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

\[ A \lor B \]
Compositional Semantics

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

Compositional Semantics

- And introduction
  - You know
    \[ A \]
    \[ B \]
  - You can add
    \[ A \land B \]

Modus Ponens

- You know
  \[ A \]
  - What can you conclude?
    \[ A \rightarrow B \]
    \[ B \]
Resolution

- You know
  \[ A \lor B \]
  \[ \neg B \lor C \]
  \[ A \lor C \]

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...
  \[ \neg S_{1,1} \rightarrow \neg W_{1,1} \land \neg W_{2,1} \land \neg W_{1,2} \]
Alternative Schemes

- Wumpuses cause stenches
  \[ W_{1,1} \rightarrow S_{1,1} \land S_{1,2} \land S_{2,1} \]
  
  Or

- S1,1 implies W1,1 or W1,2 or W2,1
  \[ S_{1,1} \rightarrow W_{1,1} \lor W_{1,2} \lor W_{2,1} \]

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. \( H = \text{Max} (h_i) \)
  - 5. False
  - 6. 81
  - 7. Number of leaves examined (number of times the eval function is called.)

Quiz
Quiz: Uniform-Cost

Quiz: A*

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]

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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 \( \alpha \) if and only if \( \alpha \) 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 \( \alpha \) if \( \alpha \) is true in \( m \)
- \( M(\alpha) \) is the set of all models of \( \alpha \)
Wumpus world model

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

Consider possible models for ?
assuming only pits

3 Boolean choices ⇒ 8 possible models
Logical inference

• The notion of entailment can be used for logic inference.
  - Model checking: enumerate all possible models and check whether \( \alpha \) 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 \( \alpha \) 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