User Interface for Trust Decision Making in Inter-Enterprise Collaborations

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***Abstract*—Trust decisions on inter-enterprise collaborations involve a trustor's subjective evaluation of its willingness to participate in the specific collaboration, given the risks and incentives involved. In earlier work, we have built support on automating routine trust decisions based on a combination of risk, reputation and incentive information. Non-routine cases must be dealt with by human users, who require access to supporting information for their decisions; further, their needs differ somewhat from the needs of automation tools. This paper presents work in progress to provide a usable user interface for manual trust decisions on inter-enterprise collaborations in situations where automated decisions cannot be made. We have implemented a trust decision expert tool and are in the process of evaluating it and incorporating it into a broader collaboration management toolset.**

***Keywords*-trust decisions; reputation; risk; inter-enterprise collaboration; expert tool**

I. INTRODUCTION

The emergence of technology support ranging from service-oriented architecture and Web Services to cloud infrastructures are paving the way for semi-automated and low-cost setup and management of inter-enterprise collaborations. An inter-enterprise collaboration involves a network of autonomous enterprises working towards a shared goal, e.g., to provide a composed service to end users. An online travel agency, for example, can compose travel packages for its customers by utilizing a set of services provided by its partners for payment handling, booking flights, hotel itinerary, car rental and other location-specific arrangements, where each partial service is provided by a separate autonomous enterprise.

Inter-enterprise collaborations are particularly useful for small and medium-sized enterprises, which hold expertise in their own domain but have limited resources. By collaborating with other enterprises, they can attain a competitive edge in fields outside their individual scope, and also join forces to expand their business into fields dominated by large enterprises [1], [2]. Large enterprises can apply the same methods to organize their production life-cycles in-house, or to experiment on new service concepts together with external collaborators.

The success of inter-enterprise collaborations relies on a flexible infrastructure that reduces the cost of setting up and managing the collaborations, so that individual enterprises do not need to solve issues of interoperability, collaboration coordination and trust management using costly ad hoc solutions. The Pilarcos open service ecosystem we have proposed in earlier work [2] provides infrastructure services for, e.g., finding potential partners and ensuring service interoperability, collaboration management and semi-automated trust decisions [1]. In this paper, we focus on the trust management support specifically.

Inter-enterprise collaboration depends on trust, as the autonomy of partners causes uncertainty and risk that must be found acceptable for the collaboration to proceed. The distributed infrastructure services in Pilarcos allow the enterprises to make local, private trust decisions on whether they want to join or continue in an inter-enterprise collaboration, subjectively analyzing the risks and incentives involved in the endeavour [3]. To ensure a combination of efficiency and a swift reaction to any major changes in the risk estimations, routine decisions are automated, following local policies [1].

Automated trust decisions can only be relied on in routine cases: human intervention is required for making trust decisions in situations where the risk or incentives are particularly high, or the information available for supporting the decisions is insufficient. In earlier work, we have set the basis for how to identify these special cases in policy, including support for, e.g., measuring the amount and quality of the input information [1], [4], and investigating the information needs of human users in this context [5]. Our goal in this paper is to provide a usable user interface for human intervention in semi-automated trust decisions on inter-enterprise collaborations.

The rest of the paper is organized as follows: Section II discusses related work in human trust decision making, and summarizes our earlier findings on the topic. Section III provides an overview of the Pilarcos trust management system and compares it to related work. Section IV presents the implemented expert tool user interface. Section V presents initial results of user evaluations, and Section VI concludes the paper.

II. TRUST DECISIONS ON INTER-ENTERPRISE COLLABORATIONS

Trust decisions measure a subjective willingness of a trustor to perform a given action with a given trustee,

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considering the risks and incentives involved [3]. In the context of our work, both the trustors and trustees are business services; this level of abstraction reflects the fact that two services even within the same enterprise may hold different information, have a different effect on assets, and be governed by different policies. When a trust decision is delegated to a human user, therefore, the interventions are made on behalf of a specific service.

Some of the expected risks and gains can be estimated based on past behaviour, i.e. the reputation of the trustee, while other incentives are created by the business importance of the activity itself, such as a need to fulfil existing contracts, or a desire to try out a new way of making business or a new set of partners.

A large body of existing work on reputation systems has focused on electronic markets, aiming to support either human or automated decisions specifically. Work in this environment involves one-on-one transactions to purchase goods or services, and often focuses on a relatively narrow view of reputation information only [6]. We have found that inter-enterprise collaborations, which involve multiple partners and a wide range of interdependent services, require a broader information model in order to capture the variety of risks and incentives as well as their dependence on the decision context [3].

