Trustworthy Agents for B2B operations under Normative Environment

Eugénio Oliveira, Henrique Cardoso, Joana Urbano and Ana Paula Rocha
LIACC and DEI
Faculty of Engineering, University of Porto
R. Dr. Roberto Frias, 4200-465 Porto, Portugal
eco@fe.up.pt

***Abstract*—Agents intending to be involved in joint B2B operations need to rely on trust measures pointing to possible future solid and secure partnerships. Using Multi-Agent Systems (MAS) as a paradigm for an electronic institution framework enables both to simulate and facilitate the process of autonomous agents, as either enterprises or individual representatives, reaching joint agreements through automatic negotiation. In the heart of the MAS-based electronic institution framework, a Normative Environment provides monitoring capabilities and enforcement mechanisms influencing agents' behavior during joint activities. Moreover, it makes available relevant data that can be important for building up contextual-dependent agent's trust models which, consequently, also influence future possible negotiations leading to new and safer agreements. To support agents information generation, monitoring and fusion, we here present ANTE platform, a software MAS integrating Trust models with negotiation facilities and Normative environments, for the creation and monitoring of agent-based networks.**

I. Introduction

During a Virtual Organisation (VO) lyfe cicle, represented in a computer networking environment by a Multi-Agent System (MAS) several operations, including VO formation and operation, are under monitoring capabilities made possible through the MAS environment. The role of an Environment has traditionaly been defined [1] as a support for agents to exist and the medium for agents to communicate. However, other than being a kind of a passive services provider facilitating, under request, agents' task execution and goals achievement, Environment can also be seen as an active component, reacting to the information produced during MAS activity. This is mostly the case when the MAS is seen as a support for electronic institutions, a base for automatic B2B operations [2] [3]. In this paper we see the MAS environment as a component that actively monitors all the information produced by different agents engaging both in forming a VO, getting in joint agreements through electronic contracts and in the subsequent VO operation phases. Combining that information becomes then useful for agents in the network(enterprises or individuals) to infer on other agents' trustworthiness.

In this paper, we introduce ANTE platform (Agreement Negotiation in Normative and Trust-enabled Environments) [4]. ANTE enables agents, representing enterprises, to negotiate contracts and encompasses a normative framework guiding agents interaction through norms that apply either sanctions or incentives according to their respective behavior. Useful information regarding agents' performance is gathered and used to influence future interactions and possibly agents joint work [5].

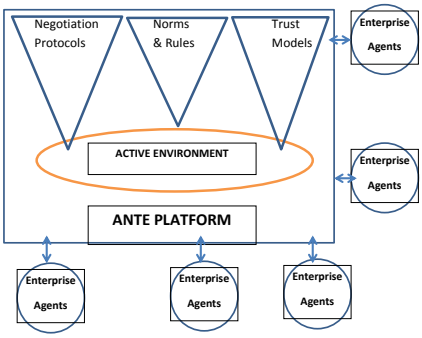

Fig. 1. ANTE MAS-based platform and available services for enterprise networking

After this introduction, we briefly describe how MAS environment is used, based on the power of a normative environment, for producing and gathering relevant information about agents activity. Then, in section 3 we introduce a computational Trust Model that benefits from such information in order to assign trust measures to agents, preventing an agent from future involvement with undesirable or untrustworthy partners. Section 4 briefly presents the ANTE platform that provides all the needed services plus the environment for agents to interact in a trustworthy way. We close the paper with a brief conclusion.

II. The relevance of the Environment

Many sophisticated problems we usually addresse can be classified as belonging to the so called 3D class of problems [6]. They reflect a reality that simultaneously is of a Distributed, Decentralized as well as Dynamic nature. This means that, besides input data and output actions being disperse (Distributed) at different nodes, also, and most important, decision-making can be, at least partially, taken at different nodes of the (Decentralized) system. Moreover, the system trying to solve the overall problem at stake, has to deal with

