Normative Agents in Health Care

Normative Agents in Health Care: Uses and Challenges

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Invited talk

ECAI 2004

Second Workshop on Agents Applied in Health Care

Motivation

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Motivation (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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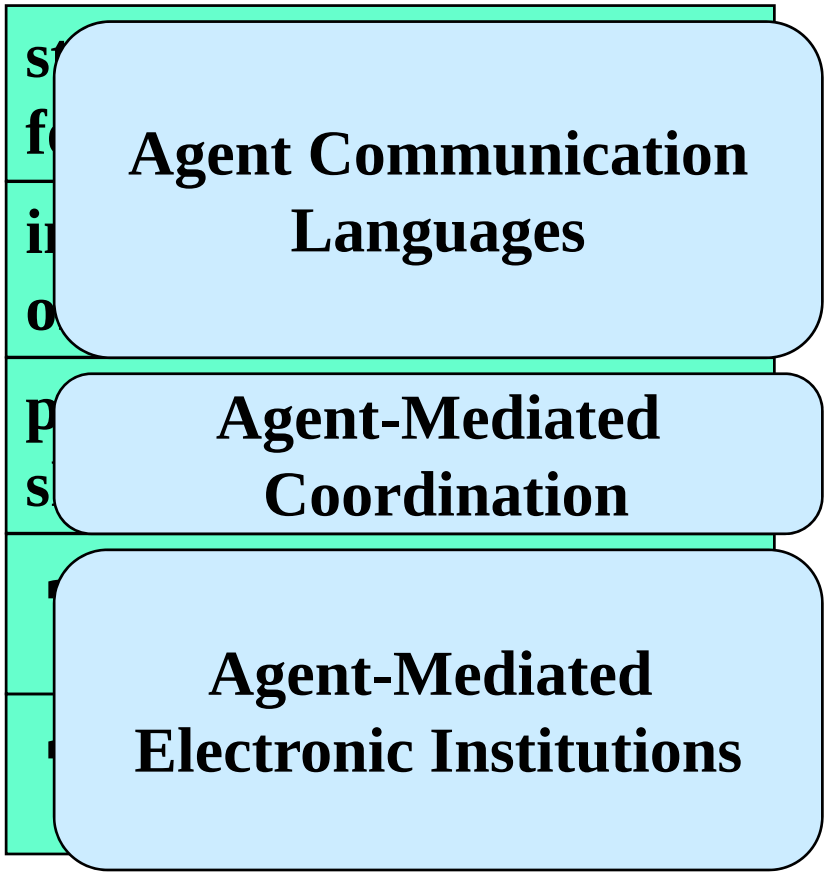
Motivation (II)

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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Contents

- A Language for Norms
- Normative Agents
- Norms and Agent Platforms: Electronic Institutions
- Conclusions and Challenges

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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

OBLIGED, PERMITTED, FORBIDDEN

IF *C*

BEFORE *D*, **AFTER** *D*

→ variant of Deontic Logic

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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)

