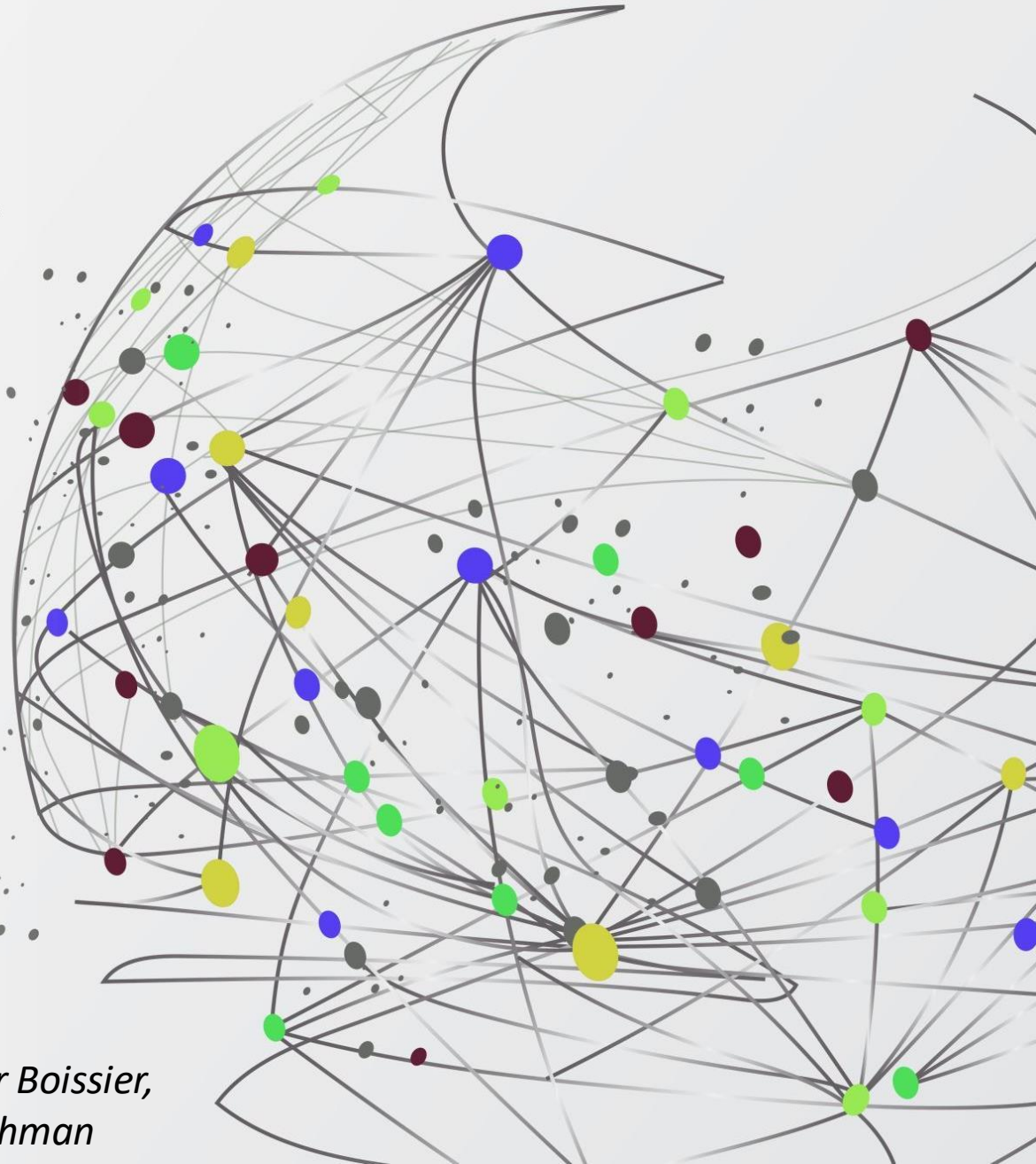
Multi-Agent Oriented Programming

Organization Dimension



***Credits**: Slides are based on previous presentations by Olivier Boissier, Rafael Bordini, Maiquel de Brito, Jomi F. Hübner, Jaime S. Sichman*

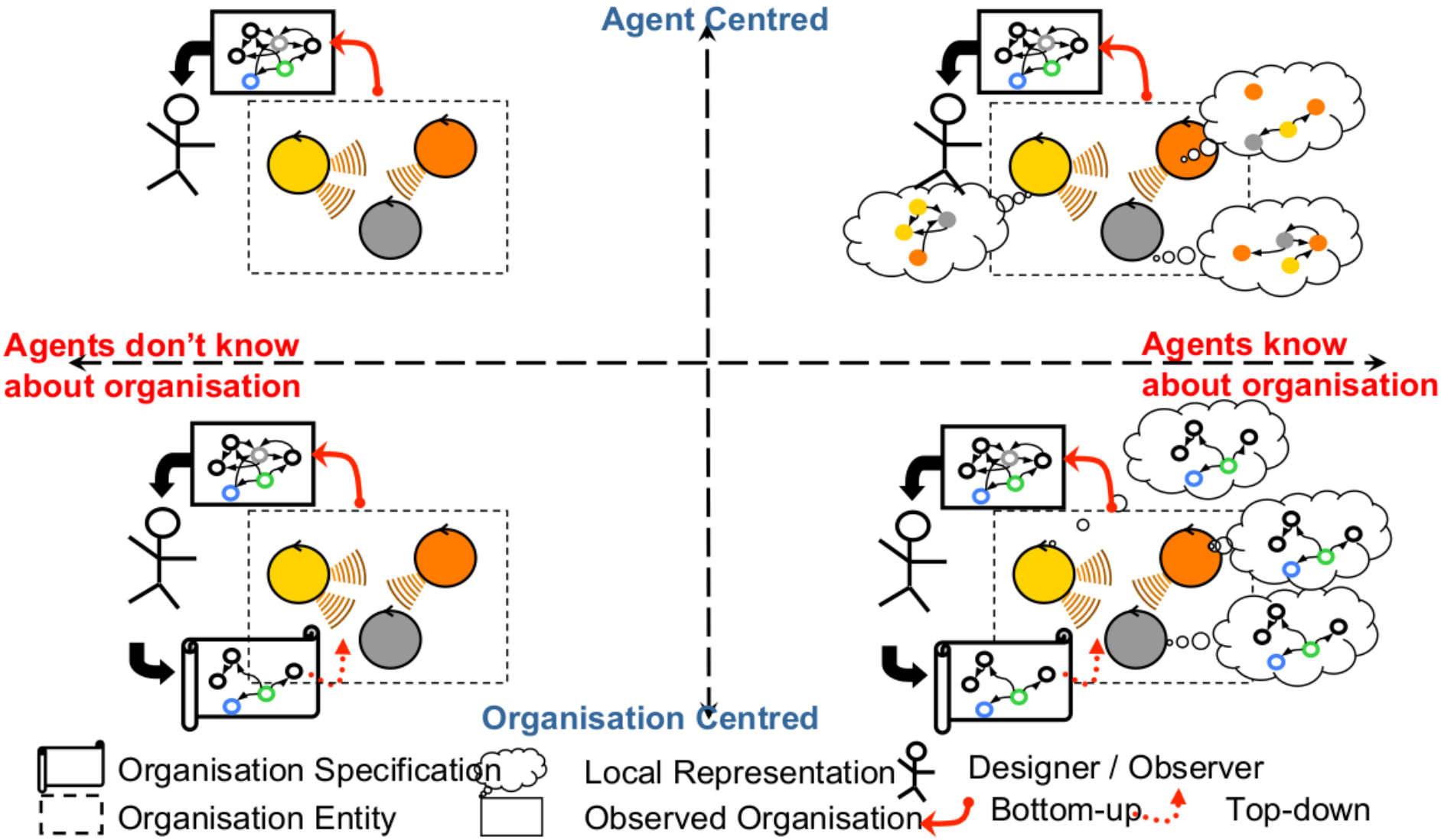
Introduction: Some definitions

- Organizations are structured, patterned systems of activity, knowledge, culture, memory, history, and capabilities that are distinct from any single agent (Gasser, 2001)
  - ⇝ organizations 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 organization 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**

