

Delegation in a Role-based Organization

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Abstract. In an organizational context the norms that apply to an agent depend on the roles he holds in the organization. The deontic characterization of structural roles is defined when the organization is created. But an organization is not a static entity. Among the dynamic phenomena that occur in an organization there are interactions between agents consisting in a transference of obligations or permissions from an agent to another. These kind of interactions are called delegation. In this paper we analyze different ways in which delegation occurs in an organizational context. We argue that the concept of “agent in a role” is relevant to understand delegation. A deontic and action modal logic is used to specify this concept.

1 Introduction

In an organizational context, agents’ behavior are ruled through norms defined by the organization. By norms we mean obligations, permissions, prohibitions or other deontic attributes. The norms that apply to an agent depend on the roles he holds in the organization. The deontic characterization of a role of the structure of an organization (structural role) is defined when the organization is created and is part of its identity. But an organization is not a static entity: it interacts with the external world (e.g. establishing contracts with other agents) and the agents that hold roles in its structure interact with each other. Among the dynamic phenomena that occur in an organization there are interactions between agents consisting in a transference of obligations, permissions, responsibilities, powers or other normative attributes, from an agent to another, or to be precise, from an agent in a role to other agents in roles. These transfereces may be temporary or permanent, and correspond to a sort of redistribution of competences, temporary in many cases, that may change the organization way of working but do not change its identity.

These kind of interactions are usually called *delegation*. Delegation is a complex concept, having multiple interpretations depending on the context where

it is used. Several authors have addressed this issue, like [5], [12], [13], [4], [18], among others.

With this paper we want to contribute to the understanding of this concept, analyzing different ways in which delegation occurs. We focus the study in a role-based organizational context, taking organizations as normative systems (set of interacting agents whose behavior is ruled by norms). A role-based organization has a stable structure consisting of a set of roles, whose deontic characterization is described by a set of obligations, permissions or prohibitions. Within this context, agents always act in some role.

A delegation relationship may be established between agents holding roles of the organization structure or between agents inside the organization and agents outside of the organization.

We do not analyze motivations of agents to enter in a delegation relationship, nor the success or failure of delegation. We do not consider, either, informal or implicit delegation. We are interested in explicit and formal delegation relationships, where the agents involved are aware of the relationship, as well as all the agents that interact with them.

In this paper we will show how the delegation concept can be clarified in a role-based organization, using a deontic and action logic to express its different meanings.

The rest of the paper is organized as follows: we briefly summarize the deontic and action logic we will use to formally express the concepts analyzed. Next we present the formal model we adopt for organizations, based on this logic. Then we discuss the concept of delegation and how it could be expressed in the formal model proposed. We conclude with the discussion of further logical principles in order to deal with delegation in a role-based organization.

2 Action and deontic logic

Following the tradition initiated by Kanger ([9], [10]), Pörn ([15], [16]) and Lindahl [11], and followed by many others, of combining deontic and action logics to describe social interaction and complex normative concepts, a logical framework has been proposed by Pacheco and Carmo ([2], [14]) that tries to capture the notion of *action of an agent playing a role*. To know the role an agent is playing when he acts is crucial to analyze the deontic classification of the action (e.g. is it a permitted action?) and the effects of the action (e.g. on action of other agents, or legal effects – obligations resultant from the action). It was proposed a new action operator of the form $E_{a:r}$ (for a an agent and r a role), being expressions of the form $E_{a:r}\psi$ read as *agent a , playing the role r , brings it about that ψ* . These actions operators were combined with personal deontic operators in order to express obligations and permissions of agents in roles ($O_{a:r}\psi$ – read as *agent a is obliged to bring about ψ by acting in role r* ; $P_{a:r}\psi$ – read as *agent a is permitted to bring about ψ when acting in role r*). In [2] and [14] it is discussed if these operators should be primitive or derived from impersonal deontic opera-

tors and action operators (e.g. $O_{a:r}\psi \stackrel{def}{=} OE_{a:r}\psi$). Here we omit that discussion and adopt $O_{a:r}$ and $P_{a:r}$ as primitives, and define $F_{a:r}$ as $\neg P_{a:r}$.

This logic has been used as the formal support to the specification and analysis of role-based organizations. In this paper we will use it to discuss the concept of delegation in the same organizational context.

Next, we will present the main features of the logic proposed in [2] and [14], in a simplified way and omitting reference to the underlying semantics.

2.1 The logic $\mathcal{L}_{\mathcal{DA}}$: formal language

$\mathcal{L}_{\mathcal{DA}}$ is a modal (deontic and action) first-order many-sorted language. The non-modal component of $\mathcal{L}_{\mathcal{DA}}$ is used to express factual descriptions, and properties and relationships between agents. It contains a finite number of sorts, not related with agents or roles, and three special sorts: Ag (the agent sort), R (the role sort) and AgR (the agent in a role sort).

As usual, for each of these sorts we assume an infinite number of variables, and possibly some constants. (We are not considering for the moment variables of the sort AgR). There may be functions between these sorts, but we do not consider any function with Ag as co-domain (the terms of sort Ag are either variables or constants.). The terms of each of these sorts are defined as usual.

$\mathcal{L}_{\mathcal{DA}}$ also contains a finite number of role generators, generically denoted by rg , of sort $(\rightarrow R)$. There is always a role generator, denoted by *itself*. Moreover, for each role generator rg , there exists a predicate (qualification predicate), denoted by *is-rg* of sort (Ag) and denotes a property that an agent may have.

The terms of the sorts R and AgR are built as follows:

- (i) If rg is of sort $(\rightarrow R)$, then $rg()$ is a term of sort R (we will write rg , instead of $rg()$);
- (ii) If t is a term of sort Ag and r is a term of sort R , then $t : r$ is a term of sort AgR .

