Intelligent Systems: Reasoning and Recognition

James L. Crowley

MoSIG M1 Second Semester 2017/2018

Lesson 15 29 March 2017

Structured Knowledge Representations: Relations, Predicates, Situation Models and the Semantic Web

Bibliography:

1) J.F. Sowa, Knowledge Representation: Logical, Philosophical, and Computational Foundations, Brooks/Cole Publishing Co., Pacific Grove, CA., 2000
2) P. N Johnson-Laird, Mental models, MIT Press Cambridge, MA, USA, 1989.
3) T. Berners-Lee et al., The Semantic Web", Scientific American, 1991

Frames (revisited)

Frames are Schema with "Procedural attachment" - Procedures to find and reason with slots. Slots can represent properties (color, size, position) or relations (next-to, part-of, etc).

For example - My breakfast table. Breakfast table

```
(frame
        (name Breakfast-Table)
        (is-a table-context)
        (knife (find-knife()))
        (spoon (find-spoon()))
        (cup  (find-cup()))
        ...
        (meaning  (remember-episode(breakfast)))
        ...
)
```

```
(frame
        (name Knife)
        (is-a eating-utensil)
        (size 10cm)
        (meaning (get-meaning remember(knife)))
        (role (spread butter))
        (on table)
        (right-of plate)
        (left of <nil>)
)
```

The role can change according to the context. I use the knife to spread butter. My wife uses the knife to open jar of jam. Last night I used the knife to cut beans.

The set of relations is unbounded. Left-of, on, before, under....

Problems with Frames.

Last lesson I listed 5 problems with the Frames
Two in particular are important:

1) Top down reasoning
2) Cost of knowledge acquisition is very high

An additional problem: Reasoning is context dependent.
Consider frames for words, numbers, tools, etc.

Concepts, and their schema, can be used in many (an unbounded number) of contexts.

Depending on the context, the relations, the roles and the meanings for a frame can change.

Relations

Relations are used to organize concepts.
Examples include temporal relations, spatial relations, Part-whole relations, family relations, social relations, administrative organizations, military hierarchies, and class hierarchies.

A non-exhaustive list of relations between concepts includes:
1) Class membership (ISA, AKO) relations
2) Structural (Part-of) Relations
3) Ordinal relations (bigger-than, smaller than)
4) Spatial Relations (right-of, left-of, above, below, in-front-of, behind, etc)
5) Temporal relations (Allen's 13 relations between intervals).
6) Organizational relations (team member, leader, etc)
7) Family (parents, brothers, sisters, etc)
8) Causal (action A caused phenomena P)
This list is NON-EXHAUSTIVE. Relations can be defined as needed by a domain.

Class membership (is-a) are useful as part of the definition of a schema.
Other relations can be Over the schema:
on(knife, table), in(coffee, coffee-pot), before(cook, eat).

Predicates

Relations are formalized as Predicates (Truth functions).

A predicates is function that assigns a property to an association of arguments. Normally, predicates are assumed to be Boolean functions, but an interesting research problem is how to use probabilistic predicates to represent relations.

A predicates is a function that tells whether or not a relation is valid for a set of entities. Classically, predicates are treated as Boolean functions that can only return a value of TRUE or FALSE. As we have seen, in probabilistic reasoning, predicates represent the likelihood that the relation holds, with a value between 0 and 1.

Relations as N-Ary Predicates

The "Arity" of a relation is the number of arguments. Arity represents the number of entities associated by the relation. Relations may have an arity of 0 or more arguments.

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

Nullary:	Friday()	;; a statement. An assertion. An axiom.
Unary:	Man(Bob)	;; Bob is a human of of gender male
Binary	Brother(Bob, Chris)	;; Bob and Chris are brothers
Ternary	Triangle(A, B, C)	;; a geometric relation associating points or lines

In some systems it is possible to have functions with variable arity. These are called polyadic functions or variadic functions. Set(A, B, C, D)

The philosopher CS Pierce (1871) demonstrated that any system of relations could be reduced to a hierarchy of binary relations by chunking. This is used in the widely used notation: (Subject Relation Object).

