Models for Inexact Reasoning

Introduction to Uncertainty, Imprecision and Approximate Reasoning

Miguel García Remesal
Department of Artificial Intelligence
mgremesal@fi.upm.es
Uncertainty and Imprecision

• The ideal model of reasoning (human or computer-based) is the *exact reasoning*

• However, in the real world, reasonings are made with information that is either:
  – Uncertain
  – Imprecise
Uncertainty

• Uncertainty Principle (Heisenberg, 1927)
  – In quantum physics, the outcome of an ideal measurement of a system is not deterministic:
    • It is not possible to exactly determine the position and speed of a particle
  – It is characterized by a probability distribution
    • The larger the associated standard deviation is, the more "uncertain" we might say that that characteristic is for the system.
Uncertainty

• Uncertain knowledge:
  – Expressed with precise predicates
  – It is not possible to extrapolate a truth value from the statement
  – Examples:
    • I believe that John weights 80 Kg
    • It is possible that I will be visiting you at 8 pm
    • It is probable that this car can reach 200 Km/h
Imprecision

• Imprecise Knowledge:
  – Expressed with imprecise predicates
  – The variables are assigned imprecise values
  – Examples:
    • Charles is tall
    • John is between 30 and 35 years old
  – Note that “tall” and “between 30 and 35 years old” are imprecise subsets
Uncertainty vs Imprecision

• Knowledge can be exact
  – John is 1.90 m tall
• Knowledge can be imprecise but not uncertain
  – John is tall
• Knowledge can be uncertain but not imprecise
  – I believe that John is 1.90 m tall
• Knowledge can be uncertain and imprecise
  – I believe that John is tall
Sources of Uncertainty and Imprecision

- Information
  - Incomplete
    - Lack of analysis in medicine
    - Lack of field variables in control systems, etc.
  - Unreliable
    - Unrealiable measurements and analysis
    - Imprecise tools and instruments
- Noise and Distortion
  - Artificial Vision, Speech Recognition Systems, etc.
Sources of Uncertainty and Imprecision

• Knowledge
  – Uncertain/Imprecise
    • “If she has a headache \textit{probably} she has the flu”
    • “The patient has high temperature”
  – Contradictory
    • \textbf{Physician 1}: “If she has a headache \textit{probably} she has the flu”
    • \textbf{Physician 2}: “It is also \textit{possible} that she has not the flu”

• The world itself: it is imprecise and non-deterministic
Sources of Uncertainty and Imprecision

• Representation
  – Wrong choice
    • The formalism used to represent the available knowledge is not adequate
  – Lack of Expressive Power
    • The formalism does not provide enough expressive power
      – It is not possible to fully represent the background knowledge (as provided by experts)
Examples

• Incomplete Information
  – In many cases the clinical record of a given patient is not available
  – The patient cannot remember all the experimented symptoms

• Erroneous Information
  – Incorrectly described symptoms
  – The patient deliberately lies to the physician about her symptoms
Examples

• Imprecise Information
  – Non-quantifiable parameters:
    • pain
    • fatigue, etc.

• Non-deterministic world (e.g. medicine)
  – General laws cannot be applied in some situations
  – Each patient is different
    • Same causes may produce different effects in different patients with no apparent explanation
Examples

• Incomplete Models
  – Some medical phenomena arise due to unknown reasons
  – It is normally difficult to reach a consensus among different medical experts
  – If this information was available it would be difficult to include it into an expert system due to practical issues
Examples

• Examples of domains involving uncertainty and imprecision
  – Medical diagnosis and prognosis (expected outcome of a disease)
  – Financial prediction
  – Prospection (mines, petrol)
  – Image interpretation and artificial vision
  – Speech recognition
  – Monitoring/Control of complex industrial processes
Handling Uncertainty and Imprecision

• To handle uncertainty and imprecision:
  – It is necessary to take them into consideration in an explicit way at two different stages:
    • Representation
    • Inference
  – There are many different techniques that can be classified into two different groups:
    • Symbolic techniques
    • Numerical techniques
Handling Uncertainty and Imprecision

• Symbolic Approaches
  – Based in non-monotonous reasoning:
    • If there is not enough available information, the system makes assumptions than can be corrected later when new information is received
  – Default reasoning Systems (Reiter)
  – Truth Maintenance Systems (Doyle & DeKleer)
    • TMS and Assumption-based TMS
  – Theory of Endorsements (Cohen & Grinberg)
Handling Uncertainty and Imprecision

- Symbolic Approaches: Drawbacks
  - Cualitative nature \(\rightarrow\) it is difficult to take into account the different uncertainty degrees of the hypothesis
  - Present serious combinatorial explosion problems
  - Not suitable for practical applications
Handling Uncertainty and Imprecision

• Numerical Approaches
  – Theoretical Methods
    • Probabilistic Models
      – Probabilistic Logics (Nilsson)
      – Entropy Maximization
    • Dempster-Shafer Theory
    • Fuzzy Logic Theory (Zadeh)
  – Heuristic Methods
    • Certainty Factors (MYCIN, Prospector)
    • Bayesian Inference
Approximate Reasoning

• Definition:

“Reasoning involving imprecise and uncertain knowledge and made using numerical methods”