From now on, we use r, r_1, \dots , to generically refer to roles, and a, a_1, \dots , to generically refer to a term of sort Ag (either a constant and a variable), and we will continue using t, t_1, \dots , to generically refer to terms of the appropriate sorts. Finally, $a : a$ is used as an abbreviation of $a:itself$, and $qual(a : rg)$ is an abbreviation of *is-rg*(a), and intuitively means that agent a is qualified to play the role rg .

The formulas of $\mathcal{L}_{\mathcal{DA}}$ are inductively defined as follows:

- (i) if p is a predicate symbol of sort (s_1, \dots, s_n) and t_1, \dots, t_n are terms of sort s_1, \dots, s_n , then $p(t_1, \dots, t_n)$ is an atomic formula;
- (ii) if B is a formula, then $\neg B$ is a formula;
- (iii) if B_1 and B_2 are formulas, then $(B_1 \wedge B_2)$ is a formula;
- (iv) if B is a formula and x^s is a variable of sort s , then $(\forall_{x^s})B$ is a formula;
- (v) if B is a formula and $a : r$ is a term of sort AgR , then $E_{a:r}B$, $O_{a:r}B$ and $P_{a:r}B$ are formulas.

The other standard logical connectives (\vee , \rightarrow and \leftrightarrow) and the existential quantifiers are introduced through the usual abbreviation rules, and parentheses may be omitted assuming the following priorities: first \wedge ; then \vee ; and finally \rightarrow and \leftrightarrow . The forbidding operator is defined as follows: $F_{a:r}B \stackrel{abv}{=} \neg P_{a:r}B$

2.2 Axiomatization of $\mathcal{L}_{\mathcal{DA}}$

The logical principles satisfied by the proposed operators have been discussed and presented in [2] and [14]. Here we just list some of those principles.

Naturally, we assume that all tautologies are axioms of our logic, and that we have the rule of Modus Ponens (in the sense that the set of theorems of our logic is closed under Modus Ponens).

With respect to the first-order component, we have the general properties of quantifiers. We have the generalization rule (if $\vdash B$ then $\vdash (\forall_x)B$), and the following axioms (schema):

$$\frac{(\forall_x)(B_1 \rightarrow B_2) \rightarrow ((\forall_x)B_1 \rightarrow (\forall_x)B_2) \quad B \rightarrow (\forall_x)B, \text{ if } x \text{ does not occur free in } B \quad (\forall_x)B \rightarrow B[x\text{free}/t], \text{ for } t \text{ a constant of sort } s \text{ or a variable } x_1 \text{ such that } x \text{ does not occur free in } B \text{ within the scope of } (\forall_{x_1}).}{(B[x^s\text{free}/t] \text{ denotes the formula we obtain when we replace (in } B) \text{ the free occurrences of } x^s \text{ by } t.)}$$

The formal properties of the action operator $E_{a:r}$ are described bellow:

Axioms:

$$\begin{array}{ll} (T_E) & E_{a:r}B \rightarrow B \\ (C_E) & E_{a:r}A \wedge E_{a:r}B \rightarrow E_{a:r}(A \wedge B) \\ (\text{Qual}) & E_{a:r}B \rightarrow \text{qual}(a : r) \\ (\text{Itself}) & (\forall_x)\text{qual}(x : \textit{itself}) \end{array}$$

Proof rule:

$$(RE_E) \quad \text{If } \vdash A \leftrightarrow B \text{ then } \vdash E_{a:r}A \leftrightarrow E_{a:r}B$$

With respect to the formal properties of the deontic operators, and of the relationships between each other and with the action operator, we consider the following axioms and proof-rules:

Axioms:

$$\begin{array}{ll} (C_O) & O_{a:r}A \wedge O_{a:r}B \rightarrow O_{a:r}(A \wedge B) \\ (O \rightarrow P) & O_{a:r}B \rightarrow P_{a:r}B \\ (O \rightarrow \neg P \neg) & O_{a:r}B \rightarrow \neg P_{a:r}\neg B \\ (O \wedge P) & O_{a:r}A \wedge P_{a:r}B \rightarrow P_{a:r}(A \wedge B) \end{array}$$

Proof rules:

$$\begin{array}{ll} (RE_O) & \text{If } \vdash A \leftrightarrow B \text{ then } \vdash O_{a:r}A \leftrightarrow O_{a:r}B \\ (RM_P) & \text{if } \vdash A \rightarrow B \text{ then } \vdash P_{a:r}A \rightarrow P_{a:r}B \\ (RM_{EP}) & \text{If } \vdash E_{a_1:r_1}A \rightarrow E_{a_2:r_2}B \text{ then } \vdash P_{a_1:r_1}A \rightarrow P_{a_2:r_2}B \end{array}$$

More details can be found in the above referred papers.

3 Formal specification of role-based organizations

3.1 Organizations as institutional agents

Organizations are legally classified as *artificial persons*. Artificial persons are collective entities that have a real existence in human societies: they have *juridical personality*, which means that they may be the subject of obligations or rights and they also have *legal qualification*, which means that they can exercise their rights and be responsible for the unfulfillment of their obligations. Based on this legal concept of artificial person, we introduced in [14] the concept of *institutional agent* to model organizations.

Institutional agents are agents. They interact in the society like any other agent: they can establish contracts or other normative relationships with other agents, they can hold roles, they may be the subject of obligations or other normative attributes, and may be responsible for the nonfulfillment of obligations or other “non ideal” situations.

An institutional agent has a structure formed by a set of roles. Each structural role is deontically characterized by a set of obligations, permissions, or other normative attributes. This abstract structure is supported by other agents: the holders of the roles. When an agent act in a role, his behavior will be evaluated according to the deontic characterization of the role he is playing.

