Improving the Efficiency of an Online Marketplace by Incorporating Forgiveness Mechanism

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Reputation plays a key role in online marketplace communities improving trust among community members. Reputation works as a decision-making tool for understanding the behavior of the business partners. Success of any online business depends on the trust the business agents share with each other. However, untrustworthy agents have anno place in online marketplaces and are forced to leave the market even if they will potentially cooperate. In this study, we propose an exploration strategy based on a forgiveness mechanism for untrustworthy agents to recover their reputation. Furthermore, a number of experiments based on the NetLogo simulation are performed to validate the applicability of the proposed mechanism. The results show that the online marketplaces incorporating a forgiveness mechanism can be used with the existing reputation systems and improve the efficiency of online marketplaces.

CCS Concepts: • **Applied computing** → **Secure online transactions**; • **Security and privacy** → *Social aspects of security and privacy*; • **Human-centered computing** → *Empirical studies in collaborative and social computing;*

Additional Key Words and Phrases: Online marketplaces, reputation, forgiveness mechanism, NetLogo

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1. INTRODUCTION

In recent years, online marketplaces have made consumers and service providers in the form of software agents participate in business transactions easily, irrespective of their locations. Their transaction strategies commonly maximize their individual benefits. Generally, service providers try to maximize their profits by producing products and services at a lower cost and selling them at a higher cost. Consumers, on the other hand, try to obtain superior-quality products and services at a low cost. However, similarly to the problems that always arise when society evolves and increases in complexity [Axelrod 1984], problems arise in online marketplaces as well. These problems might occur because of the following: when there is no historical information regarding the behavior of a partner's trustworthiness, implementing an approach that prevents fraudulent service providers from not delivering products or delivering low-quality

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products, or an approach that prevents dishonest consumers from not paying for the ordered products. To overcome such problems, the notion of trust and reputation has emerged and become an essential decision-making tool.

Trust is an individual subjective perception that plays a vital role in our decision making and in improving the efficiency of an online marketplace. Gambetta [2000] defined trust as a belief, which in mathematical terms is described as a probability. The probability of trust often varies based on subjective evaluations and the reliability of a partner in an interaction. In other words, an individual counterpart will only engage in a transaction if the level of trust exceeds some acceptable trustworthiness threshold. This extensively depends on the outcomes of transactions between the partners. Moreover, the success of transactions in online marketplaces crucially depends on establishing, maintaining, and managing trust in an online setting [Braynov and Sandholm 2002]. However, a common challenge of online transaction environments is asymmetric information about the product between the service provider and the consumer. The service provider usually has complete information about the product, whereas the consumer rarely has 100% confidence regarding the product quality or the reliability of a service provider before making the payment for the product. This information asymmetry between interacting partners was pointed out by the analysis of Akerlof [1970], when he introduced the Market for Lemons problem. To cope with such problem, reputation of each participant can be used to alleviate this information asymmetry and facilitate trustworthy online marketplaces.

Reputation is a decision-making tool for assessing possible interactions, selecting as well as understanding the behaviors of trading partners [Giardini et al. 2013]. Most reputation-based systems use historical information either reported by each participant's direct observation or indirect feedback from others to derive reputation of interacting partners [Wang and Vassileva 2007; Tavakolifard and Almeroth 2012]. Most online transactions are driven by the cooperation of trading members with high reputation scores, while low reputation holders are judged as untrustworthy members and are inevitably forced to leave the marketplace. Nevertheless, this ideal concept is only possible in the ideal online marketplaces. In real-world scenarios, the modeling of reputation-based systems requires great flexibility to maintain and sustain market efficiency.

As stated by Teacy et al. [2008], agents in business environments always encounter the dilemma of whether to keep interacting with the same "trusted" agents or to keep experimenting by trying other agents with whom they have not had much experience thus far (i.e., explore in order to discover better providers). In other words, future welfare plays a major role in choosing trading partners irrespective of their trustworthiness. According to Braynov and Sandholm [2002], an efficient market does not require trust assessment or the collection of information regarding untrustworthy agents. Agents truthfully reveal their trustworthiness at the beginning of every transaction. Untrustworthy agents can possibly transact as efficiently as trustworthy agents if they estimate each other's abilities accurately. Therefore, a market in which agents are trusted to the degree they deserve to be trusted is as efficient as a market with complete trustworthiness.

However, the process of finding potential untrustworthy agents to engage in future transactions is considered to be a crucial step. Several conditions need to be considered; for example, an agent becomes untrustworthy because of some unintentional behavior, or an agent violates another agent's trust but expresses regret or apologizes thereafter, or an agent provides a valuable product or service that other agents are unable to provide. To address this issue, the concept of forgiveness can be applied to not only eliminate negative motivations towards untrustworthy agents but also to identify whether the reinstatement of their trust is beneficial to all parties. Specifically, forgiveness can be used as a tool to help sustain cooperation and maintain relationships

with qualified untrustworthy agents [Maio et al. 2008]. Note that the success of forgiveness needs to be conditional, including the choice of punishment (not to forgive) and the expectation that the transgression will not be repeated. In fact, implementing psychological mechanisms like forgiveness in the context of trust and reputation in an online setting has received minimal attention. Therefore, in this study, we propose an exploration approach based on the evaluation of five forgiveness motivations, that is, intent, history, apology, severity, and importance from the viewpoints of different agents concerned. In other words, apart from the victim, both victim and transgressor community members also determine the tendency to forgive transgression in a given scenario. The outcome of our proposed forgiveness mechanism can be utilized by online marketplaces for more reliable and acceptable transactions.

The rest of the article is organized as follows. In Section 2, we present related work on enhanced trust and reputation systems based on both non-psychological and psychological approaches. This is followed by some theoretical background on forgiveness in Section 3. Section 4 is dedicated to our forgiveness mechanism. Simulations to evaluate the effectiveness of the framework are provided in Section 5. The last section concludes our study mentioning the scope for future work in this field.

2. RELATED WORK

A categorization of previous studies based on non-psychological and psychological approaches to deal with the process of trust recovery of untrustworthy agents is discussed in the following subsections.

2.1. Non-Psychological Approaches

The study by Griffiths [2006] defines rebootstrap rate referring to a strategy when there are no trusted agents providing the required capabilities, such that the agent with the highest trust level based on some probabilistic models from the pool of untrustworthy agents will be selected. Specifically, the rebootstrap rate is adopted to avoid deadlock when in a certain situation all interacting agents are distrusted and are not considered for cooperation. In our study, a comprehensive exploration strategy based on the evaluation of different factors from various information sources is introduced to discover potential untrustworthy agents.

