Normative Agents in Health Care

Norms, Normative Agents and Electronic Institutions for Safety and Soundness in Distributed Environments

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Invited talk

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- Introduction
- A Language for Norms
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- Conclusions and Challenges

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Introduction

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Introduction (I)

- Now a days, computing trends move toward **distributed solutions**
  - computer systems are networked into large distributed systems;
  - processing power can been introduced in almost any place and device
    → processing becomes ubiquitous

- The **agent paradigm** is one way to conceptualize and implement distributed (intelligent) systems
  - Agents are *human-oriented* abstractions
  - Each agent can specialize in some (sub)problems and take decisions *locally*
  - Solutions to coordinate the agent society can be borrowed from human organizations and human societies

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Introduction (II)

- *"An **Intelligent Agent** is a computer system that is capable of flexible, **autonomous** action on behalf of its user or owner"*
- *"By flexible we mean **reactive**, **pro-active** and **social**"*
  [M. Wooldridge]

- Other desired properties: ***rationality***, ***learning/adaptation***.
  - Agents should be able to *adapt* their behavior to new, unexpected situations
- A **Multiagent System** (MAS) consists of a number of agents, *interacting* with one-another
  - It is desirable that agents in a MAS coordinate their behaviour and *collectivelly adapt* to unforeseen events
- Problem: how can we meet all these spectatives?

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Introduction (III)

- **Autonomy** is one of the most desired properties of agents. We want agents to be autonomous in order to be able to (proactively) take their own decissions and to adapt to new, unexpected situations.

- We want agents to behave as expected, in order to achieve one or several goals. Therefore some **control** should be applied to the agents' behaviour.

- Agent **Autonomy** VS **Control**: problem:
  - How to ensure (**control**) an efficient and acceptable behaviour of a Multiagent System without diminishing the agents' **autonomy**?

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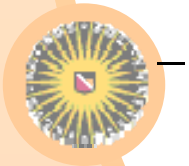
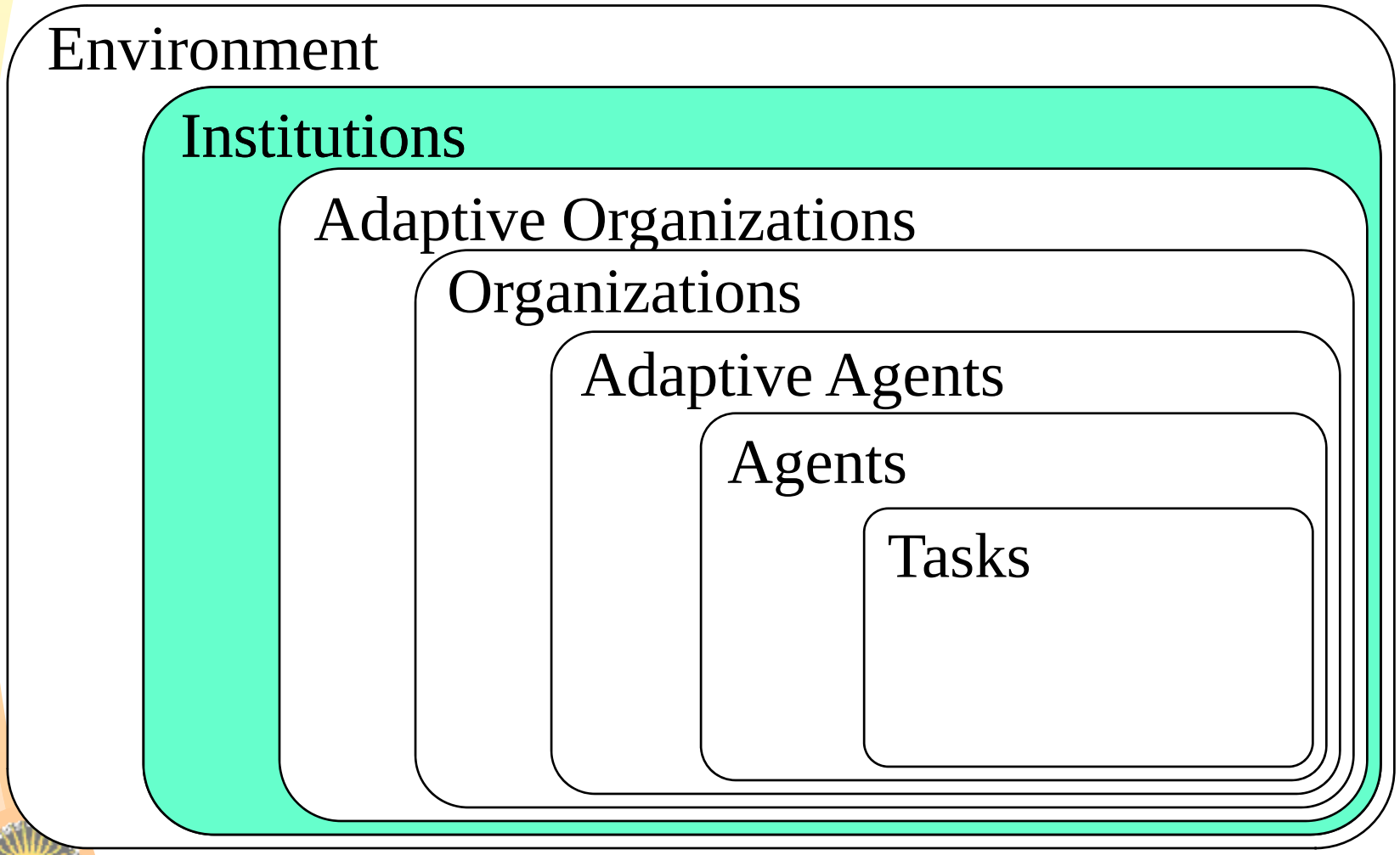
Introduction (IV)

- **Norms** are a flexible way to specify the boundaries of acceptable (legal) behaviour
  - They specify WHAT is acceptable and WHAT is not, but not HOW
  - Agents have autonomy to reach their goals as far as they "move" within the acceptable boundaries.
- Norms ease agent interaction:
  - 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)
- To ensure acceptable behaviour, a safe environment is needed: **Electronic Institutions**
  - Safe agent interaction environments
  - They include definition of norms and enforcement mechanisms



Introduction (V)

From individual to social view



[graph by L. Gasser]

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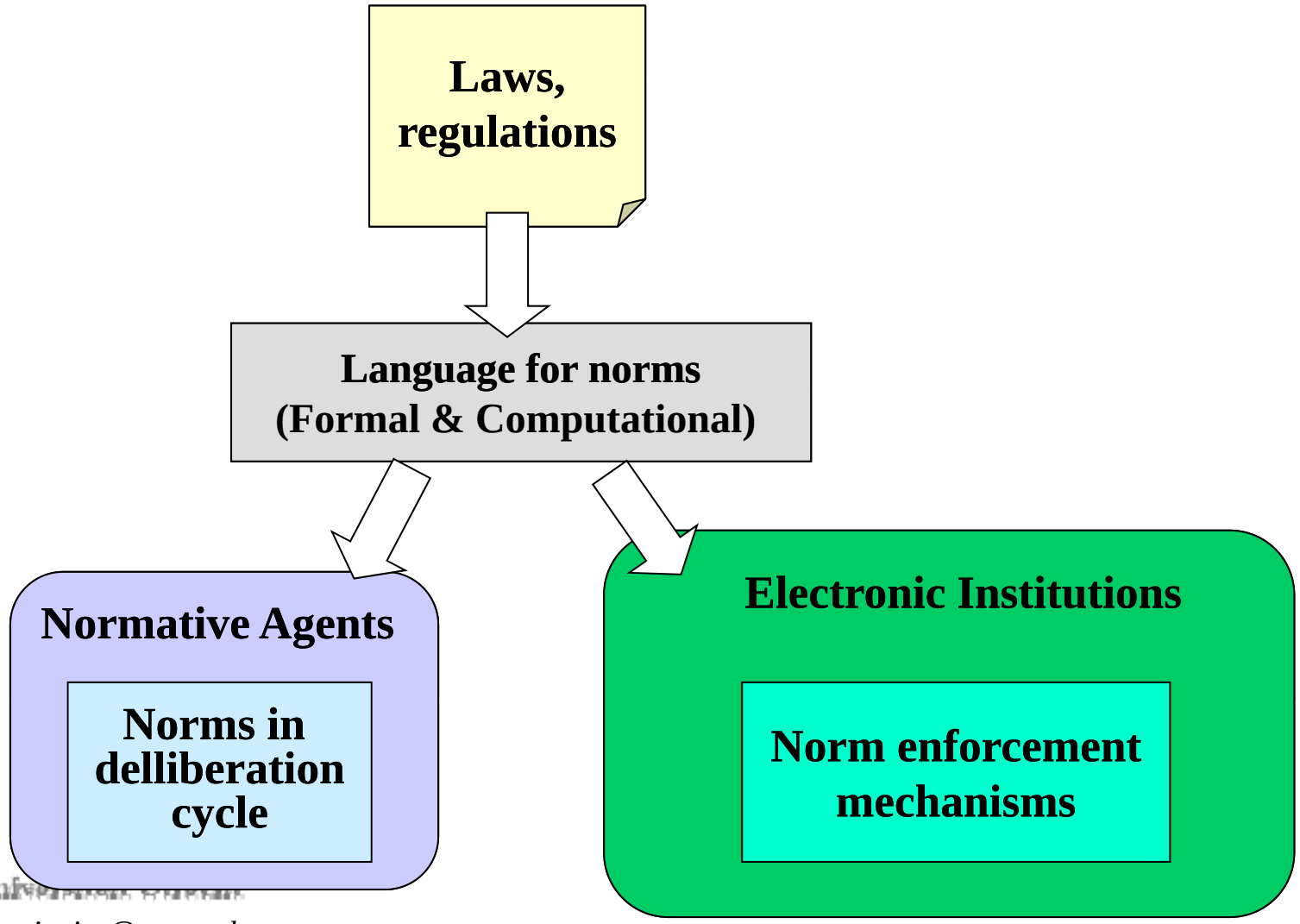
Introduction (VI)

