

# Logic

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CS 4480

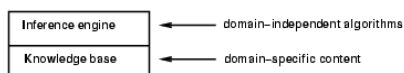
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Based on slides from  
<http://aima.eecs.berkeley.edu/2nd-ed/slides-ppt/>

# Outline

- Knowledge-based agents
- Wumpus world
- Logic in general - models and entailment
- Propositional (Boolean) logic
- Equivalence, validity, satisfiability
- Inference rules and theorem proving
  - forward chaining
  - backward chaining
  - resolution

# 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

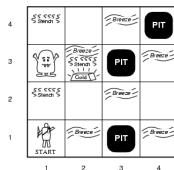
```

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

# Wumpus World PEAS description

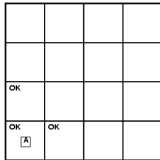
- Performance measure
  - gold +1000, death -1000
  - -1 per step, -10 for using the arrow
- Environment
  - Squares adjacent to wumpus are smelly
  - Squares adjacent to pit are breezy
  - Glitter iff gold is in the same square
  - Shooting kills wumpus if you are facing it
  - Shooting uses up the only arrow
  - Grabbing picks up gold if in same square
  - Releasing drops the gold in same square
- Sensors: Stench, Breeze, Glitter, Bump, Scream
- Actuators: Left turn, Right turn, Forward, Grab, Release, Shoot



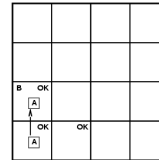
# Wumpus world characterization

- Fully Observable No – only local perception
- Deterministic Yes – outcomes exactly specified
- Episodic No – sequential at the level of actions
- Static Yes – Wumpus and Pits do not move
- Discrete Yes
- Single-agent? Yes – Wumpus is essentially a natural feature

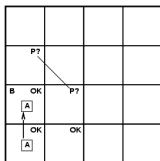
### Exploring a wumpus world



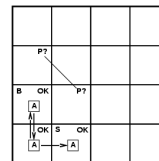
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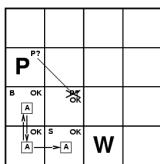
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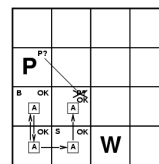
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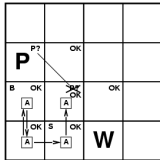
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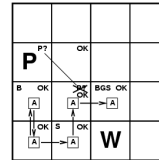
### Exploring a wumpus world



## Exploring a wumpus world



## Exploring a wumpus world



## 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
- ◇ E.g., the language of arithmetic
  - $x+2 \geq y$  is a sentence;  $x+2 > \{ \}$  is not a sentence
  - $x+2 \geq y$  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:
 
$$KB \vdash \alpha$$
- Knowledge base  $KB$  entails sentence  $\alpha$  if and only if  $\alpha$  is true in all worlds where  $KB$  is true
  - E.g., the  $KB$  containing "the Giants won", and "the Reds won" entails "Either the Giants won or the Reds won"
  - E.g.,  $x+y = 4$  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  $\alpha$  if  $\alpha$  is true in  $m$
- $M(\alpha)$  is the set of all models of  $\alpha$
- Then  $KB \models \alpha$  iff  $M(KB) \subseteq M(\alpha)$ 
  - E.g.  $KB =$  Giants won and Reds won  $\alpha =$  Giants won