Braynov and Sandholm [2002] propose a trust revelation mechanism that involves agents holding accurate estimates of one another at the beginning of every transaction, even if they are untrustworthy. In other words, agents having trust values to the degree they deserve to be trusted can transact as efficiently as trustworthy agents. However, it will be costly and time-consuming for the system to evaluate trust values of interacting agents before engaging in a transaction. Similar to a multi-criteria rating system called FIRE [Huynh et al. 2006], which is capable of handling the changeability problem in participant's behaviors or relationships (for example, when a former trustworthy partner becomes unreliable or breaks old relationships). To cope with such circumstances, FIRE, which is a decentralized model, continuously monitors the performance of components and adopts learning techniques with the purpose of adjusting respective parameters tailored to a given situation. Our approach, on the contrary, makes use of a centralized agent that monitors, collects, and accumulates evaluation information.

The most famous online auction site, eBay, provides a feature called the "feedback revision" (formerly mutual feedback withdrawal) [eBay 2015] to facilitate the reparation of trust breakdowns. Since there are a variety of reasons for buyers to leave negative feedback, eBay's feedback revision provides a place for the seller to identify, apologize, and solve issues that the buyers may encounter. Once the buyer is satisfied with the seller's response, the seller sends a request asking the buyer to revise his or

her negative feedback. Differently from our approach, when a transactional conflict occurs, it will be investigated through both subjective (individual level) and objective (community level) perspectives to provide a more reliable assessment.

2.2. Psychological Approaches

In order to allow untrustworthy agents to build up their reputation, two main prosocial motivations are required: forgiveness and regret. A combinatorial framework of trust, reputation, and forgiveness has been proposed by the study of Vasalou and Pitt [2005] called the DigitalBlush System. The system, which was inspired by human forgiveness, uses expressions of shame and embarrassment to elicit potential forgiveness by others in society. In more detail, an offender's natural reactions of shame and embarrassment can prompt sympathy or forgiveness from the victim. However, misinterpretation of emotional signals can be more problematic than if they are completely ignored. In subsequent works of Vasalou et al. [2006, 2008], when trust breaks down, the trustworthiness of the offender will be detected by identifying a number of motivation constituents [Vasalou et al. 2006]. If the result is positive, then the victim will be presented with those motivation constituents for consideration before reassigning a reputation score to the offender. Specifically, this intervention mechanism intends to alleviate the victim's possibly negative attributions, while, at the same time, it aims to prevent an unintentional/infrequent offender from receiving an unfair judgement. In Vasalou et al. [2008], they investigate trust reparation in one-off online interactions by conducting an experiment that hypothesizes and shows that systems designed to stimulate forgiveness can restore a victim's trust in an offender.

The concept of regret has been proposed by Marsh and Briggs [2009] as a cognitive inconsistency. Regret can occur from truster, trustee, or both counterparts. A truster can experience regret because a positive trust decision is betrayed by a trustee. In other words, a truster's regret occurs when their expectations of the interaction toward a trustee were violated and the resultant corresponding betrayal severely damages trust. A trustee may experience regret due to a negative trust decision being erroneous. This means that a trustee may experience regret even if no wrongdoing has been committed. Both truster and trustee can feel regret over a missed opportunity. Forgiveness and regret are considered as implementable properties to formalize the incorporation of trust defining a computational model.

A forgiveness factor has been used in Burete et al. [2010, 2011] as an extended component of the classical reputation model. It is an optimistic view of reconciliation based on the fact that individuals are more likely to forgive someone who committed an offence in the distant past rather than one just recently committed. Intuitively, an agent should forgive a counterpart's mistake after a sufficiently long amount of time has passed without any interaction. Specifically, forgiveness of the offended counterpart is triggered in the form of the increment of direct reputation as a result of subsequent successful transactions or a quiescence period.

The majority of approaches in this category are close to the mechanism proposed in our study. However, the major difference is that they only consider the information source as dyadic interactions, whereas our approach combines information from both dyadic and community interactions. Furthermore, some approaches consider applying only one aspect (e.g., regret, forgetting based on a quiescence time) to evaluate the possibility to forgive transgressors. Our proposed mechanism covers the evaluation of five different factors to ensure a more accurate realization of the real-word model.

3. FORGIVENESS

Undoubtedly, violations of norms and regulations are inevitable in human societies. As a result, punishments are implemented either emotionally (e.g., experiencing

embarrassment) or practically (e.g., prosecution) as a social protective mechanism to maintain a sense of standard order within a community. However, some kinds of transgressions can be forgivable [Vasalou and Pitt 2005]. From the perspective of religious beliefs, the key word in learning to forgive is the willingness to forgive [Jampolsky 2011]. Forgiveness is the way out of the darkness and into the light. The very important issue when considering forgiveness is it somehow can abandon all sense of security. Even so, allowing forgiveness does not conclude that other parties agreed with the actions of the transgressor. The value of forgiveness can be attained by first eliminating the unwillingness to change our belief systems regarding the disposition of humans. This is also supported by the study of Haselhuhn et al. [2010] in which individuals who believe that moral character can change over time are more likely to trust their counterpart following an apology and subsequent trustworthy behavior than individuals who believe that moral character is fixed.

Forgiveness is a consequence of prosocial motivational changes that heal an individual's initial negative disposition towards the transgressor (i.e., revenge, avoidance, etc.) with a positive motivation [McCullough et al. 2001]. Additionally, issuing forgiveness can encourage the transgressor's voluntary reparative actions. More importantly, applying punishment to the transgressor for an unintentional action will often result in displeasure and low-compliancy behaviors, making forgiveness more difficult [Vasalou and Pitt 2005; Vasalou et al. 2006]. The change of motivation depends on a number of factors, which help to alleviate the soreness of the victim, for example: (1) the severity of the fault occurrence, (2) the transgressor's intent, (3) the expression of apology and regret, (4) reparative actions, (5) the transgressor's prior interactions, and (6) the importance of service or product the transgressor provides.

More specifically, the victim first assesses the severity of the current transgression before considering forgiveness. This means that a transgression resulting in serious damage has a smaller possibility of being forgiven than those resulting in minor damage [Boon and Sulsky 1997]. Moreover, persistent transgressions resulting in minor damage tend to lead to situations where forgiveness is impossible [Buss 1980]. A transgressor may violate the victim's trust unintentionally. In such a case, an unintentional act can lead to a more positive attitude than an intentional act [Vasalou et al. 2008; Boon and Sulsky 1997]. Furthermore, a sincere apology and regret can restore a more favorable impression and a perception of trust towards the transgressor. Besides, the transgressor's expression of apology and regret can evoke more empathy, which is in turn more likely to grant forgiveness [McCullough et al. 2001]. In business environments, reparative responses (e.g., a discount for the next purchase or acts of compensation and complimentary goods for future service) are the most effective means of retaining a partner's reputation in order to show that the transgressor has taken responsibility for the mistake [Vasalou et al. 2008; Xie and Peng 2009]. Additionally, the outcome of past behaviors or previous interactions can assist in deciding whether or not to forgive the transgressor [McCullough et al. 2001]. In other words, poor historical experiences decrease the likelihood of forgiving the current transgression. Last, if the transgressor is the only one to have a prominent service or product that is required by another party, forgiveness tends to be granted to fulfill the requirement of the transaction. Similarly, the importance of a specific relationship can also override any negative dispositions leading to ultimate forgiveness, which is expected to restore cooperation between partners after a transgression [Marsh and Briggs 2009; McCullough et al. 1998; Burnette et al. 2012].