Designing Normative MAS



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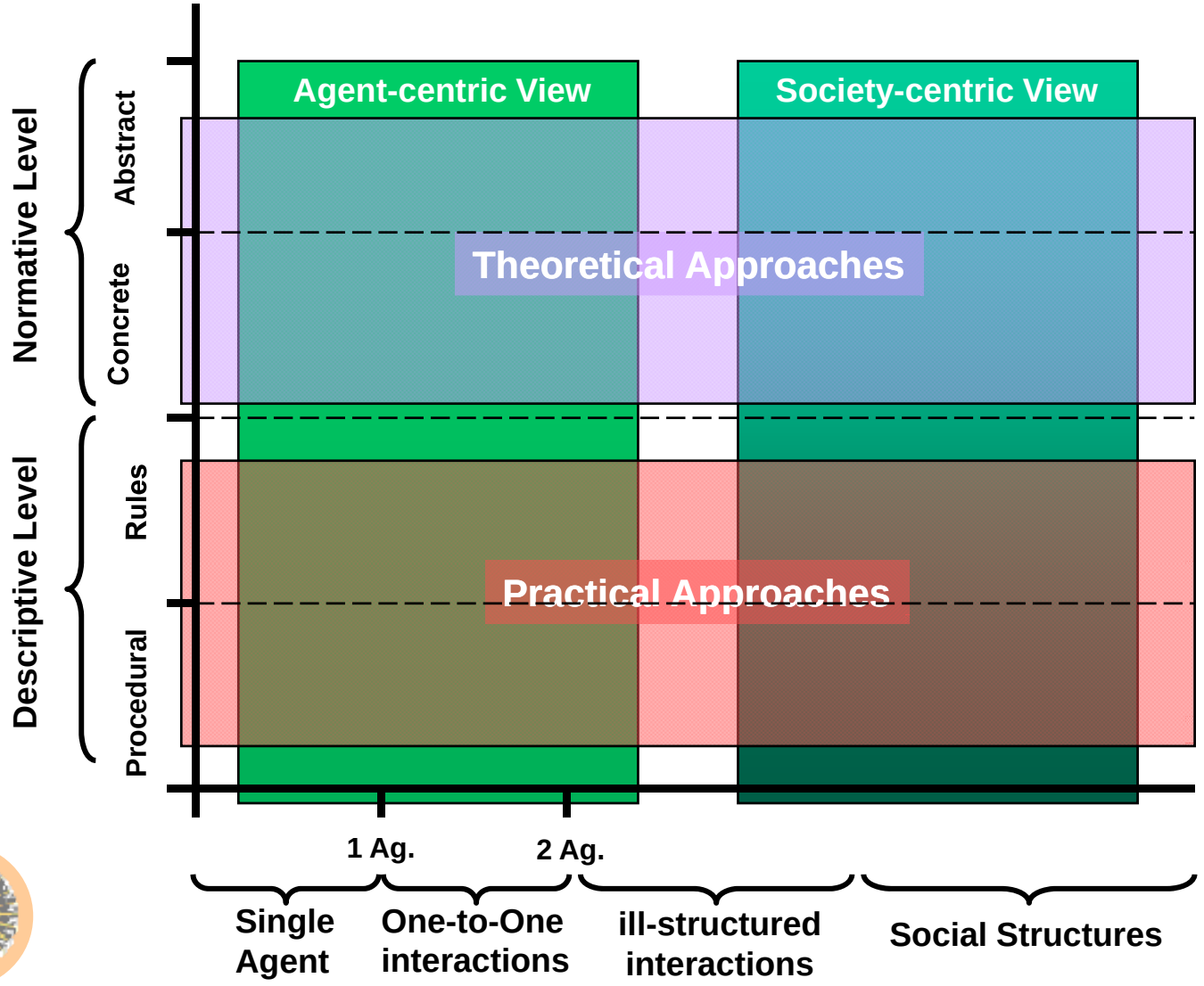
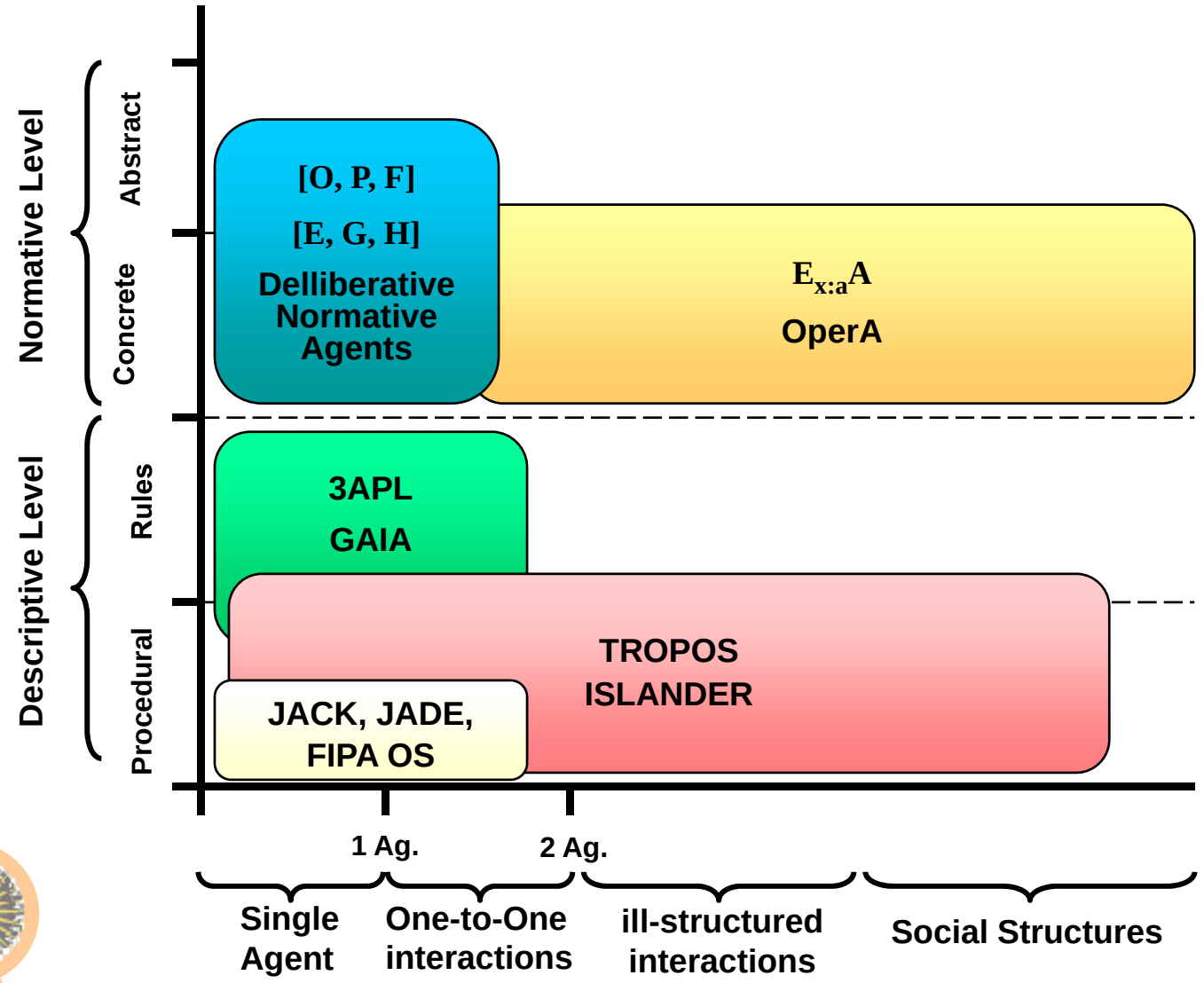
Normative MAS: state of the Art (I)



Normative MAS: state of the Art (II)



Example: Distributed e-Health (I)

- New environment for Health Care services
  - Need to promote innovative HC services
  - patient-centered services
  - inter-connectivity
- the European e-Health Area