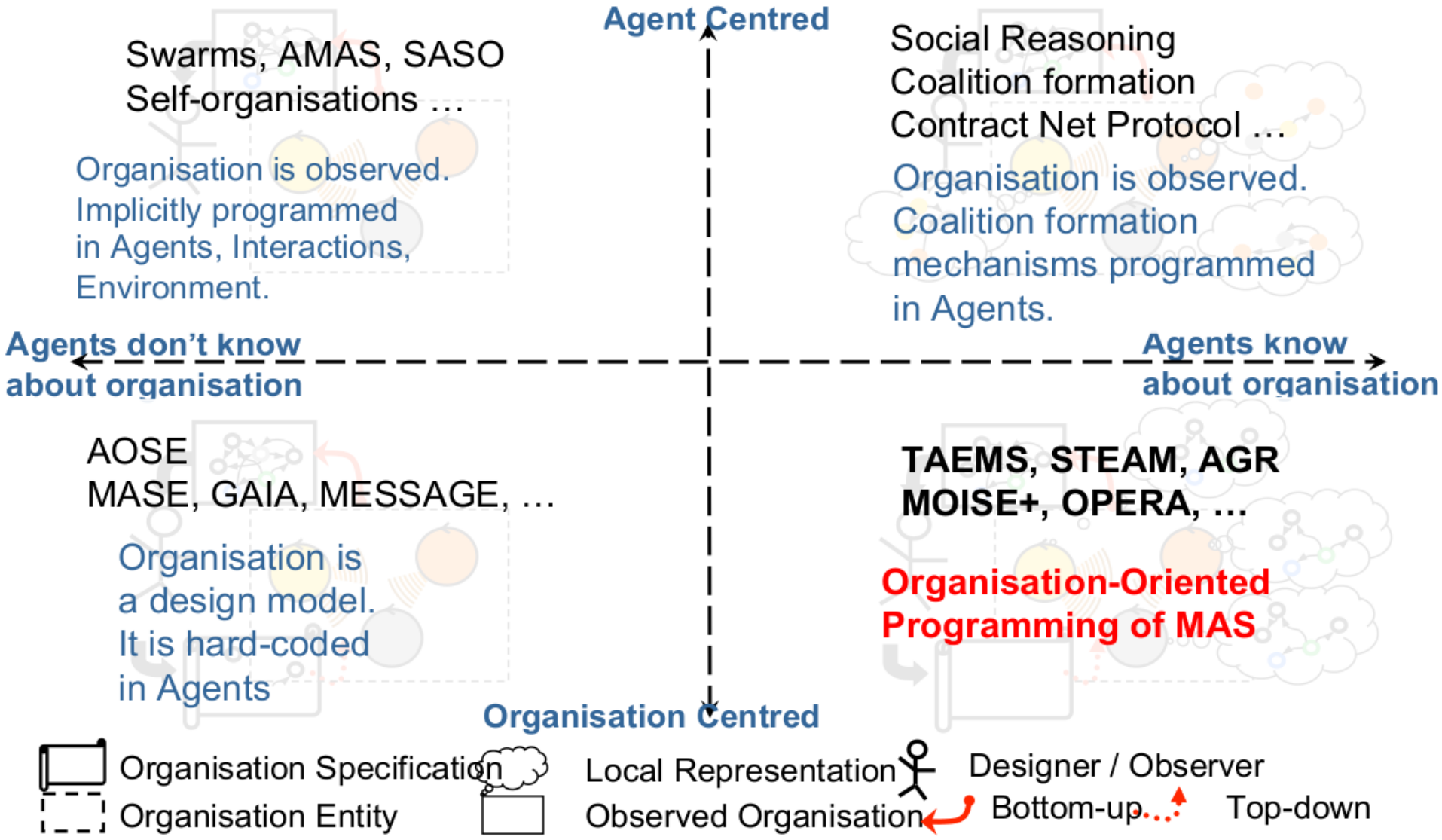
Organization in MAS

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

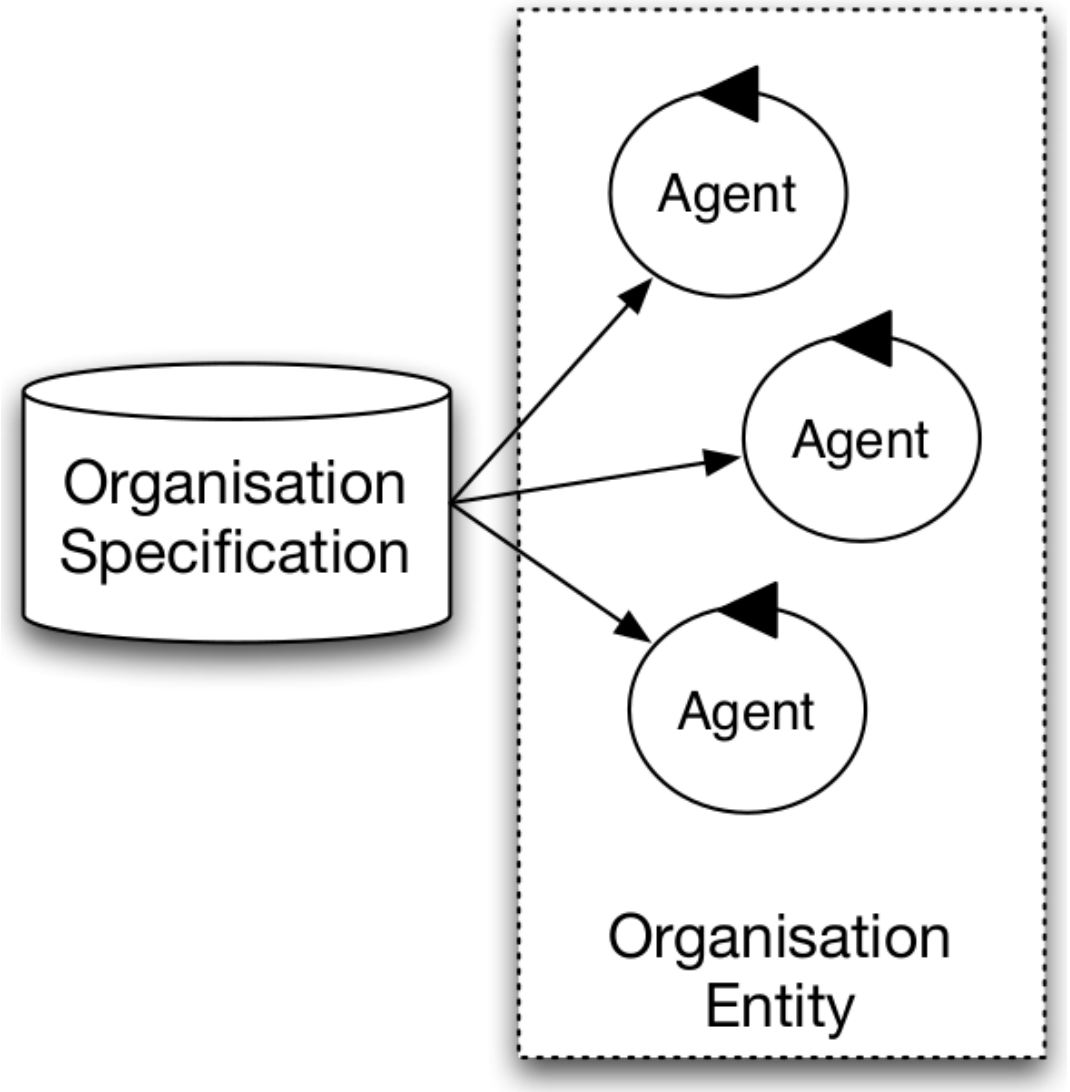
Perspective on Organizations



Perspective on Organizations



Organization Oriented Programming

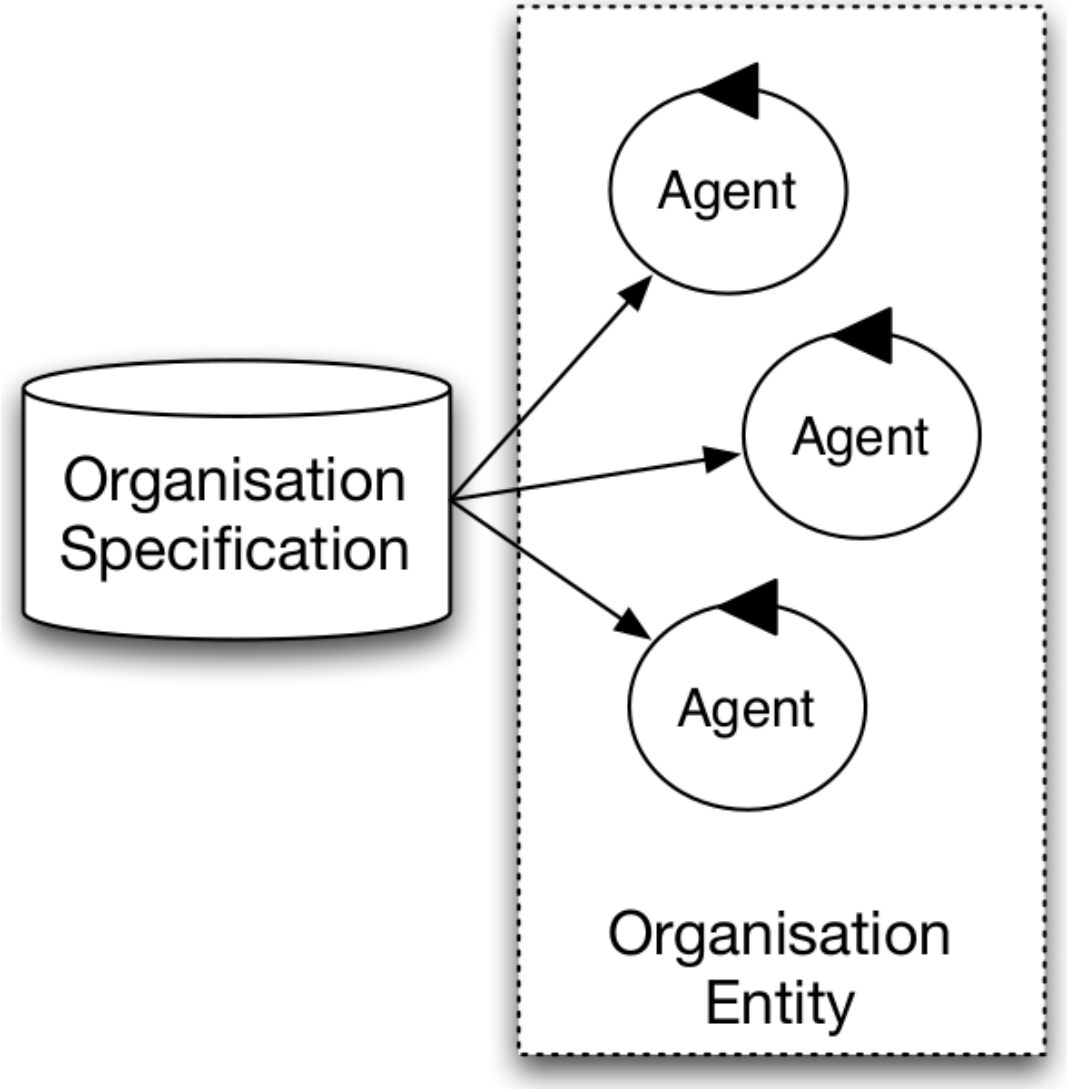


Programming **outside the agents** using of **organizational concepts** to **coordinating and regulating** autonomous agents

```
Program = Specification
```

By changing the specification, we can change the MAS behavior

Organization Oriented Programming



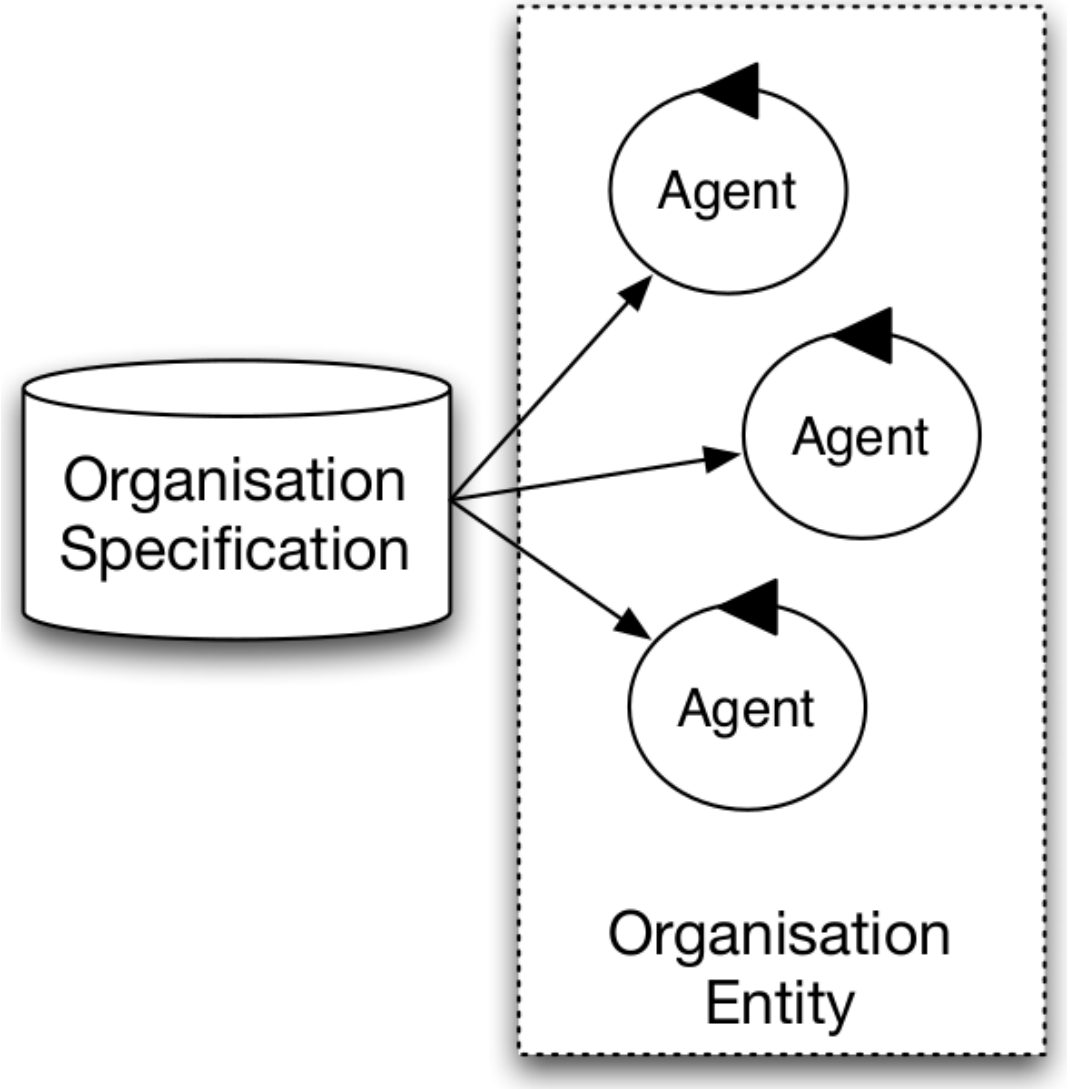
First approach

- Agents read the program/specification and follow it

Second approach

- Agents **are forced** to follow the program/specification
- Agents **are rewarded/punished** if they follow/not follow the program/specification

