

# Dynamics of Contracts-Based Organizations\*

## A Formal Approach Based on Institutions

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### ABSTRACT

An organization comprises a group of collaborating agents (individual agents or nested organizations) that exhibit complex behaviors. Of particular interest are dynamic organizations that form and dissolve as their members' needs change. Such organizations are important in many applications, including scientific and business computing. Contracts among autonomous agents have long been used to facilitate their collaboration. This paper provides a contracts-based approach for managing organizations. The proposed approach places organizations within *institutions*, themselves modeled as specialized organizations. Commitments form the basis of contracts and this paper establishes some important dynamic aspects by providing a commitment life cycle analysis. This approach has been applied in a prototype tool to manage organizations.

### Categories and Subject Descriptors

I.2.11[Artificial Intelligence]: Distributed Artificial Intelligence – *multi-agent systems*.

### General Terms

Management, Design.

### Keywords

Contracts, organizations, institutions, commitments.

## 1. INTRODUCTION

An organization comprises a dynamic collection of entities such as individuals, enterprises, and their resources collaborating on some computational activity. The key properties of autonomy, heterogeneity, dynamism (membership and structural) distinguish organizations from traditional

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IT architectures. Thus agents can best model organizations and their members.

An *institution* is an organization with an identity of its own and whose life time exceeds that of its members. The US Supreme Court and universities are examples of institutions. Markets such as eBay are institutions. An institution can be modeled as an agent, and defines one or more *roles*, each of which might be played by zero or more agents. For example, eBay supports creating an indefinite number of auctions; each auction must have exactly one (registered) seller and as many (registered) buyers as happen to participate in the auction. Each auction corresponds to a dynamic organization, which exists temporarily within the eBay institution, and is subject to eBay's requirements.

Our main contribution is in the form of a dynamic conceptual model for contracts-based organizations formed within institutions. It demonstrates how organizations are created within institutions and provides a life cycle analysis of commitments, which form the basis for the enactment of contracts. The proposed approach has been implemented in a prototype tool to manage organizations.

## 2. CONCEPTUAL FRAMEWORK

This section introduces our static conceptual model, which builds on our previous research [4]. This model forms the basis for our contracts-based model for organizations. This paper extends our previous work with institutions. It introduces several dynamic aspects of organizations that have not been formalized before.

**Organizations.** An organization is an agent that comprises other agents, in particular, other organizations. That is, an agent may be either an individual (representing a person, business partner, or a resource), or an organization. Note that an organization in this sense is a computational entity and may not necessarily correspond to a real-life organization. We can create as many organizations as needed.

**Commitments.** Commitments form the key abstraction for expressing organizational interactions among agents [3]. Commitments capture the essence of obligations in a three-party manner, involving a *debtor*, a *creditor*, and an organization serving as the *context* for the commitment. Commitments are directed obligations from a debtor agent to a creditor agent, but within the scope of a parent organization, which forms the context. Commitments can be manipulated through several operations. In our framework, we consider seven operations on commitments namely, *create*, *discharge*, *cancel*, *release*, *delegate*, *assign*, and *escalate*

[4]. The above operations are ways of manipulating commitments and hence form the key components of the agent interactions. Such commitments provide a natural basis for contracts. Also, the context of a commitment provides the means to handle exceptions and opportunities by delimiting the scope of a commitment to its context organization. Thus the context provides an organizational basis for revoking or otherwise manipulating commitments.

**Contracts.** A contract among two or more agents encapsulates a related set of commitments. A contract is formed within the same context organization as its constituent commitments. If such an organization doesn't already exist, the act of contracting creates it. The operations on a contract can have ramifications on the commitments formed within this contract, and vice versa. A contract is *created* when a set of agents collaborate by forming a related set of commitments within a specified context. A contract can be *completed* by the context organization if all the commitments specified in the contract are successfully discharged. A contract can be *released* by the context organization, which essentially eliminates all the commitments. A context organization can also release the commitments of an individual contracting agent, in effect releasing it from the contract. A contract is *canceled* by the context organization if the commitments fail to discharge or if they cause violations.

**Institutions.** An institution is a kind of an organization that provides a means of describing the social environment within which organizations (managing various contracts) are hosted, i.e., come into being. Each such organization might itself be an institution, and thus host additional organizations to solve more specific problems for their members. An institution encapsulates a set of roles, a nonempty set of agents, policies, and a set of commitments. The policies include entry and exit policies for agents to join and exit the institution, policies regarding the life time of the organizations hosted, their functioning, penalties, rewards, and so on. eBay's membership policies are good examples.

