Objectification of Feedback Based Trust Evaluation Considering Social Relationship in Sharing Economy

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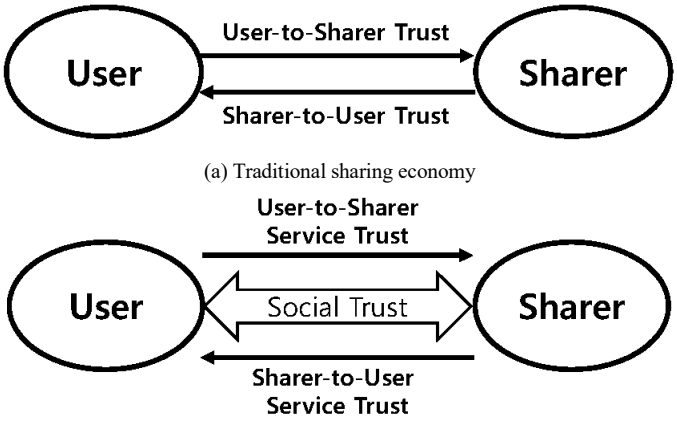
***Abstract*—** With the growth of sharing economy, P2P resource sharing services are combined with social networks for improving user experience and giving more trustworthiness to users. For trust management, many P2P resource sharing services adopt feedback-based reputation system. Since peers in services have their social relationship in the community, reputation includes not only trust related to services but also subjective social trust which causes bias of reputation. In this paper, we propose the method that objectifies feedback-based trust by removing social trust from rating points. We conduct simulation and verify the proposed method can objectify feedback-based trust preciously with optimized parameters by using lambda square discrepancy measure.

Keywords—sharing economy; social trust; service trust; trust objectification

I. INTRODUCTION

An evolution of information communication technology (ICT) leads the advent of the peer-to-peer (P2P) resource sharing services from the traditional rental economy. The P2P resource sharing service has been the promising business model due to sharing possessions that are not usually used and alleviating the cost of utilizing things such as a house, clothes, or a car with the economic coordination. Airbnb[1] is one of the pioneer in the P2P resource sharing market which provides the platform to share users' houses. P2P resource sharing services tried to collaborate to online social network services for improving user experience and giving more trustworthiness to guests[2]. On the other hands, P2P resource sharing services also tried to utilize user's location information. Peerby[3] provides a platform to share not only a car or a house, but also small things such as a camera, camping tools, and so on with peers lived in same town.

For enriching the sharing economy, trust management is inevitable, because the appearance of malicious user without trust declines the user participation to services and ruins the ecosystem of sharing economy. Thus, trust analysis of sharing economy has been studied in a variety of research area. The most popular method to assess trustworthiness of peers in P2P resource sharing services is using the feedback-based reputation. Many P2P resource sharing services such as Airbnb[1], Uber[4], and Blablacar[5] are using the feedback based reputation scoring to evaluate the trust of peers who act as sharers and users. Each of them assesses their opponent in respect to his/her honesty or cooperativeness by the rating point as a feedback. If someone got lower rating point than the policy ruled by each service, he/she receives disadvantage from the service, e.g. temporal ban on the service.



(a) Traditional sharing economy

(b) Sharing economy with social group

Fig. 1. Entities in trust relationship in the sharing economy

This typical feedback based trust evaluation currently does not adapt to recent approaches on P2P resource sharing services. In the past, a user and a sharer in the online service rarely know each other and it makes peers assess their trust related on the service only as Fig. 1(a). However, the effort to adopt the social network to the P2P resource sharing services make that social groups involve in the online sharing community. That is, reputation score depends on not only the quality of service provided by a sharer but also the social relationship between a user and the sharer as Fig. 1(b).

If a user and a sharer are friends, then they can overrate their trustworthiness by assessing high rating point each other. It can bias the decision of peers who newly join the sharing community or do not participate in social groups. Indeed, a research of Blablacar[6] shows that 94% and 92% of respondents in 11 countries score their feedback with 4 or 5 points out of 5 as their level of trust to their family and friends, whereas only 58% of them rank 4 or 5 points out of 5 as their level of trust to their colleague who has less social relationship than friends and family. Therefore, it is necessary to figure out the objectified trustworthiness of each peer in respect to the service.