However, just because you can, does not mean you should. Some computations are made easier by explicitly listing a set of N-ARY relations.

Implicit vs Explicit representations for Relations

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

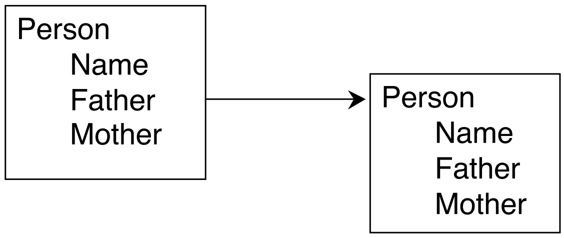
Implicit representation

Frames, and most schema systems use implicit relations.
With an implicit representation, the relation is represented as a pointer in a slot.

For example, with family relations:

(defclass PERSON (slot NAME) (slot FATHER) (slot MOTHER)).

The slot FATHER contains a pointer to an object of the class PERSON that represents the father of the person. The pointer is the object address.



Implicit representations are simple and more efficient in computing and memory.

However, with an implicit (slot based) representation for a concept, the set of relations is fixed and cannot change dynamically.

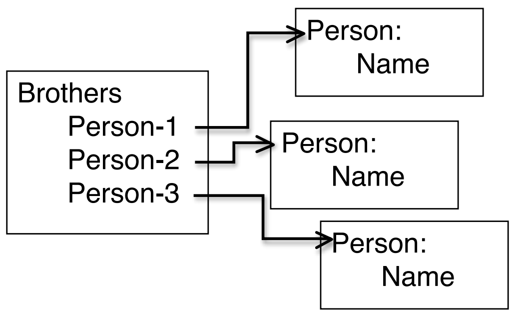
An implicit (slot based) representation for relations is not easily completed with meta information. Some forms of reasoning are much easier with an explicit representation.

Explicit representation

With an explicit representation, relations are represented by a schema whose arguments are concepts.
Explicit Representations for relations can be changed dynamically without changing the underlying concept.

(defclass PERSON (slot NAME))
(defclass Brothersp (slot person1), (slot person2), (slot person2))

A slot holds a pointer to the object that represents the relation. This object can then provide additional information about the object, such as what, where, why, when, who and how.



With an explicit representation for relations, it is possible to write a set of general procedures for acquiring (learning), reasoning, and explaining that apply to all relations.

With an implicit representation, such procedures would be specific to each class.

Thus explicit relations support generalized methods acquiring (learning), reasoning, and explaining about relations.

For example, Allen's temporal reasoning is much easier to program using explicit models of relations because the set of relations between intervals changes dynamically.

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 and reason.

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

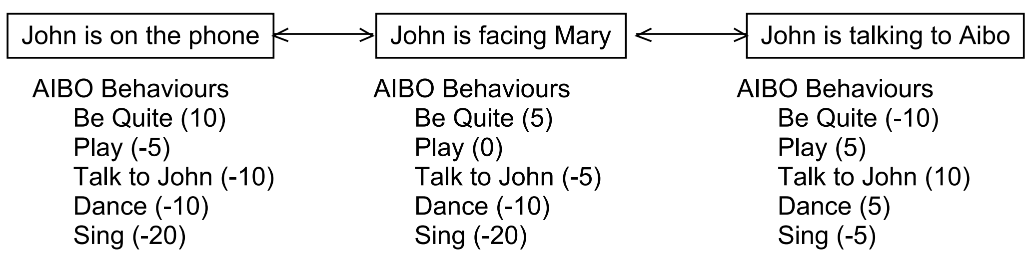
Example: John is facing Mary. John is talking to Mary. Mary is not listening.

facingP(John, Mary) ^ talkingP(John,Mary)^ not listeningP(Mar, John))

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).

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 define a "Context".

Situation models are used to construct context aware systems.

