Optik 125 (2014) 2104–2108

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

A kind of network survivability assessment model based on subjective logic

Hongqiang Jiao [a,b,*], Limin Jia [a], Wanning Ding [a]

[a] Electronic and Information Engineering Experiment and Training Center, Handan College, China
[b] School of Management, Hebei University, 071002 Baoding, Hebei, China

ARTICLE INFO

Article history:
Received 9 May 2013
Accepted 10 October 2013

Keywords:
Dynamic survivability assessment
Subjective Logic
Trajectory of the opinion
Fitting line

ABSTRACT

This paper improved the Jøsang's subjective logic through the establishment of rectangular coordinate system, study on subjective logic properties in the two-dimensional image and using fitting line algorithm to depict dynamic trajectory of the opinion. At the same time, the Consensus operator was improved and made it more realistic. On this basis, this paper proposed a network survivability assessment model. It established a set of indicator system that could reflect the survivability and the formal description was given. Using the structures of the network environment for testing, the simulation results show that the indicator system is normative and complete. This model has higher sensitivity and effectiveness, which can better adapt to dynamic changes in the assessment of environment.

1. Introduction

The research on network information system survivability is a breakthrough and innovation to the concept about traditional network security. Its core idea is that the systems can complete the task and repair the damaged service timely after the intrusion or the important part of systems are destroyed [1]. While the survivability evaluation, especially the quantitative characterization of survivability of information system survivability, is the important foundation of existing research, mainly from the system the actual communication connection reliability, performance of system security, system task and goal achievement, analyze, and not on performance indicator are discussed and the relevant definitions [2]. Moitra S.D. et al described the survivability approach to helping assure that a system that must operate in an unbounded network is robust in the presence of attack and will survive attacks that result in successful intrusions [3]. D.-Y. Chen et al proposed a quantitative approach to evaluate network survivability [4]. They perceived the network survivability as a composite measure consisting of both network failure duration and failure impact on the network. Survivability is significantly more difficult to quantify than fault tolerance, and it has been formalized as a set-theoretic and state-machine based formulation: survivability = {S; E; D; V; T; P} [5]. Survivability has also been quantified using multidimensional Markov chains to consider simultaneous failures; however, it is not obvious how to evaluate the management schemes, not only because the size and complexity of the problem is a huge modeling challenge, but also because the definition, metrics, and quantification methods of survivability are anything but clear. Survivable system and survivable network have been designed and evaluated in the literature for many years. Y. Liu et al [6] presented a general survivability quantification approach that is applicable to a wide range of system architectures, applications, failure/recovery behaviors, and metric. The many definitions of survivability can be summarized as survivability is the system's ability to continuously deliver services in compliance with the given requirements in the presence of failures and other undesired events [7], in which one dimension captures the failure of components and the other dimension the perform ability. Sterbenz provides an architectural framework for resilience and survivability in communication networks and provides a survey of the disciplines that resilience encompasses, along with significant past failures of the network infrastructure [8]. Wang et al. presented a quantitative evaluation method based on gray relation analysis is proposed. The typical gray relation analysis method is improved and the quantitative evaluation model based on the network entropy of information is established. The change of every key service's survivability situation is assessed by using the network entropy of information [9]. Wang et al. provides a complete overview on survivability index from the aspects of index content, attack phases and evaluating standard [10] and other related work [18]. In this paper, a comprehensive literature [8,10] established the index system and has carried on the revision and perfection. Subjective Logic corresponds with people's intuition

* Corresponding author at: Electronic and Information Engineering Experiment and Training Center, Handan College, China.
E-mail address: jhq1983@163.com (H. Jiao).

0030-4026/$ – see front matter © 2013 Elsevier GmbH. All rights reserved.
http://dx.doi.org/10.1016/j.ijleo.2013.10.033

and can be explained on probability. Jøsang et al. presented Subjective Logic which was used to model the trust relationships and reputation system [11–13] and other related works [16,17]. But there are still some problems in practical application, and this paper improved the Jøsang's subjective logic, through establishment of the rectangular coordinate system, study on subjective logic properties in the two-dimensional image, using the algorithm of fitting a straight line depict dynamic trajectory of the opinion, at the same time, improving its Consensus operator to make it more realistic. On this basis, this paper establishes a set of indicator system that can reflect the survivability and gives the formal description and the establishment of network survivability assessment model. Using the structures of the network environment for testing, simulation results show that the indicator system is normative, and complete; this model has higher sensitivity and effectiveness, and better able to adapt to dynamic changes in the assessment of environment.

The rest of the paper is organized as follows. Section 2 introduces related knowledge of Subjective Logic and the improvement. Section 3 establishes indicator system and assessment model. Section 4 describes the experimental setup and evaluates the performance of framework in virtual data set. Section 5 concludes the paper.

2. Jøsang's subjective logic and improvement

2.1. Jøsang's subjective logic

Jøsang's subjective logic is based on describing the beta distribution function of two events' posteriori probability. It proposes a certainty probability density function computing by an observed Positive Event *r* and a Negative Event *s*. On this basis, the probability trust of each event produced among entities is calculated.

