The Use of Norms and Electronic Institutions in Multi-Agent Systems

(The HARMONIA framework.)

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Motivation
Motivation (I)

- Open multi-agent systems (MAS) have to cope with several issues
  - Heterogeneity among members
  - Communication
  - Participants’ trust

- Idea: multi-agent design can benefit from social abstractions
  - Study the problem from the societal and the individual points of view.

- Agent **Autonomy VS Control**

- Coordination
- Cooperation
Motivation (II)
From individual to social view

Environment

Institutions

Adaptive Organizations

Organizations

Adaptive Agents

Agents

Tasks

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Motivation (III)
Society’s View

- **Social Structures** define a social level to enhance coordination by means of *interaction patterns*
- **Institutions** are a kind of social structure where a corpora of constraints (the *institution*) shape the behaviour of the members of a group (the *organization*)
- An **e-Institution** is the computational model of an institution through the specification of its *norms* in (some) suitable formalism(s). In the context of MAS they:
  - reduce *uncertainty* of other agents’ behaviour
  - reduce *misunderstanding* in interaction
  - allows agents to **foresee the outcome** of an interaction
  - simplify the *decision-making* (reduce the possible actions)

  Agent **behaviour guided by Norms**
Motivation (IV)
Electronic Institutions?

- Most authors use the term e-Institution to refer to a multi-agent system following an institutional framework, but:

  - From now on we will talk about e-Organizations following institutional patterns
Motivation (V)

Agent View

- Norms should guide the behaviour of the Agent
- Problems:
  - Norms are more abstract than the procedures
  - Norms do not have operational semantics

Example:

Regulation: “It is forbidden to discriminate potential recipients of an organ based on their age (race, religion,...)”

**Formal norm**: $F(\text{discriminate}(x,y,\text{age}))$

**Procedure**: does not contain action “discriminate”
Motivation (VI)

Application in a highly regulated eHealth environment

- **CARREL**: a project on distributed organ and tissue allocation.
- 2 kinds of transplants:
  - organs
    - You can not conserve them on banks
    - Every new organ donation ➔ (manual) search for the recipient
  - tissues
    - You can keep them on banks, (not very long)
    - Every new recipient ➔ (manual) search for tissue

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Motivation (VII)

Application in a highly regulated eHealth environment

- Scarcity of donors → international coalitions → distributed environment

- Need of a distributed software solution to:
  - Data exchange problem:
  - Communication problem:
  - Coordination issues:
  - Variety of regulations:

standard data interchange formats
Agent Communication Languages
or translation mechanisms
Agent-Mediated Coordination
Agent-Mediated Electronic Institutions

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State of the Art (I)

The Use of Norms and Electronic Institutions...
State of the Art (II)

Descriptive Level
- Rules
- Procedures

Normative Level
- Norms
- Values

Delliberative Normative Agents
- [O, P, F]
- [E, G, H]

E_x:A
OperA

GAIA

TROPOS ISLANDER

The Use of Norms and Electronic Institutions...

1 Ag. 2 Ag.

Single Agent One-to-One ill-structured interactions Social Structures
Objectives

- To present a **normative framework** to fill the gap between theoretical and practical approaches:
  - identify the different **abstraction levels** involved in a normative framework
  - define a **connection** between abstraction levels
  - identify the **influence of context** for each abstraction level

- To propose a **standard terminology** to refer to the concepts:
  - institutions, e-institutions, organizations, e-organizations, abstract norms, concrete norms, rules…

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Norms and Agents
Norms and Agents (I)
Influence of norms in the BDI deliberation cycle

The Use of Norms and Electronic Institutions...

percepts → beliefs → desires → intentions → plans → actions

norms
(obligations, permissions...)

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Norms and Agents (II)

- How do norms influence the behaviour of the agent?
  - Agent has no knowledge about norms
  - Norms are built-into the agent’s code
  - Norms are built-into the plans and protocols the agent uses
  - Norms are explicit elements in the agent’s reasoning
    - Agent may or may not adopt the norms
    - Agent may or may not follow the norms
      - agent follows the norm whenever possible
      - agent violates the norm sometimes
      - agent violates the norm always if possible

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Norms and Agents (III)

- Most of the approaches talk about norms, but a close-up look shows that they are working at completely different levels of abstraction.

- Idea: there are several levels of abstraction involved in a normative system.

- Objectives: to identify these levels and define an standard terminology.
Agent view (I)

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Agent view (II)

• **Problem**: in this model interpretation of norms is completely done by the agents.

