

# Multi-Agent Programming

– Organisation –

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CPS2 M1 – Fall 2020



# Tutorial Organisation

- ▶ Introduction
  - ▶ Multi-Agent Systems
  - ▶ Multi-Agent Oriented Programming (MAOP)
- ▶ Agent
  - ▶ Concepts and approaches
  - ▶ Programming agents in a shared working environment
- ▶ Agent working environment
  - ▶ Concepts and approaches
  - ▶ Programming agents and their working environment
- ▶ Agent organisation
  - ▶ Concepts and approaches
  - ▶ Programming organisations of agents
- ▶ Integrating Intelligent Systems with MAS
- ▶ Conclusion & Perspectives

Multi-Agent Oriented Programming  
**Agent Organization: concepts and approaches**

# Outline

Fundamentals

Existing approaches

# Intuitive notions of organisation

- ▶ Organisations are structured, patterned systems of activity, knowledge, culture, memory, history, and capabilities that are distinct from any single agent [Gasser, 2001]  
↳ Organisations are **supra-individual** phenomena
- ▶ A decision and communication schema which is applied to a set of actors that together fulfill a set of tasks in order to satisfy goals while guarantying a global coherent state [Malone, 1999]  
↳ definition by the designer, or by actors, to achieve a **purpose**
- ▶ An organisation is characterized by : a division of tasks, a distribution of roles, authority systems, communication systems, contribution-retribution systems [Bernoux, 1985]  
↳ **pattern of predefined cooperation**
- ▶ An arrangement of relationships between components, which results into an entity, a system, that has unknown skills at the level of the individuals [Morin, 1977]  
↳ **pattern of emergent cooperation**

# Organisation in MAS

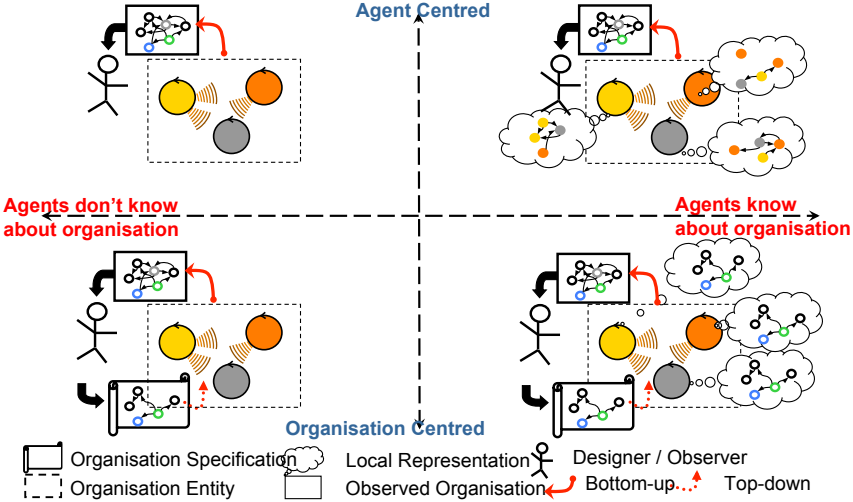
## Definition

Purposive **supra-agent** pattern of emergent or (pre)defined agents cooperation, that could be defined by the designer or by the agents themselves.

- ▶ Pattern of emergent/potential cooperation
  - ▶ called **organisation entity**, institution, social relations, commitments
- ▶ Pattern of (pre)defined cooperation
  - ▶ called **organisation specification**, structure, norms, ...

