Evolution of Cooperativeness in a Business Game Relying on Acquaintance Based Trustworthiness Assessment

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Abstract— Reputation systems have been popular in several online market places involving anonymous players as it can provide crucial information on the trustworthiness of an object or individual player to combat selfish and deceptive behaviors from peers. Individual feedbacks on the quality of past association are the fundamental building blocks of reputation systems. Careful consideration in aggregating feedbacks from different sources is in fact very important in computing a reliable value for trustworthiness to facilitate decision making in a social dilemma situation like that of online market places.

In this paper we are considering a possible improvement to a reputation model like that of eBay, with our interest lying on investigating how the cooperativeness and population of cooperators would evolve if the weight of the feedback source was assigned on the basis of past association between players. We categorize the feedback source as direct source, gray source and opposition friendly source to define an aggregation method for trustworthiness assessment that considers applying a dynamically computed weight to each source of feedback. Our result shows that breaking feedback sources on the basis of acquaintance and assigning weight accordingly favors the evolution of cooperativeness in the player society as compared to models which do not classify the feedback sources. A genetic algorithm based spatial iterated prisoner’s dilemma (SIPD) environment has been used to simulate the experiments.

Keywords—Evolution of Cooperation; Online Markets; Reputation; Trust; Trust Models

I. INTRODUCTION

Certainty, belief, faith, assurance, confidence, security, integrity, strength, ability, surety, honesty, are just among few of the words that we would use to define what does trust mean to us. Due to the subjective nature of trust many people would define it in many different ways. The context sensitiveness of trust implies that the definition might again change with time and environment. Let’s imagine a situation where a buyer is intending to purchase goods from some anonymous seller online. Provided that the feedback history of past transactions for the sellers are available- the buyer is naturally inclined to choose one with higher number of positive feedbacks for reliability reason. But this might not always be true for some buyers who can take greater risk to obtain a better price bargain. This just illustrates the subjectivity aspect of trust. Further, in a situation, like scarcity of particular goods in market, the buyer might not look for the same level of reliability that would otherwise be expected to make a decision- and this illustrates the context sensitiveness of trust. Considering these aspects we build upon the definitions of Gambetta [1] and Josang [2] to provide the following definition of trust for the purpose of our research: Trust is a subjective probability that a player performs in favour of all other players with whom it plays, such that collectively all of them obtain higher payoff and associated incentives for truthfulness, thus increasing cooperation and each other’s reputation in the society.

At a finer level, trust in someone or something emerges out of the quality of experience in dealings that the trustor has had with the trustee in the past. When such information from direct interaction is not available, the assessor might turn to the society and gather all relevant information on other’s experiences in their past dealings with the candidate, before finally placing its trust in it[2-5]. Such an estimation in which an object is held is known by the term “reputation” [6, 7]. Reputation mechanisms have grown as a powerful method of assessing trust worthiness of an object or individual in online trading, peer to peer and multi-agent environments [4, 5, 8, 9]. Open environments like online business sites and Peer to Peer networks where people can easily join and leave pose special challenges to the system’s quality assurance procedure[4]. On the other hand, openness is an important characteristic of such systems, the more they become restrictive, the lesser their popularity is[10]. The real challenge in this case is to find out ways in which there could be cooperation without any enforcement to the individual. This however, is not straight forward, as defection earns an immediate gain, and thus defection becomes a prominent action for ‘short sighted’ mass[11]. Reputation mechanism in this case could be useful in filtering the possibly deceptive player from getting into action [5, 12, 13].

Successful implementation of a simple and effective reputation mechanism can be seen in eBay [14]. Amazon [15] also lists product and service reviews that could be useful for buyer’s decision making. eBay follows a binary
reputation mechanism assigning (+1) for positive and (-1) for negative feedbacks. These values are awarded as buyers and sellers rate each other after a transaction. These feedback values are processed to compute a positive feedback percentage which denotes the reputation of a buyer or seller. A feedback score here is the percentage of positive rating (to the total positive and negative ratings) obtained through the transactions that ended in last 12 months, but excluding repeat feedback from the same member in the same week[16]. We are considering a possible improvement to the model like that of eBay described above. Our interest lies in investigating how the entire population would evolve (cooperative or defective) if the weight of the feedback source was assigned on the basis of past association between players. We categorize the feedback source into three different types and define an aggregation method for trustworthiness assessment that considers applying a dynamically computed weight to each source of feedback.

