CAS CS 440
Lec 12

Logic I

1. Skipped Stuff
    a. Local CSP search
        i. Fast (can use hill climbing!)
        ii. Really fast
        iii. Works surprisingly well
            1. Solutions to CSPs are densely grouped on the objective surface!
            2. Lots of plateaus (lots of complete assignments are one off from legal!)
    b. Special Graphs Solving:
        i. Convert CSPs to graphs and solvers solve the graph
        ii. Connected Components (islands) subproblems!
            1. Islands that are not connected to each other
            2. In this case, consider the two islands as separate and solve them separately (they are independent to each other)
        iii. Tree graph topological sort! Solve in linear time!
2. Logical Agents
    a. CSPs are pretty abstract
        i. Good!
        ii. If we can model problem as variables + domains + constraints
            1. CSP solvers!
        iii. It is more powerful than A* since it is more general
    b. CSPs are a form of "logic"
        i. Inference is a form of "logic"
    c. Can we be more abstract?
        i. If we can, we can solve more problems!
    d. Need:
        i. Internal representation of "the stuff"
        ii. Ways to manipulate "the stuff"
    e. Internal Mechanism:
        i. Knowledge Base
            1. A set of sentences
            2. Each sentence written in a "knowledge representation language"
    f. Manipulating Sentences:
        i. Derive new sentences from existing ones
        ii. Base case: axioms = sentences assumed to be true without derivation

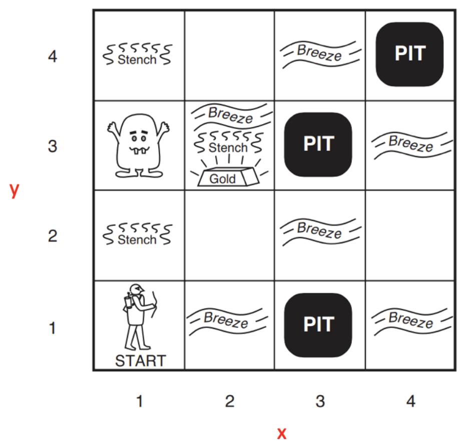
g. Two primary operations:
   i. TELL
      1. Add new sentences to KB
   ii. ASK
      1. Query what is known

h.

```
function KB-AGENT(percept) returns an action
  persistent: 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
```

3. Example World

   a. 

   b. Performance Measure:
      i. +1000 when escaping w/ gold
      ii. -1000 for dying (falling into pit / eaten)
      iii. -1 for each action taken
      iv. -10 using your only arrow
   c. Environment:
      i. 4x4 grid
      ii. Agent always starts in (1,1)
      iii. Gold + Wumpus chosen randomly (uniformly) from squares not (1,1)
      iv. Pit appears in each square with prob 0.2
   d. Actions:
      i. Go forward 1 square
      ii. Turn left/right by 90 degrees
   e. Sensing:
      i. Squares adjacent to Wumpus have stenches

ii. Squared adjacent to pits have breezes

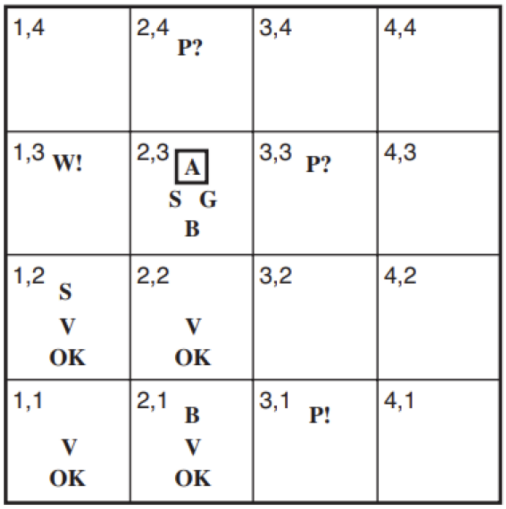
iii. Square with gold in it is glittery

iv. Bump when agent walks into a wall

v. Wumpus emits a scream when killed (heard anywhere)

f. Percept(t) = [Stench, Breeze, Glitter, Bump, Scream]

4. Inference in the Wumpus World

a. 

Legend

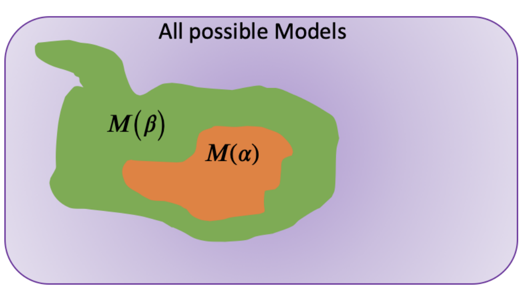
A = *Agent*
B = *Breeze*
G = *Glitter, Gold*
OK = *Safe square*
P = *Pit*
S = *Stench*
V = *Visited*
W = *Wumpus*

b.