An institutional agent is not capable of direct action. It always act through the holders of the roles of its structure. There must be defined how obligations of an institutional agent are transmitted to the roles of its structure (and indirectly to the holders of those roles), stating who is responsible for fulfilling them. It must be also defined what are the representative roles of the institutionalized agent, stating who is authorized to act on behalf of the institutional agent.

An agent may hold several roles.

3.2 Some extensions to the logic

Next we extend the logic in order to obtain a framework with the adequate expressive power to specify organizations as institutional agents.

Deontic characterization of roles and agents in roles The deontic characterization of a role in an organization is part of the identity of the organization and does not depend on the agent that hold that role in a particular moment. To capture this idea, deontic notions are attached to roles, but they are actually interpreted as applied to the holders of such roles, when acting in such roles (deontic notions are only meaningful when applied to agents). Thus, we do not introduce new operators, but just new abbreviations:

$$\begin{array}{l} \overline{O_r B \stackrel{abv}{=} (\forall x)(qual(x : r) \rightarrow O_{x:r} B)} \\ \overline{P_r B \stackrel{abv}{=} (\forall x)(qual(x : r) \rightarrow P_{x:r} B)} \\ \overline{F_r B \stackrel{abv}{=} (\forall x)(qual(x : r) \rightarrow F_{x:r} B)} \end{array}$$

Apart from the set of obligations, permissions and prohibitions that are intrinsic to the role and characterize the identity of the organization, other obligations or permissions may be attributed to the role dynamically, resultant from the interaction of the organization with the external world. For instance, when an organization i has an obligation ψ resultant from a contract established with other agent, that obligation will have to be transmitted to specific roles of the organization's structure, stating who is responsible for its fulfillment (on behalf of the organization): $O_{i:i}\psi \rightarrow O_r\psi$ (for r a structural role).

By knowing the qualifications of an agent, that is, the roles the agent holds, we know what are the obligations, the permissions and the prohibitions that apply to him. But there are situations where the deontic characterization of an agent may be more complex.

A first case, happens when an agent establishes a contract with an organization accepting to hold a particular role of its structure. In most cases (e.g. collective labor contract) the agent, by accepting to hold a role, just inherits the deontic characterization of the role. But, in other cases, other obligations or permissions may be attributed to the agent in that role, distinct from the ones of the deontic characterization of the role. For example, an administrator may negotiate with a company to have his personal phone bills payed by the company; or an employee of a foreign company that has to work abroad, may negotiate with the company to have some compensation (e.g. take his family with him, pay for children school). These obligations will be called *personal obligations in a role*, represented by $O_{a:r}\psi$ (where a is an agent and r is a role) and are not intrinsic to the role.

Representative roles Some roles may be classified as *representative roles* of other agents. This means that the holders of those roles may act on behalf of the represented agents within the scope of representation defined for those roles.

In order to represent this, the following notation has been introduced in [14]: $r:REP(a, B)$, that is read as follows: “ r is a representative role of a with scope of representation B ”. The expression $r:REP(a, B)$ can be seen as an abbreviation of:

$$(\forall_x)(E_{x:r}B \rightarrow E_{a:a}B).$$

Here we extend this notation allowing the represented agent to be in a role other than the role *itself*. So we have:

$$r1 : REP(a : r2, B) \stackrel{def}{=} (\forall_x)(E_{x:r1}B \rightarrow E_{a:r2}B).$$

We can now add two properties imposing that B should be in the scope of $r2$ and in the scope of $r1$:

$$\begin{aligned} r1 : REP(a : r2, B) &\rightarrow P_{r2}B \\ r1 : REP(a : r2, B) &\rightarrow P_{r1}B \end{aligned}$$

When an agent acts as representative of another agent he does not act on his own behalf. So, it is natural to impose that:

$$E_{x:r_1}B \wedge r_1 : REP(a : r_2, B) \rightarrow \neg E_{x:x}B \text{ }^3$$

There might exist cases where we can consider that a role r_1 is a representative role of an agent a in a role r_2 , for everything permitted in r_1 . Using $r_1 : REP(a : r_2, *)$ to denote that, we can capture such situation by imposing the following axiom: $r_1 : REP(a : r_2, *) \wedge P_{r_1}B \rightarrow r_1 : REP(a : r_2, B)$

Representative roles are crucial for organizations because an organization cannot act directly - it needs other agents to act on his behalf. Those agents are the titular of the representative roles.

Representative roles are not necessarily roles of the structure of an institutionalized agent. They may result from contracts or other normative relations that agents are free to establish between each other. An institutionalized agent, for instance, may also establish arbitrary representation contracts with other agents attributing to them representative roles for specific situations. Contracts are discussed below.

3.3 Contracts

Agents in a society are free to establish arbitrary normative relationships between each other. A particular kind of those relationships are *contracts*.

When two agents⁴ establish a contract between each other, they attribute obligations, permissions and prohibitions to each other. They may also attribute roles (contractual roles) to each other and deontically characterize those roles (that means, they define what are the obligations, permissions or prohibitions associated to each role). Some of the roles may be classified as representative roles of one of the agents. In that case, it must be also defined in the contract, the scope of representation for that role.

Frequently, contracts also include conditional obligations (or conditional permissions). In particular, in legal contracts it is usual to include conditional obligations describing the effects of the fulfillment or violation (unfulfillment) of other obligations in the contract. For instance, besides an obligation $O_{x:r_1}A$ on x a contract $C(x, y)$ may include an obligation on y on the condition that x fulfills the previous obligation

$$E_{x:r_1}A \rightarrow O_{y:r_2}B,$$

or another obligation on x if he does not fulfill it

$$\neg E_{x:r_{g_1}}A \rightarrow O_{x:r_{g_1}}B.$$

³ This does not mean that the representative agent is not responsible for “bad behavior”.