In this paper, we investigate on whether such a reputation system could be useful in the evolution of a cooperative society. We design a business game model, analogous to anonymous online trading environments to study this impact. The simulations have been carried out in the business game models which are in turn based on the principles of Iterated Prisoner’s Dilemma[17].

The remaining part of this paper is structured as follows: Section II presents an overview of the related work; Section III describes the experimental model while section IV is dedicated to experimental results and analysis. Section V at the end presents conclusion and recommendation for future work.

II. RELATED WORK

Issues related to the evolution of cooperation, Trust and Reputation have been addressed by various authors in [3], [5] 18], [19]. Aberer in [3] outlines the complexity of Trust and Reputation and discusses different approaches to computing trust and reputation. The authors have considered evolutionary approach as one of the many popular approaches that game theorists have been using. In [5] the authors have presented a social mechanism of reputation management in electronic communities. In their discussion around electronic communities, the authors have described the Prisoner’s dilemma situation in it.

Prisoner’s dilemma has been a very popular framework for investigating behavioral fitness and evolution in a wide range of settings [3, 18, 20-23]. In one of the most remarkable works on the evolution of cooperation, Axelrod in [11] addressed fundamental questions about human nature. Starting from basic questions like when should a person be cooperative and when selfish, his work tries to demystify the complexity of cooperation in humans by relating it to a Prisoner’s dilemma situation. Based on Prisoner’s dilemma again, Axelrod in [20] conducted a tournament of strategies using Genetic Algorithms to identify a fittest and an evolutionarily stable strategy.

In a related work Janssen in [18] has studied the role of reputation scores in the evolution of cooperation in online e-commerce sites. The author discusses whether or not reputation alone can be meaningful in evolving a cooperative society. The paper concludes that high level cooperation is not possible with only reputation scores. In [24] the authors have studied the accuracy of reputation estimation in reflecting strategy behaviors. The authors have illustrated the accuracy to be a function of how previous game memory is used to compute reputation and how frequently the reputation information is updated. In one of our earlier work reported in [21], we have studied the role of providing compensation to loss in business games. Our results showed loss compensation schemes to have positive impact in curbing the defectors, but we concluded that this scheme alone wasn’t enough to promote cooperation significantly- hence a need for further research in composite models.

The work of identifying trust related parameters and designing suitable trust models for distributed environments have also been of much interest among researchers. The three noted models of trust and reputation in Peer to Peer environment are, EigenTrust[25], PeerTrust[8] and PowerTrust[9]. Xiong and Liu [8] have presented a reputation based trust framework relying on transaction feedbacks from peers in a P2P network. The authors have identified trust parameters and defined a general trust metric to define those parameters. EigenTrust[25] considers developing an algorithm to compute global trust values based on power iterations- thus enabling the system in identifying malicious peers in the network. In [9] the authors propose a trust overlay network to model local trust and reveal peer feedback relationships. By selecting a small number of reputable power nodes by using distributed ranking mechanism, the system claims to improve global reputation accuracy and aggregation speed.

In this paper we investigate the impact of having an acquaintance based reputation aggregation in the evolution of cooperativeness in the player society. Simulations in both acquaintance based and non-acquaintance based settings have been conducted to study the comparative evolution of cooperativeness. The subsequent sections below describe in detail the experimental models and results obtained from it.