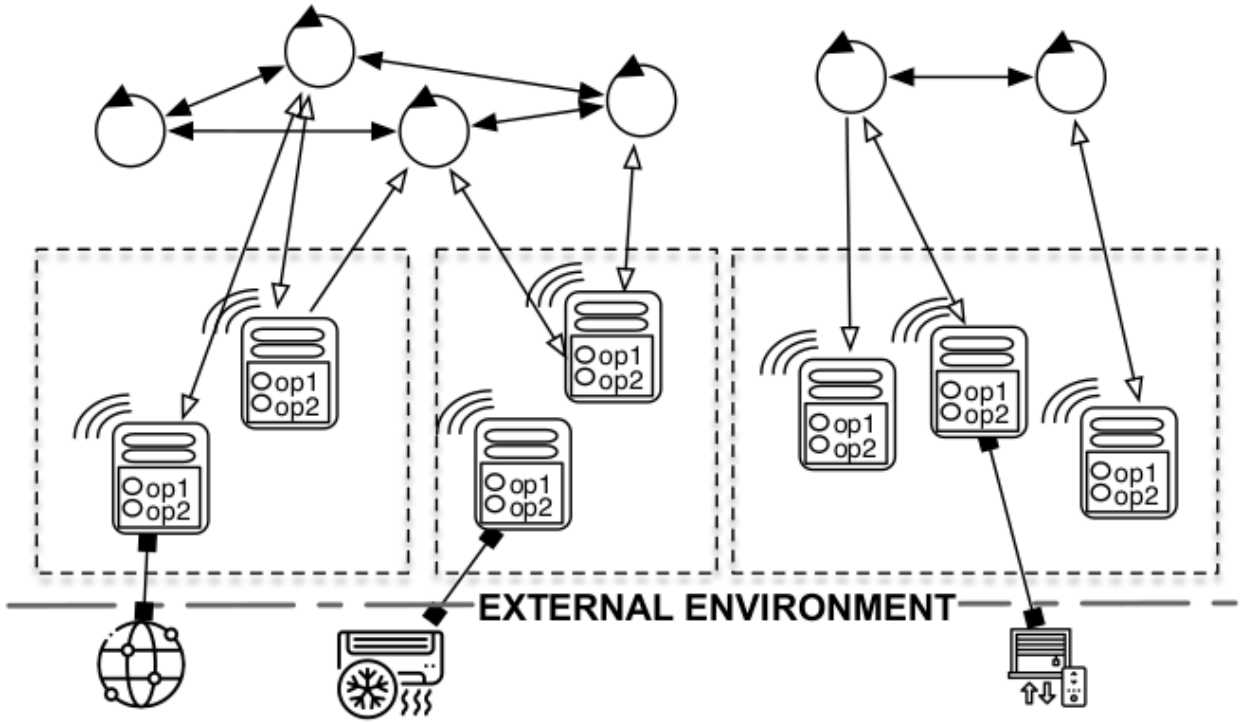
Organization Oriented Programming



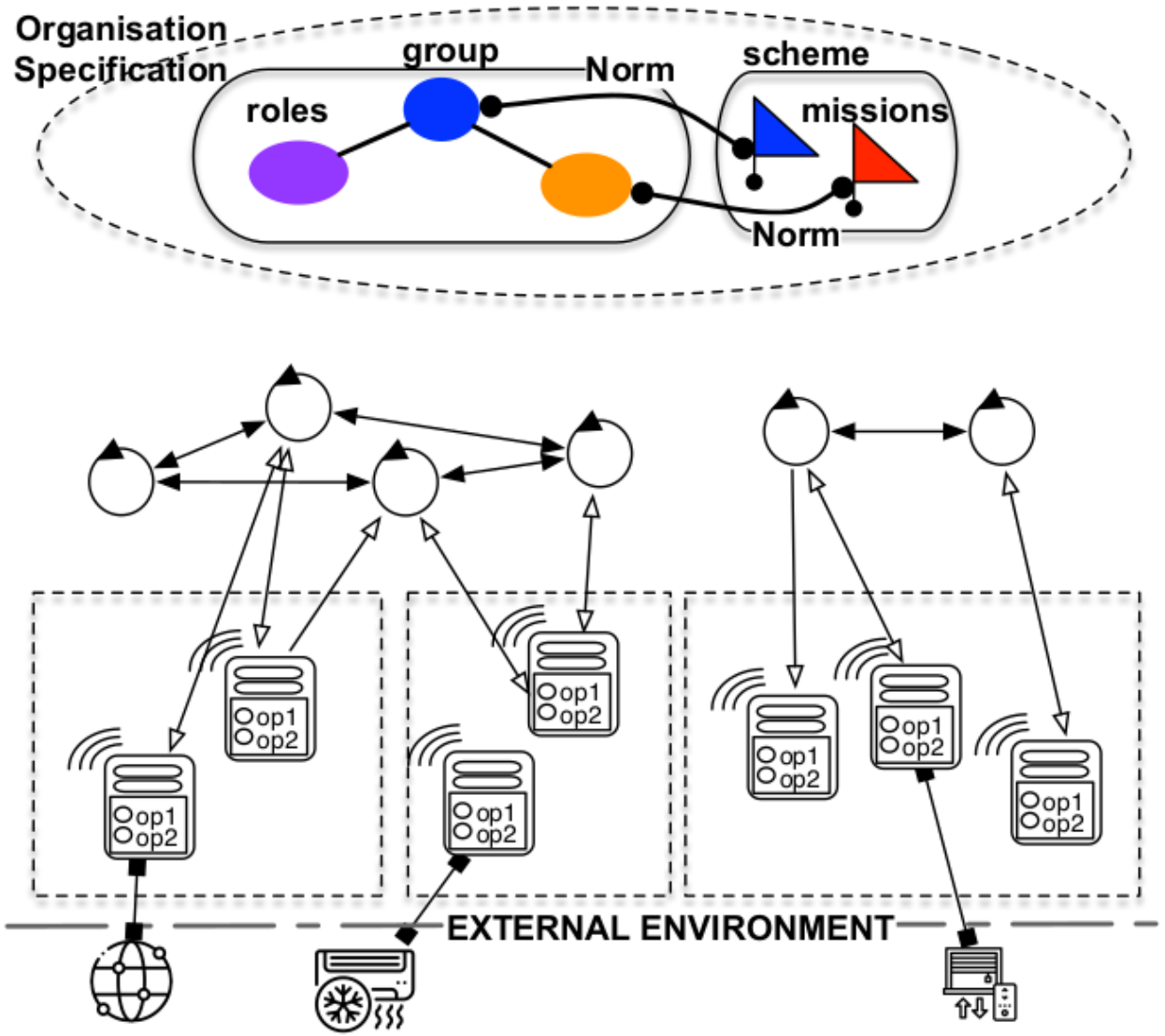
Components

- Programming language
- Platform
- Integration to agent architectures and to the environment

