Modelling Electronic Organizations

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1 Introduction

Institutions are established to regulate the interactions between parties that are performing some (business) transaction. One of the main roles of institutions is to inspire trust into the parties that perform the transaction. (see [2] for more details on the roles of institutions). The main focus of this paper is how an electronic organization[1] should be specified on the basis of the abstract patterns given by the institution on which the organization is formed. I.e. how can we define a (formal) relation between the (abstract) norms specified in the regulations of the institution and the concrete rules and procedures of the organization such that the agents operating within the organization will operate according to these norms or can be punished when they are violating the norms.

Current approaches of the problem in the agent community either work at a low level (policies and procedures) or at a very high level, formally specifying norms in e.g. deontic logic. The low level approaches allow an easy implementation, but the problem arises when the correctness of the procedures and policies should be checked against the original regulations. High level approaches are closer to the way regulations are made, so verification is easier to be done through e.g. model checkers. However, high level approaches usually use one or several computationally hard logics like deontic logic ([8, 12]). Although it is possible to capture the norms in this way and even give them a certain kind of semantics to reason about the consequences of the norms, this kind of formalization does not yet indicate how the norm should be interpreted within a certain institution. For instance, we can formalize a norm like *"it is forbidden to discriminate on the basis of age"* (when determining the best possible recipient for an organ) in deontic logic as $F(\mathit{discriminate}(x,y,\mathit{age}))$ (stating that it is forbidden to discriminate between x and y on the basis of age). However, the semantics of this formula will get down to something like that the action `discriminate(x,y,age)` should not

[1] In our view, institutions consist only of the abstract patterns that regulate the interaction between the parties. Herewith we deviate from the common way of regarding the organizations that are built according to these patterns as institutions as well.

occur. It is very unlikely that the agents operating within the institution will explicitly have such an action available. We claim that the level on which the norms are specified is more abstract and/or general than the level on which the processes and structure of the organization are specified. Therefore we need to "translate" the norms specifically to a level where their impact on the institution can be described directly.

In this paper we introduce HARMON*IA*, a framework that defines a multi-level structure, from the most abstract level of the normative system to the final implementation of the organization. It is composed of four levels of abstraction:

- the **Abstract Level**: where the statutes of the organization are defined in a high level of abstraction along with the first abstract norms.
- the **Concrete Level**: where abstract norms are iteratively concretized into more concrete norms, and the policies of the organization are also defined.
- the **Rule Level**: where concrete norms and policies are fully refined, linking the norms with the ways to ensure them.
- the **Procedure Level**: where all rules and policies are translated in a computationally efficient implementation easy to be used by agents.

The division of the system into these four levels aims to ease the transition from the very abstract statutes, norms and regulations to the very concrete protocols and procedures implemented in the system, filling the gap between theoretical (abstract) approaches and practical (concrete) ones.

In the remainder of this paper we will describe each of the four levels and their relationships in the next four sections. Then in section 6 we describe the role of policies, goals, role hierarchies and ontologies in the definition of e-organizations. We finish the paper with some conclusions and areas of further research.

2 The Abstract level: Statutes, Objectives, Values and Abstract Norms

The *statutes* of the organization are the most abstract specification of the objective of the organization and its values and norms. The statutes will indicate the main *objective* of the organization, the *values* that direct the fulfilling of this objective and they also point to the *context* where the organization will have to perform its activities.

For example, the statutes of the National Organization for Transplants (ONT) [9] in Spain state the following:

> *The principal objective of the ONT is the promotion of donation and the consequent increase of organs available for transplantation, from which all its other functions result. The ONT acts as a service agency for the National Health System, works for the continuing increase in the availability of organs and tissues for transplantation and guarantees the most appropriate and correct distribution, in accordance with the degree of technical knowledge and ethical principles of equity which should prevail in the transplant activity.*

