Evidential Reasoning Framework for Trust Services

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Outline

- Introduction and Objectives
- Evidential Reasoning Framework for Trust Services
- Dempster-Shafer Theory of Belief Functions
- Evidential Diagram
- Decision Theoretic Approach for Cost-Benefit Analysis.
- Conclusion and Discussion

Evidential Reasoning in Assurance Services

Definition of Assurance Services: Collection, evaluation, and aggregation of evidence to decide whether the assertion on which an opinion is being provided is true or not true.

For a Financial Statements audit …to determine whether the Financial Statements are fairly stated.

Introduction

- The main purposes of this paper:
  - To provide a structured framework for aggregating evidence for making overall judgment about the system's reliability in the context of Trust Services.
    - The framework is based on the evidential reasoning approach of Srivastava (1995) and uses the criteria established by AICPA/CICA for Trust Services to develop the evidential diagram.
  - To develop a decision theoretical approach for cost-benefit analysis.

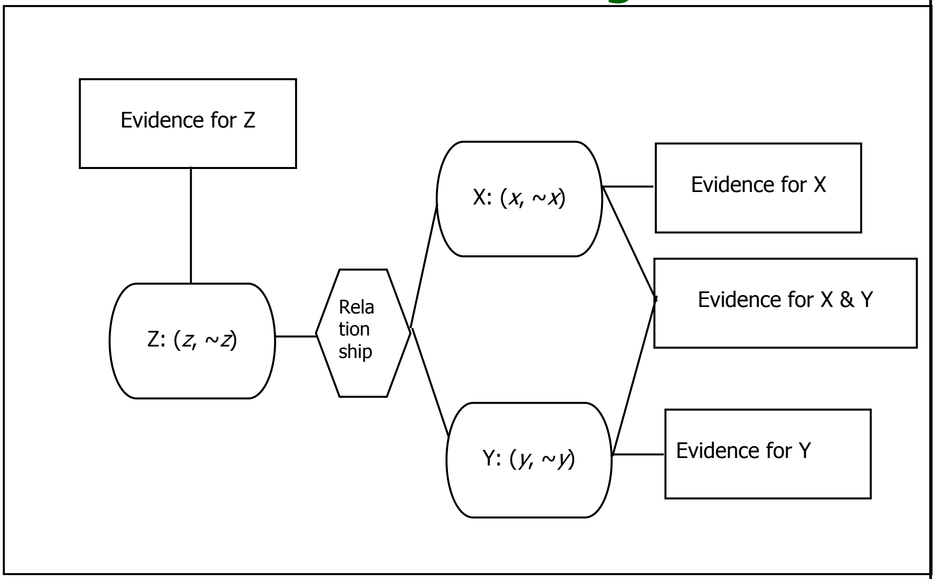
Introduction (Continued)

- Companies are now relying heavily on information systems more than ever before.
- It is imperative that IT systems be protected and reliable.
- In response to the growing concerns about reliabilities of systems, AICPA/CICA developed Trust Services, which incorporate "SysTrust" and "WebTrust" assurance services (AICPA 2003).
  - Five main assertion categories underlying reliable business systems: Security; Availability; Processing Integrity; Online Privacy; Confidentiality.

Introduction (Continued)

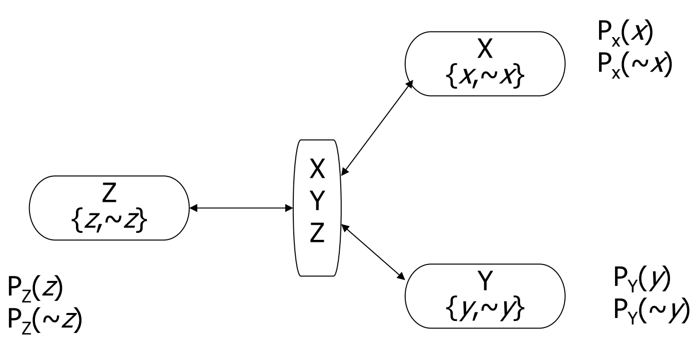
- A company's information system is a complex system.
- The existing methodologies (see. Post and Diltz 1986; Rainer et al. 1991) are inadequate in properly incorporating complexities of risk.
- The representing uncertainties associated with items of evidence is another problem.
  - Probability theory does not provide a natural and logical way to model uncertainties encountered in the real world.
  - In contrast, Dempster-Shafer theory of belief functions provides a better framework for modeling such uncertainties (see, e.g., Gordon and Shortliffe 1990, Shafer and Srivastava 1990, and Srivastava and Mock 2000).
  - Empirical evidence shows the better performance of belief functions in mapping the uncertainty judgments (Harrison et al 2002; Curley and Golden 1994) .
- The evidential reasoning approach under DS theory of belief functions provides a structured approach for evaluating and aggregating all the evidence gathered in the process.