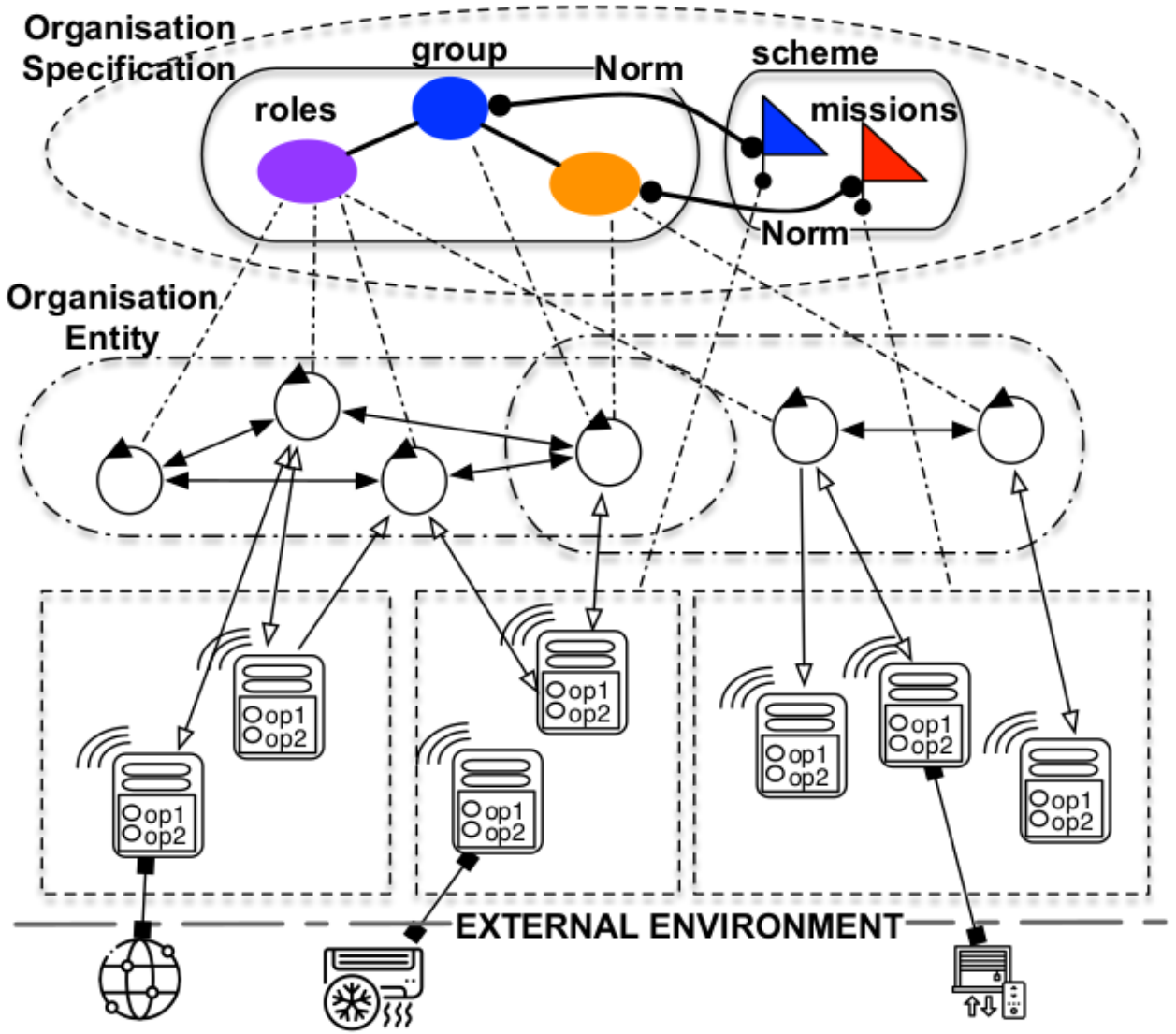
JaCaMo Organization Dimension



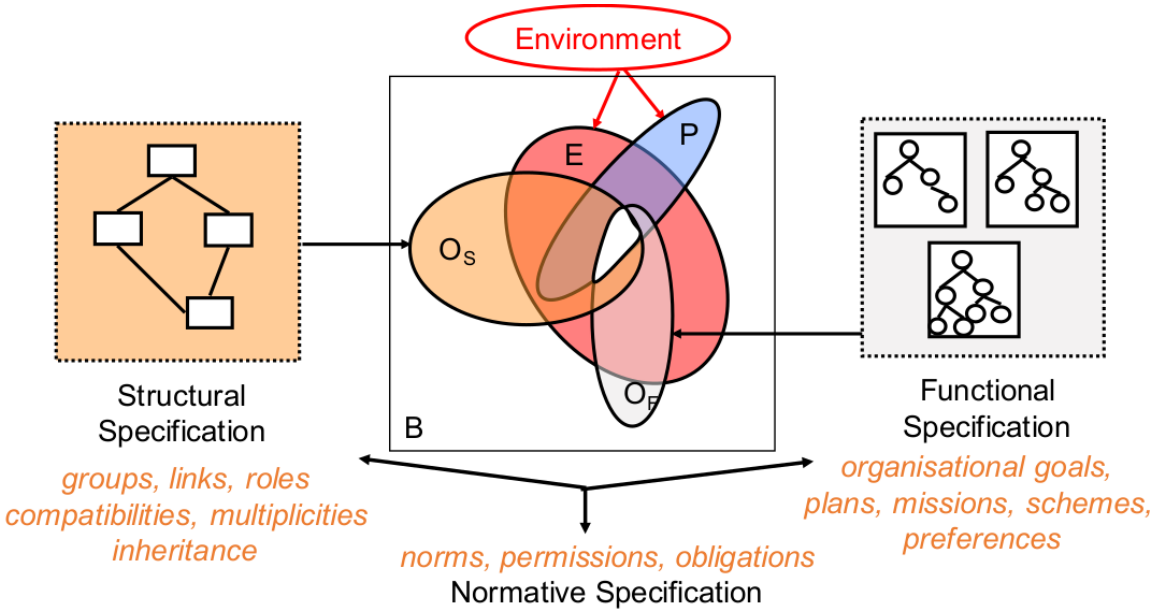
JaCaMo Organization Dimension



JaCaMo Organization Dimension



JaCaMo Organization Dimension

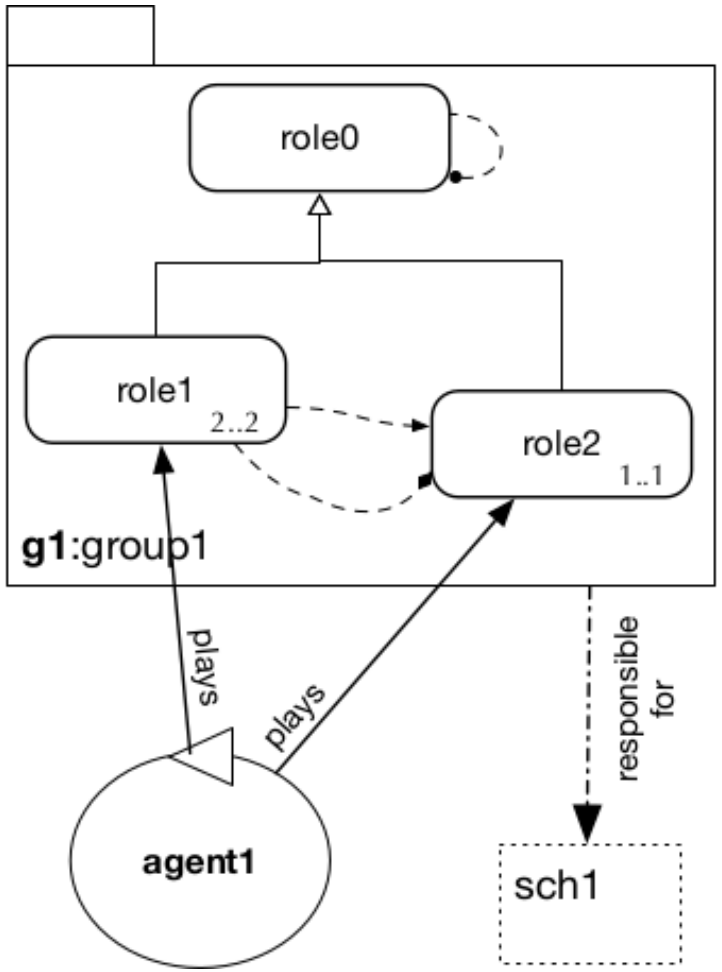


- Dimensions (Hübner et al. 2007)
  - **Structural** (i.e., Roles, Groups),
  - **Functional** (i.e., Organizational Goals, Missions, Schemes)
  - **Normative** (i.e., Norms with obligations, permissions, interdictions)
- Enable agent's autonomy w.r.t. organization (enforcement vs regimentation)
- Programming and representing the organization
  - make it accessible to the designers, the agents, the coordination and regulation management infrastructure (Hübner et al., 2010)

Structural Specification

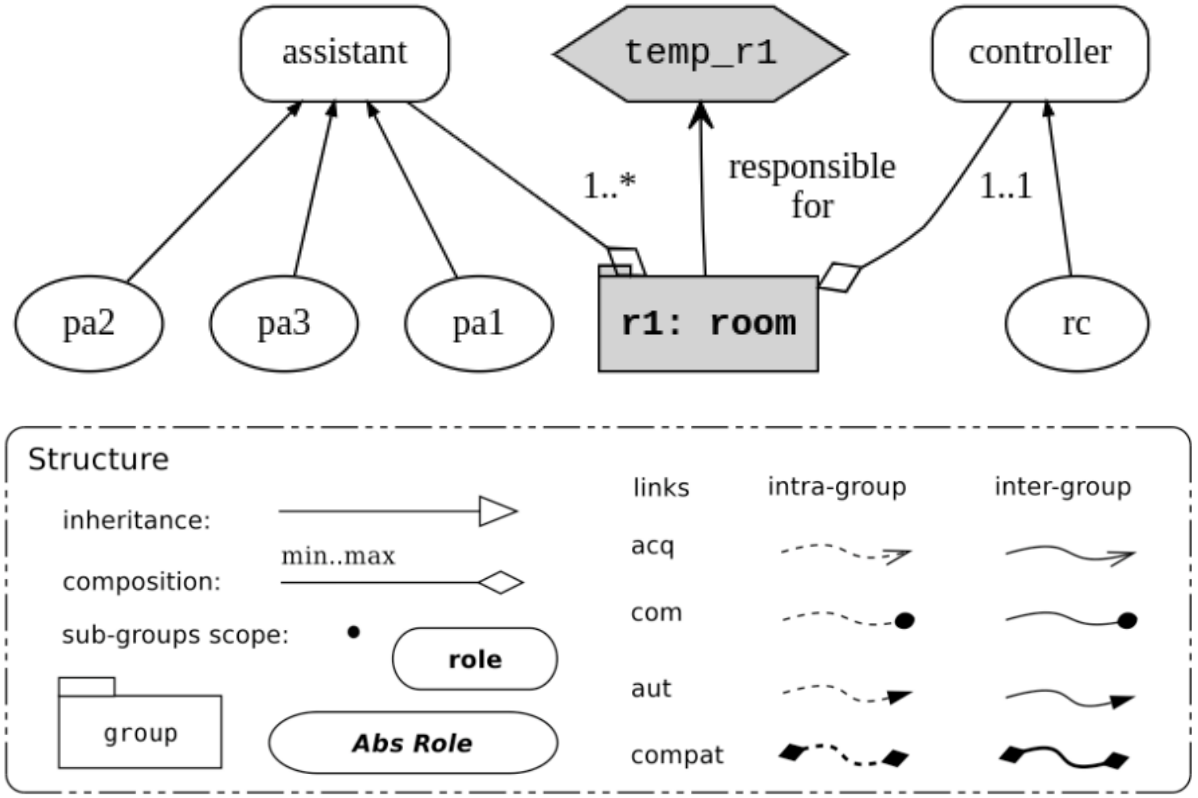
- Specifies the structure of an MAS along three levels:
  - **Individual** with **Role**
  - **Social** with **Link**
  - **Collective** with **Group**
- Components:
  - **Role**: label used to assign rights and constraints on the behavior of agents playing it
  - **Link**: relation between roles that directly constrains the agents in their interaction with the other agents playing the corresponding roles
  - **Group**: set of links, roles, compatibility relations used to define a shared context for agents playing roles in it

Structural Specification




```
<structural-specification>

<role-definitions>
    <role id="role0"/>
    <role id="role1"> <extends role="role0"/> </role>
    <role id="role2"> <extends role="role0"/> </role>
</role-definitions>

<group-specification id="group1">
    <roles>
        <role id="role1" min="1" max="2"/>
        <role id="role2" min="1" max="1"/>
    </roles>

    <links>
       <link from="role1" to="role2" type="authority"
             scope="intra-group" bi-dir="false" />
       <link from="role0" to="role0" type="communication"
             scope="intra-group" bi-dir="true" />
    </links>
    <formation-constraints>
       <compatibility from="role1" to="role2" bi-dir="true"/>
    </formation-constraints>
</group-specification>
</structural-specification>
```

Structural Specification Example

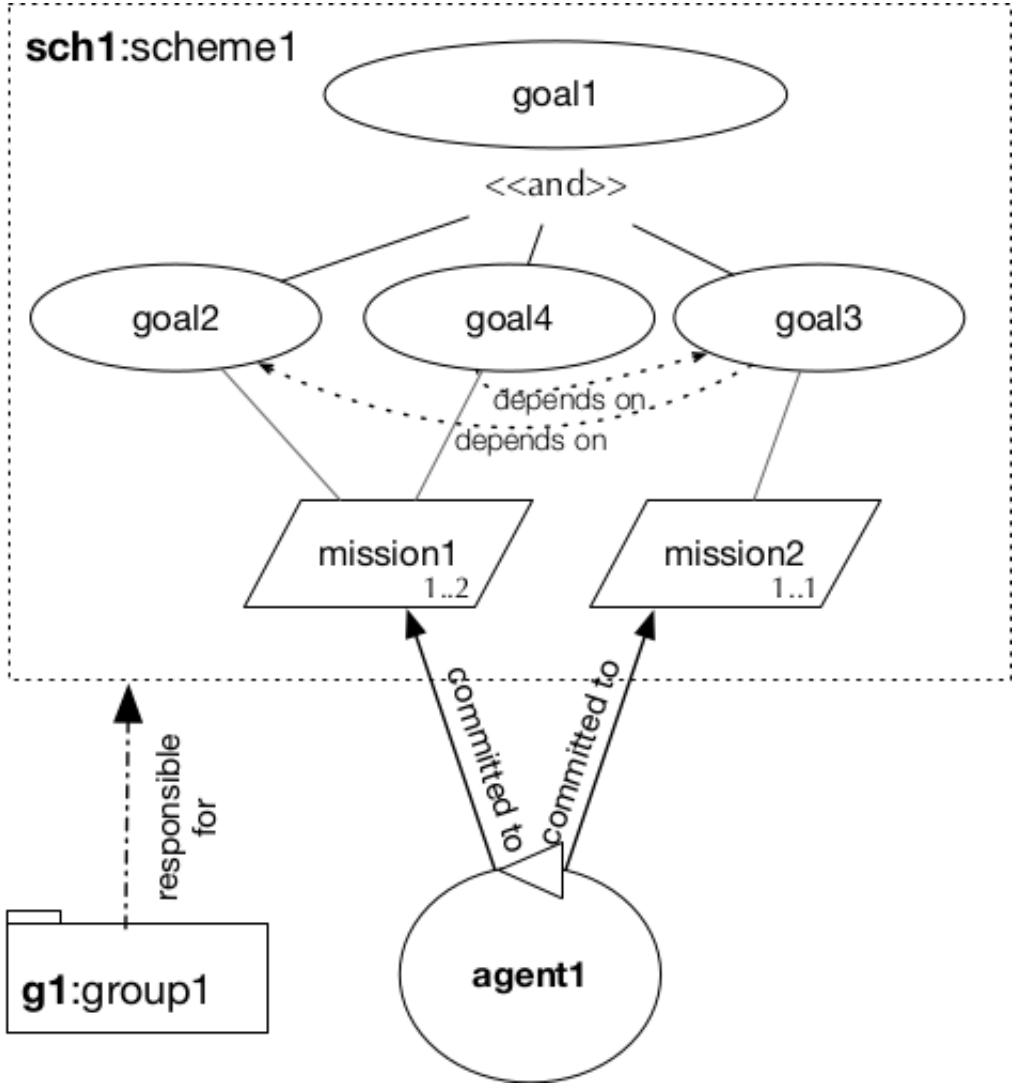



```
<structural-specification>
    <group-specification id="room">
        <roles>
            <role id="assistant" min="1" />
            <role id="controller" min="1" max="1" />
        </roles>
    </group-specification>
</structural-specification>
```

