A Dempster-Shafer Theory Based Witness Trustworthiness Model

(Extended Abstract)

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ABSTRACT

The problem of unfair testimonies remains to be a big concern in reputation systems. To address this problem, we propose a witness trustworthiness model based on Dempster-Shafer theory for reputation systems using multi-nominal testimonies. The proposed approach uses Dempster-Shafer theory to model a witness's trustworthiness from both personal and public aspects. Experimental evaluation demonstrates promising results of the proposed approach in modeling witnesses' trustworthiness and adapting to the buyer specified subjective difference tolerance level.

Categories and Subject Descriptors

I.2.11 [**ARTIFICIAL INTELLIGENCE**]: Distributed Artificial Intelligence – Intelligent agents, Multiagent systems

General Terms

Design, Measurement

Keywords

Reputation System, Unfair Testimony, Dempster-Shafer Theory

1. INTRODUCTION

The problem of "*unfair testimonies*" remains to be a big concern in reputation systems. In our previous work [2] [3], we proposed to use clustering to filter unfair testimonies. But the previous approaches cannot exactly indicate how trustworthy the testimonies can be. In this paper, we propose a novel approach based on Dempster-Shafer theory [4] to address the problem of unfair testimonies. The proposed approach uses Dempster-Shafer theory to model a witness's trustworthiness to indicate how trustworthy a witness is by adapting to the subjective difference tolerance level specified by the buyer.

2. THE PROPOSED WITNESS TRUSTWORTHINESS MODEL

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Suppose that there are N sellers $\{S_1, S_2, \ldots, S_N\}$ in a reputation system. Now a buyer B is evaluating a seller S_i's $(1 \leq i \leq N)$ reputation. To facilitate B's evaluation regarding S's reputation, B may request ratings from other buyers who had transactions with S_i before. From B's point of view, these buyers providing ratings regarding S_i are called witnesses, and the ratings provided are called testimonies. Now a new problem arises – how does B know a witness W's testimonies are trustworthy? To address this problem, we propose using Dempster-Shafer theory to model a witness's trustworthiness from both personal and public aspects.

The witness W's personal trustworthiness is evaluated through comparing W's testimonies with B's personal ratings regarding all the sellers. Suppose a transaction between B (or W) and a seller S_i happens at time t. After the transaction is completed, the rating from B (or W) is r^t_{B,S_i} (or $r^t_{W,Si}$), which is a value k from the integer set of $\{1, 2, ...K\}$ (K is the number of rating levels the reputation system adopts). Suppose in a time period $[\mu, \mu+\varepsilon]$, B has a rating vector $R^{\mu,\mu+\varepsilon}_{B,S_i}$ and W has a rating vector $R^{\mu,\mu+\varepsilon}_{W,S_i}$. Then $[\mu, \mu+\varepsilon]$ is partitioned into some consecutive elemental time windows [5]. For each rating r^t_{B,S_i} in $R^{\mu,\mu+\varepsilon}_{B,S_i}$, we find a mapped rating $r^{t'}_{W,S_i}$ in $R^{\mu,\mu+\varepsilon}_{W,S_i}$. The mapped rating should be the rating provided by W at time t' which is closest to time t and in the same elemental window. Then $< r^t_{B,S_i}, r^{t'}_{W,S_i} >$ is called a rating pair. We calculate the difference d as $r^t_{B,S_i} - r^{t'}_{W,S_i}$ for the rating pair. d has a total of $2K-1$ possible values and $-(K-1) \leq d \leq K-1$. We count the number of d happenings as α_d in all elemental windows. According to subjective logic [1], we assign the *B*asic *B*elief *A*ssignment function (BBA) [4] for S_i. After we get the BBAs for the N sellers, we use the Dempster-Shafer combination rule [4] to combine the N BBAs together. Denote the combined BBA as m and corresponding belief function [4] as Bel. The witness W's personal trustworthiness T^{Per}_W is calculated as:

$$T^{Per}_W = Bel(\{d|\sigma_1 \leq d \leq \sigma_2\}) = \sum_{\sigma=\sigma_1}^{\sigma_2} m(\{d\}) \qquad (1)$$

where $-(K-1) \leq \sigma_1 \leq \sigma_2 \leq K-1$. We call $\sigma_1 \sim \sigma_2$ as the buyer's subjective difference tolerance level, meaning the extent of the subjective difference the buyer can tolerate. For example, if $\sigma_1 = -1$ and $\sigma_2 = 1$, it means that the buyer considers the witnesses whose testimonies have -1, 0, and $+1$ difference from the buyer's personal opinions as acceptable and trustworthy.

