Artificial Intelligence

Open Elective

Module 3: Symbolic Reasoning Under Uncertainty CH7

Dr. Santhi Natarajan
Associate Professor
Dept of AI and ML
BMSIT, Bangalore

Non Monotonic Reasoning

Humans & Reasoning !!!

- We take pride in the way we reason !!!
- What exactly is reasoning?
  - A ‘process’ of thinking/arguing ‘logically’.
    - Verifications or Adaptation.
    - New deductions.

Reasoning

Predicate Logic?

- Symbolic representation of facts.
- Deduction of new facts.
- Certainty.

- In diagnosis of diseases, where system decides the disease, given the symptoms.

  What if:

  - No information for given set of symptoms.
  - Facts are not enough.
  - Multiple diseases.
  - A new case in medical history.
- In such cases, the reasoning by expert systems using Predicate Logic fails.

Monotonicity

Knowledge Properties

- Complete with respect to domain of interest. All facts necessary to solve a problem are present in the system or can be derived from those that are by the conventional rules of first order predicate logic.
- Information is consistent
- New facts can be added when they are available.
- Nothing will be retracted from the facts that are already known to be true

Non-Monotonicity

Knowledge Properties

- How can the knowledge base be extended to allow inferences to be made on the basis of lack of knowledge as well as on the presence of it?

- How can the knowledge base be updated properly when a new fact is added to the system (or when an old one is removed)?

- How can knowledge be used to help resolve conflicts when there are several inconsistent non monotonic inferences that could be drawn?

Uncertainty

- Predicate logic used - only if there is no uncertainty.
- But uncertainty is omnipresent.
- The sources of uncertainty:
  - Data or Expert Knowledge
    - Prior Knowledge.
    - Imprecise representation.
    - Data derived from defaults/assumptions.
    - Inconsistency between knowledge from different experts.
    - “Best Guesses”.
  - Knowledge Representation
    - Restricted model of the real system.
    - Limited expressiveness of the representation mechanism.
  - Rules or Inference Process
    - Conflict Resolution
    - Subsumption: To incorporate something under a more general category
    - Derivation of the result may take very long.

NMR

Intelligence in Reasoning

- Adaptability.

  Capability of adding and retracting beliefs as new information is available.

- This requires non-monotonic reasoning.

In a non-monotonic system:

- We make assumptions about unknown facts.
- The addition of new facts can reduce the set of logical conclusions.
- S is a conclusion of D, but is not necessarily a conclusion of D + {new fact}.
- Humans use non-monotonic reasoning constantly!

NMR Knowledge Base

Conflicting consequences of a set of facts:

- Rank all the assumptions and use rank to determine which to believe.
- Tag given (and some other) facts as protected, these cannot be removed or changed.

When a new fact is given:

- Get the explanation (list of contradicting facts).
- Maintain consistency.

Example of Uncertainty

- With First Order Logic we examined a mechanism for representing true facts and for reasoning to new true facts.

- The emphasis on truth is sensible in some domains.

- But in many domain it is not sufficient to deal only with true facts. We have to “gamble”.

Airport Example

- E.g., we don’t know for certain what the traffic will be like on a trip to the airport.

But how do we gamble rationally?

- If we must arrive at the airport at 9pm on a week night we could “safely” leave for the airport ½ hour before.
- Some probability of the trip taking longer, but the probability is low.
- If we must arrive at the airport at 4:30pm on Friday we most likely need 1 hour or more to get to the airport.
- Relatively high probability of it taking 1.5 hours.

Example of Uncertainty

Dental Diagnosis example.

- In FOL we might formulate

∀P. symptom(P,toothache) → disease(p,cavity) ∨ disease(p,gumDisease) ∨ disease(p,foodStuck) ∨ L

- When do we stop?
- Cannot list all possible causes.
- We also want to rank the possibilities. We don't want to start drilling for a cavity before checking for more likely causes first.

Non Monotonous Logic (NML)

Construction of sensible guesses when some useful information is lacking and no contradictory evidence is present.

Can Tweety fly???

- Birds typically fly
- Tweety is a bird.
  - **Tweety flies**

- Birds typically fly
- Penguins are birds
- Penguins typically do not fly
- Tweety is a Penguin.
  - **Tweety does not fly.**

Non Monotonous Logic (NML)

Can Tweety fly???