Aims:
- improve patient care
- more efficient & responsive HC services

Means:
- integrate EU h
- concentrate res
- avoid duplicity

[EU Health Stra

Patient Mobility

[Health Council report, December 2003]

Target IST's:
- European electronic HC card
- EU Heath Information Networks
- On-line services
  - info on illness prevention
  - teleconsultation
  - electronic records
  - e-reimbursement

Europe 2005 priorities, 2002]

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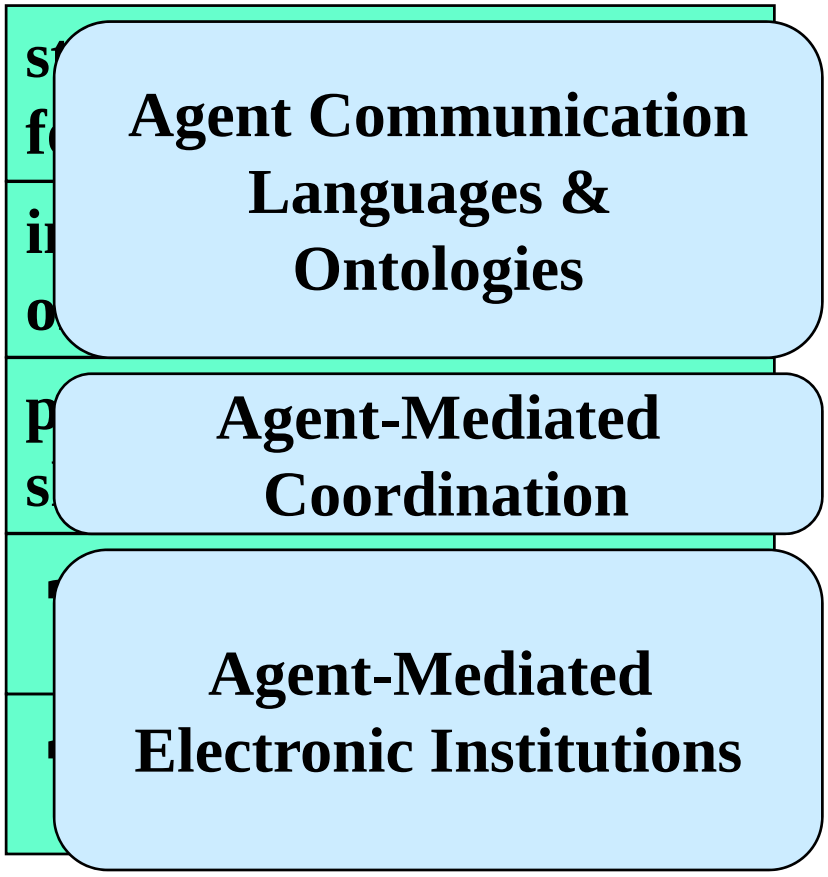
Example: Distributed e-Health (II)

Application in a distributed, highly regulated *e*Health environment

- Distributed software solutions should address:
  - ***Data exchange problem*:**
  - ***Communication problem*:**
  - ***Coordination issues*:**
  - ***Variety of regulations*:**
  - ***Trust*:**



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Case Study (I)

- 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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Case Study (II)

- Organ and tissue allocation not only a national, but a trans-national problem
  - Scarcity of donors led to international coalitions
    - *United Network for Organ Sharing* (USA)
    - *EUROTRANSPLANT* (AS, B, D, LUX, NL, Slovenia)
    - *Scandiatransplant* (Denmark, Finland, Iceland, Norway, Sweden)
    - *Donor Action Foundation* (USA, Spain, EUROTRANSPLANT)
  - Variety of regulations
- EU projects only cover data format or networking problems
  - *RETRANSPLANT*, *TECN* (data formats, distributed DB)
  - *ESCULAPE* (tissue histocompatibility)
- Other MAS for organ allocation [Callisti et al], [Moreno et al] do not cover the normative dimension

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A Language for Norms

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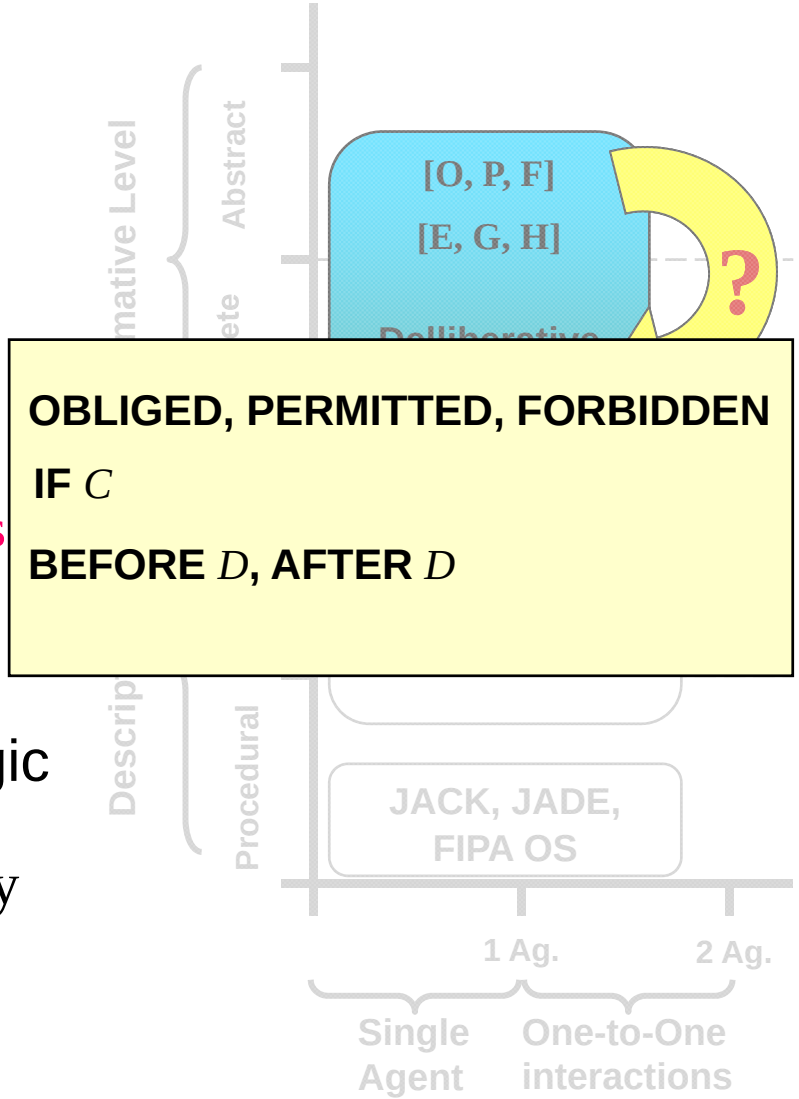
Representing Norms (I)

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



⇒ variant of Deontic Logic

- The representation should be easily parseable and usable by agents

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Representing Norms (II)

- Type 1: *Unconditional norms about predicates*
  - the norms on the value of *P* are active at all times:

$$\text{OBLIGED}(a, P) \qquad \text{PERMITTED}(a, P) \qquad \text{FORBIDDEN}(a, P)$$

  - an example:

$$\text{FORBIDDEN}(recipient, (in\_waiting\_list(hospital_1) \wedge in\_waiting\_list(hospital_2) \wedge (hospital_1 \neq hospital_2)))$$

- Type 2: *Unconditional norms about actions*
  - the norms on the execution of A are active at all times:

$$\text{PERMITTED}(a \text{ DO } A) \qquad \text{FORBIDDEN}(a \text{ DO } A)$$

  - an example:

$$\text{FORBIDDEN}(person \text{ DO } sell(organ))$$

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Representing Norms (III)

- Type 3: *Conditional norms*
  - the activation of the norms is conditional under C
  - C may be a predicate about the system or the state of an action:

$$\begin{array}{ll} \text{OBLIGED}((a, P) \text{ IF } C) & \text{OBLIGED}((a \text{ DO } A) \text{ IF } C) \\ \text{PERMITTED}((a, P) \text{ IF } C) & \text{PERMITTED}((a \text{ DO } A) \text{ IF } C) \\ \text{FORBIDDEN}((a, P) \text{ IF } C) & \text{FORBIDDEN}((a \text{ DO } A) \text{ IF } C) \end{array}$$

  - an example:

$$\begin{array}{l} \text{FORBIDDEN}((allocator \text{ DO } assign(organ, recipient)) \\ \quad \text{IF NOT}(hospital \text{ DONE } ensure\_quality(organ))) \end{array}$$

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Representing Norms (IV)

- Type 4: *Conditional norms with Deadlines*
  - the activation of norms is defined by a deadline

$$\text{OBLIGED}((a, P)\ \text{BEFORE}\ D)$$
$$\text{PERMITTED}((a\ \text{DO}\ A)\ \text{AFTER}\ D)$$
$$\text{FORBIDDEN}((a, P)\ \text{BEFORE}\ D)$$

  - absolute and relative deadlines:

23:59:00 09/05/2004 $time(done(assign(order, recipient))) + 2mins$

  - an example:

$$\text{OBLIGED}((allocator\ \text{DO}\ assign(heart, recipient))$$
$$\text{BEFORE}\ (time(done(extraction(heart, donor))) + 6hours))$$

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Representing Norms (V)

- Type 5: *Obligations of enforcement of norms*
  - norms concerning agent b generate obligations on agent a:

$$\text{OBLIGED}(a\ \text{ENFORCE}(\text{OBLIGED}(b...)))$$
$$\text{OBLIGED}(a\ \text{ENFORCE}(\text{PERMITTED}(b...)))$$
$$\text{OBLIGED}(a\ \text{ENFORCE}(\text{FORBIDDEN}(b...)))$$

  - an example:

$$\text{OBLIGED}(ONT\ \text{ENFORCE}(\text{FORBIDDEN}(person\ \text{DO}\ sell(organ))))$$

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Norms and Agents

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Normative Agents (I)

Ensuring proper agent behaviour with norms

- Medicine is a very sensible domain
  - We mush ensure proper behaviour of agents
  - Agents should keep a certain autonomy

Agents

Autonomy VS **Control**

- We can express agents´ acceptable behaviour with norms

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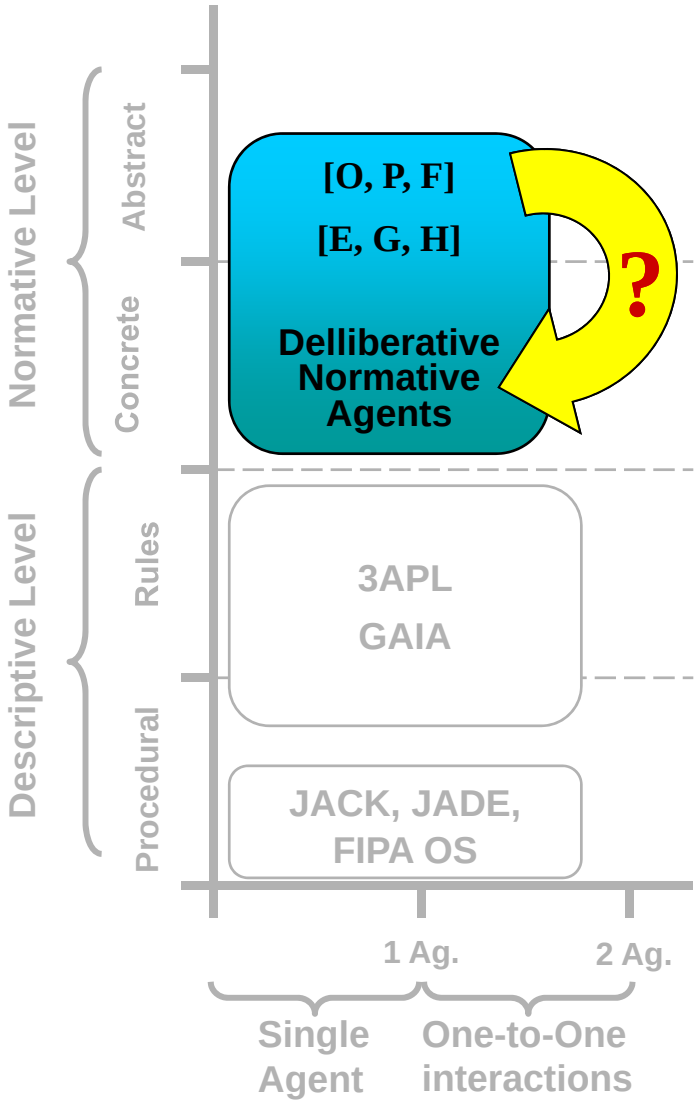
Normative Agents (II)

- Problem 1: Which is the relation between the norms and the agents beliefs, desires and intentions?
- Problem 2: How exactly can norms define acceptable behaviour?
- Idea: We should first analyse the impact of norms on cognitive agents from a theoretical perspective.



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Normative Agents (III)

- Our norms are expressed in deontic logic with proper Kripke semantics
  - Kripke model of the impact of norms
  - Possible worlds
- Our model is composed by 2 dimensions
  - *Epistemic dimension* (states and behaviours as Possible Worlds)
  - *Normative dimension* (norms applying to the agent)

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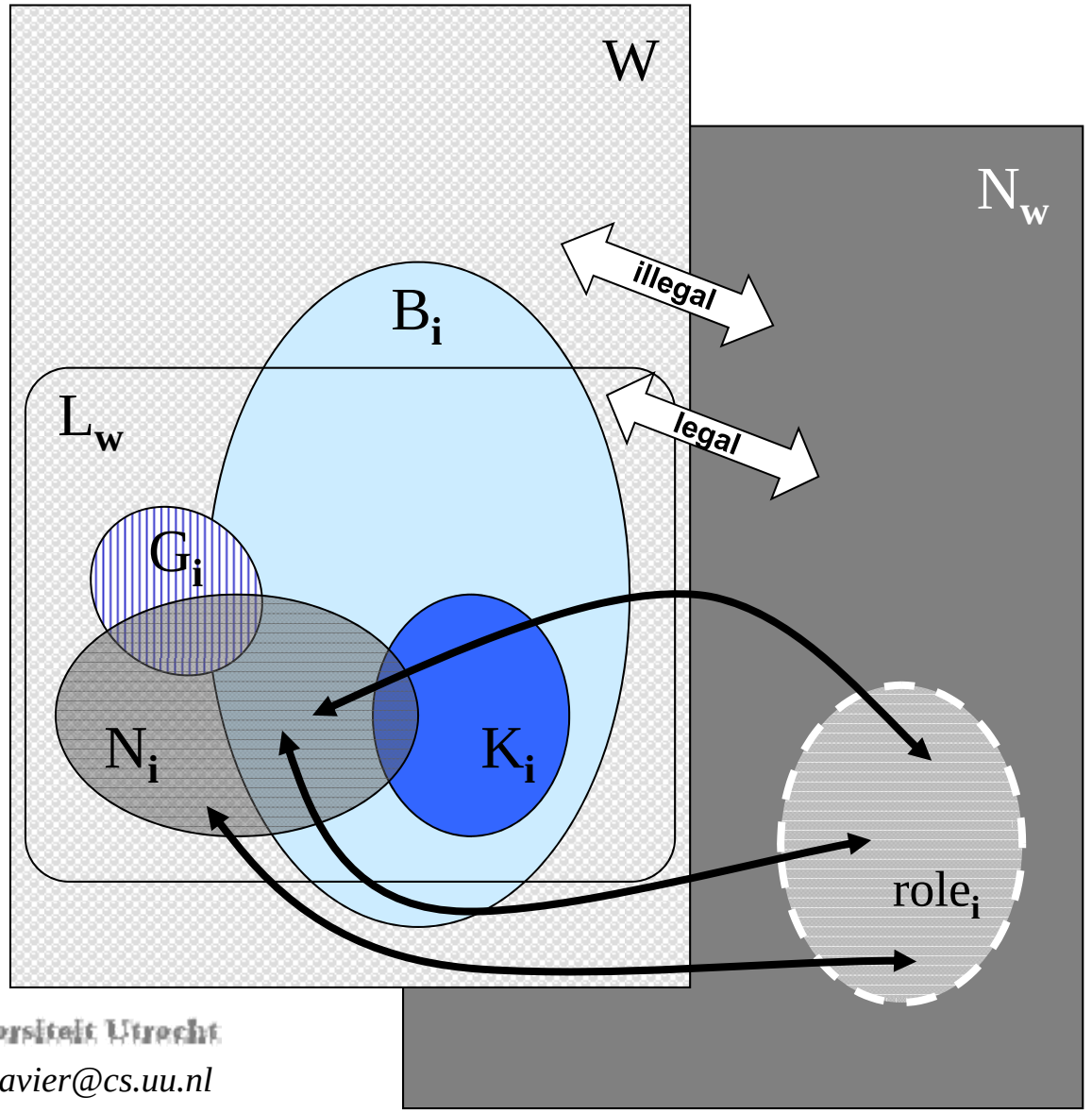
Normative Agents (IV)



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Normative Agents (V)

