Artificial Intelligence

Lecture 22

Uncertainty

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Outlines

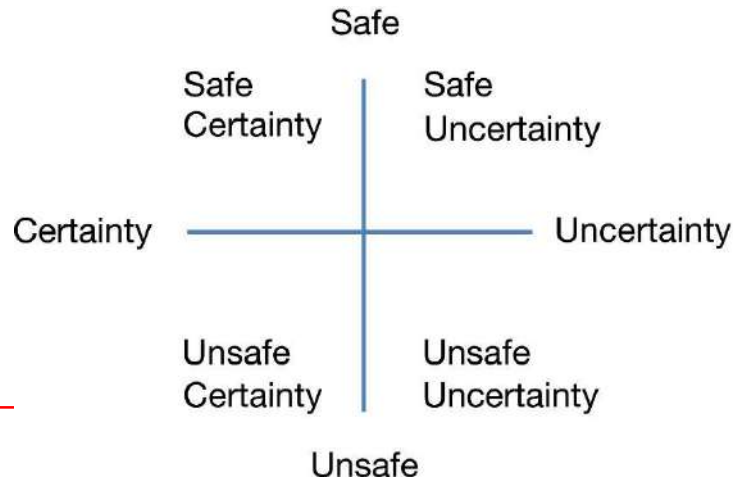
- Introduction to uncertainty
- Non-Monotonic vs Monotonic Reasoning
- Why we need more than first-order logic?
- Why do we need reasoning under uncertainty?
- …

Uncertainty…

- **Uncertainty** refers to epistemic situations involving imperfect or unknown information. It applies to predictions of future events, to physical measurements that are already made, or to the unknown.
- Uncertainty arises in partially observable and/or stochastic environments, as well as due to the lack of knowledge and information.
- It arises in any number of fields, including insurance, philosophy, physics, statistics, economics, finance, psychology, sociology, engineering, meteorology, ecology and information science.

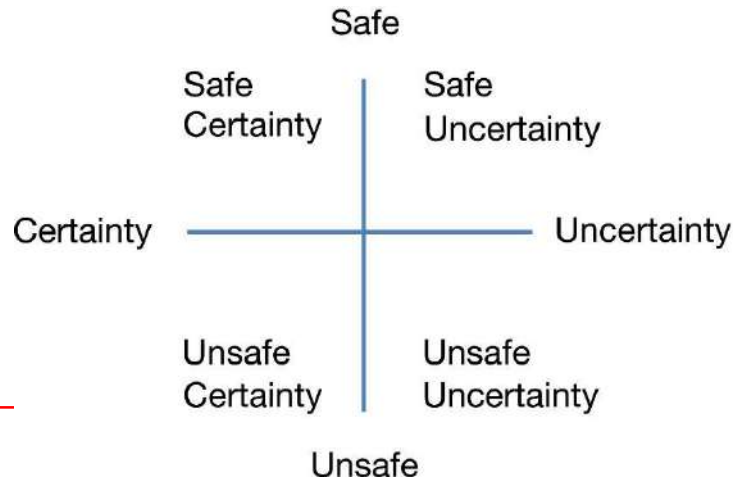
Uncertainty…

- Many specialists in various fields have defined uncertainty, risk, and their measurement as:
  - **Uncertainty:** The lack of certainty, a state of limited knowledge where it is impossible to exactly describe the existing state or a future outcome.
  - **Measurement of uncertainty:** A set of possible states or outcomes where probabilities are assigned to each possible state or outcome.
  - **Second order uncertainty:** In statistics and economics, second-order uncertainty is represented in probability density functions over (first-order) probabilities.



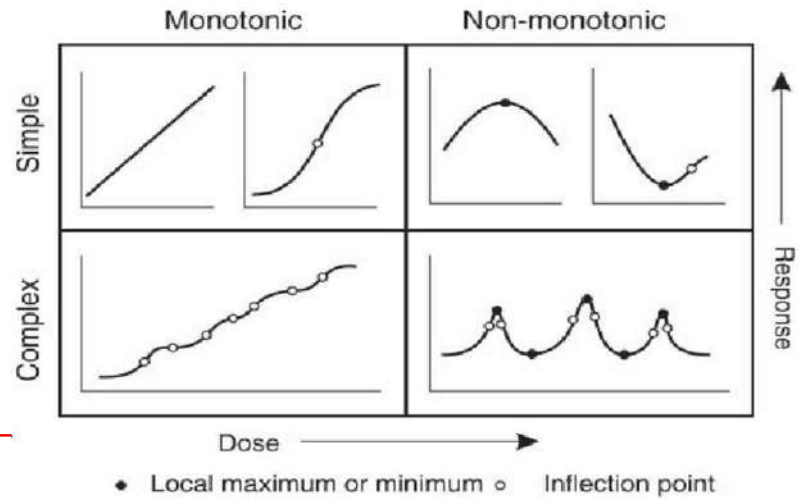
Uncertainty…

- **Risk:** A state of uncertainty where some possible outcomes have an undesired effect or significant loss.
- **Measurement of risk:** A set of measured uncertainties where some possible outcomes are losses, and the magnitudes of those losses – this also includes loss functions over continuous variables.
- **Knightian uncertainty:** In economics, Frank Knight distinguished uncertainty from risk with uncertainty being lack of knowledge which is immeasurable and impossible to calculate; this is now referred to as Knightian uncertainty. You cannot be certain about uncertainty.



Non-Monotonic vs Monotonic Reasoning…

- **Conventional reasoning systems**, such as predicate logic, are designed to work with information that has three important properties:
  - It is complete with respect to the domain of interest.
  - It is consistent.
  - The only way it can change is that new facts can be added as they become available.



Non-Monotonic vs Monotonic Reasoning

- If these (added) new facts are consistent with all the other facts that have already been asserted then nothing will ever be retracted from the set of facts that are known to be true. This property is called **monotonicity**. If something is true, it's true for all time.
- Unfortunately if any of these properties is not satisfied, conventional logic-based reasoning systems become inadequate.
- **Non-monotonic systems** on the other hand, are designed to be able to solve problems in which all of these properties may be missing. A non-monotonic logic is one in which a proposition's true value can change in time.

Why we need more than first-order logic?

- Complete ↔ incomplete knowledge: the world cannot be represented completely, there are exceptions and qualified statements.
- Generality ↔ specificity (and typicality): absolute statements ignore individual variety.
- Consistency ↔ inconsistency: conflicting views cannot be represented in first-order logic, not within one theory.
- Monotonic ↔ defeasible reasoning: a change of mind cannot be represented.
- Absolute ↔ tentative statements: partial commitment cannot be represented, statistical tendencies cannot be expressed.
- Finality ↔ openness of knowledge: learning should not only mean new theorems.

Why do we need reasoning under uncertainty?

- There are many situations where uncertainty arises:
  - When you travel you reason about the possibility of delays
  - When an insurance company offers a policy it has calculated the risk that you will claim
  - When your brain estimates what an object is it filters random noise and fills in missing details
  - When you play a game you cannot be certain what the other player will do
  - A medical expert system that diagnoses disease has to deal with the results of tests that are sometimes incorrect
- Systems which can reason about the effects of uncertainty should do better than those that don't.
- But how should uncertainty be represented?

Uncertainty

TO BE CONTINUED…