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Procedia Computer Science 00 (2019) 000–000

Procedia Computer Science

www.elsevier.com/locate/procedia

Information Technology and Quantitative Management (ITQM 2019)

Leveraging Users' Trust and Reputation in Social Networks

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Abstract

In on line communities, where there is a vaste number of users that interact under anomymous identities, it has been observed that e-word of mouth is a very powerful influence tool. So far, this technology is well known in on-line marketplaces, such as Amazon[1], eBay[2] or travel based platforms like Tripadvisor or Booking. However, these trust based approach can be leverage in other scenarios from e-democracy to trust based recommendations on e-health context and e-learning systems. The purpose of this contribution is to analyse the main existing trust and reputation mechanisms and to point out new research challenges that needs to be acomplished with the objective of fully exploiting these systems in real world on-line communities.

Selection and/or peer-review under responsibility of ITQM2019.

Keywords: Trust, reputation, social networks, influence, group decision making, e-word of mouth.

1. Introduction

Social networks enable virtual interactions between anonymous people and services without any previous real world relationship with diverse purposes from disaminating pictures and thoughts to sharing facilities like accommodation or cars.

These internet based social channels allow the users to develop explicit and implicit relationships to share and disseminate products, services, information, opinions and recommendations. However, due to this large number of users, there is an information overload coming from various diverse sources, therefore assessing the trustworthiness of each source is key to select the piece of information to trust to make a decision or to buy a product in an e-commerce scenario. Another important issue concerning these anonymous and open systems is that they provide a very favorable evironment for the proliferation of malicious users that could spread wrong information to manipulate the system or to control the systen in their own advantage, [1].

The aim of this article is to analyze the main existing mechanisms to generate and propagate trust and reputation and to present various open research challenges about how these systems can be developed, adapted and

[1] https://www.amazon.com/
[2] https://www.ebay.es/

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improved to operate on social networks and decision making scenarios. To do so, this contribution is organized in the following way: Section 2 provides the background information necessary for understanding the contribution, giving notions about Social networks and presenting the definition of reputation and trust that are going to be used thorught this study. In section 3 we carry out the revision of the approaches for trust and reputation, and in Section 4 we point out the open research challenges to integrate these systems in real world social networks. Finally in Section 5, the conclusions of our work are presented.

2. Background

In this section we briefly define the main concepts that would be used in this contribution, that is Social networks and the definitions of Trust and Reputation.

2.1. Social Networks

A social network is composed of a group of individuals that interact with different purposes such as friednship, knowledge sharing, marketing or bussiness exchange. Social network analyse consists on the analysis of the different network structures with the objective of uderstanding the different patterns that facilitatates the knowledge creation in this type of interconnected communities [2]. In comparison with a random graph, a social network has some specific characteristics that allows to undestand the procedures of opinion dynamics, trust propagation and influence. These particular properties are: (i) The **A small-world network** characterized by the higher clustering coefficient and the average path length that scales the logarithm of the number of nodes, and the (ii)**Scale Free network** that implies that only a reduced number of nodes in the network have an elevated number of connections (degree).

2.2. Trust and reputation systems

Trust between two entities can be defined as the point to which one entity desires to depend on another one in a given situation, having the feeling of relative security, even when negative consequences could be expected [3]. Reputation, has been defined by the Concise Oxford dictionary, as follows: "**reputation** is what is generally said or believed about a person's or thing's character or standing." This definition goes in the same line than the one in social network research:"reputation is a quantity measure derived from the underlying social network which is globally visible to all members of the network" [4].

Bearing in mind both concepts, in this contribution, we consider trust as the pairwise level of confidence that an entity may have on another one based on previous interactions, while reputation is considered as the "global perception that an agent creates through past actions about its intentions and norms in a global level" [5].

According to [5, 6] both trust and reputation systems should comply with the following characteristics:

1. **Self policing**: Only information privided by the peers, such as feedback and ratings are allowed.
2. **Long lasting entities**: These systems are based on the idea that the interactions between agents will be repeated during the time.
3. **Trust and reputation based on the behaviour over time:** These systems shoudl reward long term good behaviours and consequently no give advantages to newcomers.
4. **Reduced computation cost:** Trust and reputation calculation, propagation and storage must not suppose and overload for the system in terms of computational power.
5. **Robust to malicious users:** Malicious users should be inmmediatly targeted and isolated.

3. Survey of trust and reputation systems

In this subsection we present a brief review of the main trust and reputation systems both in the specialized literature and at a comercial level. To do so, first of all we point out the main ways of calculating these two measures, then the different ways to propagate them within the network and the main trust and reputation based frameworks are presented. Finally we focus on the trust and reputation in group decision making scenarios as a special case of social network.

