CSCI 5582
Artificial Intelligence

Lecture 9
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Today 9/28

- Review propositional logic
- Reasoning with Models
- Break
- More reasoning

Knowledge Representation

- A knowledge representation is a formal scheme that dictates how an agent is going to represent its knowledge.
  - Syntax: Rules that determine the possible strings in the language.
  - Semantics: Rules that determine a mapping from sentences in the representation to situations in the world.

Propositional Logic

- Atomic Propositions
- That are true or false
  - And stay that way
- Connectives to form sentences that receive truth conditions based on a compositional semantics

Semantics

- Compositional semantics
- Modus ponens
- Resolution
- Model-based semantics

Compositional Semantics

- The semantics of a complex sentence is derived from the semantics of its parts
  a

$$A \vee B$$

Compositional Semantics

- Syntactic Manipulations
  - And elimination
  - And introduction
  - Or introduction
  - Double negation removal

Compositional Semantics

- And introduction
- You know

$$A$$

$$B$$

- You can add

$$A \wedge B$$

Modus Ponens

- You know

$$A$$

- What can you conclude?

$$A \rightarrow B$$

$$B$$

Resolution

- You know

$$A \vee B$$

- What can you conclude?

$$\neg B \vee C$$

$$A \vee C$$

Modeling Wumpus World

- Environmental state
- No stench in 1,1

$$\neg S_{1,1}$$

Modeling Wumpus World

- Long term rules of the world
  - Breezes are found in states adjacent to pits
  - Stenches are found in states adjacent to Wumpi
  - No stench means no Wumpus nearby
- For example…

  $\neg S_{1,1} \rightarrow \neg W_{1,1} \wedge \neg W_{2,1} \wedge \neg W_{1,2}$

Alternative Schemes

- Wumpuses cause stenches

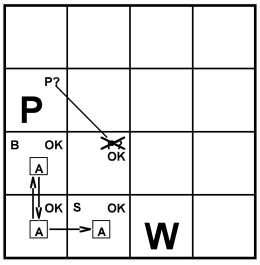
$$W_{1,1} \rightarrow S_{1,1} \wedge S_{1,2} \wedge S_{2,1}$$

Or

S1,1 implies W1,1 or W1,2 or W2,1

$$S_{1,1} \rightarrow W_{1,1} \vee W_{1,2} \vee W_{2,1}$$

Inference in Wumpus World



Organizing Inference

- By itself, the semantics of a logic does not provide a computationally tractable method for inference. It just defines a space of reasonable things to try.
- But first…

Organizing Inference

- Two ways to think about this…
  - Reason directly about models (today)
    - This turns the inference process into a search process
  - Directly harness the various rules of inference (next time)
    - This turns the inference process into a search process

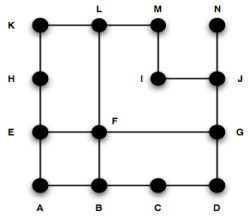
Break

- Last quiz discussion
  - 1. True
  - 2. H = Max (h_i)
  - 5. False
  - 6. 81
  - 7. Number of leaves examined (number of times the eval function is called.

Quiz

Question 2: Start F, Goal J

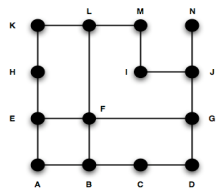
Question 3: Start F, Goal N



Quiz: Uniform-Cost

Question 2: Start F, Goal J

Question 3: Start F, Goal N

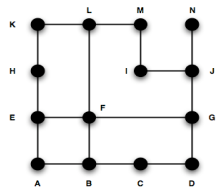


F
B E G L
E A C G L
H A C G L
A C G L K
C G L K
G L D K
L J D K
M J D K
J D J I
Done

Quiz: A*

Question 2: Start F, Goal J

Question 3: Start F, Goal N



F
G_4 L_4 $B_{4.6}$ $E_{4.6}$
J_4 L_4 $B_{4.6}$ $E_{4.6}$ D_6
N_4 L_4 $B_{4.6}$ $E_{4.6}$ $I_{5.4}$ D_6
Done.

