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

(The HARMON*IA* framework.)

Javier Vazquez-Salceda

Utrecht University

http://www.cs.uu.nl/people/javier

Universiteit Utrecht

javier@cs.uu.nl

Contents

- Motivation
- Agents and Norms
  - Agent view
- *e*Organizations and Norms
  - The **HARMON*IA*** framework
- Conclusions, Ongoing and Future Work

Universiteit Utrecht
javier@cs.uu.nl

Motivation

Universiteit Utrecht
javier@cs.uu.nl

Motivation (I)

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

  } *Coordination*, *Cooperation*

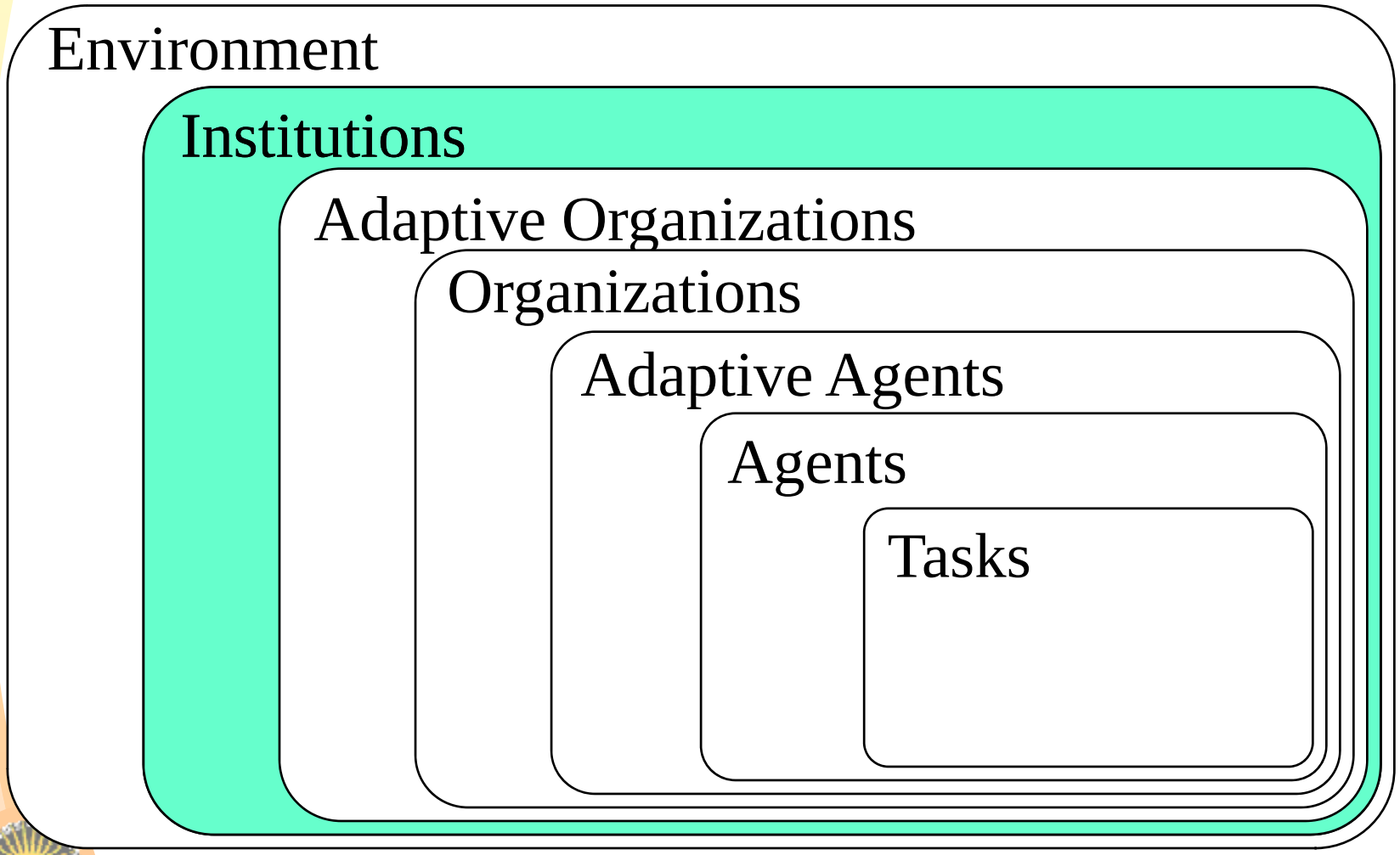
  - Agent **Autonomy** VS **Control**

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

Universiteit Utrecht
javier@cs.uu.nl

Motivation (II)

From individual to social view



Universiteit Utrecht
javier@cs.uu.nl

Motivation (III)

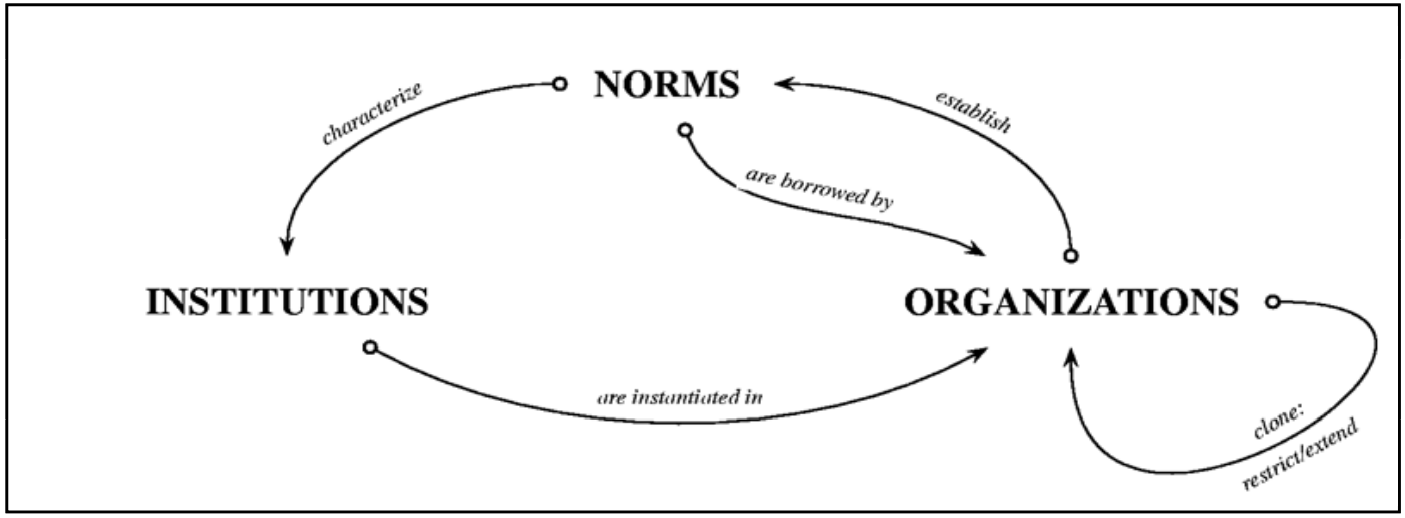
Society's View

- 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

Universiteit Utrecht
javier@cs.uu.nl

Motivation (V)

Agent View

- Norms should guide the bahaviour 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(discriminate(x,y,age))

Procedure: does not contain action "discriminate"

Universiteit Utrecht

javier@cs.uu.nl

Motivation (VI)

Application in a highly regulated *e*Health environment

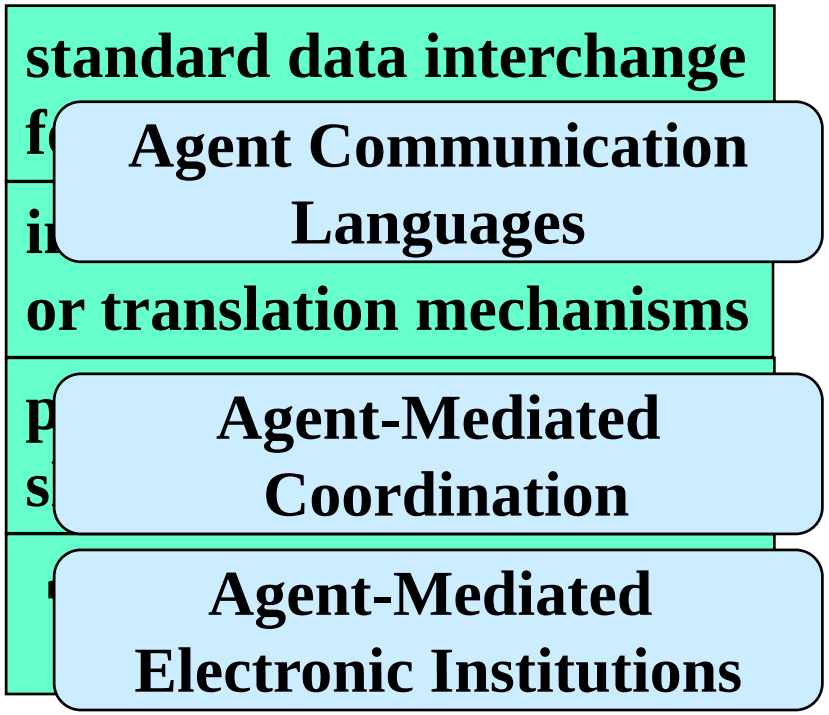
- *CARREL*: a project on distributed organ and tissue allocation.
- 2 kinds of transplants:
  - organs
    - You can not conserve them on banks
    - Every new organ donation → (manual) search for the recipient
  - tissues
    - You can keep them on banks, (not very long)
    - Every new recipient →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

Universiteit Utrecht
javier@cs.uu.nl

Motivation (VII)

