Modeling and mining of dynamic trust in complex service-oriented systems

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ABSTRACT

The global scale and distribution of companies have changed the economy and dynamics of businesses. Web-based collaborations and cross-organizational processes typically require dynamic and context-based interactions between people and services. However, finding the right partner to work on joint tasks or to solve emerging problems in such scenarios is challenging due to scale and temporary nature of collaborations. Furthermore, actor competencies evolve over time, thus requiring dynamic approaches for their management. Web services and SOA are the ideal technical framework to automate interactions spanning people and services. To support such complex interaction scenarios, we discuss mixed service-oriented systems that are composed of both humans and software services, interacting to perform certain activities. As an example, consider a professional online support community consisting of interactions between human participants and software-based services. We argue that trust between members is essential for successful collaborations. Unlike a security perspective, we focus on the notion of social trust in collaborative networks. We show an interpretative rule-based approach to enable humans and services to establish trust based on interactions and experiences, considering their context and subjective perceptions.

1. Introduction

The way people interact in collaborative environments and social networks on the Web has evolved in a rapid pace over the last few years. Services have become a key-enabling technology to support collaboration and interactions. Pervasiveness, context-awareness, and adaptiveness are some of the concepts that emerged recently in service-oriented systems. A system is not only designed, deployed, and executed; but rather evolves and adapts over time. This paradigm shift from closed systems to open, loosely coupled Web services-based systems requires new approaches to support interactions [1].

We present a novel approach addressing the need for flexible discovery and involvement of experts and knowledge workers in distributed, cross-organizational collaboration scenarios. Experts register their skills and capabilities as Human-Provided Services (HPS) [2] using the very same technology as traditional Web services to join a professional online help and support community. This approach is inspired by *crowdsourcing* techniques following the Web 2.0 paradigm. People can contribute HPSs to offer their skills to a broad number of Web users, service compositions, and enterprises that need to have on-demand access to experts. In such communities, not only humans participate and provide services to others, but also autonomous software agents and semantic Web services with sophisticated reasoning capabilities. A mixed service-oriented system comprises human- and software services that can be flexibly and dynamically composed to perform various kinds of activities. Therefore, interactions in such a system do not only span humans, but also software services. Recently, *trust* has

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been identified as a beneficial concept in large-scale networks [3,4]. Considering trust relations when selecting people for communication or collaboration, services to be utilized, and resources to be applied leads to more efficient cooperation and compositions of human- and software services [5]. In contrast to many others, we do not discuss trust from a security perspective. In this work we share the view of [6] that is related to how much humans or other systems can rely on services to accomplish their tasks.

Unlike several other systems in the agent domain, e.g., see [7], we follow a centralized trust management approach [5]. In SOA, central registries and logging facilities are common mechanisms. Applying them avoids various issues, such as the malicious manipulation of interaction data and dishonesty regarding recommendations. Moreover, some trust inference mechanisms are only applicable if the participants of the network have a global view on the system. However, on the other side, a centralized approach may raise privacy issues that have to be considered in the system design. In this paper, we present the following key contributions:

- *Social and behavioral trust model.* We define a trust model that relies on interaction dynamics, supporting wide personalization by accounting for user preferences, and discuss its realization in the introduced use case.
- *VieTE framework.* We outline VieTE (Vienna Trust Emergence), a modular framework that supports the management of trust in SOA-based environments. In particular, we introduce key implementation aspects, such as interaction mining, and *Web of Trust* provisioning.
- *Evaluation and discussion.* Since our work is not only theoretical, but closely coupled to SOA technology, we evaluate various functional and non-functional aspects of VieTE and its trust model.

The paper is organized as follows. In Section 2, we introduce the Expert Web case showing the need for flexible expert discovery and involvement. Our novel approach is based on *social* trust. We introduce trust concepts in collaborative environments in Section 3. Section 4 details the concept of interaction-based behavioral trust which will be the basis for our trust inference model. Trust can be based on different metrics whose meaning is highly subjective. In Section 5, we show our trust model established on fuzzy set theory. The trust model manages context-dependent trust between actors, i.e., humans and services, emerging from interactions. The subsequent Section 6 formalizes the fundamental trust model relying on captured and interpreted interactions. Successful, thus highly trusted network members, are valuable collaborators. However, overload due to large amounts of work represent bottlenecks. In Section 7, we present a balancing approach to prevent inefficient interactions. Our architecture is implemented on-top of SOA and Web services. We show the implementation details of the system in Section 8. Section 9 deals with evaluations to test the performance of the presented system as well as effectiveness of balancing algorithms. Finally, we discuss related work in the area of SOA, social trust, and flexible interactions models in Section 10 and conclude the paper in Section 11.

2. Service-oriented collaborations

In virtual communities, where people dynamically interact to perform activities, reliable and dependable behavior promotes the emergence of trust. As collaborations are increasingly performed online, supported by service-oriented technologies, such as communication-, coordination-, and resource management services, interactions have become observable. By monitoring and analyzing interactions, trust can be automatically inferred [1,7–9]. In contrast to manual rating approaches for mainly static communities, automatic inference is well-suited for complex networks with short-running interactions between potentially thousands of rapidly changing network members.

We motivate our work with a scenario showing discovery of experts and flexible interaction support as depicted in Fig. 1. In this use case, a higher level process model may be composed of single tasks assigned to responsible persons, describing the steps needed to
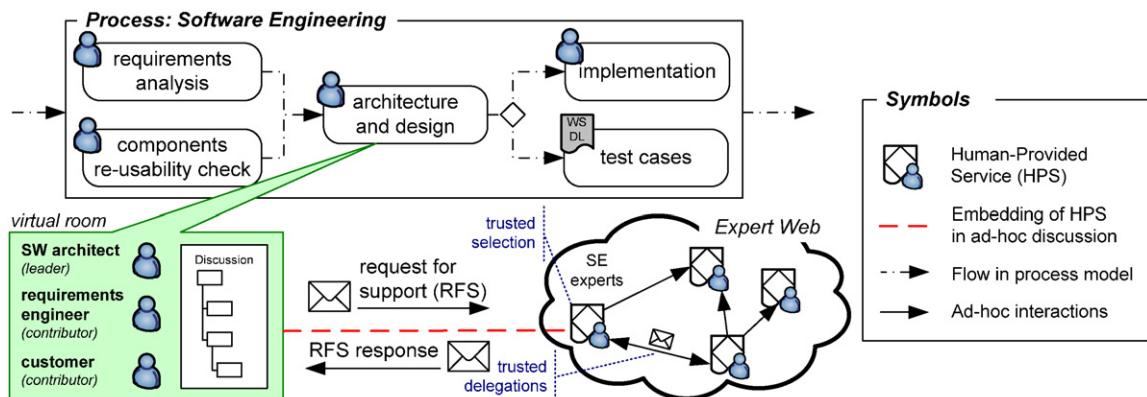

Fig. 1. Service-oriented large-scale collaboration in the *Expert Web*.