Jøsang et al. proposed and used Subjective Logic to model the trust relationship. It introduced Evidence Space and Opinion Space to represent and measure the trust relationship and proposed a rich set of subjective logic operators for the deduction and calculation of trust level. Subjective Logic introduced subjective uncertainty into trust notion; thus it could express people's subjective tendency better than classical probability theory. It formed a set of relatively complete theory based on integrating predecessors' experience.

Evidence Space is comprised of a set of observed events which could be simply divided into Positive Event and Negative Event. Opinion Space is comprised of a set of Subjective Opinions which could be expressed as $\omega^i_{X_j} = \{b^i_{Xj}, d^i_{Xj}, u^i_{Xj}\}$, and satisfied following conditions:

$$b^i_{Xj} + d^i_{Xj} + u^i_{Xj} = 1, \quad b^i_{Xj}, d^i_{Xj}, u^i_{Xj} \in [0, 1]$$

where ω^i_{Xj} is the Subjective Opinion of observation period *i* to entity X_j, b^i_{Xj}, d^i_{Xj}, u^i_{Xj} describe Absolute Believability, Absolute Disbelievability and Uncertainty of entity X_j separately, ω^i_{Xj} is defined by Jøsang as the function of Positive Event r^i_{Xj} and Negative Event r^i_{Xj} as follows:

$$\begin{cases} b^i_{Xj} = r^i_{Xj}/(r^i_{Xj} + s^i_{Xj} + C^i_{Xj}) \\ d^i_{Xj} = s^i_{Xj}/(r^i_{Xj} + s^i_{Xj} + C^i_{Xj}) \\ u^i_{Xj} = C^i_{Xj}/(r^i_{Xj} + s^i_{Xj} + C^i_{Xj}) \end{cases} \tag{1}$$

The functions above are called Evidence Mapping Functions, which are proved to be reasonable [14]. The Expectation *E* could be expressed by:

$$E^i_{Xj} = b^i_{Xj} + u^i_{Xj} \times a^i_{Xj} \tag{2}$$

In Eqs. (1) and (2):

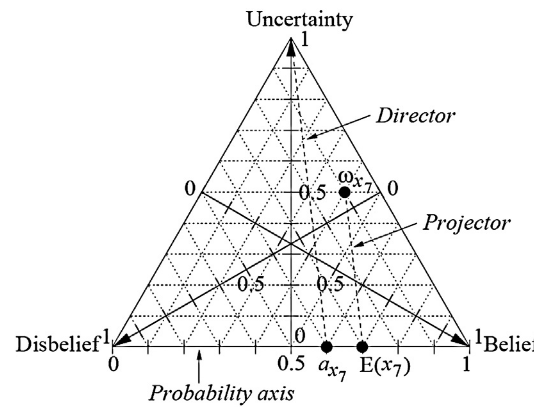

Fig. 1. Opinion triangle with ω_{x7} as example.

(1) C^i_{Xj} is the Uncertainty Factor, and has a constant value 2.
(2) a^i_{Xj} is the prior probability of entity X_j, known as Basic Rate, which represents the experience of past. Jøsang thinks Basic Rate can be viewed as the prior probability of trust evaluation to a given entity. The initial value can be 0.5 or other constant what the observer thinks the most likely.

Jøsang defined a triangle that can be used to graphically illustrate opinions as shown in Fig. 1.

Ordering of Opinions: let w_i and w_j be two opinions. They can be ordered according to the following criteria by priority:

1. The opinion with the greatest probability expectation is the greatest opinion.
2. The opinion with the least uncertainty is the greatest opinion.
3. The opinion with the least relative atomicity is the greatest opinion.

Jøsang proposed a rich set of subjective logic operators including: (1) conjunction, (2) disjunction, (3) negation, (4) consensus, (5) recommendation, etc., for the specific details see Ref. [11]. These logic operators may appear unreasonable situation in the actual application [14]. Wang et al. improved the Consensus operator, but the improved operator does not satisfy an important property that Eq. (1), especially for the design of '*u*', is not reasonable. This paper expands subjective logic and improves the Consensus operator in the following part.

2.2. The improvement of Subjective Logic

According to Jøsang defined triangle graphics, the rectangular coordinate system, is as shown in Fig. 2.

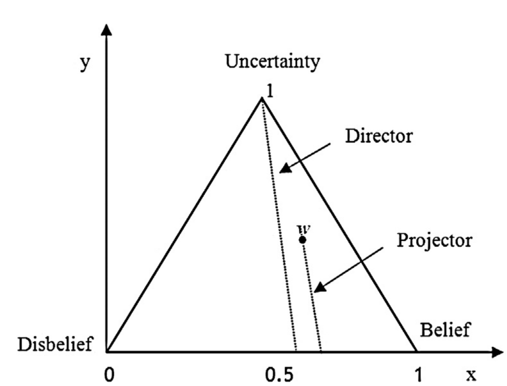

Fig. 2. Rectangular coordinate system.