- We should first analyse the impact of norms on cognitive agents
- 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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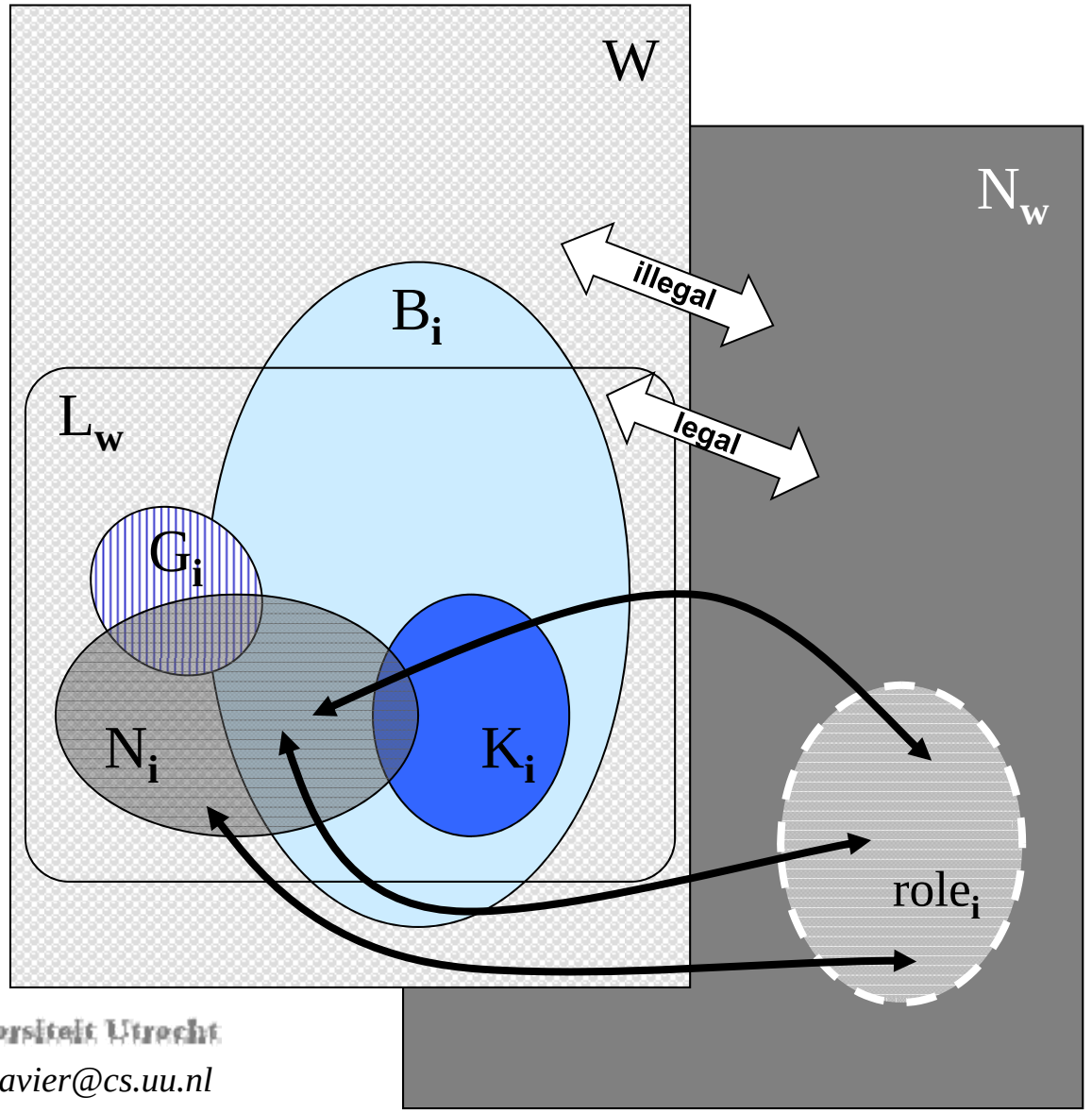
Normative Agents (III)



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Normative Agents (IV)