⁴ For simplicity reasons we only consider contracts between two agents.

The specification of an organization i may also include other components, not considered here.

The description of $\langle i, ST_i \rangle$ contains those aspects that do not change and define the identity of the organization. We need also to include in the specification of i , information describing the agents that in the present moment hold the roles r of the structure of i . Since this component corresponds to relationships between i and other agents (contracts that i establishes with each agent), we have decided to include it in component NR (normative relationships) of the specification of the society of agents (see below).

A society of agents, SA , is: $SA = \langle IA, nIA, NR, GK \rangle$ where:

IA : Specification of each institutionalized agent (organization) of the society.

So it is formed by a set of pairs $\langle x, ST_x \rangle$, as explained above.

nIA : The component nIA contains the identification of the other agents that exist in the society.

NR : Contains normative relationships that agents have established between each other, and in particular the contracts that are actually in force. Contracts between organizations and agents, attributing to the agents titularity of roles of its structure, are also included in this component.

GK : Contains general knowledge about the society.

For more details and an example see [14].

4 Delegation

The concept of delegation appears in many different contexts having distinct interpretations. Next we discuss some possible interpretations of it, and try to express them in a precise way using the action and deontic logic presented above. This formalization process may contribute to clarify the concept of delegation.

4.1 What do we mean by delegation?

We can classify as delegation a set of different situations, all having in common some kind of transference of tasks, responsibilities, permissions, obligations, powers or other normative attributes, from one agent to another. The different interpretations of the concept depend on issues like: why agents delegate, how do they delegate, what is delegated, among others.

An agent may want to delegate e.g. an obligation to other agent because he is not capable of fulfilling it (e.g. he does not have resources nor knowledge), he has not practical possibility of fulfilling it (e.g. he cannot be in two places at the same time), or any other reason.

In this paper we will not analyze *why* an agent delegates or *why* an agent accepts a delegated task, obligation, or other normative attribute. It is outside the scope of this paper to express and reason about motivations or intentions of agents involved in a delegation relationship. We also assume, without representing it explicitly, that when an agent delegates an obligation to another agent, he

also transfers to that agent all the resources required to the effective fulfillment of the obligation.

Lets discuss now what may be delegated and how this delegation may occur.

Delegation as a normative relationship First of all, we consider that delegation is a *normative relationship* between agents, or to be more precise, between agents playing roles. By this we mean that, agents do not simply delegate tasks, but delegate obligations, permissions, prohibitions, responsibilities, powers, ... to do tasks. For instance, if we simply say that *the director of the Informatics Department delegates the task of writing the annual report to his secretary*, what we usually mean is that she has the obligation of writing the annual report on behalf of the director. But that information is not explicit in the initial statement.

Another example: if we say that *a company X delegates in a specific administrator the task of selling a property*, do we mean that that administrator has permission to sell the property, or that he is obliged to sell it, or ...? The intended meaning is not clear.

On the other hand, if we say that *a company X delegates in a specific administrator the obligation to sell a property*, the meaning is clearer . Considering agents in roles instead of only agents is important, because as we will see, characterization of delegation depends on the roles agents are playing.⁵

For simplicity reasons, we use only the deontic concepts of obligation and permission, in the description of the content of a delegation act.⁶ In a deeper analysis other concepts like the one of power should be included. The normative concept of responsibility is only informally and indirectly referred.

Thus, we want to express statements similar to:

agent x delegates on agent y the obligation to bring about ϕ and the permission to bring about ψ .

What do we mean by this statement is not clear, yet.

A first remark that should be made, is that the agents involved in this delegation process, are part of some organization or some society. So, according to the perspective we adopt in this paper, they are playing roles (at least the role

⁵ We can be more precise and say that in some situations what is delegated are obligations (permissions, powers, ...) to do some actions and in other situations what is delegated are obligations (permissions, powers...) to bring about certain states of affair, without specifying the concrete actions that should be made to achieve that state of affairs. It is a question of abstraction, that we do not address in this paper. Here, we adopt the latter version, omitting details about concrete actions. For works that use and discuss this distinction, see, for example, [1], [12], [13], [8].

⁶ Moreover, it seems strange to us that agents could delegate prohibitions: they delegate obligations and/or permissions to bring about a state of affairs, and not to avoid a certain state of affairs. Formulas like $F_{i:r}A$ seen as $O\neg E_{i:r}A$, in our opinion, should not be delegated. However, formulas like $OE_{i:r}\neg A$ would be acceptable. But this issue needs further research.

of *itself*). So we should reformulate the above statement:

agent x, playing role r1, delegates on agent y, which is playing role r2, the obligation to bring about ϕ and the permission to bring about ψ .

This new statement poses some other questions:

- *Is agent x (when acting in role r1), permitted to delegate the obligation to bring about ϕ and the permission to bring about ψ ?*
- *Is agent y (when acting in role r2), permitted to accept the delegated obligation to bring about ϕ and permission to bring about ψ ?*

The answer to these questions depends on the deontic characterization of the roles played by the agents.

It seems reasonable to require that the obligation ϕ and the permission ψ referred, should be in the *scope of* role r1 (i.e. it should be possible to infer them from the deontic characterization of role r1). According to this interpretation, we can only delegate obligations and permissions attributed to us.⁷ Here, we only consider delegation cases that verify this restriction.

We also assume that an agent cannot delegate the obligations and permissions he has in a role that are not intrinsic to the role (that are not in the deontic characterization of the role), but result from the interaction of the agent with the organization, such as personal obligations or permissions negotiated in the labor contract, or obligations that result from sanctions to his behavior.