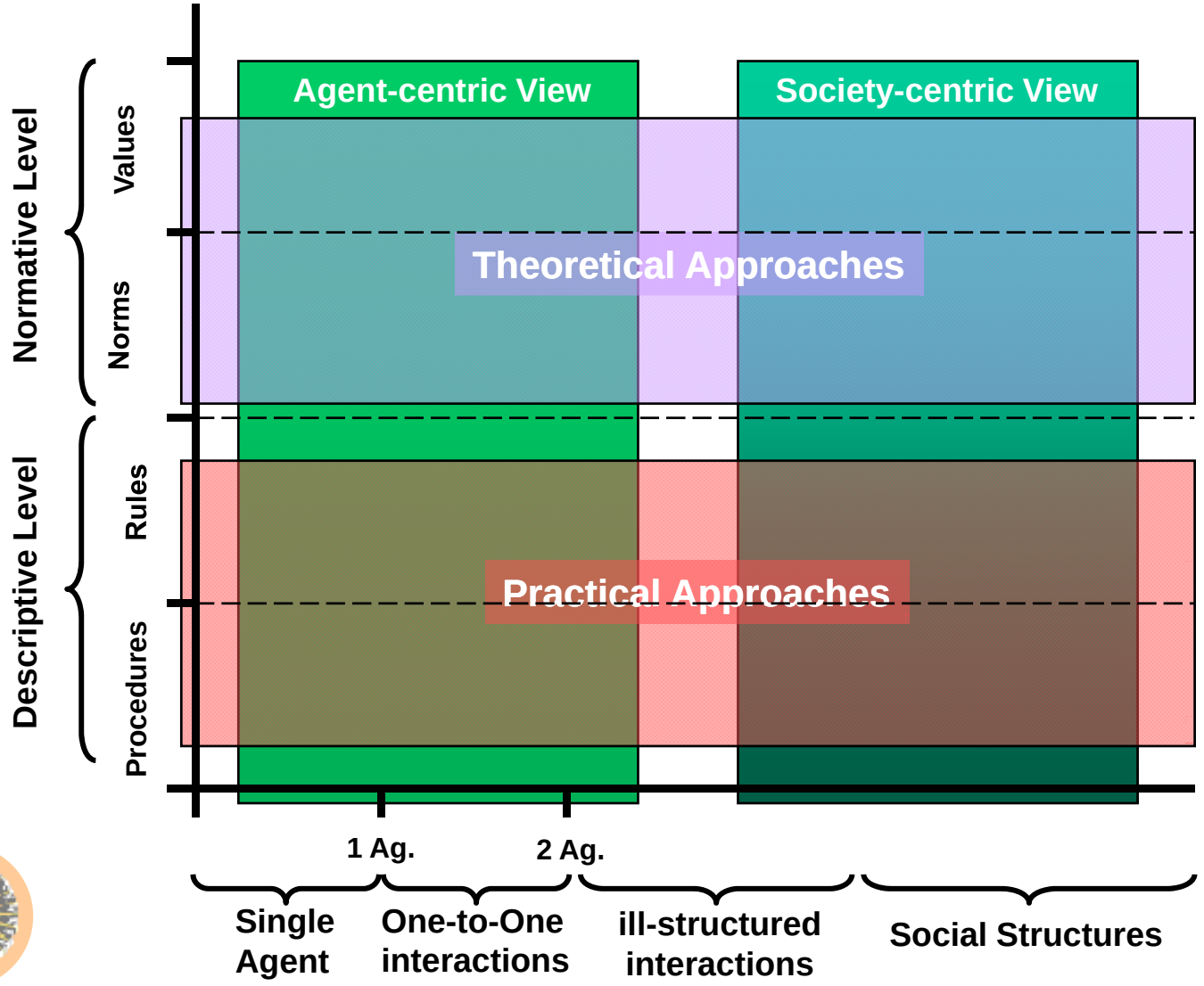
Application in a highly regulated *e*Health environment

- Scarcity of donors → international coalitions → distributed environment
- Need of a distributed software solution to:
  - ***Data exchange problem*:**
  - ***Communication problem*:**
  - ***Coordination issues*:**
  - ***Variety of regulations*:**

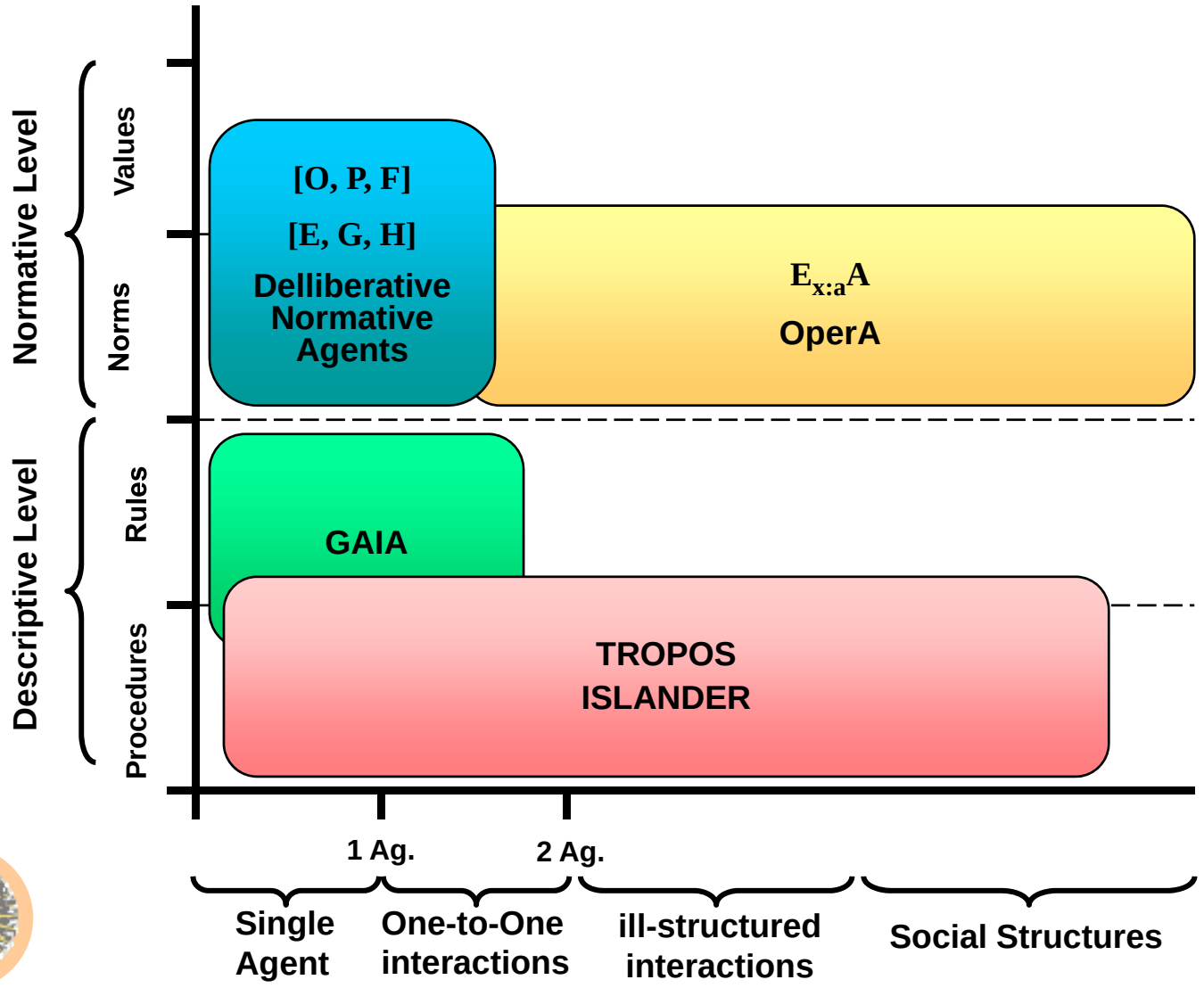


Universiteit Utrecht
javier@cs.uu.nl

State of the Art (I)



State of the Art (II)



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…*

Universiteit Utrecht
javier@cs.uu.nl

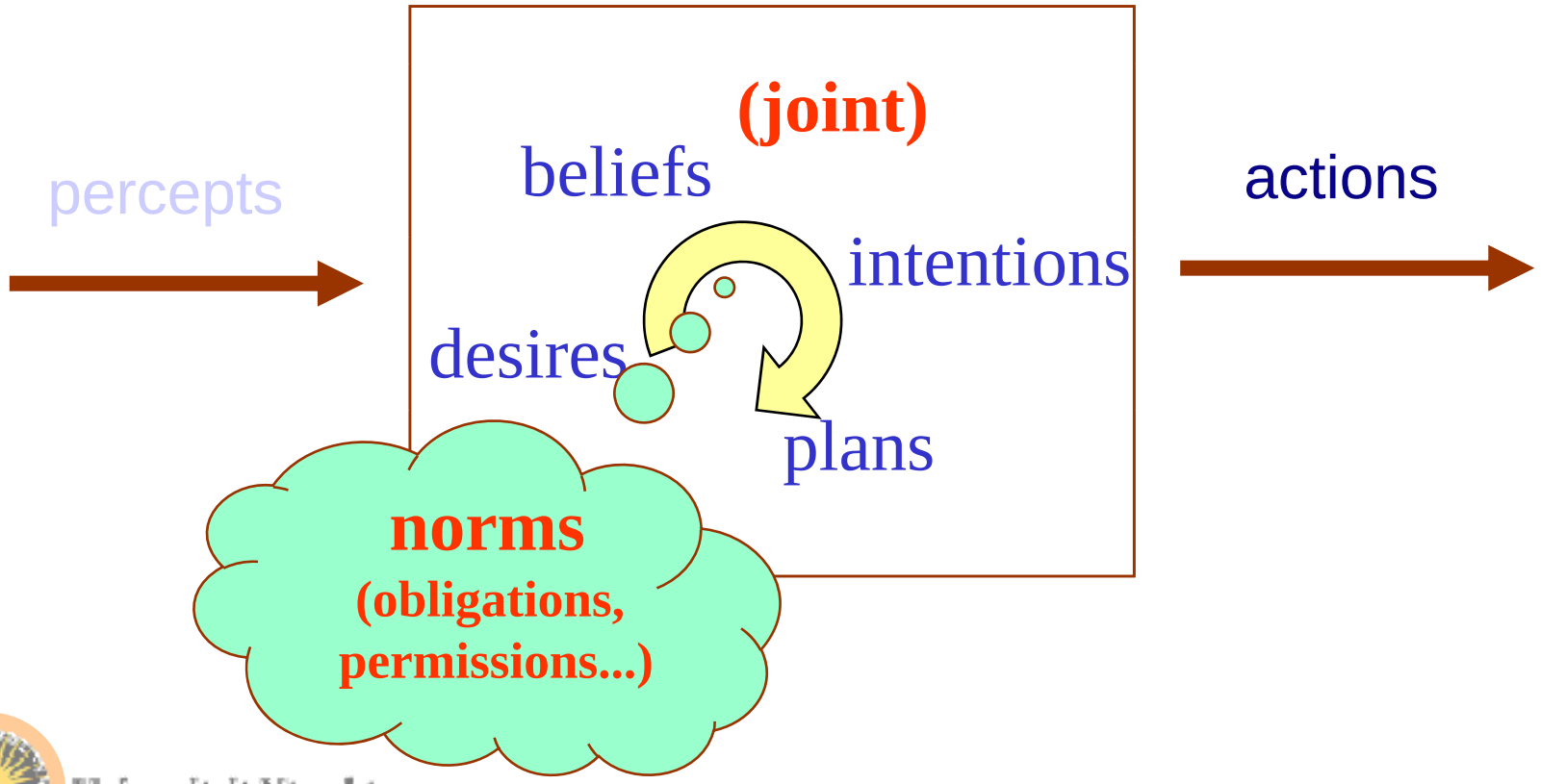
The Use of Norms and Electronic Institutions...

