Knowledge Representation

What Is Knowledge Representation?

- Representing facts
- Reasoning with available facts

Can computers create meaningful knowledge?

Brief History of Logic

- Ancient Logics:
  - Chinese Logic: Mozi (c. 400 BC)
  - Greek Logic: Aristotle (c. 320 BC)
  - Indian Logic: Medhātithi Guatama (c. 600 BC)
- Leibnez (1670-1690): inference as a math system
- Boole (1847): application of algebra to logical relations
- Frege/Peirce (1879, 1885): first-order logic
- Dartmouth Workshop (1956): founding of Artificial Intelligence

Intelligent Action

The **Physical Symbol System Hypothesis**: A physical symbol system has necessary and sufficient means for general intelligent action.

Symbol: a designating pattern that can be combined with other symbols to form another designating pattern

Designation: assigning a symbol meaning of something in the world

Propositional Logic

Propositional Logic

$it - is - raining$

$i - am - wet$

$it - is - raining \rightarrow i - am - wet$

x	y	$x \wedge y$
F	F	F
F	T	F
T	F	F
T	T	T

x	y	$x \rightarrow y$
F	F	T
F	T	T
T	F	F
T	T	T

$$\frac{x \qquad x \rightarrow y}{y}$$

modus ponens

operators: $\wedge, \vee, \neg, \rightarrow, \leftrightarrow$

Logic

A logic is a formal system:

- syntax: defines sentences
- semantics: relation to world
- inference rules: reaching new conclusions based on available knowledge

three layers: proof, models, reality

Exercise

Convert to propositional logic using implications:

If the unicorn is mythical, then it is immortal, but if it is not mythical, then it is a mortal mammal. If the unicorn is either immortal or a mammal, then it is horned. The unicorn is magical if it is horned.

Semantics

- interpretation: possible world = truth of each proposition
- meaning: values across all interpretations
- model of P: an interpretation in which P is true
- satisfiable: $\exists$ a model in which P is true
- entailment: if α is true in every model of KB, then $KB \models \alpha$
- valid: if true in all interpretations

Reasoning

Conversion to Conjunctive Normal Form

1. Eliminate $\leftrightarrow$: convert $a \leftrightarrow b$ to $a \rightarrow b \wedge b \rightarrow a$
2. Eliminate $\rightarrow$: convert $a \rightarrow b$ to $\neg a \vee b$
3. Move $\neg$ inwards: eliminate double negatives and apply De Morgan's law
4. Distribute $\vee$: convert $(a \wedge b) \vee c$ to $(a \vee c) \wedge (b \vee c)$

Just as expressive, easier for an algorithm to process

Propositional Reasoning

resolution of unicorn facts – what can we prove?

Entailment

entailment: if α is true in every model of KB, then $KB \models \alpha$

$KB \models \alpha$ iff $KB \rightarrow \alpha$ is valid

$KB \models \alpha$ iff $KB \wedge \neg\alpha$ is unsatisfiable

determining satisfiability is NP-complete: tough to solve, easy to verify