When an agent accepts a delegated obligation (permission,...), this new obligation will be “added” to the deontic characterization that applies to him resultant from the roles he holds. Therefore, his actions will be evaluated in this new deontic context. But, in the model we adopt, obligations and permissions are assigned to agents in roles. Thus, a question arises:

Are the obligations and permissions delegated to an agent attributed to that agent in the role he is playing in an organization?

In most cases yes, but in some other cases no.

In the former cases, the delegated obligations and permissions are just added to the agent in the role deontic characterization. For example, when the director of Department of Informatics delegates on his secretary the obligation to produce the annual report, this new obligation will be *added* to the deontic characterization of the person playing the secretary role ($O_{x:sec}\phi$). This new deontic attributes are not intrinsic to the secretary role, they are resultant from the interaction between the holder of secretary role and the holder of director of

⁷ There are situations where an agent has permission to “delegate” on others obligations (permissions,...) that are not attributed to him. For example, an administrator may “delegate” on an employee the obligation to perform a task that he is not obliged to perform. Although in natural language, the word “delegate” is sometimes used in similar contexts, we have doubts that this situation should be classified as a delegation case. So, we do not consider this kind of situations in this paper.

Department of Informatics. In this context, it seems natural to impose that the delegated obligation or permission should not enter in conflict with the deontic characterization of the role played by the agent that accepts them. By not entering in conflict we mean, in this context, that the same agent should not be under the obligation or permission to bring about A because he holds a role and, at the same time, under the obligation or permission to bring about $\neg A$, because he accepts a delegated obligation or permission. For later reference, we will call this kind of delegation *composed delegation*.

There are, however, other situations where what is delegated is a set of obligations and permissions that should not be seen as an additional characterization of the role played by the agent who accepts them, because they have a distinct nature. In this cases, what is delegated may be seen as a set of obligations and permissions – a new role, as we will see below – that is attributed to the agent independently of other roles he is playing (although the role an agent is playing may be relevant to choose him as delegate). In this case, avoiding conflicts (of the kind mentioned above) is not relevant: agents may have conflicting obligations when playing different roles. For instance, it is possible to have $O_{x:r2}A$ and $O_{x:r3}\neg A$. As an agent can act only in a role at a time ⁸ he will have to decide what obligation he will fulfill and what obligation he will violate.⁹

A typical example of this kind of delegation is when an agent in a role delegates some of its obligations or permissions to another agent (that may even be from outside the organization) through a contract, attributing to him a specific role. For later reference, we will call this kind of delegation *independent delegation*.

Role-based Delegation In the role-based organizational model proposed in the previous section, roles are characterized by a set of obligations, permissions and prohibitions. So, we can aggregate the delegated obligations and permissions in a role and say that *agents delegate roles*. This delegated role may be just an artifact (a way of aggregating obligations and permissions and naming it) or, on the contrary, may be a role of the organization structure (usually part of another role of the structure), or a new role defined in a contract. In this paper we assume that the roles of the structure of an organization are composed of smaller roles corresponding to functions or competences associated to the former role. Those smaller roles may be viewed as a way of structuring the set of obligations, permissions, ... that deontically characterize the role, into units that

⁸ In cases where we can assume that agents may play several roles at the same time, we consider that there is some kind of composition of those roles, as discussed above.

⁹ There are other kind of conflicts related, for instance, with incompatibility of goals (functions, competences,...) associated to roles. For instance, the President of BP cannot be President of GALP (BP and GALP are two known oil companies). We can express this kind of incompatibility using the relation $\langle \rangle$ proposed on [14], where $r2 \langle \rangle r3$ is defined as $(\forall x)(qual(x : r2) \rightarrow \neg qual(x : r3))$, stating that the same agent cannot hold the two roles. Although in this paper we do not consider this kind of incompatibilities to restrict delegation, we intend to do it in the future.

“make sense”. For example, a lecturer at some university, has obligations related with his competence of teaching, others related with research, other related with bureaucratic functions, ... We will assume, in this paper, that an holder of a role may only delegate one of its role units. The deontic characterization of each of the role units that constitute a role, is defined in the structure of the organization. So, we don't need to deontically characterize the delegated role when two agents establish a delegation relationship. We shall return to this issue later.

In order to represent this role-based delegation, we introduce the following notation $Delegate(x : r1, y : r2, r3)$, that is read as follows: “agent x playing role $r1$ delegates the role $r3$ on agent y that is playing role $r2$ ”. Before we define the kind of formulas that correspond to the expression $Delegate(x : r1, y : r2, r3)$, we need to discuss some additional features of the delegation concept.

If we assume the properties discussed above for what is being delegated, we may say that an agent in a role may only delegate roles that are part of the role he is playing: $Delegate(x : r1, y : r2, r3) \rightarrow r3 \leq r1$, where $r3 \leq r1$ is read “ $r3$ is part of role $r1$ ” (the predicate symbol \leq will be discussed later).

In the context of *composed delegation*, the role $r3$ that is being transferred to agent y will now be “added” to the role $r2$ he was playing, in the sense that the deontic characterization of the two roles will be joined, as if there were a new role. To capture this idea we will use the function on roles, $+ : R \times R \rightarrow R$ (to be discussed later). We can say, then, that delegation makes y hold role $r2 + r3$. This is in fact a new role of the organization and its inclusion in the structure depends on the permanent or transitory character of the delegation. So, in the definition of the delegation relationship the following role attribution must occur:

$$Delegate_c(x : r1, y : r2, r3) \stackrel{def}{=} is - r2 + r3(y) \wedge \dots$$

As we said before, in a context of *independent delegation* this role composition should not occur. The delegated role exists by itself and the agent to whom the role is delegated may act either in role $r2$ or in role $r3$. In this case we must have:

$$Delegate_i(x : r1, y : r2, r3) \stackrel{def}{=} is - r3(y) \wedge \dots$$

Transfer of responsibility Another issue that must be discussed is whether the obligations and permissions delegated to other agents, stay or not in the role played by the agent that delegates them. We will consider two situations: share of responsibilities and complete transfer of responsibilities.