Research on human information needs for trust decisions has been made both in general and in the aforementioned electronic commerce setting; we have surveyed the work and translated it into inter-enterprise collaborations [5]. As a well-known example, McKnight and Chervany have proposed a model of trust decisions that takes into account a variety of factors, ranging from a situational willingness to trust to a mental disposition, a belief that the target will behave in a trustworthy manner and even whether structural assurances make the situation appear less risky [7]. Different factors affecting trust decisions can be categorized based on whether they are specific to the trustor only (such as disposition), depend on the trustee (such as reputation), or the given decision context (such as the business importance of the action) [5].

We have gathered the aforementioned information requirements and evaluated the Pilarcos trust information model and trust decision process against them to ensure that the expert tool provides the information needed for human trust decision making [5]. Further input on the user interface design was gained from Nielsen's usability principles for designing user interfaces [8] and different cognitive strategies: Cognitive Fit Theory, Cognitive Load Theory, Unified Theory of Acceptance and Use of Technology and Technology Acceptance Model [9], [10], [11].

III. Semi-Automated Trust Decisions In Pilarcos

In this section, we first discuss trust management foundations in Pilarcos, and then present related work on trust-aware inter-enterprise collaboration management.

A. The Pilarcos trust management system

The Pilarcos trust management system makes semi-automated, local and context-aware trust decisions. These decisions are repeated through the entire life cycle of the collaboration, whenever further resources need to be committed [1]. They compare a risk estimation, based on the past behaviour of the trustee represented as its reputation, against a chosen risk tolerance, which reflects the strategic importance of the tasks and the goals of the enterprise.

While routine trust decisions are automated to ensure the efficiency of collaboration management, there are always situations that require human intervention, for example due to a combination of high risk and high strategic importance. The local trust decision policies in Pilarcos therefore define risk tolerance ranges for automatic acceptance, automatic rejection, or for requesting a manual trust decision from a human user.

The Pilarcos trust management system makes automated trust decisions based on seven different parameters: trustor, trustee, action, risk, reputation, importance and context [3]. As discussed in the previous section, the trustor and trustee are business services operating within their respective enterprises. The action represents a collaboration task that needs to be performed, involving a commitment of the trustor's resources.

The risk and reputation factors are closely connected: risk estimates present probabilities of different outcomes, and reputation information is stored as experience counters of different observed outcomes so far. These experiences are gathered both directly through local monitoring, and as shared information through reputation networks [3]. While shared reputation information may be erroneous and is therefore locally evaluated for credibility, it provides a valuable extension to the first-hand information particularly in the case of actors that are not previously known, and actors who have recently changed their behaviour.

Instead of trying to capture all possible outcomes of all actions, Pilarcos represents their effects on assets. There are four high-level asset classes: monetary, reputation, satisfaction and control [3]. Probabilities of the outcome effects are presented on the scale of large negative effect, slight negative effect, no effect, slight positive effect and large positive effect that the action has been observed to have on that asset. This condensation of possible outcomes to a set of categories for affected assets improves the reusability and interoperability of reputation information across different enterprises.

The monetary asset denotes any resources that can be represented in monetary terms. The reputation *asset* reflects the trustor's own public relations, appearance in the media, and attitudes of their customers and partners towards them [3]; in contrast, the reputation *information* discussed

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above concerns the past behaviour of the trustee. The need for security, privacy and other aspects related to autonomy are represented by the control asset. Lastly, the degree of fulfillment of the trustor's expectations by the trustee is represented by the satisfaction asset: it is used to measure whether the trustee tends to respect its agreements [3].

The reputation counters of observed outcomes are converted into a risk estimate by transforming the absolute numbers into ratios: essentially, 5 major positive experiences out of 10 total experiences translates into a probability of 50% of a major positive outcome for that asset. Relevant adjustments are made to accommodate, e.g., low-stake actions that cannot have a large monetary effect, and credibility-based weighting between local and shared reputation information.

The risk estimate is compared to risk tolerance formulae to determine the outcome of the decision. The risk tolerance formulae may be adjusted automatically according to the strategic importance specified for the action; this essentially represents the known outcome of a positive decision, such as not having to compensate other collaborators due to withdrawal from the collaboration during its operation. In the automated trust decision making process, the different factors are also subject to change by the context parameter, which manifests as conditional filters, or modifiers, of the data to allow temporary situational adjustments in the system. One example of a context modifier is insurance, which can apply to all actions in one specific collaboration and essentially eliminate the monetary risk involved.

