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A simulation testbed for analyzing trust and reputation mechanisms in unreliable online markets

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ABSTRACT

Modern online markets are becoming extremely dynamic, indirectly dictating the need for (semi-) autonomous approaches for constant monitoring and immediate action in order to satisfy one's needs/preferences. In such open and versatile environments, software agents may be considered as a suitable metaphor for dealing with the increasing complexity of the problem. Additionally, trust and reputation have been recognized as key issues in online markets and many researchers have, in different perspectives, surveyed the related notions, mechanisms and models. Within the context of this work we present an adaptable, multivariate agent testbed for the simulation of open online markets and the study of various factors affecting the quality of the service consumed. This testbed, which we call *Euphemus*, is highly parameterized and can be easily customized to suit a particular application domain. It allows for building various market scenarios and analyzing interesting properties of e-commerce environments from a trust perspective. The architecture of *Euphemus* is presented and a number of well-known trust and reputation models are built with *Euphemus*, in order to show how the testbed can be used to apply and adapt models. Extensive experimentation has been performed in order to show how models behave in unreliable online markets, results are discussed and interesting conclusions are drawn.

1. Introduction

Open distributed environments have successfully been modeled as multi-agent systems comprising agents that interact with each other under specific protocols and service-level agreements. Most of these systems take the availability of information for granted and just focus on the decision-making strategies of agents. In real-life environments, though, it is practically impossible for agents to have perfect information about the environment, properties and possible strategies or interests of others. Thus, agents have to make decisions under uncertainty.

One way to tackle uncertainty in open distributed systems is through the definition of a ***trust and reputation*** scheme. Trust and reputation (TR) models may guide an agent in deciding with whom to (prefer to) interact. In fact, trust and reputation have been recognized as key issues in autonomic, peer-to-peer and grid computing, as well as in service-oriented architectures and e-commerce applications.

In online markets, with millions of nearly-anonymous agents buying and selling a plethora of goods, self-interested selling agents may act maliciously by not delivering products with the same quality as promised. Thus, trust is a critical issue and it is important for buying agents to reason about the trustworthiness of sellers and determine with which sellers to interact. The higher the value of the products being transacted, the higher the importance of trust for the successful engagement of buyers and sellers.

Trust in online markets seems to be more important than in physical ones (Bakos and Bailey, 1997), since neither seller identity nor product characteristics can be evaluated during the transaction. For this reason, users usually request reliable reports on past performance and truthful statements of future guarantees, and are more likely to participate in web transactions and relationships if they receive strong assurances that they are engaging in a trusting relationship.

As commerce in high-value items becomes increasingly profitable on the Internet, online merchants and auctioneers face enormous challenges in overcoming the trust problem and creating attractive trading environments. In this context, trust and reputation systems provide a foundation for security, stability, and efficiency in the online environment because of their ability to stimulate quality and to sanction poor quality. Trust and

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reputation scores are assumed to represent and predict future quality and behaviour and thereby to provide valuable decision support for relying parties.

Current work aspires to investigate issues related to trust and reputation in open online markets. Towards this aim we have developed *Euphemus*, a multivariate agent-based platform for simulating online markets, where agents offer a specific service that others may consume. Setting up a set of example scenarios, we have studied the impact of various sources of information and evaluation criteria in decision making, as well as the effect of altering agents' behavior for various trust and reputation models.

The paper is organized as follows: Section 2 discusses the state-of-the-art on the available trust and reputation models and testbeds. Section 3 discusses the basic trust and reputation concepts that *Euphemus* builts upon, the models that have been developed through *Euphemus*, the architecture and the data flow in the developed framework. Finally, Section 4 discusses the categories of the experiments conducted, while Section 5 summarizes work performed, probes on future extensions and concludes the paper.

2. State of the art

2.1. Trust and reputation models

The terms of trust and reputation have been used in the literature in various ways, but there is no commonly accepted definition. Josang et al. (2007) divide trust in reliability trust and decision trust, where reliability trust focuses on dependence on the trusted party, as seen by the trusting party (Gambetta, 1990), while decision trust is the extent to which one party is willing to depend on something or somebody in a given situation with a feeling of relative security (McKnight and Chervany, 1996). One should strongly emphasize that reliability trust is a clearly subjective notion and is context-dependent, while decision trust refers to dependence and reliability as the previous one, but it also refers to *utility*, as well as a *risk*. Besides, every trust action entails some risk (Luhmann, 1990) and cooperation under conditions of large potential losses shows greater reliability than in other cases (Yamagishi et al., 1998).

