Key Ideas of Knowledge Representation

Ontology

Ontological Engineering

FOL and Categories

Relations between Categories

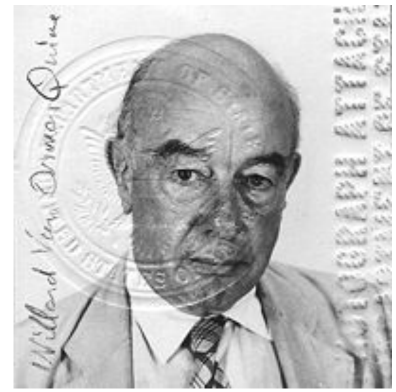
Actions, Events and Situations

Describing Change

Etc.

Ontology - On What There Is

A curious thing about the ontological problem is its simplicity. It can be put in three Anglo-Saxon monosyllables: ‘What is there?’ It can be answered, moreover, in a word - ‘Everything’ - and everyone will accept this answer as true. However, this is merely to say that there is what there is. There remains room for disagreement over cases; and so the issue has stayed alive own the centuries.



Willard Van Orman Quine

Ontology - On What There Is

Now suppose that two philosophers, McX and I, differ over ontology. Suppose that McX maintains that there is something which I maintain there is not. McX can, quite consistently, with his own point of view, describe our difference of opinion by saying that I refuse to recognize certain entities. I should protest, of course, that he is wrong in his formulation of our disagreement, for I maintain that there are no entities of the kind which he alleges for me to recognize; but my finding him wrong in his formulation of our disagreement is unimportant, for I am committed to considering him wrong in his ontology anyway.

When *I* try to formlate our difference of opinion, on the other hand, I seem to be in a predicament. I cannot admit that there are some things which McX countenances and I do not, for in admitting that thee are such things I should be contradicting my own rejection of them.

Ontology - On What There Is

It would appear, if this reasoning were sound, that in any ontological dispute the proponent of the negative side suffers the disadvantage of mot being able to admit that his opponent disagrees with him.

This is the old Platonic riddle of nonbeing. Nonbeing must in some sense be, otherwise what is it that there is not? This tangled doctrine might be nicknamed *Plato's beard;* historically it has proved tough, frequently dulling the edge of Occam's razor.*

*Occam's razor is a principle that generally recommends selecting the competing hypothesis that makes the fewest new assumptions

Ontology - On What There Is

It is some such line of thought that leads philosophers like McX to impute being where they might otherwise be quite content to recognize that there is nothing. Thus, take Pegasus. If Pegasus *were* not, McX argues, we would not be talking about anything when we use the word; therefore it would be nonsense to say even that Pegasus is not. Thinking to show thus that the denial of Pegasus cannot be coherently maintained, he concludes that Pegasus is.

McX cannot, indeed, quite persuade himself that any region of space-time, near or remote, contains a flying horse of flesh and blood. Pressed for further details on Pegasus, then, he says that Pegasus is an idea in men's minds. Here, however, a confusion begins to be apparent. We may for the sake of argument concede that there is an entity, and even a unique entity (though this is rather implausible), which is the mental Pegasus-idea; but this mental entity is not what people are talking about when they deny Pegasus.

Ontology - On What There Is

McX never confuses the Parthenon with the Parthenon-idea. The Parthenon is physical; the Parthenon-idea is mental (according anyway to McX's version of ideas, and I have no better to offer. The Parthenon is visible; the Parthenon-idea is invisible. We can not easily imagine two things more unlike; and less liable to confusion, than the Parthenon and the Parthenon-idea. But when we shift from the Parthenon to Pegasus, the confusion sets in - for no other reason that that McX would sooner be deceived by the crudest and most flagrant counterfeit than grant the nonbeing of Pegasus.

Ontology - On What There Is

The notion that Pegasus must be, because it would otherwise be nonsense to say even that Pegasus is not, has been seen to lead McX into an elementary confusion. Subtler minds, taking the same precept as their starting point, come out with theories of Pegasus which are less patently misguided than McX's, and correspondingly more difficult to eradicate. One of these subler min ds is named, let us say, Wyman. Pegasus, Wyman maintains, has his being as an unactualized possible. When we say of Pegasus that there is no such thing, we are saying, more precisely, that Pegasus does not have the special attribute of acdtuality. Saying that Pegasus is not actual is on a par, logically, wih saying that the Parthenon is not red; in either case we are saying something about an entity whose being is unquestioned.

To continue - read chapter 1 in From a Logical Point of View by Willard Van Orman Quine (1953)

Knots - R.D.Laing

They are playing a game.

They are playing at not playing a game.

If I show them I see they are, I shall break the rules and they will punish me.
I must play their game, of not seeing I see the game.