3.1. Trust and Reputation calculation

Among the best known trust and reputation commertial mechanisms are eBay and Amazon. Both of them use the technique denominated as *counting* [7, 8]. In the case of eBay this technique consists on a summation of the positive ratings minus the negative ones whereas in the case of Amazon a weighted average of the ratings is carried out considering other factors such as the rater trustworthiness and the number of provided ratings.

On the other hand, a statistical approach presented in [9, 3], estimates the probability that a future transaction would be positive or negative given the historic of the previous ones. We can find as well systems that use fuzzy numbers or linguistic ratings modelled as fuzzy sets in which the membership function describes to what extend an agent can be trustworthy or not. Some examples of these systems are the Regret System presented in[10] and some trust based group decision making methodologies [11, 12, 13].

3.2. Propagation approaches

These approaches deal with the situation where there might not be direct trust relationship between all the agents in the network. Therefore their goal is to estimate an unknown trust value between two agents using existent indirect trust paths betwen them. Flow propagation models are the most frequently used. They assume that an user would likely trust the statements coming from a trusted user, and so, they make use of a transitive property to estimate the trust score through iterative aggregation along transitive chains until they become stable for all agents [14].

The most representative of these approaches is the one proposed by Guha in [14], which carries out atomic propagation of the trust in four different ways:

1. If agent i trusts agent j ($t_{ij} = 1$), and agent j trusts agent k ($t_{jk} = 1$), then agent i will trust agent k ($t_{ik} = 1$). This is known as **direct propagation** of trust.

2. In agent i_1 trusts agents j_1 and j_2, and agent i_2 trusts agent j_2, the **co-citation** propagation of trust assumes that agent i_2 may trust agent j_1.

3. Given that agent i trusts agent j then the **transpose trust** propagation implies that agent j might present some level of trust towards agent i.

4. Given that agent i trusts agent j then the **trust coupling** propagates to agent k if agent j and agent k trust agents in common.

In the same line, Kamvar et al. propose in [6] a methodology to compute a universal value of trust for each node, in contrast with the pairwise one in [14], with two objectives: (i) To isolate malicious agents from the network by encouraging agents to interact with reputable ones; (ii) To motivate agents to interact by rewarding reputable ones.

3.2.1. Trust and reputation frameworks

In this subsection the main trust and reputation based systems are briefly enumerated and their main characteristics are presented:

- **RateWeb**[15] is decentralised and unstructured framework applied to web services. In thius system each agent stores a personal perception of the services it has interacted with. In order to select a partner, the trusting entity queries the community obtaining a set of eligible services providers including a list of past entities that used the service. The reputation of each service provider is calculated based on the obtained feedback in the following way:

$$Rep_i = \frac{\sum_{j=1}^{L} t_{ij} \lambda_f Cr_j}{\sum_{j=1} Cr_j}$$

  Where L denotes the set of trusting agents which have interacted with the service provider i; t_{ij} represents the pairwise trust value that an agent j has towards agent i; $Cr_j \in [0, 1]$ is the credibility of each agents, as viewed by the inquiring entity, and $\lambda_f \in [0, 1]$ is a trust decay factor over time.

- **R2Trust** has been proposed in [16] as a fully distributed reputation system in which the reputation of an agent is estimated as an aggregation of the obtained feedback weighted by local pairwise trust values. These trust values, calculated using social relationships, consist on probabilistic ratings computed as a function of the past interactions. This approach presents fast reaction in case of an irregular variation on the behaviour of an agent.
- The **GRAft** distributed reputation system [17] is characterised by the use of both explicit reputation information such us feedback, scores and rating, and implicit structural information of the given node in the social network, i.e. the in-degree and out-degree.
- **Random Walk** trust measure is based on the well known Page Rank algorithm [18]. In this system, a random walker surfs the network in a similar way that in the web with the popular Google's algorithm.
- **SocialTrust** [19] is a Random Walk based framework that combines factors such as trust group feedback, user's relationship quality and user behaviour over time to model trust between the users.
- **PCR** was proposed in [20] in the same line than SocialTrust [19]. This system consists on a multigraph based social network where users are characterised and interconnected keeping track of various criteria such as the behavioural activities and social relationship in order to build trust relationships between them even in the case of scarce first hand information. In addtion, in order to discard bad-mouthing and personalized direct distrust propagation a deception filtering approach is included.

