

Norms, Institutional Power and Roles : towards a logical framework

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Abstract. In the design of the organisation of a multiagent system the concept of role is fundamental. We informally analyse this concept through examples. Then we propose a more formal definition that can be decomposed into: the conditions that have to be satisfied to hold a role, the norms and institutional powers that apply to a role holder. Finally, we present a modal logical framework to represent these concepts.

1 Introduction

In the design of the organisation of a multiagent system the concept of role is fundamental. That is especially important in the context of intelligent artificial agents that have some level of autonomy. However there is no agreement in the literature about what a role is [15, 8, 5]. The reason is that the concept of role refers to concepts like rights and powers, which are not very well defined. Therefore, there is a need for a formal definition of roles to make it possible to reason clearly about their properties.

In this paper³ we start from an informal analysis of these concepts which is based on typical examples (section 2). From the synthesis of this analysis a more structured definition of roles is proposed, and then a possible way of formalising it in a modal logical framework is shown (section 3).

2 Informal analysis of the concept of role

2.1 Definition

In natural language the term “role” may have many different meanings. For instance in some French dictionary we can find this definition in the context of sociology: *implicit or explicit set of rights and obligations about some individual*

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in a social group, in connection with her or his legal status or her or his position in this group. In the following, such “social groups” will be called “institutions”.

In [15], Pörn proposes this definition: *“Because of their prevalence in normative systems clusters of norms organised in this way deserve a name on their own. We shall call them role structure because in terms of them it is possible to define the sociological notion of a role.”* In other words, if, in a normative system, we repeatedly need to talk about the set of individuals to whom a given set of norms applies, it is convenient to create a name for this set of norms, and this set of norms is called a “role”. Later on, Pörn refines his definition, and he says that there are two components in a role:

1. a set of **conditions** that characterises the individuals who hold this role,
2. a set of **norms** that applies to the individuals who hold this role.

For instance, the role of minor is defined by a descriptive property: to be less than 18 years old, and by normative properties, for instance, the obligation to have the parents’ authorisation to go to a foreign country. In the same way, we can talk about the roles of supplier and customer in the trade environment, or to talk about the roles of professor, lecturer, PhD student or secretary, in the environment of a university.

We can give more details about what the conditions and the norms are in the case of the role of professor (in French universities):

1. Conditions: to be less than 65 years old, to have a PhD, to have been appointed to the position of professor, etc.
2. Norms: obligation to give x lectures a year, obligation to prepare the exams, prohibition to talk about politics during lectures, right to have an office, power to give marks to the students, etc.

It is worth noting that though the conditions in the part 1 are descriptive, it may happen that the truth value of some of them is defined only in the context of a particular institution. For example, the fact that some individual has a PhD may be recognised in some countries, and not recognised in other countries. In other words, the fact: “to have a PhD” depends on the referred institution. This kind of facts will be called in the following “**institutional facts**” (see [16]) and the term “**institution**” will refer to entities like: a state, a company, an association or any group organised for a common purpose.

Obviously, the norms in the part 2 are dependent on an institution, but the difference between **norms** and **institutional facts** is that the former ones define how the world **should** be, while the latter ones define how the world **is**.

To sum up, the conditions in a role definition specify descriptive properties, and some of them depend on an institution. The norms specify normative properties and all of them depend on an institution.

In the following we will use the term “agent” for an individual who may be a person or an artificial system that has some degree of autonomy.

2.2 From normative positions to institutional power

Now we analyse which kinds of norms can be found in the definition of a role.

In 1913, Hohfeld expressed in natural language the first attempt to classify the normative relationships between two agents [9]. Later, Kanger formalised all these normative positions using only the primitive concepts of obligation and action [12].

Back to roles, according to some dictionaries, a role can also be defined as a set of rights and obligations. As proposed by Kanger, we now investigate how to express the notion of right only in terms of obligations applying to actions.

Some possible dictionary definitions of right are: “*possibility to require something from someone*”, or: “*something that is due to someone in a social group*”. In both of these definitions there is the idea that an agent who has some right can require something of another agent, and this capacity depends on an institution. This concept of right can be made clearer through the following example.

