Multi-agents Coordination

Organization-based Coordination

Outline

- **A broad concept: several organization viewpoint**
- **Organization with Jacamo**

Illustration

- **Soccer is a game with**
  - Two teams and a referee
  - Rules
  - Players with role: goalkeeper, attacker, defender, …
  - Teams have an objective
  - Strategies
  - ...

- **Building example (cf labs)**
  - A owner
  - Companies
  - Constraints / obligation
  - …

Organisation

Definition

- Organisations are **supra-individual phenomena**

Organisations are structured, patterned systems of activity, knowledge, culture, memory, history, and capabilities that are distinct from any single agent [Gasser, 2001]

- Organization defines the system in which agents act.
- It gives a model of the system

Building Site Organization

- Architect designs the map of the building
- Architect is the head of the Building Site
- …

In which system I'm working?

What is the equivalent in the soccer example?

Organisation

Definition

- **Definition by the designer, or by actors, to achieve a purpose**

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]

- Organisation structures and aids in the decision and interaction of the agents to fulfill tasks and achieve goals

- Organisation garanties a global coherent state of the system

- Companies have the goal to achieve their work
- A painter does the task “paint”
- Architect decides of the order of the tasks

What I have to do in this system?

What is the equivalent in the soccer example?

Organisation

Definition

- **Pattern of predefined cooperation**

An organisation is characterized by: a division of tasks, a distribution of roles, authority systems, communication systems, contribution-retribution systems [Bernoux, 1985]

- Organisation specifies what has to be done and by which role

Building Site Organization

- Architect decides when companies access to the building site
- Company with a delay has to pay a penalty

What are the rules of this system?

What is the equivalent in the soccer example?

Organisation

Definition

- **Pattern of emergent 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]

Building Site Organization

- A painter paint
- An electrician « electrify »
- …
- They act without knowledge about cooperation

System observation

What is the equivalent in the soccer example?

Synthesis

- **Organisation has to be formalized in addition of the agents**
- **Organization specifies what agents have to do**
- **Organisation is defined to satisfy a global goal that may be decomposed in sub-goals**
- **Organization rules how the agents behaves**

Application with JACAMO

- **Moïse Framework with**
  - A tag-based language (from Moise [Hannoun et al., 2000], Moise+ [Hübner et al., 2002], MoiseInst [Gâteau et al., 2005])
  - Infrastructure for supporting organisation execution

- **Implementation**
  - XML file in the org repository that is loaded at the beginning of the execution
  - Dedicated command processed by agents
    - adoptRole
    - createScheme
    - commitMission
    - …

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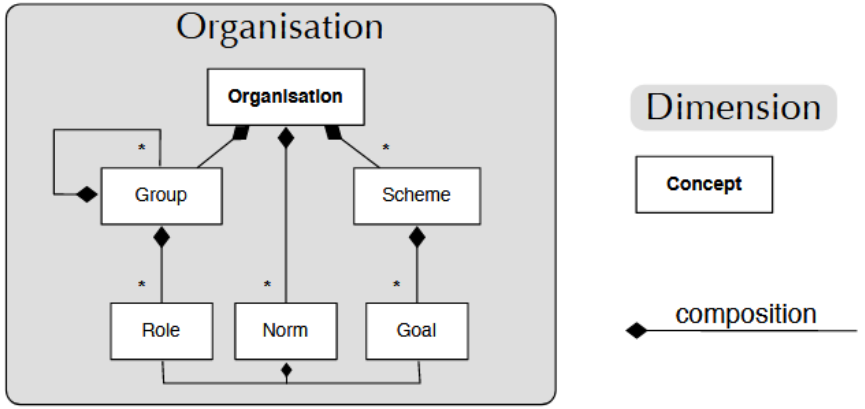
Application with JACAMO

Organisation dimension – Basic concepts

Organisation dimension



Simplified Conceptual View ($\mathcal{M}$oise meta-model [Hübner et al., 2009])