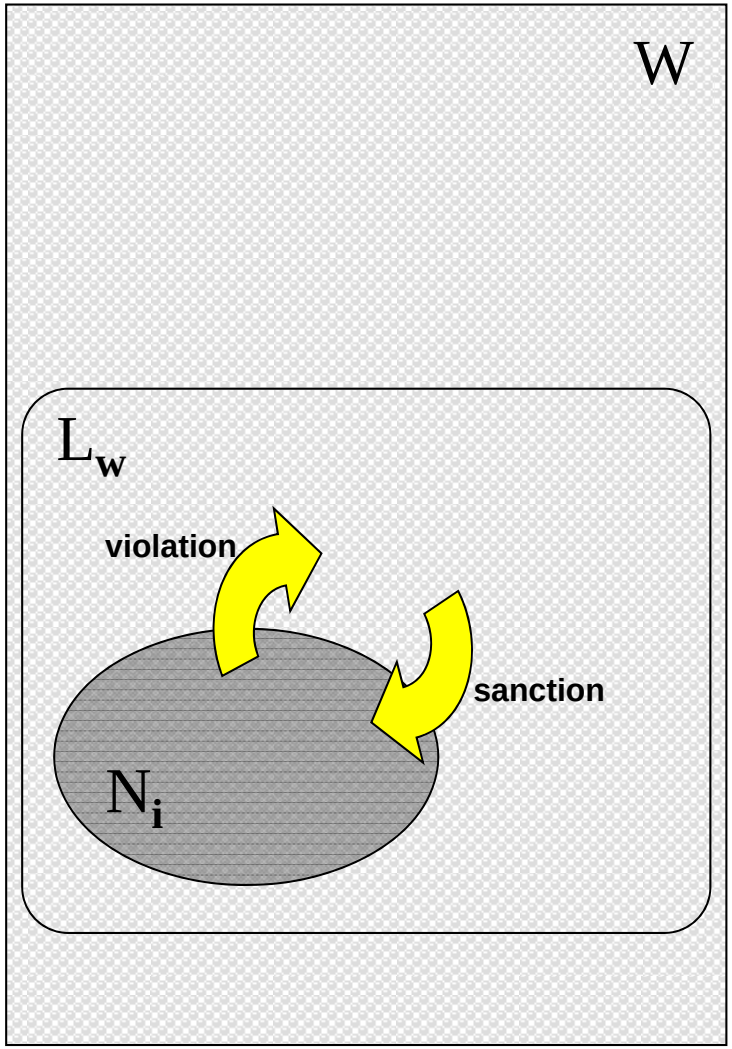
Safety and Soundness

- 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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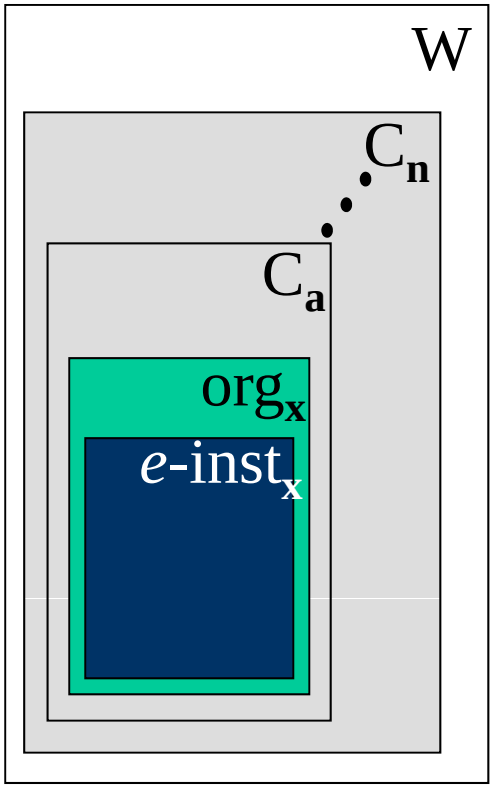
Normative Agents (V)