At ONERA a person who holds the role of engineer has the right to enter the centre with his car. To exercise his right ⁴ when he arrives at the entrance with his car, the engineer must show to the guard a sign on the glass of the car, which testifies that he has the right to enter.

When the guard sees the sign, he knows that the engineer has the right to enter. Then, if the entrance gate is not raised, the guard has the obligation to raise the gate, and if the entrance gate is raised, the guard is prohibited to prevent the engineer to enter (for example, by lowering the gate).

From this example we can extract a more general pattern which is based on the notion of power. An agent i who has some right is an agent who has the power, when he requires another agent j to exercise his right, and when he has testified that he has this right, to create new obligations that apply to j . The difference between Hohfeld’s definition of a right and this definition is that in this definition we point out the power to change the obligations.

The kind of power we have exhibited in this example belongs to what Pörn calls the norms in his role definition. To avoid misunderstanding between this kind of power and practical ability we will use in the following the term: “institutional power” as in [10].

Even if the concept of right can be defined in terms of institutional power it is not the case that any institutional power is of the type of a right, as shown through the following example of the power to appoint a professor.

A person who holds the role of president of the university has the power to appoint a professor. That means that after some given selection procedure has been performed, if he signs some particular document, then the person who applied to the role of professor holds the role of professor.

The relationship between the “cause” (to sign the document) and the “consequence” (to hold the role of professor) has a value only in the context of the institution of the university. It is worth noting that here the consequence is not an obligation, as it is the case for a right, but an institutional fact.

⁴ We have slightly simplified the actual procedure.

This example shows that if, in the context of a given institution, an agent has some institutional power, then, if in some circumstances he performs some procedure, he creates a new normative situation.

In general an institutional power is defined as follows:

$power(i, s, cond, proc, n)$: if the conditions $cond$ are fulfilled, then, in the context of the institution s , the agent i has the power to create the institutional fact represented by n by performing the procedure $proc$.

In semi-formal terms we have:

IF $cond$ AND $done(i, proc)$ THEN n [in the context of s].

The main difference between the institutional powers and the normative positions defined by Hohfeld is that the institutional powers allow to change a normative situation, while the normative positions define the normative situation as it is at a given moment.

In [14] Makinson has shown that we can define an extremely large number of normative positions. Then, the Hohfeld's classification is not based on the most relevant criteria. For that reason we have only distinguished two kinds of norms: norms like normative positions, which will be called in the following **static** norms, and institutional powers, which will be called **dynamic** norms.⁵

2.3 A new definition of roles

We propose to define a role in the context of an institution s as a tuple $\langle R, C, N, P \rangle$, such that:

1. R is the role name.
2. C is a set of descriptive sentences that defines the necessary and sufficient conditions that are satisfied by an agent who holds the role R .
3. N is the set of **all** the static norms that apply to an agent as holder of the role R .
4. P is the set of **all** the dynamic norms (institutional powers) that apply to an agent as holder of the role R .

This definition is basically a refinement of Pörn's definition. It requires some additional comments.

- A role is always defined in the context of an institution. For instance, the role of president is not the same in all countries. As a matter of simplification the name of the institution is left implicit if there is no risk of confusion.
- The sentences in C are descriptive sentences. They describe the properties that **are** satisfied by the role holder, and not the properties that **should be** satisfied.
- The sets of norms N and P apply to any agent who holds the role R . However, it may happen that other norms apply to such an agent. For instance, because he also holds another role.

⁵ Not all the institutional powers represent dynamic norms. There are institutional powers that allow to create descriptive institutional facts like: to hold a role (see the formal definition proposed in next sections).

- The norms in N may be conditional norms. In particular we frequently distinguish the norms that apply only when the agent exercises his role. To do so, it is more convenient to split N in two subsets: the norms N_H that apply in every circumstances, and the norms N_E that apply only when the agent exercises his role. In this case, the set C_E of necessary and sufficient conditions that are satisfied by an agent exercising his role has to be defined, in addition to C .

For example, it is forbidden for a professor to talk about politics when he is exercising his role at the university, but he is authorized to talk about politics outside the university.

- It is assumed that all the dynamic norms in P are institutional powers of the form $power(i, s, cond, proc, n)$.