a changing, evolving reality (Dynamic). To work jointly in solving this kind of problems, agents need to select, in runtime, their best and more trustworthy partners for executing the tasks ahead in order to successfully reach mutual agreements and coordinate joint work. Since in the core of software agent's definition we find the "situatedness" property, the Environment becomes an important component to be specified and designed for multi-agent systems. As a relevant component of a MAS, the Environment can be seen as an active medium to facilitate the way how to reach certain consensus, agreements or mutual contracts. We are here not interested to look at the Environment as a regulator through the Normative environments [7] [5]. Environment is here seen as a medium in which the outcomes of previously contractually agreed actions appear and are combined as meaningful knowledge for future use. More precisely, ANTE takes advantage of relevant data that can be important for building up contextual-dependent trust models which, as a consequence, influences future possible negotiations leading to new, and better, agreements.

A. Environment as a facilitator

It is out of the scope of this paper to here describe the negotiation protocols and mechanisms we advocate for a dynamic and adaptive convergence towards mutual agreements that may be materialized into contracts. We, along this paper, want to highlight the importance of the Environment in recording all the relevant events produced by the agents and the normative framework outputs as a result of agents' activities during contract enactment. Appropriately merging and combining the trace of such events, leads to a tightly coupled connection between electronic contract monitoring and a computational trust model for estimating agents' trustworthiness [8].

Since we adhere to J. Searle institutional reality related concepts [9], the Normative dimension of the Environment handles a normative state NS (including all elements - "brut facts"- that characterize the current state of affairs for each agreement established within the environment), a set IR of institutional rules that manipulates a normative state and a set N of norms, which can be seen as a special kind of rules. The normative state includes institutional facts that represent institutional recognition (through third parties) of contract related real-world events. The Normative Environment also notifies the agents about relevant contract related events. The same mechanism conveys information to feed the computation Trust model. A contract C = $< T; CA; CI >$ is included (and accessible) in the normative environment and is defined as follows: A contract C is a normative relation of type T within which a group of agents identified in set CA commits to a joint activity. An electronic representation of a contract includes a set of norms that specify how a specific business is to be enacted. A norm is a rule whose conditions analyze the current normative state and whose conclusion prescribes obligations agents ought to fulfill. As a consequence, sanctions may be imposed by prescribing obligations upon violation events [8], thus producing more and relevant information in the environment.

In the context of a MAS in which agents represent entities (e.g. Enterprises) looking for potential partners to establish agreements and commit themselves to joint actions, the role of a normative environment is twofold. Given the agreement on possible joint actions as obtained from a previous negotiation phase, it is necessary to check out whether or not individual agents partial contributions made their way in enabling a successful execution of tasks leading to the agreed overall goal that solves the problem at stake. In many cases, the execution of the needed tasks is itself distributed, requiring from agents to enact by themselves their part of the agreement. Monitoring this phase is therefore an important part of the all process. This monitoring capability is possible through the analysis of the interactions and facts produced, and made visible, in the Environment. Furthermore, in non-cooperative or dynamic scenarios, it is possible that after successfully negotiating and reaching agreements, self-interested agents are no longer willing to fulfill their commitments, which becomes also visible to the environment, since normative rules generate notifications (in this case prescribing sanctions) in reaction to such events. An example of a rule executing in the Environment and reacting to a previous event (contract violation by an agent) is:

$(defrulen$
$(violation(obl?obl)(when?w))$
$?obl < -(obligation(bearer?b)(counterparty?c)$
$(factdeliveryXqt?q))$
$=>$
$(assert(obligation(bearer?b)(counterparty?c)$
$(factpayment10)(when?w))))$

The meaning of the rule is straightforward: the normative environment may apply norm n enforcing a sanction (a payment of 10) when a violation regarding delivery has been detected. This puts in evidence the second role of a normative environment, that of enforcing norms by coercing agents to stand for their commitments. At the same time, the whole idea of an active environment is to use the relevant information generated through the normative environment and make it useful for further agents' reasoning strategy.