B. Related Work

The TrustCoM framework [12] and the ICT infrastructure of ECOLEAD [13] are trust management systems for inter-enterprise collaborations. Their approaches differ somewhat from Pilarcos.

The TrustCoM framework [12], [14] performs trust decision making during the joining and continuation of the collaboration. In constrast to Pilarcos, TrustCoM makes trust decisions only when a new partner needs to be added or previous partner needs to be replaced, not routinely at each resource commit. The trust decisions are made based on reputation information measuring trustee capabilities, integrity and benevolence, in addition to functional definitions of the role, requirements of quality of service, cost and security. The TrustCoM framework also involves a user interface in the form of an eLearning portal in a scenario demonstrator [14], helping users find the best service suitable for them. In the general case, the design of trustworthy and secure user interfaces falls outside the scope of TrustCoM, although its importance is acknowledged.

In ECOLEAD [13], [15], trust decisions are made at two points: base trust is established during the entry into the ecosystem and specific trust evaluated when each inter-enterprise collaboration is set up. For base trust, all enterprises entering the ecosystem answer a questionnaire on, e.g., organizational competences, prior successful collaborations, prior engagment in opportunistic behaviour, and adherence to technology standards and delivery dates. Collaboration-specific trust is established in a hierarchical manner, starting from the specification of objectives in terms of measurable elements. The ICT infrastructure of ECOLEAD also provides support for portlets for interaction with the users [15]. The trust prototype has a web and mobile portlet, providing a list of potential partners for collaboration, where the users can select those found most suitable for the task. Like TrustCoM, ECOLEAD does not focus on user interfaces for trust-decision making specifically.

Handling human intervention for semiautomated trust decisions remains an open research question in related work. Factors to consider include the phenomenon of human trust decision making, information requirements of the human users, the appropriate way of presenting the information, and reducing the frequency of calls for human intervention in the future, to ensure that the efficiency of collaboration management is maintained. We have summarized our earlier work [5] on the two former in earlier sections, and continue on the two latter in the following section.

IV. User Interface of the Trust Decision Expert Tool

In this section, we present the design of the user interface handling human interventions on trust decisions. The presented user interface extends the Pilarcos trust management system.

In accordance with the Pilarcos trust information model, the user interface presents information about risk, reputation, goals affecting the importance of the action, and context [16]. Within its main information views, it presents further details on the credibility of the information, behavioural changes that can affect the validity of the reputation information, assets endangered according to the risk tolerance comparison, and the progress status of the collaboration when trust decisions need to be made during the operational phase of the collaboration. The information is presented as a combination of textual and graphical formats. Figure 1 shows an example risk view of the user interface; the other major views of reputation, context and progress information are minimized in the screenshot.

On the top, the user interface presents the goals of the inter-enterprise collaboration, such as earning money, gaining experience or building reputation. The importance of the goals that the enterprise has set for the collaboration encourage a positive trust decision. In addition to the goals, the deadline for making the trust decision is prominently shown. Both these information elements and their placement promote transparency.

The risk view presented in the figure shows the produced risk estimate, represented in the form of probabilities of

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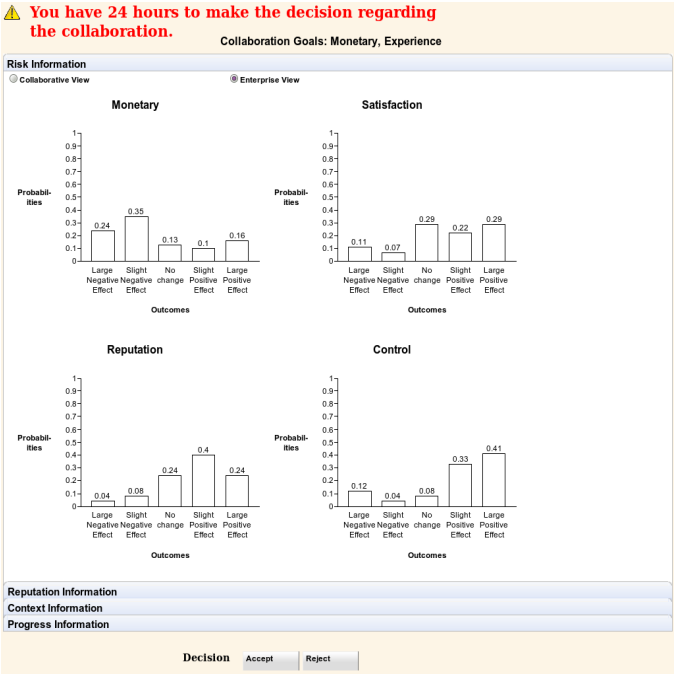

Figure 1. Risk information view of the trust decision expert tool.

different outcomes. These outcomes for different assets follow the trust information model of Pilarcos, as described in the previous section. The four asset classes correspond to four graphs in the risk information view.