Norms and Agents

Universiteit Utrecht
javier@cs.uu.nl

Norms and Agents (I)

Influence of norms in the BDI deliberation cycle



Universiteit Utrecht
javier@cs.uu.nl

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

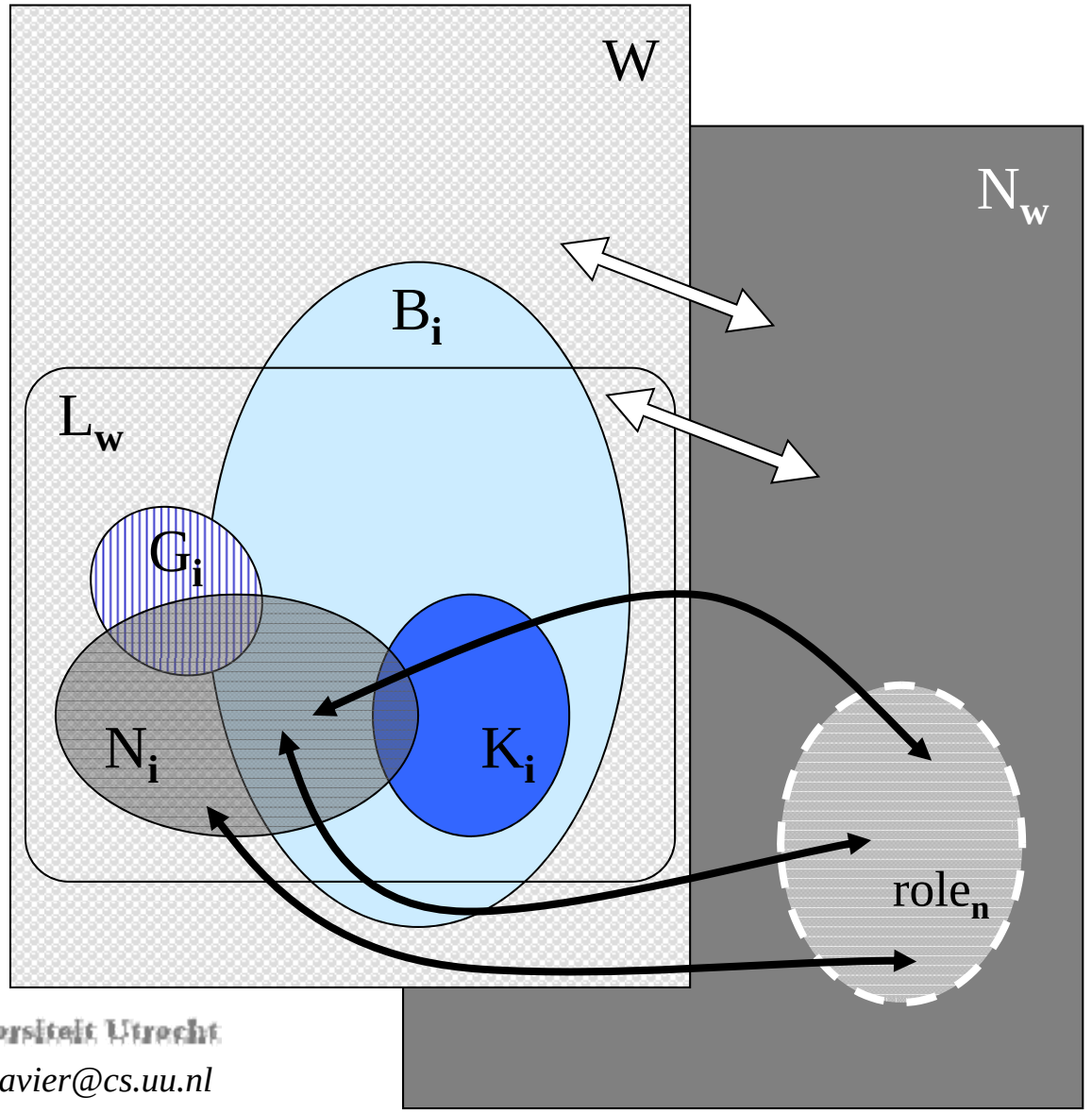
Universiteit Utrecht
javier@cs.uu.nl

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.

Universiteit Utrecht
javier@cs.uu.nl

Agent view (I)



Universiteit Utrecht
javier@cs.uu.nl

Agent view (II)

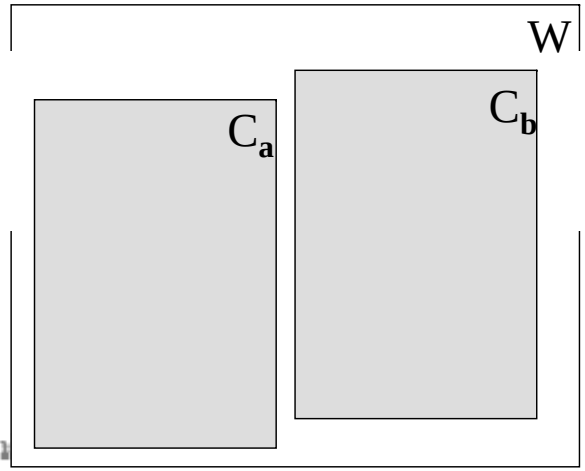
- Problem: in this model interpretation of norms is completely done by the agents.
  - How to ensure that two agents that play the same role have similar sound interpretations of the norms that apply to them?
- Solution: to fix part of the interpretation in a given context.

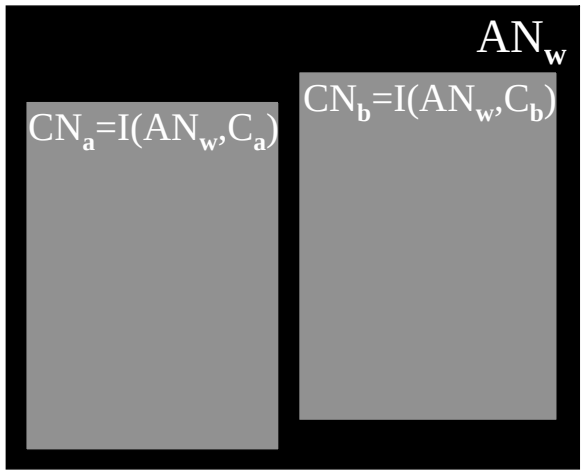
- Idea: Agents do not have a relation with the WHOLE world but a part → context of an agent.

Universiteit Utrecht
javier@cs.uu.nl

Agent view (III)

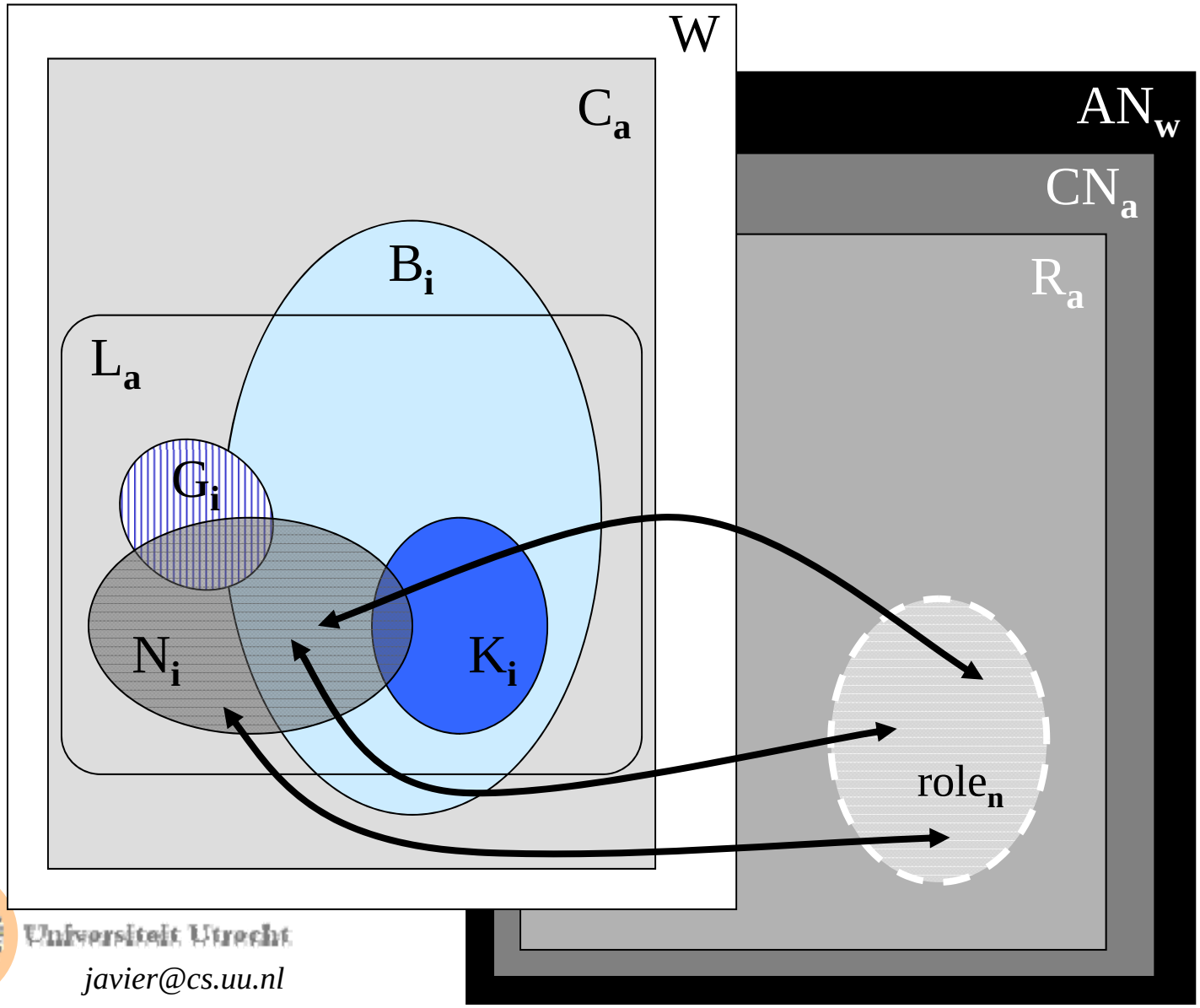
- A Context is a set of worlds with a shared vocabulary and a normative framework
- Effects on the Normative Dimension
  - The generic norms applied to the world as a whole are called Abstract Norms.
  - Concrete Norms are interpretations of the abstract norms in a given context





javier@cs.uu.nl

Agent view (IV)



Universiteit Utrecht
javier@cs.uu.nl

The Use of Norms and Electronic Institutions...