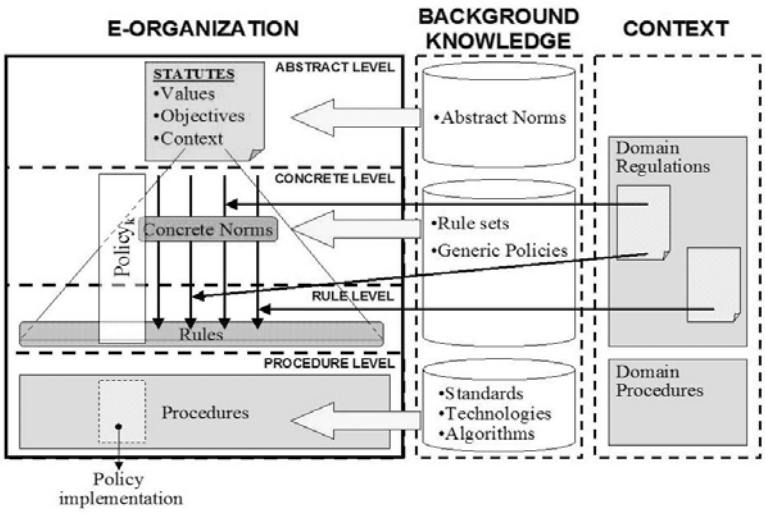

Fig. 1. The HARMON*IA* framework.

In that statement we can find:

1. the *objectives*: the main objective is to increase the number of organs available for transplants. Another objective is to properly allocate organs.
2. the *context*: ONT states that it operates inside the Spanish National Health System, and such statement clearly defines the context of the organization.
3. the *values*: The latter part indicates the values according to which the ONT operates. I.e. to guarantee the most *appropriate*, *correct* and *equal* distribution among potential recipients. Where *appropriate*, *correct* and *equal* are vague terms defined by both technical (medical) and ethical standards. Implicitly it also says that ethical values are part of the organization.

At this highest level of abstraction, the *values* fulfill the role of norms in the sense that they determine the concepts that are used to determine the value or utility of situations. However, they do not tell us explicitly how we should behave appropriately in any given social situation. This is the part played by abstract norms, concrete norms (see section 3) and rules (see section 4).

In our framework the meaning of the values is defined by the norms that contribute to this value. In an intuitive way we can see this translation process as follows:

$$\vdash_{org} D(\varphi) \longrightarrow O_{org}(\varphi)$$

meaning that, if an organization org values situations where φ holds higher than situation where φ does not hold, then such value can be translated in terms of a norm (an obligation of the organization org) to fulfill φ. In our framework

a norm *contributes to a value* if fulfilling the norm always leads to states in which the value is more fully accomplished than the states where the norm is not fulfilled. So, each value has attached to it a list of one or several norms that contribute to that value. The total list of norms (the ones in the abstract level plus the ones in the concrete level) together "defines" the meaning of the value in the context of the organization.

$$\vdash_{ONT} D(\textit{appropiate}(\textit{distribution})) \longleftrightarrow \{O_{ONT}(\textit{"ensure an appropiate distribution"})\}$$

The *objectives* of the organization can be represented as the goal of an organization. As far as the organization has control over the actions of the agents acting within that organization, it will try to ensure that they perform actions that will lead to the overall goal of the society. See section 6 for more details.

Although the most abstract level of normative behavior in the statutes is determined by the values, we also include the abstract norms related to these values in this level. We define $ANorms$ (the language for abstract norms) to be a deontic logic that is temporal, relativized and conditional. I.e. an obligation to perform an action or reach a state can be conditional on some state of affairs to hold, it is also meant for a certain type (or role) of agents and should be fulfilled before a certain point in time. E.g. the following norm might hold: *"The donor should consent to the transplantation before the transplantation can take place"*, which can be formalized as:

$$O_{hospital}(\textit{consent}(\textit{donor}) < \textit{transplant}(\textit{hospital,donor,recipient,organ}))$$

The obligation is directed towards a hospital, assuming that the hospital is responsible for fulfilling it. I.e. it is the responsibility of the hospital to acquire the consent of the donor before (indicated by the "$<$") the transplantation is performed. In some sense this obligation has an implicit conditional. It only comes into effect if the hospital intends to perform a transplantation.

3 The Concrete Level: from abstract norms to concrete norms

In order to check norms and act on possible violations of the norms by the agents within an organization, the abstract norms have to be translated into actions and concepts that can be handled within such organization. Concrete norms pertain to actions that are described in terms of the ontology of the organization and from which therefore the meaning and effect is known or they pertain to situations that can be checked directly by the institute. The norms at this level are described in $CNorms$ (the language for concrete norms), which we assume for the moment to be equal to $ANorms$, but which might use different predicates. In addition we define a function $\mathtt{I}$: $ANorms \rightarrow CNorms$ which is a mapping from the abstract norms to the concrete ones. For each abstract norm $\mathtt{I}$ indicates which concrete norms are implementing it within the context of this

organization. This function is based on the counts-as operator as developed in [5].