Excerpts from organisation program:

```
<structural-specification>

<role-definitions>
 <role id="auctioneer" />
 <role id="participant" />
</role-definitions>

<group-specification id="auctionGroup">
 <roles>
  <role id="auctioneer"  min="1" max="1"/>
  <role id="participant" min="0" max="300"/>
 </roles>
</group-specification>
</structural-specification>
```

```
<functional-specification>
 <scheme id="doAuction">
  <goal id="auction">
   <argument id="Id" />
   <argument id="Service" />
   <plan operator="sequence">
    <goal id="start" />
    <goal id="bid"    ttf="10 seconds" />
    <goal id="decide" ttf="1 hour" />
   </plan>
  </goal>
  <mission id="mAuctioneer" min="1" max="1">
   <goal id="start" />
   <goal id="decide" />
  </mission>
```

```
<normative-specification>
  <norm id="n1"  type="permission"
        role="auctioneer"
        mission="mAuctioneer" />
  <norm id="n2"  type="obligation"
        role="participant"
        mission="mParticipant" />
</normative-specification>
```

Normative spec.

```
norm n1 : plays(A, auctionneer, G) ->
  forbidden(A,n1,plays(A,participant,G),
    'forever').
```

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 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

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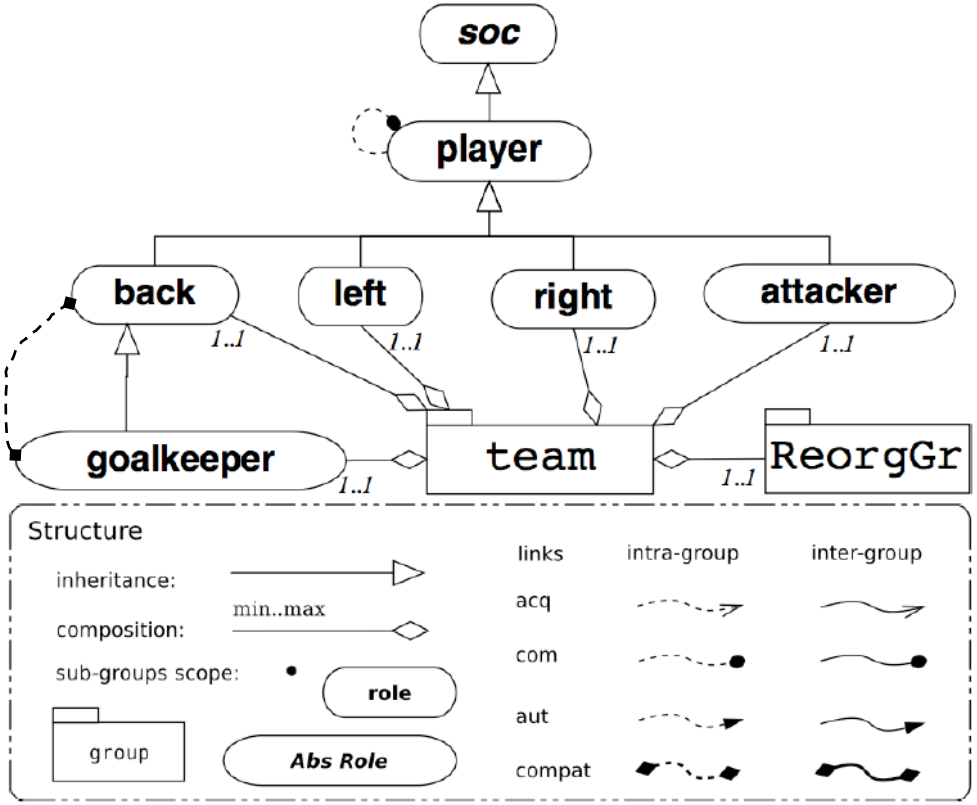
Example

Football team

Structural specification example (1)



Graphical representation of structural specification of Joj Team

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Structural specification

XML specification

- Defined with the tag structural-specification in the context of an organisational-specification
- One section for definition of all the roles participating to the structure of the organisation (role-definitions tag)
- Specification of the group including all subgroup specifications (group-specification tag)
- Example

```
<organisational-specification
        <structural-specification>
                <role-definitions> ... </role-definitions>
                <group-specification id="xxx"> ... </group-specification>
        </structural-specification>
        ...
</organisational-specification>
```