It is worth noting that forgiving a single transgression cannot override someone's attitude as a whole [Exline et al. 2003]. Specifically, while a current violation may be forgiven, the transgressor's violation of trust towards others in the past may still impede. Therefore, it is not necessary to consider forgetting or condoning as a part

of forgiveness. There are many benefits fostered by forgiveness. Relationships, for example, after individuals grant forgiveness to someone who has committed an offence, include a willingness to sacrifice negative motivation, which can improve and maintain relationship satisfaction [Maio et al. 2008]. Furthermore, social interactions with other parties also improve as they become more supportive and altruistic in general [Karremans et al. 2005]. Also, individuals' status and power can be compromised when someone has transgressed towards them [Wenzel and Okimoto 2010]. The act of forgiveness in this sense can be considered as a sense of justice providing individuals with an opportunity to reassert their status and position of power.

However, apart from highlighting the benefits of forgiveness, Luchies et al. [2010] argue that forgiveness can be disadvantageous in some circumstances, especially when it applies to an untrustworthy and disagreeable person. Specifically, a reasonable and agreeable person who has acted offensively will always apologize sincerely, take responsibility, and even compensate in some sense. As a result, the relationship between the victim and the transgressor can be maintained. Moreover, forgiveness tends to be appropriate and foster self-respect. On the other hand, if the person who has acted offensively continues to be unreliable and disagreeable, the victim is unlikely to benefit from allowing forgiveness to this person, leading to the reduction of self-respect. Therefore, forgiveness in this context is, instead, indignity and humiliation.

4. PROPOSED FORGIVENESS MECHANISM

In this section, we present a novel forgiveness mechanism that is used to explore untrustworthy agents who possess the required capabilities to fulfill future transactions. Based on these required capabilities, forgiveness is formulated to reflect, to some extent, the positive motivations that the untrustworthy agents have. Moreover, the implementation of the mechanism is centralized in nature. It is activated by a specialized agent within the online marketplace called the "Forgiveness Facilitator" either in a request from a transgressor when the transgression occurs or on request from a consumer to discover potential service providers from a pool of untrustworthy agents.

4.1. Defining Forgiveness Factors

We start by analyzing the factors that motivate forgiveness by alleviating the victim's negative responses. We modify a motivation-driven conceptualization of forgiveness that is identified by Vasalou et al. [2006] where positive motivations are collectively evaluated to formulate forgiveness. These following factors are used to find the prospective untrustworthy agents who can potentially reestablish their reputation.

—**Intent (PM_{in}).** An offence is more or less forgivable depending on the victim's attribution of the transgressor's intention. In the event of an intentional act, a transgressor has committed his-/herself to deliberately harm a victim, resulting in the formation of a victim's harsh dispositional judgments. As a consequence of such an intentional offence, forgiveness is unlikely for the victim to be conducted. However, the action of an unintentional/infrequent offence can lead to a more positive judgement and is more likely to foster forgiveness [Boon and Sulsky 1997]. Also noting that lack of information about the transgressor's intention can presumably make the victim's perception of the transgressor's actions as being intentional even though they are in fact unintentional.

—**History (PM_{hi}).** Productive past interactions of a transgressor at both the dyadic and corporate levels are a key component for trust building, as they assist in fostering benevolence. Such benevolence can also increase the tendency towards forgiveness. Conversely, offensive historical experiences of a transgressor decrease the likelihood

of positive motivations that result in a negative inclination to forgive [Vasalou et al. 2008].

—**Apology (PM_{ap}).** The transgressor's expression of a truthful apology as a form of an affective recovery effort can enhance the victim's perceptions of interactional justice and improve post-recovery satisfaction [Smith et al. 1999]. Apart from an interpersonal apology, a corporate apology for negative consequences and its willingness to assume relevant responsibility can lead to a favorable impression that the transgressor and his/her organization are problem solving-oriented rather than inclined to conceal reality. Additionally, forgiveness is related to the time of expressing apology as it shows a sense of taking responsibility. In other words, the transgressor who apologizes immediately after an offence takes place is more likely to be forgiven than who apologizes later.

—**Severity (PM_{se}).** Forgiveness is more easily granted when the transgression is perceived as less severe [Boon and Sulsky 1997]. Severe transgressions have a tendency to lead to less positive judgments. However, the severity assessment requires some serious consideration as the transgression might not only impact the present but also the past and inevitably the future. If the consequences of the current transgression are forgiven, then its future consequences are also likely to be continually granted forgiveness. Moreover, the transgressor's past offences are compared to the current event. The frequency and severity of past offences can also impact an individual's inclination to forgive [Buss 1980].

—**Importance (PM_{im}).** If the transgressor is the sole provider of a product or service that is most required by the victim or other members in the community, then forgiveness tends to be granted in order to fulfill the transaction's requirement and avoid deadlock even knowing that the outcome of future transactions may not be maximized. Also, the extent of relationship between the victim and the transgressor has the potential to override the victim's negative disposition towards an offence, thereby resulting in positive judgements that are expected to assist in restoring cooperation [Marsh and Briggs 2009; McCullough et al. 1998; Burnette et al. 2012]. Furthermore, the role played by the transgressor within the community that influents the victim or other members in several ways either directly or indirectly can lead to a more positive disposition.

4.2. Sources of Forgiveness

Our reputation system applies the concept of community [Malik and Bouguettaya 2009] to categorize agents related to a specific domain, for example, car dealer, book dealer, real estate agency, travel agency, and so on. However, each community member may possess different expectations of attributes (e.g., price, quality, and delivery time) for the same product or service. For purposes of simplification, we assume there are two communities: consumer and service provider communities. The consumer community consists of consumer agents who purchase the product or utilize the service provided by service provider agents, while the service provider community consists of service provider agents whose functionalities are to serve, maintain, and deliver high-quality products and/or services to consumer agents.

In this study, we assume a transgression occurs when a service provider agent breaks the transactional agreement by not delivering the product or delivering a product of inferior quality. The consumer agent as a victim not only suffers from failure of receiving the product as promised but also spending unnecessary time to lodge a complaint and the additional cost in finding a new service provider. In many cases, it is not only the consumer agent who directly suffers the transgression but also their community members from both the consumer and the service provider communities. For example, a car dealer A of brand B sells an inoperable or unusually problematic new car to a

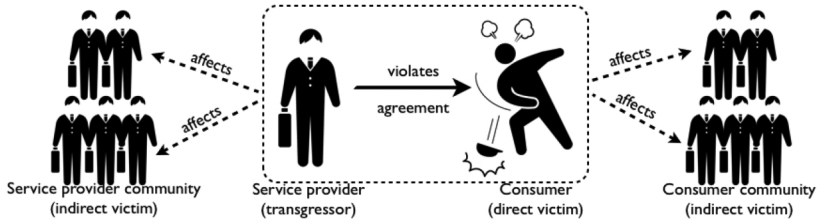

Fig. 1. Direct and indirect sources of forgiveness.