There are several ways in which norms can be "abstract" and thus several ways to make them more concrete:

- **Abstract actions**: Norms often refer to an abstract action that can be implemented in many ways. E.g. *"a living donor should consent to the donation of an organ"*. The translation in this case is a kind of definition of the abstract action in terms of the concrete actions. In the above case one could define this as follows:

  $$Consent(donor) \equiv sign(donor,contract) \cup carry(donor,codicil) \cup tell(donor,family)$$

  i.e. "to consent" is performing either of the three more specific actions. Important to note is that this definition closes the way consent can be given.
- **Vague terms**: Norms use terms that are vague (have no precise meaning) and that have to be defined separately. E.g. *"the ONT should provide for an appropriate distribution"*. The term *"appropriate"* is so vague that there is a need to refine it in terms that are easier to check and/or implement:

  $$O_{ONT}(ensure\_quality(organ)) \wedge O_{ONT}(ensure\_compatibility(organ,recipient)) \Rrightarrow_{ONT} O_{ONT}(appropiate(distribution))$$

  In this case the appropriateness has been refined, using the "counts-as" operator, in terms of two procedures: 1) to check that the organ has the minimum quality required to be transplanted, and 2) to ensure that the organ and the recipient are compatible[2]. See [5] for more about the "counts-as" operator.
- **Temporal abstractness**: Often there is an implicit deadline for obligations, which is implied by the fact that the fulfillment of an obligation is also the fulfillment of a condition for a permission. Returning to the appropriateness example, there is a missing temporal relation: the obligation of ensuring the quality and compatibility of the organ is limited by the temporal constraints of the assignation process (organs can only be preserved out of a human body for some hours), as the quality and compatibility tests should be performed before the assignation is made. We can then extend the formula as follows:

  $$O_{ONT}(ensure\_quality(organ) < assign(organ,recipient)) \wedge$$

  $$O_{ONT}(ensure\_compatibility(organ,recipient) < assign(organ,recipient))$$

- **Agent and role abstraction**: Norms abstract from the role or agent for whom the norm holds. The process to refine responsibilities is done as roles are refined in the *role hierarchy* (see section 6).
- **Actions or situations not directly checkable**: E.g. "the decision of who is the best recipient for an organ cannot be based on the recipient's age. Although the norm is clear, it is impossible to check directly on which basis a

[2] As we will see in section 7, this refinement is imposed by the context of the ONT.

decision is taken by an agent. This is an internal (mental) action. Therefore the organization has to devise some constraints and/or procedures that are checkable (or controllable) by the organization and which take care of the fulfillment of the norm. E.g. the e-organization might withhold all information about age to the decision makers.

4 The Rule Level: translating norms into rules

The translation from norms to rules marks the border among the *Normative System* in HARMONIA to the *Practical System*, from the normative dimension to the descriptive one. Such translation also implies a change in the language, from a deontic logic to a language more suitable to express actions and time constraints.

In [7], Meyer proposed a reduction from deontic logic to a Propositional Dynamic Logic. In this approach, deontic formulae such as $O(\alpha)$, $F(\alpha)$ and $P(\alpha)$ are reduced to dynamic logic as follows:

$$O(\alpha) \equiv [\neg\alpha]\, V$$

Informally, it expresses that α is obligatory iff not doing α leads to a violation. An example of this kind of translation in the organ and tissue allocation problem is the following:

$$O_{hospital}(ensure\_quality(organ)) \equiv [\neg ensure\_quality(organ)]\, V(hospital)$$

Following this idea, norms can be translated for some part into restrictions on behavior and for the other part into triggers on unwanted behavior of the agents interacting in the e-organization. The main idea is that an e-organization cannot actually force agents to do an action (i.e. to pay for a good, as this is the autonomous decision of the agent), but it can control the fact that the agent cannot leave before the action is done.

