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Electronic Institutions are comprehensive frameworks that may effectively help in the collaborative work of virtual organization activities. This paper focuses on an effort to create e-contracting and ontology-based services in the context of Electronic Institutions. The e-contracting services provide automatic specification of business agreements by formalizing them through e-contracts, plus the procedures for enforcing them. Moreover, ontology-based services enable the interoperability between agents representing organizations using different ontologies. Ontology services provide useful advices on how to negotiate specific items, leading to appropriate conversations and making agreements possible. We believe that the rendering of these services will provide a level of trust and normative behavior allowing the creation, through electronic institutions, of dynamic virtual organizations and their operation.

1. INTRODUCTION

Virtual organizations (VOs) are a major trend in cooperative business. Some of the key aspects of modern businesses include specialization and flexibility. The temporary nature of VOs requires that they should be formed quickly, allowing them to start operating as soon as possible. Technological support towards VO formation is a strong research topic. Some approaches include the multi-agent systems (MAS) paradigm, which aim at automating the process of creation and operation of dynamic VOs. A related topic within the MAS community is how to develop means to allow the interoperation of agents in open environments (that is, with no centralized approach).

Electronic institutions are frameworks that provide and enforce rules and norms of behavior, offering services to assist both interaction and operation monitoring of computational business entities. In (Rocha *et al.*, 2005) we presented a sketch of an electronic institution, relating it to the virtual enterprise lifecycle. Moreover, we detailed an advanced negotiation protocol, and delved into the state-of-the-art on e-contracting automation. In this paper, we present an integration of services that allow for the establishment and execution of contracts. We then describe our approach towards handling e-contracts within an institutional environment, and on developing services that provide automatic monitoring and enforcement of business

agreements. We also present ontology-based services that enable interoperability between agents representing organizations using different ontologies.

The paper addresses the aforementioned concepts as follows. Section 2 introduces the electronic institution and its services. Section 3 details the issue of contracts and norms, together with related institutional services, and section 4 presents ontology-based services. We conclude in section 5, referring also to some related work.

2. ELECTRONIC INSTITUTIONS

Human societies are governed by institutions providing services or regulating the way citizens interact. The same approach has been proposed, in the last years, as a means to regulate the interaction among software agents. The *electronic institution* (EI, for short) concept represents the virtual counterpart of real-world institutions.

According to (Dignum and Dignum, 2001), the benefit of an EI resides in its potential to assure legitimacy and security to its members, through the establishment of norms. Besides enforcing norms, institutional services should be provided to assist the coordination efforts between agents which, representing different real-world entities, interact towards the establishment of business relationships.

In our perspective, an EI is thus a comprehensive framework that provides a set of institutional services, while assuring norm enforcement through the imposition of sanctions and reputation mechanisms. The EI provides an environment where regulated agent interactions can take place. One of the main roles of such an environment is to provide the necessary level of trust that enables agents from different sources to safely engage in business interactions.

As the establishment of business engagements is central to our purposes, we consider an evolving normative environment, including formalizations of “handshakes” by means of contracts that the EI monitors and enforces.

2.1 Institutional Services

We may summarize the main goals of an EI as follows: (1) to support agent interaction as a coordination framework, making the establishment of business agreements more efficient; and (2) to provide a level of trust by offering an enforceable normative environment. These two issues are closely related to the lifecycle of contractual relationships, namely information discovery, contract negotiation and execution. In the particular case of a virtual organization’s lifecycle, (Rocha *et al.*, 2005) dissects institutional modules assisting the formation, operation and dissolution stages, and focuses on advanced features for the first stage.

We identify institutional services addressing both identified main goals, as depicted in Figure 1, where we omitted typical e-market facilities, such as registration and brokering.

Towards assisting the establishment of contracts, we emphasize on negotiation mediation, based on appropriate negotiation protocols and contract templates, which is complemented with ontology-based services. These are necessary if we aim at automating the whole process while keeping an open environment, since different domain-dependent vocabulary may be used by different business entities. However,

a common institutional ontology must be used regarding general contract-related terms. The validation and registration of contracts allows for their “legal” existence. This may happen as a result of a successful mediated negotiation; however, contracts can be created by other (external) means, still being possibly registered within the EI.

An enforceable normative environment is established by rendering a contract monitoring and enforcement service, which registers transactions and verifies norm applicability, as well as the fulfillment of signed contracts.

Every agent intending to use an institutional service must be registered as a member. Agents have, inside the EI’s boundaries, a record of reputation concerning their observance to past contractual relationships.

