Artificial Intelligence

Logical Agents

In which we design agents that can form representations of the world, use a process of “inference” to derive new representations about the world, and use these new representations to deduce what to do.
Knowledge-Based Logical Agents

- Two central AI concepts
  - Representation of knowledge
  - Reasoning processes acting on knowledge
- Play crucial role in “Partially Observable” environments
  - Combine general knowledge with current percepts to infer hidden aspects before acting
- Aids in agent flexibility
  - Learn new knowledge for new tasks
  - Adapt to changes in environment by updating relevant knowledge

Logic

- For logical agents, knowledge is definite
  - Each proposition is either “True” (1) or “False” (0)
- Logic has advantage of being a simple representation for knowledge-based agents
  - But limited in its ability to handle uncertainty
- We will examine “propositional logic” and “first-order logic”
Knowledge Base

- Central component is its knowledge base (KB)
  - Contains set of “sentences” or factual statements
    - Some assertions about the world expressed with a knowledge representation language
  - KB initially contains some background knowledge
    - “Innate” knowledge
- How to add new information to KB?
  - TELL function, or
  - Inference (deriving new sentences from old ones)
- How to query what is known?
  - ASK function
    - Answers should follow what has been told to the KB previously

A Simple Knowledge-Based Agent

- Agent needs to know
  1. Current state of world
  2. How to infer unseen properties of world from percepts
  3. How world evolves over time
  4. What it wants to achieve
  5. What its own actions do in various circumstances
“Wumpus World” Environment

- Simple environment to motivate logical reasoning
- Agent explores cave with rooms connected by passageways
- “Wumpus” beast lurking somewhere in cave
  - Eats anyone who enters its room
  - Agent has one arrow (can kill Wumpus)
- Some rooms contain **bottomless pits**
- Occasional heap of **gold** present
- Agent task:
  - Enter cave, find the gold, return to entrance, and exit

Wumpus World PEAS Description

- (P)erformance measure
  - Receive +1000 for picking up gold
  - Cost of −1000 for falling into pit or being eaten by Wumpus (GAME OVER!)
  - Cost of −1 for each action taken
  - Cost of −10 for using up the only arrow
- (E)nvironment
  - 4x4 grid of rooms
  - Agent starts in square [1,1]
  - Wumpus and gold locations chosen randomly
  - Probability of square being a pit is .2
    - [0=no, ..., 0.5=m\_aybe, ..., 1=yes]
Wumpus World PEAS
Description

• (A)ctuators
  – Move forward, turn left, turn right
    • Note: die if enter pit or live wumpus square
  – Grab (gold)
  – Shoot (arrow)
    • Kills wumpus if facing its square

• (S)ensors
  – Nose: squares adjacent to wumpus are “smelly”
  – Skin/hair: Squares adjacent to pit are “breezy”
  – Eye: “Glittery” if and only if gold is in the same square
  – Percepts: [Stench, Breeze, Glitter]
Wumpus World Characterization

- Is the world deterministic?
  - Yes, outcomes exactly specified
- Is the world fully accessible?
  - No, only local percepts
- Is the world static?
  - Yes, Wumpus and pits do not move (though would be interesting!)
- Is the world discrete?
  - Yes, blocks/cells

Exploring a Wumpus World

\[
\begin{array}{c|c|c|c|c|c|c|c|c}
\hline
 & \text{OK} & & & & & & & \\
\hline
\text{A} & & & & & & & & \\
\text{B} & & & & & & & & \\
\text{G} & & & & & & & & \\
\text{OK} & & & & & & & & \\
\text{P} & & & & & & & & \\
\text{S} & & & & & & & & \\
\text{V} & & & & & & & & \\
\text{W} & & & & & & & & \\
\hline
\end{array}
\]

From local percepts, determines that \{(1,1), (1,2), (2,1)\} are free from danger.
Exploring a Wumpus World

A = agent
B = breeze
G = glitter, gold
OK = safe square
P = pit
S = stench
V = visited
W = Wumpus

From breeze percept, determines that (2,2) or (3,1) is a pit. Go back to (1,1) and move up to (1,2).

Exploring a Wumpus World

A = agent
B = breeze
G = glitter, gold
OK = safe square
P = pit
S = stench
V = visited
W = Wumpus

From stench and no-breeze percept in (1,2), determines that Wumpus in (1,3), pit in (3,1), and (2,2) clear.
Exploring a Wumpus World

A = agent
B = breeze
G = glitter, gold
OK = safe square
P = pit
S = stench
V = visited
W = Wumpus

From local percepts, it is OK to move up or right.

Found gold! No need to explore further. Time to head back.
Exploring a Wumpus World

A = agent
B = breeze
G = glitter, gold
OK = safe square
P = pit
S = stench
V = visited
W = Wumpus

Then go home using OK squares
(retrace route or use solution path)

Tight Spots

Breeze in (1,2) and (2,1) → no safe actions!
Pit may actually only be in (2,2), but can’t tell.
More Tight Spots

Smell in (1,1) → Cannot move!
Possible action: shoot arrow straight ahead

Online Examples

http://thiagodnf.github.io/wumpus-world-simulator/
Logical Agent

• Need agent to represent beliefs
  – “There is a pit in (2, 2) or (3, 1)”
  – “There is no Wumpus in (2, 2)”

• Need to make inferences
  – If available information is correct, draw a conclusion that is guaranteed to be correct

• Need representation and reasoning
  – Support the operation of knowledge-based agent

Knowledge Representation

• For expressing knowledge in computer-tractable form

• Knowledge representation language defined by
  – Syntax
    • Defines the possible “well-formed configurations” of sentences in the language
  – Semantics
    • Defines the “meaning” of sentences (need interpreter)
    • Defines the truth of a sentence in a world (or model)
The Language of Arithmetic

Syntax: “$x + 2 > y$” is a sentence

“$x2 + y >$” is not a sentence

Semantics: $x + 2 > y$ is True IFF the number $x + 2$ is larger than the number $y$

$x + 2 > y$ is True in a world where $x=7, y=1$

$x + 2 > y$ is False in a world where $x=0, y=6$

Inference

• Sentence is valid IFF it is true under all possible interpretations in all possible worlds
  – Also called tautologies
  – “There is a stench at (1,1) or there is not a stench at (1,1)”
  – “There is an open area in front of me” is not valid in all worlds

• Sentence is satisfiable IFF there is some interpretation in some world for which it is true
  – “There is a wumpus at (1,2)” could be true in some situation
  – “There is a wall in front of me and there is no wall in front of me” is unsatisfiable
Summary

• Intelligent agents need knowledge about the world and a means to reach good decisions
  – Representation of knowledge
  – Reasoning processes acting on knowledge
• Knowledge is contained in the form of sentences in a knowledge representation language that are stored in a knowledge base (KB)
• Representation language defined by syntax and semantics
  – Structure and meaning
• Inference is deriving new sentences from old ones