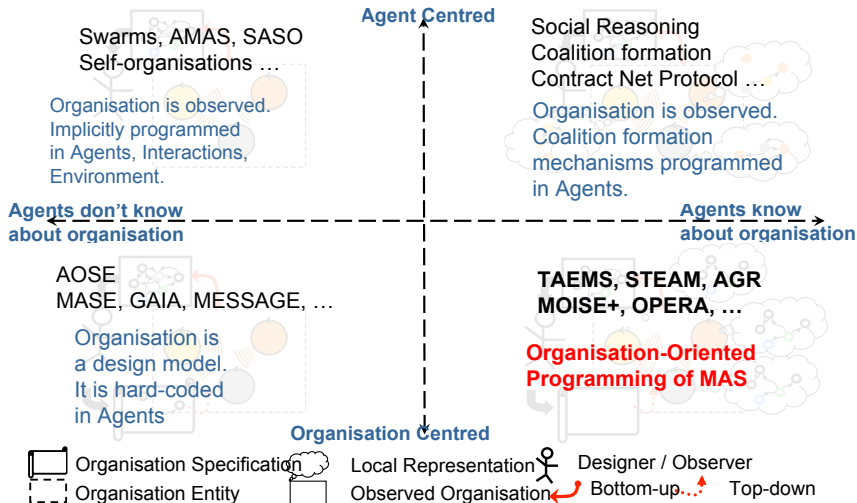
# Perspective on organisations

from EASSS'05 Tutorial (Sichman, Boissier)



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from EASSS'05 Tutorial (Sichman, Boissier)





# Perspective on Org.-Oriented Programming of MAS

**From** organisations as

- ▶ an explicit description of the structure of the agents in the MAS in order to help them to interact

**To** organisations as

- ▶ the declarative and explicit definition of the coordination scheme aiming at “controlling/coordinating” the global reasoning of the MAS

↪ Normative Organisations

# Norms

## Norm

Norms are **rules** that a society has in order to influence the behaviour of agents.

## Norm mechanisms

- ▶ **Regimentation**: norm violation by the agents is prevented
  - e.g. the access to computers requires an user name
  - e.g. messages that do not follow the protocol are discarded
- ▶ **Enforcement**: norm violation by the agents is made possible but it is monitored and subject to incentives
  - e.g. a master thesis should be written in two years
  - ↪ Detection of violations, decision about ways of enforcing the norms (e.g. sanctions)

# Normative Multi-Agent Organisation

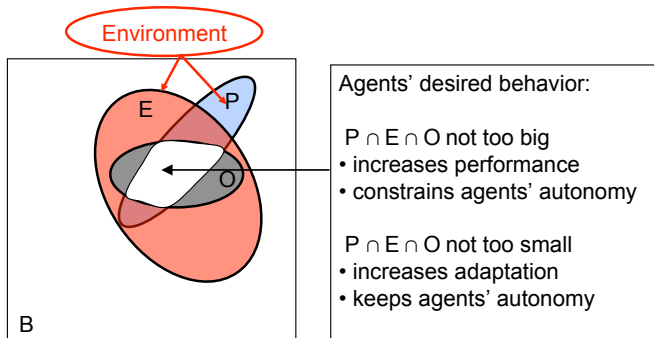
## Normative Multi-Agent System [Boella et al., 2008]

A MAS composed of mechanisms to represent, communicate, distribute, detect, create, modify, and enforce norms, and mechanisms to deliberate about norms and detect norm violation and fulfillment.

## Normative Multi-Agent Organisation [?]

- ▶ Norms are expressed in the organisation specification to clearly define the coordination of the MAS:
  - ▶ anchored/situated in the organisation
  - ▶ i.e. norms refer to organisational concepts (roles, groups, etc. )
- ▶ Norms are interpreted and considered in the context of the organisation entity
- ▶ Organisation management mechanisms are complemented with norms management mechanisms (enforcement, regimentation, ...)