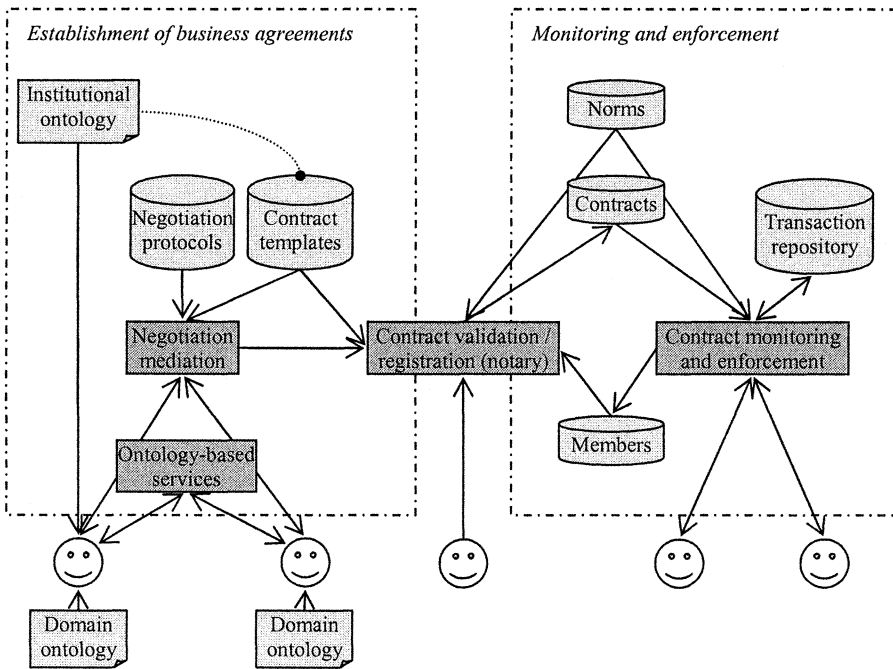


Figure 1 – Services of an electronic institution

The identified services are quite challenging, from an agent-based automation point of view. While advanced features (such as adaptive aspects) included in a negotiation mediation service are dealt with elsewhere (Rocha *et al.*, 2005), in this paper we give particular emphasis to ontology-based services and to the normative framework that allows for contract monitoring and enforcement.

3. CONTRACTS AND NORMS

Contract monitoring and enforcement is achieved by considering the EI as a normative framework. E-contracts are achieved inside this controlled environment,

which establishes certain rules of behavior to be followed by members. The EI imposes a set of institutional norms by ensuring that norm violation is penalized.

We approach contract representation using norms, which will complement the institutional normative background. Contract creation may be greatly simplified with templates, which provide a structure for negotiation. Agents negotiate contract details by instantiating template parameters into a mutually agreeable contract, reusing domain-independent interaction schemes.

The temporary nature of VOs requires a quick set-up phase, allowing them to start operating as soon as possible. Templates and automated negotiation tools serve this purpose. Different templates for diverse VO settings may be provided.

In fact, the VO/VE spectrum covers a wide range of organizational structures (Camarinha-Matos and Afsarmanesh, 1999). We consider an open environment, with agents representing the interests of different entities (organizations or business units). Agents negotiate to establish dynamic virtual organizations, which stipulate cooperation terms, may exist for a period of time and have a variable topology. There will typically be a dominant participant, embodying the final destination of products (as far as the consortium is concerned). This entity can be regarded as a customer (Oliveira and Rocha, 2000), or participate in the production process.

Considering these properties, we aim at automating the monitoring of well-defined contractual agreements that establish multi-lateral business relationships between self-interested entities, which may not have worked together in the past.

3.1 A Structured Normative Framework

Considering the ongoing nature of virtual organizations, and taking into account that these are created inside our EI environment, we conceive a structured normative framework (see Figure 2) that considers both institutional as well as contractual norms (Lopes Cardoso and Oliveira, 2004).

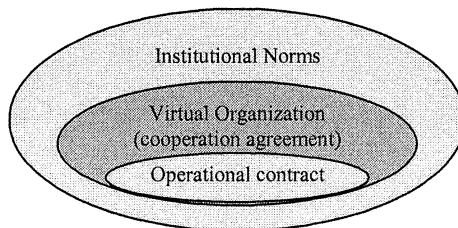


Figure 2 – Normative framework

Institutional norms and rules include default contract clauses, allowing contracts to be underspecified, thus further facilitating their creation. General regulations concerning the nature of consortiums may also be defined. Agents can rely on these regulations as a ground basis to raise VO contractual formalizations.

