Expert Systems with Applications 39 (2012) 3611–3623

Contents lists available at SciVerse ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

Assessment of E-Commerce security using AHP and evidential reasoning

Yajuan Zhang [a,b], Xinyang Deng [a,b], Daijun Wei [a,b], Yong Deng [a,b,c,*]

[a] School of Computer and Information Sciences, Southwest University, Chongqing 400715, China
[b] Hangzhou Key Lab of E-Business and Information Security, Hangzhou Normal University, Zhejiang 310036, China
[c] School of Electronics and Information Technology, Shanghai Jiao Tong University, Shanghai 200240, China

ARTICLE INFO

Keywords:
E-Commerce security
Analytical Hierarchical Process
Evidential reasoning
Dempster–Shafer theory

ABSTRACT

In the development of E-Commerce, security has always been the core and key issue. In this paper, a new model is proposed to assist E-Commerce practitioners in the assessment of E-Commerce security. The proposed model is based on Analytical Hierarchy Process (AHP) and Dempster–Shafer (DS) theory of evidence. First, according to the characteristics of E-Commerce, a hierarchical structure of E-Commerce security is established to calculate the weights of relevant issues using AHP. Then Dempster–Shafer theory of evidence is applied to combine all the issues, regarded as evidences, in order to derive a consensus decision for the degree of E-Commerce security. An illustrative example is given to show the efficiency of our model.

1. Introduction

With the development of information technology and communication technology and the popularization of the Internet, E-Commerce is sweeping through all walks in world with an irreversible trend. E-Commerce holds many advantages for the commercial world, such as efficiency and convenient, but unfortunately there are also some disadvantages. Due to the virtuality of E-Commerce and the open of the Internet, security issues are emerging and have become the bottleneck of E-Commerce development (Gerber & von Solms, 2001).

The study of Ngai and Wat (2002) indicated that 42% of the articles in topics of technological issues, were on E-Commerce security. And many researches have been conducted on a variety of security technologies, such as: E-Commerce protocols (Adi, Debbabi, & Mejri, 2000; Brlek, Hamadou, & Mullins, 2006; Ogata & Futatsugi, 2010), user authentication (Lin & Chang, 2009), electronic signatures (Srivastava, 2009), electronic payment (Guan, Tan, & Hua, 2004) and so on. The investigation of Belanger, Hiller, and Smith (2002) indicated that consumers valued specific security technologies significantly more than three other trust indices, which are third party privacy seals, privacy statements and third party security seals. However, technology protections alone are far from enough. A number of security issues should be take into consideration to increase the whole security of E-Commerce, such as: legal security (de Lamberterie, 2003), physical security (Furnell, 2004), managerial security (Tomlinson, 2000) and so on (Oosthuizen, 1998; Tsiakis & Sthephanides, 2005).

In addition, some of the studies on E-Commerce security were focused on E-Commerce security solutions. Zuccato (2004, 2005) proposed an approach to elicit security requirements and then developed a security management framework to improve E-Commerce security. Meanwhile, an adaptive secure methodology has been proposed by Tak and Park, to support non-repudiation service in E-Commerce and provides E-Commerce transactions with high quality of security services (Tak & Park, 2004).

However, because of the limitation of security technology and the complexity of security issues, it is difficult to find a complete and absolute secure E-Commerce security solution. Therefore, some qualitative and quantitative analysis and necessary assessment of E-Commerce security will be imperative. Best to our knowledge, we do not find any works on constructing comprehensive model to assess the E-Commerce security. This paper is primarily concerned with providing a model to solve such problems. Analytic Hierarchy Process (AHP) integrated with Dempster–Shafer (DS) theory of evidence is used in the model to assist in the assessment of E-Commerce security.

The paper is organized as follows. Section 2 begins with a brief introduction to the basic theory used in the model. Then, procedure of the proposed model for evaluating E-Commerce security is depicted in Section 3. And a numerical example is presented in Section 4. Section 5 concludes the paper.

2. Preliminaries

2.1. Analytical Hierarchy Process

Analytical Hierarchy Process (AHP) developed by Saaty (1980) is a powerful tool for handling both qualitative sand quantitative

* Corresponding author at: School of Computer and Information Sciences, Southwest University, Chongqing 400715, China.
E-mail address: ydeng@swu.edu.cn (Y. Deng).

0957-4174/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.eswa.2011.09.051

multi-criteria factors in decision-making problems. With this method, a complicated problem can be converted to an ordered hierarchical structure. AHP method has been widely applied to multi-criteria decision making situations, such as: web sites selection (Ngai, 2003), tools' evaluation (Ngai & Chan, 2005), weapon selection (Deng & Shen, 2006), drugs selection (Vidal, Sahin, Martelli, Berhoune, & Bonan, 2010) and so on Chen and Wang (2010), Amiri (2010).

The first step of AHP is to establish a hierarchical structure of the problem. Then, in each hierarchical level, use a nominal scale to construct pairwise comparison judgement matrix.