Share of responsibilities

In this case, the agent that delegates obligations and permissions, also keeps them. So he shares the responsibility with the agent to whom he delegated them. This delegation case corresponds to a representation relationship. This means that when an agents delegates a sub-role to another agent, he his assigning him

a representative role. We can express this in our logic through the following formulas, for composed delegation and independent delegation, respectively:

$$Delegate_{cs}(x : r1, y : r2, r3) \stackrel{def}{=} is - r2 + r3(y) \wedge r3 : REP(x : r1, *)$$

or

$$Delegate_{is}(x : r1, y : r2, r3) \stackrel{def}{=} is - r3(y) \wedge r3 : REP(x : r1, *)$$

In this case the agent y will act on behalf of the agent x .

Complete transfer of responsibilities

In this situation, when the agent delegates obligations or permissions he is no longer responsible for them. This means that those obligations and permissions are excluded from his role. The delegated role should be “subtracted” from the role held by the agent that delegates it. In this case, the role of the agent that delegates, is changed and becomes a sub-role of the initial role.

A possibility to express these role changes, would be to introduce in the language another function on roles: $- : R \times R \rightarrow R$ (to be discussed later) and use it as follows:

$$Delegate_{ct}(x : r1, y : r2, r3) \stackrel{def}{=} is - r1 - r3(x) \wedge is - r2 + r3(y)$$

or

$$Delegate_{it}(x : r1, y : r2, r3) \stackrel{def}{=} is - r1 - r3(x) \wedge is - r3(y)$$

But this possibility needs further research ¹⁰.

For simplicity reasons, in the rest of the paper we will use $Delegate(x : r1, y : r2, r3)$ whenever it is not relevant to distinguish the particular kind of delegation used.

Forms of delegating There are several forms of delegation. We will consider some of them: delegation by command, through a joint action, by institutional context, or implicitly.

Delegation by command

When agent x in role $r1$ has some kind of authority over agent y in role $r2$, delegation may be unilateral and have the form of a “command”, which can be expressed as follows:

$$E_{x:r1} Delegate(x : r1, y : r2, r3).$$

¹⁰ Examples of open questions are: *Should we cancel the qualification of x to play role $r1$?, or What is the meaning of having $r - r$?*

Delegation by joint action

Other frequent form of delegation is through a joint action, where both $x : r1$ and $y : r2$ decide to establish a delegation relationship. To express this joint action, we will use the action operator proposed in [14], $E_{\{a1:r1,\dots,a_n:r_n\}}$, indexed by a finite set of agents in roles.

Thus, we extend our logical language $\mathcal{L}_{\mathcal{DA}}$ with this operator. The formulas of the extended language ($\mathcal{L}_{\mathcal{DA}}^+$) are defined as follows:

- If B is a formula of $\mathcal{L}_{\mathcal{DA}}$, then B is (also) a formula of $\mathcal{L}_{\mathcal{DA}}^+$;
- If B is a formula of $\mathcal{L}_{\mathcal{DA}}$ and t_1, \dots, t_n ($n \geq 2$) are terms of sort AgR , then $E_{\{t_1,\dots,t_n\}}B$ is a formula of $\mathcal{L}_{\mathcal{DA}}^+$ (a joint action formula);
- Boolean combinations (through \neg and \wedge) of formulas of $\mathcal{L}_{\mathcal{DA}}^+$ and universal quantifications of formulas of $\mathcal{L}_{\mathcal{DA}}^+$, are also formulas of $\mathcal{L}_{\mathcal{DA}}^+$.

We consider that each joint action operator $E_{\{a1:r1,\dots,a_n:r_n\}}$ is of type ETC, and the qualification axiom extends naturally to joint action formulas as follows:

$$E_{\{a1:r1,\dots,a_n:r_n\}}B \rightarrow qual(a1 : r1) \wedge \dots \wedge qual(a_n : r_n)$$

We are now in position to express delegation established through a joint action :

$$E_{\{x:r1,y:r2\}}Delegate(x : r1, y : r2, r3)$$

Institutional delegation

The several delegation situations we have analyzed are just particular cases of *contracts* between agents. So, another claim could be that: to delegate is to establish a contract with the particularities we have discussed. But this is not accurate. There are cases where delegation does not correspond to a relationship between the agent that delegates and the agent that accepts the delegated role.

Consider for instance a situation where an agent x that plays role $r1$ in an organization is absent. It is usual that another agent z (e.g. his boss, that plays role r) delegates on other agent (y that plays role $r2$) the role $r1$, until x returns to the organization. We can express this situation by

$$E_{z:r}Delegate(x : r1, y : r2, r1)$$

Sometimes these situations are predefined in an organization, and agent z might be the institutional agent itself.

Informal Delegation

We do not consider implicit delegation, in the sense of informal delegation relationships that agents may define between each other. Those relationships have no normative effects, in the sense that, if something fails, responsibilities could not be attributed to the agents involved.

4.2 Examples

So, we conclude this section presenting some examples of different types of delegation.