Table I. Positive Motivations for Evaluating Forgiveness from the Points of View of the Victim, the Victim Community, and the Transgressor Community

Positive motivations (PM)	Victim (F_v)	Victim community (F_{vc})	Transgressor community (F_{tc})
Intent (PM_{in})	•		
History (PM_{hi})	•	•	
Apology (PM_{ap})	•	•	•
Severity (PM_{se})	•	•	•
Importance (PM_{im})	•	•	•

customer C. After some period of time, when a customer C discovers the problems of the car he bought, he is inevitably disappointed and retains a negative experience of buying a car of brand B, especially from car dealer A. In the event where the case of a customer C goes public (e.g., using social media), other customers who bought a car of brand B from a car dealer A are also likely to be distressed about the quality of their car.

As shown in Figure 1, violating contractual terms or agreements by a transgressor can possibly affect both direct and indirect victims. Specifically, a direct victim is the one who engages in a transaction with a transgressor and is the first one who adversely affected by the transgression, while an indirect victim is an individual or group of members in a community who does not transact with a transgressor directly or is not the direct target but still suffers as a result of that transgression. Therefore, forgiveness can be issued from both direct and indirect sources: (i) the victim of a transgression, (ii) the victim (consumer) community, and (iii) the transgressor (service provider) community. The victim community is likely to forgive a transgressor based on the fact that the future transactions between a transgressor and other members in the victim community are possible. Similarly to human societies, forgiveness from the victim community can be considered as a declaration of amnesty. Furthermore, a transgressor is likely to seek forgiveness from his/her own community for a transgression that negatively affects trust of the whole community. Forgiveness from the transgressor community can be motivated to overcome distrust and restore harmony to the relationship among community members. Hence, the overall forgiveness value is an aggregation of forgiveness evaluation from both direct and indirect victims.

4.3. Computational Model of Forgiveness

Table I presents a mapping between positive motivations described above and the sources of forgiveness. Each source of forgiveness has different points of view to evaluate and subsequently decide whether the transgressor should be forgiven. We suppose agent y violating trust of agent x also affects trust of agent x's community members (denoted as X) and agent y's community members (denoted as Y). The following subsections detail how each forgiveness factor can be calculated and how each forgiveness source provides their forgiveness value.

4.3.1. Computation of Positive Motivations. In this subsection, computational models are provided for evaluating positive motivations by taking into account the information provided by agents (i.e., agent x and agent y) and communities (i.e., community X and community Y).

—**Intent.** The number of transactions between interacting agents are used to evaluate an agent's intent. More specifically, if the number of transactions processed by agent y is high, then it means that agent y has a high level of experience. This can lead to the fact that a highly experienced agent y would transact with a similarly high degree of intention. Therefore, the agent y's intent of violating agent x's trust can be computed by the following:

$$PM_{in}(x, y) = \left(1 - \left(\frac{N_y^{all+}}{N_y^{all+} + N_y^{all-}} \times \frac{N_x^{y+}}{N_x^{y+} + N_x^{y-}}\right)\right) \times \delta_y, \tag{1}$$

where N_y^{all+} and N_y^{all-} are the total number of successful and defective transactions of agent y, respectively. N_x^{y+} and N_x^{y-} are the number of successful and defective transactions between agent x and agent y, respectively. δ_y is a factor that discounts agent y's intent in case the number of transactions of agent y is less than a predefined minimum number of transactions N_y^{min}. δ_y can be defined according to the formula:

$$\delta_y = \begin{cases} \frac{N_y^{all}}{N_y^{min}}, & \text{if } N_y^{all} < N_y^{min} \\ 1, & \text{otherwise} \end{cases}, \tag{2}$$

where $N_y^{all} = N_y^{all+} + N_y^{all-}$ and N_y^{min} can be provided by the preference of the system designer.

—**History.** The result of past interactions between agent x and agent y can be calculated by considering the number of transactions as

$$PM_{hi}(x, y) = \frac{N_x^{y+} - N_x^{y-}}{N_x^{y+} + N_x^{y-}}. \tag{3}$$

If $PM_{hi}(x, y) > 0$, then historical interactions between them are considered to be productive. Otherwise they are offensive ($PM_{hi}(x, y) \leq 0$).

—**Apology.** As apology is directly related with time, a recency factor (RF) is first defined as [Huynh et al. 2006]

$$RF(a) = e^{\frac{\triangle t(a)}{\lambda}}, \tag{4}$$

where $RF(a)$ is the recency factor for an apology a. $\triangle t(a)$ is the time difference $(t_o - t_a)$ between the time that the transgression takes place (t_o) and the time that the offender apologizes (t_a). The greater the difference between these two values indicates a significantly smaller positive judgement. The parameter $\lambda \in [0, 1]$ is the decay rate of the apology offer. Small λ indicates greater reliance on the prompt expression of an apology. On the other hand, increasing λ indicates a greater preference for late apologies. The overall apology value is an aggregation of both interpersonal and a corporate apologies as follows:

$$PM_{ap}(x, y, Y) = \frac{(a_y^x \times RF(a_y^x)) + (a_Y^x \times RF(a_Y^x))}{RF(a_y^x) + RF(a_Y^x)}, \tag{5}$$

where $RF(a_y^x)$ and $RF(a_Y^x)$ are the recency factors of apology offered to agent x by agent y and community Y, respectively. a_y^x and a_Y^x are the honesty of apology offered by agent y and community Y, respectively, and range from 0 to 1.

—**Severity.** The severity of a transgression is evaluated by considering the current utility that agent x has lost from transacting defectively with agent y:

$$PM_{se}(x, y) = \left(1 - \frac{U_x^{y+} - U_x^{y-}}{U_x^{y+} + U_x^{y-}}\right) \times PM_{im}(x, y), \tag{6}$$

where U_x^{y+} is the expected utility that agent x could have been gained from transacting with agent y and U_x^{y-} is the utility that agent x has lost from the transgression committed by agent y. $PM_{im}(x, y)$ indicates the importance of the product or service offered by agent y to agent x.

—**Importance.** We evaluate the importance of product or service offered by agent y to agent x by calculating the utility that agent x obtained from transacting with agent y compared with the utility that agent x obtained from all transactions:

$$PM_{im}(x, y) = \frac{\sum_{y_i=1}^{N_x^y} U_x^{y_i}}{\sum_{m \in all(x)} \sum_{m_i=1}^{N_x^m} U_x^{m_i}}, \tag{7}$$

where U_x^y is the total utility obtained from transactions between agent x and agent y and U_x^m is the total utility obtained from transactions between agent x and all other agents in the set $all(x)$.

