Knowledge Representation: Logic

Manuela Veloso

CMU 15-381, Fall 2001

- The need for "knowledge" representation
- Symbolic knowledge
- Propositional logic and inference
- Predicate logic
- The resolution inference procedure

Acting in the World

State and Actions

- Complete intelligent agent
  - ▷ Perception - at which *state* am I?
  - ▷ Cognition - which *action* should I take?
  - ▷ Action - how do I *execute* the action?
- State recognition implies state *representation*
- Many examples
- Symbolic knowledge about the world

Knowledge Representation

- One of the goals ("the" goal?) of AI: build intelligent agents
- Need "knowledge" – meaning of facts
- Philosophy
  - ▷ Theory of *meaning* – Natural language to meaning
  - ▷ "I think therefore I am" – logical clarification of thought
- Knowledge base in AI – a set of representations of facts about the world
  - ▷ *What* to represent?
  - ▷ Which level of *detail*? – "frame problem"

Knowledge Representation

  - ▷ Many examples – any task is an example
- Knowledge level – epistemological level: what the agent *knows*
- Implementation level – how knowledge is *represented*
- The representation of knowledge affects dramatically the problem solving capability of an agent
  - ▷ Hard to realize the effects of representation choices
  - ▷ What is a *good* representation?
  - ▷ Example: mutilated checkerboard
- Many possible representations.

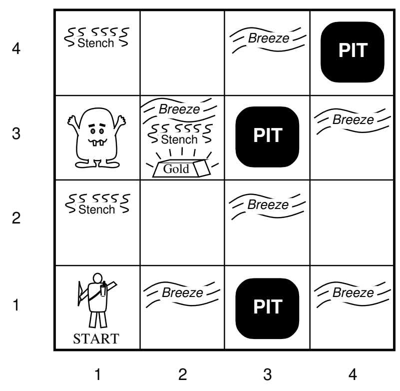
Knowledge Representation

- ▷ Logic
- ▷ Semantic networks
- ▷ Frames
- ▷ Default logics
- ▷ Probabilistic reasoning
- ▷ Graphical representations

Summary

- The wumpus world - Chapter 6, page 154
- Representing the world
- Sentences
- Propositional logic
- Syntax
- Semantics
- Proving the truth of a sentence
- Logical inference
- Discussion

The Wumpus World



Reasoning

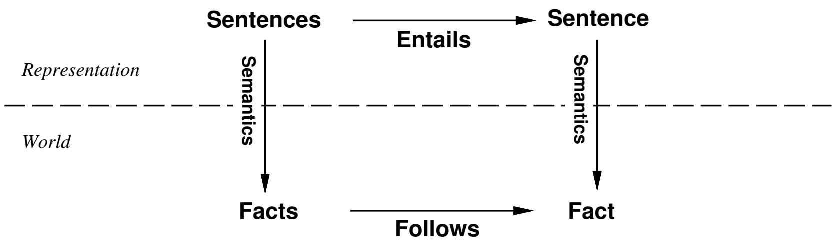
- Perceptions: stentch, breeze, glitter, bump (into wall), scream (wumpus killed)
- Actions: turn left, turn right, go forward, grab, shoot (only once), climb (at start)
- Goal: get the gold back to the start and climb out of the cave

Rules specify the actions to take at a particular state.

Need to perceive and represent the world.

Representation

- Sentences - logic
- Syntax and semantics



Sentences

- stench(2,1)
- "It's raining."
- $a \wedge \neg b$
- "Lisboa é a capital de Portugal."

Syntax

- The grammar: the rules of *legal* sentences.
- Propositional logic

Sentence ::= TerminalSentence | Non-TerminalSentence

TerminalSentence ::= **True** | **False** | *Symbol*

Non-TerminalSentence ::= Sentence Connective Sentence | $\neg$ Sentence

Connective ::= $\wedge \mid \vee \mid \Rightarrow$

Facts into logic - simple and hard

1. Marcus was a man.
2. All Pompeians were Romans.
3. Caesar was a ruler.
4. All Romans were either loyal to Caesar or hated him.
5. Everyone is loyal to someone.

Facts into logic - simple and hard

6. People only try to assassinate rulers they are not loyal to.

7. Marcus tried to assassinate Caesar.

8. All Romans who know Marcus either hate Caesar or think that anyone who hates anyone is crazy.

9. Every country has a city that has been visited by every person in the country.

Facts into logic - simple and hard

10. For every set, there is always another set with a greater cardinality.

11. All blocks on top of blocks that have been moved or that are attached to blocks that have been moved have also been moved.

Semantics

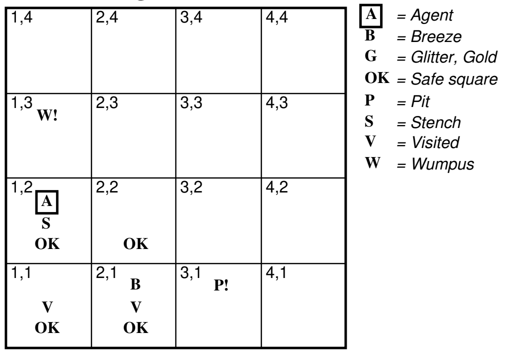
- The complete set of possible truth assignments to the symbols in the sentence: all the possible *worlds*: all **interpretations**.
- Example: $a \vee b$; (true, true), (true, false), (false, true), (true, true)
- A sentence with n propositional symbols has 2^n interpretations.
- A sentence evaluates to True or False - subsets of all interpretations.
- The truth of a sentence depends both on the interpretation and on the state of the world. Example: stench-1-2

Computing the Meaning of a Sentence

- Brute force: A truth table!
- **Valid** sentence: includes all interpretations. Examples: True, other examples?
- **Satisfiable** sentence: A sentence has at least one interpretation. Examples: ?
- **Unsatisfiable** sentence: No interpretations. Examples: False, other examples?
- If valid then satisfiable. If satisfiable, either valid or not valid.
- Either satisfiable or unsatisfiable, not both.

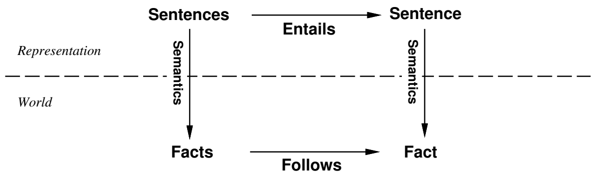
Knowledge Base

A collection of many sentences representing the complete knowledge about the world.



Contents of the knowledge base?

Entailment



The meaning of the knowledge base: other sentences may be true, i.e., other sentences can be *deduced* from the sentences in the knowledge base.

KB | = S

The sentence S is “entailed” by the knowledge base.