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Role specification

XML specification

- Role definition(role tag) in role-definitions section, is composed of
  - identifier of the role (id attribute of role tag)
  - inherited roles (extends tag) - by default, all roles inherit of the soc role –
- Example

```
<role-definitions>
    <role id="player" />
    <role id="back"> <extends role="player"/> </role>
    <role id="goalkeeper"> <extends role="back"/> </role>
    <role id="r1>
            <extends role="r2" />
            <extends role="r3" />
    </role>
...</role-definitions>
```

Group specification

XML specification

- Group definition (group-specification tag) is composed of
  - group identifier (id attribute of group-specification tag)
  - roles participating to this group and their cardinality (roles tag and id, min, max), i.e. min. and max. number of agents that should adopt the role in the group (default is 0 and unlimited)
  - links between roles of the group (link tag)
  - subgroups and their cardinality (subgroups tag)
  - formation constraints on the components of the group (formation-constraints)

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Group specification

XML specification

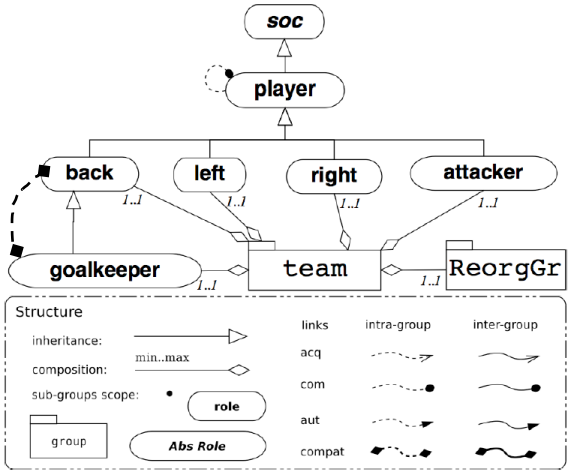
- Example

```
<group-specification id="ReorGR">
        <!--roles-->

        <!-- /roles -->
        <subgroups>
           <group-specification id="team" min="1" max = "1">
             <roles>
                    <role id="goalkeeper" min="1" max="1"/>
                    <role id="back" min="1" max="1"/>
                    …
             </roles>
         </subgroups>

<links> ... </links>
<formation-constraints> … </formation-constraints>
</group-specification>
```

Structural specification example (1)



Graphical representation of structural specification of Joj Team

Link specification

XML specification

- Link definition (link tag) included in the group definition is composed of:
  - role identifiers (from, to)
  - type (type) with one of the following values: authority, communication, acquaintance
  - a scope (scope)
  - and validity to subgroups (extends-subgroups)
- Example

```
<link    from=“player"
         to="player"
         type=“communication"
         scope="intra-group"
         extends-subgroups="true" />
```

