Artificial Intelligence 1: Logic agents

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"Thinking Rationally"

Computational models of human "thought" processes

Computational models of human behavior

Computational systems that "think" rationally

Computational systems that behave rationally

Logical Agents

Reflex agents find their way from Arad to Bucharest by dumb luck

Chess program calculates legal moves of its king, but doesn't know that no piece can be on 2 different squares at the same time

Logic (Knowledge-Based) agents combine general knowledge with current percepts to infer hidden aspects of current state prior to selecting actions
  – Crucial in partially observable environments

Outline

Knowledge-based agents

Wumpus world
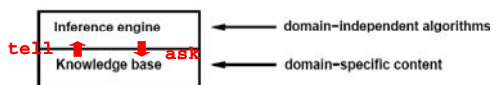
Logic in general

Propositional and first-order logic
  – Inference, validity, equivalence and satifiability
  – Reasoning patterns
    – Resolution
    – Forward/backward chaining

Knowledge Base

Knowledge Base ¬ set of sentences represented in a knowledge representation language and represents assertions about the world.

Inference rule: when one ASKs questions of the KB, the answer should *follow* from what has been TELLed to the KB previously.

Generic KB-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($percept, t$))
  $action \leftarrow$ ASK(KB, MAKE-ACTION-QUERY(t))
  TELL(KB, MAKE-ACTION-SENTENCE($action, t$))
  $t \leftarrow t + 1$
  return $action$

1

Abilities KB agent

Agent must be able to:
- Represent states and actions,
- Incorporate new percepts
- Update internal representation of the world
- Deduce hidden properties of the world
- Deduce appropriate actions

Description level

The KB agent is similar to agents with internal state

Agents can be described at different levels
- Knowledge level
  - What they know, regardless of the actual implementation. (Declarative description)
- Implementation level
  - Data structures in KB and algorithms that manipulate them e.g propositional logic and resolution.

A Typical Wumpus World
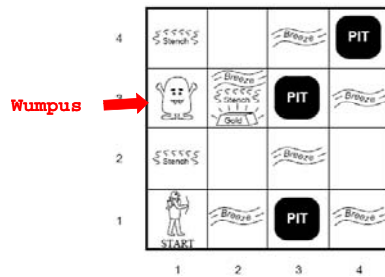
Wumpus World PEAS

Performance measure
  gold +1000, death -1000
  -1 per step, -10 for using the arrow
Environment
  Squares adjacent to wumpus are smelly
  Squares adjacent to pit are breezy
  Glitter iff gold is in the same square
  Shooting kills wumpus if you are facing it
  Shooting uses up the only arrow
  Grabbing picks up gold if in same square
  Releasing drops the gold in same square

Sensors Breeze, Glitter, Smell

Actuators Left turn, Right turn,
  Forward, Grab, Release, Shoot

Wumpus World Characterization

Observable?
Deterministic?
Episodic?
Static?
Discrete?
Single-agent?

Wumpus World Characterization

Observable? No, only local perception
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Wumpus World Characterization

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Discrete? Yes
Single-agent? Yes, Wumpus is essentially a natural feature.

Exploring the Wumpus World
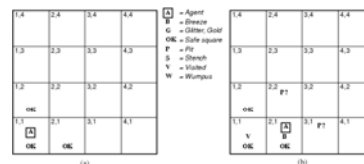
[1,1] The KB initially contains the rules of the environment. The first percept is [*none, none,none,none,none*], move to safe cell e.g. 2,1
[2,1] breeze which indicates that there is a pit in [2,2] or [3,1], return to [1,1] to try next safe cell
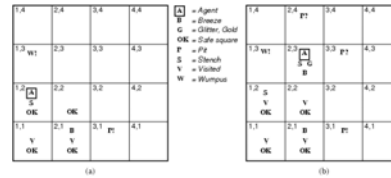
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Exploring the Wumpus World

[1,2] Stench in cell which means that wumpus is in [1,3] or [2,2]
  YET ... not in [1,1]
  YET ... not in [2,2] or stench would have been detected in [2,1]
  THUS ... wumpus is in [1,3]
  THUS [2,2] is safe because of lack of breeze in [1,2]
  THUS pit in [1,3]
  move to next safe cell [2,2]

Exploring the Wumpus World

[2,2] move to [2,3]
[2,3] detect glitter , smell, breeze
  THUS pick up gold
  THUS pit in [3,3] or [2,4]

What is a logic?

