Logical Agents

CHAPTER 7
COSC 370
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ALAN C. JAMIESON

SOME SLIDE CONTENT FROM RUSSELL & NORVIG PROVIDED SLIDES

- Knowledge-based Agents
- Wumpus World Redux
- Logic
- Propositional Logic
- Inference

Knowledge Bases

- The next step!
- Knowledge base (KB) – set of statements in some kind of formal language
- Essentially declarative (just tell it what it wants to know!)
- Then query the KB for information/moves.
- KB doesn't have to be prepped ahead of time!

Simple KB Agent

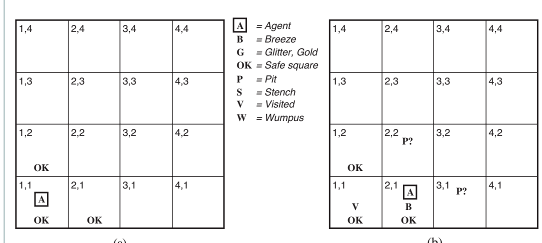
```
function KB-AGENT( percept) returns an action
   static: KB, a knowledge base
           t, a counter, initially 0, indicating time
   TELL(KB, MAKE-PERCEPT-SENTENCE( percept, t))
   action ← ASK(KB, MAKE-ACTION-QUERY(t))
   TELL(KB, MAKE-ACTION-SENTENCE(action, t))
   t ← t + 1
   return action
```

- 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 action

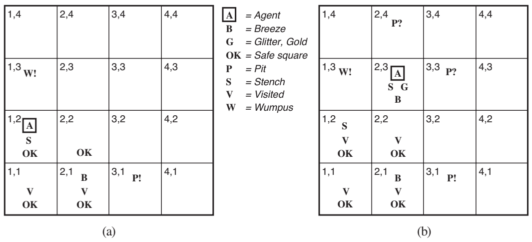
Good Problem? Wumpus World!

- Recall – classic Wumpus World
  - 1 Wumpus
  - 1 arrow
  - 4x4 grid of rooms
  - 4 pits
  - Get the agent to the gold and back out
- Perfect KB problem! Potential solution – keep track of all percepts and infer what rooms have what things?

Wumpus World Execution

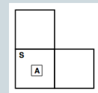


Wumpus World Execution

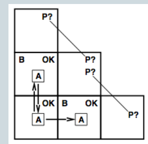


Some Other Wumpus World Notes

- Could be stuck without a safe move:



- Solution: shoot in a direction to determine safety!
- What about:



How do we represent the world?

- Logic! Great way of representing information to be used in an inference engine.
- Syntax defines the sentences in the language
- Semantics define the meaning, or truth of a sentence.
- Example: arithmetic relations
  - x + 2 <= y
  - x 2 + y <=
  - x + 2 <= y is true if x = 7 and y = 1, but not if x = 1 and y = 7

Entailment and Models

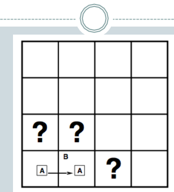
- Entailment – one thing follows from another:
  KB |= α
- KB entails α iff α is true in all worlds that the KB is true.
- Consider a baseball game: Atlanta Braves vs. Detroit Tigers – the KB here entails "either the Braves won or the Tigers won." Knowing the result from Friday, we know that the Tigers won, so the KB further entails "the Tigers won."

Entailment and Models

- Models model a world, or multiple worlds.
- m is a model of a sentence α if α is true in m. Note: m is not a KB, it is just a representation of worlds in which α is true!
- M(α) is the set of all models of α
- So – KB |= α iff M(KB) ⊆ M(α)

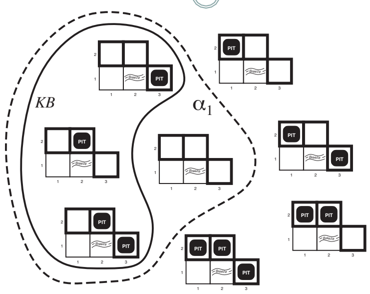
Wumpus World Entailment

- Consider:

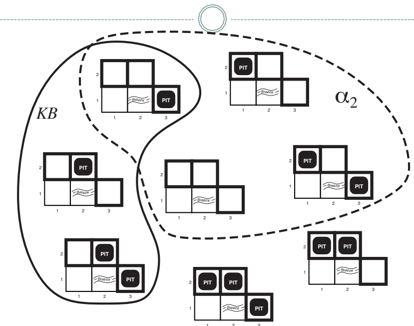


- Consider possible model for ? spaces – consider only pits. 3 Boolean choices, 8 possible models.

Wumpus World Entailment



Wumpus World Entailment



Exercise!

- 7.1 – Wumpus World modelling + entailment

Inference

- KB $|-_i$ α, sentence α can be inferred from the KB via procedure i.
- Inference is how you find your entailment statements!
- Soundness – i is sound if:
  whenever KB $|-_i$ α, it is also true that KB |= α
- Completeness – is is complete if:
  whenever KB |= α, it is also true that KB $|-_i$ α
- What we will do: define a logic (first-order) that can be used to express anything of interest, and define a procedure for inference from that logic.

Propositional Logic: Syntax

- P_1 and P_2 and so on are sentences.
- If S is a sentence, so is ¬S
- If S_1 and S_2 are sentences, so is $S_1 \wedge S_2$
- If S_1 and S_2 are sentences, so is $S_1 \vee S_2$
- If S_1 and S_2 are sentences, so is $S_1 \Rightarrow S_2$
- If S_1 and S_2 are sentences, so is $S_1 \Leftrightarrow S_2$

Propositional Logic: Semantics

- Each model specifies true/false for each propositional sentence.
- Basic rules for evaluating truth with respect to a model m:

$\neg S$	is true iff	S	is false		
$S_1 \wedge S_2$	is true iff	S_1	is true **and**	S_2	is true
$S_1 \vee S_2$	is true iff	S_1	is true **or**	S_2	is true
$S_1 \Rightarrow S_2$	is true iff	S_1	is false **or**	S_2	is true
i.e.,	is false iff	S_1	is true **and**	S_2	is false
$S_1 \Leftrightarrow S_2$	is true iff	$S_1 \Rightarrow S_2$	is true **and**	$S_2 \Rightarrow S_1$	is true

- A simple recursive process evaluates arbitrary sentences.

Relations

P	Q	$\neg P$	$P \wedge Q$	$P \vee Q$	$P \Rightarrow Q$	$P \Leftrightarrow Q$
false	*false*	*true*	*false*	*false*	*true*	*true*
false	*true*	*true*	*false*	*true*	*true*	*false*
true	*false*	*false*	*false*	*true*	*false*	*false*
true	*true*	*false*	*true*	*true*	*true*	*true*

Wumpus World Sentences

- Let $P_{i,j}$ mean that there is a pit at square i,j
- Let $B_{i,j}$ mean that there is a breeze at square i,j
- Our KB:
  $\neg P_{1,1}$
  $\neg B_{1,1}$
  $B_{2,1}$
- "Pits cause breezes in adjacent squares"
  $B_{1,1} \Leftrightarrow (P_{1,2} \vee P_{2,1})$
  $B_{2,1} \Leftrightarrow (P_{1,1} \vee P_{2,2} \vee P_{3,1})$
- "A square is breezy iff there is an adjacent pit"

Exercise

- Some logic fun: 7.2 followed by 7.4