*e*Organizations and Norms

Universiteit Utrecht

javier@cs.uu.nl

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

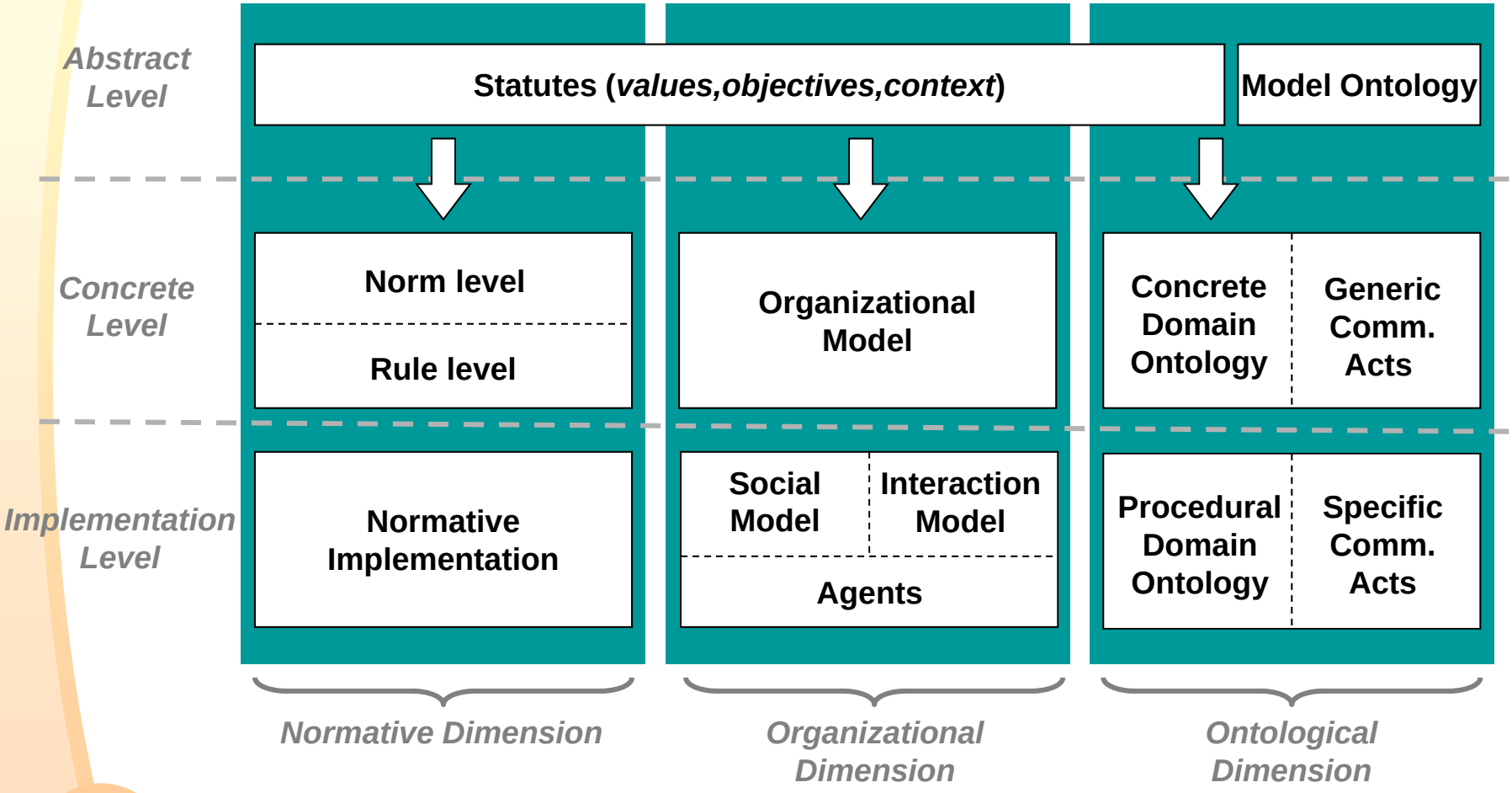
Universiteit Utrecht
javier@cs.uu.nl

The HARMON*IA* framework

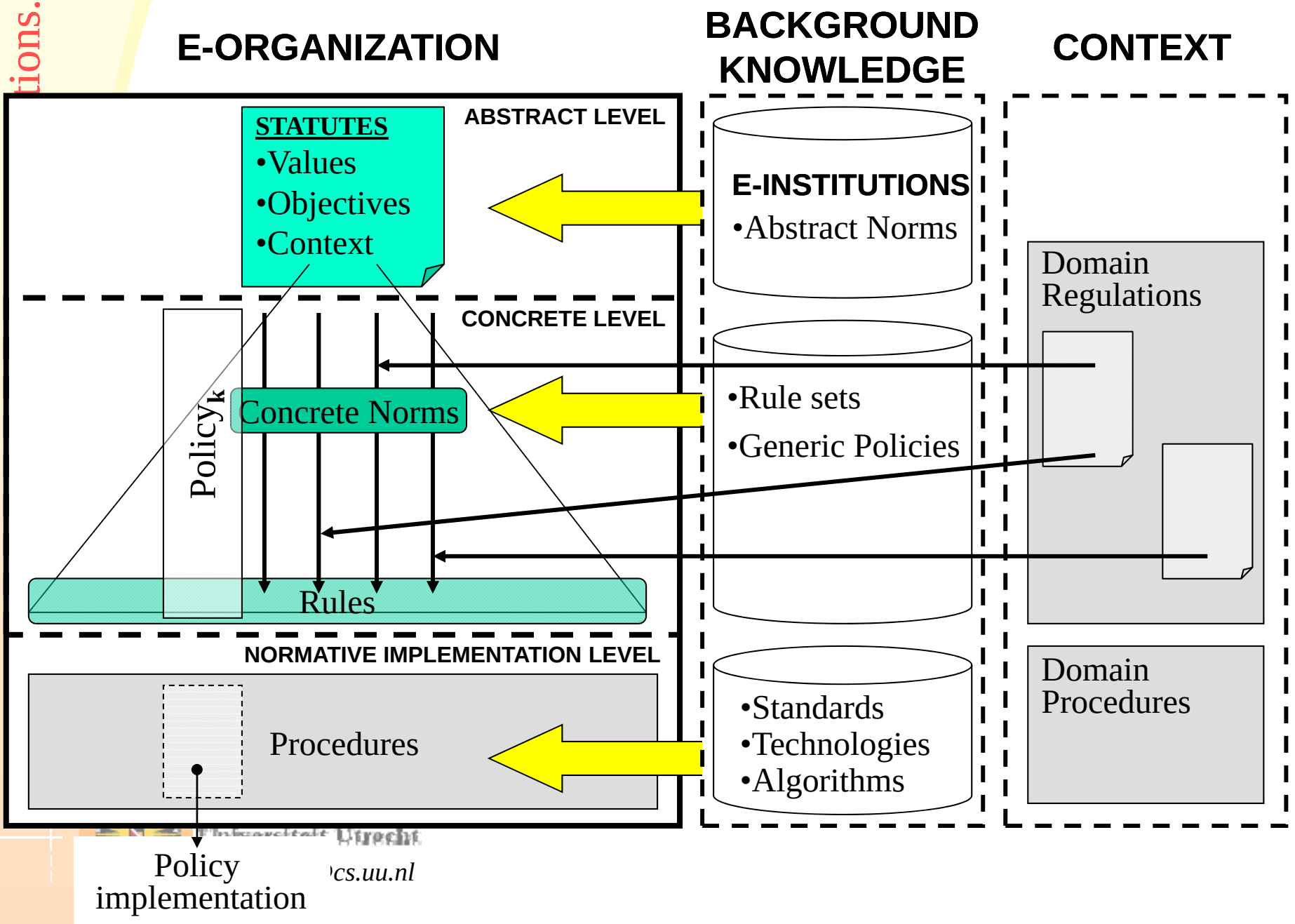
- Main Objectives
  - To identify the different levels in a Normative System
  - To find a (formal) connection between levels
- The framework identifies two kinds of elements
  - Horizontal elements: 3 levels (Abstract, Concrete and Normative Implementation)
  - Vertical elements: Policies, Roles, Ontology, Context and Background Knowledge

Universiteit Utrecht
javier@cs.uu.nl

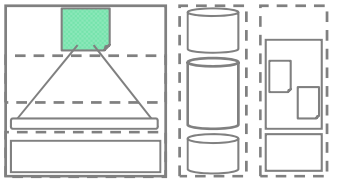
The HARMONIA framework inside OMNI



Universiteit Utrecht
javier@cs.uu.nl


E-ORGANIZATION
BACKGROUND KNOWLEDGE
CONTEXT
ABSTRACT LEVEL
STATUTES
•Values
•Objectives
•Context
E-INSTITUTIONS
•Abstract Norms
Domain Regulations
CONCRETE LEVEL
Policy$_k$
Concrete Norms
•Rule sets
•Generic Policies
Rules
NORMATIVE IMPLEMENTATION LEVEL
Procedures
•Standards
•Technologies
•Algorithms
Domain Procedures
Policy implementation
cs.uu.nl

Abstract Level: Statutes



The statutes of organizations define the

- Values
- Objectives
- Context

of the organization at the most abstract level.