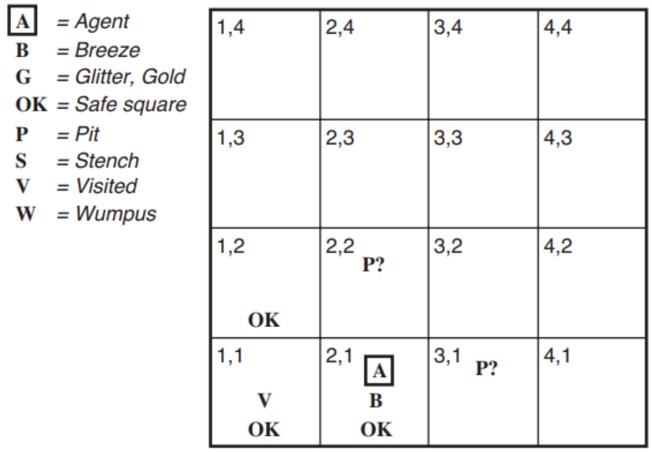
	Stench	Breeze	Glitter	Bump	Scream
Percept(0) =	[None,	None,	None,	None,	None]
Percept(1) =	[None,	Breeze,	None,	None,	None]
Percept(3) =	[Stench,	None,	None,	None,	None]

5. Logic Representation
    a. Knowledge is a collection of sentences
    b. Each sentence must have syntax
        i. Grammer
        ii. Is a sentence well formed?
    c. Each sentence must have semantics
        i. Apply a sentence to a world
        ii. Determine if that sentence is true (holds) or not given a world
            1. Could be a hypothetical world!
    d. A model in Logic
        i. A hypothetical world
    e. # pros # amateurs

       Consider sentence $x + y = 4$

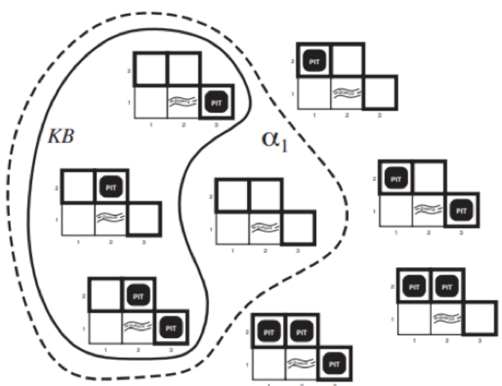
       Sentence is true when there are 4 people
       All possible models:
       - All possible # pros & # amateurs
       - Sentence is only true for some of them
       - Model fixes truth of this sentence
    f. If sentence a is true in model m:
        i. m satisfies a
        ii. M(a) = (set of) all models that satisfy a
6. Reasoning
    a. Now we have a notion of "truth"
    b. Want to relate two sentences to each other
    c. If sentence a logically follows from sentence B (entailment):
        i. a | = B (sentence a entails sentence B)
        ii. a is a stronger sentence than b (b is more general)
        iii. For every a, b also has to be true
    d. Every model in which a is true, B is also true
        i. $$\alpha \mid = \beta \; iff \; M(\alpha) \subseteq M(\beta)$$
    e. 

7. Models & The Wumpus World

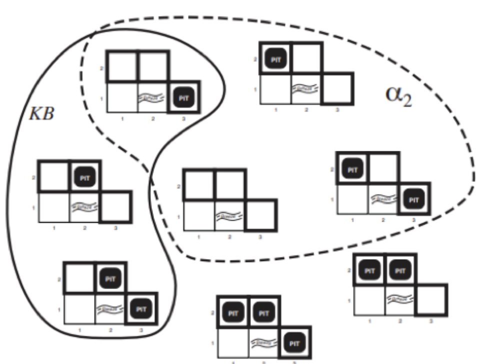
a. 

b. KB (so far):
    i. Precepts
    ii. Rules (axioms) of Wumpus World

c. Consider two possible conclusions:
    i. a1 = "There is no pit in (1,2)"
    ii. a2 = "There is no pit in (2,2)"

d. 

    i. KB | = a1
    ii. a1 is true (and should be added to KB)

e. 

    i. !(KB | = a2)
    ii. a2 is not known to be true

8. Entailment & Inference
    a. Goal:
        i. Find sentences that are entailed by our KB
        ii. Add them to our KB (add to knowledge base to infer new things)
        iii. How?
            1. Algorithm from past slide is called model checking
                a. Enumerate every possible model & check!
                b. Calculate if $M(KB) \subseteq M(\alpha)$ by brute force
    b. Inference algorithm tries to derive sentences that are entailed by KB
        i. Lets differentiate entailment from derivation (knowing and finding is two differen things)
            1. If inference algorithm A can derive a from KB:
            $KB \vdash_A \alpha$
    c. Properties of Inference algorithms:
        i. Soundness
            1. Only derive entailed sentences
        ii. Completeness
            1. Can derive every entailed sentences