In this paper, we analyze a rating point, that is, the feedback-based trust, of the P2P resource sharing service and divide the rating point into two factors: service trust and social

trust. The service trust is the trustworthiness of the sharer or the user related to the service and the social trust is the trustworthiness based on the social relationship between peers. Through subtracting the social trust from the rating point, we can get objectified trust evaluation result related to the service. We conduct simulation based on real rating point distribution, and verify to obtain the trust related to sharing services through proposed method.

The rest of this paper is composed of several chapters. Chapter 2 introduces related works about the trust evaluation and chapter 3 proposes our proposed objectification method for feedback based trust evaluation. Chapter 4 conducts the simulation and analysis, and finally we conclude the paper in Chapter 5.

II. Related Works

The trust has been studied in various research areas for a long time. The definition of trust is a measure of confidence that an entity will work in an expected way from the perspective of trustor[7]. Mayer et al.[8] define the trust with factors as integrity, benevolence, and ability. Integrity means honesty of peer participated in trust relationship and benevolence means the willingness of cooperation between peers in trust relationship. Ability implies the capacity for fulfilling requested action between peers in trust relationship. These factors are important to analyze trust in detail.

Traditional studies on trust evaluation can be separated to three categories: Policy-based, reputation-based, and social-based trust[9]. The policy-based methods evaluate the trust value whether the credentials of trustee match up to the policy which ruled by the trustor or not. Reputation-based approaches evaluate the peer's trust using a system which aggregate the feedback of peers about their opponent's integrity, benevolence, and ability[9]. Feedback based reputation evaluation is the most popular method to assess the trustworthiness of peers in e-commerce services. Paul et al.[10] studied the trust among peers in Ebay[11], which is one of the famous e-commerce service. They investigate the ability of a peer (e.g. the discount rate, fast shipping) and the integrity of a peer (e.g. the quality of a product, etc.) Mehmet et al.[12] studied the patterns of participation and exchange in Airbnb. In detail, they investigated how income, race, and education affect the economic activity on Airbnb and found that the education is a heavily influential factor.

The social trust utilizes the social relationship to evaluate the trustee's benevolence, integrity, and ability from the trustor's point of view. The social trust is divided into the explicit social trust and implicit social trust[13]. The explicit social trust comes from the social network topology, such as the graph similarity between peers, the number of friends, and betweenness centrality, etc.[14] For example, a peer who has many friends can be estimated to have more benevolence and integrity than other peers. Moreover, peers trust their friends[15], that is, peers estimate the integrity of their friends higher than others. The implicit social network is measured by checking the communication history[16]. Peers, who do not connect to each other in online social network, also can generate the social relationship. If they interact with each other

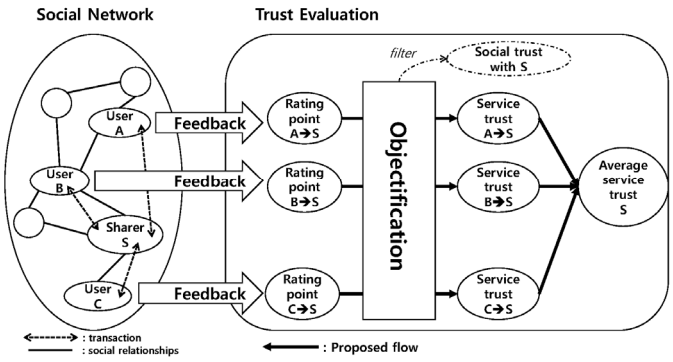


Fig. 2. Proposed trust objectification method

through messengers or e-mail, then they have implicit social trust. The frequency and the duration of the communication affect to the implicit social trust.

As the social group engaged in the P2P resource sharing community directly or indirectly, the feedback-based trust, which is usually utilized on P2P resource sharing services, has been biased because a rating point as a feedback of sharing services includes not only the trust related to sharing services itself but also subjective social trust. Therefore, in this paper, we propose the objectification of feedback-based trust by getting rid of social trust from the rating point.

III. Trust Assessment

We begin our study from the verification of the proposition that if there are social groups in the sharing community, a rating point, that is, the feedback-based trust is biased by the social trust. The rating point of a peer in P2P resource sharing services represents the ability such as the technical skill of user, the integrity such as the quality of shared thing, the honesty of a user, and the benevolence such as the cooperativeness between peers. The studies shows that if they are friends or have any social relationship, then they believe in each other more than others [6][15]. Their relationships increase the measure of integrity and benevolence, and it becomes the increase of rating point. Thus, a proposition is true that the feedback-based trust is biased by the social trust if there are social groups in the sharing community.