  – How to ensure that two agents that play the same role have similar sound interpretations of the norms that apply to them?

• **Solution**: to fix part of the interpretation in a given context.

  • **Idea**: Agents do not have a relation with the WHOLE world but a part → **context** of an agent.
Agent view (III)

- A **Context** is a set of worlds with a shared vocabulary and a normative framework.

- Effects on the Normative Dimension
  - The generic norms applied to the world as a whole are called **Abstract Norms**.
  - **Concrete Norms** are interpretations of the abstract norms in a given context.

\[ \text{AN}_a = I(\text{AN}_w, C_a) \]
\[ \text{AN}_b = I(\text{AN}_w, C_b) \]

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Agent view (IV)
eOrganizations and Norms
Organizations and Norms

- **Norms** describe which states/actions within the e-organization should *ideally* take place

- **Norms** are too abstract to be directly translated into procedures (plans/protocols) in a single step

- **Idea**: to identify the different *levels of abstraction* from the e-organization perspective

- Organizations hardly work in isolation

- **Idea**: to identify how the organization’s surrounding *context* influences the different levels
The HARMONIA framework

- **Main Objectives**
  - To identify the different levels in a Normative System
  - To find a (formal) connection between levels

- **The framework identifies two kinds of elements**
  - Horizontal elements: 3 levels (Abstract, Concrete and Normative Implementation)
  - Vertical elements: Policies, Roles, Ontology, Context and Background Knowledge
The **HARMONIA framework inside OMNI**

The Use of Norms and Electronic Institutions...

**Abstract Level**
- Statutes *(values, objectives, context)*
  - Model Ontology

**Concrete Level**
- Norm level
  - Rule level
  - Normative Implementation

**Implementation Level**
- Organizational Model
  - Social Model
  - Interaction Model
  - Agents

**Normative Dimension**
- Concrete Domain Ontology
- Generic Comm. Acts

**Organizational Dimension**
- Procedural Domain Ontology
- Specific Comm. Acts

**Ontological Dimension**

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E-ORGANIZATION

STATUTES
• Values
• Objectives
• Context

ABSTRACT LEVEL

E-INSTITUTIONS
• Abstract Norms

NORMATIVE IMPLEMENTATION LEVEL

Concrete Norms

Concrete Level

Rule level

Concrete Norms

Normative Dimension

Procedures

Domain Regulations

Domain Procedures

CONTEXT

BACKGROUND KNOWLEDGE

E-INSTITUTIONS
• Abstract Norms

CONCRETE LEVEL

Rule sets

Generic Policies

NATIONAL REGULATIONS

Rules

Policy implementation

BACKGROUNDS

KNOWLEDGE INSTITUTIONS

RESEARCH INSTITUTIONS

ABSTRACT LEVEL

• Objectives
• Context
Abstract Level: Statutes

The statutes of organizations define the

- Values
- Objectives
- Context

of the organization at the most abstract level.

Example: Organización Nacional de Trasplantes:

The main objective of ONT is to increase the number of organ donations and the subsequent increase in available organs for transplants. The ONT operates according to the regulation of the national health system and it strives to distribute the donated organs in the most appropriate and correct way according to the current technical knowledge and according to the ethical principles of equality.

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Abstract Level: Abstract Norms (I)
From Values to Abstract Norms

- **Values** are beliefs that we have about what is important and thus about how things should be.
  - “Appropriate distribution”
  - “Distribution according to ethical principles of equality”
  - “Fairness of transaction”
  - “Respect privacy of persons”

- **Values** can be considered as the most abstract level on which norms are expressed.

- The values of an organization can be defined by the set of **Abstract Norms** specified within the org. that contributes to that value

\[
D(\text{equity}) := \{ \text{F(discriminate(x,y,age))}, \\
\text{O(find_best_recipient(organ))}, \\
\ldots \}
\]
Abstract Level: Abstract Norms (II)

- Norms are abstract if they use concepts that are not fully described in the organization’s ontology.
  - “It is forbidden to discriminate based on age”

- Norms can be abstract in the following ways:
  - They refer to an abstract action
  - They use terms that are vague
  - They abstract from temporal aspects
  - They abstract from agents and or roles
  - They refer to actions or situations that are not (directly) controllable and/or verifiable by the organization
Abstract Level: Abstract Norms (III)

- example 1: Abstract actions

  "a living donor should consent to the donation of an organ"

\[
\text{sign(donor,contract) } \cup \text{ carry(donor,will) } \cup \text{ tell(donor,family)} \quad \Rightarrow \text{ONT Consent(donor)}
\]