Once the translation from norms to basic rules has been performed, these rules can be refined again. E.g. $ensure\_compatibility(organ, recipient))$ is defined in terms of donor-recipient compatibility rules[3]:

```
1- (age_donor >= 60) AND (age_donor < 74) AND (creatinine_clearance > 55 ml/min)
     -> (age_recipient >= 60) AND (transplant_type SINGLE-KIDNEY)

2- (age_donor >= 60) AND (age_donor < 74) AND (glomerulosclerosis <= 15%)
     -> (age_recipient >= 60) AND (transplant_type SINGLE-KIDNEY)
```

5 The Procedure level

The final step to build the e-organization is to implement the multi-agent system. There are two main approaches to implement the rules in the rule level:

[3] These rules for the case of kidneys are a subset of the ones presented in [11].

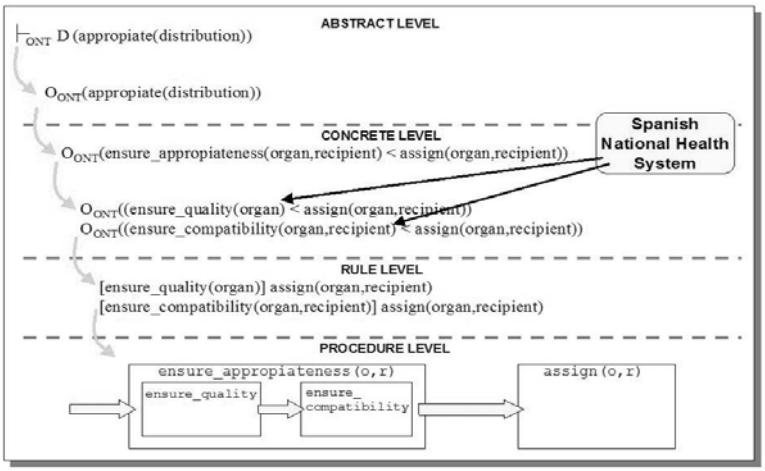

Fig. 2. An example of the refinement process, including the influence of context.

- Creating a rule interpreter that any agent entering the e-organization will incorporate.
- Translating the rules into procedures to be easily followed by the agents.

Note that in both cases it is not ensured that the agents will follow those descriptions. The violations in the rule level should also be translated in some detection mechanisms to check the behaviour of the agents.

A system where all external agents blindly follow the protocols (as in ISLANDER [4]) is quite efficient from a computational perspective but the agents have only the autonomy to accept/reject the protocol. A system where all external agents have to interpret rules could cope with these problems. However, such a system could not be applied to open environments, as there is a big assumption on the internal architecture of the agents and their way of reasoning.

The alternative is to be able to accept both kinds of agents. That means that the e-organization provides both the low-level protocols and the related rules. Those (standard) *Autonomous Agents* that are only able to follow protocols (expressed, for instance, in DAML+OIL), will blindly follow them, while the ones that can also interpret the rules (that is, the *Norm Autonomous Agents* or *Deliberative Normative Agents* [1][3]) will be able to choose among following the protocol or reasoning about the rules, or do both. With this approach the autonomy of the agents entering the e-organization is adapted to their reasoning capabilities.

In order to allow *Norm Autonomous Agents* to switch from following low-level protocols to higher level rules and norms, there should be a link from procedures to rules, and from rules to norms. An advantage of the HARMON*IA* framework is that those links are created by the designer in the process from abstract to concrete norms to rules to the final protocols by means of the successive trans-

lations that are made. Those links allow to track, for instance, which abstract norms are related to a given procedure. An example is depicted in figure 2. It is important to note here that the implementation of the rule can be more restrictive than the rule (e.g. it imposes the quality assessment to be done *before* the compatibility assessment). A deliberative normative agent will be able to detect an unusual delay of the `ensure_quality` procedure, and will break the protocol to cope with the abnormal situation, while keeping its behaviour *legal*.

6 Policies, Goals, Roles and Ontologies

Having defined the different levels we now turn to some elements of e-organizations that pertain to several levels at the same time:

Policies In our framework policies are elements that group the norms and rules at different levels together around specific topics. E.g. an e-organization trying to fulfill the role of the ONT will have to define, at least a *Security policy* (imposed by the context, as we will see in section 7) for all the information about patients it manages.

Policies go from the abstract level (where goals and values are defined) to the rule level (where those values are described in terms of rules).

Goal/Role hierarchy As mentioned in section 2, the *objectives* in the organization's statutes can be represented in terms of goals (that we will call the *overall goal* of the society). The distribution of goals is defined by means of the *role hierarchy*. Figure 3 shows part of the role hierarchy for the organ allocation example. Even though roles are tightly coupled with goals, they are also tightly connected with the norms, rules and procedures defined in the e-Organization. As the refinement process is made, norms and rules are related to roles in the role hierarchy.