III. THE EXPERIMENTAL MODEL

We relate the situation in the online business environment to that in a Prisoner’s Dilemma Game. The buyers and sellers do not know each other and the only information available is their past history of performance in
terms of feedbacks from opponents. The situation in eBay [14] is a principal example of this sort of setting. In a prisoner’s dilemma game[11, 17, 20], there are two prisoners held for some crime and being interrogated separately. They share a dilemma as they don’t get to see each other and one does not know what the other is going to say about the crime. Each prisoner has an option to give evidence against its partner by defecting him, or to cooperate by holding the evidence. Three particular situations can arise in this case:

- Both can cooperate by holding evidence, thus the judge can have a less doubt over their guilt and decides for a relatively shorter imprisonment (Say 1 year)
- Both can defect by providing evidence against each other, thus making it easy to reveal their involvement. In this case the judge might decide for a longer imprisonment for both of them (say 3 years).
- One of them can defect while the other cooperates. In this case the defector might be set free while the cooperator being proven guilty could be given an even longer sentence (say 5 years)

This situation can also be expressed in a pay off matrix as in Table I below:

<table>
<thead>
<tr>
<th>Prisoner B</th>
<th>Cooperate (C)</th>
<th>Defect (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Reward A=1 yr</td>
<td>Sucker A=5 yrs</td>
</tr>
<tr>
<td></td>
<td>Reward B=1 yr</td>
<td>Temptation B=0 yr</td>
</tr>
<tr>
<td>D</td>
<td>Temptation A=0 yr</td>
<td>Punish A=3 yrs</td>
</tr>
<tr>
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<td>Punish B=3 yrs</td>
</tr>
</tbody>
</table>

The values for the pay off are typically called Reward for cooperation (R), Temptation to defect (T), Sucker’s Payoff (S) for cooperating a defective player (we refer to buyer or seller as player(s) henceforth), and Punishment for mutual defection (P). For the dilemma to hold, the following condition must hold true:

\[ T > R > P > S \]  

(1)

This inequality ensures that cooperation is pareto optimum and that defection is the equilibrium play[11]. There is further an interesting consequence if the game is being played for more than one round. Typically known as Iterated Prisoner’s Dilemma (IPD)[26], in such game the pay-off for two times reward is higher than the summed payoff for Temptation and Sucker. Thus an additional condition given below must also hold true in this case [11] [17, 26].

\[ 2R > T + S \]  

(2)

The second condition ensures that full cooperation is optimal and can outclass swinging cooperation-defection actions in repeated games[26]. This situation in the iterated Prisoner’s Dilemma is also a representative to online business environment[3] [5]. If we consider an online trading environment where two completely anonymous buyer and seller are interacting, they share a dilemma on whether or not the other party would reciprocate its cooperation. If the seller sends the good and the buyer sends money worth the goods, both of them are rewarded and the transaction meets a happy ending. If either of them defects while the other cooperates, then the defector is badly hurt in the transaction and the defector scores highest. If both defect each other then each scores a payoff better than sucker’s score (and interestingly equal to reward in value as both posses the money and goods with them), but is nevertheless going to be a bad reference for future transaction. Further, a payoff for a both defect scenario cannot be considered equal to Reward, as there has been no transaction at all. A zero return for no transaction is what the payoff in this case would be.

To represent this situation in a pay off matrix, let \( \gamma \) be the price of goods that is being purchased by a buyer from some seller. The amount of money the buyer has to pay the seller is the price of the goods, thus in this case it also equals \( \gamma \) in value. The gains of these two players in four different possible action sequences are summarized by the matrix in Table II below:

<table>
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<th>Prisoner B</th>
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</tr>
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Our investigation basically considers this prisoner’s dilemma like business dilemma environment to study the effectiveness of reputation based decision support system on cooperative evolution. The design of our reputation model is provided below.

A. The acquaintance based Reputation Model

Reputation of a player in our model is based on the number of cooperative actions exhibited in the past, but we have further made a careful distribution of weights across the reputation of players classified according to their acquaintance with the subject player. Three different categories of players (which we call Reporters) are labeled accordingly:

i. Most Direct Reporter (\( m_R \)) is the player itself.

ii. Gray Reporters (\( g_R \)) represents the players with whom both of the players considering a transaction have played in the past.

iii. Other Reporters (\( o_R \)) reports its own experience in the past games.