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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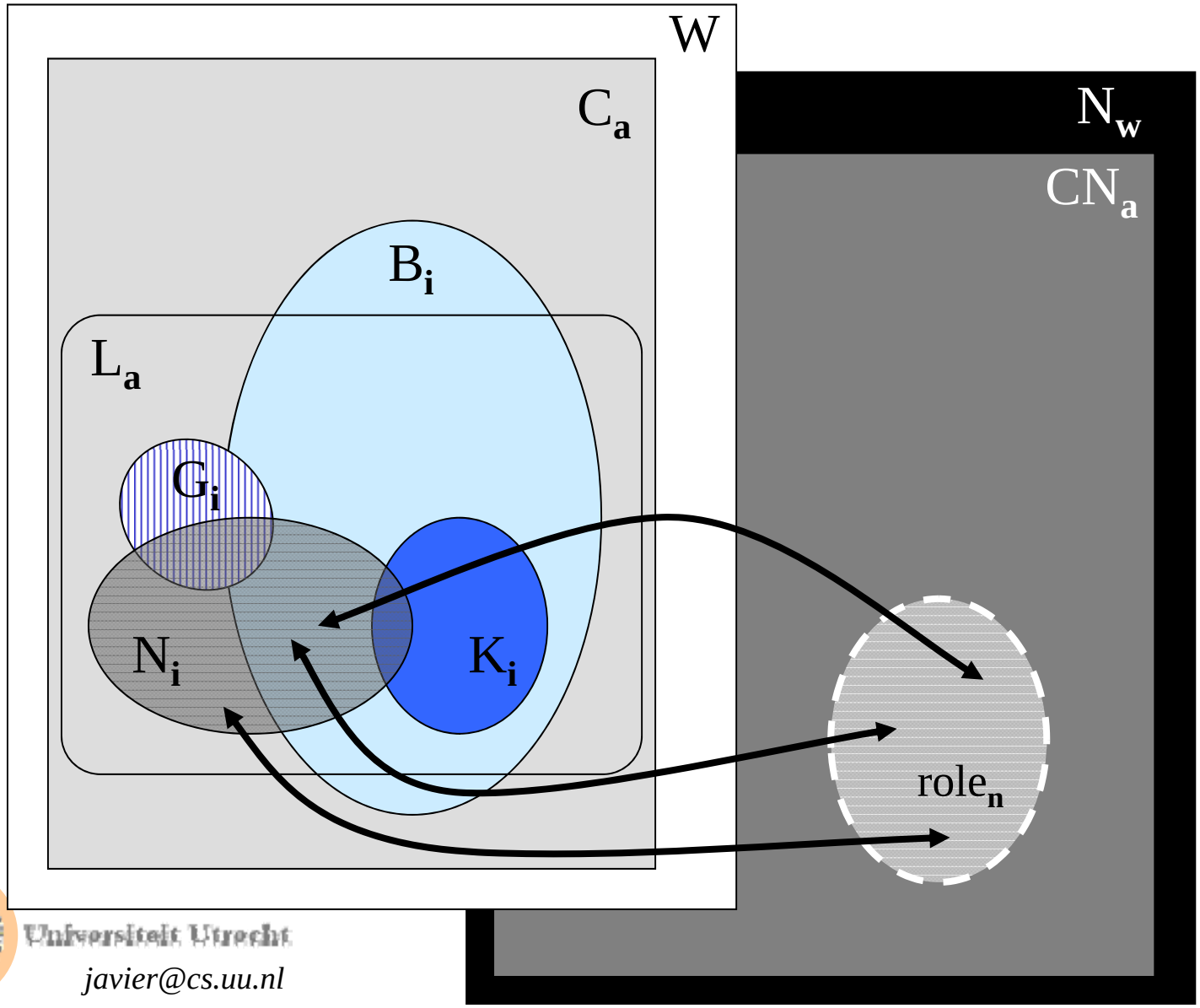
Normative Agents (VI)