# Challenges: Normative Organisation vs Autonomy



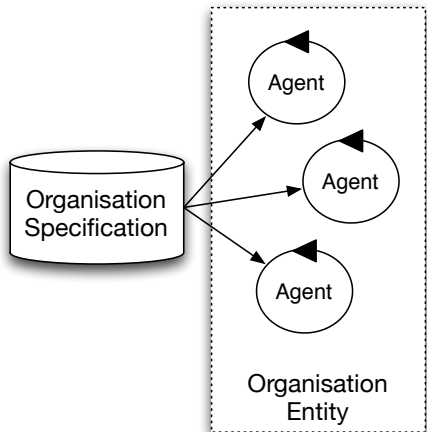
- ▶ B: agents' possible behaviors
- ▶ P: agents' behaviors that lead to global purpose
- ▶ E: agents' possible behaviors constrained by the environment
- ▶ O: agents' possible/permitted/obliged behaviors constrained by the normative organisation

# Organisation Oriented Programming (OOP)

Organisation as a **first class entity** in the multi-agent eco-system

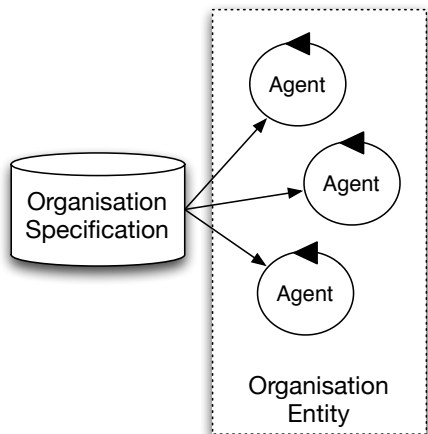
- ▶ Clear distinction between description of the organisation **wrt** agents, **wrt** environment
- ▶ Different representations of the organisation:
  - ▶ **Organisation specification**
    - ▶ partially/totally accessible to the agents, to the environment, to the organisation
  - ▶ **Organisation entity**
    - ▶ Local representation in the mental state of the agents
      - ~> possibly inconsistent with the other agents' representations
    - ▶ Global/local representation in the MAS
      - ~> difficulty to manage and build such a representation in a distributed and decentralized setting
- ▶ Different sources of actions on (resp. of) the organisation by (resp. on) agents / environment / organisation

# Organisation Oriented Programming (OOP)



- ▶ Using organisational concepts
- ▶ To define a cooperative pattern
- ▶ Programmed outside of the agents and outside of the environment
- ▶ Program = Specification
- ▶ By changing the organisation, we can change the MAS overall behaviour

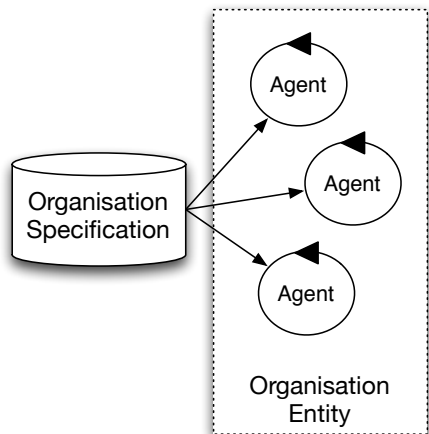
# Organisation Oriented Programming (OOP)



First approach

- ▶ Agents read the program and follow it

# Organisation Oriented Programming (OOP)



First approach

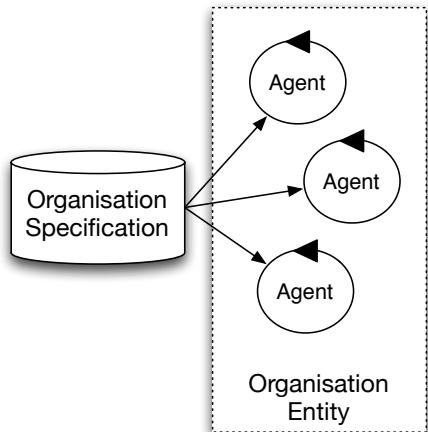
- ▶ Agents read the program and follow it

Second approach

- ▶ **regimentation**
  - ▶ Agents **are forced** to follow the program
- ▶ **enforcement**
  - ▶ Agents **are rewarded** if they follow the program
  - ▶ Agents **are sanctioned** in the other case



