Review, Fast KR&R, Classical Planning

AI Class 21 (Ch. 10.1-10.2, 10.4.2-10.4.4)

Material from Dr. Marie desJardin, Some material adopted from notes by Andreas Geyer-Schulz and Chuck Dyer

Bookkeeping

- Bookkeeping
  - HW5 due 11/21 @ 11:59pm
  - Project phase 1 code due 11/28 @ 11:59pm
  - Designs today

Today

- Quick review
  - Logical agents
  - Situation calculus
  - Forward and backward chaining
- World's fastest KR&R
- Planning
  - What is planning?
  - Approaches to planning
    - GPS / STRIPS
    - Situation calculus formalism [revisited]
    - Partial-order planning

Last Time: Agents

Wumpus percepts:
[Stench, Breeze, Glitter, Bump, Scream]

- Logical agents
  - Reflex: rules map directly from percepts → beliefs or percepts → actions

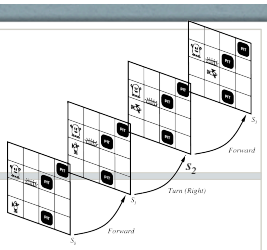
    ∀b,g,u,c,t Percept([Stench, b, g, u, c], t) → Stench(t)

    ∀t AtGold(t) → Action(Grab, t)
  - Model-based: construct a *model* (set of t/f beliefs about sentences) as they learn; map from models → actions

    Action(Grab, t) → HaveGold(t)

    HaveGold(t) → Action(RetraceSteps, t)
  - Goal-based: form goals, then try to accomplish them

Last Time: Situations



- Representing a dynamic world
  - Situations ($s_0 \ldots s_n$): the world in situation 0-n

    Teaching(DrM,s_0) — today,10:10,whenNotSick, ...
  - Add 'situation' argument to statements

    AtGold(t,s_0)
  - Or, add a 'holds' predicate that says 'sentence is true in this situation'

    holds(At[2,1], s_1)
  - Or, add a result(action, situation) function that takes an action and situation, and returns a new situation

    results(Action(goNorth), s_0) → s_1

Last Time: Goal-Based Agents

- Once the gold is found, need new goals!
  - So, need a new set of actions.
- Encoded as a rule:

  (∀s) Holding(Gold,s) → GoalLocation([1,1],s)
- How does the agent find a sequence of actions for goal?
- Three possible approaches are:
  - **Inference**: good versus wasteful solutions
  - **Search**: make a problem with operators and set of states
  - **Planning**: coming soon!

Last Time: Inference

Knowledge Base
1. Allergies lead to sneezing.
   allergies(X) → sneeze(X)
2. Cats cause allergies if allergic to cats.
   cat(Y) ∧ allergic-cats(X) → allergies(X)
3. Felix is a cat.
   cat(Felix)
4. Lise is allergic to cats.
   allergic-cats(Lise)

sneeze(Lise) ← infer truth of (query)

- Forward Chaining: apply rules

variable binding

cat(Y) ∧ allergic-cats(X) → allergies(X) ∧ cat(Felix)

→

cat(Felix) ∧ allergic-cats(X) → allergies(X) ∧ allergic-cats(Lise)

add new sentence to KB

→

allergies(Lise) ∧ allergies(X) → sneeze(X)

→

sneeze(Lise) ✓

Last Time: Inference

Knowledge Base
1. Allergies lead to sneezing.
   allergies(X) → sneeze(X)
2. Cats cause allergies if allergic to cats.
   cat(Y) ∧ allergic-cats(X) → allergies(X)
3. Felix is a cat.
   cat(Felix)
4. Lise is allergic to cats.
   allergic-cats(Lise)

sneeze(Lise) ← query

- Backward Chaining: apply rules that end with the goal

variable binding

allergies(X) → sneeze(X) + sneeze(Lise)
  new query: allergies(Lise)?

cat(Y) ∧ allergic-cats(X) → allergies(X) + allergies(Lise)
  new query: cat(Y) ∧ allergic-cats(Lise)?

cat(Felix) + cat(Y) ∧ allergic-cats(Lise)
  new sentence: cat(Felix) ∧ allergic-cats(Lise) ✓

Knowledge Representation and Reasoning (KR&R)

Chapters 12.1-12.2, 12.5-12.6

Introduction

- Real knowledge representation and reasoning systems: several varieties
- These differ in their intended use, expressivity, features,…
- Some major families are
  - Logic programming languages
  - Theorem provers
  - Rule-based or production systems
  - Semantic networks
  - Frame-based representation languages
  - Databases (deductive, relational, object-oriented, etc.)
  - Constraint reasoning systems
  - Description logics
  - Bayesian networks
  - Evidential reasoning

Ontologies

- Representations of general concepts
- Usually represented as a type hierarchy
  - Sort of a special case of a semantic network (wait for it...)
- "Ontological engineering" is hard!
  - How do you create an ontology for a particular application?
  - How do you maintain an ontology for changing needs?
  - How do you merge ontologies from different fields?
  - How do you map across ontologies from different fields?