Functional Specification

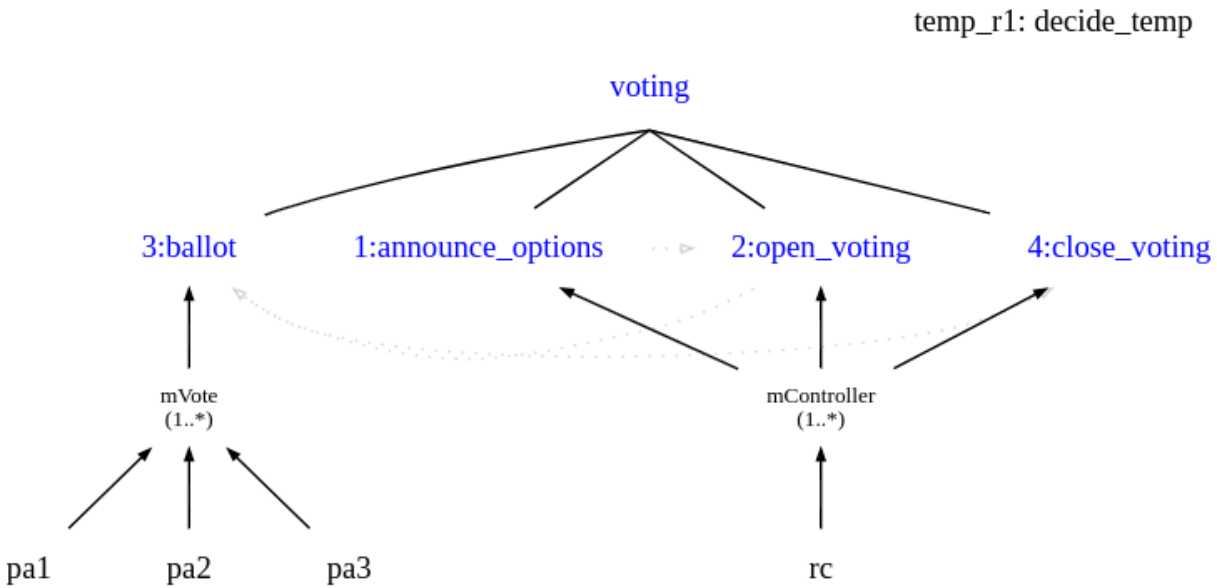
- Specifies the expected behavior of an MAS in terms of **goals** along two levels:
  - **Collective** with **Scheme**
  - **Individual** with **Mission**
- Components:
  - **Goals**:
    - **Achievement goal** (default type). Goals of this type should be declared as satisfied by the agents committed to them, when achieved
    - **Maintenance goal**. Goals of this type are not satisfied at a precise moment but are pursued while the scheme is running. The agents committed to them do not need to declare that they are satisfied
  - **Scheme**: global goal decomposition tree assigned to a group
    - Any scheme has a root goal that is decomposed into subgoals
  - **Missions**: set of coherent goals assigned to roles within norms

Functional Specification




```
<functional-specification>
    <scheme id="scheme1">
        <goal id="goal1" ds="description of goal1">
            <plan operator="sequence">
                <goal id="goal2" ttf="20 minutes" ds="description of goal2"/>
                <goal id="goal3" ds="description of goal3"/>
                <goal id="goal4" ds="description of goal4"/>
            </plan>
        </goal>

        <mission id="mission1" min="1" max="2">
            <goal id="goal2" />
            <goal id="goal4" />
        </mission>
        <mission id="mission2" min="1" max="1">
            <goal id="goal3"/>
        </mission>
    </scheme>
</functional-specification>
```

Functional Specification Example




```
<functional-specification>
    <scheme id="decide_temp">
        <goal id="voting">
            <plan operator="sequence">
                <goal id="announce_options" />
                <goal id="open_voting" />
                <goal id="ballot" ttf="10 seconds">
                    <argument id="voting_machine_id"
                    />
                </goal>
                <goal id="close_voting" />
            </plan>
        </goal>
        <mission id="mVote" min="1">
            <goal id="ballot" />
        </mission>
        <mission id="mController" min="1">
            <goal id="announce_options" />
            <goal id="open_voting" />
            <goal id="close_voting" />
        </mission>
    </scheme>
</functional-specification>
```

Normative Specification

- Explicit relation between the functional and structural specifications
- Permissions and obligations to commit to missions in the context of a role
- The normative specification makes explicit the normative dimension of a role

```
<normative-specification>
    <!-- the norms of the application -->
    <norm id="norm1" type="obligation"
          role="role1" mission="mission1"/>
    <norm id="norm2" type="permission"
          role="role2" mission="mission2"/>
</normative-specification>
```

Normative Specification Example

Normative Specification

id	condition	role	relation	mission	time constraint	properties
n1		assistant	*obligation*	mVote		
n2		controller	*obligation*	mController		

```
<normative-specification>
  <norm id="n1" type="obligation"
  role="assistant" mission="mVote" />

  <norm id="n2" type="obligation"
  role="controller" mission="mController" />
</normative-specification>
```

Basic Concepts

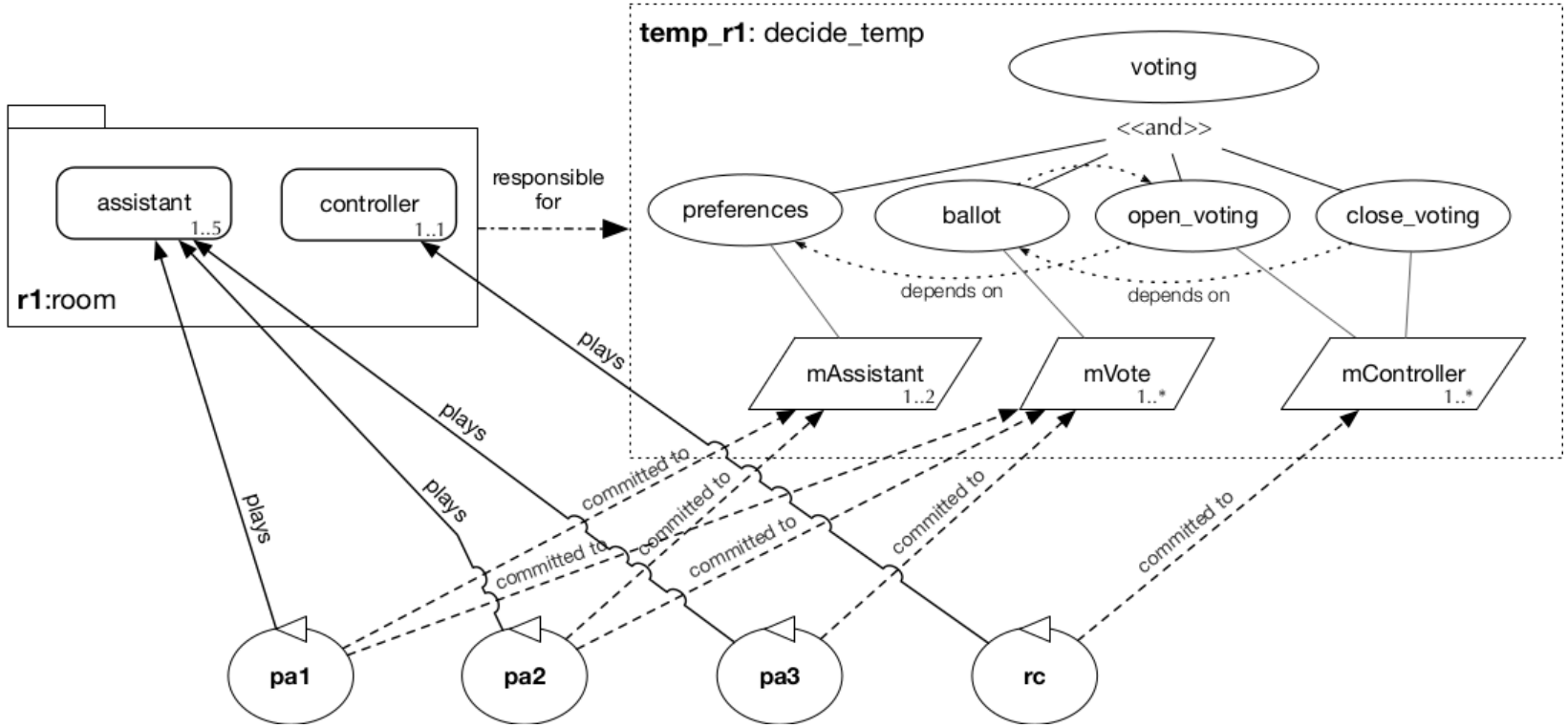
- **Organization**: abstractions to declare and make accessible to agents their (current and/or expected) collective coordinated and regulated relations and activities in the shared environment organization entity, organization specification

- **Group**: social context in which agents can play roles, undertake their expected coordinated behavior as well as their rights and duties.
- **Role**: statement that determines the interactions, relations, rights and duties taking place for an agent within a group.

