Lecture 20

Reasoning under Uncertainty(1 of 4)

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Readings:
"In Defense of Probability"
Peter Cheeseman

Presentation Overview

- Paper
  - "In Defense of Probability"
  - Author: Peter Cheeseman, SRI International
- Overview
  - Concepts in Probability
  - Common misconceptions about probability
  - Probability and Logic
  - Subjective Probability
- Goal
  - Probability is all that is needed for representing and reasoning about uncertainty
- References
  - Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Inference, by Judea Pearl

Probability (Concepts)

- Probability
  - provides a quantitative description of the likelihood of occurrence of a particular event
  - Measured on a scale from 0 to 1
- Conditional Probability
  - Denoted by P(A|B)
  - Probability that event A will occur given the knowledge that event B has already occurred
- Baye's Theorem
  - a result that allows new information to be used to update the conditional probability of an event
  - $P(H_i|E) = \frac{P(E|H_i) \cdot P(H_i)}{\sum_{n=1}^{k} P(E|H_n) \cdot P(H_n)}$

Probability Concepts (Contd.)

- Maximum Entropy
  - Entropy is a measure of the information contained in the data
  - Maximum entropy => maximum uncertainty => uniform priors
- Conditional Independence
  - When two events occurring are not related to each other in any way
  - The occurrence of an event is not dependent upon the occurrence of another event.

Presentation Outline

- Issues
  - Are the various schemes put forward for representing and reasoning about uncertainty really necessary
  - Key strengths - 'Measure of belief' definition of probability
  - Key weaknesses - highly biased opinion in favor of probability defensive approach
- Outline
  - Different approaches to probabilistic reasoning
  - Common Fallacies about probability
    - Probability as a Frequency Ratio
    - Need for large quantities of Data
    - Prior Probabilities
    - Need for numbers
    - Numbers required to represent Uncertainty
  - Logic and Probability
  - Subjective Probability

Approaches to Probabilistic Reasoning

- Statistical Approach
  - Frequency Ratio definition
    - $P(A) = \frac{\text{number of observed occurrences of event A}}{\text{total observed occurrences}}$
    - good definition provided we have enough sample data
    - Law of large numbers
- Logicist Approach
  - deals with uncertainty using nonnumeric techniques
  - nonmonotonic logic
    - a set of beliefs is assumed to be complete
    - upon uncovering of evidence to the contrary, the set of beliefs are revised to add new beliefs or to drop inconsistent beliefs.

Approaches to Probabilistic Reasoning (Contd.)

- Subjective Approach
  - Describes an individual's personal judgement about the likelihood of the occurrence of a particular event
  - Biased by the most relevant examples observed
- Bayesian Approach
  - reasoning about beliefs under uncertainty
  - P(A|K) = belief that event A occurs given certain knowledge K
  - similar to the subjective approach

Overview

- Logical approach to inference and knowledge representation is most popular
  - knowledge representations -> first order predicate logic
  - inference procedures ->logical deduction
- Human reasoning is intrinsically probabilistic
  - attempt to enforce it into a logical mould
  - alternative approaches such as default logic, nonmonotonic logic, uncertainty factor Schafer/Dempster theory, Fuzzy logic, etc. attempt to overcome some perceived difficulty of the probability theory
- Goal
  - probability is a measure of belief
  - sufficient for all uncertain inference in AI

Common Fallacies about Probability

- Probability, a frequency ratio (most common definition)
  - Definition - ratio of the number of occurrences (n) in which the event A is true to the total number of observed occurrences (m)

    $P(A) = m/n$
  - restricted to domains where repeated sampling is possible
  - law of large numbers
  - no such concept as 'the' probability
- Probability, a measure of belief (advocated definition)
  - measure of an entity's belief in that proposition, given the evidence
  - probability can be revised when new evidence comes to light
  - probability will depend on the observer's knowledge
  - probability is subjective

Common Fallacies about Probability (Contd.)

- Bayesian Analysis requires large amounts of data
  - follows from the frequency ratio definition
  - lack of available knowledge can be countered by making assumptions like conditional independence and maximum entropy
  - using maximum entropy makes stronger predictions than what the available information permits
  - detect new information
- Prior probabilities assume more information than given
  - assume uniform prior probabilities and maximum likelihood
  - there is no unique probability associated with a proposition, it is revised as more information is gained

Common Fallacies about Probability (Contd.)

- Non numeric approach is sufficient (Truth Maintenance Systems)
  - keep track of the belief and belief justification
  - maintains a dependency record for each inferred fact indicating justification in terms of both presence and absence of information
  - truth value is represented by a Boolean expression that indicates the assumptions needed for belief
  - relative probability
  - nonnumeric approaches can be used if decision making involves choosing between a set of options not if the user has a choice of not selecting any alternative
- More than one number is needed to represent Uncertainty (Schafer/Dempster)
  - uses two values, belief and plausibility
  - probability always lies within an interval set by these two values
  - accepts an incomplete probabilistic model
  - estimates the degree to which the evidence supports the hypothesis
  - the number of parameters needed depends on the questions which are to be answered

Common Fallacies about Probability (Contd.)

- Priors are not important
  - prior probabilities are subjective estimates of an expert
  - humans are not good at estimating probabilities
  - alternative is to use equiprobable priors
  - make use of whatever information is available, including priors
  - final probability is not strongly dependent upon the priors
- Vagueness (Fuzzy Logic)
  - not always possible to give a yes/no answer
  - partial membership
  - developed on the basis of the fallacy of probability being a frequency
  - probabilistic model to capture vagueness - each object has a numeric degree of membership
- Other errors

Logic and Probability

- Logical Reasoning
  - truth value of 0 or 1
  - difficult to model real world entities in this approach
  - approximation of probability
- Probabilistic Reasoning
  - different pieces of evidence are combined together to give final probability value
  - contradictions do not occur
  - no need to reject evidence which is contrary to the hypothesis
- Practical Reasoning - A combination of both logical and probabilistic reasoning

Subjective Probability

- people are poor estimators
- influenced by the most recent relevant results
- attempt to infer expert systems directly from data rather than filter them through human experts
- random sampling to find the proportion of of instances in which the predicate of interest is true
- artificial system should be based only on the basic laws of probability
- use the principle of maximum entropy in case of incomplete knowledge

Summary

- Content Critique
  - Key Contribution - promotes the principle that probability is a measure of belief, which encompasses all other definitions of probability
  - Strengths
    - Gives a brief insight into the various approaches to reasoning under uncertainty
    - convinces the reader that probability theory is sufficient for reasoning under uncertainty
  - Weaknesses
    - highly opinionated stand
    - lacking comparative analysis with alternative approaches
- Presentation Critique
  - Audience - detractors of probability theory,
  - Positive points - convincing set of examples
  - Negative points - defensive approach