An Evidential Diagram



Evidential Reasoning in Probability

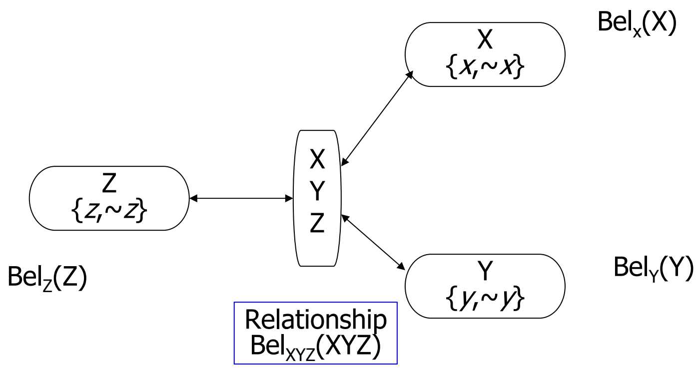
Propagation of uncertainty through a Network



Relationship
$P_{XYZ}(XY|Z)$, $P_{XYZ}(Z|XY)$

Evidential Reasoning in Belief Functions

Propagation of uncertainty through a Network



Evidential Reasoning Framework for Trust Services

- Five steps in developing and using the evidential reasoning approach for Trust Services:
  - Step 1: Identify assertions and sub-assertions for the engagement.
  - Step 2: Connect these assertions and sub-assertions through logical relationships such as "and", "or" as appropriate.
  - Step 3: Identify items of evidence pertaining to specific assertions and sub-assertions identified in Step 1 and link them to the corresponding assertions and sub-assertions.
  - Step 4: Collect and evaluate various items of evidence identified in Step 3 and express these evaluations in terms of belief functions.
  - Step 5: Aggregate all the items of evidence using Dempster's rule of combination to obtain the overall belief that the assertion is met or not met.

Problems with Probability Framework: An Example

1. Problems with interpreting risks as probability numbers:

SAS 47: AR = IR.CR.APR.DR

Consider the following situations:
(i) If the auditor does not want to depend on the inherent factors, the profession suggests to set IR = 1.
What does this mean in probability theory? P(E) = 1

(ii) If the auditor wants to depend on the inherent risk factors, which are favorable but not very strong, the profession suggests to set IR to a lower value, say, IR = 0.8.

What does this mean in probability theory? P(E)=.8, P(~E)=.2

iii) The auditor feels that inherent factors are really strong and positive then the profession suggests to reduce IR further, say, IR = 0.5.

What does this mean in probability theory? P(E)=.5, P(~E)=.5

Probability versus Belief Functions

- Probability Framework:

$$\text{Frame} = \Theta = \{a_1, a_2, a_3\},$$
$$P(a_i) \geq 0$$
$$P(a_1) + P(a_2) + P(a_3) = 1,$$
$$\text{Also, } P(A) + P(\sim A) = 1.$$

- Belief Function Framework:

$$\text{Belief Mass: } m(a_i), m(\{a_i, a_j\}), m(\{a_1, a_2, a_3\}) \geq 0,$$
$$\Sigma_{A\subseteq\Theta} m(A) = 1.$$

m(..) represents the belief mass distribution function over the superset of the frame Θ. We refer to this function as the *basic belief assignment function.*

Belief Functions-Axioms

Axioms: If Θ is a frame of discernment, then a function Bel: $2^{\Theta} \to [0, 1]$ is a belief function if and only if it satisfies the following conditions:

(1) $Bel(\emptyset) = 0$.

(2) $Bel(\Theta) = 1$.

(3) For every positive integer n and every collection $A_1, \ldots, A_n$ of subsets of Θ,

$Bel(A_1 \cup \ldots \cup A_n) \geq \Sigma_{I \subset \{1, \ldots, n\}} (-1)^{|I|+1} Bel(\cap_{i \in I} A_i)$.

