Reasoning under Uncertainty: Issues and Other Approaches

Course: CS40022
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Default reasoning

- Some conclusions are made by default unless a counter-evidence is obtained
  - Non-monotonic reasoning

- Points to ponder
  - What's the semantic status of default rules?
  - What happens when the evidence matches the premises of two default rules with conflicting conclusions?
  - If a belief is retracted later, how can a system keep track of which conclusions need to be retracted as a consequence?
Issues in Rule-based methods for Uncertain Reasoning

- **Locality**
  
  In logical reasoning systems, if we have $A \Rightarrow B$, then we can conclude $B$ given evidence $A$, *without worrying about any other rules*. In probabilistic systems, we need to consider *all* available evidence.
Issues in Rule-based methods for Uncertain Reasoning

- Detachment
  - Once a logical proof is found for proposition B, we can use it regardless of how it was derived (*it can be detached from its justification*). In probabilistic reasoning, the source of the evidence is important for subsequent reasoning.
Issues in Rule-based methods for Uncertain Reasoning

- **Truth functionality**
  - In logic, the truth of complex sentences can be computed from the truth of the components. Probability combination does not work this way, except under strong independence assumptions.

A famous example of a truth functional system for uncertain reasoning is the *certainty factors model*, developed for the Mycin medical diagnostic program.
Dempster-Shafer Theory

- Designed to deal with the distinction between *uncertainty* and *ignorance*.

- We use a belief function $Bel(X)$ – probability that the evidence supports the proposition.

- When we do not have any evidence about $X$, we assign $Bel(X) = 0$ as well as $Bel(\neg X) = 0$. 
Dempster-Shafer Theory

For example, if we do not know whether a coin is fair, then:

\[ \text{Bel}(\text{Heads}) = \text{Bel}(\neg\text{Heads}) = 0 \]

If we are given that the coin is fair with 90% certainty, then:

\[ \text{Bel}(\text{Heads}) = 0.9 \times 0.5 = 0.45 \]
\[ \text{Bel}(\neg\text{Heads}) = 0.9 \times 0.5 = 0.45 \]

*Note that we still have a gap of 0.1 that is not accounted for by the evidence*
Fuzzy Logic

- Fuzzy set theory is a means of specifying how well an object satisfies a vague description
  - Truth is a value between 0 and 1
  - Uncertainty stems from lack of evidence, but given the dimensions of a man concluding whether he is fat has no uncertainty involved
Fuzzy Logic

The rules for evaluating the fuzzy truth, $T$, of a complex sentence are

\[
T(A \land B) = \min( T(A), T(B) ) \\
T(A \lor B) = \max( T(A), T(B) ) \\
T(\neg A) = 1 - T(A)
\]