Here $power$ is not a predicate but a notation to denote a sentence of the form: IF $cond$ AND $done(i, proc)$ THEN n [in the context of s]

where $proc$ is a procedure definition, and $cond$ is a conjunction of descriptive sentences.

- In the definition of an institutional power, the institutional fact n may be of different kinds. For instance, it may be the fact that an obligation holds, the fact that an agent j is appointed to another role R' , or the fact that j has a certain institutional power.

A first step towards formalisation. We define the following predicates.

$holds(i, R)$: agent i holds the role R .

$exercises(i, R)$: agent i exercises the role R .

$done(i, proc)$: agent i has performed the procedure $proc$.

It is assumed that the following properties are satisfied by a given role R .

(H1) $\forall i$ (IF $holds(i, R)$ THEN $C(i, R)$)

(H2) $\forall i$ (IF $C(i, R)$ THEN $holds(i, R)$)

(N1) $\forall i$ (IF $holds(i, R)$ THEN $N(i, R)$)

(P1) $\forall i$ (IF $holds(i, R)$ THEN $P(i, R)$)

In the set of conditions to hold a role, $C(i, R)$, the fact that the agent i has been appointed to the role R by some other agent j can be formally represented, for example, by statements of the form $\exists j done(j, proc)$.

In order to make explicit the norms that only apply when an agent exercises his role, (N1) has to be replaced with the following properties:

(E1) $\forall i$ (IF $exercises(i, R)$ THEN $C_E(i, R)$)

(E2) $\forall i$ (IF $C_E(i, R)$ THEN $exercises(i, R)$)

(N'1) $\forall i$ (IF $holds(i, R)$ THEN $N_H(i, R)$)

(Nⁿ1) $\forall i$ (IF $holds(i, R)$ AND $exercises(i, R)$ THEN $N_E(i, R)$)

In the set of dynamic norms, $P(i, R)$, the institutional powers the agent i has only in circumstances where he exercises his role have to be defined by specifying appropriately (using the $exercises(i, R)$ predicate) the conditions $cond$ of the definition of the corresponding powers: $power(i, s, cond, proc, n)$.

3 Formalisation of the concept of role

We are now defining the main properties of a logical framework that allows to represent the most significant concepts that are involved into role definitions.

In the sentences that appear in C , N , $cond$ and n there may be sentences that are not in the scope of any modality. These sentences can be represented in a classical first order logic. There may also be sentences about agents' beliefs and actions that have been performed. These sentences respectively require the definition of an epistemic logic and of a dynamic logic. Finally, sentences about normative situations require the definition of a deontic logic.

Our guideline in the definition of this logical framework is to adopt an axiomatics as simple as possible for these logics.

3.1 Epistemic and Dynamic modalities

Beliefs are represented by the modalities:

$B_i p$: agent i believes p .

Where p may be any sentence, and involve other modalities. We adopt the system (KD) for the modality B_i (see [4]).

To represent dynamic modalities we adopt two modal operators. The first operator is used when we only need to represent the effects of the action that has been performed without making explicit this action (for example, to represent the fact that it is obligatory for the guard to bring it about that the entrance gate is raised). The second operator is used to explicitly represent the action, or the procedure, that has been performed (for example, to represent the procedure $proc$ in an institutional power).

$E_i p$: agent i has brought it about that p .

$done(i, proc, p)$: agent i has just performed the procedure $proc$, and before $proc$ was performed, we had p .

$done(i, proc)$: abbreviation for $done(i, proc, true)$, whose meaning is that agent i has just performed $proc$.

The modal operator E_i is a classical operator which is not normal (see [4]), its axiomatics is (see [15, 11]):

(RE) $\vdash p \leftrightarrow q \Rightarrow \vdash E_i p \leftrightarrow E_i q$

(C) $E_i p \wedge E_i q \rightarrow E_i(p \wedge q)$

($\neg N$) $\neg E_i(true)$

(T) $E_i p \rightarrow p$

The modal operator $done$ is a normal operator which satisfies the system (K). This operator is basically used to represent the procedure that has to be performed by an agent to exercise his power.

