Software Engineering Economics (CS656)

Economic Analysis – IV

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Coping with Uncertainties

TPS Decision Problem

- Decide to implement TPS Option B in-house
- Two primary candidates in developing OS
  - Option B-Conservative (BC)
    - Sure to work
    - Cost = $260K
    - Only achieve a peak performance of 160 tr/sec w/ 8 processor configuration
  - Option B-Bold (BB)
    - Use of the recently developed *hypermonitor* concept
    - Cost = $260K
    - Achieve a peak performance of 190 tr/sec w/ 8 processor configuration
    - If not successful, reprogram w/ Option BC, achieving 160 tr/sec and a added cost $60K

OS Development Options

	Option BB (Bold)		Option BC	Option A
	Successful	Not Successful		
Performance (tr/sec)	190	160	160	120
Value ($4K per tr/sec)	760	640	640	480
Basic cost	260	260	260	130
Total cost	260	320	260	130
Net vale NV	500	320	380	350
NV relative to Option A	150	−30	30	0

Which Option should we choose, based on net value?

Payoff Matrix: Option BC & BB

Alternative	State of Nature	
	Favorable	Unfavorable
BB (Bold)	150	-30
BC (Conservative)	30	30

Decision Rules for Complete Uncertainty

Maximin Rule

- The most pessimistic decision rule
- Determine the minimum payoff for each alternative. Choose the alternative which maximizes the minimum payoff.

Alternative	State of Nature	
	Favorable	Unfavorable
BB (Bold)	150	-30
BC (Conservative)	30	30

Maximax Rule

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Laplace (Equal-Probability) Rule

- Recognizes the relative magnitude of the payoff
- Assume all of the states of nature are equally likely. Determine the expected value for each alternative, and choose the alternative with the maximum expected value

Alternative	State of Nature		Expected Value (EV)
	Favorable	Unfavorable	
	0.5	0.5	
BB (Bold)	150	-30	60
BC (Conservative)	30	30	30

Problems with *Laplace* Rule

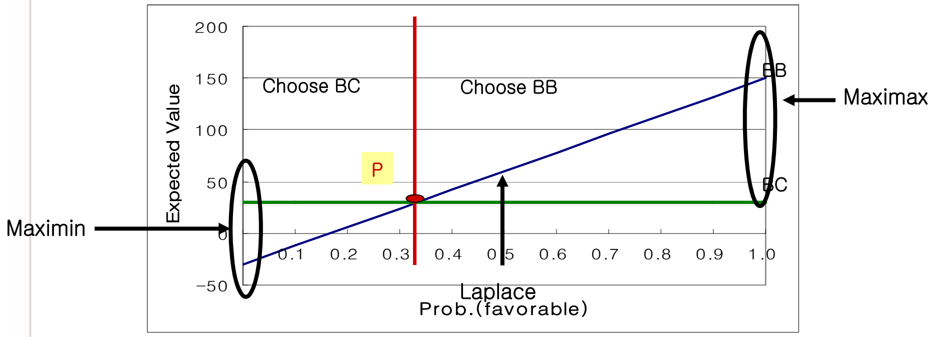
	Favorable	U_1	U_2	EV
BB	150	-30	-30	30
BC	30	30	30	30

U_1: Performance Failure of hypermonitor and U_2: Reliability Failure

- subject to pitfalls, such as duplication of the states of nature
- Nothing has changed in the real world situation, But, our labeling of the states of nature causes a significant change in the expected value and the recommended decision
  - because of the equal-probability assumption