1) Merging Information: Agents contractual behavior becomes evident for the environment, since the way agents enact their contracts provides relevant information for trust building and, as a consequence, may decisively influence the way partners are selected in future contracts. In ANTE, an image of relevant entities (modeled enterprises or individuals) real-world transactions become recognized as an "'institutional reality"' [9]. Agents in ANTE subscribe to the normative environment to be notified about eminent contractual obligations and commitments to be fulfilled. As an example, $Obl_b c(l \prec f \prec d)$ represents the obligation of agent b (the bearer) towards agent c (the counterparty) to bring about fact f between liveline l and deadline d. A normative state records every element that is relevant in contract enactment as institutional reality elements [8].

As agents go on interacting according (or not) with pre-

established contracts, the normative environment reacts appropriately to the facts recorded, and produces more (normative) information about the on-going processes. The challenge is to be able to gather and manage all that produced data, out of previous mutual interactions, in order to infer meaningful information about agents' possible future behavior.

Moreover, other than information generated during two agents' mutual interaction, there is other available information, coming from third parties, that may be relevant to characterize a specific agent. These indirect evidences about an agent's behavior (indirect in the sense that is not a consequence of two specific agents' interaction but a result of the "image" the agent builds up in the society of all the currently active agents, due to previous, more broadly considered, interactions), is called reputation. Reputation is seen as the social-based process of transmitting beliefs about a specific agent (the trustee), as a consequence of social evaluation circulating and, according to [11], are represented as reported evaluations. There are computational trust models that use reputation just as another piece of evidence to be taken into account about any particular agent. For that purpose, they need to estimate the credibility of both the transmitted information and of those agents reporting that information [12]. Providing that third party agents, not directly involved in a particular negotiation are, nevertheless, willing to provide their own perspective on a particular agent, this new piece of evidence will also be present in the environment and can also be identified as relevant for merging with the other available direct evidences [13]. The perspective an agent is now able to infer, through the combination of the available information, about another agent becomes wider and more independent of local (to the pair of agents) knowledge. However we still did not address the problem that could arise if reputation information and other available trust-based measures happen to be of different nature and formats. How to merge them, in a coherent way, through the computational Trust and Reputation Model is a challenge for our near future research.

III. Trust Model

We follow a basic and established definition for Trust (although not always consensual). Closely, but not completely following [14] a formal definition of trust is: Trust(i; j; φ) meaning that the Truster(i) trusts Trustee(j) to do Action(α) leading to the achievement of Goal(φ) if:

$(GOAL_i\varphi)$

$(BEL_iPOWER_j\varphi)$

$(BEL_i\Box(\alpha \models \varphi))$

$(BEL_iINTEND_j\alpha)$

where $\Box$ is the usual temporal modal operator and $INTEND_j\alpha$ is agent j's intention to do action α. Intention means choice with commitment according to Cohen and Levesque's well accepted theory [15].

Agents should thus rely on Trust measures to select their best potential partners, improving their chances to achieve their own intended goals.

It has been established that, whenever decisions have to be made for selecting potential partners in a future activity, it becomes mandatory to rely on some kind of past evidence pointing to an estimate of the other agents' trustworthiness. We need to remember here that Trustworthiness is an intrinsic characteristic of an entity (here an agent) while Trust measures reflect other ones' (potentially different) assessment of that particular agent under evaluation. An important book on the discussion about all the possible perspectives that can influence Trust, is the one referred in [14]. Exhaustive discussions are taking place about all the relevant factors that can influence a trust measure characterizing the perspective each agent builds up on other agent internal trustworthiness. We may identify two different categories, subjective and objective, of such factors. In the first category, it is included the propensity and disposition an agent displays regarding trusting others. In the second category, and most valuable, we may identify past experience regarding previous direct interactions with those specific agents, current social image of the agent under scrutiny, the reputation, as well as other indirect kind of evidences. Another perspective over the computational trust model is if, indeed, a single measure is enough for characterizing an agent's trust measure as seen by others. In fact, although we often look for competence, it sometimes is not the only dimension that matters for successful future joint activities. Other more subtle features like how benevolent and integer an agent can be, may be seen as determinant in the final decision-making process on how much shall an agent trust in another one. Another important concern the research community in Trust has expressed, is about the contextual nature of trust: Situation dependence, task dependence, time dependence [16] are different factors to take into account when measuring and ranking other agents' trust.