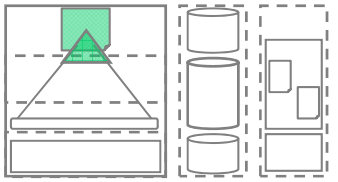
Example: Organización Nacional de Trasplantes:

> 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 a appropiate and correct way according to the current technical knowledge and according to the ethical principles of equality.

javier@cs.uu.nl

Abstract Level: Abstract Norms (I)

From Values to Abstract Norms

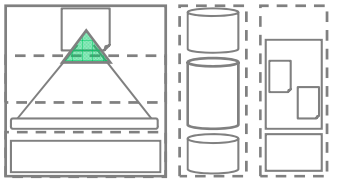


- Values are beliefs that we have about what is important and thus about how things should be.
  - *"Appropriate distribution"*
  - *"Distribution according to ethical principles of equality"*
  - *"Fairness of transaction"*
  - *"Respect privacy of persons"*
- Values can be considered as the most abstract 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(equity) =:= { F(discriminate(x,y,age)),
O(find_best_recipient(organ)),
…}

Universiteit Utrecht
javier@cs.uu.nl

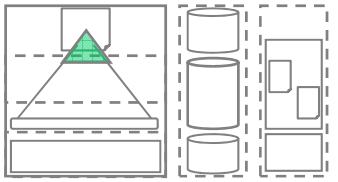
Abstract Level: Abstract Norms (II)



- 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

Universiteit Utrecht
javier@cs.uu.nl

Abstract Level: Abstract Norms (III)



- example 1: Abstract actions

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

$$\left.\begin{array}{l}\text{sign(donor,contract)} \cup \text{carry(donor,will)} \cup \\ \text{tell(donor,family)}\end{array}\right\} \Rightarrow_{ONT} \text{Consent(donor)}$$

- example 2: Vague terms

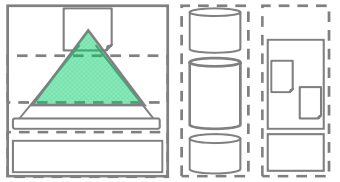
  "the ONT is obliged to ensure that the distribution of organs and tissues is appropriate"

$$\left.\begin{array}{l}O_{ONT}(\text{ensure_quality(organ)}) \wedge \\ O_{ONT}(\text{ensure_compatibility(organ, recipient)})\end{array}\right\} \Rightarrow_{ONT} O_{ONT}(\text{appropriate(distribution)})$$

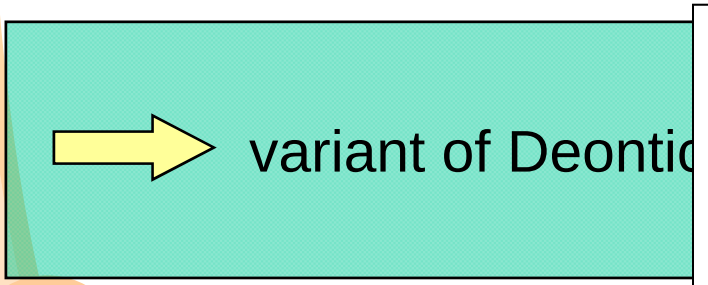
Universiteit Utrecht
javier@cs.uu.nl

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

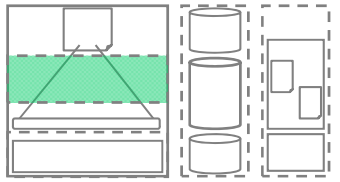


$ONT{:}C1.1.1$	$O_{ONT}(ensure_quality(piece) < do(assign(piece, recipient)))$
$ONT{:}C1.1.1.1$	$O_{origin_org}(ensure_quality(piece))$
$ONT{:}C1.1.1.1.1$	$O_{hospital}(ensure_quality(organ))$
$ONT{:}C1.1.1.1.2$	$O_{tissue_bank}(ensure_quality(tissue))$
$ONT{:}C1.1.1.2$	$O_{CARREL}(get_quality(piece, origin_org) < do(assign(piece, recipient)))$
$ONT{:}C1.1.1.2.1$	$O_{CARREL}(get_quality(organ, hospital) < do(assign(organ, recipient)))$

Universiteit Utrecht

javier@cs.uu.nl

Concrete Level: Concrete Norms



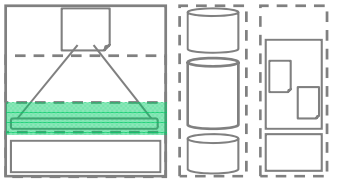
- Concrete norms are the result of translating the abstract norms in the context of the organization into norms that make use of terms and actions that are defined in the organization's ontology.

$$O_{hosp}(consent(donor(p,x)) < done(transplant(hosp,x,p,q)))$$

- Problem: HOW is a concrete norm like this implemented in an e-Organization?

Universiteit Utrecht
javier@cs.uu.nl

Concrete Level: Rules (I)



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

$$O_{hosp}(consent(donor(p,x)) < do(transplant(hosp,x,p,q)))$$

$$\downarrow$$

$$[transplant(hosp,x,p,q))]done(consent(donor))$$

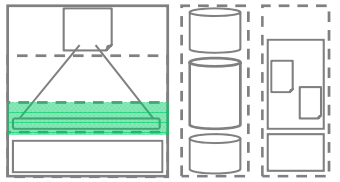
$$O_{buyer}(pay(goods,seller,price) < do(exit(buyer)))$$

$$\downarrow$$

$$not(done(pay(goods,seller,price))) \rightarrow [exit(buyer)]V(fine(buyer))$$

Universiteit Utrecht
javier@cs.uu.nl

Concrete Level: Rules (II)



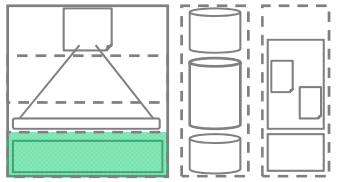
- Rules, Violations and Sanctions
  - Violation rules define violations
  - A violation is composed by
    - pre-conditions
    - sanction
    - side effects

`Violation:`	$CRL{:}V18.1$
`Pre-conditions:`	$(done(deliver(organ,\ hospital_1,\ hospital_2)) \wedge is_time(t)$ $\wedge done(wait_for(is_time(t\ +\ 1\ day)))$ $\wedge \neg done(hospital_2.send(result_transplant)))$
`Sanction:`	$\{request(hospital_2,\ send(organ,\ result_transplant));$ $inform(board,\texttt{precondition})\}$
`Side-effects:`	$\{record(\neg done(\texttt{precondition}), incident_log)\}$

  - 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.

Universiteit Utrecht
javier@cs.uu.nl

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 guar of norm
    - defining triggers on violation of norms to violation

Flexible Normative Agents

(able to interpret rules and protocols)

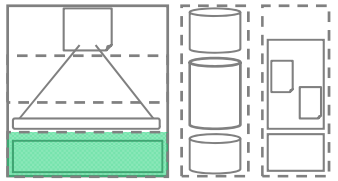
Standard Agents

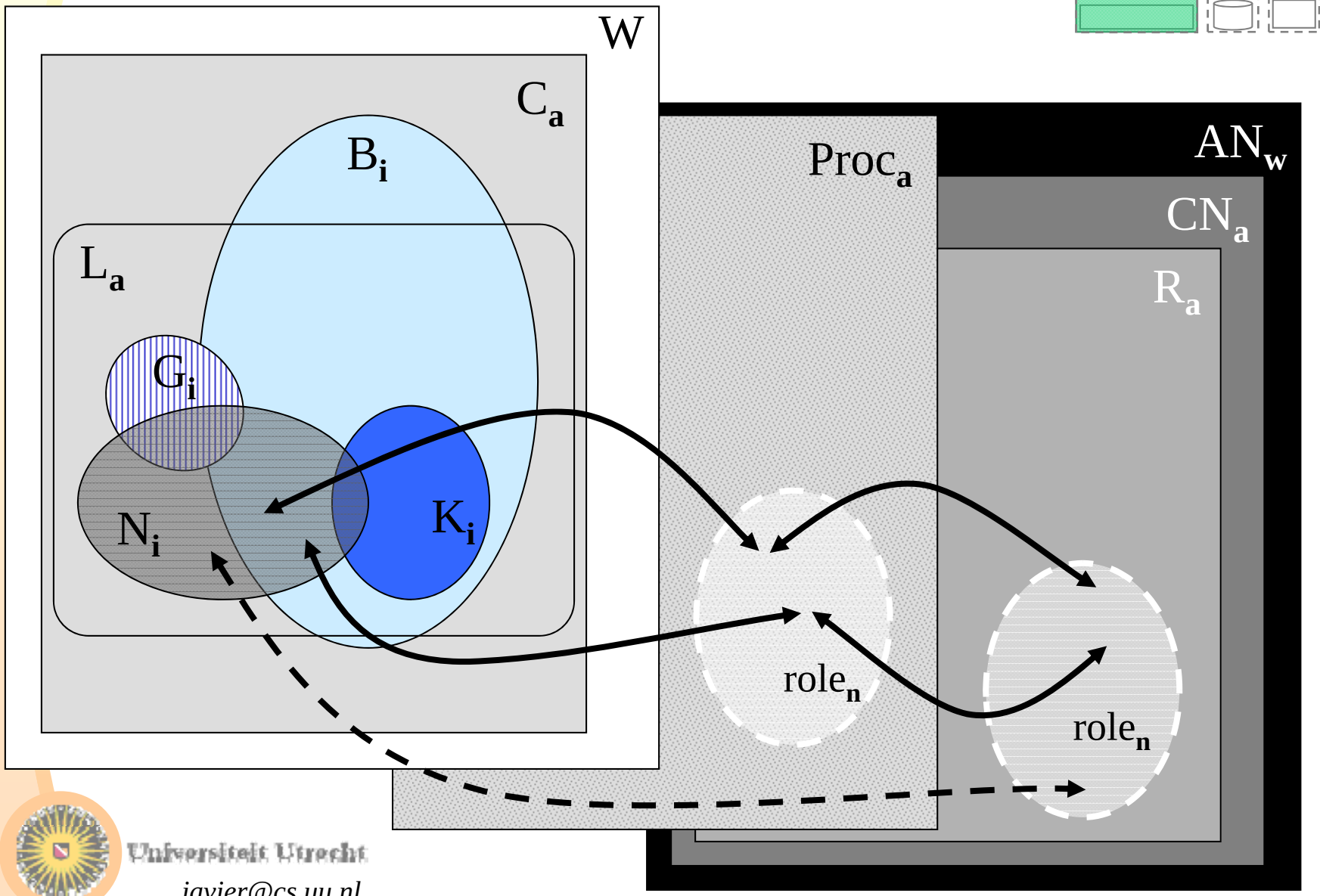
(able to choose and follow protocols)