A formal language
– Syntax – what expressions are legal (well-formed)
– Semantics – what legal expressions mean
  – in logic the truth of each sentence with respect to each possible world.

E.g the language of arithmetic
– X+2 >= y is a sentence, x2+y is not a sentence
– X+2 >= y is true in a world where x=7 and y =1
– X+2 >= y is false in a world where x=0 and y =6

Entailment

One thing follows from another
  $KB \vDash \alpha$
KB entails sentence α *if and only if* α is true in worlds where KB is true.
E.g. x+y=4 entails 4=x+y
Entailment is a relationship between sentences 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.
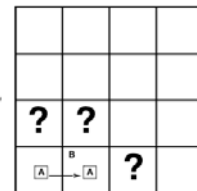m is a model of a sentence α if α is true in m
$M(\alpha)$ is the set of all models of α

Wumpus world model

Situation after detecting nothing in [1,1], moving right, breeze in [2,1]

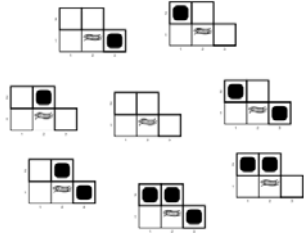Consider possible models for ?s assuming only pits
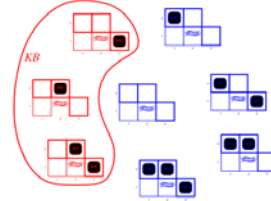
3 Boolean choices ⇒ 8 possible models

4

Wumpus world model
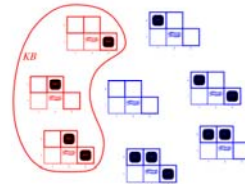
Wumpus world model

KB = wumpus-world rules + observations

Wumpus world model
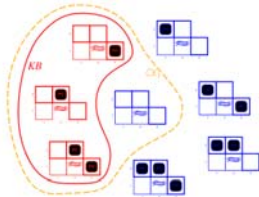
KB = wumpus-world rules + observations

α_1 = "[1,2] is safe", $KB \models \alpha_1$, proved by model checking

Wumpus world model

KB = wumpus-world rules + observations
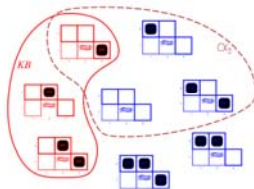
Wumpus world model

KB = wumpus-world rules + observations

α_2 = "[2,2] is safe", $KB \not\models \alpha_2$

Logical inference

The notion of entailment can be used for logic inference.
- Model checking (see wumpus example): enumerate all possible models and check whether α is true.

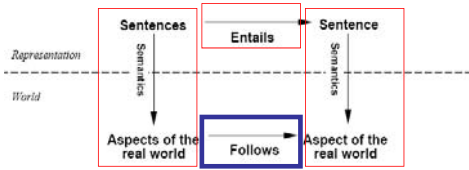If an algorithm only derives entailed sentences it is called *sound* or *truth preserving*.
- Otherwise it just makes things up.
  i is sound if whenever $KB \vdash_i \alpha$ it is also true that $KB \models \alpha$

Completeness : the algorithm can derive any sentence that is entailed.
i is complete if whenever $KB \models \alpha$ it is also true that $KB \vdash_i \alpha$

Schematic perspective

If KB is true in the real world, then any sentence α derived From KB by a sound inference procedure is also true in the real world.

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