They are not having fun.

I can't have fun if they don't.

If I get them to have fun, then I can have fun with them.

Getting them to have fun, is not fun. It is hard work.

Knots - R.D.Laing

JILL I'm upset you are upset

JACK I'm not upset

JILL I'm upset that you're not upset that I'm upset that you're upset.

JACK I'm upset that you're upset that I'm not upset that you're upset that I'm upset, when I'm not.

JILL You put me in the wrong

JACK I am not putting you in the wrong

JILL You put me in the wrong for thinking you put me in the wrong.

JACK Forgive me

Ontological Engineering

How to create more general and flexible representations.

- Concepts like actions, time, physical object and beliefs
- Operates on a bigger scale than K.E.

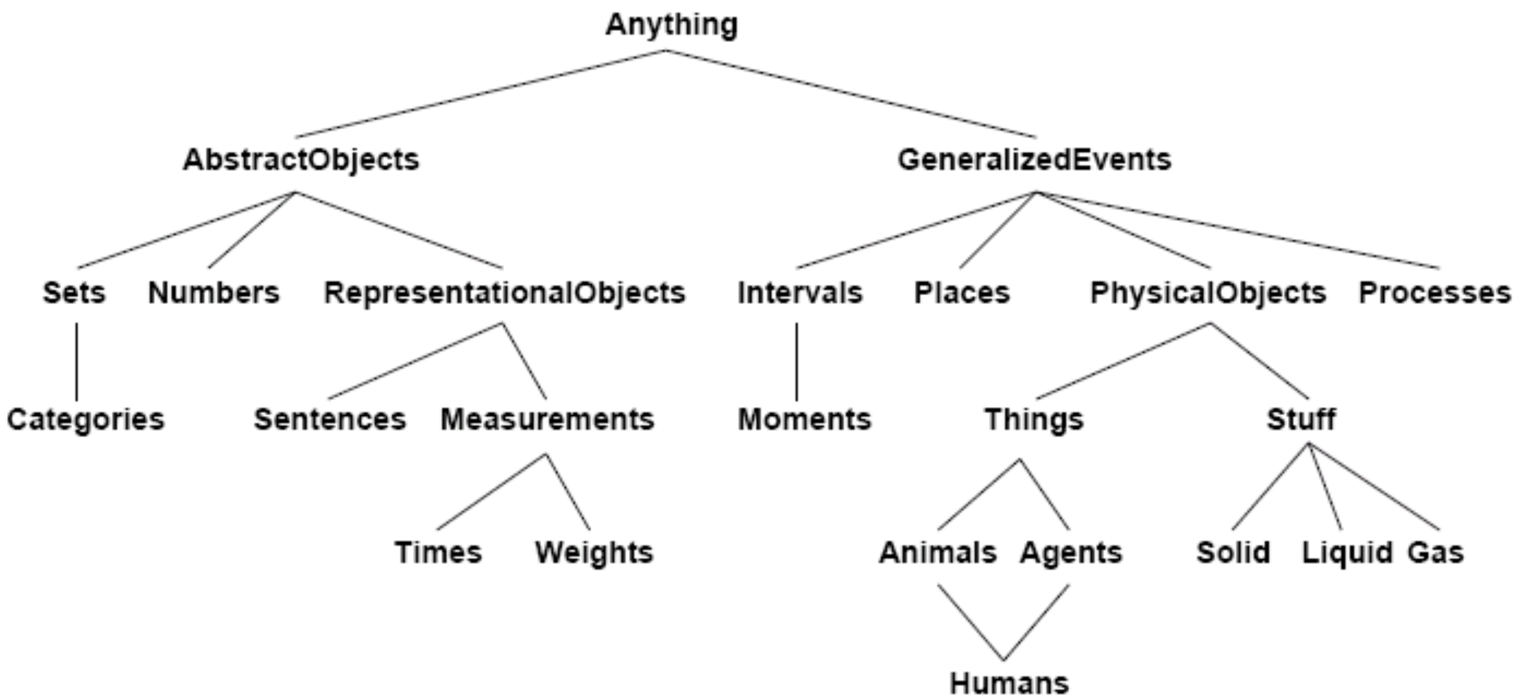
Define general framework of concepts

- Upper ontology

Limitations of logic representation

- Red, green and yellow tomatoes: exceptions and uncertainty

The Upper Ontology of the World



Difference with Special-Purpose Ontologies

A general-purpose ontology should be applicable in more or less any special-purpose domain.

- Add domain-specific axioms

In any sufficiently demanding domain different areas of knowledge need to be unified.

- Reasoning and problem solving could involve several areas simultaneously

What do we need to express?

