

Decision Making Under Uncertainty

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Objectives of Presentation

- Introduction to **concepts** of decision analysis - formal theory for decision making under uncertainty - from a **practitioner's** viewpoint
- Approximations for representing complex uncertainties - how much detail is needed?

Simple Coin-Toss Problem

- A “fair” [$\text{prob}(\text{Heads})=0.5$] coin is flipped three (3) times.
What is the probability of three heads?

NEW INFORMATION: There was at least one head among the three resulting flip outcomes.

Now what is the probability of three heads?

Probabilities Are Conditional

- Probabilities depend on information
- New information can result in a different probability distribution

**BAYES' RULE: The way to revise probabilities to reflect
NEW INFORMATION**

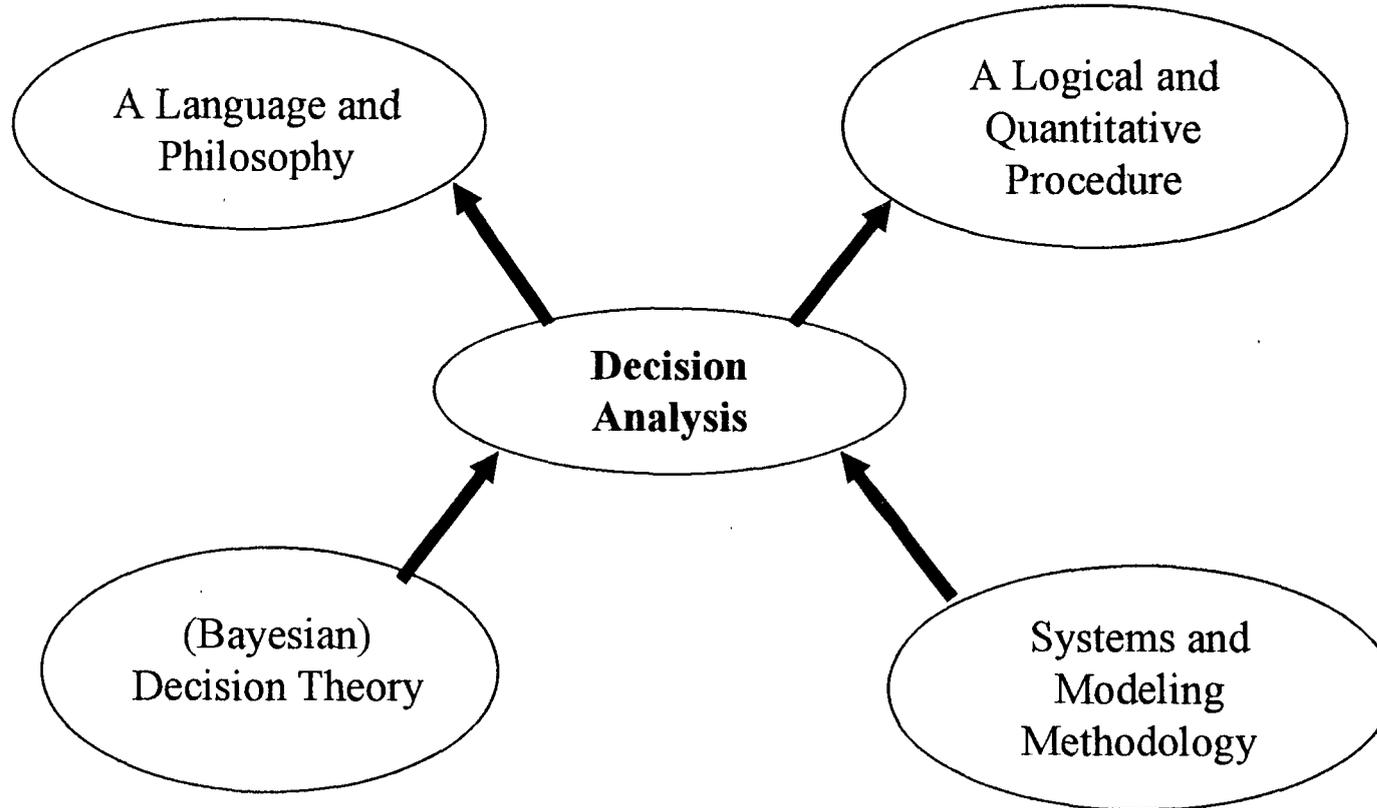
An example of Bayes' Rule: The coin example

A probability reflects a state of mind, not a state of nature

Classical and Bayesian Probability Theory

- Probabilities reflect frequencies in data - independent, identical experimental situations: Classical Statistics
- Probabilities depend on information: Bayesian
 - ◆ Subjective: betting situations
 - ◆ Necessarist: logic for reasoning about uncertainty
- **All use same axioms as basis for theory (Komogorov axioms):** $P(E) \geq 0$; $P(S) = 1$; $P(E) + P(F) = P(E \text{ or } F)$ with E,F mutually exclusive events, S certain event.

Decision Analysis: A Synthesis



Hurricane Seeding

From paper:

R.A. Howard, J.E. Matheson, D.W. North, "The Decision to Seed Hurricanes," *Science*, 176: 1191-1202 (1972).

Planetary Quarantine

From papers to be handed out:

- (1) D.W. North, B.R. Judd, and J.P. Pezier, “New Methodology for Assessing the Probability of Contaminating Mars,” *Life Sciences and Space Research XIII* - Ackademie-Verlag, Berlin, 1975, pp. 103-109.
- (2) D.W. North, “Limitations, definitions, principles and methods of risk analysis,” *Rev. sci. tech. Off. int. Epiz.*, **14**: 913-923, 1995.

Loss of Life in Airplane Accident

- What is the probability that a passenger on an airplane will be killed?
- What is the mean or expected number of fatalities per flight? Per 100,000,000 miles traveled?

Consider new information: revised probability

Quote from Robert Bernero

“Judge on a body of knowledge,
not an equation.”

R. Bernero, retired from the Nuclear Regulatory Commission, at Session 3 “The Regulatory Dilemma” at the Workshop on Disposition of HLW through Geological Isolation, Irvine, CA November 4-5, 1999)

Quote from Warner North

"Risk analysis is best used to develop insights, and not to develop numerical results which might mistakenly be considered to be highly precise. The discipline of numerical calculation can help to sharpen thinking about risks involving high levels of complexity and uncertainty and thereby enable conclusions to be drawn which could not have been reached solely on the basis of qualitative reasoning. Risk assessment provides powerful tools for reasoning, but the numerical results can easily be misinterpreted both by decision makers and stakeholders among the public." (1995 OIE paper, p. 920)

Appropriate Representation of Uncertainty in Decision Analysis

- You can't do detailed analysis of all the uncertainties in a complex decision problem - too many of them.
- Pick out the most important via sensitivity analysis - represent these via (simple) probability distributions
- Do more sensitivity analysis & value-of-information calculations - where is more detail most useful?
- My simplified guidance:
 - ◆ unimportant uncertainty - use fixed value
 - ◆ modestly important uncertainty - simple prob. distribn.
 - ◆ crucial to decision - complex probabilistic model

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**BAYES' RULE: The way to revise probabilities to reflect
NEW INFORMATION**

An example of Bayes' Rule: The coin example

Much more complex example: hurricane seeding analysis

- **A probability reflects a state of mind, not a state of nature**