To objectify the feedback-based trust, we propose trust objectification method considering social relationship. The method assumes that the rating point that the peer gives to his/her opponent includes the trust related to the quality of service as well as the social trust. Therefore, it considerately measures the social trust between peers who are participated in the sharing transaction and subtract the social trust from the rating point for obtaining the objectified trust of peers in the service. In Fig. 2, the process of the proposed method for objectifying the rating point is described. By taking average the service trust, a peer can get his/her own service trust which reveals his/her genuine trustworthiness related to the service.

The rating point of peers in the sharing community with social groups can be shown as below:

$$UR_{ab} = TUS_{ab} + \alpha TS_{ab} \quad (1)$$

$$SR_{ab} = TSS_{ab} + \beta TS_{ab} \quad (2)$$

, where UR_{ab} is the rating point of a user B from a sharer A's point of view and SR_{ab} is the rating point of a sharer B from a user A's point of view. *TUS* is the trust as a user in the service, and *TSS* means trust as a sharer in the service. TUS_{ab} means *TUS* of a user B from sharer A's point of view, and TSS_{ab} means *TSS* of a sharer B from a user A's point of view. *TS* means the social trust and TS_{ab} is the value of *TS* between A and B. Using α and β, which are normalizing constants, we handle the effect of TS_{ab} to the TUS_{ab} or TSS_{ab}. Thus, *TUS* and *TSS* can be obtained by subtracting normalized *TS* between peers in the sharing transaction. It is described in below:

$$TUS_{ab} = max[UR_{ab} - \alpha TS_{ab}, 0] \quad (3)$$

$$TSS_{ab} = max[SR_{ab} - \beta TS_{ab}, 0]. \quad (4)$$

To figure out the representative peer's trust related on the sharing service, we need to find the *TUS* and *TSS* values from entire sharing transactions, and take average these values. They are shown as below:

$$TUS_b = \frac{\sum_{a=1}^{n} TUS_{ab}}{n} \quad (5)$$

$$TSS_b = \frac{\sum_{a=1}^{m} TSS_{ab}}{m} \quad (6)$$

, where n is the number of sharing transactions that the user is B, and m is the number of sharing transactions that the sharer is B. After the calculation, we obtain the representative trust of peers as a user and a sharer in the service.

To find the *TUS* and *TSS*, we need to define the social trust in detail. The social trust is divided into implicit and explicit social trust. Therefore, *TS* is figured out through the equation below:

$$TS_{ab} = \gamma TSI_{ab} + (1-\gamma)\, TSE_{ab} \quad (7)$$

, where TSI_{ab} means the implicit social trust, TSE_{ab} means the explicit social trust between peer A and B, respectively, and γ is the weighted factor between the explicit social trust and the implicit social trust.

The implicit social trust can be obtained by the communication history, its frequency, and the amount of communication [16]. For example, although two people do not have any social relationship in online social network, if they communicate each other frequently for a long time through other methods, then they also have the social trust. Information entropy is utilized to measure the implicit social trust from the communication history. Let p_a is the fraction of message of peer A to peer B in the communication space and the implicit social trust is shown as below:

$$TSI_{ab} = \begin{cases} \delta \times \{-p_a \log p_a - (1-p_a)\log(1-p_a)\} & n \geq c_{th} \\ 0 & n < c_{th} \end{cases} \quad (8)$$

, where n is the amount of messages on the communication space, c_{th} is the threshold of the available number of messages on the communication space and p_b is same as $1 - p_a$ because the subject of sending message is composed of {A, B}, that is, Bernoulli trial. δ is the normalizing constant, because the value of information entropy is up to 0.5. n needs to be more than c_{th}, because it is possible that only two mutual messages in the communication space make the maximum value on the implicit social trust.