- Categories, Measures, Composite objects, Time, Space, Change, Events, Processes, Physical Objects, Substances, Mental Objects, Beliefs

Categories and Objects

KR requires the organisation of objects into categories

- Interaction at the level of the object
- Reasoning at the level of categories

Categories play a role in predictions about objects

- Based on perceived properties

Categories can be represented in two ways by FOL

- Predicates: apple(x)
- *Reification* of categories into objects: apples

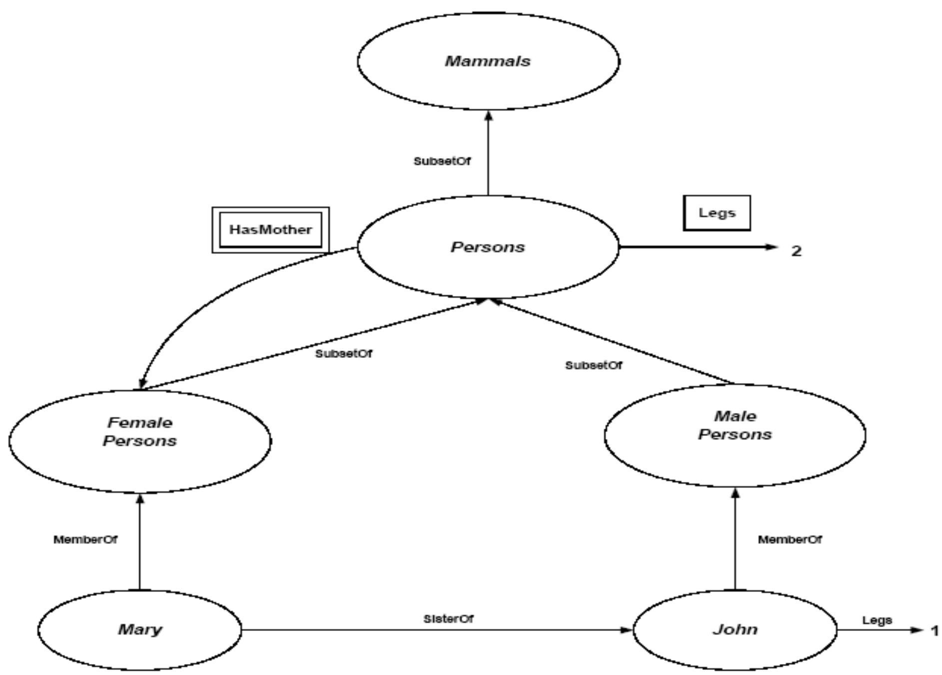
Category = set of its members

Category Organization

Relation = *inheritance*:

- All instance of food are edible, fruit is a subclass of food and apples is a subclass of fruit then an apple is edible.

Defines a taxonomy



FOL and Categories

An object is a member of a category
- MemberOf(BB_{12},Basketballs)

A category is a subclass of another category
- SubsetOf(Basketballs,Balls)

All members of a category have some properties
- $\forall$ x (MemberOf(x,Basketballs) $\Rightarrow$ Round(x))

All members of a category can be recognized by some properties
- $\forall$ x (Orange(x) $\wedge$ Round(x) $\wedge$ Diameter(x)=9.5in $\wedge$ MemberOf (x,Balls) $\Rightarrow$ MemberOf(x,BasketBalls))

A category as a whole has some properties
- MemberOf(Dogs,DomesticatedSpecies)

Relations between Categories

Two or more categories are *disjoint* if they have no members in common:

- Disjoint(s)$\Leftrightarrow(\forall\ c_1,c_2\ \ c_1 \in s \wedge c_2 \in s \wedge c_1 \neq c_2 \Rightarrow$ Intersection $(c_1,c_2) = \{\})$
- Example; Disjoint({animals, vegetables})

A set of categories *s* constitutes an *exhaustive decomposition* of a category *c* if all members of the set *c* are covered by categories in *s*:

- E.D.(s,c) $\Leftrightarrow (\forall\ i\ \ i \in c \Rightarrow \exists\ c_2\ \ c_2 \in s \wedge i \in c_2)$
- Example: ExhaustiveDecomposition({Americans, Canadian, Mexicans},NorthAmericans).

Relations between Categories

A ***partition*** is a disjoint exhaustive decomposition:

- Partition(s,c) $\Leftrightarrow$ Disjoint(s) $\wedge$ E.D.(s,c)
- Example: Partition({Males,Females},Persons)

Is ({Americans,Canadian, Mexicans},NorthAmericans) a partition?