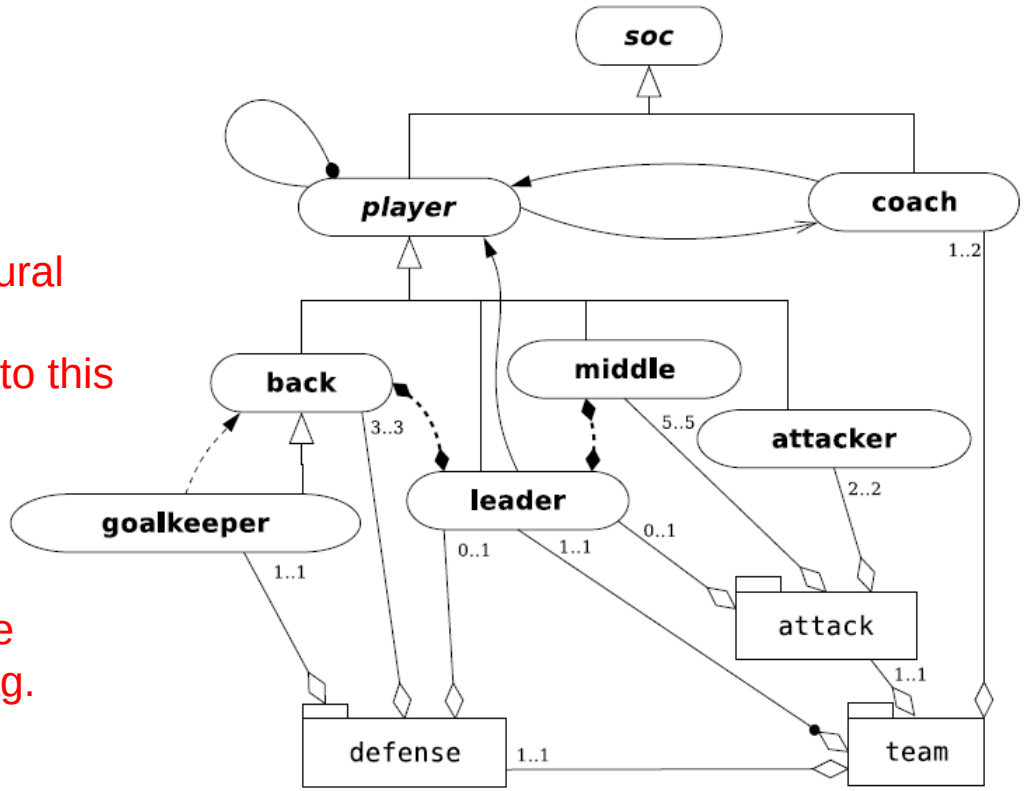
Exercise

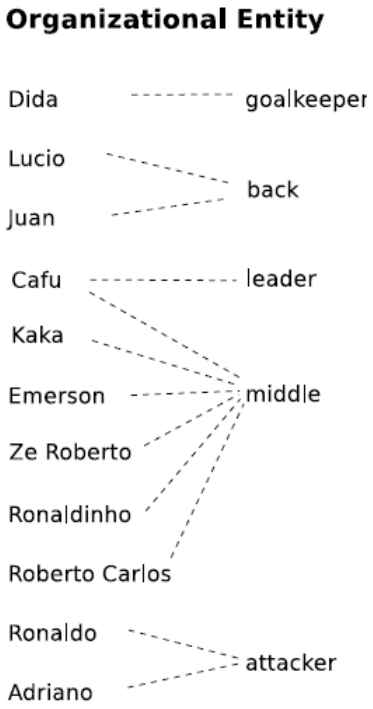
Football team

Structural specification example (2)

Give the structural specification corresponding to this graphical representation

Define only one example per tag.





Graphical representation of structural specification of 3-5-2 Joj Team

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Functional specification

- Specifies the expected behaviour of an MAS in terms of **goals** along two levels:
  - **Collective** with **Scheme**
  - **Individual** with **Mission**
- Components:
  - **Goals**:
    - Performance goal (default type). Goals of this type should be declared as done by the agents committed to them, when realized
    - Achievement goal. Goals of this type should be declared as satisfied by the agents committed to them, when realized
    - Maintenance goal. Goals of this type are not realized 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

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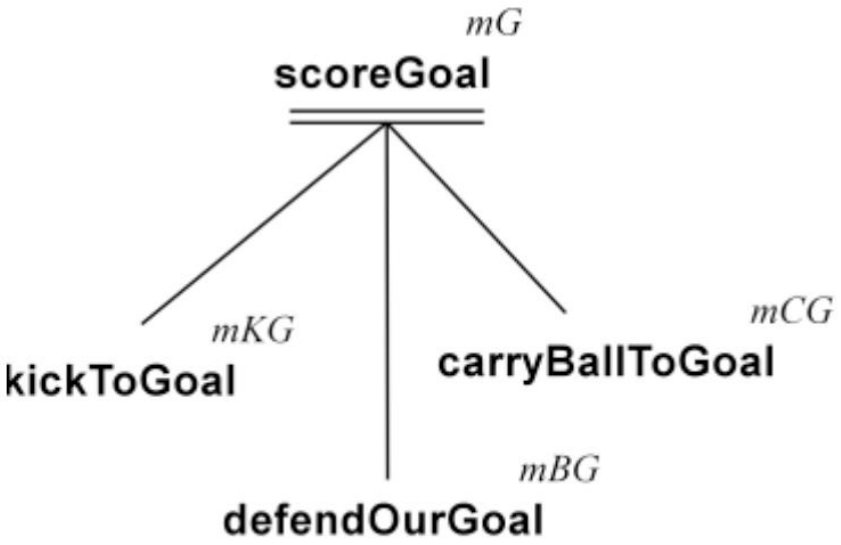
Functional specification