An institution encloses *abstract* and *instantiated* organizations. An *abstract* organization is a conceptual model of an organization, with a set of member *roles* and commitments that are associated with a role. An *instantiated* organization is formed when an abstract organization and its roles are instantiated by agents who form a contract under the context of this instantiated organization.

### 3. DYNAMIC CONCEPTUAL MODEL

We demonstrate how organizations are created within institutions and describe the life cycle of commitments, which form the basis of the contracts.

**Creation of Organizations within Institutions.** Figure 1 illustrates the current scenario. An institution  $T$  already exists that includes a repository of abstract organizations, and a repository for instantiated organizations. Here, agents  $A_1$ – $A_6$  attempt to enter the institution  $T$  (by registering with  $T$ ).  $A_1$ – $A_5$  qualify as members, while  $A_6$  fails to get registered in  $T$  (Steps 1 and 2).  $A_1$  and  $A_2$  wish to contract with each other, and choose an existing abstract organization ( $O^i$ ), instantiate the roles defined in it, and create an instantiated organization:  $O_1^i$ . Similarly,  $A_4$  and  $A_5$  create  $O_2^i$ . If  $O_1^i$  is open to new members,  $A_3$  may enter it, provided  $A_3$  is already a member of  $T$ , and meets the entry requirements of  $O_1^i$  (Step 3).  $A_3$  becomes a member

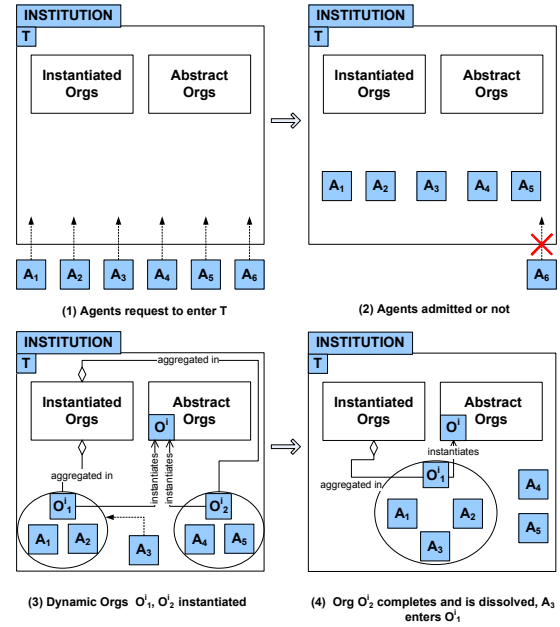


Figure 1: The creation of organizations

of  $O_1^i$  due to an operation such as a delegation of a commitment by  $A_1$  or  $A_2$ , and is situated below the delegator agent in the organizational hierarchy (not shown in the Figure). The organization  $O_2^i$  is dissolved when the contract is either enacted successfully, or canceled (Step 4).

In simple terms, this means agents must find their way into an institution. Once there they have the credentials and capabilities needed to enter into contracts with their peers. The institution thus provides critical functions (as needed) such as helping agents find one another, credentialing, and nonrepudiation of contracts.

**An Example Scenario.** Consider a scenario where universities  $Univ_1$  and  $Univ_2$  form a contract ( $Cn_1$ ) to provide the *InterLibrary Loan (ILL)* services to each other.  $Univ_1$  commits to providing the service of lending a book to any request from  $Univ_2$ , and vice versa. An organization ( $Org_1$ ) is created for this contract and it forms the context for the contract and its associated commitments. Each university delegates and assigns the two commitments to its library.

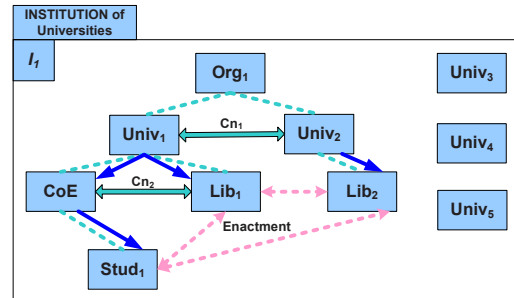


Figure 2: An example of contract enactment

Figure 2 illustrates this scenario.  $Univ_1$  contains  $Lib_1$  and a *College of Engineering (CoE)*, which contains the student  $Stud_1$ . Likewise,  $Univ_2$  contains  $Lib_2$ . The dashed edges

without arrows indicate this organizational structure. Solid arrows indicate the delegations of the commitments. The dashed lines with bidirectional arrows indicate the commitment enactments in the Org, where the actions required to discharge a commitment occur.