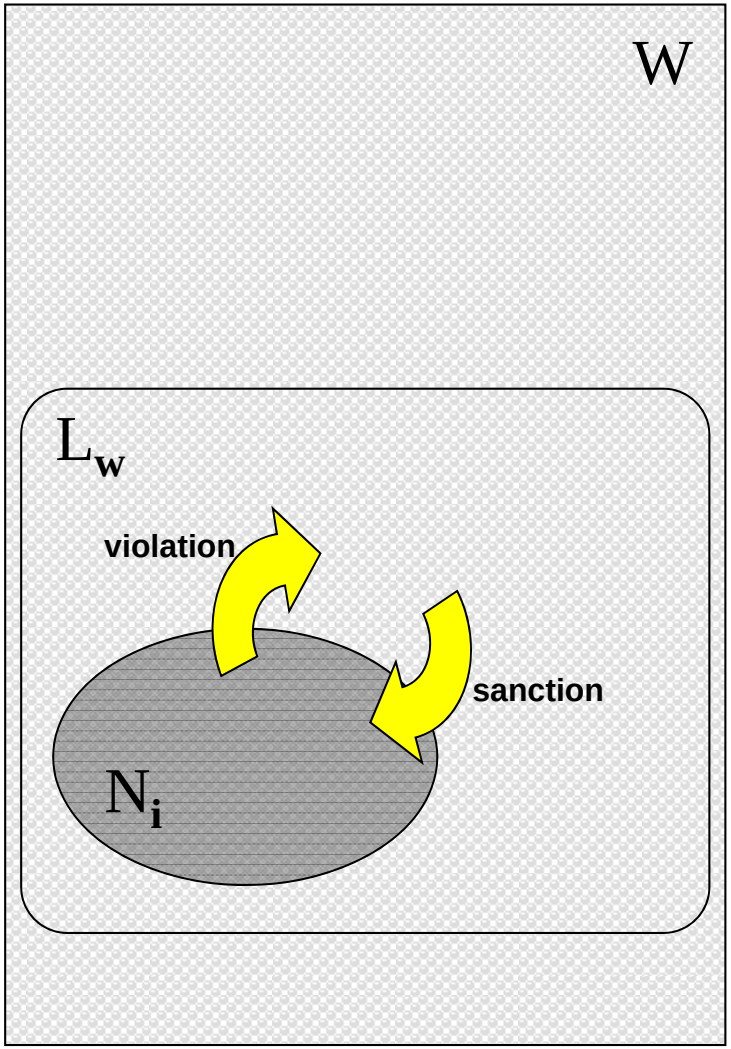
Safety and Soundness

- The concept of legally accessible worlds allows to describe
  - wanted (legal) and unwanted (illegal) behaviour
  - acceptable (safe) and unnacceptable (unsafe) states
- *Violations* when agents breaks one or more norms, entering in an illegal (unsafe) state.
- *Sanctions* are actions to make agents become legal (safe) again.

Safety

- Sanctions include the actions to recover the system from a violation

Soundness



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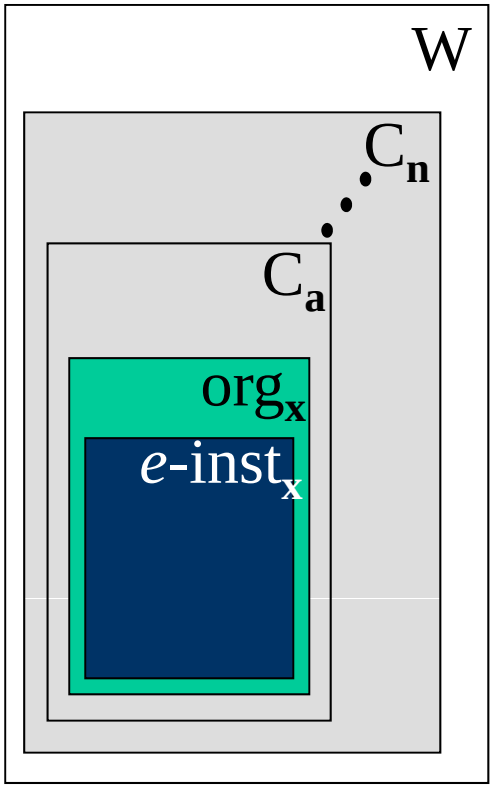
Normative Agents (VI)

Context

- In real domains norms are not universally valid but bounded to a given context.
  - HC norms bounded to trans-national, national and regional contexts
- A Context is a set of worlds with a shared vocabulary and a normative framework
  - *e*-inst$_X$ is a context defining a ontology and a normative specification
- Usually nested contexts
  - there are super-contexts that have an influence in *e*-inst$_X$ ontology and norms
- Special impact on the Ontologies
  - Proposal: not to force a single representation for all contexts, but interconnected ontologies (multi-contextual ontologies).



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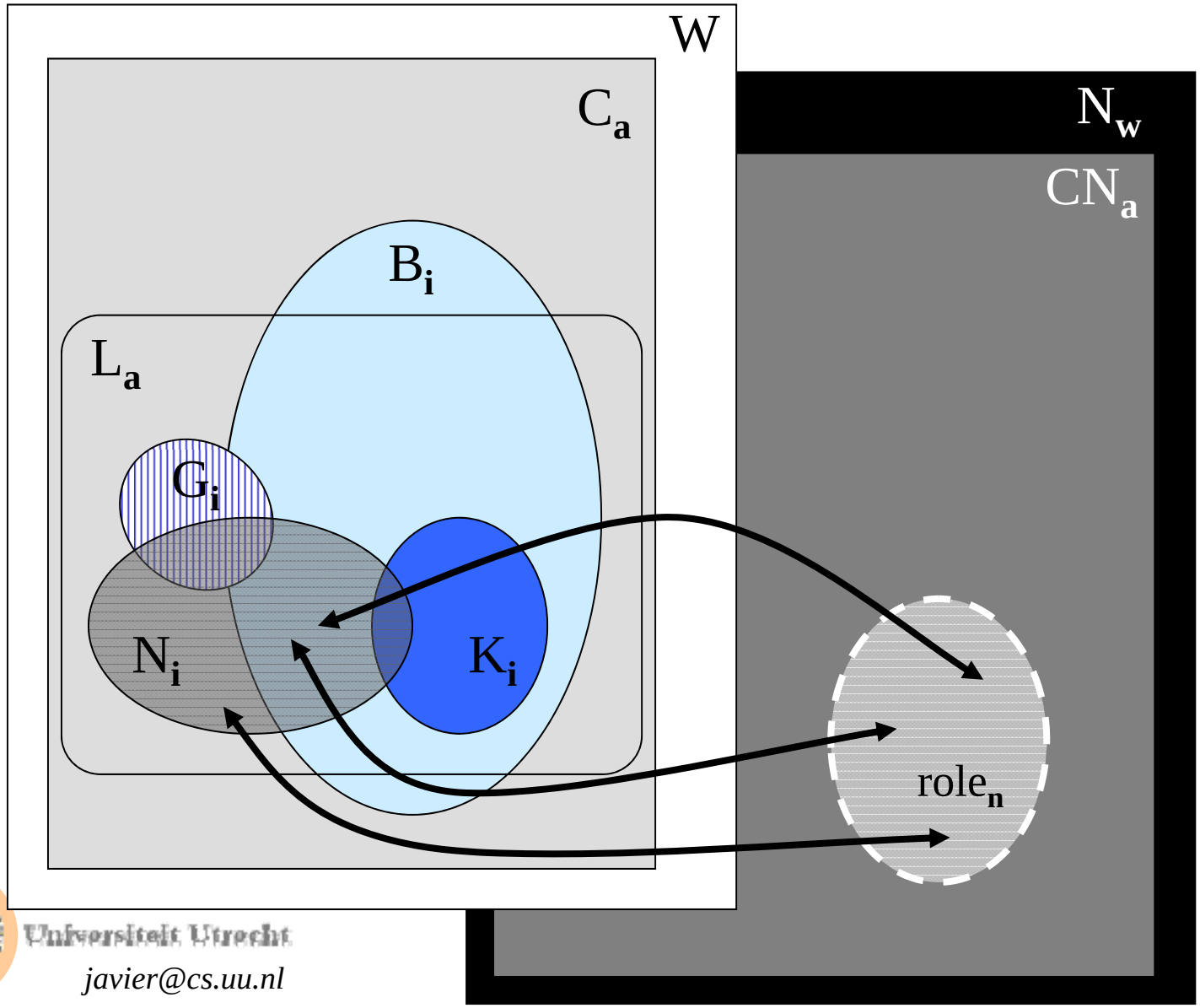
Normative Agents (VII)