3.3. Trust based Group decision Making approaches

Group decision making approaches, specially those where a large number of experts interact can be considered as social networks in which users exchange opinions with the objectiove of obtaining a final solution agreed by the majority of the experts, i.e. a consensus solution. In this particular scenario trust and reputatation play an emergent role. The main points where trust and reputatation can be included, as depicted in Fig. 1, are (i)Trust Propagation , (ii)Trust based opinion fusion and (iii)Trust modeling, briefly analysed in the following subsections.

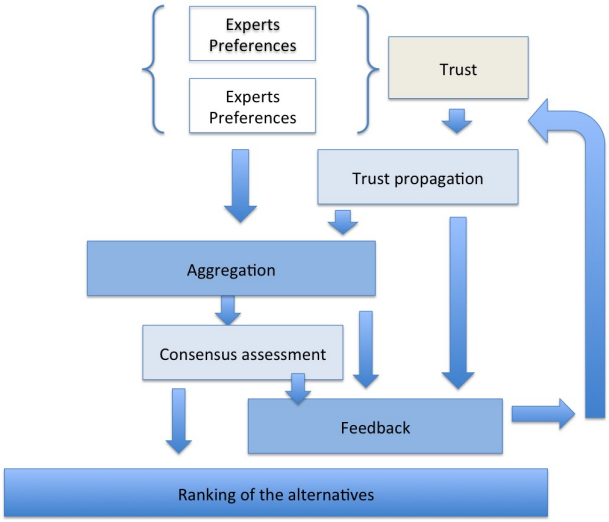

Fig. 1. GDM scenarios architecture with trust

3.3.1. Trust Propagation in GDM

Trust is propagated following a transistivity property using different types of operators. For example, one of the main contributrion has been presened in [11] were the trust, and distrust are propagated using the Uninorm

operator. Notice that the Uninorm presents the same expected behavior of the t-norm when all values are below the identity element, whereas in the case of values being higher than the identity element it behaves as a t-norm, working like a symmetric mean otherwise. On the other hand, in [21] the t-norm and the t-conorm operators are used to propagate trust and distrust respectively. However, according to [11] using two different operators to propagate information might not be optimal since trust and distrust are not independent. Moreover the t-norm favors the minimum value in the aggregation whereas the t-conorm favors maximum ones, therefore, this predictibiulity in the aggregation makes the system more vulnerable to malicious attacks.

3.3.2. Trust based opinion fusion

In decision making scenarios the use of Yager's Order Weighted Averaging (OWA) operator [22] is widely adopted to carry out the fusion of the information. This operator, that gives different importance degree in the aggregation based on the order of the elementes according to a certain criteria, has been recently demonstrated as effective against the malicious behavior [23].

Some extensions of this OWA operator to include trust have been proposed: For example, in [11] the uninorm trust weighted average operator (UTWA) that use trust as a measure to calculate both the weights and the elements ordering is introduced. Later on in [12] an extension of the approach in [11] all the possible paths to estimate trust and distrust are considered and to fuse them, an OWA operator that takes into account the risk attitude of the members in the network has been proposed. This approach leverage trust as well to estimate missing experts' preferences. Another interested approach is the one in [13] where the systems is represented as a trust based graph in which each node is an expert and each edge represents the trust degree, and the importandece that each expert has in the aggregation is determined by its centrality in the network.

3.4. Trust modeling

In the literature trust has been modeled in very different ways from a crisp or binary relation, that is, 'trusting' and 'not trusting' to a more "gradual concept" where people trust someone in a 'high', 'middle' and/or 'low' way [21]. With regard to the last case, in [13] the concept of distributed linguistic trust has been defined in order to establish the trust relationship between a group users. On the other hand, in [24] trust has been modeled as an interval-valued trust function with the objective of allowing more flexibility in the expression of opinions to include trust, distrust, hesitancy and conflict.

4. Discussion and Open research challenges

Motivated by the analysis and observations carried out in this survey in the following we point out the research challenges that arises from this study:

4.1. Recognize digital sources of trust and reputation

Most of the commercial systems based on trust and reputation , i.e amazon or e-bay, uses almost exclusively the explicit feedback from other users after one interaction [17]. Nevertheless there are various drawbacks associated to direct ratings, like the low motivation of users to provide positive ratings, the unfair ratings and various malicious users behaviours that may use the rating as a way to manipulate and eventually control the system imposing their will [5].

Fortunately, on-line social networks provide other types of information that can be leveraged to infer trust and reputation between users. Some examples are the interactions between users, their degree of similarity, their position in the network or going further the historical behavior evolution of the users. Taking all of this information into consideration new approaches of behavior scoring could be proposed to estimate the users' reputation and trust. The challenges with this regard are twofold: 1. Evaluating and identifying patterns of both good and bad behavior and using them as a source of trust and reputation. 2. Merging both global behavior with pairwise interaction between users to asses peer to peer related trust. In this sense similarity between users could be useful as a measure of trust since, as stated by some opinion dynamics models, it has been proved that users tend to take the opinions of the users whose opinion are closed [25, 26] and therefore trusting those users that are similar to them [13, 27, 28]. In this case, the key resides on how similarity should be defined and which are the relevant features to take into consideration.