Upper Ontologies

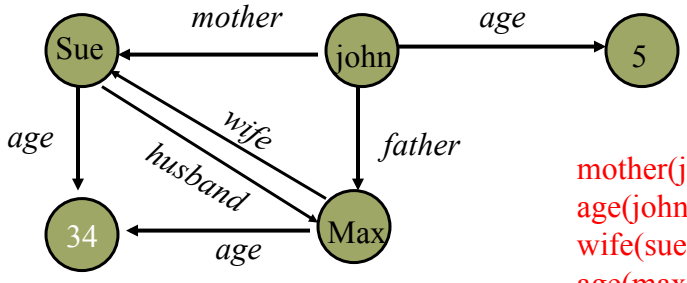
- Highest-level categories: typically these might include:
  - Measurements
  - Objects and their properties (including fluent, or changing, properties)
  - Events and temporal relationships
  - Continuous processes
  - Mental events, processes; "beliefs, desires, and intentions"
- Also useful:
  - Subtype relationships
  - PartOf relationships
  - Composite objects

Semantic Networks

- A *semantic network* is a representation scheme that uses a graph of **labeled nodes** and **labeled, directed arcs** to encode knowledge.
  - Usually used to represent static, taxonomic, concept dictionaries
- Typically used with a special set of procedures to perform reasoning
  - e.g., inheritance of values and relationships
- Semantic networks were very popular in the ‘60s and ‘70s but are less frequently used today.
  - Often much less expressive than other KR formalisms
- The **graphical depiction** associated with a semantic network is a significant reason for their popularity.

Nodes and Arcs

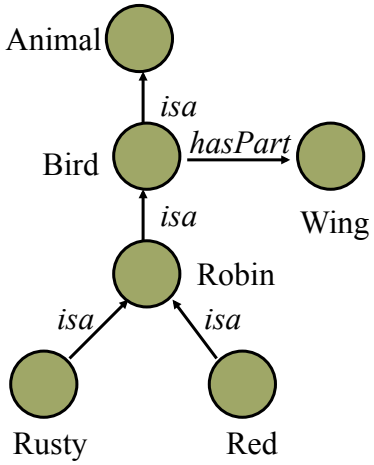
- Arcs define binary relationships that hold between objects denoted by the nodes.



mother(john,sue)
age(john,5)
wife(sue,max)
age(max,34)
...

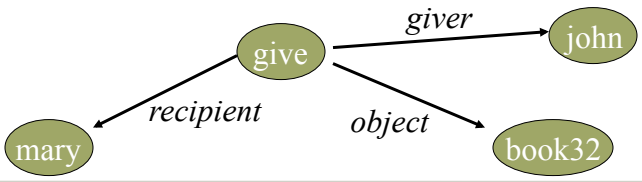
Semantic Networks

- The ISA (is-a) or AKO (a-kind-of) relation is often used to link instances to classes, classes to superclasses
- Some links (e.g. hasPart) are inherited along ISA paths.
- The semantics of a semantic net can be informal or very formal
  - often defined at the implementation level



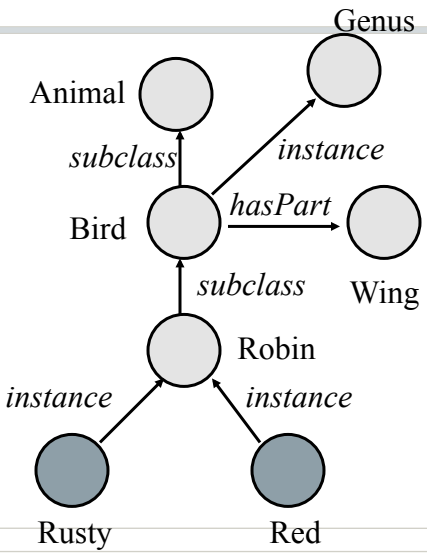
Reification

- Non-binary relationships can be represented by "turning the relationship into an object"
- This is an example of what logicians call "reification"
- We might want to represent the generic **give** event as a relation involving three things: a giver, a recipient and an object, give(john,mary,book32)



Individuals and Classes

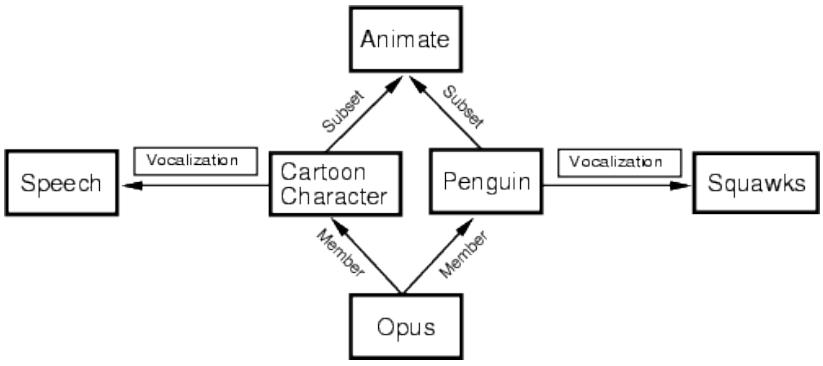
- Many semantic networks distinguish
  - Nodes representing individuals and those representing classes
  - The "subclass" relation from the "instance-of" relation