- **Organizational goal**: state of affair that has to be (or has been) satisfied by one or several agents
- **Mission**: set of organizational goals that have to be achieved under the responsibility of an individual agent in the organization
- **Social scheme**: a goal decomposition tree executed in a coordinated manner under the responsibility of agents participating to a group in accordance to their rights and duties

- **Norm**: statement of the rights and duties of agents in the context of an organization

Declarative Organization Programming



- Structural patterns (groups (r1:room), roles (assistant, controller), links)
- Coordination patterns (
  - goal decomposition trees (voting, preferences, ballot, open_voting, close_voting)
  - missions (mAssistant, mVote,mController)
- Rights and duties (norms)

Organization Dynamics

In the context of Organization life-cycle

- Creation/Deletion of an Organization from an Organization specification
- Entrance/Exit of an agent
- Change of Organization specification

In the context of Organization structure life-cycle

- Creation/Deletion of a group
- Adoption/Leave of a role

In the context of Coordination activity life-cycle

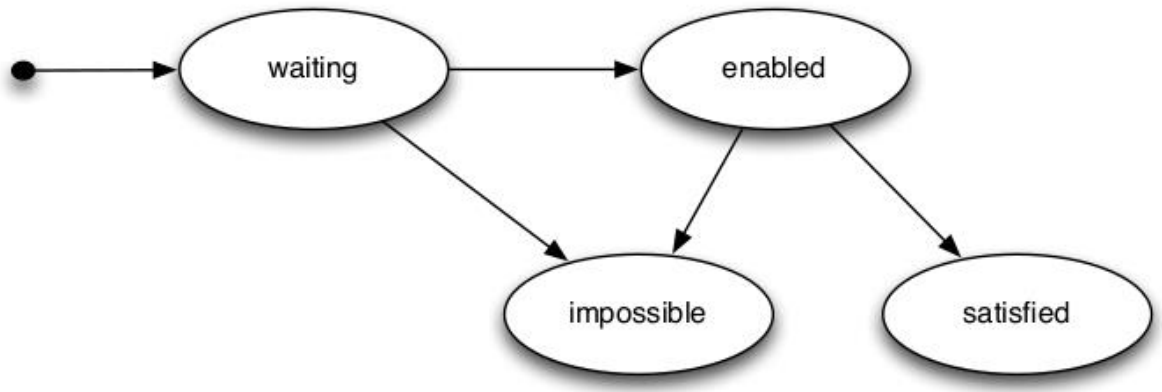
- Creation/End of a schema
- Commitment/Release of a mission
- Change of goal state

In the context of Normative Regulation activity life-cycle

- Activation/De-activation of norms
- Fulfillment/Violation of norms
- Enforcement of norms

Organization Dynamics

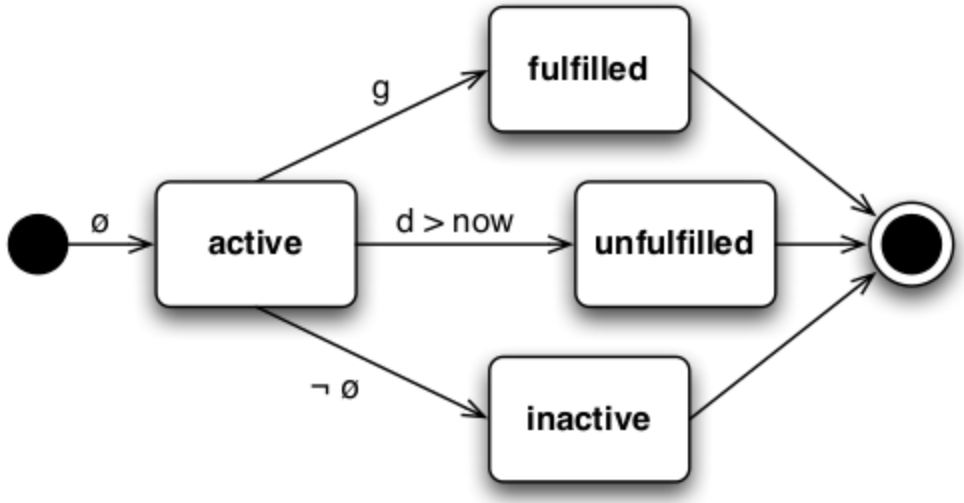
Organization Goal Dynamics



waiting initial state
enabled goal pre-conditions are satisfied and scheme is well-formed
satisfied agents committed to the goal have achieved it
impossible the goal is impossible to be satisfied

NOTE: goal state from the Organization point of view may be different of the goal state from the Agent point of view

Norm Dynamics



norm n : ϕ -> obligation(a, r, g, d)

ϕ: activation condition of the norm (e.g., play a role)
g: the goal of the obligation (e.g., commit to a mission)
d: the deadline of the obligation

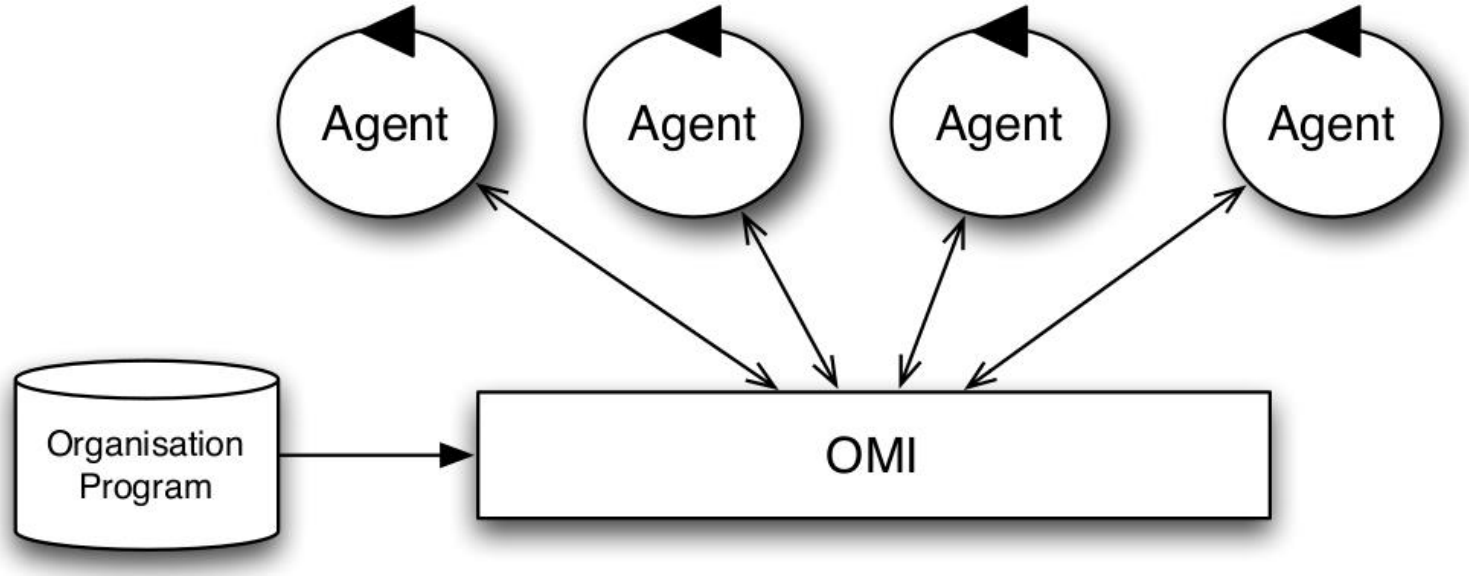
Organization Entity

smart-room.jcm

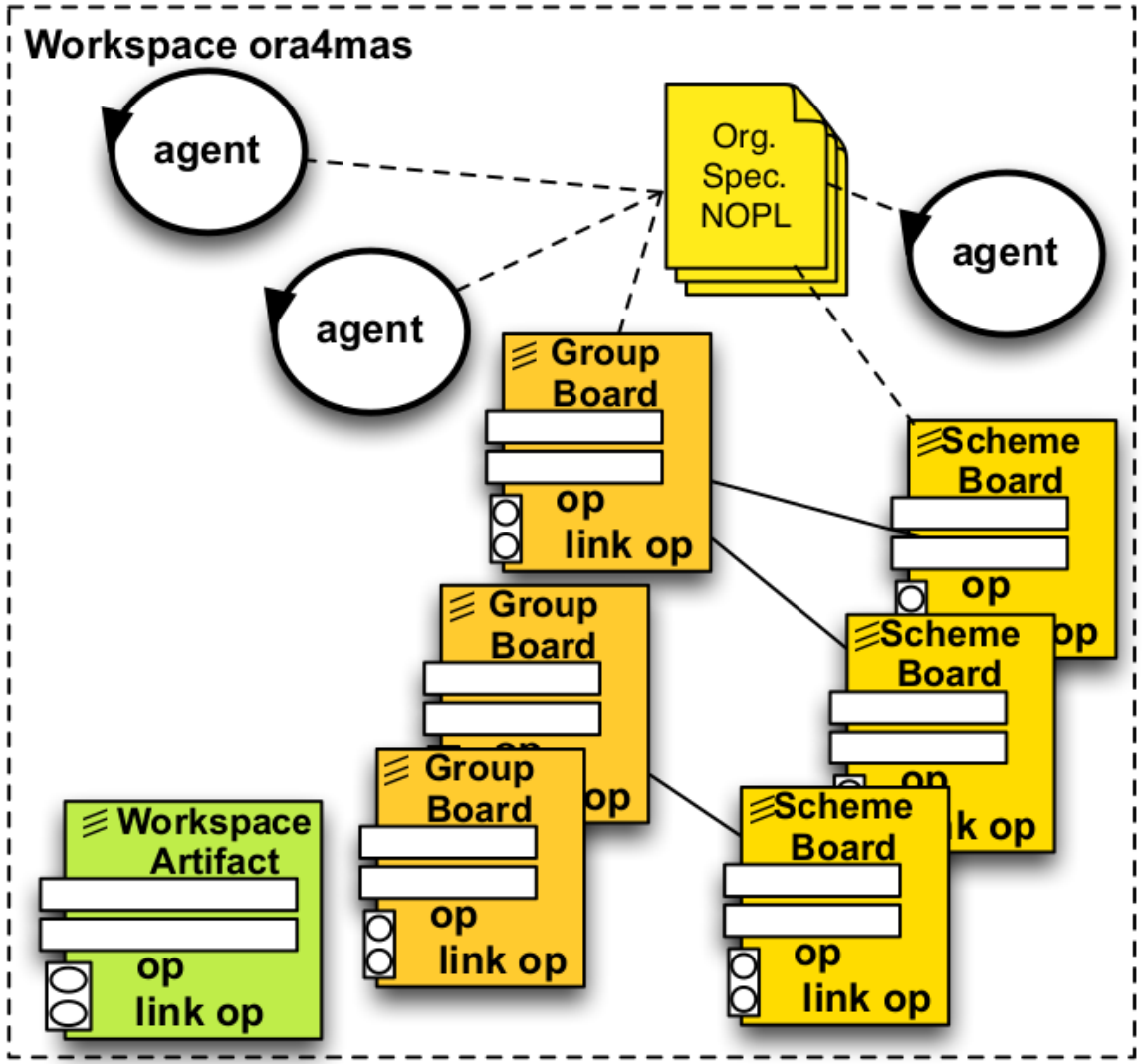
```
mas smart_room {
      …

     organisation smart_house_org : smart_house.xml {
        group r1 : room {
           players: pa1 assistant
                    pa2 assistant
                    pa3 assistant
                    rc controller
           responsible-for: temp_r1
        }

        scheme temp_r1: decide_temp
     }
}
```

Organization Management Infrastructure (OMI)

Managing – coordination, regulation – the agents' execution within organization defined in an organization specification

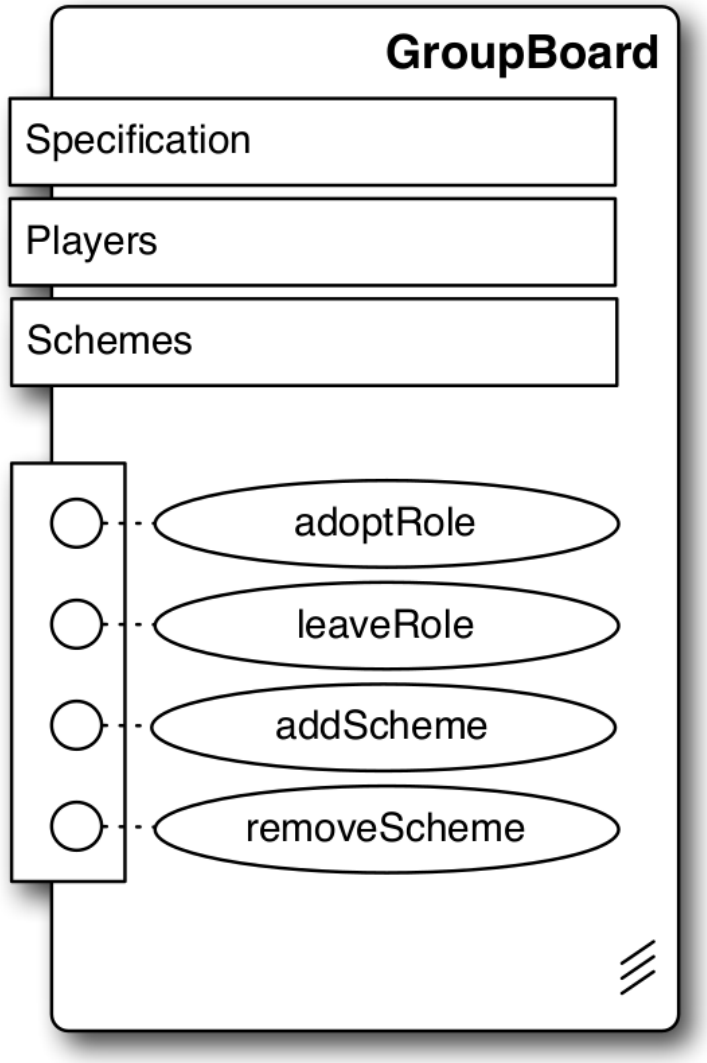


Organizational Artifacts in JaCaMo



- based on A&A and Moise
- agents create and handle organizational artifacts
- artifacts in charge of regimentations, detection and evaluation of norms compliance
- agents are in charge of decisions about sanctions
- distributed solution