An institution of universities  $I_1$  encloses  $Univ_1 - Univ_5$  who qualify as member universities. Contracts may then be formed within this institution among the member universities. Universities themselves are organizations with different contracts existing among their members. For example, the *CoE* may be involved in a contract ( $Cn_2$ ) with  $Lib_1$ .

**Life Cycle of a Commitment.** We describe the life cycle for commitments based on their states as proposed by Verdicchio and Colombetti [6]. However, our life cycle model includes transitions across commitments that are related because of delegation or assignment, which enables us to address organizational considerations more naturally. Figure 3 shows the life cycle of commitments. It shows how a commitment ( $C_i$ ) relates to a delegated or assigned commitment ( $C_{i+1}$ ).

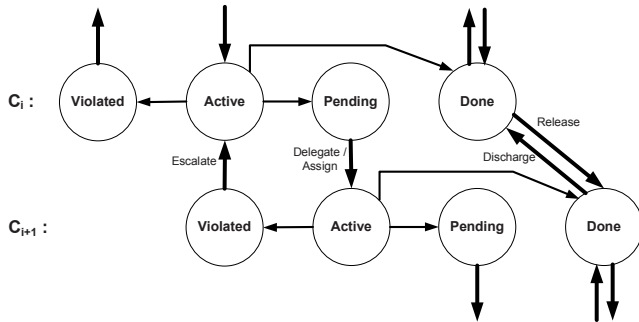


Figure 3: Two successive commitments in a chain

The following four states are considered for commitments namely, *active*, *done*, *violated*, and *pending*. A commitment is created and remains *active* until it is discharged, released, delegated, assigned, or canceled. It enters the *active* state when an escalate message from a lower (delegated or assigned) commitment is received. A *done* commitment would be discharged or released. A *violated* commitment would be canceled, or otherwise failed. A *pending* commitment would be delegated or assigned to a new agent. The *pending* state is entered concurrently with the creation of a (lower) commitment, which enters its *active* state.

**Chain of Commitments** A chain of commitments is formed due to a series of delegate and assign operations on the original commitment resulting in the formation of new commitments, each with a new debtor or a new creditor. The context organization and the discharge condition may remain the same. This chain is finite and it completes when the last commitment becomes *done* or *violated*. The following are some important observations on state transitions that occur in a chain.

A commitment is *pending* when the next *active* commitment is created. When a commitment is released, any delegated or assigned commitment next in the chain of commitments is also released. In our example,  $Univ_2$  may release  $Univ_1$  from its commitment when it discovers it (as a government university) cannot exchange books with a private university. Hence, the delegated commitments of  $Univ_1$

should also be released.

When a delegated or an assigned commitment discharges, the commitments above it in the chain of commitments are also discharged. A delegated or assigned commitment that is *violated* results in an escalate to the next higher commitment in the chain. The latter moves from *pending* to *active*. An escalation propagates up bringing back the upper commitments *active*, and continues till an agent can potentially discharge the commitment. If no agent can discharge the commitment, the first commitment in the chain is *violated*.

## 4. DISCUSSION

This paper develops a commitment-based “institutional” architecture for organizations. This architecture treats organizations as consisting of agents, potentially organizations in their own right. The dissolution of an organization may occur when all of its contracts have ended and have been archived. However, an institution may continue to exist even if it has no active contracts or instantiated organizations. An institution may dissolve an organization that is formed within it if any of its policies are violated. However, the dissolution of an institution may be due to factors such as change or inapplicability of its policies, especially if its entry requirements are no longer viable. We have implemented a prototype system that incorporates a JESS rule engine and demonstrates the enactment of contracts and commitments.

**Related Work.** We study some relevant work and provide a comparative evaluation of the present approach. Boella *et al.* [1] formalize contracts in the context of multiagent organizations. Dignum *et al.* describe an organization model for agent societies using contracts [2]. Vazquez and Lopez y Lopez describe agent-based hierarchical organizations modeled using a normative multiagent framework [5]. Our approach formalizes contracts in terms of commitments, and demonstrates the enactment of the contracts based on the various operations on commitments. The proposed approach places organizations within an institution, acting as normative system, and being modeled as special organization.

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