FOPC Knowledge Representation

now have the approaches to reasoning

how do we represent knowledge in a domain

Domain-specific Ontologies

\[ D_i \text{ object domains (sets of constants)} \]

\[ \text{e.g., numbers, persons, products, stores} \]

\[ P_i \text{ n-ary predicates} \]

\[ D_1 \times D_2 \times \ldots \times D_n \rightarrow \{\text{true, false}\} \]

\[ f_i \text{ n-ary functions} \]

\[ D_1 \times D_2 \times \ldots \times D_n \rightarrow D_r \]

\[ A_i \text{ domain axioms} \]

basic inferences for the domain
Ontologies

domain relations

people, family relations

object domains

- person
- integer
- gender
- date

predicates

- parent(< person> < person>)
- gender(< person> < gender>)
- father(< person> < person>)
- ...
- age(< person> < integer>)
- older(< person> < person>)
- birthday(< person> < date>)

functions

- age-of(< person>) -> < integer>

axioms

\[ A(x,y)[((\text{parent}(x \ y) \text{ and} \text{gender}(x \text{ male})) \text{ implies} \text{father}(x \ y))] \]

\[ A(x, y)[\text{parent}(x, y) \text{ implies} \text{older}(x, y)] \]
Knowledge Engineering

defining an adequate ontology
for a particular domain

adequacy defined with respect to
questions one wants answered

General Ontologies

measures
weight, volume, conversions

time
points, intervals

space
points, lines, planes, volumes, areas

actions/events/processes
situation calculus

things
classes, subclasses, inheritance

mental objects/processes
ideas, memories, dreams, forgetting
Time

When was Bill Clinton impeached?

When did George W. Bush declare Mission Accomplished?

When did Al Gore win the Nobel Peace Prize?

Marie couldn’t come to Bob’s party because she was studying for the LSAT exam she had last Saturday. Was Bob’s party last Sunday?

In trying to answer these questions, we can gain some insight into our temporal ontology.
Time

moments
  zero duration

intervals
  positive duration
  given an I, Start(I) and End(I) moments

time scale
  range and precision
    a hierarchy of time intervals
    e.g., day in minutes, minute in seconds
  moments related by <, ≤, =, ≥, >
    at (labeled) time points
Time

predicate, relations between time intervals

____A______  _____B______

Before(A, B), After(B, A)

__________________________

Meets(A, B)

_______A__________

_______B_____

During(B, A)  \{StartsWith, EndsWith, Same\}

________A__________

_________B______

Overlap(A, B), Overlap(B, A)
Ontology

**space**

Where is my watch?

It’s in the kitchen, near the sink on the ledge next to the vase.

Where does Harry live?

He lives in Denver, near Mile-High Stadium, on South Street next to the pharmacy.

Where’s Autzen Stadium?

It is north of the river, east of Coburg road.

similar to space, more dimensions, east-west
Ontology

Actions

situation calculus

Holds(wff, situation)

represent actions as functions on situations

Result(action, situation)  => situation
situation that results from
performing action a in situation s

General form for operator/action representation:

A(vars)[(Holds(wff, s) and .... ) {preconditions} => (Holds(wff, Result(a, s)) and ...)] {effects}
where s is a situation and a is an action

Example

A(x,y,s)[ Holds((clear(x) and clear(y)),s))
  ===> Holds((on(x,y) and clear(x) and ~clear(y)), 
              Result(put-on(x,y), s))]
Ontologies

Actions

frame problem

Inferring what has not changed when an action is performed.

Tom picked up the red block and then placed it on top of the green block.
Is the blue block still clear?

qualification problem

Inferring what has changed when an action is performed.

Harry and Mike set a bucket of water on the top of the door. A little bit later, Mary pushed open the door.
Objects and Categories

Structured Representations

Semantic Networks
Frames

general slot-filler structures
(no implied ontology)

Motivations

Computational

graph search
compiled inference

Psychological

associations
prototypicality
Semantic Networks

representation of
  human associative memory
  human taxonomic knowledge

structured logic representation

binary relations
  objects/concepts as nodes
  relations label arcs

(on a b)
  on
  a -------> b

(red barn) ==> (has-color barn red)

  has-color
  barn --------> red
Semantic Networks

to represent more complex
n-ary relations (n>2)

create a relation token node
and name each argument of
relation with its case name

Example

(buy-from tom mary clock 10)

buy-from

is-a price

bf1 10

buyer seller item

tom mary clock
Semantic Networks

used to represent

conceptual hierarchies
property inheritance

Conceptual Hierarchy

is-a

element-of

subset-of ;; confusions
token-of

Property Inheritance

has-part
has-feature
Semantic Network

Example

Living-Thing

is-a

Animal

is-a

Plant

is-a

has-part

Grass

Bush

Tree

Leaf

is-a

has-part

Oak-tree

is-a

Vein

has-part

Oak-leaf

has-shape

serrated

hierarchical (tree) search and inheritance

spreading activation
Frames

extension of semantic networks

representation of common situations

situations / object structures
scripts / event sequences

features

slots

each frame is a set of slots
each representing a binary relation

each slot has set of facets
representing value or
modifiers of relation
Frames

features

procedural values

specialized inference procedures for determining the value of particular slots

procedural attachment (demons)

if-altered, if-added demons to-establish procedures

default slot values
Frames

Example

(def-frame rectilinear-object
  (is-a (value (planar-object)))
  (height (default 100)
    (trigger
      (when-set
        (if height == width
            then (set-slot type square)
            else (set-slot type rect))))
  )
  (width (default 100)
    (trigger
      (when-set
        (if height == width
            then (set-slot type square)
            else (set-slot type rect))))
  )
  (type (default square))
  (area (value (! (* height width))))
Frames

scripts --- common event scenarios

(def-frame restaurant-script
  (is-a (value (event-script)))
  (sequence
    (default
      (entering
        seating
        ordering
        eating
        paying
        leaving))))

(def-frame entering
  (is-a (value (event)))
  (agent (default person))
  (time)
  (from-loc)
  (to-loc))
Reasoning

Semantic Nets

generalization/specialization
  hierarchy traversal

analogy
  associative distance
  and intersection

logical inference
  partitioned networks

Frames

inheritance
  hierarchy traversal

situational matching
  completion by defaults

script matching
  exception notification