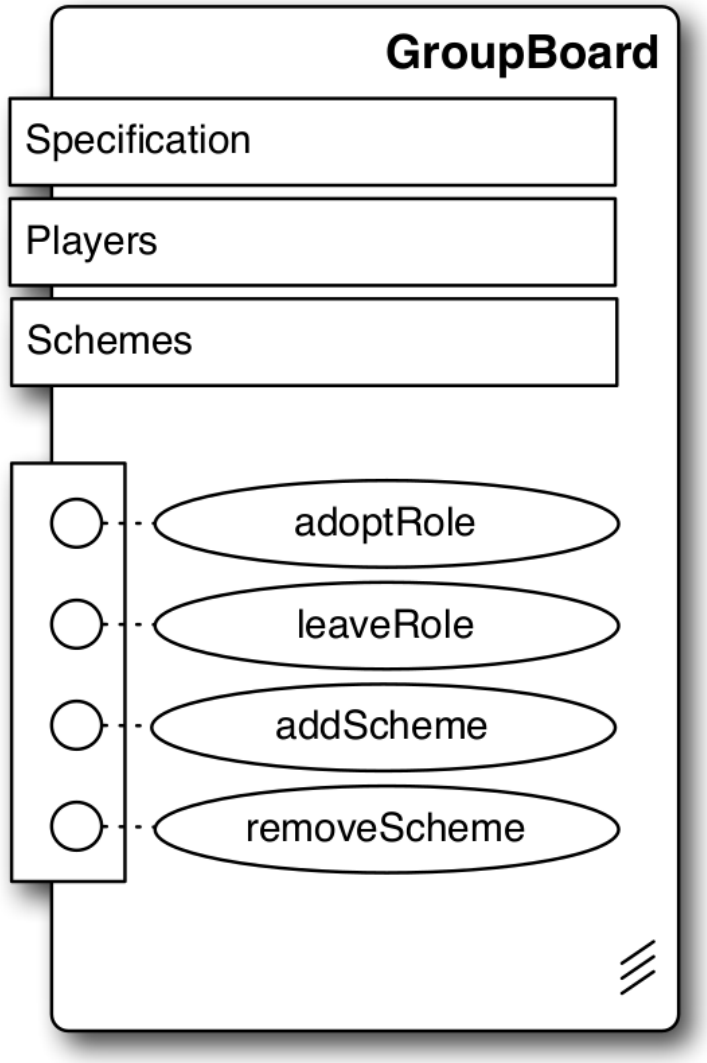
GroupBoard Artifact



Observable Properties

- **specification**: the specification of the group in the OS
- **players**: a list of agents playing roles in the group. Each element of the list is a pair (agent x role)
- **schemes**: a list of scheme identifiers that the group is responsible for

GroupBoard Artifact



Operations

- **adoptRole(role)**: the agent executing this operation tries to adopt a role in the group
- **leaveRole(role)**
- **addScheme(schId)**: the group starts to be responsible for the scheme managed by the SchemeBoard **schId**
- **removeScheme(schId)**

SchemeBoard Artifact

Observable Properties

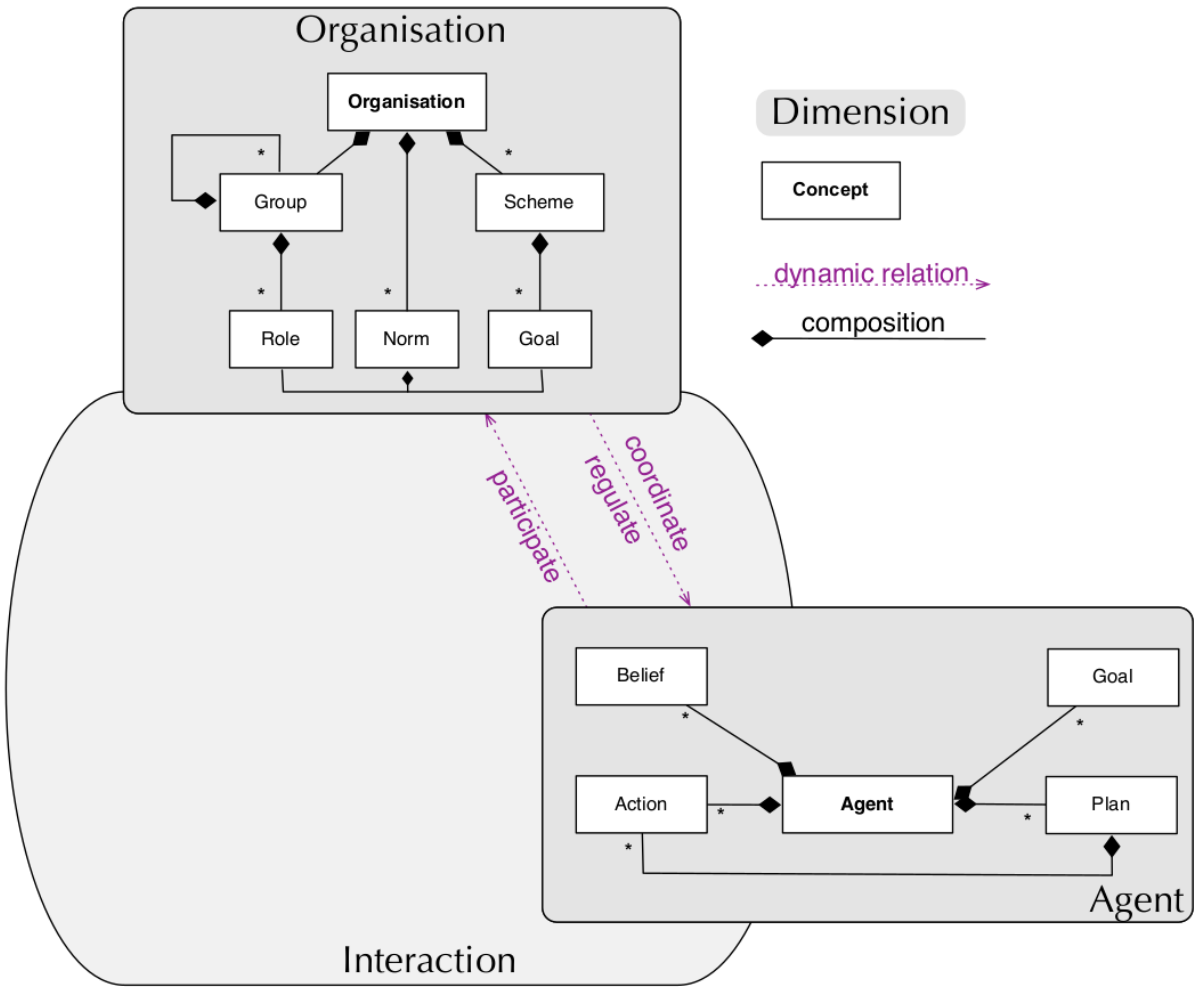
- **specification**: the specification of the scheme in the OS
- **groups**: a list of groups responsible for the scheme
- **players**: a list of agents committed to the scheme. Each element of the list is a pair (agent, mission)
- **goals**: a list with the current state of the goals
- **obligations**: list of obligations currently active in the scheme

SchemeBoard Artifact

Operations

- **commitMission(mission)** and **leaveMission**: operations to "enter" and "leave" the scheme
- **goalAchieved(goal)**: defines that some goal is achieved by the agent performing the operation
- **setGoalArgument(goal,argument, value)**: defines the value of some goal's argument

Integrating Agent and Organization Dimensions



- Agents can interact with organizational artifacts as with ordinary artifacts by perception and action
- Agent integration provides “internal” tools for the agents to simplify their interaction with the organization:
  - maintenance of a local copy of the organizational state
  - production of organizational events
  - provision of organizational actions

Integrating Agent and Organization Dimensions

GroupBoard

```
...
joinWorkspace("ora4mas",O4MWsp);
makeArtifact(
    "auction",
    "ora4mas.nopl.GroupBoard",
    ["auction-os.xml", auctionGroup],
    GrArtId);
adoptRole(auctioneer);
focus(GrArtId);
...
```

SchemeBoard

```
...
makeArtifact(
   "sch1",
   "ora4mas.nopl.SchemeBoard",
   ["auction-os.xml", doAuction],
   SchArtId);
focus(SchArtId);
addScheme(Sch);
commitMission(mAuctioneer)[artifact_id(SchArtId)];
...
```

Including organization-reasoning abilities into agents

```
+play(Ag,assistant,GrId) <- .send(Ag,tell,hello).
+goalState(_,close_voting,_,_,satisfied) <- ...
```

Including norm-reasoning abilities into agents

```
+obligation(Ag,Norm,achieved(_,Goal,_),DeadLine)
    : .my_name(Ag) & good(mood)
<- !Goal.
```

Organization Beliefs

Belief	Description
`play(A,R,G)`	Agent `A` is playing role `R` in group `G`
`commitment(A,M,S)`	Agent `A` is committed to mission `M` in scheme `S`
`formationStatus(S)[artifact_name(_,A)]`	The formation status for scheme or group `A` is `S` (possible values for `S` are `ok` or `nok`)
`goalState(S,G,LC,LA,T)`	Goal `G`, of scheme `S`, is in state `T` (possible values for `T` are `waiting`, `enabled`, `satisfied`); `LC` is a list of agents committed to the goal, and `LA` is the list of agents that have already achieved the goal
`goalArgument(S,G,A,V)`	Argument `A` of goal `G` has value `V` in scheme `S`
`obligation(A,R,G,D)`	Agent `A` is obliged to achieve `G` before `D` while `R` holds
`permission(A,R,G,D)`	Agent `A` is permitted to achieve `G` before `D` while `R` holds

Organization Events

Event	Description
`oblCreated(O)`	Obligation `O` was created
`oblFulfilled(O)`	Obligation `O` was fulfilled
`oblUnfulfilled(O)`	Obligation `O` was unfulfilled
`oblInactive(O)`	Obligation `O` is inactive