Example



Graphical representation of social scheme for joj team

Functional specification

XML specification

- Defined with the tag f*unctional-specification* in the context of an *organisational-specification*
- Specification in sequence of the different schemes participating to the expected behaviour of the organisation

- Example

```
<functional-specification>
    <scheme id="firstAttack" >
      <goal id="scoreGoal" > ... </goal>
      <mission id="m1" min="1" max="5">   <goal id = "firstAttack"> ...  </mission>
      ...
    </scheme>
  ...
</functional-specification>
```

Scheme/goal/plan specification
XML specification

- Scheme definition (scheme tag) is composed of:
  - identifier of the scheme (id attribute of scheme tag)
  - the root goal of the scheme with the plan aiming at achieving it (goal tag)
  - the set of missions structuring the scheme (mission tag)
- Goal definition within a scheme (goal tag) is composed of:
  - an idenfier (id attribute of goal tag)
  - a type (performance default, achievement or maintenance)
  - min. number of agents that must satisfy it (min) (default is "all")
  - optionally, an argument (argument tag) that must be assigned to a value when the scheme is created
  - optionally a plan
- Plan definition attached to a goal (plan tag) is composed of
  - one and only one operator (operator attribute of plan tag) with sequence, choice, parallel as possible values
  - set of goal definitions (goal tag) concerned by the operator

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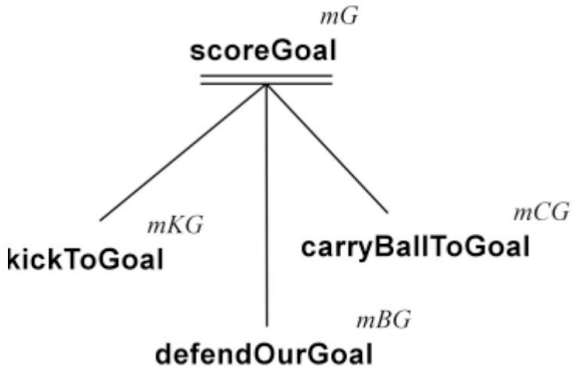
Scheme/goal/plan specification
XML specification

```
<scheme id="myAttack">
    <goal id="scoreGoal" min="1" >
      <plan operator="parallel">
        <goal id="g1" min="1" ds=" kick to goal" />
         <goal id="g2" min="1" ds=" defend Our Goal "/>
         <goal id="g3" min="1" ds=" carry ball to goal " />
      </plan>
    </goal>
</scheme>
```



Graphical representation of social scheme for joj team

Mission specification

XML specification

- Mission definition (mission tag) in the context of a scheme definition, is composed of:
  - identifier of the mission (id attribute of mission tag)
  - cardinality of the mission min (0 is default), max (unlimited is default) specifying the number of agents that can be committed to the mission
  - the set of goal identifiers (goal tag) that belong to the mission