Universiteit Utrecht

javier@cs.uu.nl

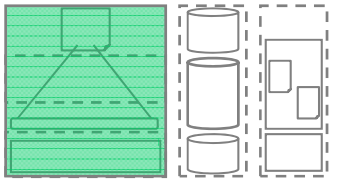
Normative Implementation Level (II)





Universiteit Utrecht
javier@cs.uu.nl

Example



ABSTRACT LEVEL

D(appropriate(distribution))

O_{ONT}(appropriate(distribution))

(CONCRETE) NORM LEVEL

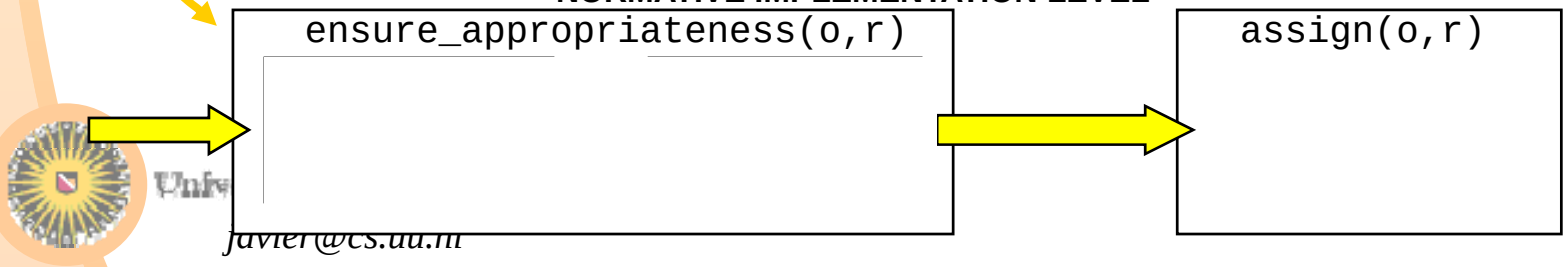
O_{ONT}(ensure_appropriateness(organ,recipient) < do(assign(organ,recipient)))

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

RULE LEVEL

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

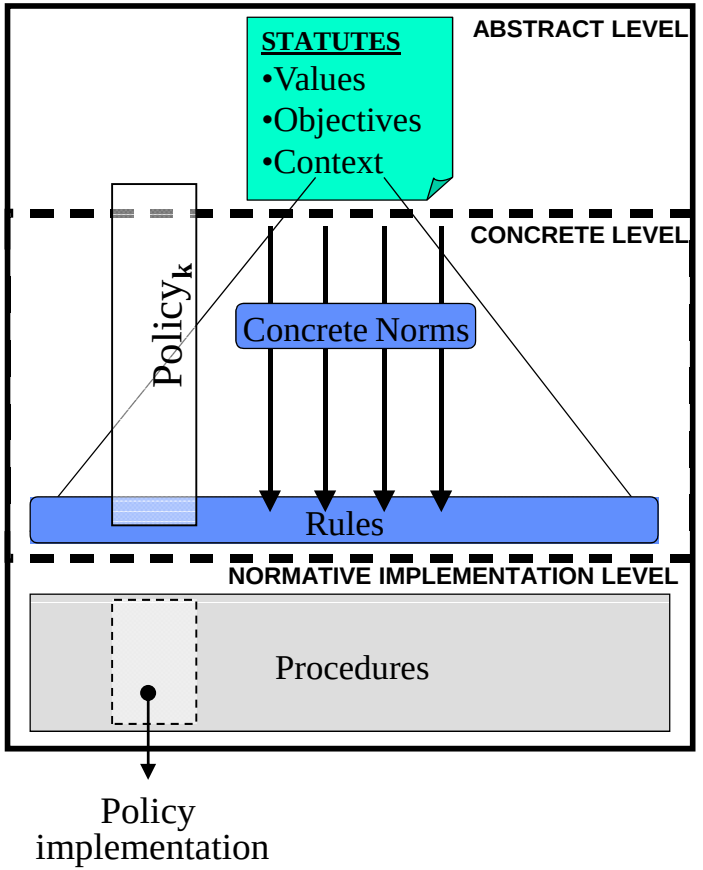
NORMATIVE IMPLEMENTATION LEVEL



javier@cs.uu.nl

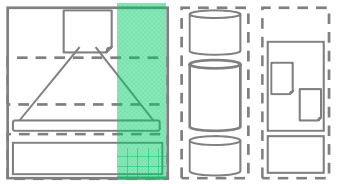
All levels: Policies

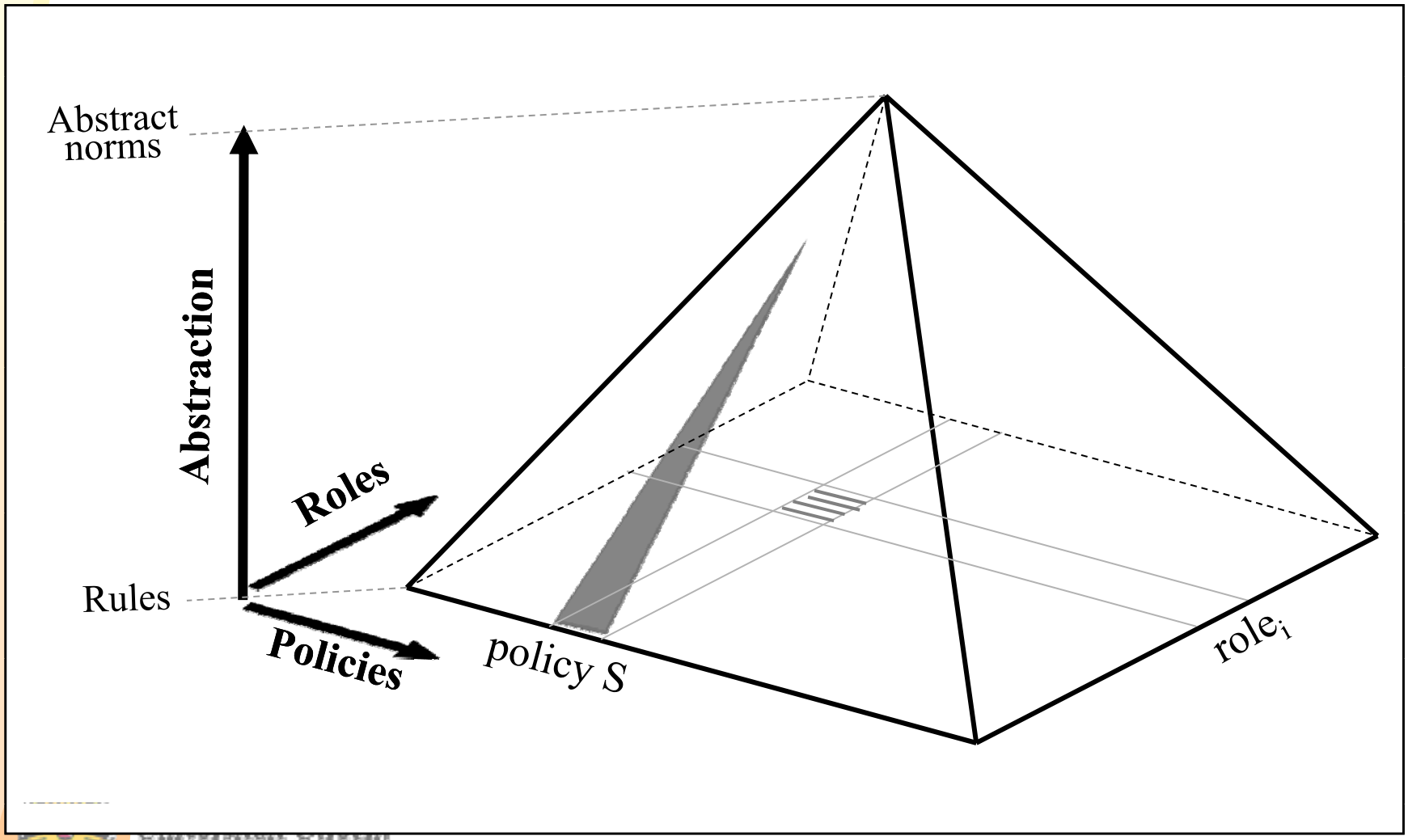
- There are several definitions of Policy
  - Policies as low-level plans or protocols
  - Policies as values or aims of the organization
  - Policies as high-level plans, relating organizational aims with procedures
- Policies are vertical elements,linking organization's values with the related norms and rules to the final implementation
  - e.g.: *allocation policy,security policy*



Universiteit Utrecht
javier@cs.uu.nl

All levels: Roles (I)