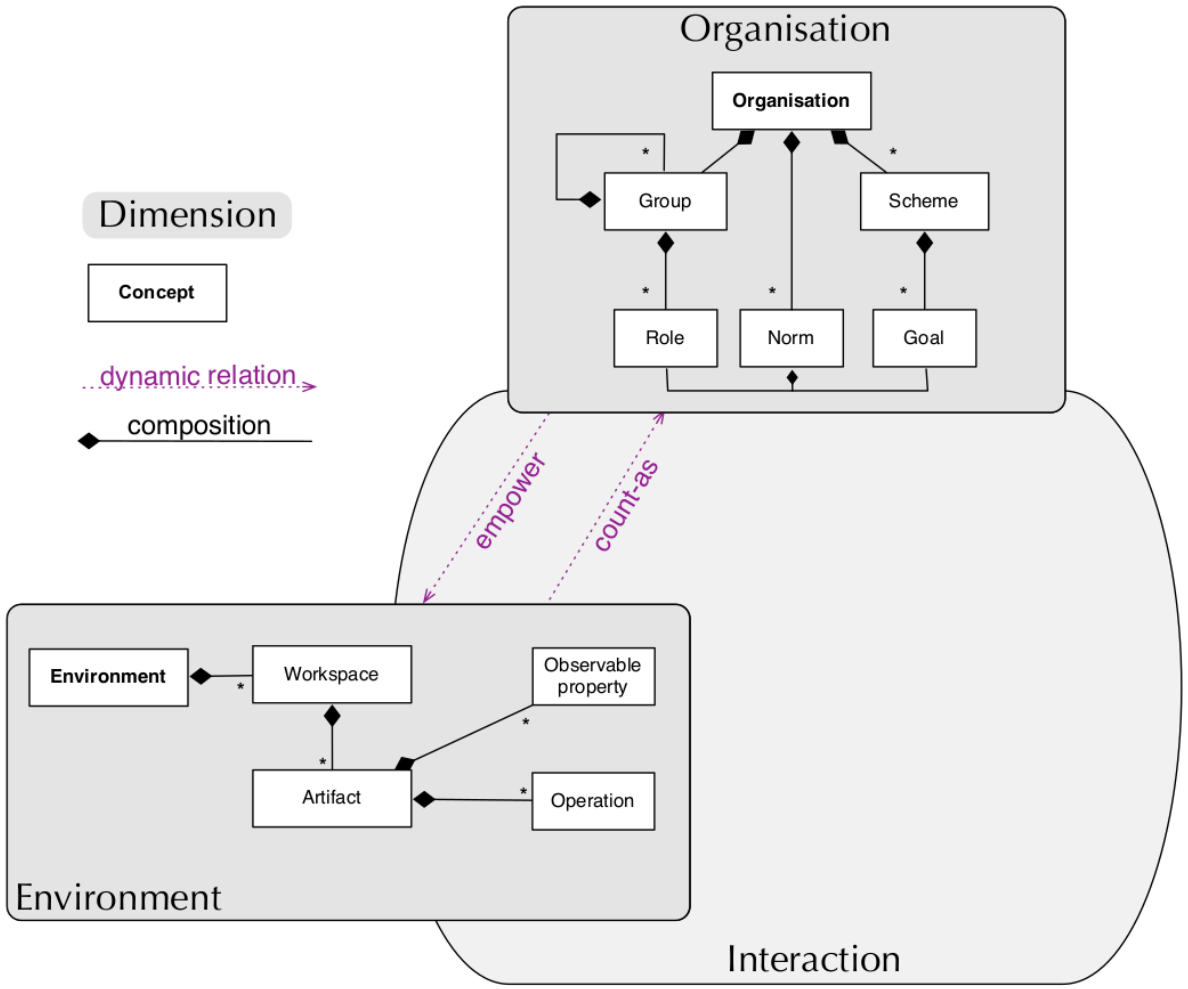
Organization Actions

Belief	Description
`createGroup(Name,Type,ArtId)[artifact_name(O)]`	Creates a new group of name `Name`, following the group specification `Type` defined in the organization specification used to create organization `O`. The organization artifact `GroupBoard` that manages it is identified by `ArtId`
`createScheme(Name,Type,ArtId)[artifact_name(O)]`	Creates a new scheme of name `Name`, following the scheme specification `Type` defined in the organization specification used to create organization `O`. The organization artifact `SchemeBoard` that manages it is identified by `ArtId`
`adoptRole(R)[artifact_name(G)]`	Adopt role `R` in group `G`
`leaveRole(R)[artifact_name(G)]`	Leave role `R` in group `G`
`addScheme(S)[artifact_name(G)]`	Add scheme `S` to the responsibility of group `G`
`removeScheme(S)[artifact_name(G)]`	Remove scheme `S` of the responsibility of group `G`

Organization Actions

Belief	Description
`commitMission(M)[artifact_name(S)]`	Commit to mission `M` in scheme `S`
`leaveMission(M)[artifact_name(S)]`	Leave mission `M` in scheme `S`
`resetGoal(G)[artifact_name(S)]`	Set goal `G` to not satisfied in scheme `S`
`setArgumentValue(G,A,V)[artifact_name(S)]`	Set `V` as the value of argument `A` of goal `G` in scheme `S`

Integrating Environment and Organization Dimensions



- Changes in the state of the environment may **count-as** changes in the state of the organization
- This dynamic relation is a **practical way of situating organizations in an environment**, as happens for the agents, regulating some part of the environment (e.g., a traffic light at a crossroads) in a particular way and ruling it differently in other parts
- Organizations may **empower** the elements of the environment by allowing them to control and regulate actions or perception of the agents

Integrating Environment and Organization Dimensions

Constitutive norms

```
X count as Y in C
```

Constitutive rules

```
X count-as Y
   when Event
   while Condition
```

Example

```
play(A, assistant, "room")
  count-as committed(A, mVote, "decide_temp")
  while responsible("r1", "temp_r1")
```

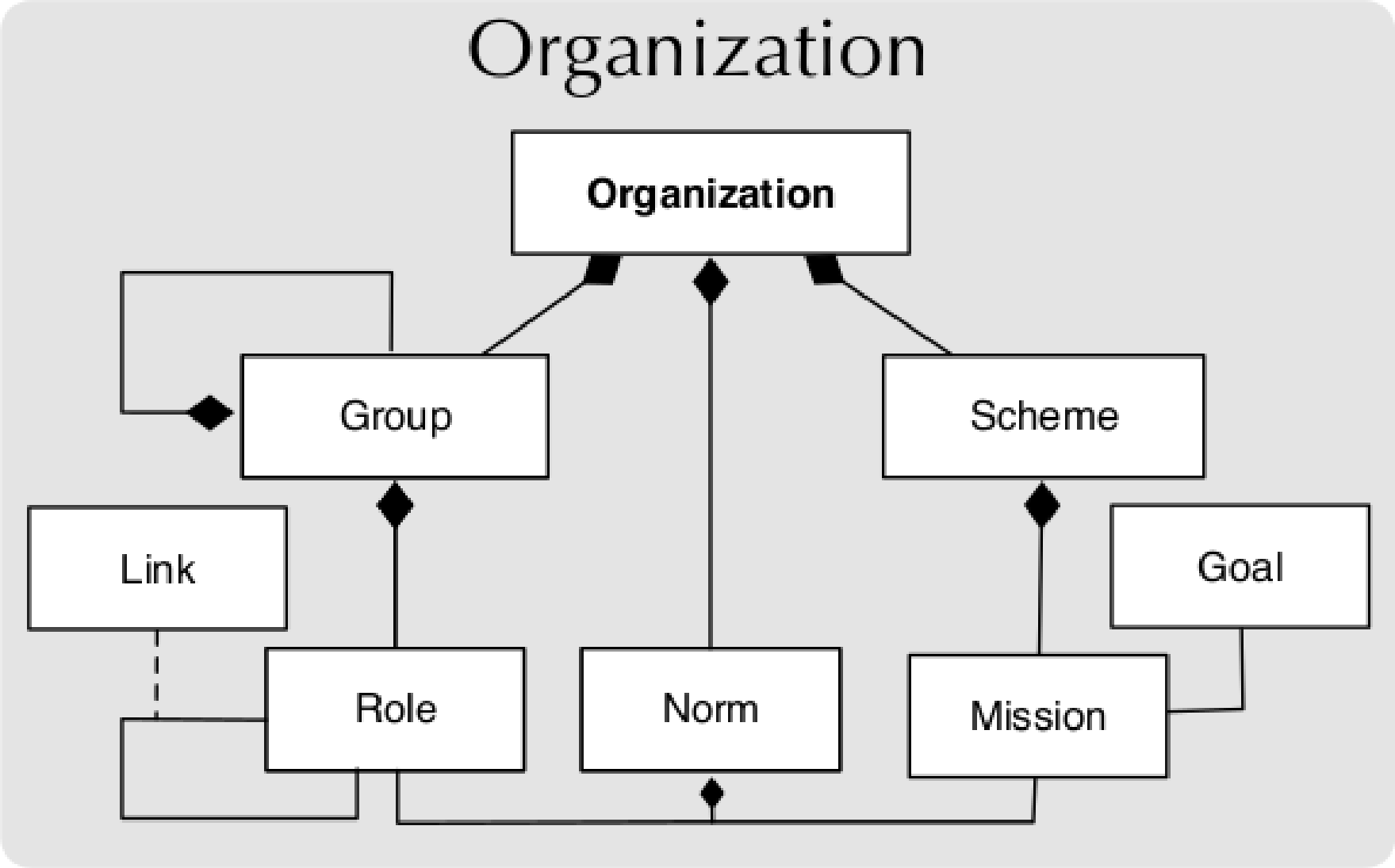
Integrating Environment and Organization Dimensions

```
institution_id : shInst.
status_functions:
states: play(A,R,G), responsible(G,S),
committed(A,Mission,S), achieved(S,G,A),
done(S,G,A).

constitutive_rules:
...
2:
play(A,assistant,''room'')
count-as committed(A,mAssistant,''decide_temp'')
3:
play(A,assistant,''room'')
count-as committed(A,mVote,''decide_temp'')
4:
play(A,controller,''room'')
count-as committed(A,mController,''decide_temp'')
...
```

Transforming organizations into situated organizations so that

- organization may act on the environment (e.g., enact rules, regimentation)
- environment may act on the organization (e.g., count-as rules) based on Situated Artificial Institution (de Brito et al., 2015)

Wrap-up: Organization Dimension



Wrap-up: Organization Dimension

- Model to specify global orchestration
  - team strategy is defined at a high level
- Ensure agents follow some of the constraints specified by the organization
- Help agents to work together
- The organization is interpreted at runtime, it is not hardwired in the agents' code
- The agents can ‘handle’ the organization (i.e., their artifacts)
- It is suitable for open systems as no specific agent architecture is required
- Organization can easily be changed by the developers or by the agents themselves

References

- Bernoux, P. (1985). *La sociologie des organisations*. Seuil, 3ème edition.
- de Brito, M., Hübner, J. F., & Boissier, O. (2015). Bringing constitutive dynamics to situated artificial institutions. In *Proc. of 17th Portuguese Conference on Artificial Intelligence (EPIA 2015)*, LNCS, vol. 9273, pp. 624–637. Springer.
- Gasser, L. (2001). Organizations in multi-agent systems. In *Pre-Proceeding of the 10th European Workshop on Modeling Autonomous Agents in a Multi-Agent World* (MAAMAW'2001), Annecy.
- Hübner, J. F., Sichman, J. S., and Boissier, O. (2007). Developing Organised Multi-Agent Systems Using the MOISE+ Model: Programming Issues at the System and Agent Levels. *Agent-Oriented Software Engineering*, 1(3/4):370–395.
- Hübner, J. F., Boissier, O., Kitio, R., & Ricci, A. (2010). Instrumenting multi-agent organisations with organisational artifacts and agents: "Giving the organisational power back to the agents". *Journal of Autonomous Agents and Multi-Agent Systems*, 20(3):369–400.
- Malone, T. W. (1999). Tools for inventing organizations: Toward a handbook of organizational process. *Management Science*, 45(3):425–443.
- Morin, E. (1977). *La méthode (1) : la nature de la nature*. Points Seuil.