The witness W's public trustworthiness value is calculated through comparing W's ratings with other witnesses' ratings regarding all the sellers. Suppose there are other L witnesses, $W_1, W_2, \ldots, W_L$, for a seller S_i for whom W provides testimonies. We still partition the time period into some elemental windows. Now we only consider the last rating provided by each witness regarding S_i in each elemental window. Suppose in an elemental window, the last rating provided by the majority witnesses is $r^{last}_{majority,S_i}$ and the last rating provided by W is r^{last}_{W,S_i}. We calculate the difference d' as $r^{last}_{majority,S_i} - r^{last}_{W,S_i}$. d' still has a total of $2K-1$ possible values. By counting the number of d' happenings as $\alpha_{d'}$ in all elemental windows, we have the BBA assignment for S_i. Then we can get the combined BBA and belief function after combining the BBAs for the N sellers. The public trustworthiness T^{Pub}_W is calculated using the similar equation as Eq.(1) in the personal trustworthiness part.

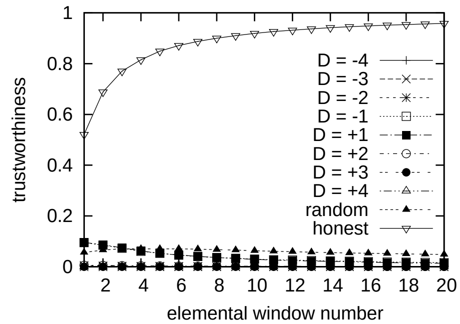
Finally, we calculate the weighted sum of personal trustworthiness and public trustworthiness as the estimation regarding W's trustworthiness. The weights of the personal trustworthiness ω_{per} and public trustworthiness ω_{pub} are assigned based on the uncertainty in the personal trustworthiness part. The more uncertainty in the personal trustworthiness part, the more public trustworthiness is required to be considered. As the last step, the witness W's trustworthiness T_W is calculated as:

$$T_W = \omega_{per} \times T^{per}_W + \omega_{pub} \times T^{pub}_W \qquad (2)$$

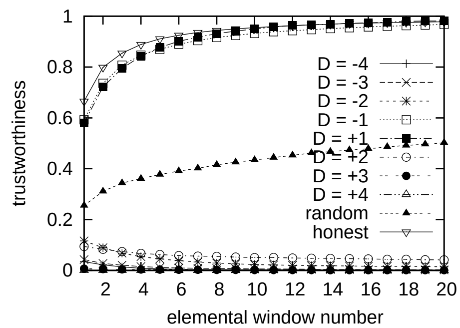
3. EXPERIMENTAL STUDIES

We simulate an e-commerce environment to investigate the witnesses' trustworthiness using the proposed model. Five rating levels are adopted. We simulate 20 sellers and 51 buyers. From the last buyer's point of view, the first 50 buyers are witnesses. We simulate two types of unfair witnesses. The first type is D-shifting witnesses who report real rating adding D rating level, where D is from the value set $\{-4, -3, -2, -1, 1, 2, 3, 4\}$. The second type is random witnesses who report a randomly selected rating level except the real rating. We simulate 2000 time units (a time unit can be a minute, an hour, a day..., depending on different reputation systems) and run 100 rounds for each simulation scenario to achieve a statistical accuracy. For each buyer's transaction, a seller is randomly selected. The rating for each transaction is simulated from a normal distribution.

Figure 1 shows the witnesses' trustworthiness changes with the number of elemental windows when the length of an elemental window is 100 time units and there are 30% unfair witnesses. Figure 1(a) and (b) show the results when the subjective difference tolerance level is set as $\sigma_1 = \sigma_2 = 0$ and $\sigma_1 = -1$ and $\sigma_2 = 1$, respectively. According to the results, the witnesses' trustworthiness value will stabilize after about 10 elemental windows which are 1000 time units. When $\sigma_1 = \sigma_2 = 0$, only the 0-shifting witnesses can get a high trustworthiness value. When $\sigma_1 = -1$ and $\sigma_2 = 1$, the -1-shifting and 1-shifting witnesses can also get a high trustworthiness value. Therefore, the buyer can use σ_1 and σ_2 to indicate the subjective difference tolerance level that is acceptable.



(a) $\sigma_1 = \sigma_2 = 0$



(b) $\sigma_1 = -1$, $\sigma_2 = 1$

Figure 1: Trustworthiness changes with the number of elemental windows

4. CONCLUSIONS

In this abstract, we proposed a witness trustworthiness model based on Dempster-Shafer theory to address the problem of unfair testimonies in reputation systems. Our approach models a witness's trustworthiness from both personal and public aspects. It supports reputation systems using multi-nominal rating levels, and provides buyers a great extent of flexibility to identify the trustworthy witnesses by specifying their own subjective difference tolerance level. Experimental results show that the proposed approach can effectively model witnesses' trustworthiness and adapt to the buyer's specified subjective difference tolerance level.

5. REFERENCES

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