# Organisation Oriented Programming (OOP)



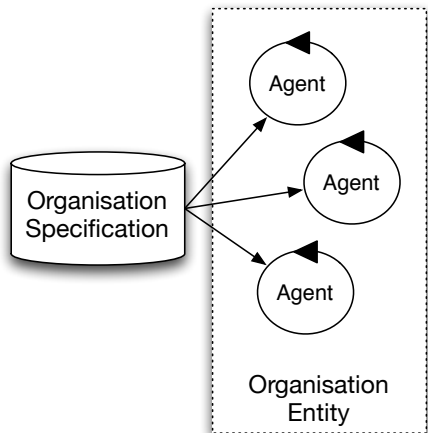
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# Organisation Oriented Programming (OOP)



## Components

- ▶ Programming Language (Org. Modeling Lang. – OML)
- ▶ Management Infrastructure (Org. Mngt Inf. – OMI)
- ▶ Integration to Agent architectures and to Environment

# Components of OOP: Organisation Modelling Language (OML)

- ▶ Declarative specification of the organisation(s)
- ▶ Specific constraints, norms and cooperation patterns imposed on the agents
  - e.g. AGR [Ferber and Gutknecht, 1998],  
TeamCore [Tambe, 1997],  
Islander [Esteva et al., 2001],  
*Moise*<sup>+</sup> [Hübner et al., 2002], ...
- ▶ Specific anchors for situating organisations within the environment
  - e.g. embodied organisations [Piunti et al., 2009]

# Components of OOP:

## Organisation Management Infrastructure (OMI)

- ▶ **Coordination mechanisms**, i.e. support infrastructure  
e.g. MadKit [Gutknecht and Ferber, 2000],  
karma [Pynadath and Tambe, 2003],  
...
- ▶ **Regulation mechanisms**, i.e. governance infrastructure  
e.g. Ameli [Esteva et al., 2004],  
*S-Moise*<sup>+</sup> [Hübner et al., 2006],  
ORA4MAS [Hübner et al., 2009],  
...
- ▶ **Adaptation mechanisms**, i.e. reorganisation infrastructure

# Components of OOP:

## Integration mechanisms

- ▶ **Agent** integration mechanisms allow agents to be aware of and to deliberate on:
  - ▶ entering/exiting the organisation
  - ▶ modification of the organisation
  - ▶ obedience/violation of norms
  - ▶ sanctioning/rewarding other agents

e.g.  $\mathcal{J}$ -Moise<sup>+</sup> [Hübner et al., 2007], Autonomy based reasoning [Carabelea, 2007], *ProsA*<sub>2</sub> Agent-based reasoning on norms [Ossowski, 1999], ...
- ▶ **Environment** integration mechanisms transform organisation into embodied organisation so that:
  - ▶ organisation may act on the environment (e.g. enact rules, regimentation)
  - ▶ environment may act on the organisation (e.g. count-as rules)

e.g. [de Brito et al., 2012], [?], [Okuyama et al., 2008]

# Motivations for OOP:

## **Applications** point of view

- ▶ Current applications show an increase in
  - ▶ Number of agents
  - ▶ Duration and repetitiveness of agent activities
  - ▶ Heterogeneity of the agents, Number of designers of agents
  - ▶ Agent ability to act, to decide,
  - ▶ Action domains of agents, ...
  - ▶ Openness, scalability, dynamicity, ...
  
- ▶ More and more applications require the integration of human communities and technological communities (ubiquitous and pervasive computing), building connected communities (ICities) in which agents act on behalf of users
  - ▶ Trust, security, ..., flexibility, adaptation

# Motivations for OOP:

## **Constitutive** point of view

- ▶ Organisation **helps** the agents to cooperate with the other agents by defining **common** cooperation schemes
  - ▶ global tasks
  - ▶ protocols
  - ▶ groups, responsibilities
- e.g. 'to bid' for a product on eBay is an **institutional action** only possible because eBay defines the rules for that very action
  - ▶ the bid protocol is a constraint but it also **creates** the action
- e.g. when a soccer team plays a match, the organisation helps the members of the team to synchronise actions, to share information, etc