Breakeven Analysis

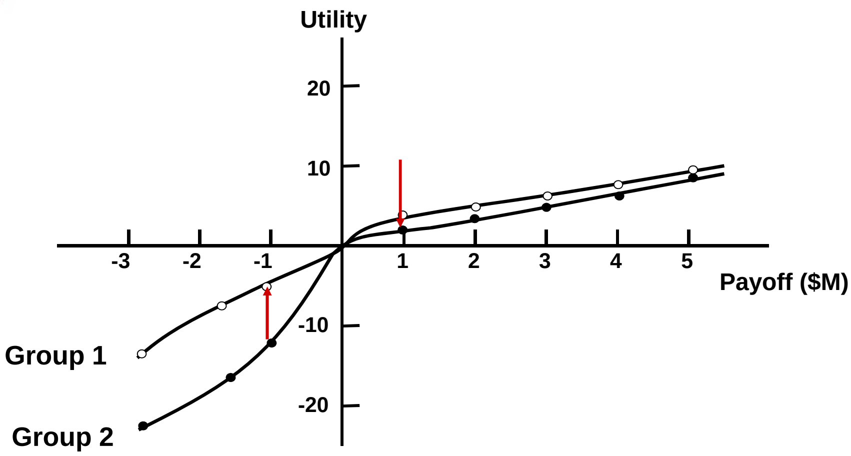
- Treat uncertainty as a parameter: P= Prob (favorable)
- Compute expected values as f(P)
  - **EV (BB) = P(250) + (1-P)(-50) = -50 + 300P**
  - **EV (BC) = P(50) + (1-P)(50) = 50**
- Determine breakeven point P such that
  - **EV (BB) = EV (BC): -50 + 300P = 50, P=0.333**



Utility Function

- Suppose you are a manager presented with the following two choices:
  - Option 1: guaranteed payoff of $60K
  - Option 2: 50% chance of a payoff of $150K, and a 50% chance of a loss of $30K
- Which one would you prefer?
  - The same expected values

Utility Function for 2 Groups of Managers



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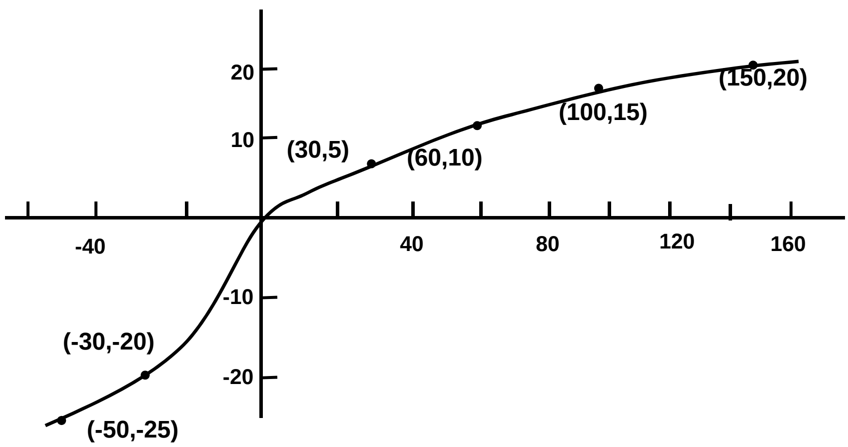
Possible TPS Utility Function



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Software Engineering Implications

- Managers prefer loss-aversion
  - EV-approach unrealistic with losses
- Managers' U.F.'S linear for positive payoffs
  - Can use EV-approach then
- People's U.F.'S aren't
  - Identical
  - Easy to predict
  - Constant

Statistical Decision Theory: The Value of Information

TPS: Decision under Uncertainty

Alternative	State of Nature	
	Favorable	Unfavorable
BB (Bold)	150	-30
BC (Conservative)	30	30

- Available decision rules are inadequate
  - Absence of any information about the probable occurrence of the states of nature
- Need better information
- Information → Considerable Economic Value in decision problems under uncertainty

Expected Value of Perfect Information

- Build a Prototype for $10K
  - **If prototype succeeds, choose BB**
    Payoff: $150K – 10K = $140K
  - **If prototype fails, choose BC**
    Payoff: $30K – 10K = $20K
- If equally likely,
  Ev = 0.5 ($140K) + 0.5 ($20K) = $80K
- Could invest up to $30K and do better than before
  - **thus, EVPI = $30K**

Working with Imperfect Information

- Can not obtain perfect Information
  - By a Prototype or other investigations
- Two Sources of Imperfection expressed as probabilities