Categories can be defined by providing necessary and sufficient conditions for membership

- $\forall$ x Bachelor(x) $\Leftrightarrow$ Male(x) $\wedge$ Adult(x) $\wedge$ Unmarried(x)

Natural Kinds

- Many categories have no clear-cut definitions (chair, bush, book).
- Tomatoes: sometimes green, red, yellow, black. Mostly round.
- One solution: category *Typical(Tomatoes).*
  - $\forall$ x, x $\in$ Typical(Tomatoes) $\Rightarrow$ Red(x) $\wedge$ Spherical(x).
  - We can write down useful facts about categories without providing exact definitions.
- What about "bachelor"? Quine challenged the utility of the notion of *strict definition*. We might question a statement such as "the Pope is a bachelor".

Physical Composition

- One object may be part of another:
  - PartOf(Bucharest,Romania)
  - PartOf(Romania,EasternEurope)
  - PartOf(EasternEurope,Europe)
- The PartOf predicate is transitive (and irreflexive), so we can infer that PartOf(Bucharest,Europe)
- More generally:
  - $\forall$ x PartOf(x,x)
  - $\forall$ x,y,z PartOf(x,y) $\wedge$ PartOf(y,z) $\Rightarrow$ PartOf(x,z)
- Often characterized by structural relations among parts.
  - E.g. Biped(a) $\Rightarrow$

$$(\exists l_1, l_2, b)(Leg(l_1) \wedge Leg(l_2) \wedge Body(b) \wedge$$

$$PartOf(l_1, a) \wedge PartOf(l_2, a) \wedge PartOf(b, a) \wedge$$

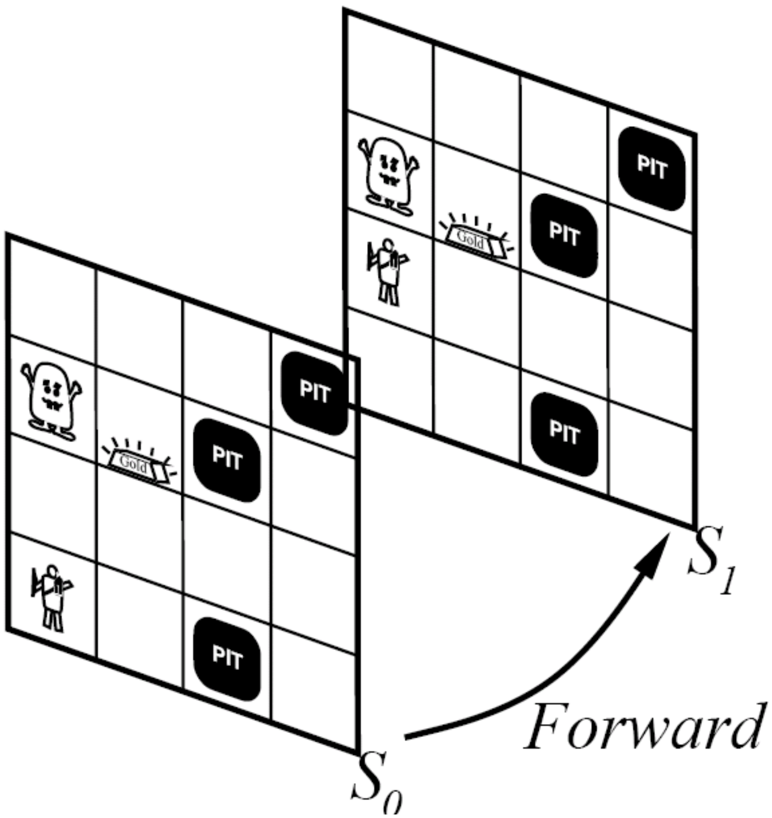
$$Attached(l_1, b) \wedge Attached(l_2, b) \wedge$$

$$l_1 \neq l_2 \wedge (\forall l_3)(Leg(l_3) \Rightarrow (l_3 = l_1 \vee l_3 = l_2)))$$