# Motivations for OOP:

## Normative point of view

- ▶ MAS have two properties which seem contradictory:
  - ▶ a **global** purpose
  - ▶ **autonomous** agents
  - ↪ While the autonomy of the agents is essential, it may cause loss in the global coherence of the system and achievement of the global purpose
- ▶ Embedding **norms** within the **organisation** of a MAS is a way to constrain the agents' behaviour towards the global purposes of the organisation, while explicitly addressing the autonomy of the agents within the organisation
  - ↪ Normative organisation
  - e.g. when an agent adopts a role, it adopts a set of behavioural constraints that support the global purpose of the organisation. It may decide to obey or disobey these constraints



# Motivations for OOP:

## Agents point of view

An organisational specification is required to enable agents to “reason” about the organisation:

- ▶ to decide to enter into/leave from the organisation during execution
  - ↪ Organisation is no more closed
- ▶ to change/adapt the current organisation
  - ↪ Organisation is no more static
- ▶ to obey/disobey the organisation
  - ↪ Organisation is no more a regimentation

# Motivations for OOP:

## Organisation point of view

An organisational specification is required to enable the organisation to “reason” about itself and about the agents in order to ensure the achievement of its global purpose:

- ▶ to decide to let agents enter into/leave from the organisation during execution
  - ↪ Organisation is no more closed
- ▶ to decide to let agents change/adapt the current organisation
  - ↪ Organisation is no more static and blind
- ▶ to govern agents behaviour in the organisation (i.e. monitor, enforce, regiment)
  - ↪ Organisation is no more a regimentation

# Outline

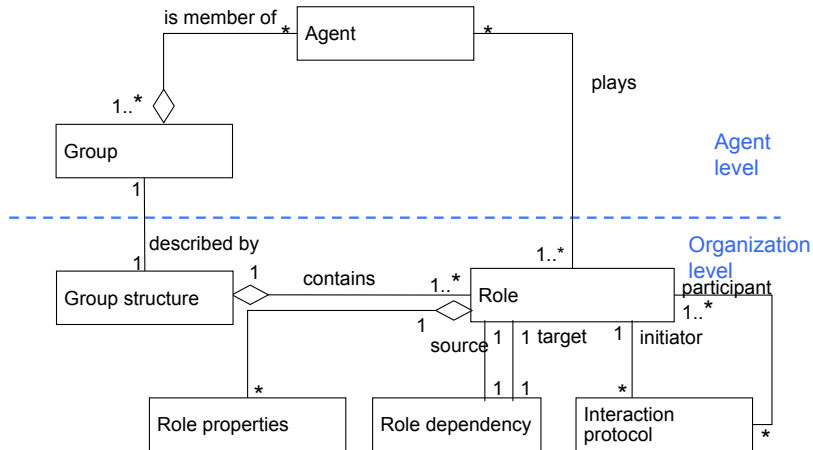
Fundamentals

Existing approaches

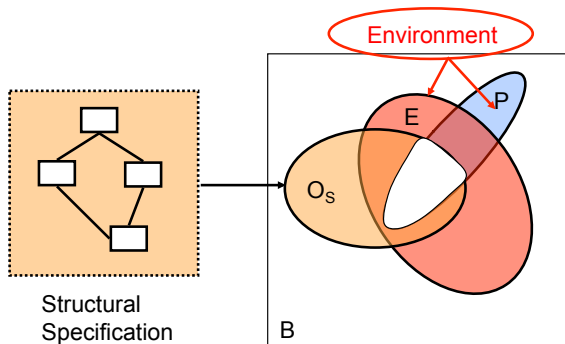
# AGR [Ferber and Gutknecht, 1998]