Inference by Inheritance

- One of the main kinds of reasoning done in a semantic net is the inheritance of values along the subclass and instance links.
- Semantic networks differ in how they handle the case of inheriting multiple different values.
  - All possible values are inherited, ***or***
  - Only the "lowest" value or values are inherited

Conflicting Inherited Values

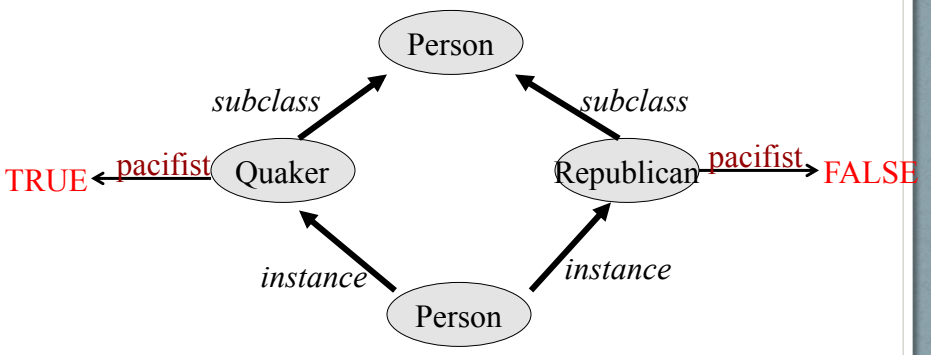


Multiple Inheritance

- A node can have any number of superclasses that contain it, enabling a node to inherit properties from multiple "parent" nodes and their ancestors in the network.
- These rules are often used to determine inheritance in such "tangled" networks where multiple inheritance is allowed:
  - If X<A<B and both A and B have property P, then X inherits A's property.
  - If X<A and X<B but neither A<B nor B<Z, and A and B have property P with different and inconsistent values, then X does not inherit property P at all.

Nixon Diamond

- This was the classic example circa 1980.



From Semantic Nets to Frames

- Semantic networks morphed into Frame Representation Languages in the ‘70s and ‘80s.
- A frame is a lot like the notion of an object in OOP, but has more meta-data.
- A **frame** has a set of **slots**.
- A **slot** represents a relation to another frame (or value).
- A slot has one or more **facets.**
- A **facet** represents some aspect of the relation.

Planning

Chapter 10.1-10.2, 10.4.2-10.4.4

Planning Problem

- Find a **sequence of actions** that achieves a given **goal** when executed from a given **initial world state**.
- That is, given
  - A set of operator descriptions (possible primitive actions by the agent)
  - An initial state description
  - A goal state (description or predicate)
- Compute a **plan**, which is
  - A sequence of operator instances,
  - Executing them in initial state → state satisfying description of goal-state
- Goals are usually a *conjunction of things to be achieved*

Planning vs. Problem Solving

- Planning and problem solving methods can often solve the same sorts of problems
- Planning is more powerful
  - Because of the representations and methods used
- States, goals, actions decomposed into sets of sentences
  - Usually in FOL
- Search proceeds through ***plan space*** rather than ***state space***
  - Usually – state space planners exist
- Subgoals can be planned independently, reducing the complexity of the planning problem.

Typical Assumptions

- **Atomic time**: Each action is indivisible
- **No concurrent actions** allowed
  - But, actions do not need to be in order in the plan
- **Deterministic actions**
  - The result of actions are completely known
  - No uncertainty in results
- Agent is the **sole cause of change** in the world

Typical Assumptions

- Agent is **omniscient**
  - Has complete knowledge of the state of the world
  - AKA…
- **Closed world assumption**:
  - Everything known to be true about the world is in the *state description*
  - Anything not in the state description is false

Blocks World

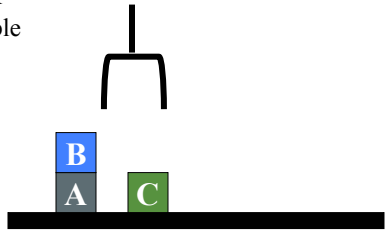
The **blocks world** is a micro-world that consists of a table, a set of blocks and a robot hand.

Some domain constraints:

- Only one block can be on another block
- Any number of blocks can be on the table
- The hand can only hold one block

Typical representation:

ontable(a)
ontable(c)
on(b,a)
handempty
clear(b)
clear(c)



Major Approaches

- GPS / STRIPS
- **Situation calculus**
- **Partial order planning**
- Hierarchical decomposition (HTN planning)
- Planning with constraints (SATplan, Graphplan)
- ***Reactive planning***

General Problem Solver

- The **General Problem Solver (GPS)** system
  - An early planner (Newell, Shaw, and Simon)
- GPS generates actions that *reduce the difference* between some state and a goal state
- GPS uses *Means-Ends Analysis*
  - Compare what is given or known with what is desired
  - Select a reasonable thing to do next
  - Use a table of differences to identify procedures to reduce differences
- GPS is a state space planner: operates on state space problems specified by an initial state, some goal states, and a set of operations