Measurements

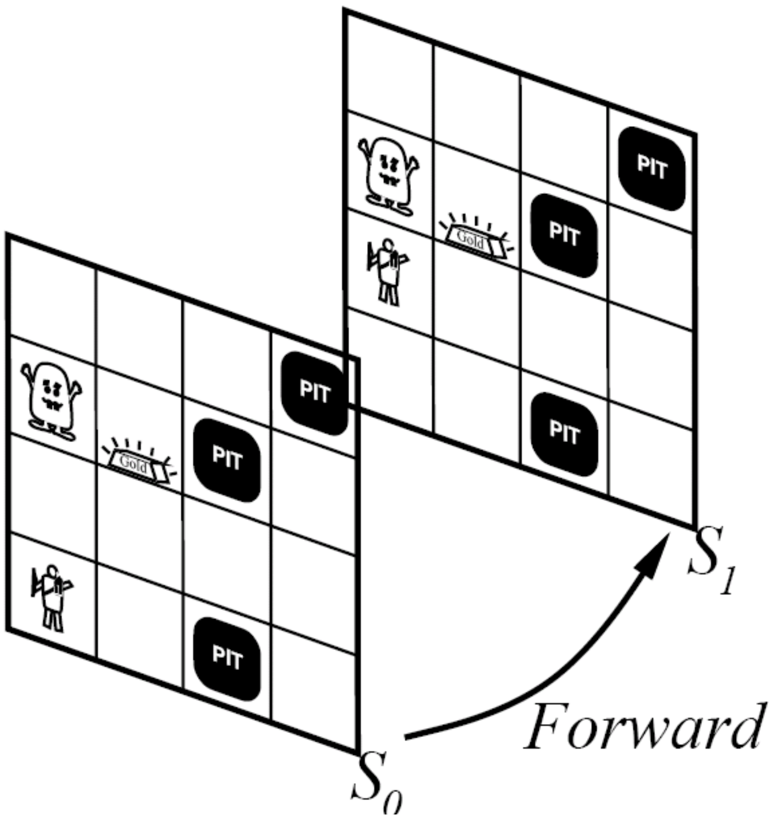
- Objects have height, mass, cost, ...
  Values that we assign to these are measures
- Combine Unit functions with a number: Length(L_1) = Inches(1.5) = Centimeters(3.81).
- Conversion between units:
  $\forall$ i Centimeters(2.54 x i)=Inches(i).
- Some measures have no scale: Beauty, Difficulty, etc.
  - Most important aspect of measures: is that they are orderable.
  - Don't care about the actual numbers. (An apple can have deliciousness .9 or .1.)

Actions, Events and Situations



- Reasoning about outcome of actions is central to KB-agent.
- How can we keep track of location in FOL?
  - Remember the multiple copies in PL.
- Representing time by situations (states resulting from the execution of actions).
  - Situation calculus

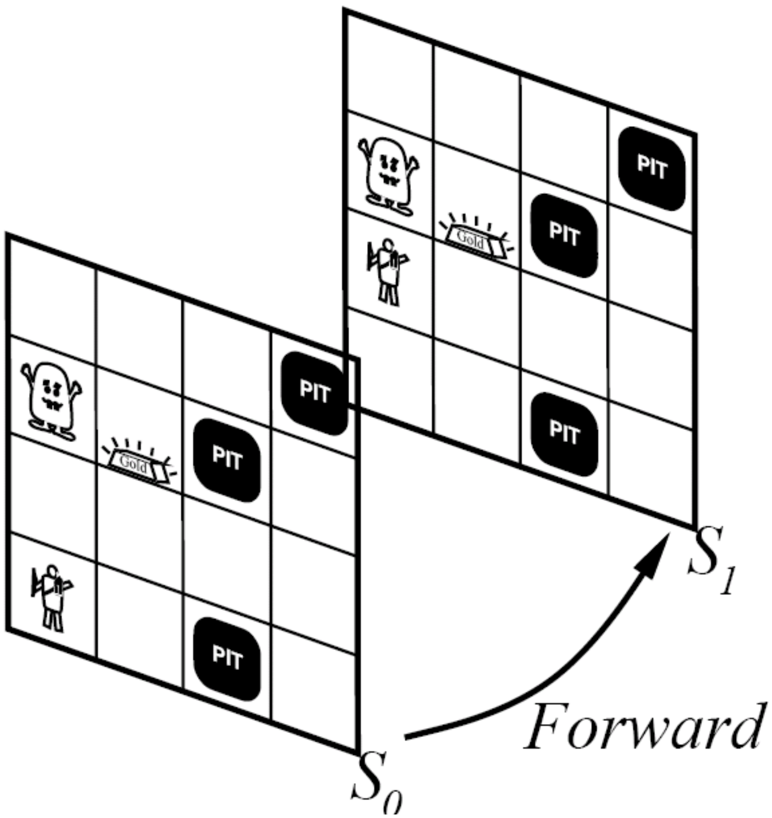
Actions, Events and Situations



Situation calculus:

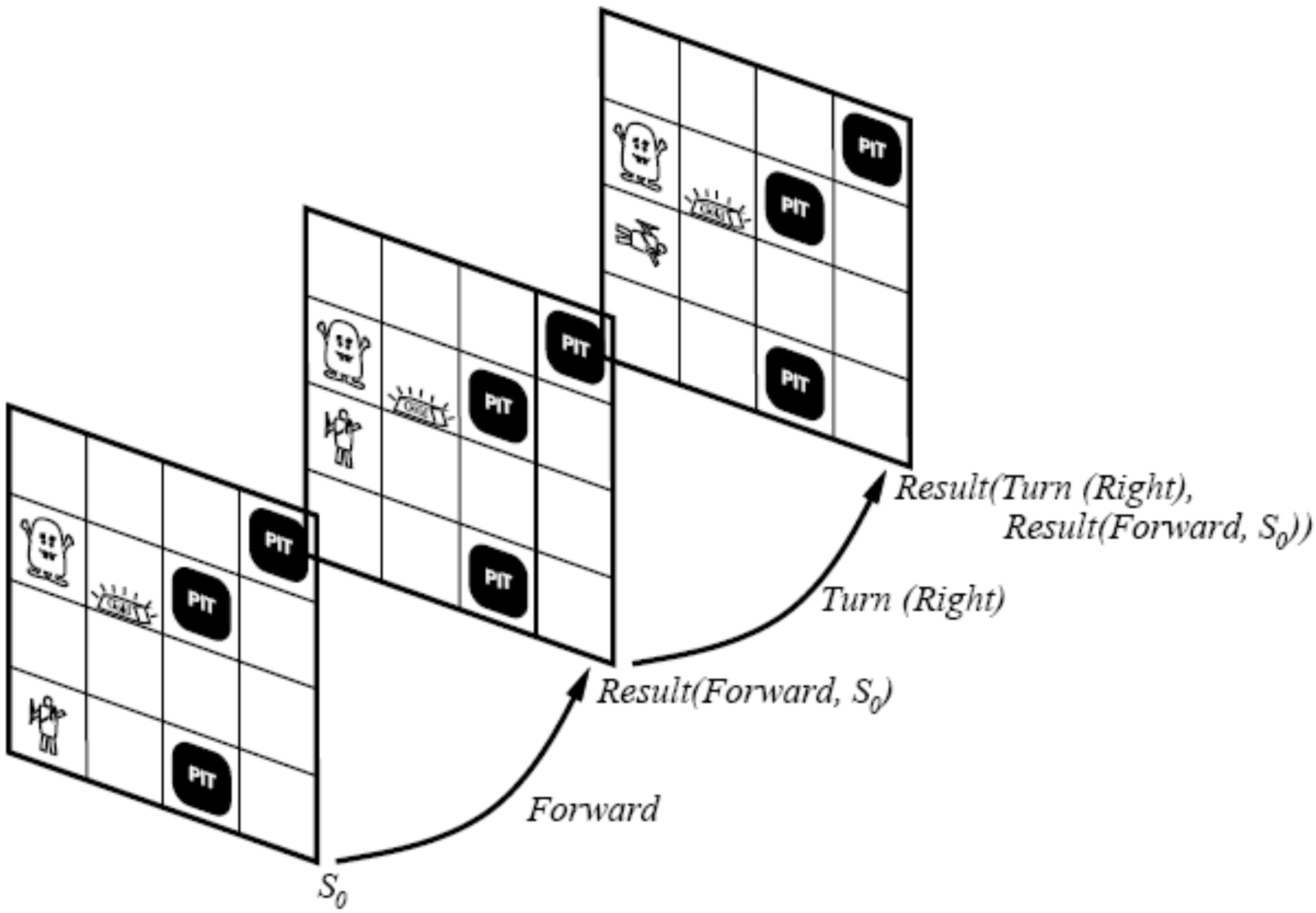
- Actions are logical terms
- Situations are logical terms consiting of
  - The initial situation I
  - All situations resulting from the action on I (=*Result(a,s)*)
- Fluent are functions and predicates that vary from one situation to the next.
  - E.g. $\neg Holding(G_1, S_0)$
- Eternal predicates are also allowed
  - E.g. $Gold(G_1)$

Actions, Events and Situations



- Results of action sequences are determined by the individual actions.
- *Projection task:* an SC agent should be able to deduce the outcome of a sequence of actions.
- *Planning task:* find a sequence that achieves a desirable effect

Actions, Events and Situations



Describing Change

- Simple Situation calculus requires two axioms to describe change:
  - Possibility axiom: when is it possible to do the action

    $At(Agent,x,s) \wedge Adjacent(x,y) \Rightarrow Poss(Go(x,y),s)$
  - Effect axiom: describe changes due to action

    $Poss(Go(x,y),s) \Rightarrow At(Agent,y,Result(Go(x,y),s))$
- What stays the same?
  - Frame problem: how to represent all things that stay the same?
  - Frame axiom: describe non-changes due to actions

    $At(o,x,s) \wedge (o \neq Agent) \wedge \neg Holding(o,s) \Rightarrow At(o,x,Result(Go(y,z),s))$

Representational Frame Problem

- If there are F fluents and A actions then we need AF frame axioms to describe other objects are stationary unless they are held.
  - We write down the effect of each actions
- Solution; describe how each fluent changes over time
  - Successor-state axiom:

    $$Pos(a,s) \Rightarrow (At(Agent,y,Result(a,s)) \Leftrightarrow (a = Go(x,y)) \vee (At(Agent,y,s) \wedge a \neq Go(y,z))$$

  - Note that next state is completely specified by current state.
  - Each action effect is mentioned only once.