- ▶ Agent Group Role, previously known as AALAADIN
  - ▶ Agent: Active entity that plays roles within groups. An agent may have several roles and may belong to several groups.
  - ▶ Group: set of agents sharing common characteristics, i.e. context for a set of activities. Two agents can't communicate with each other if they don't belong to the same group.
  - ▶ Role: Abstract representation of the status, position, function of an agent within a group.
- ▶ OMI: the Madkit platform

# AGR OML



# AGR OML Modelling Dimensions



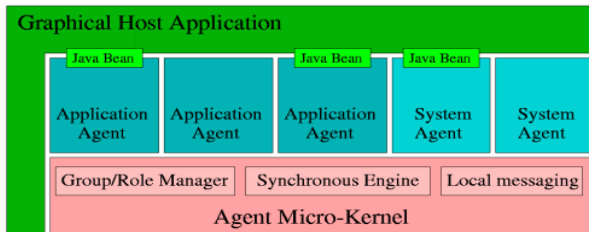
B: agents' possible behaviors

P: agents' behaviors that lead to global purpose

E: agents' possible behaviors constrained by the environment

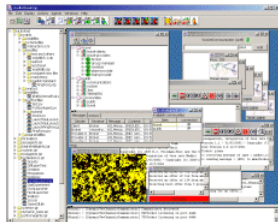
$O_s$ : agents' possible behaviors structurally constrained by the organization

# AGR OMI: Madkit



Multi-Agent Development Kit

[www.madkit.org](http://www.madkit.org)

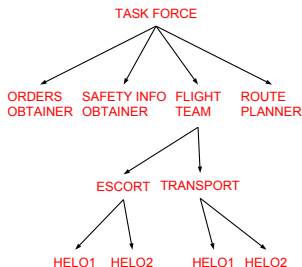


# STEAM [Tambe, 1997]

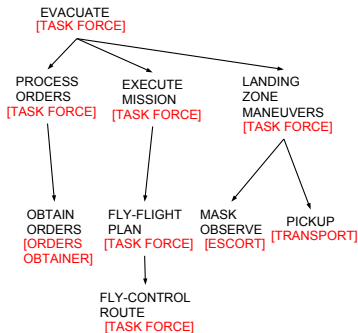
- ▶ Shell for TEAMwork is a general framework to enable agents to participate in teamwork.
  - ▶ Different applications: Attack, Transport, Robocup soccer
  - ▶ Based on an enhanced SOAR architecture and 300 domain independent SOAR rules
- ▶ Principles:
  - ▶ Team synchronization: Establish joint intentions, Monitor team progress and repair, Individual may fail or succeed in own role
  - ▶ Reorganise if there is a critical role failure
  - ▶ Reassign critical roles based on joint intentions
  - ▶ Decision theoretic communication
- ▶ Supported by the TEAMCORE OMI.



# STEAM OML [Tambe, 1997]



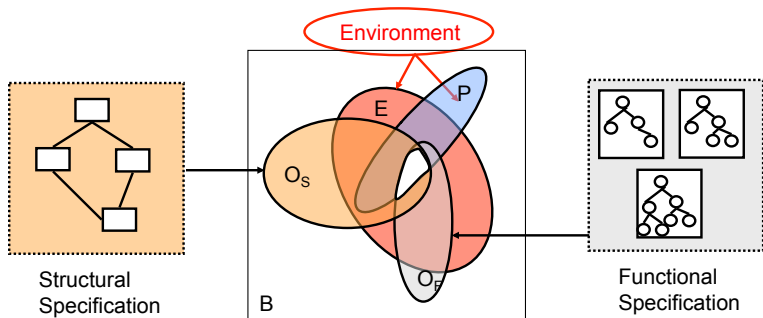
**Organization:** hierarchy of roles that may be filled by agents or groups of agents.



## Team Plan:

- initial conditions,
- term. cond. : achievability, irrelevance, unachievability
- team-level actions.