Example 1 *One of the functions of the Director of Department of Informatics (ddi), a , is to produce an annual report (wr). Associated to this sub-role (wr) there is the obligation to write the annual report of the Department (ψ) and the permission to use the director's computer(ϕ). He delegates on his Secretary (sdi), c , this role wr .*

$$\begin{aligned} E_{a:ddi} \text{ Delegate}_{cs}(a : ddi, c : sdi, wr) &\stackrel{abv}{=} \\ E_{a:ddi} \text{ is} - sdi + wr(c) \wedge wr : REP(a : ddi, *) \end{aligned}$$

The role delegated is called wr and is a part-of role ddi . Role wr is characterized as: $P_{wr}\phi \wedge O_{wr}\psi$ The secretary writes the report on behalf of the director (i.e. her action will count as an action of the Director). He is still responsible for the report. Notice that this delegation has the form of a command (due to the authority the Director has over the Secretary).

Example 2 *The Director of Department of Informatics (ddi), a , has the obligation to convoke the General Assembly of the Department (ϕ), once a year. He delegates this task, permanently, on the Assistant-Director ($addi$).*

$$\begin{aligned} E_{\{a:ddi,b:addi\}} \text{ Delegate}_{ct}(a : ddi, b : addi, cga) &\stackrel{abv}{=} \\ E_{\{a:ddi,b:addi\}} \text{ is} - addi + cga(b) \wedge \text{is} - ddi - cga(a) \end{aligned}$$

The role delegated is called cga and is part of role ddi and is characterized by $O_{cga}\phi$. This role is added to the role $addi$ and subtracted from the role ddi . So, from now on, the agents a and b will hold different roles.

Example 3 *The Director of Department of Informatics (ddi), a , will be absent and delegates in the Assistant-Director ($addi$), b , all his competencies.*

$$\begin{aligned} E_{\{a:ddi,b:addi\}} \text{ Delegate}_{cs}(a : ddi, b : addi, ddi) &\stackrel{abv}{=} \\ E_{\{a:ddi,b:addi\}} \text{ is} - ddi + addi(b) \wedge ddi : REP(a : ddi, *) \end{aligned}$$

The role delegated to b is now the whole role ddi . In the absence of the Director of Department a , b will act as his representative, for everything the Director would have to do or would be permitted to do.

Another possible interpretation of this situation would be to say that, during that period, b is the director of the Department of Informatics. The main difference between this interpretation and the one presented before, is that in this case, b would be the only responsible for his actions as Director of Department. While in the previous case, the responsibility also goes to a . In this latter case

we would have:

$$\begin{array}{l} E_{\{a:ddi,b:addi\}} \quad Delegate(a : ddi, b : addi, ddi) \stackrel{abv}{=} \\ E_{\{a:ddi,b:addi\}} \quad is - ddi(b) \end{array}$$

5 Extensions to the formal specification of role-based organizations

In order to include the previous role-based delegation on the formal specification of organizations we need to consider further deontic logical principles related with the concepts of part-of-role, joining roles and role subtraction mentioned before.

With respect to the concept of *part-of-role* we introduce in the language a new predicate symbol \leq where $r1 \leq r2$ expresses the fact that $r1$ is part of role $r2$, which means that all obligations and permissions that characterize $r1$ also characterize $r2$. Thus the logical principles:

$$\begin{array}{l} r1 \leq r2 \rightarrow (O_{r1}\phi \rightarrow O_{r2}\phi) \text{ and} \\ r1 \leq r2 \rightarrow P_{r1}\phi \rightarrow P_{r2}\phi. \end{array}$$

follow intuitively from what we want to express.

The joining roles function $+ : R \times R \rightarrow R$ also brings the need for the following logical principles:

$$\begin{array}{l} O_r A \rightarrow O_{r+s} A \\ O_{r+s} A \rightarrow (O_r A \vee O_s A) \\ P_r A \rightarrow P_{r+s} A \\ P_{r+s} A \rightarrow (P_r A \vee P_s A) \end{array}$$

that follow the idea that a composite role also inherits all the obligations and permissions of its role composites.

On the other hand, the subtracting role function $- : R \times R \rightarrow R$, introduces the need for the following logical principles:

$$\begin{array}{l} O_s A \rightarrow \neg O_{r-s} A \\ P_s A \rightarrow \neg P_{r-s} A \end{array}$$

following the idea that role obligations and permissions no longer apply when this role is subtracted from another role (the main role). Note however that the other obligations and permissions remain in the main role, i.e.

$$\begin{array}{l} O_r A \wedge \neg O_s A \rightarrow O_{r-s} A \\ O_{r-s} A \rightarrow O_r A \end{array}$$

Over and above the deontic principles we naturally assume role composition expressed by functions $+$ and $-$ as a way of expressing part-of-roles:

$$\begin{array}{l} r \leq r + s \\ r - s \leq r \end{array}$$

Finally,

$$E_{x:r}A \wedge is - r + s(x) \rightarrow E_{r+s}A$$

may help to characterize obligation fulfillment in this new deontic context.

Concerning the specification of organizations, our main idea is to specify organizations by roles r fragmented into smaller roles $r1, r2, \dots, rn$ and express this by $r = r1 + r2 + \dots + rn$. Intuitively, each part ri of role r may correspond to a particular function (or competence) associated to role r . We will assume that an holder of role r may only delegate one of this units.

Introducing a predicate symbol $=$ of sort (R, R) , reflexive, symmetric and transitive, we foresee the need for the following principles:

$$\begin{aligned} r1 + r2 &= r2 + r1 \\ (r1 + r2) + r3 &= r1 + (r2 + r3) \\ r + r &= r \\ r = s &\rightarrow r \leq s \quad (r - s) + s = r \\ r = s &\rightarrow (t - s = t - r) \\ r = s &\rightarrow (t + s = t + r) \\ r = s &\rightarrow (O_r A = O_s A) \end{aligned}$$

Due to space limitations it is not possible to present a full example of an organization and of a society of agents that includes that organizations. Examples can be found in [14]. We conclude this section with some comments about the inclusion of delegations cases in the formal specification of organizations. We need to include a component in the structure of the organization describing the units that compose each role. Delegations that occur in an organization are included in the NR component of a society of agents that contains normative relations of the agents of the society.