MDR reports its own experience in the past games.

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<th>Player</th>
<th>Cooperate (C)</th>
<th>Defect (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>( R_{seller} = \gamma )</td>
<td>( S_{seller} = -\gamma )</td>
</tr>
<tr>
<td></td>
<td>( R_{buyer} = \gamma )</td>
<td>( T_{buyer} = 2\gamma )</td>
</tr>
<tr>
<td>D</td>
<td>( T_{seller} = \gamma )</td>
<td>( P_{seller} = 0 )</td>
</tr>
<tr>
<td></td>
<td>( S_{buyer} = \gamma )</td>
<td>( P_{buyer} = 0 )</td>
</tr>
</tbody>
</table>
iii. *Opposition Friendly Reporters* (of) are the players who have only played with the opposition and not the self in the past.

We are assuming that such information in the real world scenario like that in a Peer-to-Peer business environment or a centralized environment like that of eBay would be available for public reference. Currently, eBay provides a detailed list of all feedbacks to and by a particular seller or buyer, which can be seen as a source data for the classification like the one we mentioned above.

As an example, the 4x4 grid in Figure 1 holds an all together 16 players in it. Let’s say P\text{X} and P\text{Y} (P5 and P6 in the grid) are to decide on whether to play or not play the game. In this case P\text{X} and P\text{Y} are themselves the mRs. P1, P2, P9 and P10 are the gRs to both P\text{X} and P\text{Y}. P0, P4 and P8 are ofRs to P\text{Y} whereas P3, P7 and P11 are ofRs to P\text{X}.

![Figure 1. Distribution of Players in a 4X4 spatial Grid](image)

In set theoretic notation: 
\[ mR(P\text{X}) = \{P\text{X}\}, \quad mR(P\text{Y}) = \{P\text{Y}\}, \]
\[ gR(PXY) = \{P1, P2, P9, P10\}, \quad oR(P\text{X}) = \{P3, P7, P11\}, \]
\[ and \quad oR(P\text{Y}) = \{P1, P5, P9\}. \]

The decision on whether to play a game or not is a function of the *Trust Worthiness Factor (TWF)* which is generated by compiling reports from all three categories of players. Each report comprises of *Reputation* of the player which is computed as an estimation of cooperation based on the past history of interaction. A past interaction history of player X with any player Y (H\text{XY}) is a vector containing a record of the total number of Cooperative (C\text{Y}) and Deceptive (D\text{Y}) interactions with X. Thus, 
\[ H\text{XY} = [C\text{Y}, D\text{Y}], \]
where C\text{Y} ≥ 0 and D\text{Y} ≥ 0. Probability distribution of trustworthiness from such data can be inferred by the use of beta probability distribution function and has also been used by different authors in [27-29]. Beta probability distribution function \( f(p|C\text{Y}, D\text{Y}) \) can be expressed using the gamma function \( \Gamma \) as:
\[
f(p|C\text{Y}, D\text{Y}) = \frac{\Gamma(C\text{Y} + D\text{Y})}{\Gamma(C\text{Y}) \Gamma(D\text{Y})} p^{C\text{Y}-1} (1-p)^{D\text{Y}-1}
\]

Where 0 ≤ p ≤ 1, C\text{Y} > 0, D\text{Y} > 0

With a condition that p ≠ 0 if C\text{Y} < 1, and p≠1 if D\text{Y} < 1, the probability expectation value of beta distribution is given by:
\[
E(p) = \frac{C\text{Y}}{C\text{Y} + D\text{Y}}
\]

If \( mR, \) \( gR, \) and \( oR \) represent the past interaction history for Most Direct, Gray and Opposition Friendly reporters respectively, then the TWF of Player Y as assessed by Player X, based on the probability expectation of Beta Distribution, is given by:
\[
TWF(P\text{XY}) = W\text{MR} \sum_{Y} E(P)mR + W\text{GR} \sum_{Y} E(P)gR + W\text{OR} \sum_{Y} E(P)oR
\]