Belief Functions and Plausibility Functions

$$Bel(A) = \sum_{B \subseteq A} m(B)$$

$$Pl(A) = \sum_{A \cap B \neq \emptyset} m(B) = 1 - Bel(\sim A)$$

Simple Example

<u>Analytical Procedure:</u>

m(a) = 0.3, m(~a) = 0, m({a,~a}) = 0.7

Based on the above evidence:

Bel(a) = 0.3,

Bel(~a) = 0,

Pl(a) = 1.0,

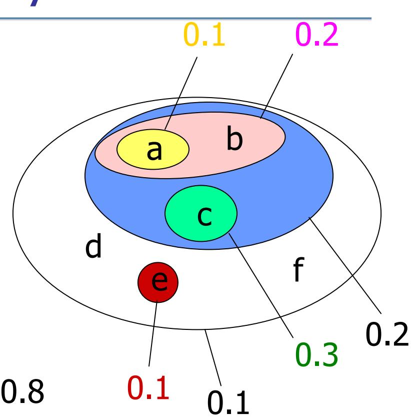
Pl(~a) = 0.7,

Plausibility that material errors are present defines the risk (Analytical Procedure Risk)

Complex Example: Belief Functions and Plausibility Functions

$$\mathrm{Bel}(A) = \sum_{B \subseteq A} m(B)$$

m(a) = .1, m({a,b}) = 0.2,
m(c) = 0.3, m({a,b,c}) = 0.2
m(e) = 0.1, m({a,b,c,d,e,f}) = 0.1



Bel({a,b,c}) = m(a) + m({a,b}) + m(c)+ m({a,b,c}) = 0.1+0.2+0.3+0.2 = 0.8

$$\mathrm{Pl}(A) = \sum_{A \cap B \neq \emptyset} m(B) = 1 - \mathrm{Bel}(\sim A)$$

Pl({a,b}) = m(a) + m({a,b}) + m({a,b,c}) + m({a,b,c,d,e,f})
= 01.+ 0.2 + 0.2+ 0.1 = 0.6

Security: Objectives and Sub-objectives

1.1. Protection against unauthorized logical access

- Policies exist to ensure systems are protected against unauthorized logical access.
- System security policies pertaining to logical access are communicated to authorized users.
- Procedures exist to protect against unauthorized logical access.

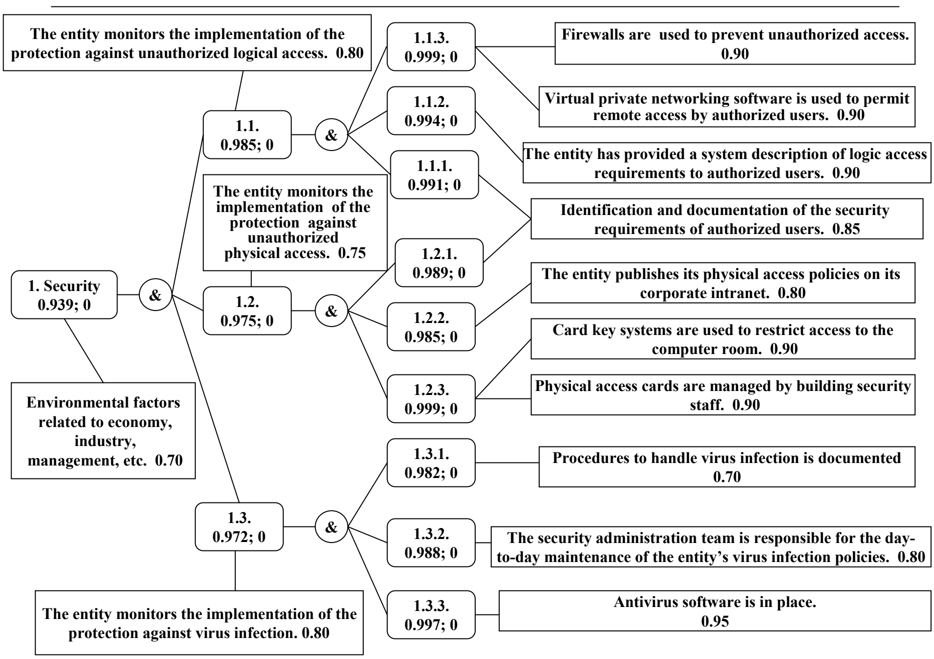
1.2. Protection against unauthorized physical access

- Policies exist to ensure systems are protected against unauthorized physical access.
- System security policies pertaining to physical access are communicated to authorized users.
- Procedures exist to protect against unauthorized physical access.

1.3. Protection against infection by computer viruses

- Policies exist to ensure systems are protected against virus infection.
- System security policies pertaining to virus infection are
- communicated to authorized users.
- Procedures exist to protect against virus infection.