A. Proposed Trust Model

Mutual past direct interaction experience is the most common factor trust models take into consideration as it is the case of [17]. A few computational models already include some kind of agent disposition to trust [12] and emphasize the importance of context [18] [19].

Our computational Trust model, included in the ANTE software platform, includes different components responsible for managing most of the factors that have been recognized as influencing trust-based decision-making. As a model, it encompasses both the different dimensions of trustworthiness (integrity, ability, benevolence) and the truster's disposition to trust. As a software program, implementing most of the referred important aspects, although not yet all of them, it already includes an aggregator of past direct experience Sinalpha, a Contextual Fitness component, a Social and an Integrity Tuner.

The two main components first aggregate past contractual behavior evidences (Sinalpha) and then consider how agents fit into the context under consideration (Contextual Fitness). The aggregator part gets information from the environment about agents' performance regarding their past obligations (either

fulfilments, partial fulfilments or violations). It uses a sinus-based curve that is reshaped at both top and bottom extremities. Asymmetry about gaining and loosing Trust, maturity after reaching a certain status and distinguishing different patterns of past behaviour are properties that can be featured by the model [20] [21].

Sinalpha models the trustworthiness of an agent using a function of α that presents a sinusoidal shape (see Equation 1). By setting $\delta = +0.5$, the trustworthiness value is restricted to the range [0;1]. $trustworthiness = \delta * (sin\alpha + 1)$ (1)

The second component of the model counts for the specific appropriateness of the target agent (the one under evaluation, the Trustee) regarding that particular situation in which the other agent (the Trustier) is willing to get help, to work jointly or to engage in a relationship with. It is the concept of a Context that captures and represents the relevant information about the current situation and it is based on the description of those contexts that Contextual Fitness appreciates how an agent can be, at that specific time, trustworthy or not. A Context is here defined as an N-tuple including agent identity, current time, location and a set of task-related attributes Contextual Fitness component, a situation-aware tuner that downgrades the trustworthiness scores computed by the aggregator (Sinalpha) in cases where the agent under assessment has proved to behave poorly in that specific situation. We are using the information gain metric [22] on the previous evidences on the agent different tendencies of failure. This approach differs from other situation-aware computational trust approaches by its flexibility and ability to reason in terms of context even when the evidence on the agent in evaluation is scarce.

Briefly, we endow the environment with the capabilities of clustering different potential partners waiting for being selected (for example by issuing bids as a response to a call for proposals) and extract stereotypes characterizing in what conditions they have either fulfilled or violated their obligations. Therefore, it may be the case that a particular agent has a good trust measure, however it has an handicap regarding an important feature for the concrete partnership another agent is interested in (for example, a faster delivery time of a product).

The most important to stress here is that the environment is empowered with the means to strongly influence the decision-making process of agents, here by providing indicators that, once combined, become relevant for trust evaluation. Moreover, a social environment is the ideal medium to collect and aggregate information about widespread (not local to specific agents) activities and derive a Reputation measure that will influence, together with Trust, later decisions about possible future agreements. This will enable for the possibility of the Environment to establish specific context-dependent rules to decide when data can be considered either as relevant or irrelevant for building Reputation [23].

IV. ANTE Platform

Grounded on the recognition of the Environment as a relevant component to give structure and support situated MAS, we have developed ANTE a software framework in which agents can both establish agreements (and contracts) through supporting negotiation protocols and, simultaneously, benefit from monitoring capabilities that guarantee more transparency of joint activities. Through the development of ANTE software platform, we intended to illustrate how an active environment may help in reliable and informed agents decision-making in what joint agreements is concerned [10] [8]. ANTE supports multi-agent collective work leading to agents' intention satisfaction, by providing negotiation as a mechanism for finding mutually acceptable agreements with trusted partners and the enactment of such agreements (contracts). Gathering appropriate data and evaluating the Environment state enables feeding the Computational Trust model which, in turn, provides information for better selecting partners for future agreements. In ANTE, the environment actively mediates interaction among agents, acting as delegates of either enterprises or individuals, in several different ways:

i) Environment primarily is a Facilitator by providing negotiation protocols, Ontology translation services and Contract building process. In this perspective we can see it as an Interaction-Mediation level[24] offering support to regulate access to resources and mediate interaction between agents leading to possible agreements.
ii) Environment also provides mechanisms for the normative enactment of those agreements (that may lead to the establishment of contracts among agent partners), generating comprehensive normative states and then becoming responsible for monitoring them in an active way. ANTE includes a normative framework of constitutive and institutional rules according to the institutional reality model.
iii) Through evaluating the contract enactment phase, Environment improves the chances for better future negotiations by progressively updating the available Trust measures to help in the partners' selection process. ANTE includes, at present, SINALPHA plus the contextual fitness based model.
iv) In ANTE a "social Environment" is responsible for adaptive deterrence mechanisms reacting to different agents population behaviours. Fines associated with normative states are dynamically changed according to a "social"-based tolerance calculated threshold. This dynamic threshold depends on the current number of violations and takes into account the number of running agents as well as the number of agents at that particular normative state to which the fine applies.

Monitoring rules, referred in ii) are responsible for gathering all the needed information that becomes relevant to feed the computational Trust model mentioned in iii) which dynamically combines that information to infer current agents' trust measures.

ANTE is a modular and extensible JADE-based architecture implementation, integrated with JESS Java-based rules

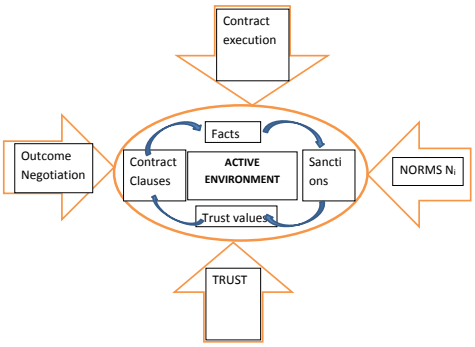

Fig. 2. Automatic Active Environment in ANTE platform

engine, accessible through several different GUIs for agents to announce their needs as well as for inspecting negotiation process and normative states and the final contracts results. Although ANTE has been targeting electronic contracting in B2B domains, and because it encompasses several agreement technologies like negotiation, normative environments and computational trust models, it was conceived as a more general framework having in mind a wider range of application domains including social networks.

A. Experiments

Different experiments with ANTE platform [25], enable the agents to use Trust either to pre-select the most promising partners for the future joint activity or to use trust only during the negotiation phase. Other experiments combine these two possibilities. After a number of experiments we concluded that, by using the Computational Trust Model, the outcomes (the number of well succeeded contracts that have been established) were strongly influenced, besides the agents behavior type, by other factors like, for example, the degree of similarity or dissimilarity of the agent proposals under comparison. Using Trust for selecting partners significantly increased the number of succeeded contracts.

V. Conclusions

Distributed, decentralized systems for dynamic situations, appropriate for the so-called triple-D kind of problems, are well represented by Multi-Agent System architectures. Following the same line of those authors who claim that the Environment should be considered as an important, separate component in the specification and design of Multi-agent Systems, we here advocate a set of capabilities that should be made available for more secure, comprehensive and trusted agents mutual activities possibly leading to more fruitful agreements. Besides facilitating functionalities like negotiation protocols, ontology services, normative framework application and monitoring, we strongly emphasize the importance of an Environment active role. Gathering and evaluating normative states and agents behaviour regarding norms abidance and contracts fulfillment, is of paramount importance for feeding computational Trust models. Updated and contextualized agents' Trust measure s becomes important to guide future agents activity and mutual agreements. A "social-based" Environment can also have the privilege of, by reasoning about all agents activity, to detect, prevent (or incentivise), patterns in the society regarding maleficent (or beneficial) agents' behaviour. Moreover, and having in mind its active role to ease and promote possible agent agreements, "social Environment" has been empowered with the capability of adaptively impose fines for the sake of better regulate the agent population and promoting confidence in the possibility of future better agreements.

ANTE software platform has been developed taking all these features into consideration.

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