Reputation is obviously closely connected to the concept of trust. Nevertheless, it is obvious that there are significant and clear differences. Reputation can be defined as *a meta-belief, a belief about others' minds, or more specifically about others' evaluations of the target* (Conte and Paolucci, 2002) and is often expressed as *a quantity derived from the underlying social network which is globally visible to all the members of the network* (Josang et al., 2007).

According to Huang et al. (2008), all trust- and reputation-related concepts, techniques and models can be defined with respect to the trust management process adopted, which has to address three fundamental questions: (a) why does an agent trust another, (b) how do agents judge or evaluate the trustworthiness of others and, (c) what does an agent do after obtaining the trustworthiness of others. Artz and Gil (2007) classify trust and reputation models along four axes:

- **Policy-based:** These models employ schemes to promote trust in terms of exchanging credentials and imposing access strategies. Such schemes are network security credentials, trust negotiation, security policies and trust languages, distributed trust management, effect of the type of credentials etc. One may refer to work by Winsborough et al. (2000), Li et al. (2003) and Tonti et al. (2003) as representative approaches to policy-based TR models.
- **Reputation-based:** These models calculate trust based on the behavior of an entity and data may come from either third-party information or direct experience. Basic approaches are related to decentralization and referral trust, trust metrics in a web of trust, trust in P2P networks and grids, and application-specific reputation. One may refer to work by Sabater and Sierra (2002), Josang and Ismail (2002), Kamvar et al. (2003), Xiong and Liu (2004) and Guha et al. (2004) as representative approaches to reputation-based TR models.
- **General models of trust:** These types of models employ primitives drawn from psychology and sociology, in order to define the factors that affect trust. These factors deal with general characteristics of trust, computational and online trust models, game theory and agents, as well as software engineering metrics. Work by Friedman et al. (2000), Mui et al. (2002) and Huynh et al. (2006) are typical approaches of general trust models.
- **Trust in information resources:** From a different viewpoint, trust has to do with whether various sources of information or websites are reliable. In this context, research focuses on trust concerns in the Web and/or the Semantic Web, trust using hyperlinks, subjectivity analysis, provenance information, content trust, site design and human factors. Grandison and Sloman (2000), Clarke et al. (2001) and Gyongyi et al. (2004) propose such TR models.

This classification of trust and reputation models is quite generic and covers most of the research approaches followed (including current work). Nevertheless, other classifications exist. One may refer to work by Sabater and Sierra (2005) for more information.

Finally, it is worth mentioning that there are some fuzzy approaches to trust. Fuzzy logic offers a qualitative approach which is very useful for modeling several cognitive dynamics (Dubois and Prade, 1980) and provides the ability to handle uncertainty and imprecision effectively (Ross, 2004). Thus, it is ideally suited to the concept of trust. Indicatively, we refer to the work of Falcone et al. (2005) and Griffiths (2006).

2.2. Trust and reputation testbeds

Many researchers have dealt with the analysis and effect of various trust and reputation mechanisms, through the development of respective simulation schemes/platforms. Although it is essential to have a scalable, multivariate platform for testing and assessing different models, no such generic framework exists, mainly because of the inherent software complexity generated by the models applied. Each proposed model is evaluated within a testbed, specifically designed to verify and evaluate that model. The main reason is that different models usually have different inputs, generate different outputs, trigger different interactions and are assessed against different key performance indicators, thus making the design of a generic trust evaluation testbed difficult.

One of the most popular trust testbeds is ART – Agent and Reputation Testbed (Fullam et al., 2005). ART provides the trust and reputation research community with a unified platform for evaluation and competition. Agents use trust strategies to exchange expertise with others in order to appraise paintings and make money by providing accurate appraisals to receive more paintings in the next time step. However, ART is not flexible enough for carrying out realistic simulations and robustness evaluations for many of the proposed models. Harbers et al. (2007) report that some aspects of their model could not be verified in ART and that the performance of the trust model in ART depends too much on the opponents. Hang et al. (2008) face a similar problem and point out that ART does not support agents providing referrals. They overcome this by designing their own trust evaluation testbed where agents estimate the trustworthiness of others without pre-existing knowledge. Finally, Kerr (2009) states that he was not able