Definition 2.1. Assuming $(E_1,\ldots,E_i,\ldots,E_n)$ are n decision elements, the pairwise comparison judgement matrix is denoted as $M_{n\times n}=[m_{ij}]$, which satisfies:

$$m_{ij}=\frac{1}{m_{ji}} \tag{1}$$

where each element m_{ij} represents the judgment concerning the relative importance of decision element E_i over E_j.

With the matrix constructed, the third step is to calculate the eigenvector of the matrix.

Definition 2.2. Eigenvector of $n\times n$ pairwise comparison judgement matrix can be denoted as: $\vec{w}=(w_1,\ldots,w_i,\ldots,w_n)^T$, which is calculated as follows:

$$A\vec{w}=\lambda_{\max}\vec{w},\quad \lambda_{\max}\geqslant n \tag{2}$$

where $\lambda_{\max}$ is the maximum eigenvalue in the eigenvector $\vec{w}$ of matrix $M_{n\times n}$.

Before we transform the eigenvector into the weights of elements, the consistency of the matrix should be checked.

Definition 2.3. Consistency index (CI) (Saaty, 1990) is used to measure the inconsistency within each pairwise comparison judgement matrix, which is formulated as follows:

$$CI=\frac{\lambda_{\max}-n}{n-1} \tag{3}$$

Accordingly, the consistency ratio (CR) can be calculated by using the following equation:

$$CR=\frac{CI}{RI} \tag{4}$$

where RI is the random consistency index. The value of RI is related to the dimension of the matrix, which is listed in Table 1.

If the result of CR is less than 0.1, the consistency of the pairwise comparison matrix M is acceptable. Moreover, the eigenvector of pairwise comparison judgement matrix can be normalized as final weights of decision elements. Otherwise, the consistency is not passed and the elements in the matrix should be revised.

2.2. Dempster–Shafer (DS) theory of evidence

The DS theory of evidence, which was first proposed by Dempster (1967) and then developed by Shafer (1976), is regarded as a generalization of the Bayesian theory of probability. With the ability of coping with the uncertainty or imprecision embedded in evidence, the DS theory has been widely applied in recent years (Deng & Chan, 2011; Deng, Chan, Wu, & Wang, 2011; Dymova, Sevastianov, & Bartosiewicz, 2010; Hu, Si, & Yang, 2010; Huynh, Tri, & Cuong, 2010; Mas, Salinas, Cuevas, & Carnicer, 2010; Wang, Yang, & Xu, 2006). Yang et al. have developed DS theory to deal with multiple attribute decision analysis problems (Yang, Wang, Xu, & Chin, 2006; Wang, Yang, Xu, & Chin, 2006; Xu, Yang, & Wang, 2006). And a framework based on DS theory of belief functions has been designed for sensor reliability evaluation in classification problems (Guo, Shi, & Deng, 2006). Meanwhile, Khokhar et al. have applied the theory in a decision making system for risk assessment of E-Commerce projects (Khokhar, Bell, Guan, & Wu, 2006). What's more, a method based on DS theory is introduced by Deng, Jiang, and Sadiq (2011) to estimate the "risk" of contaminant intrusion in a water distribution network.

Table 1
The value of RI (random consistency index).

Dimension	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49

Table 2
Ultimate factors associated with E-Commerce.

Variables	Description of the variables
V_1	data backup and restore
V_2	Local area network (LAN) security
V_3	Web server security
V_4	Firewall security
V_5	Operating system (OS) security
V_6	Applications security
V_7	Database security
V_8	Terminal security
V_9	Identity authentication
V_{10}	E-Commerce protocol
V_{11}	Electronic payment security
V_{12}	Data encryption mechanism
V_{13}	Digital signature mechanism
V_{14}	Completeness of international legal standards
V_{15}	Stability of legal landscape
V_{16}	Certainty of legal jurisdiction
V_{17}	Cultural difference between customers
V_{18}	Language barrier
V_{19}	Security awareness of staffs
V_{20}	Equipped with the key technical personnel
V_{21}	Human resource management
V_{22}	Equipment protection and maintenance
V_{23}	Site security
V_{24}	Key management
V_{25}	User password management
V_{26}	Privilege management
V_{27}	Logistics management

The introduction of the DS theory are briefly reviewed as the following. Let Θ denote a finite nonempty set of mutually exclusice and exhaustive hypotheses, called *the frame of decernment*.

Definition 2.4. A mass function is a mapping m: $2^{\Theta}\rightarrow[0,1]$, which satisfies:

$$m(\emptyset)=0\quad\text{and}\quad\sum_{A\subseteq\Theta}m(A)=1 \tag{5}$$

A mass function is also called a *basic probability assignment (BPA)* to all subsets of Θ.

There are two useful oprerations which play a crucial role in evidential reasoning, that is *discounting* and *Dempster's rule of combination*.

Definition 2.5. Discounting Evidences: If a source of evidence provides a mass function m which has probability α of reliability. Then the discounted belief m′ on Θ is defined as:

$$m'(A)=\alpha m(A),\quad\forall A\subset\Theta,\quad A\neq\Theta \tag{6}$$

$$m'(\Theta)=1-\alpha+\alpha m(\Theta) \tag{7}$$

All mass function is discounted by α, which is called discount coefficient.