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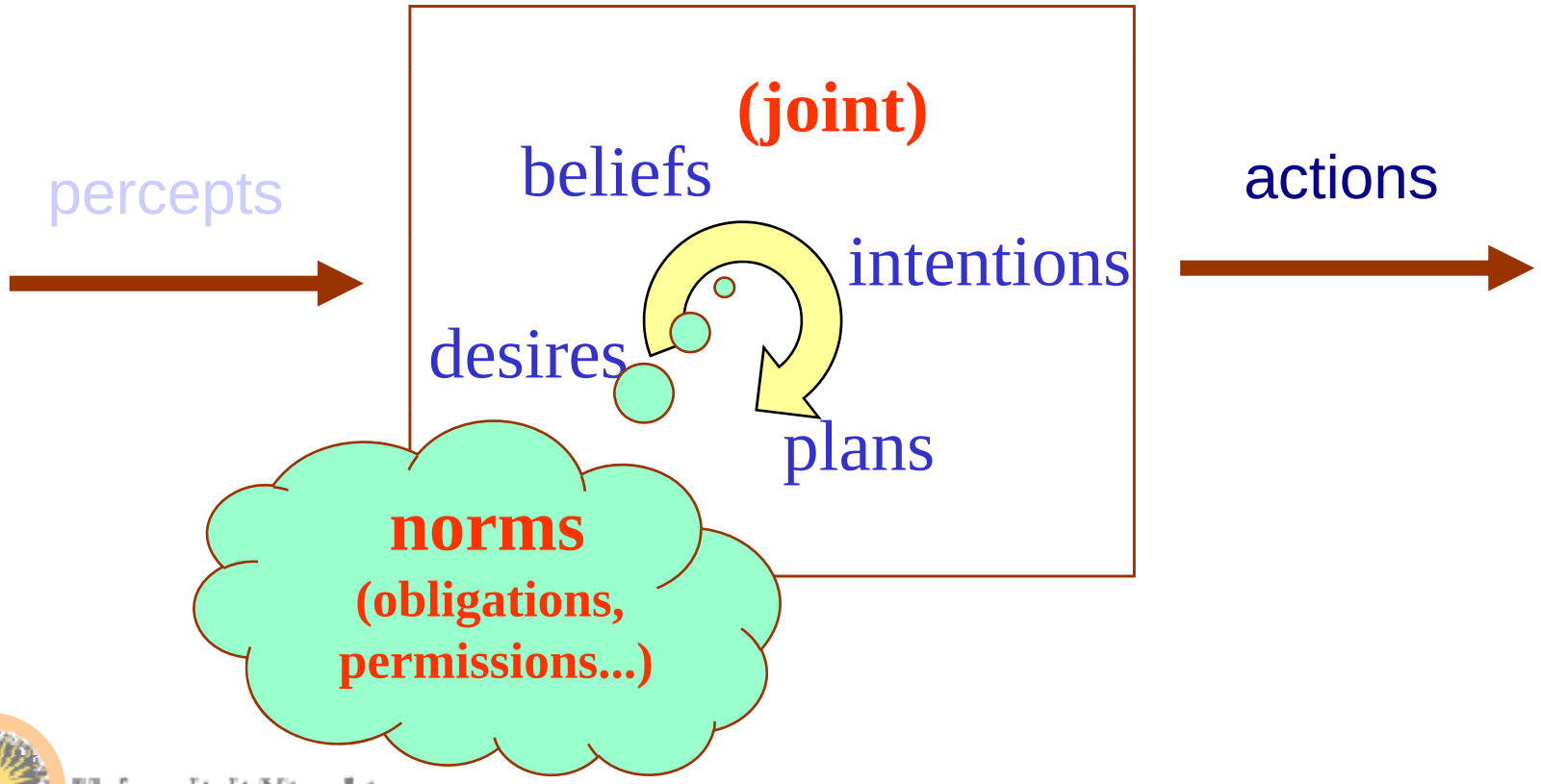
Implementing Normative Agents (I)

Influence of norms in the BDI deliberation cycle



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Implementing Normative Agents (II)

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 (III)

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 (IV)

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). 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**