# STEAM OML Modelling Dimensions



B: agents' possible behaviors

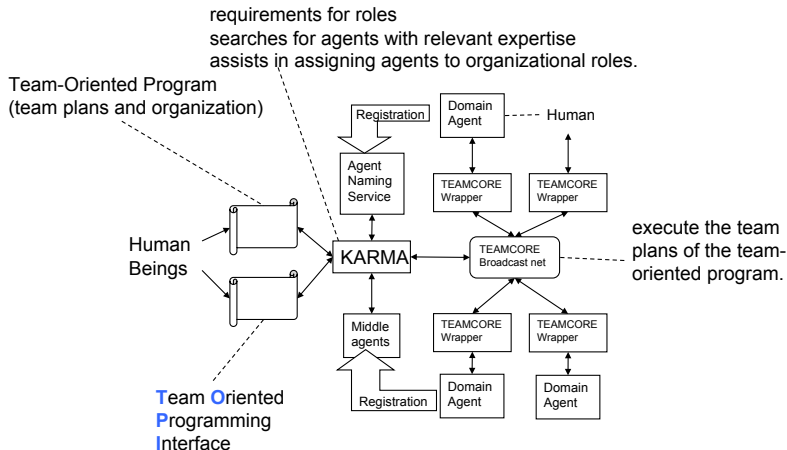
P: agents' behaviors that lead to global purpose

E: agents' possible behaviors constrained by the environment

$O_S$ : agents' possible behaviors structurally constrained by the organization

$O_F$ : agents' possible behaviors functionally constrained by the organization

# STEAM OMI: TEAMCORE [Pynadath and Tambe, 2003]

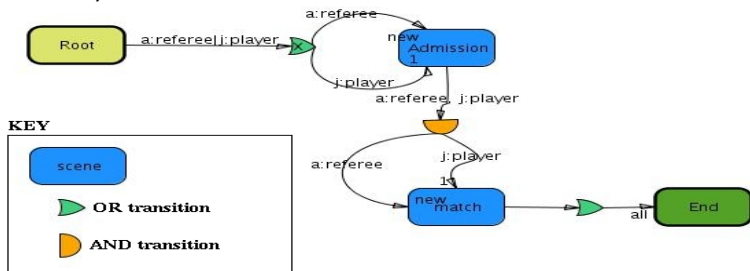


# ISLANDER

- ▶ Based on different influences: economics, norms, dialogues, coordination
- ~> electronic institutions
- ▶ Combining different alternative views: dialogical, normative, coordination
- ▶ Institution Description Language:
  - ▶ Performative structure (Network of protocols),
  - ▶ Scene (multi-agent protocol),
  - ▶ Roles,
  - ▶ Norms
- ▶ Ameli as OMI

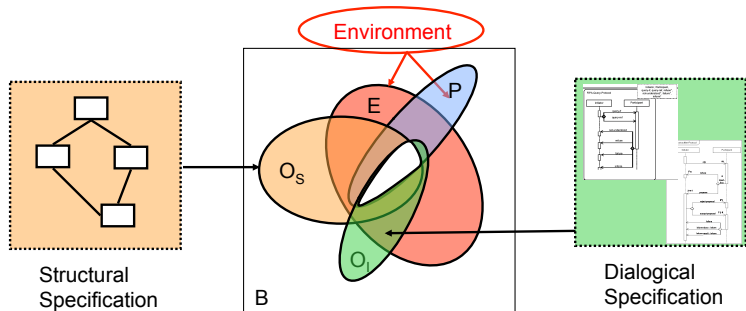
# ISLANDER OML: IDL [Esteva et al., 2001]

(define-institution  
  soccer-server as  
  **dialogic-framework** = soccer-df  
  **performative-structure** = soccer-pf  
  **norms** = ( free-kick coach-messages ... )  
)