We have not enough room here to go deeply into the language which is used to represent the procedure $proc$. The following example: $proc = A; (any/B); (C|D)$, shows the main kinds of constructs that can be used to represent procedures that may be performed either by human agents or by artificial agents. Its intuitive meaning is: do A , then it is permitted to do any sequence of actions but B , and then do C or D . The formal semantics of this language can be found in [7].

3.2 Deontic modalities

Deontic modalities play a fundamental role for the representation of normative sentences. They express what is obligatory, permitted or prohibited. A large number of proposals exist in the literature to represent these modalities (see [15, 3, 13, 19, 1]), and depending on the kind of issue under consideration, some axiomatics or another can be chosen.

However, we need to consider at least two kinds of deontic modalities to represent the obligations to be (for instance, the obligation to be sitting during a lecture), and the obligations to do (for instance, the obligation to bring some object somewhere).

Some authors also consider personal obligations (for instance, the obligation for a given agent to pay a given bill) and impersonal obligations that do not refer to a particular agent (for instance, the obligation not to park a car in a given place). Here we only consider impersonal obligations. This is not too strong a limitation because personal obligations can be reformulated in terms of impersonal obligations about sentences where the obliged agent is explicitly mentioned.

Impersonal obligations to be are represented by the modality:

Op : it is obligatory that p .

Permissions and prohibitions can be respectively represented as usual in terms of obligations by: $\neg O\neg p$ and $O\neg p$. The axiomatics of the operator O satisfies the system (KD).

Obligations to do require specifying the deadline before which the action must be performed. If no deadline is specified it is impossible to say when the obligation has been violated. There is a very limited number of proposals for a logic of obligations with deadline (see [18, 17, 2]). In [6] we have defined a logic for obligations, permissions and prohibitions with deadlines that extends the logic proposed by Segerberg in [17, 18]. Finally, to simplify, we accept to represent conditional obligations using the material implication. The fact that p is obligatory in the circumstances where we have q is represented by: $q \rightarrow Op$. Contrary-to-duty obligations can be represented with the logic proposed in [3].

3.3 Normative consequences

We have seen that in the semi-formal definition of institutional powers we have sentences of the form: “IF p THEN q [in the context of s]”. We need a logical connective that correctly represents the link between p and q in these kinds of sentences.

We cannot use the material implication for that because $\neg p$ entails $p \rightarrow q$, and it would not be correct to infer that some agent has some institutional power from the fact that the conditions in the antecedent of the definition of this power are false. More specifically, if $power(i, s, cond, proc, n)$ is formally represented by: $cond \wedge done(i, proc) \rightarrow n$, from the fact that $\neg cond$ or $\neg done(i, proc)$, we can infer that the agent i has any power of the form $power(i, s, cond, proc, n)$, whatever n is.

That is the reason why we adopt the following connective to represent normative consequences, which has been defined by Jones and Sergot in [10]:

$p \Rightarrow_s q$: in the context of the institution s , p entails q .

In addition to the connective \Rightarrow_s Jones and Sergot have introduced the modal operator:

$D_s p$: in the context of the institution s we have p .

For instance, if the meaning of p is that two persons are married and s represents a given state, $D_s p$ means that, in the context of the regulation of this state, these persons are considered as two legally married persons. However, it may happen that with respect to the regulation of another state s' they are not married.

The D_s modality satisfies the system (KD). The axiomatics of \Rightarrow_s is defined as follows.

For the antecedent and the consequent we have the inference rules of substitutivity of logically equivalent formulas. In addition we have the axiom schemas:

(CC) $(p \Rightarrow_s q) \wedge (p \Rightarrow_s q') \rightarrow (p \Rightarrow_s (q \wedge q'))$

(CA) $(p \Rightarrow_s q) \wedge (p' \Rightarrow_s q) \rightarrow ((p \vee p') \Rightarrow_s q)$

(S) $(p \Rightarrow_s q) \rightarrow ((q \Rightarrow_s r) \rightarrow (p \Rightarrow_s r))$

The links between \Rightarrow_s and D_s are expressed by the axiom schemas:

(SD) $(p \Rightarrow_s q) \rightarrow D_s(p \rightarrow q)$

(SC) $(p \Rightarrow_s q) \rightarrow (p \rightarrow D_s p)$

We also adopt the following additional schemas⁶:

(DD) $D_s D_s p \rightarrow D_s p$

(DP) $D_s(p \Rightarrow_s q) \rightarrow p \Rightarrow_s q$

3.4 Formal representation of roles

The role definitions are formalised using \Rightarrow_s and D_s . We have:

(H1) $\forall i D_s(\text{holds}(i, R) \rightarrow C(i, R))$

(H2) $\forall i (C(i, R) \Rightarrow_s \text{holds}(i, R))$

(N1) $\forall i D_s(\text{holds}(i, R) \rightarrow N(i, R))$

(P1) $\forall i D_s(\text{holds}(i, R) \rightarrow P(i, R))$

Note that the sentences of the form: IF...THEN... are not all formalised in the same way. This depends on whether IF...THEN... represents an entailment relation or if the antecedent counts as the consequent in the context of the institution s . In particular, in the context of s , $C(i, R)$, $N(i, R)$ and $P(i, R)$ are necessarily true when $\text{holds}(i, R)$ is true.

For example, the fact that if i holds the role of minor then i is less than 18 years old does not mean that the fact that i holds the role of minor counts as the fact that i is less than 18 years old. That is why in (H1) we have used a material implication in the scope of D_s . In (N1) and (P1) we have used the material implication for the same reason.

In (H2) the fact that we have $C(i, R)$ counts as the fact that we have $\text{holds}(i, R)$ in the context of s . That is why we have used the connective \Rightarrow_s .

⁶ The schemas (DD) and (DP) are not in [10].

An institutional power denoted by $power(i, s, cond, proc, n)$, is formally represented by:

$$(cond \wedge done(i, proc)) \Rightarrow_s n$$

Let us illustrate this logical framework with a simple example. Let us assume that: (1) when an agent i holds the role R_1 , he has the institutional power to appoint j to the role R_2 , (2) i has been appointed to the role R_1 , and (3) i has performed the appropriated procedure to appoint j to R_2 in circumstances where the conditions $cond$ hold. These assumptions are formally represented by:

$$(1) D_s(holds(i, R_1) \rightarrow power(i, s, cond, proc, holds(j, R_2)))$$

$$(2) D_s holds(i, R_1)$$

$$(3) cond \wedge done(i, proc)$$

From (1) and (2) we have: (4) $D_s(power(i, s, cond, proc, holds(j, R_2)))$, and from the definition of $power$ we have:

$$(5) D_s(cond \wedge done(i, proc) \Rightarrow_s holds(j, R_2))$$

From (5) and (DP) we have:

$$(6) cond \wedge done(i, proc) \Rightarrow_s holds(j, R_2)$$

From (6) and (SD) we have:

$$(7) D_s((cond \wedge done(i, proc)) \rightarrow holds(j, R_2))$$

From (6) and (SC) we have:

$$(8) (cond \wedge done(i, proc)) \rightarrow D_s(cond \wedge done(i, proc))$$

Finally, from (3), (8) and (7) we infer $D_s(holds(j, R_2))$, which means that in the context of s it is recognised that j holds the role R_2 .

It is interesting to notice that in $p \Rightarrow_s q$, the sentence q may itself embed the connective \Rightarrow_s . This makes it possible to represent, for example, that the agent i has the power to assign to the agent j the power to create some normative situation n . This is denoted by:

$$power(i, s, cond, proc, power(j, s, cond', proc', n))$$

and this is formally represented by:

$$(cond \wedge done(i, proc)) \Rightarrow_s ((cond' \wedge done(j, proc')) \Rightarrow_s n)$$

4 Conclusion

We have shown that a role can be defined, in the context of an institution in terms of the conditions to hold the role, a set of static norms that apply to the agents who hold the role, and a set of dynamic norms that apply to the agents who hold the role.

We have presented a formal logical framework to represent the conditions and the norms. In this framework we have selected an axiomatics for epistemic, dynamic and deontic modalities. We have seen that the connective \Rightarrow_s introduced by Jones and Sergot is very important to represent dynamic norms.

There are some technical issues that require more investigations. The first one is the formal representation of the fact that N and P represent **all** the static and dynamic norms that apply to a role holder. Another one is to find a complete axiomatics for the obligations to do with time limits.

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