- example 2: Vague terms

  "the ONT is obliged to ensure that the distribution of organs and tissues is appropriate"

\[
\text{O_{ONT}(ensure\_quality(organ)) } \land \\
\text{O_{ONT}(ensure\_compatibility(organ, recipient))} \quad \Rightarrow \text{ONT O_{ONT}(appropriate(distribution))}
\]
Abstract/Concrete Level

Representing Norms

- Formal representation of norms needed
- Which logic?
  - Abstract and Concrete Norms permit, oblige or prohibit
  - Concrete Norms may be conditional
  - Concrete Norms may have temporal aspects
  - Concrete Norms are relativized to roles

```
ONT:C1.1.1  O_{ONT}(ensure\_quality(piece) < do(assign(piece, recipient)))
ONT:C1.1.1  O_{origin\_org}(ensure\_quality(piece))
ONT:C1.1.1.1 O_{hospital}(ensure\_quality(organ))
ONT:C1.1.1.2 O_{tissue\_bank}(ensure\_quality(tissue))
ONT:C1.1.2  O_{CARREL}(get\_quality(piece, origin\_org)
            < do(assign(piece, recipient)))
ONT:C1.1.2.1 O_{CARREL}(get\_quality(organ, hospital)
            < do(assign(organ, recipient)))
```
Concrete Level: Concrete Norms

- Concrete norms are the result of translating the abstract norms in the context of the organization into norms that make use of terms and actions that are defined in the organization’s ontology.

\[ O_{\text{hosp}}(\text{consent(donor(p,x)) < done(transplant(hosp,x,p,q)))} \]

- **Problem**: HOW is a concrete norm like this implemented in an e-Organization?
Concrete Level: Rules (I)

- Translation from **Normative** dimension to a **Descriptive** one
  - Idea: reduction from **Deontic Logic** to **Dynamic Logic**
    [J.-J. Meyer]

\[
\begin{align*}
O_{\text{hosp}}(\text{consent(donor}(p,x)) & < \text{do(transplant}(\text{hosp},x,p,q))) \\
\downarrow \\
\text{[transplant}(\text{hosp},x,p,q))\text{]}\text{done(consent(donor))}
\end{align*}
\]

\[
\begin{align*}
O_{\text{buyer}}(\text{pay(goods,seller,price}) & < \text{do(exit}(\text{buyer}))) \\
\downarrow \\
\text{not(done(pay(goods,seller,price))}) & \rightarrow \text{[exit}(\text{buyer})]\text{V(fine(buyer))}
\end{align*}
\]
Concrete Level: Rules (II)

- Rules, Violations and Sanctions
  - Violation rules define violations
  - A **violation** is composed by
    - **pre-conditions**
    - sanction
    - side effects
  - **Pre-conditions** are used by Police Agents to detect violations.
  - **Sanctions** are used by Flexible Normative Agents to reason about the utility of breaking the related rule.
  - **Side effects** are used by internal agents to recover the system from the violation.

```plaintext
Violation: CRL:V18.1
Pre-conditions: (done(deliver(organ, hospital1, hospital2)) \& is_time(t)
\& done(wait_for(is_time(t + 1 day)))
\& \neg done(hospital2.send(result_transplant)))
Sanction: {request(hospital2, send(organ, result_transplant)); inform(board,precondition})
Side-effects: {record(\neg done(precondition), incident_log})
```
Normative Implementation Level (I)

- Idea: the final implementation of the system
- two options (non-exclusive!):
  - To have an interpreter that can “read & execute” directly the formulae in the rule level.
  - To translate the formulae into concrete protocols programmed in a standard programming language
    - defining constraints on procedures to guarantee enforcement of norm
    - defining triggers on violation of norms to detect and respond to violation

Flexible Normative Agents
(able to interpret rules and protocols)

Standard Agents
(able to choose and follow protocols)
Normative Implementation Level (II)

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Example

D(appropriate(distribution))

O_{ONT}(appropriate(distribution))

O_{ONT}(ensure_appropriateness(organ,recipient) < do(assign(organ,recipient)))

O_{CARREL}(ensure_appropriateness(organ,recipient) < do(assign(organ,recipient)))

[assign(organ,recipient)] done(ensure_appropriateness(organ,recipient))

\[\text{assign(o,r)}\]

\[\text{ensure_appropriateness(o,r)}\]
All levels: Policies

- There are several definitions of Policy
  - Policies as low-level plans or protocols
  - Policies as values or aims of the organization
  - Policies as high-level plans, relating organizational aims with procedures