Where \( W\text{MR}, \) \( W\text{GR}, \) and \( W\text{OR} \) are the weights associated with each report and \( W\text{MR} + W\text{GR} + W\text{OR} = 1. \) The value for \( W\text{MR}, \) \( W\text{GR}, \) and \( W\text{OR} \) are obtained from the evolutionary data, as the game continues. The Most Direct Report (M\text{R}) being a direct representation of first hand information (zero hop reporters) is considered to be more influential in decision making and thus is assigned to as \( W\text{MR}. \) Out of the remaining sum available for weight, three quarters is assigned to \( W\text{GR} \) as a single hop reporter to X, while one fourth is assigned to \( W\text{OR} \) as a double hop reporter. This approach gives a least priority to the report from the players with whom no game has ever been played, but at the same time does not ignore them totally.

Players have an associated variable threshold (T\text{H}) which determines the minimum level of trustworthiness expected from the opponent in order to play a game. A function CAN_PLAY (P\text{X}, P\text{Y}) representing a decision module for a game of P\text{X} with P\text{Y} returns TRUE if and only if, 
\[
TWF(P\text{XY}) \geq T\text{HX}, \text{ where } T\text{HX} \text{ represents the threshold value of player X.}
\]

B. The method of investigation

The experiments for this investigation were carried out in an Iterated Prisoner’s Dilemma [11] like setting over a spatial distribution of players. IPD environment represents social dilemma situation [3] [11] [18]. A variation of IPD called Spatial IPD has been used for the experiments. In spatial IPD the players are arranged in some “geographical” positions and most of the interactions take place between the neighboring players[17]. Such arrangements exhibit games in clusters thus providing natural representation of our problem [30]. In the simulation, number of players would play the cooperation-defection over generations in a genetic algorithm based environment. The payoff values as obtained would work as a fitness function for the GA based simulation, where the player strategies are represented by the chromosomes and each chromosome is a fixed length representation of player strategies in terms of cooperation
An important aspect of the simulation is the initial composition of the players. In our experiments we have chosen a balanced population of strategies where a larger number of players would act in a balanced way and a smaller number of them would act as either of the extreme ones. Our composition of the players is not based on any particular application scenario, but it is rational to assume that many players in society would play balanced games and cheaters as well as blind co-operators would remain a minority. 

IV. RESULTS AND ANALYSIS

Two things primarily noted to study the Evolution of Cooperativeness were: firstly, the evolution of ‘cooperativeness Index’ and secondly, the Population of highly cooperative Strategies. The Cooperativeness Index is a ratio of the expected probability of cooperation of the strongest strategy to that of the weakest strategy in each generation. Any strategy that could obtain a highest pay-off was termed Strongest while the one leading to lowest pay-off was termed weakest. In the business game that we modeled, a strongest strategy with high expected probability of cooperation indicates that such a strategy has more instances guiding cooperation and that cooperation in the game is earning more than defection. Thus, this entails that a higher Cooperativeness Index (CoOPIndex) means a more cooperative society. This index was calculated for each of the hundred generations of Evolution for each experimental setting considered. The population study of the highly cooperative strategies concerned the study of the evolution of strategies with expected probability of cooperation greater than 90 percent. This was studied by analyzing the number of cooperative actions against the defective actions of each chromosome representing strategies for a memory-3 game. 