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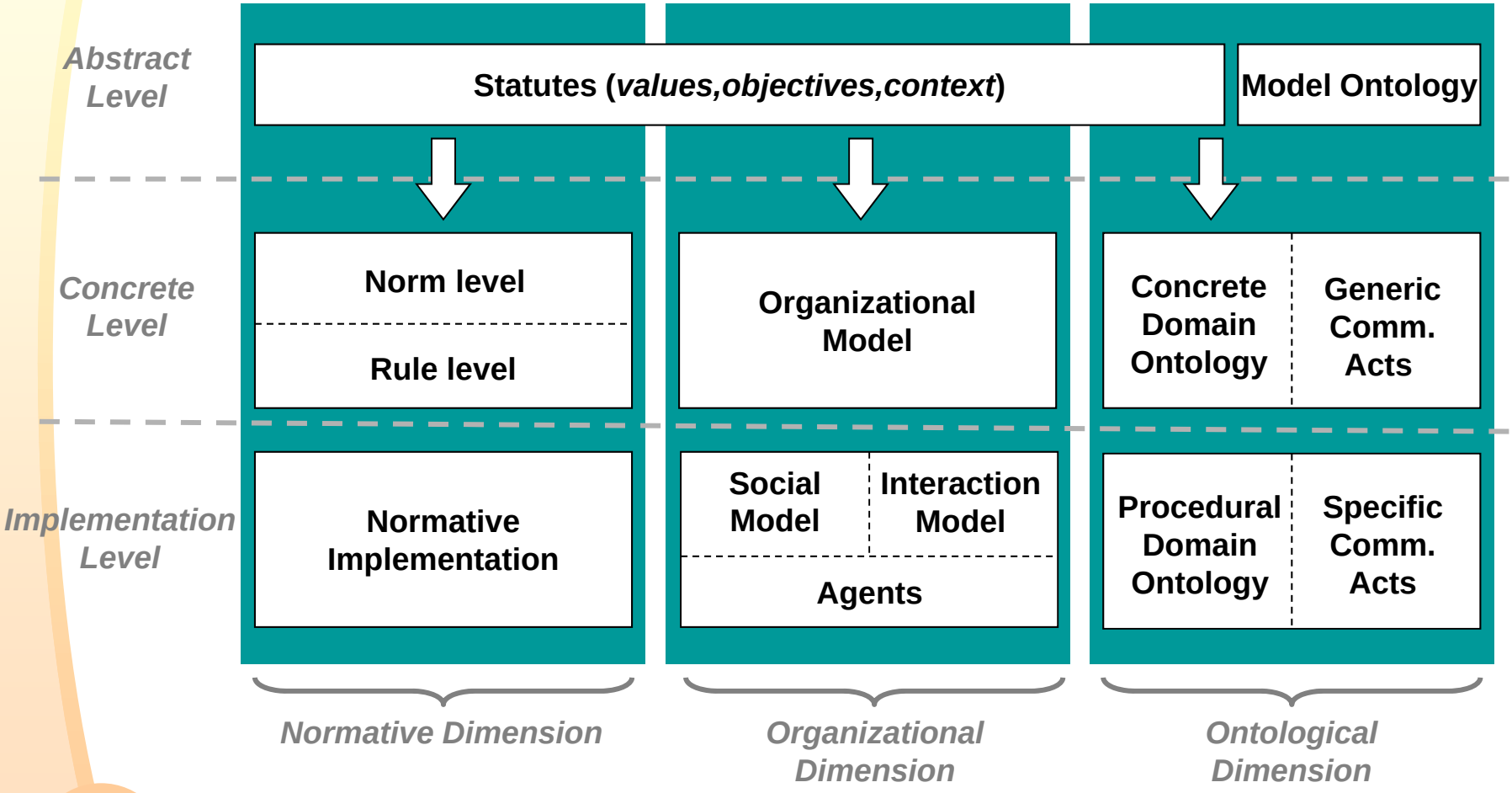
Electronic Institutions (II)