- Policies are vertical elements, linking organization’s values with the related norms and rules to the final implementation
  - e.g.: allocation policy, security policy
All levels: Roles (I)

Abstract norms
Abstraction

Roles

Rules

Policies

policy S

role_i

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All levels: Roles (II)

- Role definition guided by goal distribution
  - Origin: Objectives in Statutes
- Distribution of responsibilities
All levels: Context (I)

- **Statutes** make reference to a surrounding context
- Links with the idea of **nested contexts**
  - $e\text{-}org_X$ is a context defining a **vocabulary** and a **normative system**
  - there are super-contexts that have an **influence** in $e\text{-}org_X$ definition
- **formal view**: influence as **interpretation** in the subcontext
  - counts-as operator $\Rightarrow_S$ as a link between interpretations
- influence in several levels of abstraction
  - vocabulary (terms, predicates)
  - values, norms, rules and procedures
All levels: Context (II)

D(appropriate(distribution))

\( O_{ONT}(\text{appropriate(distribution)}) \)

(CONCRETE) NORM LEVEL

\( O_{ONT}(\text{ensure_appropriateness(organ,recipient) < do(assign(organ,recipient)))} \)

\( O_{\text{CARREL}}(\text{ensure_appropriateness(organ,recipient) < do(assign(organ,recipient)))} \)

RULE LEVEL

[\text{assign(organ,recipient)}]\text{done(ensure_appropriateness(organ,recipient))}

NORMATIVE IMPLEMENTATION LEVEL

\[
\text{assign(o,r) \quad ensure_appropriateness(o,r)}
\]
All levels: Context (II)

**ABSTRACT LEVEL**

- $D(\text{appropriate(distribution)})$
- $O_{\text{ONT}}(\text{appropriate(distribution)})$

**CONCRETE NORM LEVEL**

- $O_{\text{ONT}}(\text{ensure_appropriateness(organ,recipient)} < \text{do(assign(organ,recipient)))}$
- $O_{\text{CARREL}}(\text{ensure_quality(organ)} < \text{do(assign(organ,recipient)))}$
- $O_{\text{CARREL}}(\text{ensure_compatibility(organ,recipient)} < \text{do(assign(organ,recipient)))}$

**RULE LEVEL**

- $[\text{assign(organ,recipient)}] \text{done(ensure_quality(organ))}$
- $[\text{assign(organ,recipient)}] \text{done(ensure_compatibility(organ,recipient))}$

**NORMATIVE IMPLEMENTATION LEVEL**

- $\text{ensure_appropriateness(o,r)}$
- $\text{ensure_quality}$
- $\text{ensure_compatibility}$
- $\text{assign(o,r)}$
All levels: Background Knowledge

- The **Background Knowledge** is a repository containing templates that can be adapted to create new eOrganizations
  - At the **abstract level**, it provides a collection of abstract norms and the related ontology and abstract roles
  - At the **concrete and rule levels**, it provides templates for some generic policies
    - e.g., the security policy
      - concrete norms, rules and ontology
  - At the **procedure level** it provides a link with the standards, technologies and algorithms needed to implement the policies

- **Idea:** e-Institutions as templates to be *parametrized, adapted or implemented* to build e-Organizations.
HARMONIA and other approaches

The Use of Norms and Electronic Institutions...
Conclusions, Ongoing and Future Work
Conclusions

- The design of MAS in complex, open environments can benefit from social abstractions
  - Coordination, Cooperation and Trust issues

- An e-Institution is a Social Structure defined by means of norms

- Current approaches are too theoretical or too practical
  - There is a gap between the specification of abstract norms and the concrete implementation inside e-Organizations

- We presented HARMONIA, a multi-level framework that proposes a formal connection between the different abstraction levels of a Normative System

- We apply HARMONIA to a real, complex and highly regulated scenario
  - Distribution of organs and tissues for transplantation purposes
Ongoing and future work (I)

- Creation of tools for e-Organizations
  - Tools currently developed in collaboration with Bath.

- Definition of a generic, modular architecture for e-Organizations
  - Current work: OMNI

- Extension of the theoretical normative framework
  - Sanctions from cumulative violations
  - formalize normative influence dynamics

- Study the use of other languages/formalisms

- Application to other highly-regulated domains

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Ongoing and future work (II)

- OMNI
Ongoing and future work (III)

- Study of dynamic aspects of normative systems

![Diagram]

a) change of context

b) consensus

c) collision in context definition

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