4.3.2. Forgiveness Values from Different Sources. In order to ascertain the possibility of issuing forgiveness for a transgression committed by agent y, agent x as a direct victim and community X and community Y as indirect victims evaluate all possible factors according to positive motivations as described below.

—**Victim of a transgression.** All positive motivations are assessed from the point of view of the victim, that is, agent x as follows:

$$F_v(x, y, Y) = PM_{hi}(x, y) + PM_{ap}(x, y, Y) + PM_{im}(x, y) - PM_{in}(x, y) - PM_{se}(x, y), \tag{8}$$

where $F_v(x, y, Y)$ is the forgiveness value evaluated by agent x for the violation made by agent y, who is a member of community Y. $PM_{in}(x, y)$ is the intent assessment of the transgression reported by both agent x and agent y. $PM_{hi}(x, y)$ is the result of past interactions between agent x and agent y. $PM_{ap}(x, y, Y)$ is the apology offered by agent y towards agent x incorporating the apology offered by community Y towards agent x. $PM_{se}(x, y)$ is the severity of the transgression made by agent y and reported by agent x. $PM_{im}(x, y)$ is the importance of agent y to agent x either in the form of product offered or relationship.

—**Victim community.** Positive motivations from the viewpoint of the victim community differ from that of the victim. According to Table I, all positive motivations are used to formulate forgiveness, except PM_{in} as the victim community is considered to be an indirect target of the transgression. Therefore, the victim community's forgiveness can be evaluated according to the expression:

$$F_{vc}(x, X, y, Y) = \sum_{\substack{i \in X \\ i \neq x}} (PM_{hi}(i, y) - PM_{se}(i, y)) + PM_{ap}(X, y, Y) + PM_{im}(X, y), \tag{9}$$

where $F_{vc}(X, y, Y)$ is the forgiveness value aggregated from the members of community X for the transgression made by agent y, who is a member of community Y. $PM_{hi}(i, y)$ is the historical interaction between agent i of community X and agent y. $PM_{se}(i, y)$ is the assessment of severity of the transgression made by agent y towards agent i. Both $PM_{hi}(i, y)$ and $PM_{se}(i, y)$ probably differ for each member in

the community. $PM_{ap}(X, y, Y)$ is the apology expressed by agent y towards community X incorporating the apology expressed by community Y towards community X. $PM_{im}(X, y)$ is evaluated by considering the importance of the product or service that agent y has offered to community X.

—**Transgressor community.** Apart from the victim community, the transgressor community also suffers indirectly from the transgression committed by the transgressor. Some positive motivations are collected and aggregated to formulate the transgressor community's forgiveness as defined below:

$$F_{tc}(Y, y) = PM_{ap}(Y, y) + PM_{im}(Y, y) - \sum_{\substack{j \in Y \\ j \neq y}} (PM_{se}(j, y)), \tag{10}$$

where $F_{tc}(Y, y)$ is the forgiveness value calculated from the members of community Y for the transgression committed by agent y. $PM_{se}(j, y)$ is an assessment of the severity of the transgression made by agent y towards agent j of its own community Y. $PM_{ap}(Y, y)$ is the result of the interpersonal apology offered by agent y towards its own community Y and can be calculated similarly to Equation (5) as $PM_{ap}(Y, y) = a_y^Y \times RF(a_y^Y)$. $PM_{im}(Y, y)$ indicates the importance of the product or service provided by agent y to its own community Y.

In the case where the community consists of a large number of members. It is nearly impossible to request forgiveness assessment from all community members as it is costly and time-consuming. A set of community leaders or members with high reputation values who have experienced interacting with agent y can be used to represent the evaluation of positive motivations for the entire community. The set is provided by the forgiveness facilitator. For example, we assume $X^+ = \{x_1^+, x_2^+, \ldots, x_m^+\}$, where X^+ is a set of high-reputation members of community X. The victim community's forgiveness can then be as follows: $F_{vc}(x, X^+, y, Y) = \sum_{\substack{i \in X^+ \\ i \neq x}} (PM_{hi}(i, y) - PM_{se}(i, y)) + PM_{ap}(X, y, Y) + PM_{im}(X, y)$. Similarly to the transgressor community, if we assume $Y^+ = \{y_1^+, y_2^+, \ldots, y_n^+\}$, where Y^+ is a set of high-reputation members of community Y, then the forgiveness value calculated by the transgressor community can be expressed as follows: $F_{tc}(Y^+, y) = PM_{ap}(Y, y) + PM_{im}(Y, y) - \sum_{\substack{j \in Y^+ \\ j \neq y}} (PM_{se}(j, y))$.

4.3.3. An Overall Forgiveness Value. All forgiveness assessment values from agent x as the victim (F_v), the victim community X (F_{vc}), and the transgressor community Y (F_{tc}) will be transformed by applying the normalized inverse tangent function, which is monotonically increased in a range between 0 and 1 [Zhang et al. 2008]. As a result, the victim's (F'_v), the victim community's (F'_{vc}), and the transgressor community's (F'_{tc}) functions can be formulated as shown in Equations (11), (12), and (13), respectively:

$$F'_v = \frac{atan(F_v(x, y, Y) - \alpha_v) + atan(\alpha_v)}{\pi/2 + atan(\alpha_v)}, \tag{11}$$

$$F'_{vc} = \frac{atan(F_{vc}(x, X, y, Y) - \alpha_{vc}) + atan(\alpha_{vc})}{\pi/2 + atan(\alpha_{vc})}, \tag{12}$$

$$F'_{tc} = \frac{atan(F_{tc}(Y, y) - \alpha_{tc}) + atan(\alpha_{tc})}{\pi/2 + atan(\alpha_{tc})}, \tag{13}$$

where α_c, α_{vc}, and α_{tc} are forgiveness increasing factors of the victim, the victim community, and the transgressor community, respectively. Figure 2 provides a

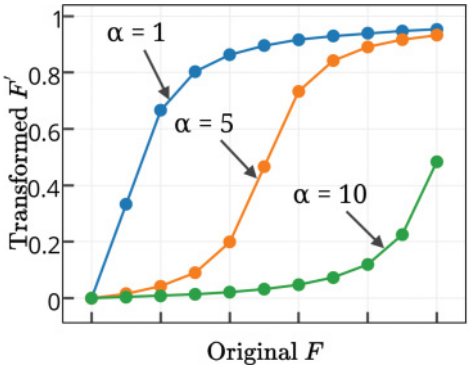

Fig. 2. The normalized inverse tangent function with $\alpha = 1, 5$, and 10.

general trend of transformed forgiveness values for different increasing factors. As α goes higher, the increasing speed of the transformed forgiveness value goes down. Moreover, the transformed forgiveness value increases slowly when the original calculated forgiveness value is less than α and then increases rapidly and ultimately flattens out when the calculated forgiveness value is large enough.