Ontologies Ontologies are shared conceptualizations of terms and predicates in order to define a given domain. In our framework *Domain ontologies* define the vocabulary to be used by all the agents in the e-organization. They are defined in the abstract level and then extended in the following levels, as new norms and rules refer to new terms that are missing in the ontology.

7 Influence of the e-Organization's context

In section 2 we saw how statutes make reference to a certain *context* where the organization performs its activities. The context of an organization includes regulations that are applied to the organization's internal and/or external behaviour. Usually regulations define constraints in several levels, from the more abstract (*"do not discriminate because of race or sex"*) to the rule level and,

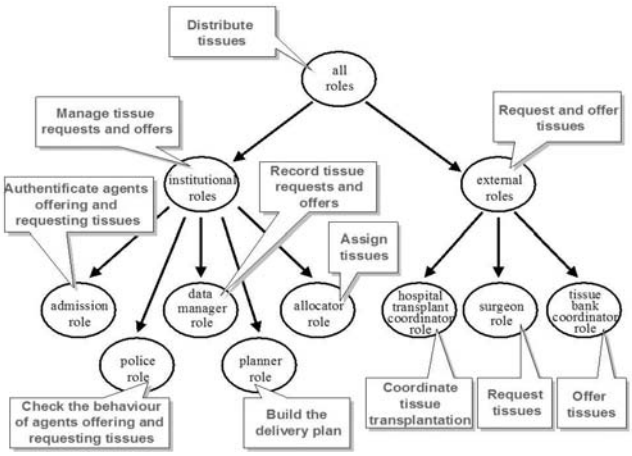

Fig. 3. An example of role hierarchy and goal distribution.

event, at the procedure level, by defining protocols to be followed (*"in situation A first do α, then..."*).

An example are the ONT statutes presented in section 2. They state that the ONT operates according to the Spanish National Health system. Therefore ONT "inherits" the norms and values of this system as well and they restrict the ways in which the objectives of the ONT can be reached.

One of the **Values** inherited from the National Health System is that : *"Patients should not be discriminated because of race, social status, sex, economical issues, ideology or political affiliation"*(Article 10.1 LGS [6])

Some**Obligations** imposed to the ONT by the National Health System are e.g. O_{ONT}(*Coordination of Organ and tissue allocation*),
O_{ONT}(*Ensure quality and safety of organs and tissues*) and
O_{ONT}(*Ensure equity in selection of recipients*)

Figure 2 summarizes the example of the appropriateness of the distribution, and how it evolves through the different levels. In that example we already included the obligation O_{ONT}(*Ensure quality and safety of organs and tissues*) as part of the refinement process, splitting the *appropiate* predicate in the Concrete Level into the *ensure_quality* and *ensure_compatibility* predicates.

The norms and values inherited from other organizations can be described at the top level of the e-organization explicitly. These norms have the highest priority and will "overwrite" any norms specified by the e-organization itself if they are contradictory. In our current work we are not considering those conflicting situations in the framework, but a quite simple solution to this scenario could be the use of a prioritized deontic logic, where default rules are used.

Another aspect of the context of an e-organization consists of the standards and available protocols and procedures for specifying its norms and procedures. An example is to design the search procedure to obtain a *"correct/fair distri-*

bution of organs". One possible option is to simply translate the current ONT procedure, which is *"appropriate"* but not *"efficient"* in time. An alternative would be to use *standards*, for instance, the FIPA Call-For-Proposals (CFP) protocol, in order to do a more efficient distributed search for recipients.

In our framework we propose to implement a repository where solutions used in the modelling of previous e-organizations could be used again to create new ones. This idea is depicted in figure 1, where the Background Knowledge is explicitly represented. A good example is security standards and policies.

8 Conclusions

In this paper we introduce HARMON*IA* , a framework to model electronic organizations from the abstract level where norms usually are defined to the final protocols and procedures that implement those norms. The main objective is to fill the existing gap in previous approaches, which work either at the level of norm formalization or at the procedural level. Some important parts of this model are formalized using multi-modal logics. A main area of further research is the formal description of the semantic relations between the levels. Another research issue is to formally define mechanisms such as Delegation of responsibility in our framework.

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