$P(IB|SF) \neq 0.0$

Investigation (Prototype) would lead us to choose bold alternative in a state of nature in which the Bold option will fail

$P(IB|SS) \neq 1.0$

Investigation (Prototype) would lead us to choose bold alternative in a state of nature in which the Bold option will succeed

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Example

- Suppose we assess the prototype's imperfections as
  P(IB|SF) = 0.20, **P(IB|SS) = 0.90**
- Suppose the states of nature are equally likely
  P(SF) = 0.50 **P(SS) = 0.50**
- Compute the expected value of using the prototype
  EV(IB,IC) = P(IB) (Payoff if use Bold)
  +P(IC) (Payoff if use Conservative)

  = P(IB) [P(SS|IB) ($150K) + P(SF|IB) (-$30K)] + P(IC) ($50K)

But these are the probabilities we don't know

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How to get the probabilities we need

$$P(IB) = P(IB|SS)P(SS) + P(IB|SF)P(SF)$$

$$P(IC) = 1 - P(IB)$$

$$P(SS|IB) = \frac{P(IB|SS)P(SS)}{P(IB)}$$ ⇐ Bayes' Formula

$$P(SF|IB) = 1 - P(SS|IB)$$

P(SS|IB) = $\frac{\text{Prob(we will choose Bold in a state of nature where it will succeed)}}{\text{Prob(we will choose Bold)}}$

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Expected Value for TPS

$$P(IB) = (0.50)P(0.90) + (0.50)P(0.20) = 0.55$$

$$P(IC) = 1 - 0.55 = 0.45$$

$$P(SS \mid IB) = \frac{(0.50)(0.9)}{0.55} = 0.82$$

$$P(SF \mid IB) = 1 - (0.82) = 0.18$$

$$EV(IB, IC) = (0.55)[(0.82)(\$105K) + (0.18)(\$-30K)] + (0.45)(\$30K)$$
$$= (0.55)(\$117.6K) + \$13.5K = \$78.2K$$

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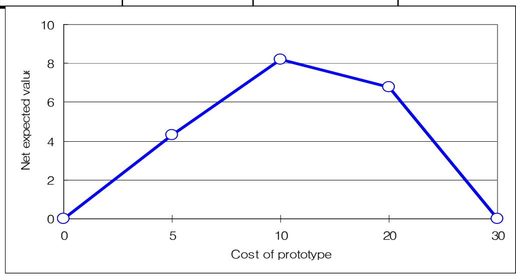
Net Expected Value Maximization

Cost of Prototype, $K	Estimated		Expected Value, $K	Expected Value of Information	Net Expected Value, $K
	P (PS|SF)	P (PS|SS)			
0			60	0	0
5	0.30	0.80	69.3	9.3	4.3
10	0.20	0.90	78.2	18.2	8.2
20	0.10	0.95	86.8	26.8	6.8
30	0.00	1.00	90	30.0	0



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Value of Information in SE

- Value of Information Procedure
  - Can help to resolve a number of key software engineering decisions

  "How much should we invest in further information gathering and analysis investigations before committing ourselves to a course of action"
- Four major issues of this nature in SE

  How much should we invest in:
  - **Feasibility studies**
  - **Alternative vendor h/w-s/w product analysis**
  - **Risk analysis**
  - **V & V**

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Conditions for Successful Prototyping

1. There exist alternatives whose payoffs vary greatly depending on some states of nature.
2. The critical states of nature have an appreciable probability of occurring.
3. The prototype has a high probability of accurately identifying the critical states of nature.
4. The required cost and schedule of the prototype does not overly curtail its net value.
5. There exist significant side benefits derived from building the prototype.

Pitfalls Avoided by Using VOI

1. Always build a prototype or simulation
   - **May not satisfy conditions 3,4**
2. Always build the software twice
   - **May not satisfy conditions 1,2**
3. Build the software purely top-down
   - **May not satisfy conditions 1,2**
4. Prove every piece of code correct
   - **May not satisfy conditions 1,2,4**
5. Nominal-case testing is sufficient
   - **May need off-nominal testing to satisfy conditions 1,2,3**

Q & A

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