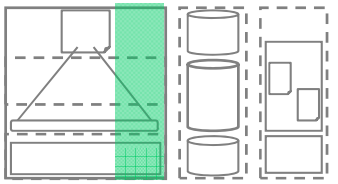


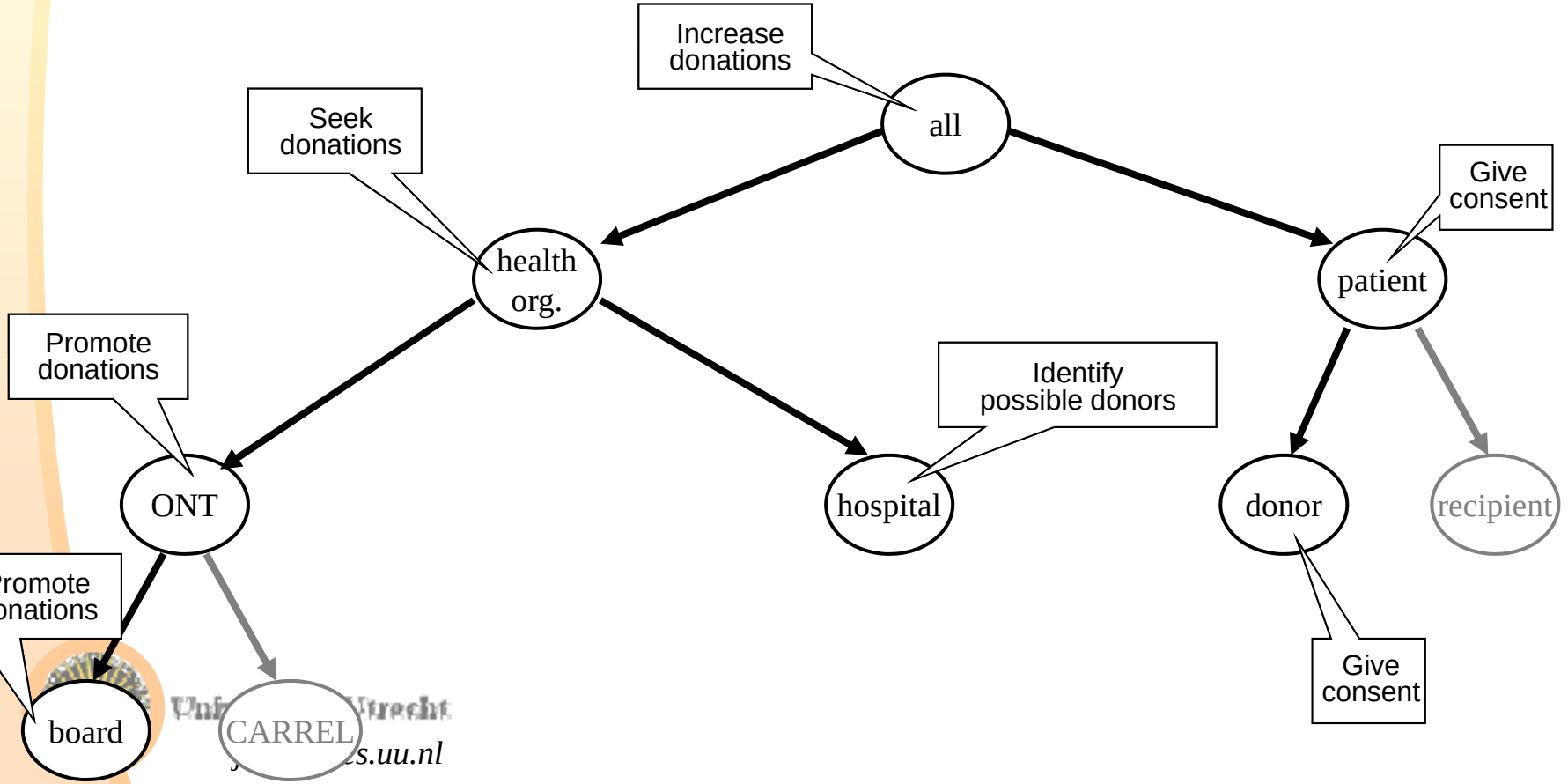


javier@cs.uu.nl

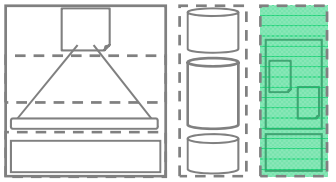
All levels: Roles (II)

- Role definition guided by goal distribution
  - Origin: Objectives in Statutes
- Distribution of responsibilities

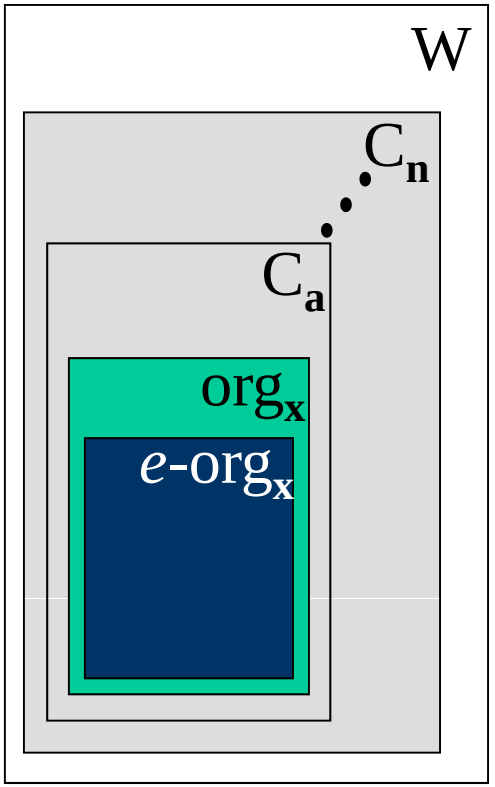




All levels: Context (I)

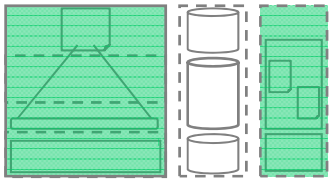


- Statutes make reference to a surrounding context
- Links with the idea of nested contexts
  - *e*-org$_X$ is a context defining a vocabulary and a normative system
  - there are super-contexts that have an influence in *e*-org$_X$ definition
- formal view: influence as interpretation in the subcontext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



Universiteit Utrecht
javier@cs.uu.nl

All levels: Context (II)



ABSTRACT LEVEL

D(appropriate(distribution))

O_{ONT}(appropriate(distribution))

(CONCRETE) NORM LEVEL

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

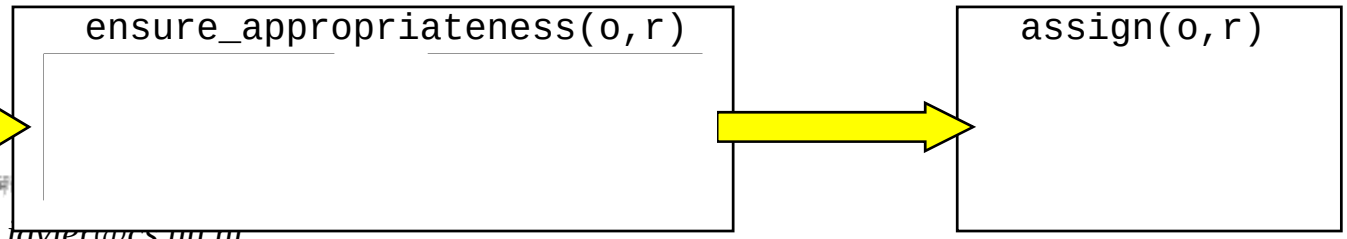
Spanish National Health System

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

RULE LEVEL

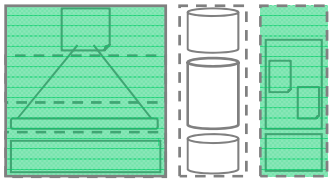
[assign(organ,recipient)]done(ensure_appropriateness(organ,recipient))

NORMATIVE IMPLEMENTATION LEVEL



javier@cs.uu.nl

All levels: Context (II)



ABSTRACT LEVEL

D(appropriate(distribution))

O_{ONT}(appropriate(distribution))

(CONCRETE) NORM LEVEL

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

Spanish National Health System

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

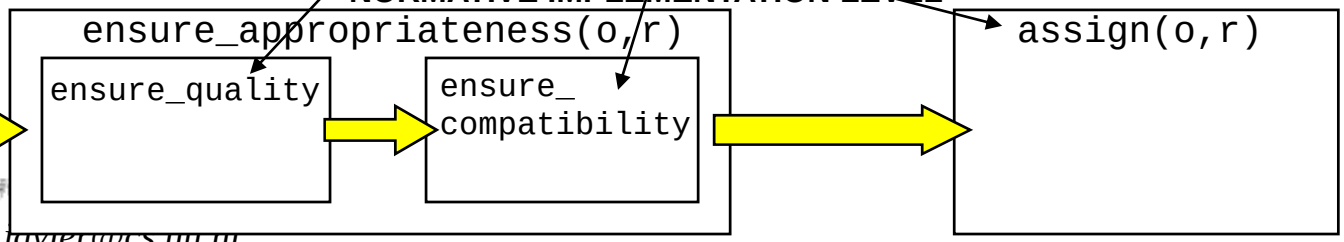
O_{CARREL}(ensure_compatibility(organ,recipient) < do(assign(organ,recipient)))

RULE LEVEL

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

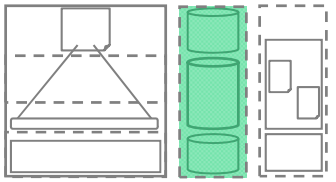
[assign(organ,recipient)]done(ensure_compatibility(organ,recipient))