Other Problems

- How to deal with secondary (implicit) effects?
  - If the agent is carrying the gold and the agent moves then the gold moves too.
  - Ramification problem
- How to decide EFFICIENTLY whether fluents hold in the future?
  - Inferential frame problem.
- Extensions:
  - Event calculus (when actions have a duration)
  - Process categories

Mental Events and Objects

- So far, KB agents can have beliefs and deduce new beliefs
- What about knowledge about beliefs? What about knowledge about the inference process?
  - Requires a model of the mental objects in someone's head and the processes that manipulate these objects.
- Relationships between agents and mental objects: believes, knows, wants, …
  - Believes(Lois,Flies(Superman)) with Flies(Superman) being a function … a candidate for a mental object (reification).
  - Agent can now reason about the beliefs of agents.

The Internet Shopping World

- A Knowledge Engineering example
- An agent that helps a buyer to find product offers on the internet.
  - IN = product description (precise or ¬precise)
  - OUT = list of webpages that offer the product for sale.
- Environment = WWW
- Percepts = web pages (character strings)
  - Extracting useful information required.

The Internet Shopping World

- Find relevant product offers

  RelevantOffer(page,url,query) ⇔ *Relevant(page, url, query)* ∧ *Offer(page)*

  – Write axioms to define Offer(x)
  – Find relevant pages: Relevant(x,y,z) ?
    - Start from an initial set of stores.
    - What is a relevant category?
    - What are relevant connected pages?
  – Require rich category vocabulary.
    - Synonymy and ambiguity
  – How to retrieve pages: *GetPage(url)*?
    - Procedural attachment
- Compare offers (information extraction).