Rules recognizing violation or fulfillment conditions are also defined at this level, as these are contract-independent concepts. Specific policies may be defined towards institutional penalizing of violations (e.g. through reputation mechanisms).

Virtual organization constitutional norms describe the terms of cooperation that parties adhere to. Our first approach considers that each partner states workloads and

prices for its contribution, and that a general business process outline is specified. This umbrella agreement represents a set of norms parties commit to, and which set up the ground for the VO operation phase. Specific contracts indicating actions to be performed make up the third normative layer. Operational contracts are proposed and signed within the context of VO contractual agreements, and their creation and execution are subject to enforcement and monitoring procedures.

3.2 Contract Monitoring and Enforcement

Taking into account the described normative framework, our contract monitoring and enforcement infrastructure is illustrated in Figure 3.

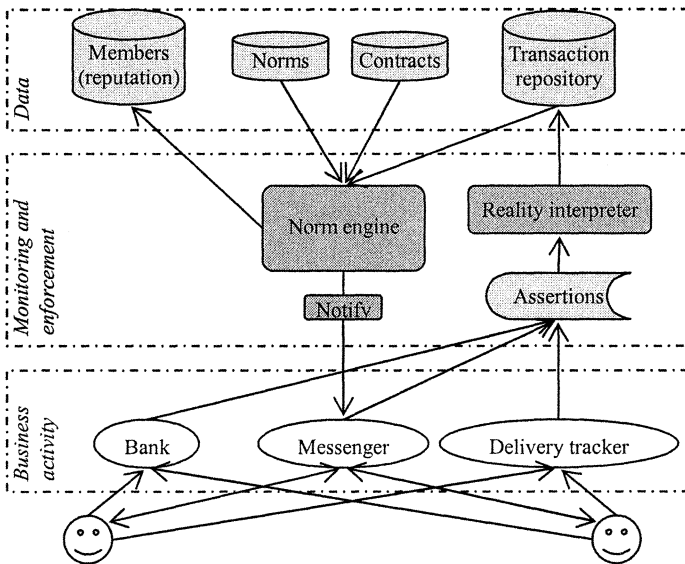


Figure 3 – Contract monitoring and enforcement

In order to fulfill their contractual promises, agents have a set of institutional facilities (roles performed by institutionally certified agents) related to different kinds of operations. Namely, we consider actions that involve information exchanges, monetary value transfers, and product delivery. These services allow for acknowledging what is going on in the real world. The reality interpreter establishes authoritative relations between institutional roles and the assertions of agents enacting those roles: these are interpreted to check which contractual transactions are being accomplished.

Transactions feed a rule-based engine applying both institutional and contractual norms; some, prescribing penalties in case of contract violation, are applied as enforcement measures. Violations may also imply updates concerning the reputation of prevaricators. Notifications are sent to contractual parties concerning the state of their contracts, in the event of obligation fulfillment, violation, or arising.

4. ONTOLOGY-BASED SERVICES

An ontology is required to help in the collaborative work and ensure that enterprises (represented by software agents in the context of our work) are negotiating about the very same good/product/service. Agents may use different ontologies to represent their view of a domain. Each domain may be specified in many different ways, and this ontology mismatch is a question under intensive research.

As cited in subsection 2.1, one of the main goals of an EI is to make the establishment of business transactions more efficient. The enterprises involved in the same transaction are interested in products in the same application domain. However, both use their own private domain ontology.

We provide an institutional ontology defining a business vocabulary to be used for all registered agents. This ontology contains terms which are used during the negotiation process, ensuring a meaningful communication since all agents will uniformly interpret the messages exchanged. Moreover, the contract templates are based on this ontology and new terms may be added according to contractual needs.

The institutional ontology (see Figure 4) defines *Concepts* (for example “Price”), *AgentActions* (for example “Buy”) and *Predicates* (for example “IsPurchasable”), which describe the basic concepts and relationships used when any information in a business context is expressed in natural language. The institutional ontology may be applied for any domain.