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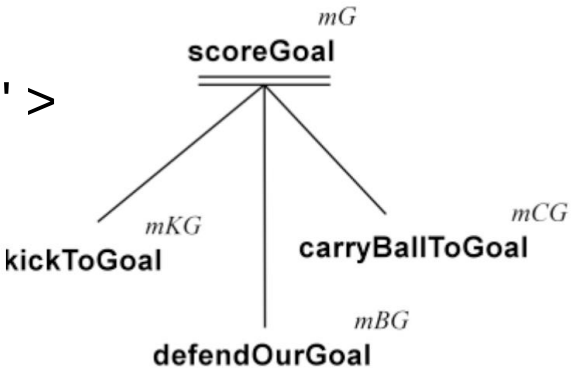
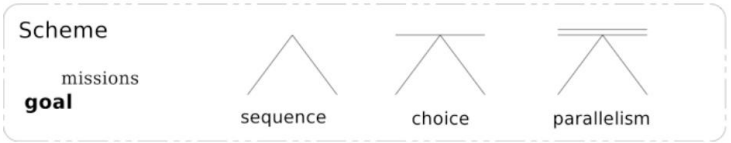
Scheme/goal/plan specification

XML specification

```
<scheme id="myAttack">
    <goal id="scoreGoal" min="1" >
      <plan operator="parallel">
        <goal id="g1" min="1" ds=" kick to goal" />
        <goal id="g2" min="1" ds=" defend Our Goal "/>
        <goal id="g3" min="1" ds=" carry ball to goal " />
      </plan>
    </goal>
    <mission id = "mKG" min="1" max="1" >
        <goal id = "g1">
    </mission>
    …
</scheme>
```