The OMNI framework



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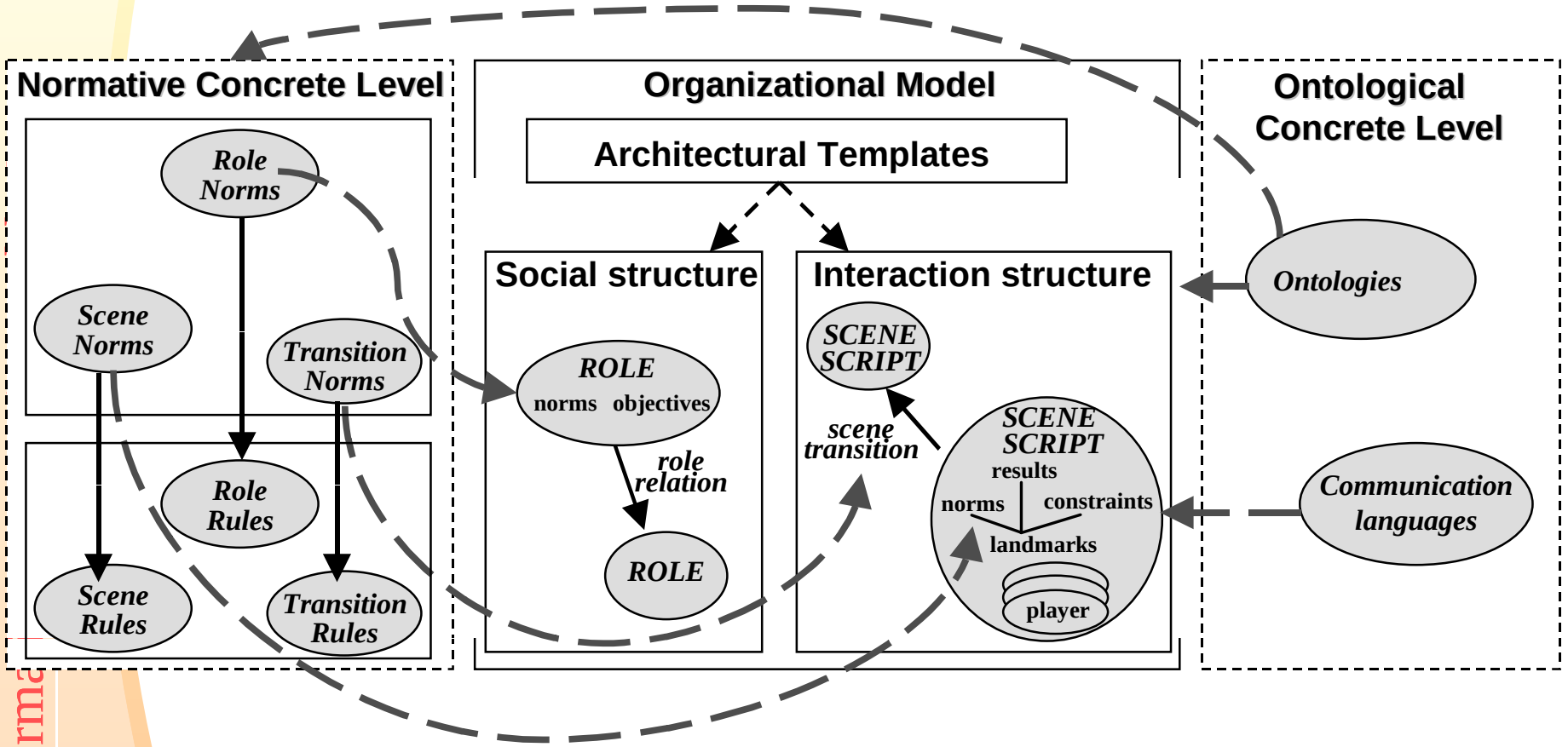
Electronic Institutions (II)

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 Health Care services interconnnected in trans-national scenarios
- Need to explicitly handle the problem of
  - variety of regulations
  - trust, coordiantion 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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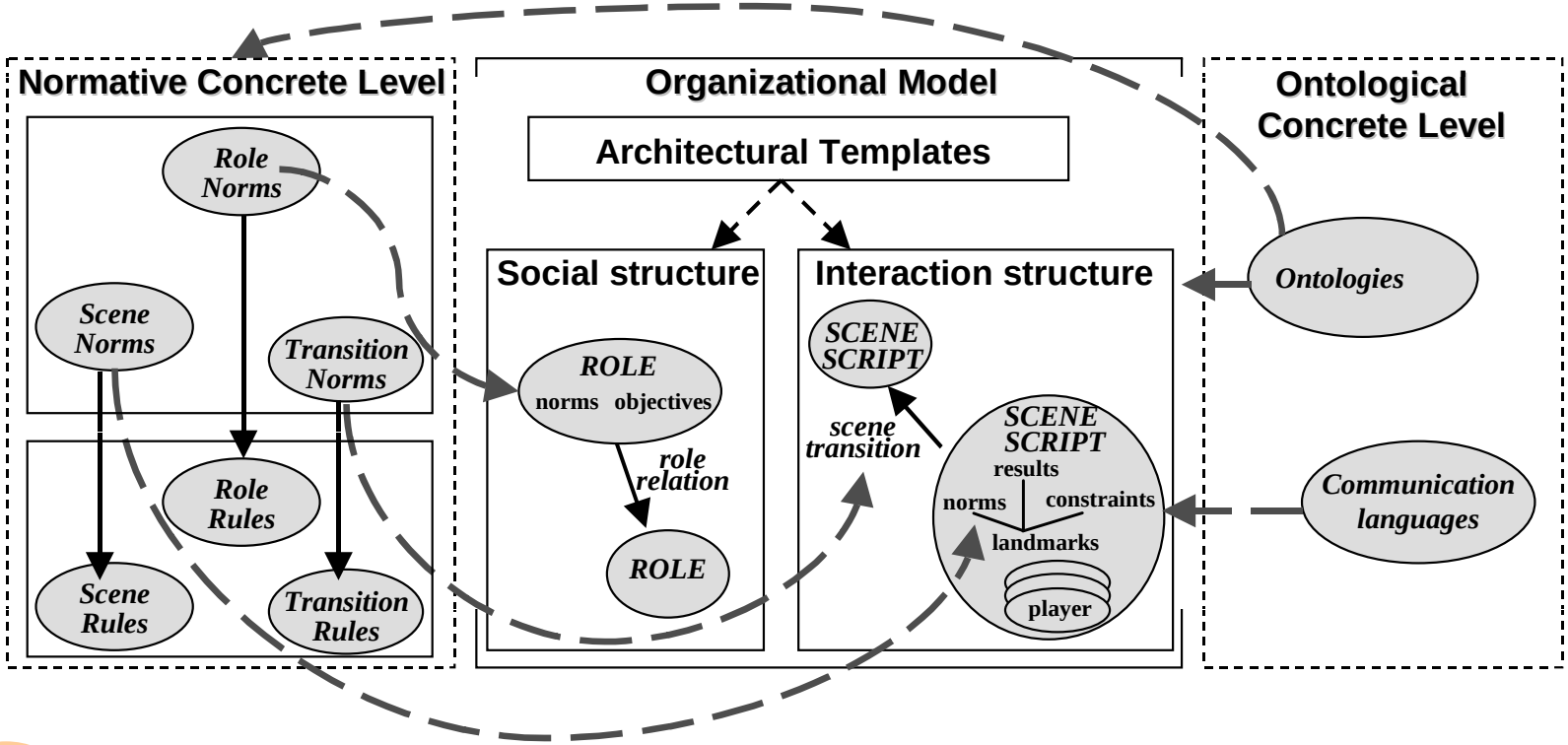
Challenges (I)

