serve as examples in reasoning, and default values that are used if no entity has been found to fill the slot.
Thus frames can be used for abstract reasoning or for reasoning when perception is not possible.

The term Frames has come to represent any general representation of common sense knowledge using a slot and filler structure. Slots tell what entities to find and fillers are procedures to find entities that can fill slots.

Discovering the appropriate frame for reasoning is called "The Frame Problem".

Scripts

A script is a schema structure used to represent a stereotypical sequence of events.

Scripts are used for interpreting stories. For examples, scripts used to construct systems that interpret and extract information from Newspaper Stories. Scripts are used in natural language understanding systems to organize a knowledge base in terms of the situations that the system should understand. Scripts are also used to observe an actor and to describe (or recognize) what the actor is doing. This includes plan-recognition as well as activity description. Scripts are also be used to represent procedural knowledge for plans.

Scripts are schema much like Frames, except that the slots point to a sequence of situations.

A script is composed of

1) Scene: situation in which the script takes place
2) Props: Entities (objects) involved in the script.
3) Roles: Actors (agents) that can provoke changes in the scenes.
   Actors are typically people, but may be artificial.
4) Events (acts): A sequence of events that lead to changes in situations and make up the script.

The script can be represented as a tree or network of scenes, driven by actions of 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: Restaurant Script.

The classic example is the restaurant script:
Props: A restaurant with an entrance, tables, chairs, plates, eating utensils, glasses, menu, etc
Actors: The host (Maitre d'Hotel), clients, servers, chef, bus-boy, etc.
Scenes: Entry, seating, reading the menu, ordering, serving, requesting the check, paying, leaving, etc.

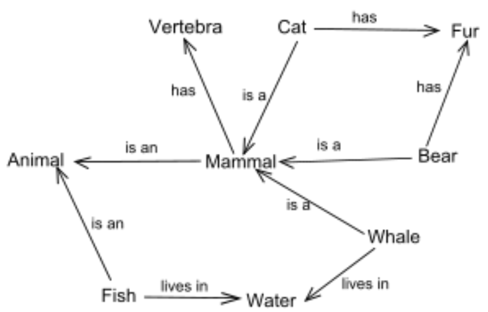
Scripts provide context for default reasoning.

As with Frames, scripts drive interpretation by providing procedures that tell a system what to look for and where to look for it.

Scripts also provide default knowledge for reasoning about stories or actions.
For example, for story understanding, the story will typically only provide sparse detail of what happened. The reader is expected to fill in the missing knowledge with default knowledge.

Semantic Networks

A semantic network, or frame network, is a network that represents semantic relations between concepts. This is often used as a form of knowledge representation. It is a directed or undirected graph in which nodes represent concepts and arcs represent relations between concepts.



Common relations include class hierarchies (ISA, AKO) and part hierarchies (PART-OF and COMPOSED-OF), Spatial relations (left-of, right-of, above, below), temporal relations (Before, after, during, etc).

ISA represents class hierarchy for entities. Is-a enable for reasoning about classes and categories. Has associates a concept with components. (Fish Has eyes).

Problems with Structured Knowledge Representations.

Structured knowledge representations were invented as a programming tool for intelligent systems. This approach suffers from a number of open problems:

1) Top down reasoning: Frames (and most schema systems) are designed for top-down reasoning. Most human reasoning is both top-down and bottom-up (active), with associations flowing both ways.

2) Knowledge Acquisition: Building a Frame system by hand is long, tedious, and ad hoc process. There is a temptation to overload the system with useless information, "just in case". Automatic acquisitions (learning) of frame systems for recognition and reasoning is a notoriously hard research problem for classical AI.

3) Context Recognition (The Frame problem): Many problems are easily solved once the appropriate frame is known. Recognizing the correct context can be very difficult.

4) Semantic Alignment: Two Frame systems describing the same concepts, may not have the same relations. Meanings of similar concepts might be slightly different. However, communication and integration of conceptual knowledge from different sources requires a shared ontology.