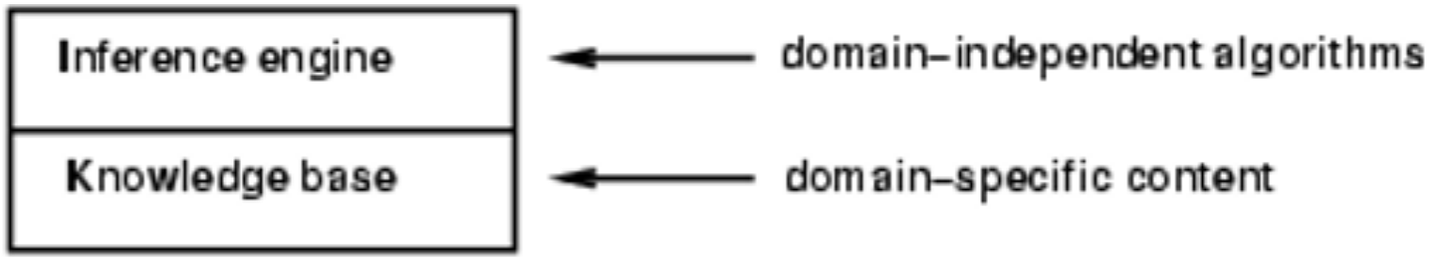
Artificial Intelligence

Logic Agent

Outline

- Knowledge-based agents
- Logic in general
  - models
  - entailment
  - Inference

Knowledge Bases



- Knowledge base = set of sentences in a formal language
- Declarative approach to building an agent (or other system):
  - Tell it what it needs to know
  - Then it can Ask itself what to do — answers should follow from the KB
- Agents can be viewed
  - at the knowledge level
    - i.e., what they know, regardless of how implemented
  - Or at the implementation level
    - i.e., data structures in KB and algorithms that manipulate them

A simple knowledge-based agent

```
function KB-AGENT(percept) returns an action
    static: KB, a knowledge base
            t, a counter, initially 0, indicating time

    TELL(KB, MAKE-PERCEPT-SENTENCE(percept, t))
    action ← ASK(KB, MAKE-ACTION-QUERY(t))
    TELL(KB, MAKE-ACTION-SENTENCE(action, t))
    t ← t + 1
    return action
```

- The agent must be able to:
  - Represent states, actions, etc.
  - Incorporate new percepts
  - Update internal representations of the world
  - Deduce hidden properties of the world
  - Deduce appropriate actions

Logic in general

- Logics are formal languages for representing information such that conclusions can be drawn
- Syntax defines the sentences in the language
- Semantics define the "meaning" of sentences;
    - i.e., define truth of a sentence in a world
- For example, the language of arithmetic
    - syntax: $x+2 \geq y$ is a sentence; $x2+y > \{\}$ is not a sentence
    - Semantics: $x+2 \geq y$ is true iff the number $x+2$ is no less than the number y
    - $x+2 \geq y$ is true in a world where $x = 7, y = 1$
    - $x+2 \geq y$ is false in a world where $x = 0, y = 6$

Entailment

- Entailment means that one thing follows from another:
  KB ⊨ α

- Knowledge base KB entails sentence α if and only if α is true in all worlds where KB is true

- Examples:

  - the KB containing “All roses are red” and “the Damask is a type of rose” entails “the Damask is red”

  - the KB containing “Some roses are red” and “the Damask is a type of rose” does NOT entail “the Damask is red”

  - x+y = 4 entails 4 = x+y

- Entailment is a relationship between sentences (i.e., syntax) that is based on semantics

Models

- Logicians typically think in terms of models, which are formally structured worlds with respect to which truth can be evaluated

- We say m is a model of a sentence α if α is true in m

- M(α) is the set of all models of α

- Then KB ⊨ α iff M(KB) ⊆ M(α)

  - E.g. KB = “Some roses are red and the Damask is red”, while α = “the Damask is red”

Inference

- KB ⊢ $_i$ α means “sentence α can be derived from KB by procedure i”
- Soundness: i is sound if whenever KB ⊢ $_i$ α, it is also true that KB ⊨ α
- Completeness: i is complete if whenever KB ⊨ α, it is also true that KB ⊢ $_i$ α
- Preview: we will define two logic languages (propositional logic and first-order logic) which are expressive enough to say a lot of things of interest, and for either there exists a sound and complete inference procedure.
- That is, the procedure will answer any question whose answer follows from what is known by the KB.