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Modeling the rational behavior of individuals on an e-commerce system

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ABSTRACT

With the increasing popularity of e-commerce systems, commercial transactions are becoming more and more frequent. Such transactions are not direct but mediated, putting the buyer in a position of weakness with respect to the seller, especially in the case of a failure of a transaction. The literature showed that the reputation can play an important role to reduce the risks of the buyer in the current e-commerce environment. An online reputation management system (RMS) maintains the reputation, made of beliefs and/or opinions, that are generally held about someone or something, and it can guarantee the reliability of the transactions that take place in an e-commerce system. Despite of the fact that the basic element of a RMS – the interaction between the seller and the buyer – is a classical field of application of the Game Theory (GT) methodologies, the use of a GT approach in this context seems quite limited and this is probably due to its solution complexity. A way to deal with such a complexity is by exploiting the capability of the agent based simulation (ABS) approach. In this paper, we propose a hybrid GT and ABS model for the analysis of an e-commerce system in which a centralized reputation system is maintained by a trusted third party. We report an extensive quantitative analysis in order to validate the proposed model, and to evaluate the impact of a set of buyers' and sellers' policies on the behavior of the e-commerce system.

1. Introduction

With the increasing popularity of e-commerce systems, commercial transactions become more and more frequent. Such transactions are not direct but mediated by the supporting online platforms, that is the payment and delivery of the good (or the use of the service) are not at the same time. In the current practice, the seller delivers the good only after receiving the proof of payment from the buyer. In this context, the buyer is in a position of weakness with respect to the seller, especially in the case of a failure of the transaction.

Reputation is *an aggregate composite of all previous transactions over the life of the entity, a historical notion, and requires consistency of the entity's actions over a prolonged time* [1]. Reputation includes not only the direct experiences of the buyer but also any other form of communication – reviews, scores – that provides information about the seller [2]. Reputation can play an important role to reduce the risks of the buyer in the current e-commerce environment. In [3], the authors showed that positive online review scores can positively influence the firm financial performance while the heterogeneity of different product classes moderates the relationship between review score and performance. Furthermore, in [4], the authors reported that a limited number of fake reviews can determine a consistent reduction of the reputation of a competitor.

In order to limit the impact of malicious behaviors, online reputation management systems (RMS) have been developed over the years. RMS is a system that maintains the beliefs or the opinions that are generally held about someone or something. Such a RMS can provide a solution to guarantee the reliability of the transactions that take place in an e-commerce system [5–7]. Several RMS are proposed in the literature: those systems are based on different methodologies, such as artificial intelligence, multi-agent systems, cognitive science, game theory, and the social and organi-

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zational sciences [8]. In computer science, particular attention has been dedicated to the analysis of the RMSs operating on a peer-to-peer systems [9–13].

The interaction between the seller and the buyer, which is the basic element of a RMS, is a classical field of application of the Game Theory (GT) methodologies, which allow modeling the rational behavior of the individuals [14]. On the contrary, the use of a GT approach in this context seems quite limited despite of its potential (see, e.g., [15–17]).

This is probably due to the resulting solution complexity of the GT approach. Such a complexity does not depend on the complexity of each single transaction: actually, the strategic interaction model of a single transaction between seller and buyer is extremely simple as the buyer has to decide whether to buy or not, while the alternative of the seller are to fully comply with the request or not. On the contrary, the complexity relies on the fact that the reputation is the result of (i) A number of repeated transactions between pairs of sellers and buyers, not necessarily the same, and (ii) the sharing with other sellers and buyers of the outcomes of the transactions. Note that the sharing of the outcomes of the transactions represents the learning effect that is typical of repeated games.

A way to deal with such a complexity is by exploiting the capability of the agent based simulation (ABS) approach, widely applied in economics [18,19]. An ABS model allows tracking the behavior of each individual acting in the simulated environment [20]. A set of rules describes the agent behavior and its interaction with the environment; as a consequence, the state of each agent is determined [21].

In this paper, we propose a hybrid game theory and agent based simulation model for the analysis of an e-commerce system in which a centralized reputation system is maintained by a trusted third party. The individuals' behavior is modeled with a game with incomplete information, which is then *solved* through an agent based simulation model. In order to validate the proposed hybrid model, we assume equal prices for all the sellers. In this way the behavior of the whole system is more predictable to get information about the quality of the results. Then, we relax such an assumption considering variable prices and evaluating the introduction of an insurance system.

The paper is organized as follows. The game theoretic approach and its complexity are discussed in Section 2. The proposed hybrid model is presented in Section 3: first, we report a basic model in Section 3.1 in such a way to ease the validation, and to introduce the basic notation; then, we extended such a model including the items with variable prices and an insurance system in Sections 3.2 and 3.3, respectively. An extensive quantitative analysis is reported and discussed in Section 4 evaluating the model behavior on several scenarioes and under the application of several buyers' and sellers' policies. Section 5 closes the paper.