The risk information can be studied through two different views: collaborative and enterprise view. The collaborative view presents collective risk probabilities for the collaboration as a whole; it reflects the fact that even though a trust decision is generally made concerning a one-on-one interaction within a larger collaboration, other participants in the collaboration may have a strong influence on the eventual outcome of the action. A manager may consider placing an order to a generally reliable contractor, for example, yet decide against it because it cannot trust its proposed subcontractors for this collaboration. In contrast, the enterprise view provides information about the risk posed by the single trustee individually. The current version of the trust decision expert tool presents the collaborative and enterprise view in the same format.

The reputation view provides background information to the risk estimate. Reputation information is presented as graphs. It consists of experiences, reflecting the past and present behaviour of the trustee on the same outcome scale as the risk information. The view also shows the estimated credibility of the shared reputation information, and presents whether the trustee's behaviour has been consistent or not, which may have an impact on the validity of the available reputation information. Behavioral consistency is expressed through the number of times the system has detected a change in the actor's behaviour [4], and by showing both the overall experiences and the experiences based on the current period of consistent behaviour. Finally, the view uses colours to indicate the assets for which the risk estimate is not within the automatically acceptable risk tolerance bounds, as the actor's reputation information for these specific assets may be of particular interest.

In automated trust decisions in Pilarcos, risk estimates are compared against risk tolerance, which is in turn based on the strategic importance of the action at hand. While the importance is represented through the goals of the collaboration, and tolerance constraints are partially visible through the assets shown not to be within limits, in manual trust decisions the human user is responsible for analyzing and setting the actual risk tolerance limits for the decision.

In the expert tool, the context information view presents the currently active context items to the human users through simple textual phrases, such as "Enterprise A is an important strategic partner" or "The current collaboration is covered by insurance". This information is collected from the descriptive metadata of any active context filters.

Finally, the progress information view of the expert tool supports trust decisions on ongoing collaborations. The view presents the progress of the collaboration in graphical format, visualizing the tasks completed by different partners.

The eventual user decision is either to accept and approve the action or reject it, which generally results in a withdrawal from the collaboration. In addition, the tool will ask the user to provide a scope for the trust decision: whether it applies for the remainder of the contract, or for a given time period, or for this specific decision only. This helps reduce the frequency of requests for human intervention, as further decisions needed within the set scope can be automated. The scope information is stored as a context filter, which overrides the risk tolerance formulae appropriately to automatic rejection or acceptance for future decisions within the given scope.

V. User Evaluations

This section presents the user study setup and initial results of the user evaluations of the trust decision expert tool [16]. We evaluate the interface from four points of view: (i) sufficiency of the presented information, (ii) usability, (iii) user performance and (iv) quality. All the participants are researchers more or less familiar with the Pilarcos trust management system. The main objective behind recruiting such participants is to gather feedback from users who are representative of the actual target user base of Pilarcos. The user study takes around one hour per user.

The user studies are conducted in three phases: introduction, solving test tasks and debriefing. During the introduction phase, test participants are introduced to the user interface and test setup. After the introduction by

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Statement	St. Ag.	Agree	Neutral	Disagree	St. Dis.
Sufficiency of information	-	3	-	2	-
Ease of finding information	-	3	2	-	-
Clarity of presentation	-	4	-	1	-
Correlation btw. information presentation and tasks	2	1	2	-	-
Ease of use	-	3	2	-	-
Confidence of using	-	3	2	-	-
Willingness to use in future	-	4	-	1	-
Feel safe to use	-	-	4	1	-

Table I
SUMMARY OF THE USERS' OVERALL EVALUATIONS.

the moderator, the test participants are presented with the following test scenario:

You are running an enterprise named "Quick Service", which provides online logistic services within Europe. Your enterprise is involved in collaborating online with other enterprises throughout the world. You are using the Pilarcos middleware for managing your online collaborations. Usually, Pilarcos middleware makes automated decisions regarding your enterprise's participation in the online collaborations, but now you have received an email, containing a link, asking you to make a decision regarding your continuation in an ongoing collaboration.