Bird(x) ^ **M** fly(x)-> fly(x)
Bird(Tweety)

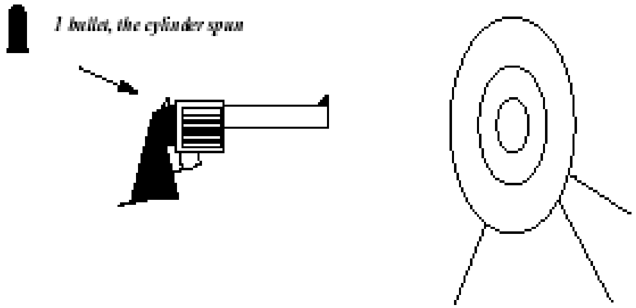
M is known as *MODAL* operator.

Read it as: *'If it is consistent to assume'*

penguin(x) -> bird(x)
penguin(x) -> ~fly(x)
penguin(Tweety)

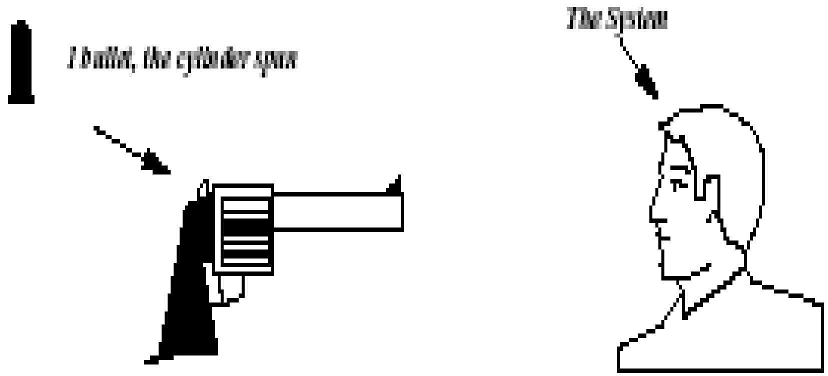
- If there is no reason to believe otherwise, assume that *fly (x)* is TRUE.
- The default is that everything is *normal*.
- Now we only need to supply additional information for *exceptions*.

Example: Russian Roulette Example



- A revolver is loaded with *1 bullet* (it has 5 empty chambers), and the cylinder is spun.
- With these stakes:
  - If correct, the system wins $1.
  - If wrong, the system loses $1.

Example: Russian Roulette Example



- Again the revolver is loaded with exactly *1 bullet* and the cylinder is spun.
- With these new stakes:
  - If correct, the system wins $1.
  - If wrong, the system loses its **life**.

In these two scenarios the uncertainty is the same, but *it is not rational* to draw the same conclusion.

Default Logic

- Default logic introduces a new inference rule:
- which states if A is deducible and it is consistent to assume B then conclude C.
- Now this is similar to Non-monotonic logic but there are some distinctions:
- New inference rules are used for computing the set of plausible extensions.
- In Default logic any non monotonic expressions are rules of inference rather than expressions.

$$\frac{\text{Prerequisite} : \text{Justification}_1, \ldots, \text{Justification}_n}{\text{Conclusion}} \qquad D = \left\{ \frac{\text{Bird}(X) : \text{Flies}(X)}{\text{Flies}(X)} \right\}$$

Default Logic

- Default logic can express facts like “by default, something is true”;
- By contrast, standard logic can only express that something is true or that something is false.

- A classical example is: “birds typically fly”. This rule can be expressed in standard logic either by “all birds fly”, which is inconsistent with the fact that penguins do not fly, or by “all birds that are not penguins and not ostriches and ... fly”, which requires all exceptions to the rule to be specified. Default logic aims at formalizing inference rules like this one without explicitly mentioning all their exceptions.

Abduction

$$\forall x : A(x) \rightarrow B(x)$$
$$A(C)$$

B (C) can be concluded by abduction

You have a cough, a fever of 101 degrees Fahrenheit, a runny nose, chills, an aching body, nausea and diarrhea. You have had these symptoms for five days. Given this information, your best guess is that you have influenza, or the flu. But you are not completely certain. This is an example of abductive reasoning.

Inheritance

Ex: Base Ball Game

In this we can combine more than one statement in the following way.

1. Adult Male (x)**:** height (x, 5'10")

Height (x, 5'10")

2. Baseball player (x)**:** height(x, 6' 1")

Height(x, 6' 1")

If it is considered to assume that, x is not a baseball player then x height is 5' 10".

∀ **x:**Adult Male (x)**:** ¬Baseball player (x) ^ Height (x, 5'10")

Height (x, 5'10")