2. The game theoretic approach

In this section we recall the basic notion and notations of non-cooperative games and present the game theoretic model. In the literature there exist both cooperative (see, e.g.,[22]) and non-cooperative (see e.g., [23]) models for market situations. Here we consider a non-cooperative model because, in our setting, the buyer and the seller may have different objectives, making impossible the agreement that is at the basis of a cooperative model. Even if, we suppose that the two individuals have the common aim of increasing the number of transactions, they have difficulties in trusting each other.

2.1. Preliminaries

We start by recalling some basic definitions on non-cooperative games, i.e., when interacting individuals, or *players*, cannot subscribe binding agreements.

First, we consider a game in *extensive form*; more precisely, we refer to the tree representation where each node, but the leaves, represents a possible situation of the game and is associated to the player that has the role of moving in that situation, the outgoing arcs are associated to the possible choices, or *moves*, that are available to that player in that situation and each terminal node, i.e., a leave, represents an exit of the game; the terminal nodes are associated with no player, but to a tuple of real values, each representing the payoff of the corresponding player when the game ends with that exit. This way to represent a game is sometimes cumbersome, but on the other hand it provides a very detailed description of all the possible developments of the game according to all the possible choices of the players.

In order to reduce the amount of data necessary for describing the game, often it is represented in *strategic form*. In this case the game is formally described by a triple $G = (N, (\Sigma_i)_{i \in N}, (u_i)_{i \in N})$ where $N = \{1, 2, \dots, n\}$ is the set of players, $\Sigma_i = \{\sigma_i^1, \sigma_i^2, \dots, \sigma_i^{k_i}\}$ is the set of pure strategies of player $i \in N$, where a strategy is an ordered sequence of moves of player i, one for each situation in which s/he has to move, and $u_i\colon E \to \mathbf{R}$ is the utility function of player $i \in N$, i.e., a function that associates to each possible termination of the game in the set of exits E the payoff of player i. Sometimes, we use the preference relations, $\succ_i, i \in N$ of the players instead of the utility functions, where $\alpha \succ_i \beta$ means that player $i \in N$ prefers the exit α to the exit β. In fact, the individuals are able to say which exit they prefer for any pair of exits, but it may be very difficult to define the utility associated to an exit. The two concepts are related in the sense that a utility function has to assign a higher utility to a preferred exit, i.e., $\alpha \succ_i \beta \Leftrightarrow u_i(\alpha) > u_i(\beta)$ for each $\alpha, \ \beta \in E$ for every $i \in N$. The possible exits may be associated, not biunivocally, with a *strategy profile* $(\sigma_1, \sigma_2, \dots, \sigma_n) \in \prod_{i \in N} \Sigma_i$, where $\sigma_i \in \Sigma_i$, $i \in N$ is a strategy of player i. The correspondence is not biunivocal as different strategy profiles may lead to the same exit of the game.

More generally, we can introduce the set of *mixed strategies* for player $i \in N$, that is a probability distribution over the set of her/his pure strategies Σ_i. We denote a mixed strategy by $p_i = (p_i(\sigma_i^1), p_i(\sigma_i^2), \dots, p_i(\sigma_i^{k_i}))$ where $p_i(\sigma_i^j) \geq 0$ represents the probability of choosing the pure strategy $\sigma_i^j \in \Sigma_i$, with the condition $p_i(\sigma_i^1) + p_i(\sigma_i^2) + \dots + p_i(\sigma_i^{k_i}) = 1$; the set of mixed strategies of player $i \in N$ is denoted by $\Delta(\Sigma_i)$.

Given a mixed strategy profile $p = (p_1, p_2, \dots, p_n)$, where $p_i \in \Delta(\Sigma_i)$, $i \in N$, the corresponding utility for player $i \in N$ is:

$$u_i(p) = \sum_{(\sigma_1, \sigma_2, \dots, \sigma_n) \in \prod_{i \in N} \Sigma_i} \left(\prod_{i \in N} p_i(\sigma_i) \right) u_i(\sigma_1, \sigma_2, \dots, \sigma_n)$$

The most usual solution concept for a non-cooperative game is the *Nash Equilibrium* (NE) [24]. A NE in mixed strategies is a strategy profile $(p_1^*, \dots, p_n^*)$ such that $u_i(p_1^*, \dots, p_i^*, \dots, p_n^*) \geq u_i(p_1^*, \dots, p_i, \dots, p_n^*)$, for each $p_i \in \Delta(\Sigma_i)$ and for every $i \in N$, i.e., no player has an incentive to unilaterally deviate from $(p_1^*, \dots, p_n^*)$. For further details we address the interested reader to the book of [25].

2.2. The model

The basic scheme of a simple e-commerce situation may be represented using a 2-person game where the players are the buyer (B) and the seller (S). Considering just one transaction of an