The overall forgiveness value for the transgression committed by agent y is the aggregation of both subjective (at the individual level) and objective (at the community level) perspectives:

$$F_{total}(y) = \omega_v F'_v + \omega_{vc} F'_{vc} + \omega_{tc} F'_{tc}, \tag{14}$$

where ω_v, ω_{vc}, and ω_{tc} are the weight factors reflecting the major victim of the transgression and the major contributor to the forgiveness assessment. The summation of all weight factors is equal to 1. In our case, we set $\omega_{tc} < \omega_{vc} < \omega_v$, meaning that even there are collective views of positive motivations at the community level, the primary decision for granting forgiveness is still made by the victimized individual.

5. EXPERIMENTS AND RESULTS

In this study, the use of NetLogo [Wilensky 1999] has been proposed to simulate and compare online marketplaces along with their interacting agents. NetLogo is an open-source multi-agent-based simulation environment developed by the Northwestern University Center for Connected Learning and Computer-Based Modeling. It is well suited for modeling and simulating time-varying complex scenarios. It is therefore capable of exploring connections between the micro-level behavior of individual interactions and the macro-level patterns that emerge from the collection of their interactions. As an agent-based modeling tool, NetLogo has been used to design and simulate various complex systems in a variety of domains such as art, biology, chemistry, physics, computer science, mathematics, and many other natural and social sciences [NetLogo 2015].

Our general NetLogo model interface consists of three parts as presented in Figure 3. The top left part is the area for controlling and initializing the model's input parameters, while the bottom left and right parts are the areas for monitoring and displaying the model's output parameters. On the right side is our simulated online marketplace (or patches) along with visualization of interacting agents.

5.1. Experimental Setting in NetLogo

In NetLogo, our simulated online marketplace is represented as the NetLogo World, a two-dimensional grid of squares called *patches*. The online marketplace consists of two types of agents: the service provider agents and consumer agents, interacting for the

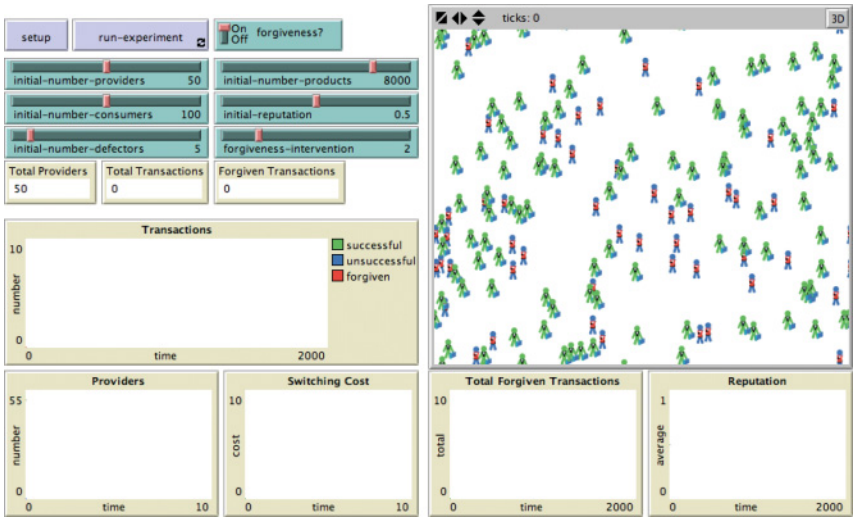

Fig. 3. Model interface in NetLogo.

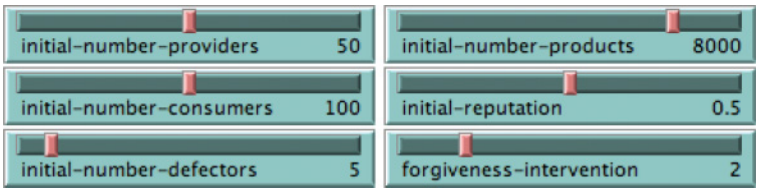

Fig. 4. Initial model's settings in NetLogo.

same type of product with homogeneous acceptable quality. Both agents have different shapes and colors; the service provider agents are in blue while the consumer agents are in green. At the beginning, we set the numbers of service provider agents and consumer agents as 50 and 100, respectively. All service provider agents are initially "trustworthy" and bootstrapped by assigning a reputation value of 0.5.

Each service provider agent has the same initial number of products, that is 8,000 units, which is sufficiently large enough to prevent service provider agents from running out of products. Only one unit of product is traded for each transaction. The prices of the product are valued differently by service provider agents and consumer agents, that is, randomly distributed between 100 and 200 for service provider agents and randomly distributed in a given range between 200 and 250 for consumer agents. The initial settings for the number of service provider agents, consumer agents, products, reputation value, defectors, and forgiveness interventions in NetLogo can be seen in Figure 4.

Consumer agents randomly move around the patches to find service provider agents for interaction. However, there is a maximum number of service provider agents who are randomly marked as "defective" ($Def_{sp} = 5, 10, 15, 20$) for every time period of interaction. As a result, after each transaction reputation values of service provider agents increase if they are not defective; otherwise reputation values will be decreased. The reputation values of service provider agents lie in the range between -1 and 1. Moreover, service provider agents will be marked as "untrustworthy" by changing their color from blue to red if their reputation values fall below 0.

Table II. Summary of Experimental Parameters

Number of service provider agents	50
Number of consumer agents	100
Reputation value of service provider agents	[−1, 1]
Initial reputation value of service provider agents	0.5
Number of products	8000
Service provider agents' price of product	[100, 200]
Consumer agents' price of product	[200, 250]
Number of defective service providers	5, 10, 15, 20
Switching cost	10
Number of efforts in switching to another service provider agent	3
Forgivability threshold	0.5
Number of forgiveness interventions	2
Forgiveness increasing factors ($\alpha_v, \alpha_{vc}, \alpha_{tc}$)	0.5, 5, 5
Forgiveness contribution weight factors ($\omega_v, \omega_{vc}, \omega_{tc}$)	0.5, 0.3, 0.2

There are two types of online marketplaces in our experiment, that is, the online marketplace incorporating a forgiveness mechanism (called the "forgiving marketplace") and the other where the proposed forgiveness mechanism is absent (called the "unforgiving marketplace"). Consumer agents use different strategies when dealing with untrustworthy service provider agents in each online marketplace. Specifically, consumer agents switch to another service provider agent if they are randomly matched with untrustworthy service provider agents in the unforgiving marketplace. However, each switching entails a cost of 10 to consumer agents and the number of efforts in switching to another service provider agent is set to a maximum of 3. The transaction of this type of online marketplaces is not carried out if consumer agents' switching process is unsuccessful, while, in the forgiving marketplace, consumer agents interact with untrustworthy service provider agents if their forgiveness value is greater than a predefined forgivability threshold (i.e., 0.5) and the number of forgiveness intervention is not more than 2. Otherwise, consumer agents switch to another service provider agent same as in the case of the unforgiving marketplace. To calculate the overall forgiveness value, each positive motivation will be stochastically assigned a real number in the interval [0,1].