Break

Readings for logic

- Chapter 7 all except circuit-agent material
- Chapter 8 all
- Chapter 9
  - 272-290, 295-300
- Chapter 10
  - 320-331, Sec 10.5

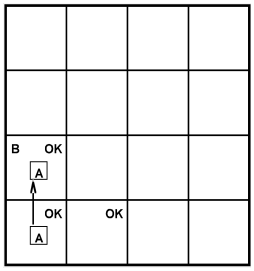
Models

- Inference, entailment, satisfiability, validity, possible worlds, etc, ugh…
- Let's go back and cover something I skipped last time…
  - What's a model
    - A possible world
      - Possible?

Models

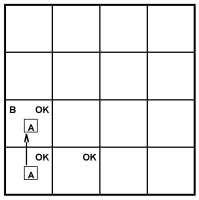
- Assume for a moment that there's only one pit.

Percept [Breeze]



Models

- Can there be a pit in 4,4?
- Can there be a pit in 3,1?
- Does there have to be a pit in either 3,1 or 2,2?
- Is there gold in 4,1?



Models

- Can there be a pit in 4,4?
  - No, because there are no models with a pit there.
- Can there be a pit in 3,1?
  - Yes, because there is a model with a pit there.
- Does there have to be a pit in either 3,1 or 2,2?
  - Yes, because that statement is true in all the models.
- Is there gold in 4,1?
  - Dunno. Some models have it there, some don't.

Models

- So… reasoning with models gives you all you need to answer questions.
  - Yes, no, maybe
    - Yes: True in all possible worlds
    - No: False in all possible worlds
    - Could be: True in some worlds, false in others

Model Checking

- If you ask me if something is true or false all I have to do is enumerate models.
  - If it's true in all it's true, false in all it's false.
- If you ask me if something could be true or false then I just need to find a model where its true or false.
  - If I can't find any model where it could be true then it's false.

Entailment

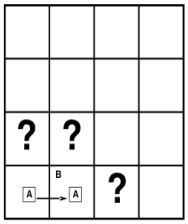
- One thing follows from another
  $KB \models \alpha$
- KB entails sentence α *if and only if* α is true in all the worlds where KB is true.
- Entailment is a relationship between sentences that is based on semantics.

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*(α) is the set of all models of α

Wumpus world model

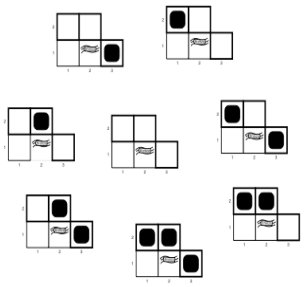
Situation after detecting nothing in [1,1], moving right, breeze in [2,1]



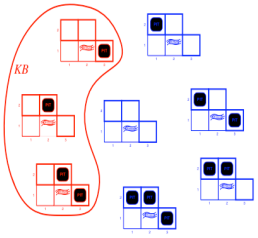
Consider possible models for ?s assuming only pits

3 Boolean choices $\Rightarrow$ 8 possible models

Wumpus world model

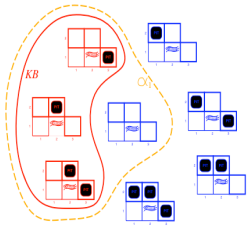


Wumpus world model



KB = wumpus-world rules + observations

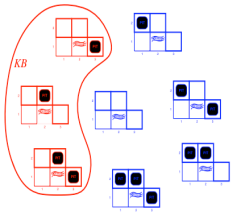
Wumpus world model



KB = wumpus-world rules + observations

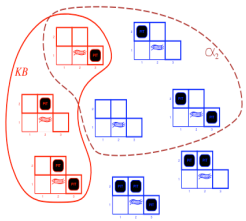
α_1 = "[1,2] is safe", $KB \models \alpha_1$, proved by model checking

Wumpus world model



KB = wumpus-world rules + observations

Wumpus world model



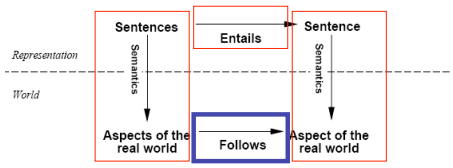
KB = wumpus-world rules + observations

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: 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 is just makes things up.
- Completeness : the algorithm can derive any sentence that is entailed.

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.

Next time

- Focus on inference algorithms
  - Resolution
  - Forward and backward chaining
  - DPLL
  - WalkSat