Figure 1 Evidential Diagram for "System Security" Assurance



Decision Theoretical Approach for Cost-Benefit Analysis

- The management will buy the assurance service when:

$$F + \sum_{i=1}^{5} m'_A(\sim a_i)L_i \le \sum_{i=1}^{5} m'_{NA}(\sim a_i)L_i$$

- For the most conservative case ($\rho = 0$), the management will buy the assurance service when:

$$F + \sum_{i=1}^{5} \{1 - m_A(a_i)\}L_i \le \sum_{i=1}^{5} \{1 - m_{NA}(a_i)\}L_i$$

or

$$F \le \sum_{i=1}^{5} \{m_A(a_i) - m_{NA}(a_i)\}L_i$$

Decision Theoretical Approach for Cost-Benefit Analysis

- The break-even dollar amount for a company to obtain the assurance service is determined by:
  - The management's own beliefs on its system reliability in terms of the five principles before obtaining the assurance service;
  - The management's own beliefs on its system reliability in terms of the five principles after obtaining the assurance service;
  - The degree of loss associated with each principle if it is not met;
  - Management's attitude towards resolving the ambiguity (ρ);
  - The audit fee for the assurance service.

Conclusion and Discussion

- The approach proposed in the paper
  - uses Dempster-Shafer theory of belief functions for modeling uncertainties associated with the evidence gathered in the process.
  - allows the decision makers to incorporate relevant relationships and interdependencies among assertions and items of evidence.
- The cost-benefit analysis shows
  - the break-even point for a company to obtain the Trust Service.
  - the factors influencing a company's purchase decision of the assurance services.
- Future research
  - Develop an analytical model of the assurance services
  - Empirical work is needed to demonstrate the value of evidential reasoning approach to Trust Services.

Prior Publications & Applications

- Financial Statement Assurance: Srivastava, R. and G. Shafer. 1992. Belief-Function Formulas for Audit Risk. *The Accounting Review*.
- Risk of Impaired Independence: Turner, J., T. Mock, and R. Srivastava. 2002. A Formal Model of Auditor Independence Risk. *Australian Accounting Review*.
- WebTrust Assurance: Mock, T. and R. Srivastava. 2000. Evidential Reasoning for WebTrust Assurance Services, *Journal of Management Information Systems.*
- Fraud Risk Assessment: Mock, T., J. Turner & R. Srivastava. 2002. A Conceptual Framework and Case Studies on Audit Planning and Evaluation Given the Potential for Fraud. Deloitte & Touche /University of Kansas Symposium On Auditing Problems.
- Health Care Audit: Srivastava, R. P., S. K. Dutta, and R. Johns. 1996. An Expert System Approach to Audit Planning and Evaluation in the Belief-Function Framework. *International Journal of Intelligent Systems in Accounting, Finance and Management.*
- Information Quality: Bovee, M, R. P. Srivastava, and B. Mak. 2003. A Conceptual Framework and Belief-Function Approach to Assessing Overall Information Quality. *International Journal of Intelligent Systems.*
- Causal Mapping: Srivastava, Buche & Roberts. 2004. Belief Function .. in Causal Maps. In *Causal Mapping for Information Systems and Technology Research: Approaches, Advances and Illustrations* (Forthcoming).

Current Research Applications

- Risk of Impaired Independence: Turner, J., T. Mock, and R. Srivastava. 2004. *A Model for Assessing the Risk of Impaired Auditor Independence.*
- Fraud Risk Assessment: Srivastava, R., T. Mock & J. Turner. 2004. *A Comprehensive Model of Financial Statement Fraud Risk*
- Audit Risk assessment: Srivastava, R., J. Turner & T. Mock. 2004. *The Evolution of Audit Risk: Integrating Fraud Risk into the Audit Risk Model*
- Information System Security Assurance: Sun, L., R. Srivastava & T. Mock. 2004. *Risk Analysis of Information Systems Security: An Evidential Reasoning Approach*
- SysTrust Assurance Services*:* Chan Li and R. Srivastava
- Assurance on the Internal Control over Financial Reporting [SOX 404]: Research proposal by Sun, L., R. Srivastava & T. Mock.

Other Applications

- Value Judgment (Srivastava, *Research in Accounting Ethics*, Vol. 2, 1996, pp. 109-130)
- Decision Making under Ambiguity (Srivastava, *Archives of Control Sciences,* Vol. 6 (XLII), 1997, No. 1-2, pp. 5-27

Papers on belief functions are available from the following website:

http://www.eycarat.ku.edu/CARAT/research/belief.htm

Thank You!