At the end of each time period, new service provider agents are allowed to join the online marketplace.[1] In order to maintain the number of trustworthy service provider agents as per initial setting, the number of new service provider agents is equal to the number of service provider agents that become untrustworthy in each time period. The results of agent interactions in both online marketplaces are analyzed and compared after repeatedly performing 2,000 periods of time. All parameter settings used in the experiment are summarized in Table II.

5.2. Model Validation

The validation of the agent-based simulation is essential for its acceptance and the accurate representation of the real world. It is a dynamic process that determines the behavior of interacting agents and the relevancy between a theory and the system being modeled [Gilbert 2008]. In our experiment, one of the preferred validation techniques, sensitivity analysis, is applied to examine whether our agent-based model can yield the expected results. Sensitivity analysis typically refers to the mechanism to explore the conditions that reveal the effects of parameter variations [Gilbert 2008; Burgers et al. 2010]. For this purpose, we examine the conditions involving the comparison of

[1]In NetLogo, we differentiate new service provider agents from existing ones by using dark blue color.

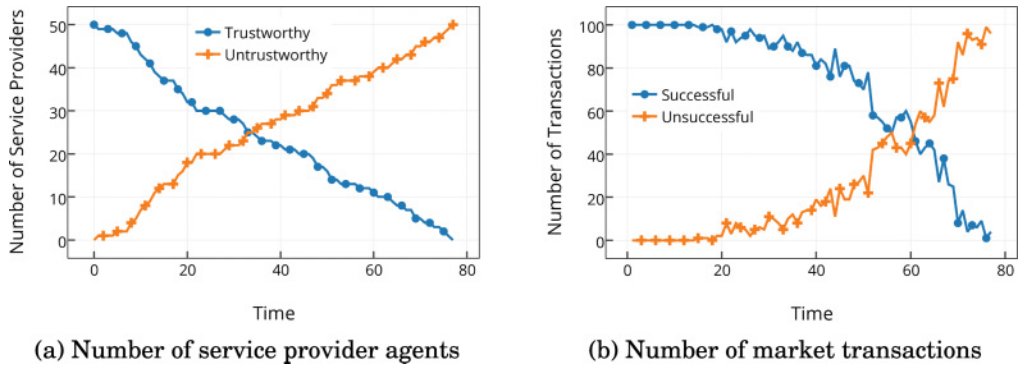

Fig. 5. Results of the pilot experiment.

the implementation of the proposed forgiveness mechanism in the simulated online marketplace and different levels of trust violation represented by the number of defective service provider agents. To initially comprehend the impact of the forgiveness mechanism, two pilot experiments of the online marketplace without incorporating the forgiveness mechanism are conducted with controlled parameter variations. These are as follows: The number of defective service provider agents in each time period is fixed to 5 and new service provider agents are prevented from joining the online marketplace.

In the first pilot experiment, we observe the changes in the number of trustworthy and untrustworthy service provider agents as time goes by. At the beginning, all service provider agents are trustworthy, as shown in Figure 5(a). However, as five defective service provider agents continuously participate in trading activities with the consumer agents in each time period, the number of untrustworthy service provider agents increases accordingly to the point where there are no trustworthy service provider agents for the consumer agents to interact with. As a consequence, the online marketplace collapses in a short period of time. The results are similar when we examine the changes in the number of market transactions in the second pilot experiment as depicted in Figure 5(b). Initially, the online marketplace is capable of completely generating successful market transactions as the consumer agents are able to switch to another trustworthy service provider agent when interacting with untrustworthy service provider agents. However, as the number of untrustworthy service provider agents increases, the consumer agents' switching performance gradually declines, resulting in the number of successful transactions eventually nosedives to zero. The outcomes of the pilot experiments confirm that our agent-based simulation is able to perform effectively and provides results that are consistent with expectations.

5.3. Experimental Results

In the first sub-experiment, we compare the number of untrustworthy service provider agents as time progresses. As shown in Figure 6, the forgiving marketplace (6(b)) is able to decrease the number of untrustworthy service provider agents making the online marketplace more reliable. In particular, when $Def_{sp} = 20$ the total number of untrustworthy service provider agents in the forgiving marketplace (6(b)) is nearly half of that in the unforgiving marketplace (6(a)).

In the second sub-experiment, numbers of market transactions generated in online marketplaces at different time periods and different numbers of defective service provider agents are measured. According to the number of consumer agents (100), the number of market transactions in each time period can practically be a maximum

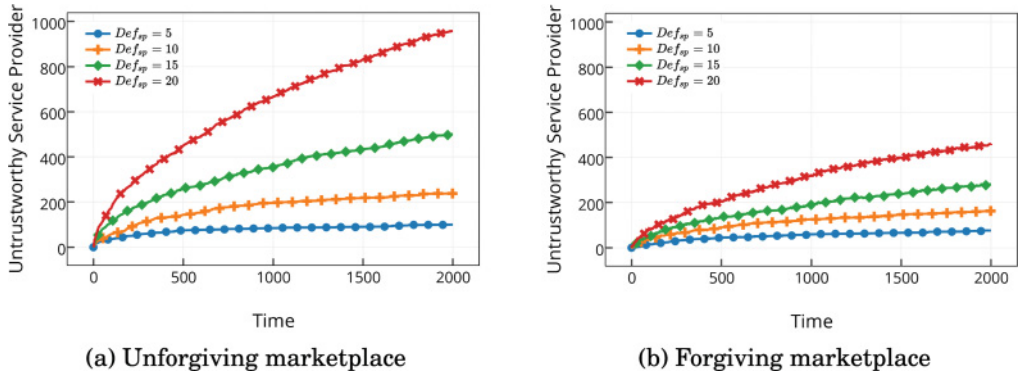

Fig. 6. Number of untrustworthy service provider agents.

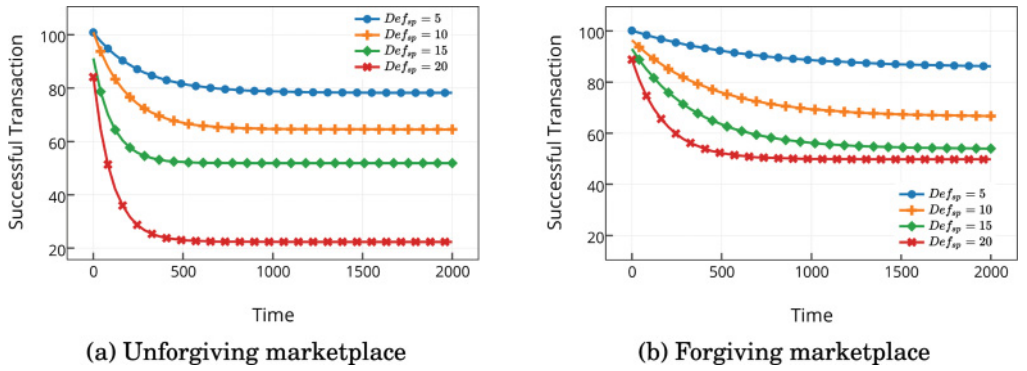

Fig. 7. Number of successful market transactions.

of 100 transactions if all service provider agents are honest. However, can be seen in Figure 7, when the online marketplaces comprise untruthful agents, the forgiving marketplace (7(b)) is able to generate successful transactions higher than that in the unforgiving marketplace (7(a)). More specifically, the forgiving marketplace is capable of generating market transactions up to 50% of total transactions, even at the highest number of defective service provider agents ($Def_{sp} = 20$) compared to the unforgiving marketplace, which is able to generate only 22% of total transactions.