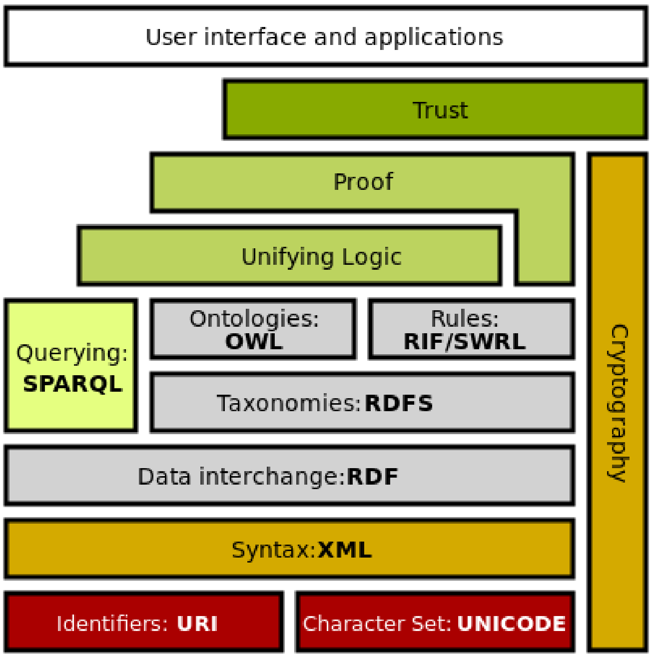
A "Context" is defined as
1) A set of entities, with their properties.
2) A set of relations between entities
3) A network of situations, such that each situation specifies
- A list of adjacent situations, possibly with transition probabilities.
-A list of system behaviors that are allowed or forbidden,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

RDF and the Semantic Web

Explicit relations are used in the semantic web.
Standards for the Semantic Web are managed by the World Wide Web Consortium (W3C).

The Semantic Web is an extension of the current WWW in which web pages are completed with descriptions of meaning, thus enabling intelligent sharing of information. (Berners-Lee et al., The Semantic Web", Scientific American, 1991). Meaning is provided by relations, expressed as semantic triples using RDF.

W3C has defined stack of standards for the Semantic Web that include XML, RDF, OWL and SPARQL.



The elements of the Semantic Web stack are:

- URI are web resources (URL or internet addresses).
- XML provides a surface syntax for structured documents, but imposes no semantic constraints on the meaning of these documents;
- RDF is a data model for resources and the relations between them. RDF provides semantics for the data model;
- RDFS is a schema system for describing properties and classes of RDF resources, with a semantics for generalization hierarchies of properties and classes;
- OWL adds constructs for describing properties and classes.

XML (Extensible Markup Language) is a markup language that defines a set of rules for encoding documents in a both human-readable and machine-readable format. An XML document consists of a nested set of open and close tags, where each tag can have a number of attribute-value pairs. The vocabulary of the tags and their allowed combinations is not fixed, but can be defined as needed for an application. XML is used as a uniform data-exchange format that provides a common syntax for exchange of data.

Semantic triples are the atomic data entity in the Resource Description Framework (RDF).

RDF (Resource Description Framework) is a W3C standard used as a general framework for modeling information about web resources. The basic construction in RDF is the triple <subject, predicate, object>. The subject denotes a resource and the predicate expresses a relation between the subject and the object. The subject and object are URIs (Uniform Record Identifiers) that can be web addresses or URL's.

RDF Schema (RDFS) provide a vocabulary for RDF data. RDFS is an extension of RDF that provides basic elements for structuring RDF resources. RDFS allows definitions for Classes, Properties, Data-types and Hierarchies for both classes and properties.

OWL (Web Ontology Language) is a semantic markup language for defining, publishing and sharing ontologies. OWL can be used to explicitly represent the meaning of terms in vocabularies and the relationships between those terms. This representation of terms and their relations is called an *ontology*

SPARQL is a query language for retrieving and manipulating data stored in RDF format. Most forms of SPARQL queries contain a set of triple patterns called a basic graph pattern in which the subject, predicate and object may be a variable (denoted by a question mark).

For example, the following SPARQL query retrieves pairs book together with its author author:

```
SELECT  ?book  ?author WHERE {?book :author ?author}
```