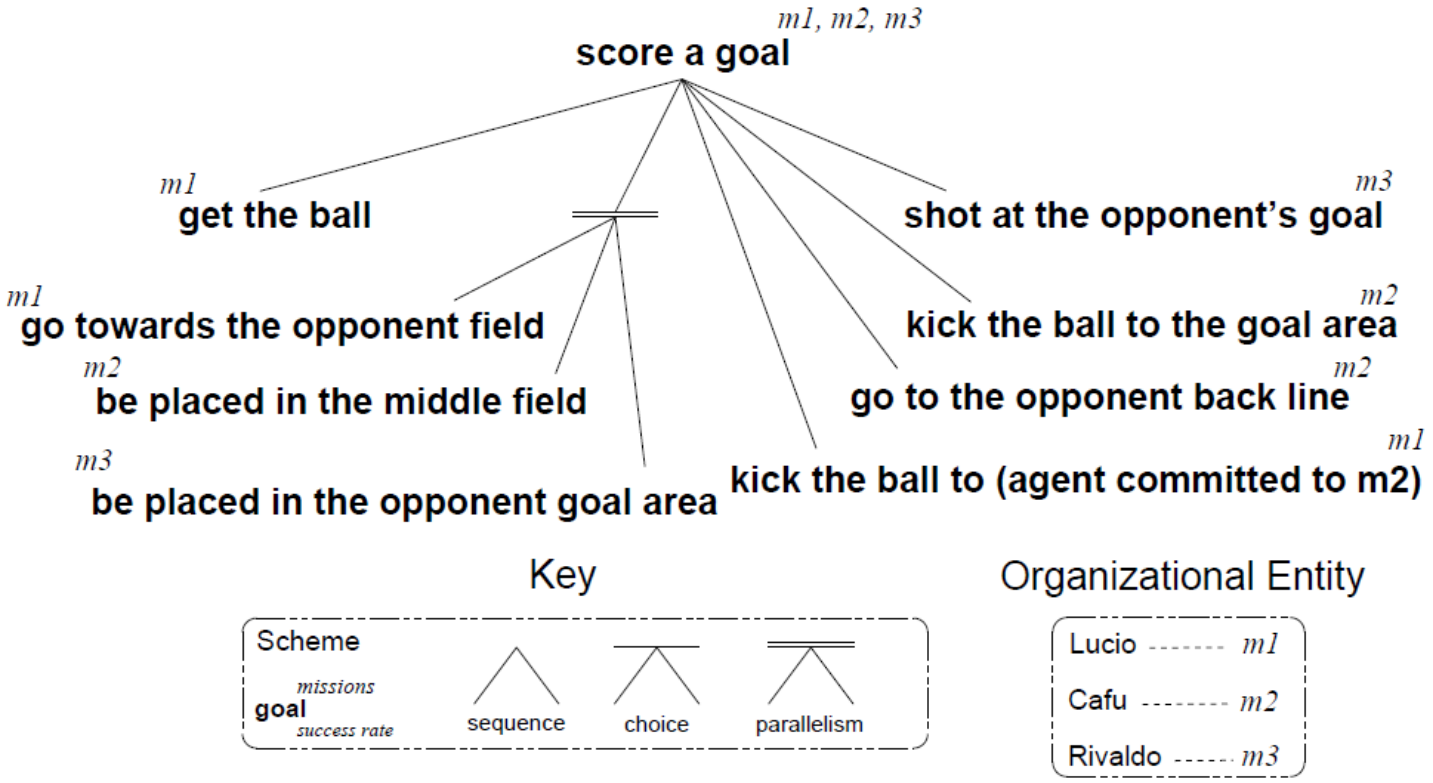


Graphical representation of social scheme for joj team

Exercise

Football team

Functional specification example (2)



Graphical representation of social scheme "side_attack" for joj team

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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

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Normative specification

XML specification

- Defined in-between the tag normative-specification in the context of an organisational-specification
- Definition in sequence of the different norms participating to the governance of the organisation
- Definition of programs written in Normative Programming Language (NPL)

Example

```
<normative-specification>
    <norm id="n1" ... />
     ...
    <norm id="..." ... />
    <npl-norms>
    ...
    </npl-norms>
</normative-specification>
```

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Normative specification

XML specification

- Norm definition with norm tag, in the context of a normative-specification definition, with attributes:
  - the identifier of the norm (id)
  - the type of the norm (type) with obligation, permission as possible values
  - a condition of activation (condition) – optional – checking:
    - properties of the organisation (e.g. #role_compatibility, #mission_cardinality, #role_cardinality, #goal_non_compliance)
    - ⇝ unregimentation of organisation properties !!!
    - (un)fulfillment of an obligation stated in a particular norm (unfulfilled, fulfilled)
  - the role identifier (role) on which the norm is applied
  - the mission identifier (mission) object of the norm
  - a time constraint (time-constraint) – optional –

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Example

Football team

Norm Definition – example

- Any agent playing *back* is *obliged* to commit to mission *m*1 and achieve its goals within 1 minute

```
<norm id = "n1" type="obligation"
      role="back" mission="m1" time-constraint="1 minute"/>
```

- Any agent playing *left* is *obliged* to commit to mission *m*2 and achieve its goals within 1 day

```
<norm id = "n2" type="obligation"
      role="left" mission="m2" time-constraint="1 day"/>
```

- Any agent playing *coach* is *obliged* to commit to mission *ms* and achieve its goals within 3 hour in case obligation of norm n2 has not been fulfilled

```
<norm id = "n4" type="obligation"
      condition="unfulfilled(obligation(_,n2,_,_))"
      role="coach" mission="ms" time-constraint="3 hour"/>
```

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Conclusion

- **Organization-based Coordination**
  - Organization is modeled apart of the agents
  - Organization model defines the behavior of the system
  - Agents' behavior is ruled by the Organization model

Bibliography

- Hannoun, M., Boissier, O., Sichman, J. S., and Sayettat, C. (2000). Moise: An organizational model for multi-agent systems. In Monard, M. C. and Sichman, J. S., editors, Proceedings of the International Joint Conference, 7th Ibero-American Conference on AI, 15th Brazilian Symposium on AI (IBERAMIA/SBIA'2000), Atibaia, SP, Brazil, November 2000, LNAI 1952, pages 152–161, Berlin. Springer.
- Hübner, J. F., Sichman, J. S., and Boissier, O. (2002). A model for the structural, functional, and deontic specification of organizations in multiagent systems. In Bittencourt, G. and Ramalho, G. L., editors, Proceedings of the 16th Brazilian Symposium on Artificial Intelligence (SBIA'02), volume 2507 of LNAI, pages 118–128, Berlin. Springer.
- Gâteau, B., Boissier, O., Khadraoui, D., and Dubois, E. (2005). Moise inst: An organizational model for specifying rights and duties of autonomous agents. In Third European Workshop on Multi-Agent Systems (EUMAS 2005), pages 484–485, Brussels Belgium.