Based on the test scenario, the participants are asked to write their expectations about information that they would like to have for making trust decisions in such a situation. After the introductory phase, the test participants are allowed to study the user interface themselves for getting familiar with it. Afterwards, the test participants are asked to perform the tasks using the user interface. The completion of each task is followed by a short questionnaire capturing the real-time experience of the participants after each task. The test participants are encouraged to think aloud while performing the test tasks. The "think aloud" methodology is employed for getting insights into the problems and thought process of the participants while they are performing the test tasks [8]. The moderator notes the participant comments while performing the test task as well as time taken by them to perform each task. Finally, during the debriefing phase, the test participants are asked to fill in a post questionnaire aimed at gathering general experience and impressions about the user interface. The user evaluations have been made with five test participants, which has provided us with quite useful feedback.

The first point of view evaluated the *sufficiency of the information presented* to the human users for trust decision making. As previously mentioned, the user interface presents risk, reputation, context, collaboration progress status, goals and credibility information for trust decision making. Table 1 shows the user rating of the user interface in terms of the sufficiency of the presented information. Based on the analysis of the debriefing phase and participant comments while performing the tasks, we believe the probable reason for disagreement might be the absence of some relevant information, such as the value of the contract in terms of possible monetary profits to the enterprise. Another suggestion for enhancing the available information concerned a more detailed representation of the collaboration progress, relating it to the underlying business process model instead of simple milestones.

The second point of view of *usability* evaluated the ease of using the user interface in terms of ease of finding the presented information, clarity and existence of correlation between the information presentation formats and tasks to be performed. Missing or unclear information were again a probable cause for critique here. For example, the test participants were unclear about the ontological meaning of the assets. Furthermore, some users suggested that a summarized and concise view of the already presented information should be added, including, for example, small textual sentences such as *"you have 63% probability of gaining monetary benefits"*.

The third point of view of the *user performance* evaluates the user interface in terms of the success rate of task completion, number of errors committed while performing the tasks, and time taken for task performance. The evaluation results reveal that the task completion rate is 100% irrespective of accuracy. However, when considering the factor of accuracy, the successful task completion rate is 100% for only two of the participants. It is 93% for two other users, and 78% for one participant. In other words, the error rate is 7%. We suspect the lack of attentive focus while reading the tasks to be the main reason for the existing error rate, because we found the same participants giving correct answers for other similar tasks. Regarding task completion timing, we found that three of the test participants are able to perform 71% of the tasks within seconds, whereas the remaining participants perform respectively 79% and 93% of the tasks in seconds. The time taken is agreeable considering the novelty of the tool, as none of the participants have ever used any kind of trust decision expert tool before.

The fourth point of view of *quality* aims to evaluate the user satisfaction of using the user interface in terms of ease of use, confidence, willingness to use and perception about security. The evaluations are summarized on the last four lines of Table 1. As mentioned previously, insufficient presented information seems to be a likely reason for disagreements or neutral opinions.

In general, we found that test participants found the information presentation formats to be easy to read and understand. They also stated they found the user interface to be intuitive.

VI. CONCLUSION AND FUTURE WORK

In this paper, we have presented a user interface for trust decisions on inter-enterprise collaborations. The motivation

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for this work arises from the fact that while we wish to automate routine decisions on collaborations, there are situations where human intervention is necessary. We have evaluated the implemented expert tool with the help of users familiar with the underlying Pilarcos system in order to collect feedback on improving the tool. We found that the current version of the user interface of the trust decision expert tool is appreciated by the test participants. However, the user evaluation also revealed a number of shortcomings, which provide significant pointers for not only improving the existing version of the tool, but also possible future research directions.

The user interface for simple trust decisions is a first step in a larger project to enable direct user interaction with the entire Pilarcos collaboration management toolset [2], which has so far focused on automating the relevant support processes. As a direct extension of the basic trust decisions, a planned collaboration negotiation expert tool should allow the user to simulate the possible outcomes of coming to a negative decision: Are there choices of better partners? Can the terms of the contract be adjusted before entering the collaboration? If a partner can no longer be trusted, can it be replaced? Would a different trust decision policy perform better for this collaboration, requiring fewer human interventions?

The work on the expert tool also unveils a need to extend the underlying information model. We concluded early in the design process that trustee-specific risk estimates must be complemented by a collaboration-wide risk estimation, and will further explore the strength of different methods of producing these collective estimates. During the user evaluation, it became apparent that human users are influenced by example, and therefore the relevant decision history (of both automated and human decisions) has an important role and should be visualized to the user. Similarly, while the textual descriptions of context filters have no effect on automated processing, they play an important role in the user interface. We will continue this work in parallel to the expert tool development.

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