NORMATIVE IMPLEMENTATION LEVEL

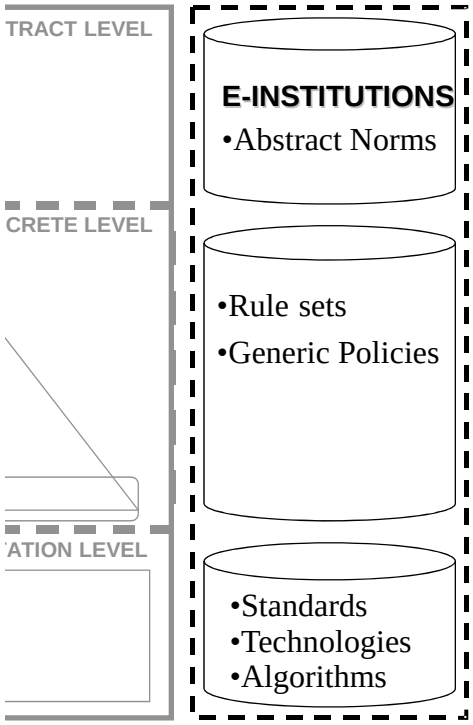


javier@cs.uu.nl

All levels: Background Knowledge

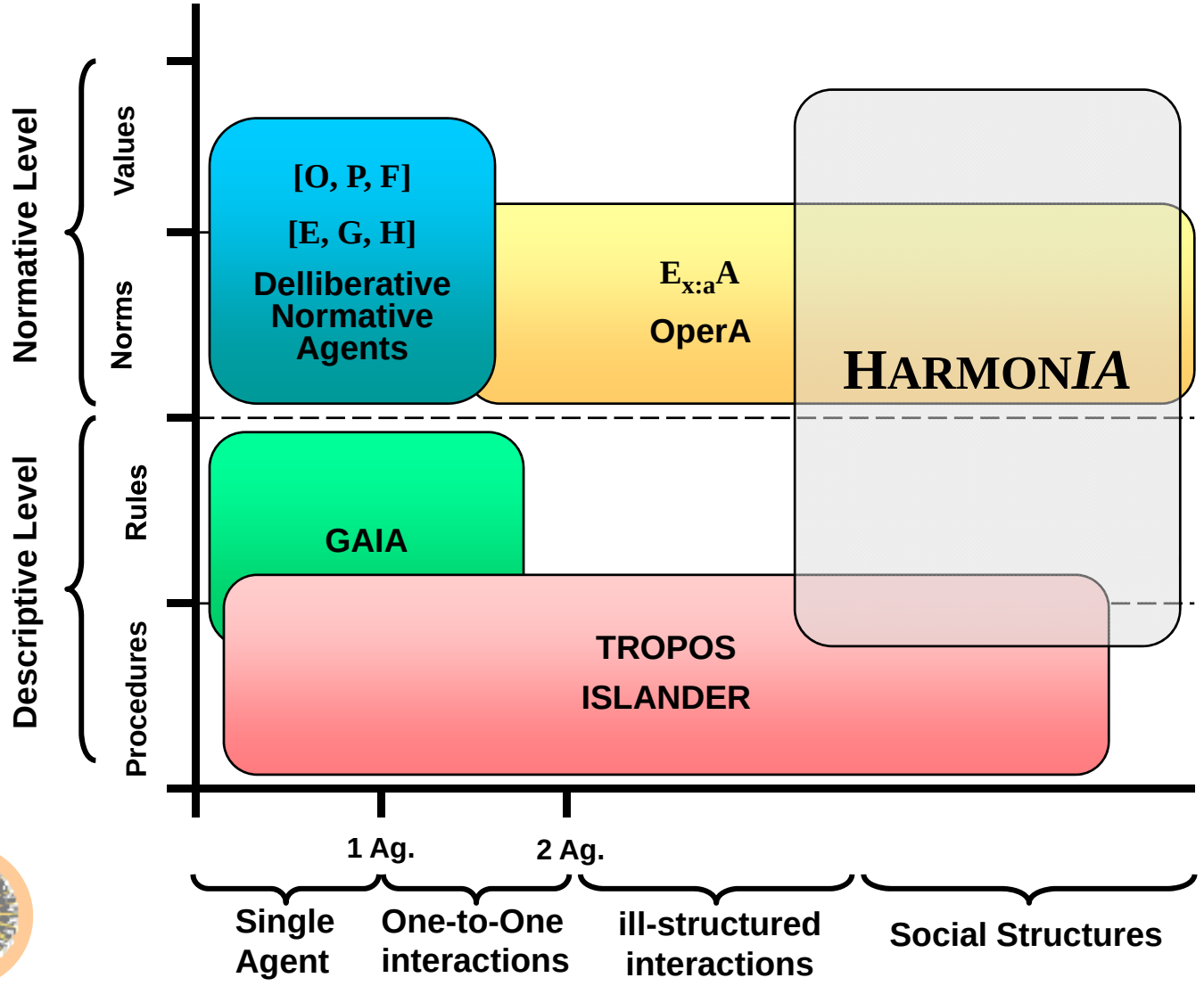


- The Background Knowledge is a repository containing templates that can be adapted to create new eOrganizations
  - At the abstract level, it provides a collection of abstract norms and the related ontology and abstract roles
  - At the concrete and rule levels, it provides templates for some generic 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.

HARMON*IA* and other approaches



The Use of Norms and Electronic Institutions...

Conclusions, Ongoing and Future Work

Universiteit Utrecht

javier@cs.uu.nl

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 betweenthe 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

Universiteit Utrecht

javier@cs.uu.nl

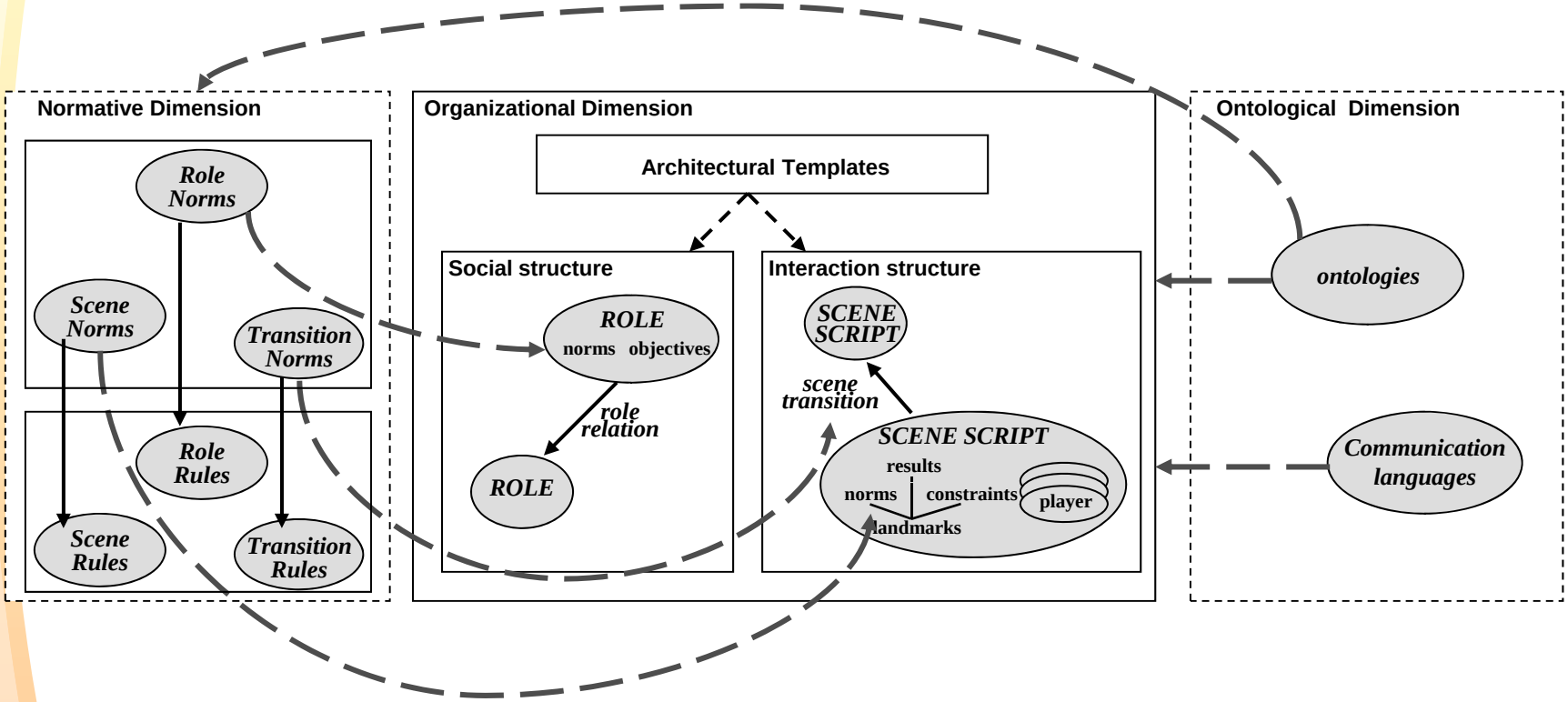
Ongoing and future work (I)

- 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

Universiteit Utrecht
javier@cs.uu.nl

Ongoing and future work (II)

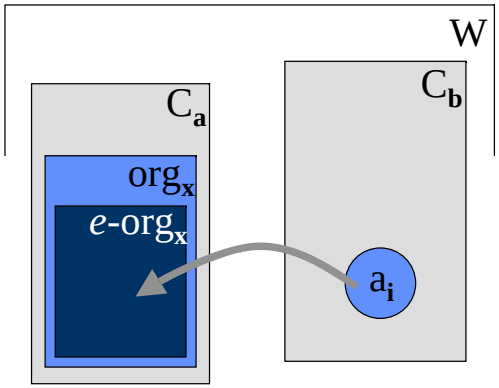
- OMNI



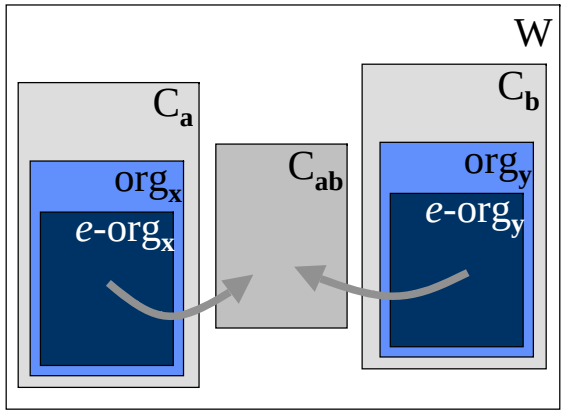
Universiteit Utrecht
javier@cs.uu.nl

Ongoing and future work (III)

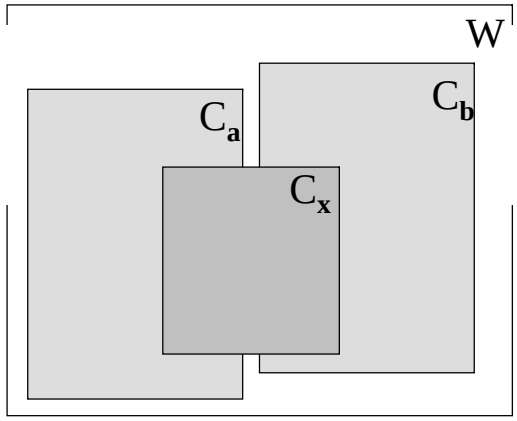
- Study of dynamic aspects of normative systems



a) change of context



b) consensus



c) colision in context definition

Universiteit Utrecht
javier@cs.uu.nl