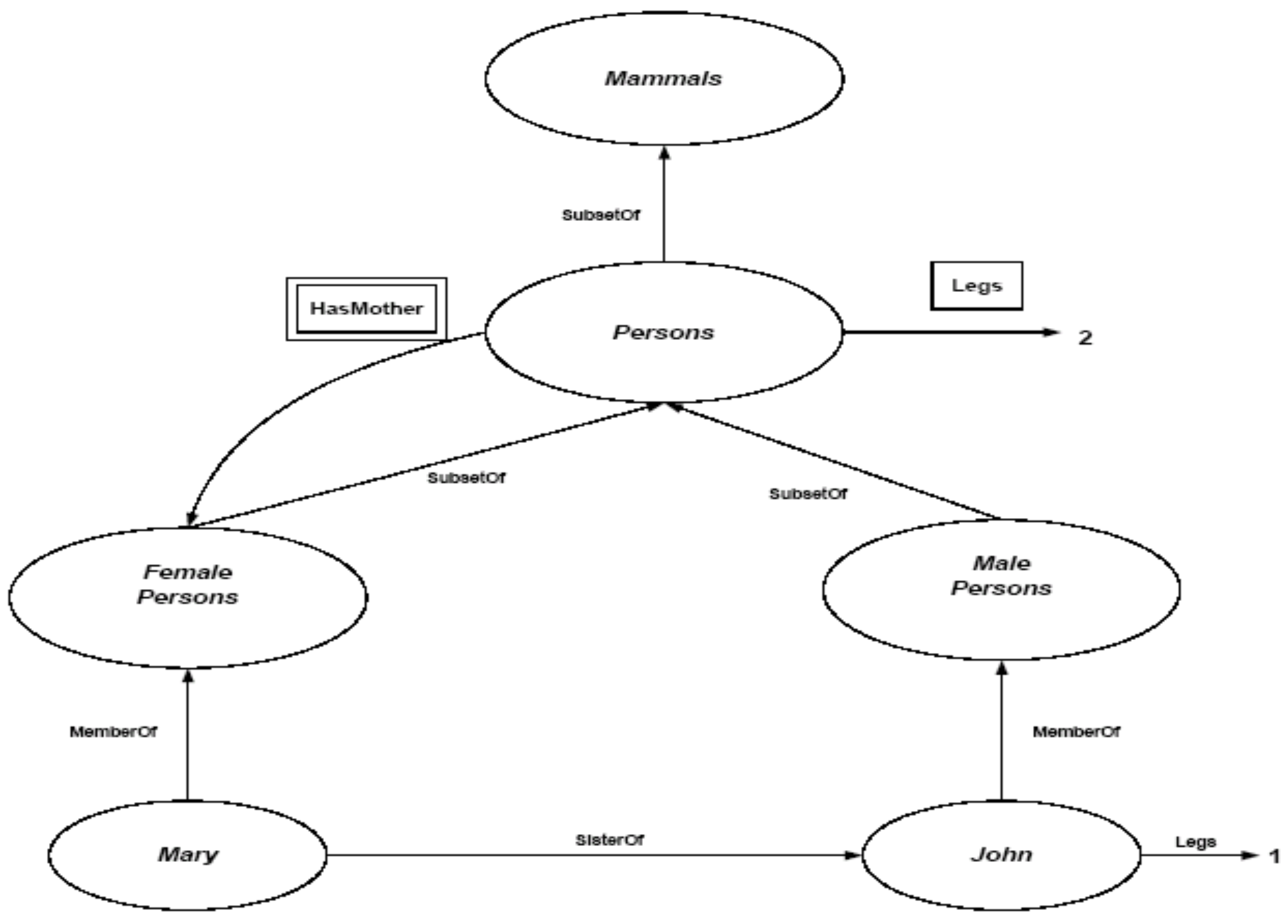
Reasoning Systems for Categories

- How to organise and reason with categories?
  - Semantic networks
    - Visualize knowledge-base
    - Efficient algorithms for category membership inference
  - Description logics
    - Formal language for constructing and combining category definitions
    - Efficient algorithms to decide subset and superset relationships between categories.

Semantic Networks

- Logic vs. semantic networks
- Many variations
  - All represent individual objects, categories of objects and relationships among objects.
- Allows for inheritance reasoning
  - Female persons inherit all properties from person.
  - Cfr. OO programming.
- Inference of inverse links
  - SisterOf vs. HasSister

Semantic Network Example



Semantic Networks

- Drawbacks
  - Links can only assert binary relations
  - Can be resolved by reification of the proposition as an event
- Representation of default values
  - Enforced by the inheritance mechanism.

Description Logics

- Are designed to describe defintions and properties about categories
  - A formalization of semantic networks
- Principal inference task is
  - *Subsumption*: checking if one category is the subset of another by comparing their definitions
  - *Classification*: checking whether an object belongs to a category.
  - Consistency: whether the category membership criteria are logically satisfiable.

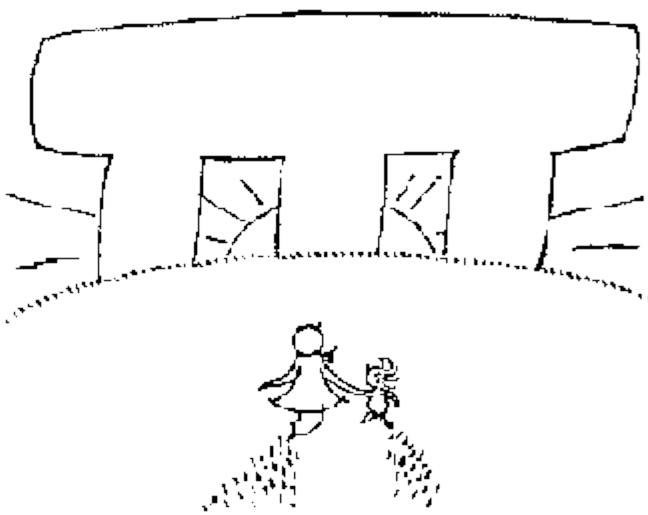
Reasoning with Default Information

- "The following courses are offered: CS101, CS102, CS106, EE101"
  - Four (db)
    - – Assume that this information is complete (not asserted ground atomic sentences are false)
    - = CLOSED WORLD ASSUMPTION
    - – Assume that distinct names refer to distinct objects
    - = UNIQUE NAMES ASSUMPTION
  - Between one and infinity (logic)
    - – Does not make these assumptions
    - – Requires completion.

Truth Maintenance Systems

- Many of the inferences have default status rather than being absolutely certain
  - Inferred facts can be wrong and need to be retracted = BELIEF REVISION.
  - Assume KB contains sentence P and we want to execute TELL (KB, ¬P)
    - To avoid contradiction: RETRACT(KB,P)
    - But what about sentences inferred from P?
- Truth maintenance systems are designed to handle these complications.

Concluding Remarks



T. T. T.

Put up in a place
where it's easy to see
the cryptic admonishment
T. T. T.

When you feel how depressingly
slowly you climb,
it's well to remember that
Things Take Time.