Three different settings were considered for the experiments. In the first setting the simulations were carried out in an environment without any sort of Trustworthiness Assessment. In the second setting a business game environment with reputation system NOT considering the weights of the feedback sources was simulated. The third instance considered having a reputation system with feedbacks being weighed and aggregated on the basis of past acquaintances between the players. In each setting that involved having a reputation system, two different thresholds 0.1 and 0.9 were considered. A threshold here represents a minimum value of Trustworthiness Factor, TWF (as obtained from equation 5 in Section III) for a player to decide on whether to play or not with its opponent. These two thresholds were chosen to represent a relatively low (0.1) and high (0.9) level of cooperation expected from the opponent. The results expressing the evolution of cooperativeness index in a system without any Trustworthiness Assessment is shown in figure 2. Initially
non steady results, with an average CoOPIndex of 0.92, attaining a steady 1 after the 60th generation was observed. Once the steady state is reached the game payoffs become constant thus indicating no significant changes in the evolution of strategies.

Fig 3 and 4 show the comparative evolution of CoOP Index in a non-weighted and weighted assessment at threshold 0.1 and 0.9 respectively. When these trends are compared to that of evolution in Fig 2, both of them seem to have better results. An average of 0.95 for non-weighted setting and 1 for weighted setting was observed at TH 0.1. The evolution showed a comparatively better outlook when the threshold was raised to 0.9. First thing to notice was that the entire evolution was smooth, with values increasing and maintaining steadiness- indicating a better and predictive probability of cooperativeness from players. As depicted in Fig. 4 an average CoOP Index of 1.16 was noted for weighted setting.

The results from figures 2, 3 and 4 suggest that presence of assessment system improves trustworthiness among the players. Further, it showed that our model of Trustworthiness Assessment performs even better in terms of increasing the overall cooperativeness of the society.

Figure 5. shows evolution of the population of very cooperative players (players with strategies having the expected probability of cooperation greater than 90 percent) in settings with and without assessment system. The thresholds considered above have also been explored for the evolutionary study. The result shows that the highest percentage of very-cooperative players evolved in the setting considering a weighted acquaintance based trustworthiness assessment.
An average of 28.88% of the population in this setting was seen to be very cooperative. While this population in a system without assessment was in an average of 1.32% only. Similarly, the population at threshold 0.9 without a weighted assessment was at 12.11% which is significantly low as compared to the weighted setting.

The overall result shows merit in classifying the feedback sources according to the past acquaintances between players.

V. CONCLUSION AND FUTURE WORK

We designed an anonymous online business model based on the foundations of Iterated Prisoner’s Dilemma to study the evolution of cooperativeness. An acquaintance based reputation system classifying and weighing feedbacks and it’s sources on the basis of the nature of past association was plugged-in to the business game model to study the contribution of such system in raising the overall cooperativeness of the society. The simulations to study the evolution of cooperativeness Index (CoOP Index) were carried out in three different settings-firstly in a model without reputation system at all, secondly in a setting where feedback sources were not weighed by the reputation system and finally in a setting relying on acquaintance based classification. Our results have shown that having a reputation system certainly aids in the promotion of cooperative society- but it is our acquaintance based model of Trustworthiness Assessment which was seen to be promoting cooperativeness among the players. It was further seen that the acquaintance based weighing model acquired a higher level of Cooperativeness Index when the threshold for the Trustworthiness Factor was set to high as compared to a lower threshold value. The population of players demonstrating cooperative actions in more than 90% of the interactions was also seen to be considerably high in an acquaintance based environment. Our approach of assessing trustworthiness also contributes in filtering possibly dishonest feedbacks by providing higher weight to the feedback source trusted by oneself in past dealings- thus enabling our system with an inbuilt exogenous filter.

All these results suggest that there is merit in classifying the source of feedback according to the nature of past association. This is in contrast to the approaches of online selling sites like eBay where there is no provision of weighing feedbacks by any means- leaving this job clearly to manual judgment. Findings of our experiment recommend having an acquaintance based weighted trustworthiness assessment in online business environments and multi-agent systems involving the problem of trustworthiness assessment in general.

Designing an improvised business model that would root down the cause of the desire to defect by analyzing profit and economy related data is our planned future work. Our belief is that such a model would promote cooperation in society without having to enforce the players. A hybrid business model with reputation system and enforcement less cooperation would also be studied to investigate its impact in cooperative evolution.

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