The explicit social trust is based on the social topology of the online social network service. There are many trust evaluations based on the social graph and network structure. For example, the betweenness centrality can be obtained by analyzing the social network topology and it means the degree of importance or influence of an entity[14]. In the P2P resource sharing service, peers are likely to trust a peer who has more similarity between he/she and a peer[17]. Thus, in this paper, we investigate the explicit social trust based on the similarity of peers' neighbors, namely, adjacent nodes, on the social topology using the Jaccard index, also known as the Jaccard similarity coefficient. Jaccard index measures the similarity between sets of peers' neighbors; Let N_A be the set of neighbors of peer A and N_B be the set of neighbors of peer B, then the Jaccard index is shown as below:

$$TSE_{ab} = \varepsilon \times \frac{|N_A \cap N_B|}{|N_A \cup N_B|} \quad (9)$$

, where ε is the normalizing constant, because the value of Jaccard index is up to 1.

IV. Simulation and Analysis

In this section, we conduct the simulation to verify the performance of proposed objectification method that gets rid of social trust from the rating point of sharing services. For environment setup, we choose Python 2.7.11 with open source library NetworkX 1.10 for simulating social network.

Our simulation starts with 100 peers in the sharing community. The peer acts as both a user and a sharer in the sharing community. All peers are connected to each other following Barabasi-Albert (BA) graph and each node has minimum five edges. Each user randomly makes transaction with each other. A number of transactions follow uniform distribution within the range of 10 to 100. In each transaction, a user and a sharer make a rating point *UR* and *SR* to each other.

The dataset of rating point is based on the rating point on the real car sharing service, Blablacar[6]. We refer to the distribution of rating point on friends who have social trust between the peer and colleague who have less social trust than friends. Table 1 shows the distribution of rating point on friends, which means the rating distribution with social relationship. Besides, Table 2 shows the distribution of rating point on colleagues, which means the rating distribution with less social relationship.

TABLE I. Rating distribution with social relationship

Ratings	**0 (min)**	**1**	**2**	**3**	**4**	**5 (max)**
Percent	1	1	2	8	37	51

TABLE II. Rating distribution without social relationship

Ratings	**0 (min)**	**1**	**2**	**3**	**4**	**5 (max)**
Percent	2	3	10	27	34	24

TABLE III. PARAMETER VALUES FOR SIMULATION

Parameter	Description	Value
N	The number of users in the network	100
UR_{ab}	the rating point of a sharer A to a user B	Integer value within [0, 5]
TSI_{ab}	the normalizing metric to reveal the implicit social trust between A and B	Float value within [0, 5]
TSE_{ab}	the normalizing metric to show the explicit social trust between A and B	Float value within [0, 5]
α	Normalizing constant for UR_{ab}	Float value within [0,1]
γ	the weighted factor for social trust	[0,1]
δ, ε	Normalizing constant for *TSI* and *TSE*	10, 5

If the proposed objectification works, the distribution of rating points of friends changes to that of colleagues.

In this simulation, we assume that *UR* and *SR* follow the same rating distribution mentioned in the Table 1, so we consider only *UR* from now on. Metrics to figure out *TUS* are *UR* and *TS*. *TS* is composed of *TSE* and *TSI*. We assume that *TSI* between two peers is a random real number value between 0 to 5 following Pareto distribution with parameter 1 because a number of peers who mutually communicate nearly are much less than a number of peers who rarely talk each other. *TSE* between two peers is based on BA model which a peer has at least five connections to other peers. Table 3 lists the default parameter values.

To manipulate *UR, TSI*, and *TSE*, α and γ are the most important constants. Increment of α means *TS*, which is the social trust and weighted summation of *TSI* and *TSE*, more affects to the *UR*, and decrement of α is the reduction of influence of *TS* from *UR*. On the other hand, increment of γ means we regard *TSI* as more important than *TSE*, otherwise, *TSE* is more important than *TSI*.

Prior to the trust objectification, we generate more than 5000 sharing transactions between two peers in the social network. Each transaction is composed of four tuples, {*user_id i, sharer_id j,* UR_{ji}, SR_{ij}}. After that, we figure out TUS_{ji} with the control of α and γ and compare the distribution of TUS_{ji} and the rating distribution in Table 2 by using lambda square discrepancy measure[18]. The lambda-square discrepancy measure is the modeling methodology to see the discrepancy, i.e., the distance between the empirical data and the analytical model. By dividing the discrepancy with the amount of the data set, it is suitable to see the distance between the massive empirical data and the model. For a value near to 0, it means there is no discrepancy, thus we can find the optimal α and γ where lambda-square value is lower than others. The lambda-square discrepancy is shown as below:

$$\lambda^2 = \frac{\chi^2 - K - (n-1)}{N-1} \quad (10)$$

, where

$$\chi^2 = \sum_{i=1}^{N} \frac{(O_i - E_i)^2}{E_i} \quad (11) \text{ and } K = \sum_{i=1}^{N} \frac{O_i - E_i}{E_i} \quad (12)$$