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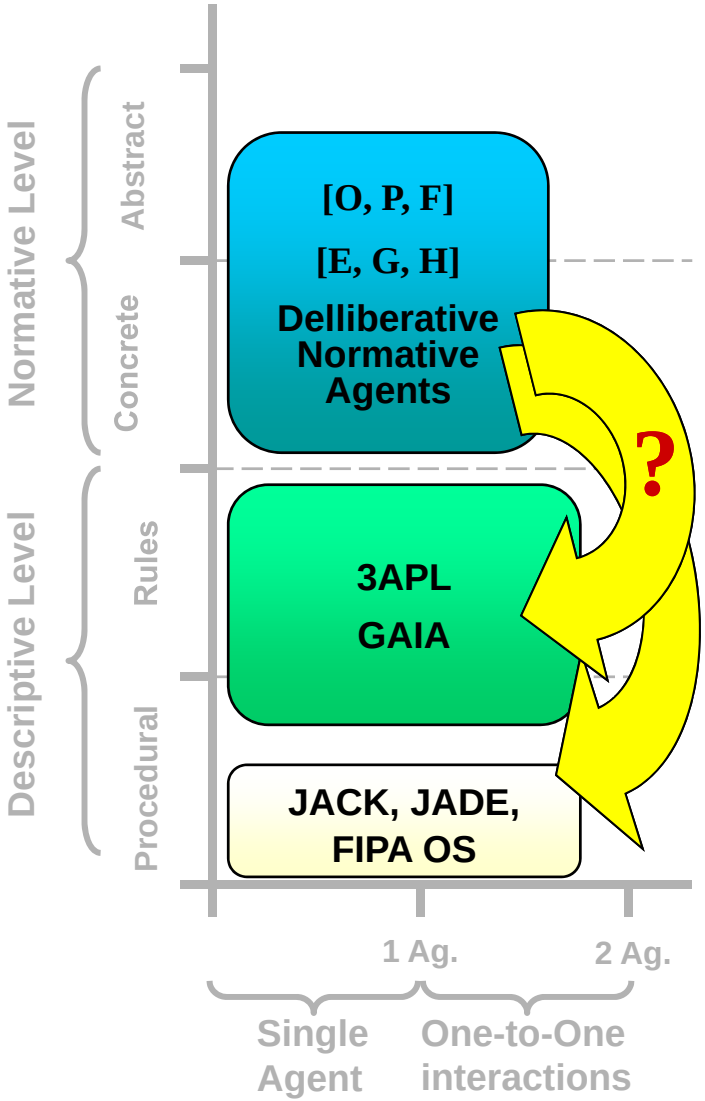
Implementing Normative Agents (I)

- Problem: HOW to introduce norms in the existing agent implementations?
- There are already implementations based in the BDI agent framework
  - E.g., 3APL agents , JACK agents, JADEx agents.
- Idea: Extend the BDI interpreter to include norms.



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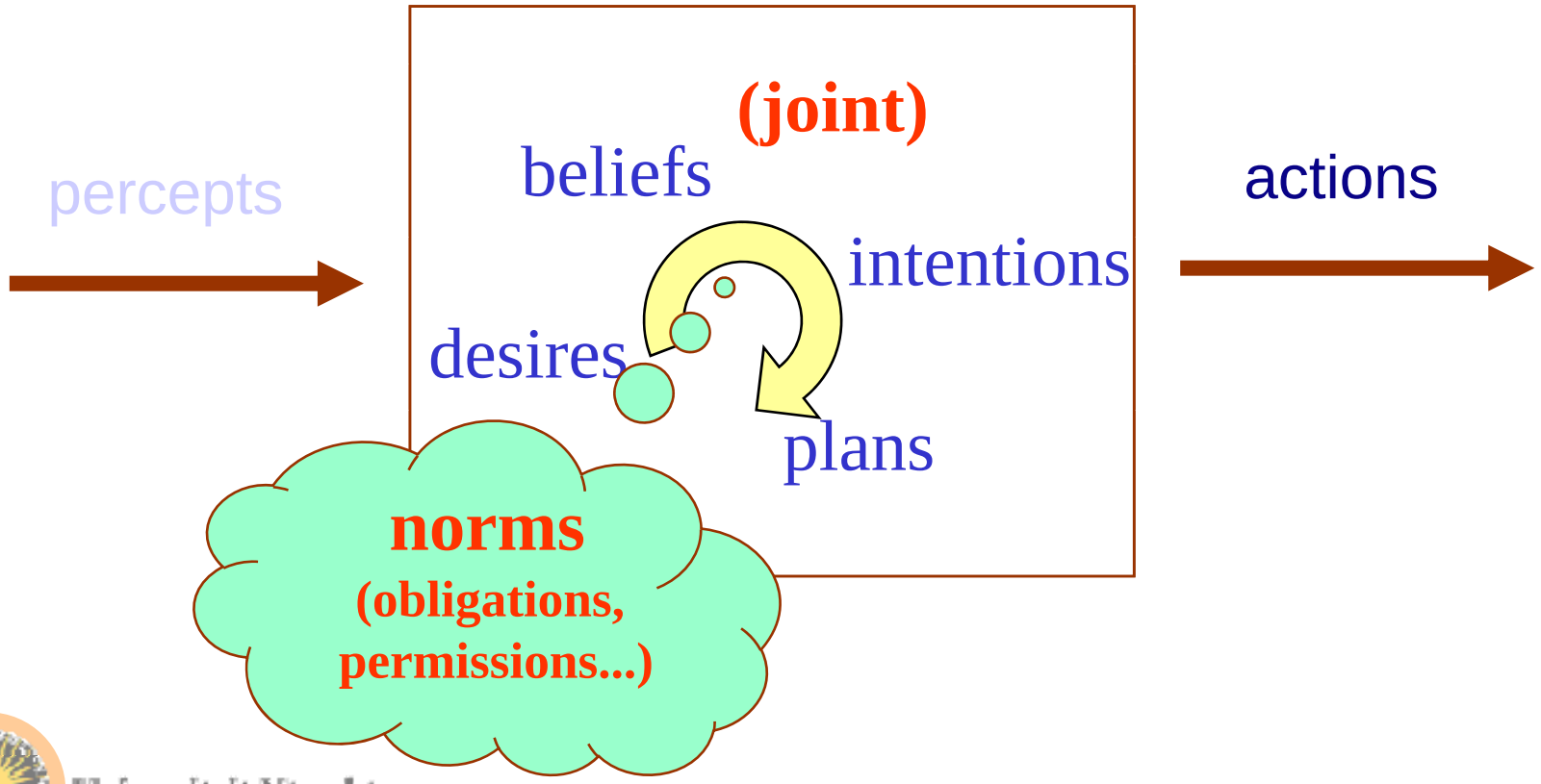
Implementing Normative Agents (II)

Influence of norms in the BDI deliberation cycle



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Implementing Normative Agents (III)

Operationalization of Norms

- 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: FORBIDDEN(discriminate(x,y,age))

Procedure: does not contain action "discriminate"

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Implementing Normative Agents (IV)

Standard BDI interpreter

```
B := B_init;
I := I_init;
while (true)
{
    get_perception(perc);
    B := belief_revision(B,perc);
    D := options(B,I);
    I := filter(B,D,I);
    plan = generate_plan(B,I);
    execute(plan);
}
```

Problems:

- too simple
- there is no new perception until the previous plan has been executed
    - overcommitment
- no support for norms

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Implementing Normative Agents (V)

Extending the BDI interpreter with norms

```
B := B_init;
I := I_init;
while (true)
{
    get_perception(perc);
    B := belief_revision(B,perc);
    D := options(B,I,oblEvents);
    I := filter(B,D,I,oblRestr);
    plan = find_plan(B,I);
    while not( empty(plan) OR succeeded(I,B)
               OR impossible(I,B)
    {
       action = next_action(plan);
       execute(action);
       get_perception(perc);
       B :=belief_revision(B,perc);
       if reconsider(I,B,oblEvents) then
       {
          D := options(B,I,oblEvents);
          I := filter(B,D,I,oblRestr);
       }
       if not(sound(plan,I,B)) then
       {
          plan = find_plan(B,I);
       }
    }
}
```

`options` considers also the obligation events imposing new actions

`filter` restricts unwanted actions. Checks not only feasibility but also legal allowance.

`reconsider` decides when to check intentions and action plans

`sound` checks if plan is still applicable. Avoids overcommitment to plans

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Norms in Agent Platforms:

Electronic Institutions

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Electronic Institutions (I)

- Need of a safe environment where proper behaviour is enforced.
- 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).

  – Agent **behaviour guided by Norms**

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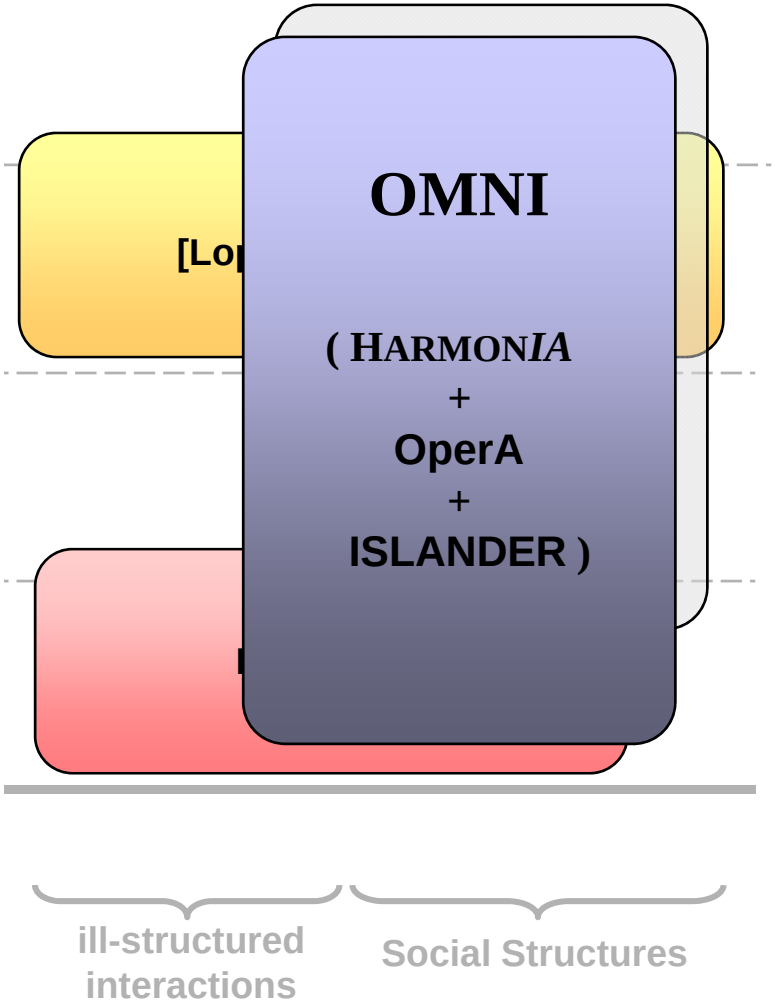
Electronic Institutions (II)