The consumer agents' cost of switching at different time periods in the forgiving and unforgiving marketplaces are compared in the third sub-experiment. The results shown in Figure 8 clearly demonstrate that the proposed forgiveness mechanism is beneficial to the online marketplace in reducing the cost of consumer agents to find new service provider agents to interact with. In other words, consumer agents in the forgiving marketplace (8(b)) have more incentives to perform transactions with service provider agents as they suffer a lower switching cost than those in the unforgiving marketplace (8(a)).

In the last sub-experiment, we measure the average reputation value of trustworthy service provider agents. Results are shown in Figure 9. Both unforgiving (9(a)) and forgiving marketplaces (9(b)) are able to maintain the same range of average reputation value between 0.8 and 1 when $Def_{sp} = 5, 10,$ and 15. However, the difference can be explicitly seen when $Def_{sp} = 20$ as the average reputation value of trustworthy service provider agents in the unforgiving marketplace falls to around 0.6 compared to that in

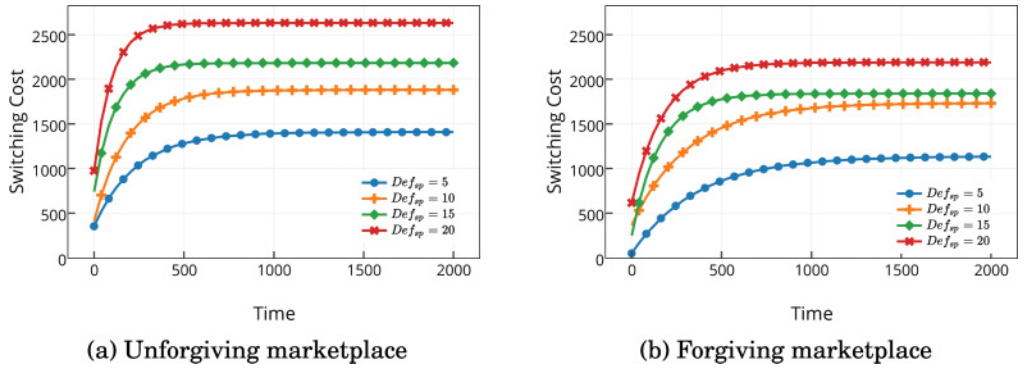

Fig. 8. Consumer agents' cost of switching to another service provider agent.

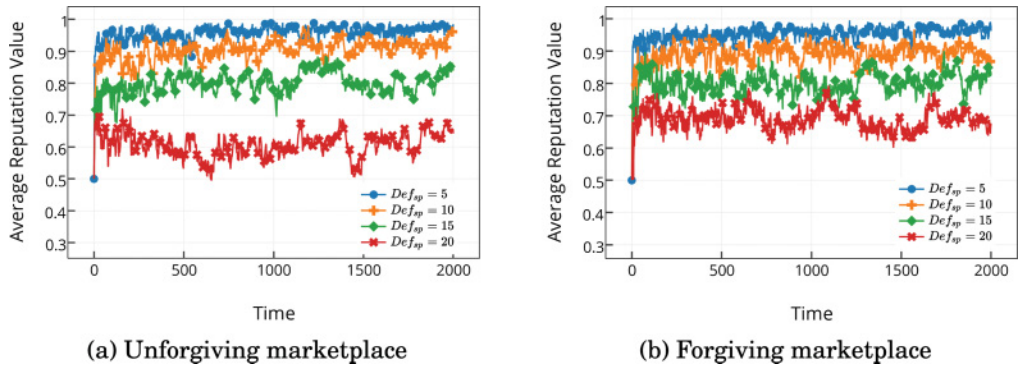

Fig. 9. Average reputation value of service provider agents.

the forgiving marketplace where trustworthy service provider agents retain an average reputation value of approximately 0.7.

5.4. Discussion

Understanding the reality of living in an imperfect world would probably be an important justification as to why humans require the notion of forgiveness. Also, this reason can be applied to the world of online transactions in which intelligent software agents operate representing human agents. However, the most controversial issue regarding the implementation of forgiveness mechanism in the context of online marketplaces is whether it is necessary to forgive transgressors since there are a number of service provider agents in the marketplace that consumer agents can choose from. According to the results presented in the previous subsection, we can consistently come to the conclusion that the online marketplace is more beneficial when it incorporates the proposed forgiveness mechanism. As we focus on the benefits at the community level, our results exhibit strong evidence both in terms of social and economic benefits to be gained in an online marketplace embodying a forgiveness mechanism.

6. CONCLUSION AND FUTURE WORK

In this study, we provide a centralized-based approach for increasing the efficiency of an online marketplace based on the integration of forgiveness mechanism. We propose a forgiveness mechanism that is the evaluation of five positive motivations, that is, intent, history, apology, severity, and importance, based on different computational

models from the viewpoints of the victim, the victim community, and the transgressor community. The outcome of the proposed forgiveness mechanism can be utilized in decision making for discovering potential transgressors. We further conduct a series of experiments based on the use of NetLogo to evaluate the effectiveness of the proposed mechanism through the comparison of different simulated online marketplaces. As a result, the findings of our study underline, by incorporating a forgiveness mechanism, that the online marketplace can benefit from collaborating with potential untrustworthy agents and is able to increase its efficiency.

There are some issues that should be addressed in future work. For example, risk assessment is considered to be necessary when interacting with untrustworthy agents, especially in risky environments. Therefore, incorporating risk assessment with a forgiveness mechanism can make the process of finding potential untrustworthy agents more robust. Apart from implementing in centralized systems, we are also interested in studying how a forgiveness mechanism can improve the performance of multi-agent interactions in distributed systems. To model such systems, a well-known game-theoretic concept, the *Iterated Prisoner's Dilemma (IPD)* game, can be adopted as the foundation of interaction between agents. In the IPD game, a strategy called *Tit-for-Tat (TFT)*, which has been illustrated by Axelrod's computer tournament [Axelrod 1984], is considered to be the most effective strategy. However, the presence of noise or transgressions during interactions lead to the possibility of getting trapped in a cycle of retaliations, thereby weakening the performance of the TFT strategy. To alleviate this situation, the TFT strategy can be extended by incorporating the notion of conditional forgiveness to deal with trust violations in noisy environments. Moreover, it may be of interest to validate the effectiveness of the proposed mechanism by extending experiments based on the use of real datasets and in even more dynamic online marketplace environments.

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