Performative Structure

# ISLANDER OML Modelling Dimensions



B: agents' possible behaviors

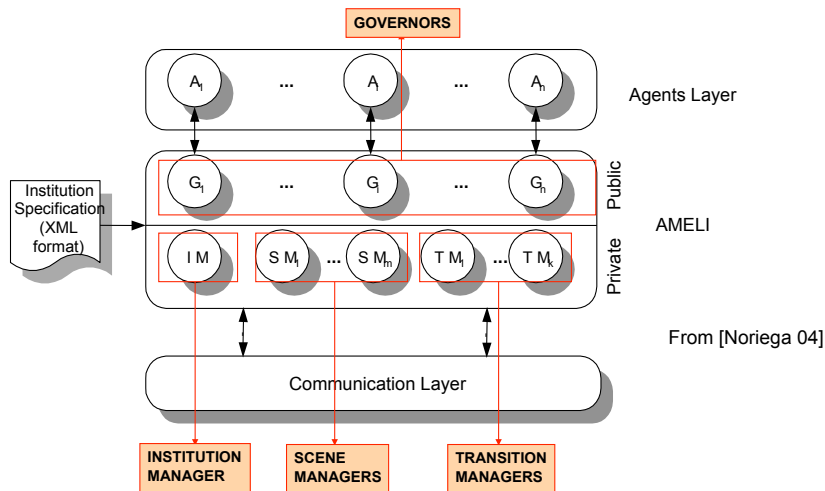
P: agents' behaviors that lead to global purpose

E: agents' possible behaviors constrained by the environment

$O_s$ : agents' possible/permitted/obliged behaviors structurally constrained by the organisation

$O_i$ : agents' possible/permitted/obliged behaviors interactively constrained by the organisation

# ISLANDER OMI: AMELI [Esteva et al., 2004]



The aim is to design and develop a programming language to support the implementation of coordination mechanisms in terms of **normative** concepts.

An organisation

- ▶ determines effect of external actions
- ▶ normatively assesses effect of agents' actions (monitoring)
- ▶ sanctions agents' wrongdoings (enforcement)
- ▶ prevents ending up in really bad states (regimentation)



## Example (Train Station)

Facts:

```
{ -at_platform , -in_train , -ticket }
```

Effects:

```
{ -at_platform }    enter        { at_platform },  
{ -ticket }        buy_ticket    { ticket },  
{ at_platform , -in_train }  
                    embark  
                    { -at_platform, in_train }
```

Counts\_as rules:

```
{ at_platform , -ticket } => { viol_ticket },  
{ in_train , -ticket }   => { viol_|_ }
```

Sanction\_rules:

```
{ viol_ticket } => { fined_10 }
```

# 2OPL Modelling Dimension

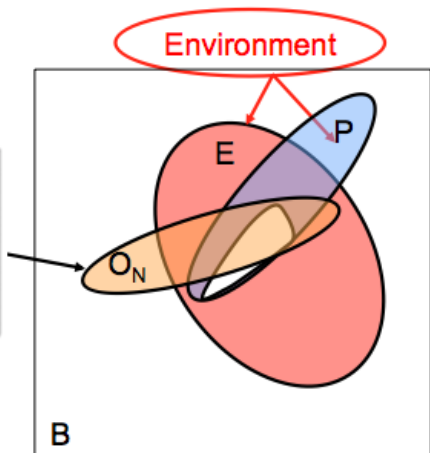
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Example (Train Station)
Facts:
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Effects:
  { -at_platform }  enter    { at_platform },
  { -ticket }      buy_ticket { ticket },
  { at_platform , -in_train }
  embark
  { -at_platform, in_train }

Counts_as rules:
  { at_platform , -ticket } => { viol_ticket },
  { in_train , -ticket }   => { viol_1, }

Reaction_rules:
  { viol_ticket } => { fined_10 }
```

Normative  
Specification



# Summary

- ▶ Several models
- ▶ Several dimensions on modelling organisation
  - ▶ Structural (roles, groups, ...)
  - ▶ Functional (global plans, ....)
  - ▶ Dialogical (scenes, protocols, ...)
  - ▶ Normative (norms)
- ▶ Several ways of managing organization within the MAS
- ▶ Several ways of addressing the autonomy of the agents

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