- Problem: no connection between theoretical work on eInstitutions and practical implementations on eInstitutions
- First proposal: the **HARMON*IA*** framework
- Ongoing work: the **OMNI** framework



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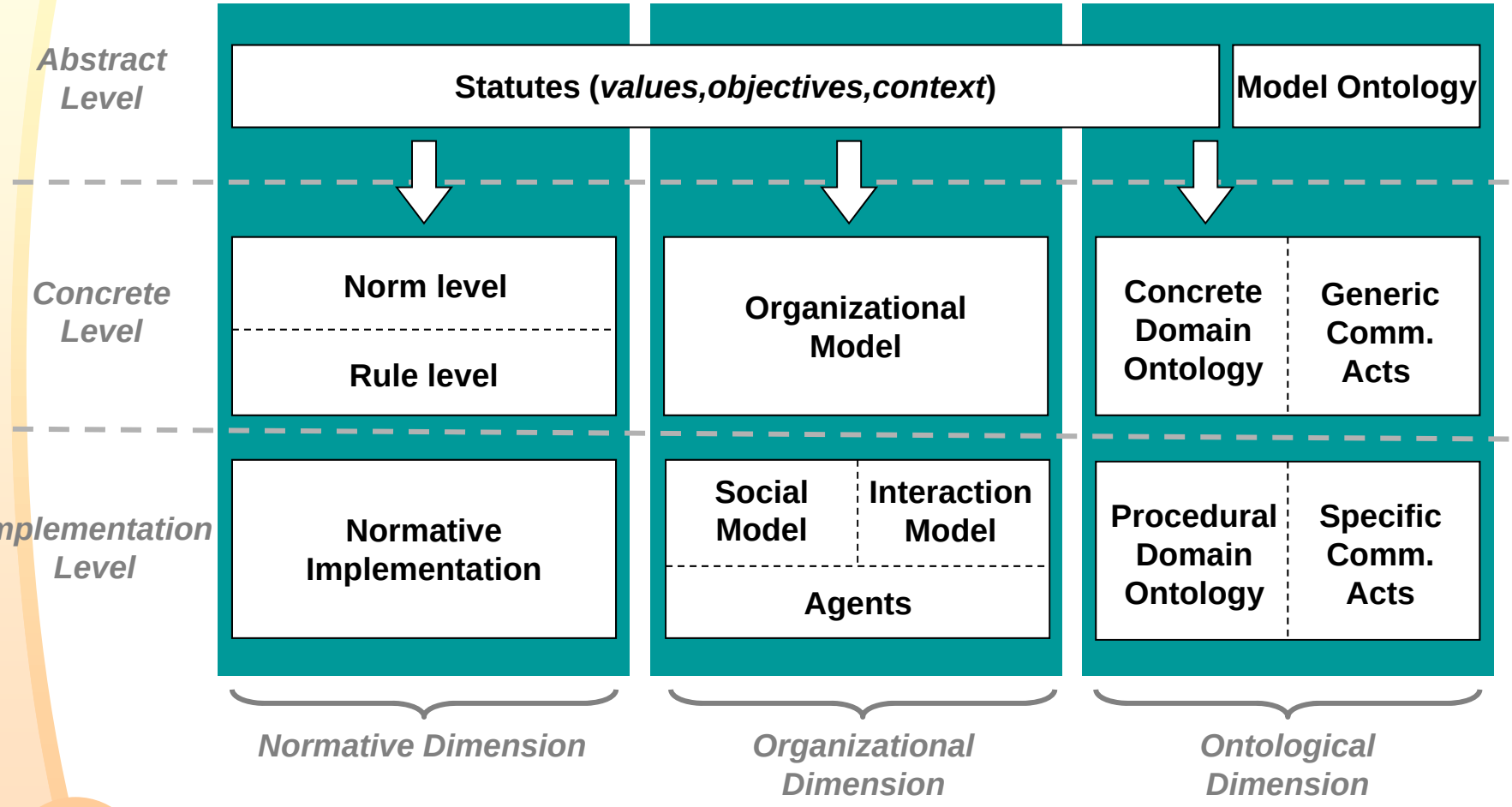
Electronic Institutions (III)

The OMNI framework



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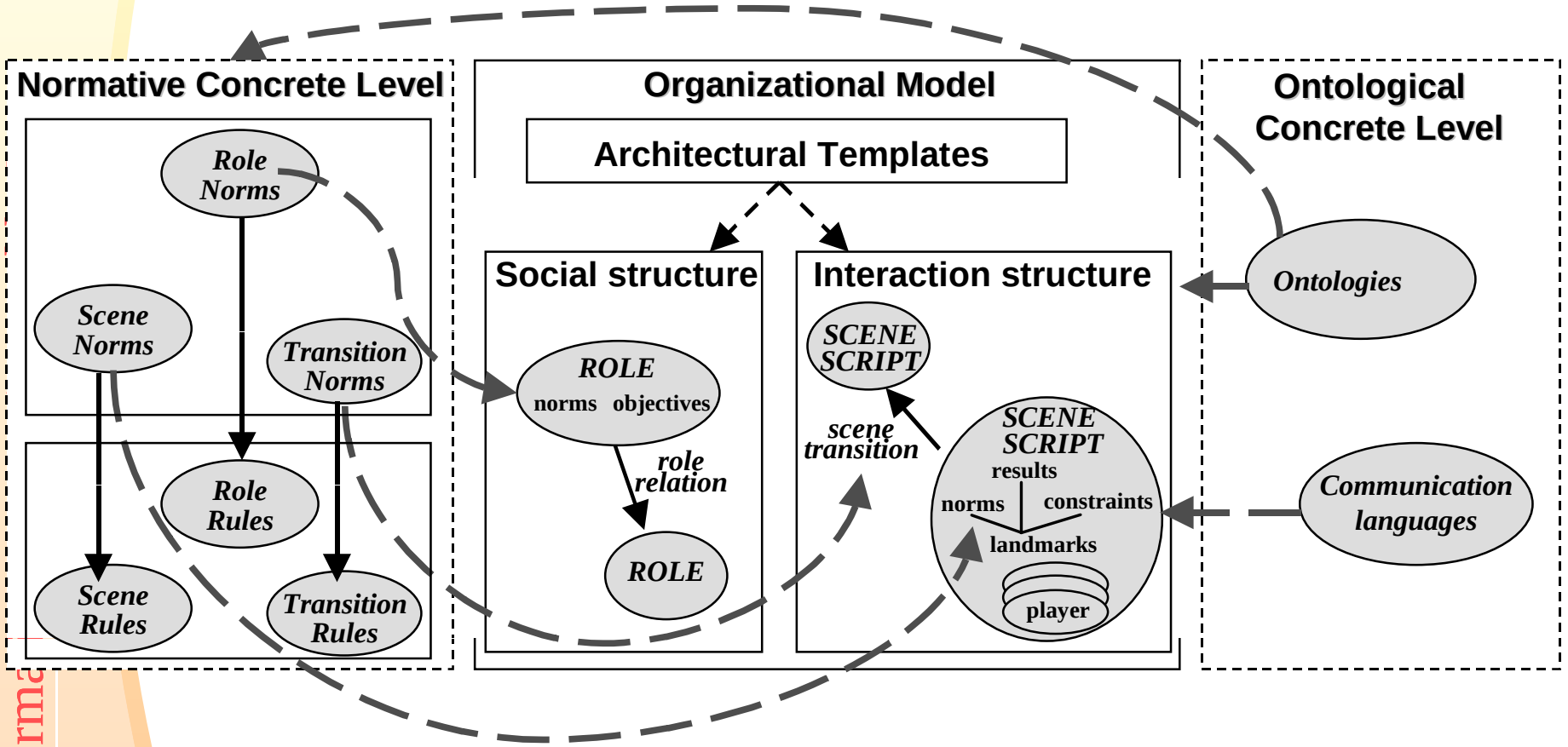
Electronic Institutions (III)

The OMNI framework



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Implementing Norms in eInstitutions (I)