, and n is the number of bins which means the unit separating the measure. As mentioned in Table 1 and 2, there are 6 bins {0, 1, 2, 3, 4, 5} for the rating point. N is the number of dataset. In this simulation, N is more than 5000, because *UR* includes in each transaction. O_i is the number of users in bin i of the empirical data which are *TUS*, on the other hand, E_i is the number of users in bin i of the analytical data, which is on Table 2.

The lambda square discrepancy measure between the distribution of rating point in Table 2 and distribution of *TUS* which is obtained by subtracting social trust from *UR* in each resource sharing transaction. To control the distribution of *TUS*, we change both α and γ from 0 to 1 in 0.1 scale. Table 4 shows the lambda square discrepancy with various α and γ.

TABLE IV. LAMBDA SQUARE DISCREPANCY WITH A AND Γ

	α=0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
γ=0	0.121	0.122	0.123	0.123	0.122	0.113	0.099	0.083	0.070	0.059	0.049
0.1	0.121	0.122	0.124	0.124	0.116	0.091	0.058	0.036	0.024	0.016	0.012
0.2	0.121	0.123	0.125	0.120	0.076	0.046	0.021	0.013	0.013	0.018	0.023
0.3	0.121	0.124	0.126	0.076	0.037	0.021	0.013	0.017	0.025	0.030	0.043
0.4	0.121	0.124	0.121	0.044	0.024	0.015	0.016	0.024	0.046	0.069	0.092
0.5	0.121	0.125	0.075	0.034	0.017	0.016	0.020	0.054	0.085	0.114	0.184
0.6	0.121	0.126	0.049	0.025	0.015	0.012	0.048	0.090	0.144	0.241	0.306
0.7	0.121	0.126	0.042	0.019	0.015	0.030	0.083	0.151	0.247	0.319	0.530
0.8	0.121	0.127	0.036	0.016	0.009	0.053	0.116	0.235	0.312	0.658	0.861
0.9	0.121	0.128	0.029	0.016	0.020	0.085	0.213	0.287	0.632	0.842	1.434
1	0.121	0.128	0.025	0.018	0.036	0.124	0.251	0.351	0.786	1.071	2.202

We find that the difference is lowest when α is 0.4 and γ is 0.8 and its value is nearly 0. That means proposed method is able to successfully objectify the feedback-based trust by removing social trust. Moreover, when we get rid of 40% of social trust which include 80% of implicit social trust and 20% of explicit social trust between two peers from rating points, we can get the optimized objectified rating points.

We also investigate the influence of elimination of the social trust to the peer with high degree and the peer with low degree in the social network because the peer with high degree has more explicit social trust than the peer with low degree. However, when we check the difference between *UR* and *TUS* as well as *SR* and *TSS* of every peers in the network with 0.4 for α and 0.8 for γ, there is no correlation between the difference between *UR* and *TUS* as well as *SR* and *TSS*. The correlation coefficient between the degree of a peer and the difference between average value of *UR* and average value of *TUS* of a peer is –0.17 and that between the degree of a peer and the difference between average value of *SR* and average value of *TSS* of a peer is –0.03, which means there are no correlation.

V. CONCLUSIONS

In this paper, we propose the trust objectification method and verify the validity of proposed method. First, we verify the proposition that the feedback-based trust is biased by the social

trust if there are social groups in the sharing community. Through the proposition, we define the equation of trust which includes the trust related on sharing service and social trust. We measure the social trust with implicit social trust based on communication history and explicit social trust based on friend similarity in the social network. By handling some parameter, we can objectify the trust which includes the social trust to trust only related on the P2P resource sharing service. With the objectified trust, we can judge the sharer or the user have enough trust to make a resource sharing transaction. The further work is to verification of proposed objectification method with massive dataset which is obtained from real online sharing services such as Airbnb and Uber.

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