4.2. Propagation of Trust

As aforementioned most of the approaches that carry out trust propagation uses the flow model that relies on a kind of trust transitivity. However, is it appropiate to use this tranbsitivity property? In other words, the assessment of coherence degree of the trust, remains a challenge.

4.3. Dealing with malicious users

Trust and reputation systems, as other informatics systems, suffer from vulnerability to attacks. In this context, one of the most common malicious behavior consists in **unfair ratings**. That is, the feedback provided by a given user is deliberately false with a unclear purpose, for example to manipulate the score towards to benefit certain entities. This type of attacks may be carried out in various different ways:

1. **Self promoting:** In this case, a group of agents collaborate with the intentions of highly rate each others to artificially boost their personal reputations.
2. **Slandering or bad mouthing:** is the opposite to the previous one. In this case, a group of users agree in unfairly low rating other users in order to destroy their reputations.
3. **Whitewashing:** This is a short term attack where the perpetrators intentionally behave unfairly to get a certain benefit knowing that their reputations will get degraded. Then, they re-enter the system with a new identity.
4. **Orchestrating:** In this case several attackers agree on using one of the aforementioned techniques simultaneously.
5. **Ballot Box Stuffing:** This consists in obtaining more votes than the expected ones.

In most of the systems we can find any type of users, from fair malicious opinion contributors as well as those who behave inconsistently when providing their ratings without any malicious intention. Therefore, it is a hard task to discern the dispersion in the feedback provoked by differences in taste from that induced by other factors such us unfair ratings. With this regard, the challenge is to develop mechanisms to flag and isolate malicious users. Some existing approaches are:

1. **Endogenous discounting**: In this case, the statistical properties of the ratings are used to give less importance or even exclude ratings that are suspected to be unfair.
2. **Exogenous discounting:** These mechanisms are based on the idea that raters with low reputation are more likely to provide unfair feedback and so rater's reputation is taken into consideration to weight the ratings.
3. **Restrict ratings provision:** In order to avoid ballot box stuffing, ratings are only allowed after the transaction has been fully accomplished.

In addition to these approaches some promising techniques, likes the ones based on game theory [29] or the use of the OWA-based operators [22] to avoid malicious behavior in the information aggregation [23] are being explored.

4.4. Reputation and trust in GDM Systems

Applied to these specific scenarios we can point out the following research challenges:

- **Modeling Trust in GDM frameworks.** Many GDM approaches based on trust rely on the users feedback. Therefore other sources of trust shoul be explore such as centrality [4] for example. An initial effort in this sense has been presented in [26] where trust has been modeled as a combination between the users' proximity, the quality of the provided opinions and the users'self confidence degree.

- **Using trust as way of influence.** The trust between agents have been considered as a mean of influence that has been widely used in e-commerce scenarios [30, 31]. Trust can be leverge as well in decision making platforms as way to influence the different experts to reach a consensus solution. In thise sense two main open questions can be identified: (i) Trust based opinion aggregation. In [32, 13] an initial effort is presented were a Trust induced aggregation operator is presented. A further endeavor in this context could be to extend the opinion dynamics and propagation approaches and including trust assessment, to see how the propagation of both influence and trust is carried out.(ii) Secondly, integrating trust in scenarios with heterogeneous users rated using both reputation and trust sources that may be contradictory.

- **Reputation based expert selection.** In the cases where there is a large number of peers, it could be necessary to select the most suitable to take part in a decision making process. In these cases reputation can be leverage as an useful criteria that also would prevent disclosing ctitical information to not very reliable users. These procedures are already being applied in P2P networks during the so called search phase.

5. Conclusions

E-word of mouth, that is users' opinions in online media, are gaining importance in users daily live to help them to make decisions and to provide recommendations, specially in e-commerce and e-marketing scenarios. However, in a media characterized by a huge information overload, indentifying the sources that are reliable constitutes a veritable challenge. In this contribution we have analysed the concepts of trust and reputation in online systems. To do so, the main comertial and academic frameworks that carry out trust and reputation calculation, propagation and utilization have been presented and the main research challegens that have arised from our study has been pointed out.

Acknowledgments

The authors would like to acknowledge the financial support from the EU project H2020-MSCA-IF-2016-DeciTrustNET-746398 and FEDER funds provided in the Spanish project TIN2016-75850-P.

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