- Human trust on MAS technologies
- Creation of tools



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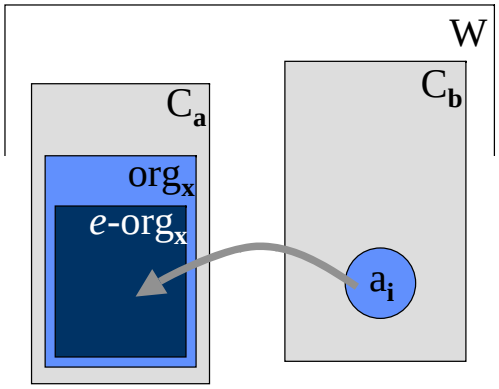
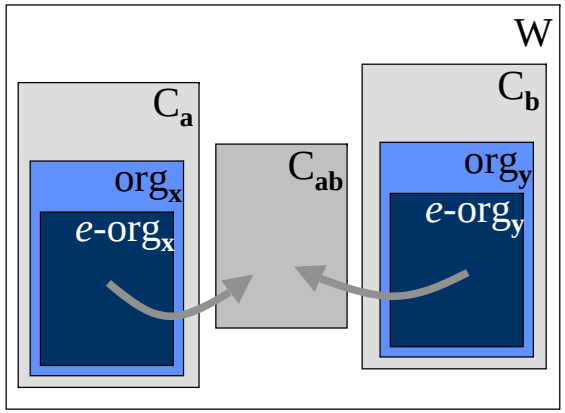
Challenges (II)

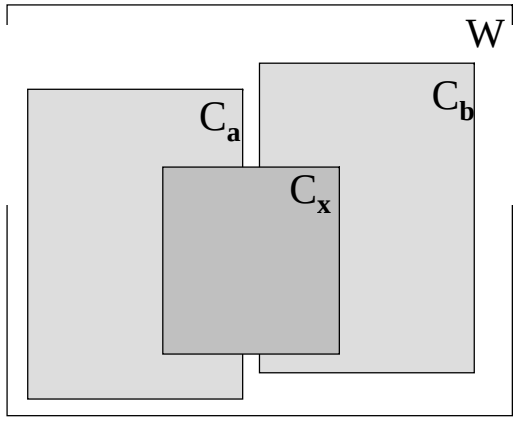
- Multi-level, multi-contextual ontologies



a) change of context



b) consensus



c) colision in context definition

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