- Implementation of norms from institutional perspective ≠ Implementing a theorem prover to check protocol compliance
- Implementation of a safe environment (***norm enforcement***)
- 2 options depending on control over agents
  - Defining constraints on unwanted behaviour
  - Defining violations and reacting to these violations
- our assumptions:
  - Norms can be sometimes violated by agents
  - The internal state of agents is neither observable nor controlable
    - actions cannot be imposed on an agent´s intentions
    - agents as black boxes
    - only their observable behaviour and actions

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Implementing Norms in eInstitutions (II)

- Norms describe which states/actions within the e-organization should ideally take place
- Norms are too abstract, no operational
  - A norm implementation is composed by:

Norm condition	FORBIDDEN($allocator$ DO $assign(organ, recipient)$) IF NOT($hospital$ DONE $ensure\_quality(organ)$))
Violation condition	NOT($done(ensure\_quality(organ))$ AND $done(assign(organ, recipient))$
Detection mechanism	$\{detect\_alarm(assign,'starting');$ $check(done(ensure\_quality(organ)));\}$
Sanction	$inform(board,$"NOT($done(ensure\_quality(organ))$ AND $done(assign(organ, recipient))$")
Repairs	$\{stop\_assignation(organ);$ $record($"NOT($done(ensure\_quality(organ))$ AND $done(assign(organ, recipient))$", $incident\_log);$ $detect\_alarm(ensure\_quality,'done');$ $check(done(ensure\_quality(organ)));$ $resume\_assignation(organ);\}$

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Implementing Norms in eInstitutions (II)

- Norm enforcement is not centralized but distributed in a set of agents, the Police Agents
  - They check if a given (observable) action was legal or illegal given the violation conditions defined for that context.
- The Agent Platform should assist the Police Agents, providing fast, very efficient aids for norm enforcement as additional platform services and mechanisms.
- *A) Detection of the occurrence of an action*
  - Police Agents may become overloaded checking ALL actions
  - **black list mechanism** (of actions to monitor) *e.g., assign*
  - **action alarm mechanism** (alarm to the Police Agent)
  - The Police Agent checks if conditions for a violation apply.

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Implementing Norms in eInstitutions (III)

- *B) Detection of activation/deactivation of norms*
  - activation = when condition C is true
  - deactivation = when P holds, A is done or C is false
  - reaction time: time allowed between norm activation and reaction
  - Depending on the complexity to check C, the platform should implement the apropriate **fast-access data structures** and/or **processing mechanisms** to reduce Police Agents´computation burden
- *C) Deadline control*
  - a **clock trigger mechanism** to detect that a deadline has passed

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Conclusions and Challenges

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Conclusions

- New systems interconnected in distributed scenarios
  - E.g. Health Care services
- Need to explicitly handle the problem of
  - variety of regulations
  - trust, coordination and communication between agents of different systems
- Proposal of a language for norms
- Concept of Normative Agents.
  - Norms to define acceptable behaviour
  - Impact on the agent implementation
- Concept of Electronic Institutions
  - Norms to build a safe environment
  - Implementation of enforcement mechanisms
    - Police Agents and platform services

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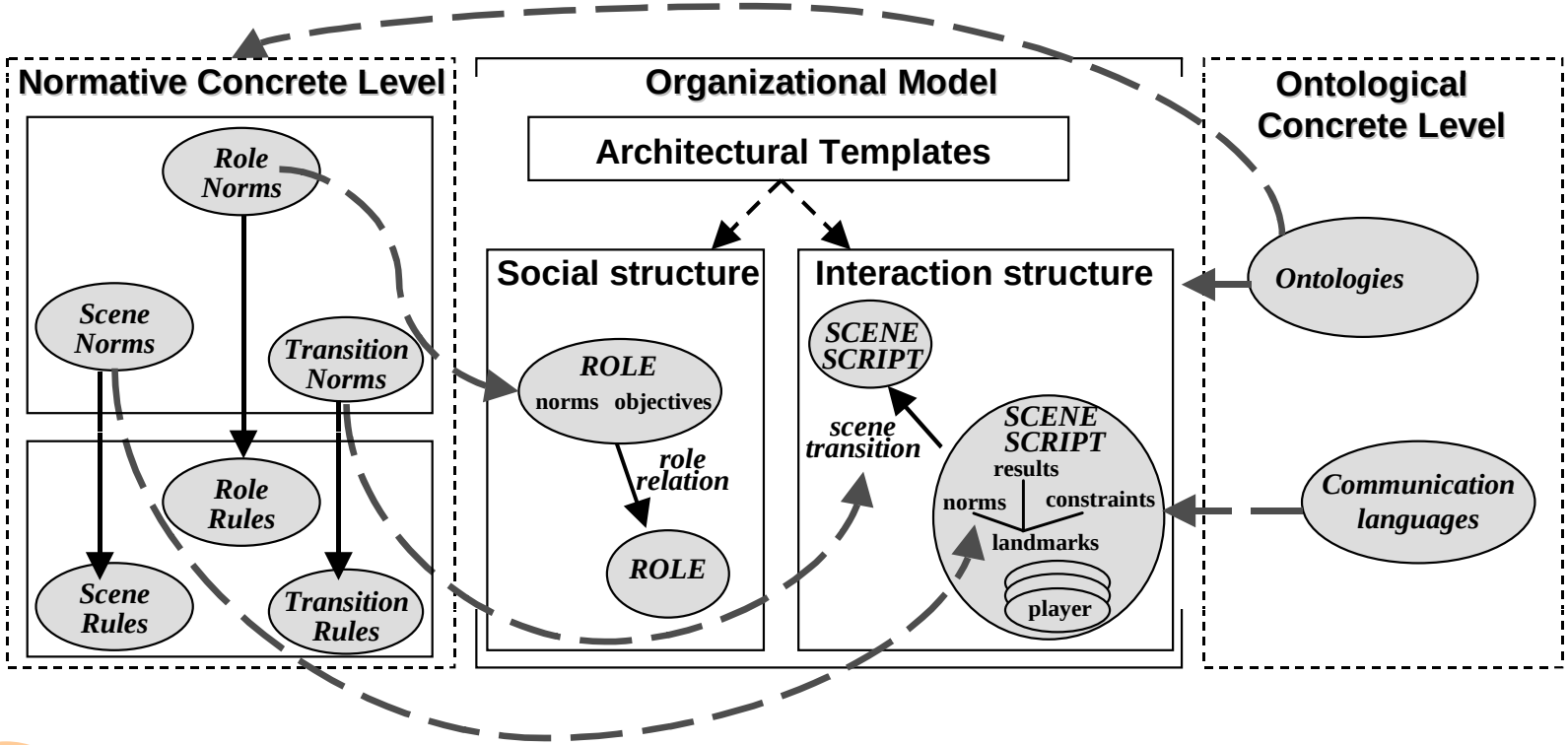
Challenges (I)

- Human trust on MAS technologies
- Creation of tools



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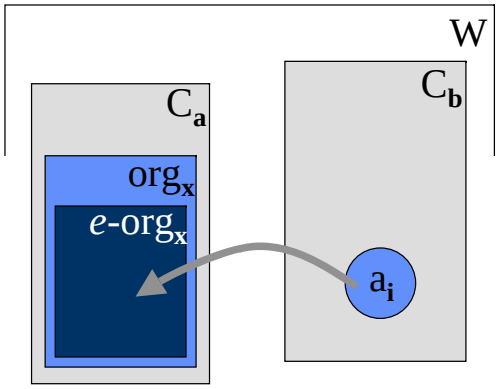
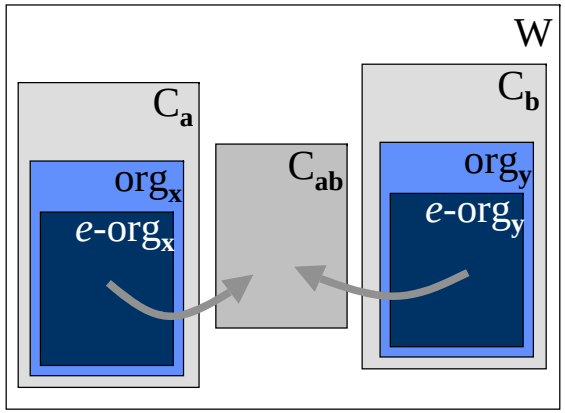
Challenges (II)

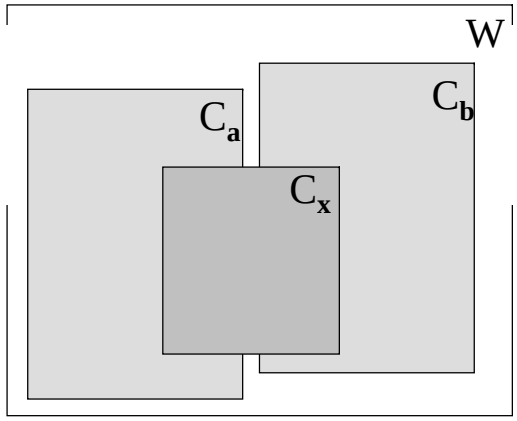
- Multi-level, multi-contextual ontologies



a) change of context



b) consensus



c) colision in context definition

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