6 Conclusion and Future Work

In this paper we discussed the concept of delegation in an organizational context. We considered role-based organizations — organizations structured by a set of roles, which are held by agents. Moreover, organizations are seen as normative systems — a set of interacting agents whose behavior is ruled by norms (obligations, permissions and prohibitions) resultant from the deontic characterization of the roles the agents' hold. In that context, delegation is classified as a normative relation between agents, where agents transfer some (or all) of their deontic qualifications to other agents. A deontic and action modal logic has been used to express the different interpretations of the delegation concept. This is a preliminary approach to delegation. Many open questions remain.

One of the questions we intend to address is how to express the fact that not everything (obligations, permissions, powers of a role) may be object of delegation. There are some cases where an obligation (permission) must be fulfilled directly by a particular agent in a role. A possible approach would be to distinguish direct and indirect action, using, for example, a direct action operator like the one proposed in [17], D_x , and adapted in [2] to direct actions of agents in roles. Using this operator we may express obligations that may be delegated

from others that may not, using expressions similar to $OE_{a,r}A$ for the former and $OD_{a,r}$ for the latter. If this approach is adopted, we have to use impersonal obligations and permissions instead of the personal ones we have used in this paper.

Another issue that needs further research is composition of roles. A formal study of the functions referred in the paper must be done.

Other deontic concepts must be included in the characterization of delegation, specially the concept of power and representation. See [4], [15], for work on this issues.

We are aware that, given its static nature, the type of logic proposed so far is not fully adequate to characterize the dynamic aspects referred in the previous delegation examples. There are in fact two relevant snapshots in the delegation process: before and after delegation. Before a delegation $Delegate(x : r1, y : r2, r3)$ we naturally expect that agents x and y hold roles $r1$ and $r2$ respectively, i.e. $is-r1(x)$ and $is-r2(y)$. However, after delegation, the deontic qualification of both agents may change and as a consequence it may happen that $\neg is-r1(x)$ or $\neg is-r2(y)$. Obviously, these formulas together introduce a logical inconsistency. To overcome, this problem a possible approach would be to introduce temporal operators.

References

1. A.Artikis, J.Pitt and M. Sergot: "Animated Specifications of Computational Societies", Proceedings of the first International Joint Conference on Autonomous Agents and Multi-agent Systems (AAMAS'02), pp. 1053-1061, ACM, 2002.
2. J. Carmo and O. Pacheco: "Deontic and action logics for organized collective agency, modeled through institutionalized agents and roles", *Fundamenta Informaticae*, Vol.48 (No. 2,3), pp. 129-163, IOS Press, November, 2001, .
3. B. J. Chellas: *Modal Logic - an Introduction*, Cambridge University Press, 1980.
4. J. Gelati and G. Sartor: "Normative co-ordination and the delegation of agency: declarative power, representation and mandate", 2002.
5. G. Governatori, J. Gelati, A. Rotolo and G. Sartor: "Actions, Institutions, Powers. Preliminary Notes", *International Workshop on Regulated Agent-Based Social Systems (RASTA'02)*, Fachbereich Informatik, Universität Hamburg, pp. 131-147, 2002.
6. A.G. Hamilton: *Logic for Mathematicians*, Cambridge University Press, 1988.
7. R. Hilpinen (ed.), *Deontic Logic: Introductory and Sistematic Readings*, Dordrecht: D.Reidel, 1971.
8. A. J. I. Jones and M. J. Sergot: "A Formal Characterization of Institutionalized Power", *Journal of the IGPL* , **4(3)**, pp.429-445, 1996. Reprinted in E. Garzón Valdés, W. Krawietz, G. H. von Wright and R. Zimmerling (eds.), *Normative Systems in Legal and Moral Theory*, (Festschrift for Carlos E. Alchourrón and Eugenio Bulygin) , Berlin: Duncker & Humblot, pp.349-369, 1997.
9. S. Kanger: *New Foundations for Ethical Theory*, Stockholm, 1957. (Reprinted in [7].)
10. S. Kanger: "Law and Logic", *Theoria*, **38**, 1972.
11. L. Lindahl: *Position and Change - A Study in Law and Logic*, Synthese Library **112**, Dordrecht:D. Reidel, 1977.

12. T.J. Norman and C. Reed: "Delegation and Responsibility", In *Intelligent Agents VII*, volume 1986 of LNAI, Springer-Verlag, 2001.
13. T.J. Norman and C. Reed: "Group Delegation and Responsibility", Proceedings of the first International Joint Conference on Autonomous Agents and Multi-agent Systems (AAMAS'02), ACM, pp. 1053-1061, 2002.
14. O. Pacheco and J. Carmo: " A Role Based Model for the Normative Specification of Organized Collective Agency and Agents Interaction", *Journal of Autonomous Agents and Multi-Agent Systems*, Vol. 6, Issue 2, pp.145-184, Kluwer, March 2003.
15. I. Pörn: *The Logic of Power*. Oxford : Blackwell, 1970.
16. I. Pörn: *Action Theory and Social Science: Some Formal Models*, Synthese Library, **120**, Dordrecht : D. Reidel, 1977.
17. F. Santos and J. Carmo: " Indirect Action, Influence and Responsibility", in M. Brown and J.Carmo (eds.), *Deontic Logic, Agency and Normative Systems*, Springer, Workshops in Computing Series, 194-215, 1996.
18. K. Vender and M. Olivier: "The delegation authorization model: a model for the dynamic delegation of authorization rights in a secure workflow management system", in ISSA2002, Muldersdrift, South Africa, 2002. Published electronically in <http://mo.co.za>.