CS344: Introduction to Artificial Intelligence

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Lecture 7– Predicate Calculus and Knowledge Representation
Logic and inferencing

Obtaining implication of given facts and rules -- Hallmark of intelligence
Inferencing through

- Deduction (General to specific)
- Induction (Specific to General)
- Abduction (Conclusion to hypothesis in absence of any other evidence to contrary)

**Deduction**

Given: All men are mortal (rule)
Shakespeare is a man (fact)
To prove: Shakespeare is mortal (inference)

**Induction**

Given: Shakespeare is mortal
Newton is mortal (Observation)
Dijkstra is mortal
To prove: All men are mortal (Generalization)
If there is rain, then there will be no picnic

Fact1: There was rain
Conclude: There was no picnic

Fact2: There was no picnic
Conclude: There was no rain (?)

Induction and abduction are fallible forms of reasoning. Their conclusions are susceptible to retraction

Two systems of logic

1) Propositional calculus
2) Predicate calculus
Propositions

- Stand for facts/assertions
- Declarative statements
  - As opposed to interrogative statements (questions) or imperative statements (request, order)

Operators

\[ \text{AND}(\wedge), \text{OR}(\lor), \text{NOT}(\neg), \text{IMPLICATION}(\Rightarrow) \]

\(\Rightarrow\) and \(\neg\) form a minimal set (can express other operations)
  - Prove it.

Tautologies are formulae whose truth value is always T, whatever the assignment is
Model

In propositional calculus any formula with \( n \) propositions has \( 2^n \) models (assignments)
- Tautologies evaluate to \( T \) in all models.

Examples:
1) \( P \lor \neg P \)

2) \( \neg(P \land Q) \iff (\neg P \lor \neg Q) \)

\( \neg \)e Morgan with AND
Inferencing in PC

- Resolution
- Forward chaining
- Backward chaining
Knowledge

- Declarative knowledge deals with factoid questions (what is the capital of India? Who won the Wimbledon in 2005? etc.)
- Procedural knowledge deals with “How”
- Procedural knowledge can be embedded in declarative knowledge
Example: Employee knowledge base

Employee record
Emp id : 1124
Age : 27
Salary : 10L / annum
Tax : Procedure to calculate tax from basic salary, Loans, medical factors, and # of children
Predicate Calculus
Predicate Calculus: well known examples

- Man is mortal: rule
  $$\forall x [\text{man}(x) \rightarrow \text{mortal}(x)]$$

- Shakespeare is a man
  $$\text{man(Shakespeare)}$$

- To infer Shakespeare is mortal
  $$\text{mortal(Shakespeare)}$$
Forward Chaining/ Inferencing

- $\text{man}(x) \rightarrow \text{mortal}(x)$
  - Dropping the quantifier, implicitly Universal quantification assumed
  - $\text{man}(\text{shakespeare})$

- Goal $\text{mortal}(\text{shakespeare})$
  - Found in one step
  - $x = \text{shakespeare}$, unification
Backward Chaining/Inferencing

- $man(x) \rightarrow mortal(x)$
- Goal: mortal(shakespeare)
  - $x = shakespeare$
  - Travel back over and hit the fact asserted
  - man(shakespeare)
Wh-Questions and Knowledge

- what
- where
- who
- when
- which
- how
- why

Factoid / Declarative
- procedural
- Reasoning
Fixing Predicates

- Natural Sentences

\[ \text{Verb(subject, object)} \]

\[ \text{predicate(subject)} \]
Examples

- Ram is a boy
  - Boy(Ram)?
  - Is_a(Ram, boy)?

- Ram Playes Football
  - Plays(Ram, football)?
  - Plays_football(Ram)?
Knowledge Representation of Complex Sentence

- “In every city there is a thief who is beaten by every policeman in the city”

\[ \forall x [\text{city}(x) \rightarrow (\exists y ((\text{thief}(y) \land \text{lives_in}(y, x)) \land \forall z ((\text{policeman}(z, x) \rightarrow \text{beaten_by}(z, y))))]) \]