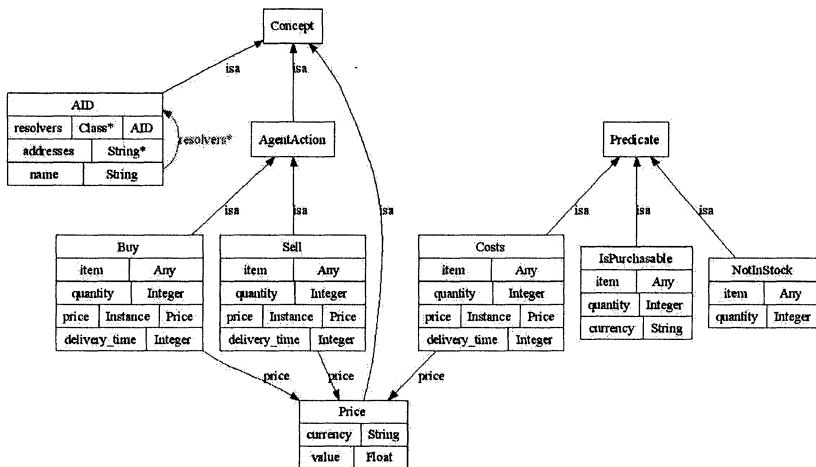


Figure 4 – Institutional ontology

Besides this shared Institutional ontology, each agent has its own private domain ontology, designed and built by some developer with some tool and, later, the agent will access the generated file/database. The characteristics of the institutional ontology do not allow identifying the right requested products/services because this is based on the domain ontology and people use different terms to represent the same concept. One of the main goals of the Ontology-based services is to provide a meaningful negotiation, to ensure that agents are negotiating about the same product/service.

The Foundation for Physical Intelligent Agents (FIPA) has analyzed the interoperability problems in heterogeneous multi-agent systems and has proposed an Ontology Agent (OA) for multi-agent platforms. FIPA proposes the following responsibilities (FIPA OSS): (i) The OA maintains ontology by defining, modifying or removing terms and definitions contained in the ontology. (ii) The OA responds to queries about the terms in an ontology or relationship between ontologies. (iii) The OA may provide the translation service of expressions between different ontologies or different content languages by itself, possibly as a wrapper to an ontology server.

A system implementing an OA should at least provide one of these functionalities. We have created an Ontology-based Services Agent (OSAg) (Malucelli and Oliveira, 2004), which is responsible for providing services to other agents in order to ensure an effective, meaningful negotiation. The OSAg provides the following services: (i) Matching terms service. (ii) Currency conversion service. (iii) Measurement conversion service.

The Matching terms service is required when some agent does not understand the content of a message, i.e., the item under negotiation. This service is the most complex one and it is implemented based on lexical and semantic similarity measures. Our approach aims at creating a methodology that assesses lexical and semantic similarity among concepts represented in different ontologies without the need to build an a priori shared ontology. The lexical measures are used to compare attributes, relations between concepts and descriptions of the concepts. We have classified attributes according to their data value types and considered the relation *has-part*. For the final validation, we are using the Leacock & Chodorow (LCH) method (Budanitsky and Hirst, 2001) based on WordNet (Miller, 1995) between concept names.

Moreover, a currency conversion service may be useful in the calculation of prices when agents are dealing with different currencies. The currency conversion service is implemented as a Web Service. Similarly, the measurement conversion service may be useful when agents are dealing with different measure units.

In addition, the ontology editor Protégé (Gennari *et al.*, 2002) is integrated in the framework to facilitate the creation and maintenance of ontologies.

5. CONCLUSIONS AND RELATED WORK

We presented a comprehensive infrastructure – an electronic institution – providing several services towards assisting the establishment of business contracts and further their execution. In (Rocha *et al.*, 2005) we presented a negotiation protocol devoted to the creation of virtual enterprises, and discussed the importance of making the outcome of a negotiation verifiable, by using e-contracts. Considering our developments presented in this paper, integration efforts are being conducted in order to achieve a computational environment that includes negotiation, ontology-based and contracting services. We believe that the rendering of these services will provide a level of trust and normative behavior necessary for the creation of dynamic virtual organizations and their operation.

The EI concept (and normative multi-agent systems in general), is being addressed by several researchers. Previous approaches towards regulating agent

behavior through EIs include (Rodríguez-Aguilar, 2001). However, this model formally defines an institution using a rigid structure that implements a well-defined protocol. It is thus not amenable to contract handling, as contracts typically alter the normative structure. As to norm organization, (Dignum and Dignum, 2001) presents a two-level approach, considering norms at institutional and operational levels.

Several approaches concerning e-contracts would also be worth mentioning. In (Milosevic *et al.*, 2004), a business contract architecture having some similarities with our monitoring infrastructure can be found, although not using a normative perspective.

An implementation of (FIPA OSS) is presented in (Suguri *et al.*, 2001), a sample application of an ontology shopping service that integrates multiple database schemata to verify and demonstrate the specification. However, there is no possible way to match terms between ontologies.

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