

4. Multiagent Systems Design

Part 4: Coordination models (I): Social Models

Social Structures

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Introduction to Social Models

- Social Studies and Organizational Studies
- Social Structures
- Agent Societies



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Social studies

Sociology and Societies

- **Sociology** is a discipline that results from an evolution of moral and ethical philosophy in order to describe the interactions that arise among the members of a group, and the social structures that are established.
- The aim of any **society** is to allow its members to coexist in a shared environment and pursue their respective goals in the presence and/or in co-operation with others.
 - Global goals and requirements
 - Predictability
 - Explicit rules and interaction possibilities
- This can also be applied to digital societies composed by computational entities
 - Agent societies

Social studies

Role

- One of the main concepts we find in complex social structures is **role**.
 - A role is a description of the tasks and objectives to be performed by an entity.
 - The idea is that it is not important who plays the role as far as there are enough entities enacting it.
- Roles have been extensively studied in the *Organizational Theory* field, in order to study
 - the relationships among the social roles an individual may play,
 - the obligations and authorizations that are associated to each one of those roles, and
 - the interaction of roles in the distribution of labour mechanisms.

Social studies

Organizational studies

- **Organizational studies**, **organizational behavior**, and **organizational theory** are related terms for the academic study of *organizations*, examining them using the methods of *economics*, *sociology*, *political science*, *anthropology*, and *psychology*
- Concepts, abstractions and techniques coming from organizational theories and organizational design have been used in MAS.
 - *Organization theory* is a descriptive discipline, mainly focusing on describing and understanding organizational functioning.
 - *Organization design* is a normative, design-oriented discipline that aims to produce the frameworks and tools required to create effective organizations

Social Studies

Organization design

- **Organization design** involves the creation of roles, processes, and formal reporting relationships in an organization.
- One can distinguish between two phases in an organization design process:
 - *Strategic grouping*, which establishes the overall structure of the organization (its main sub-units and their relationships), and
 - *Operational design*, which defines the more detailed roles and processes.
- The most frequently cited book is Thompson (1967); other key works include Galbraith (1973) and Lawrence & Lorsch (1967).

Social Structures

- In open systems, some kind of structure should be defined in order to ease coordination in a *distributed control* scenario.
- A good option taken from human and animal interactions is the definition of *social structures*.
- *Social structures* define a *social level* where the multi-agent system is seen as a *society* of entities in order to enhance the coordination of agent activities (such as message passing management and the allocation of tasks and resources) by defining *structured patterns of behaviour*.

Social Structures

Aim

- *Social structures* reduce the danger of combinatorial explosion in dealing with the problems of agent cognition, cooperation and control, as they impose restrictions to the agents' actions.
- These restrictions have a positive effect, as they:
 - avoid many potential conflicts, or ease their resolution
 - make easier for a given agent to foresee and model other agents' behaviour in a closed environment and fit its own behaviour accordingly.

Social Structures

Sociological classification

- Social structures are classified by Findler *et al.* [3] in:
 - An **alliance** is a temporary group formed voluntarily by agents whose goals are similar enough. The agents give up, while in the alliance, some of their own goals and fully cooperate with the other members of the alliance. Agents stay in the alliance as long as it is in their interest, thereafter they may join another alliance or stay on their own.
 - A **team** is a group formed by a special agent (called the *team leader*) who recruits qualified members to solve a given problem.
 - A **coalition** is similar to an alliance, as it is a temporary group where members do not abandon their individual goals but engage only in those joint activities whose goals are not in conflict with their own goals.
 - A **convention** is a formal description of forbidden or preferred goals or actions in a group of agents.
 - A **market** is a structure which defines two prominent roles (*buyer* and *seller*) and defines the mechanisms for transacting business.

Social Structures

Organizational classification

- A more generic approach is proposed by V. Dignum [2], where social structures are divided in three groups:
 - **Markets**, where agents are self-interested, driven completely by their own goals. Interaction in markets occurs through communication and negotiation.
 - **Networks**, where coalitions of self-interested agents agree to collaborate in order to achieve a mutual goal. Coordination is achieved by mutual interest, possibly using trusted third parties.
 - **Hierarchies**, where agents are (almost) fully cooperative, and coordination is achieved through command and control lines.
- the three groups proposed by V. Dignum aim to classify both human and software agent organizations.

Social Structures

Organizational classification

	Market	Network	Hierarchy
<i>Type of society</i>	Open	Trust	Closed
<i>Coordination</i>	Price mechanism	Collaboration	Supervision
<i>Relation form</i>	Competition	Mutual Interest	Authority
<i>Tone or climate</i>	Precision/ suspicion	Open-ended/ mutual benefits	Formal/ bureaucratic
<i>Conflict Resolution</i>	Haggling (Resort to courts)	Reciprocity (Reputation)	Supervision

Table 1.1: V. Dignum *et al.* classification of Social Structures.

- this classification is useful at the design stage, as it tries to motivate the choice of one of such structures based on their appropriateness for a specific environment.

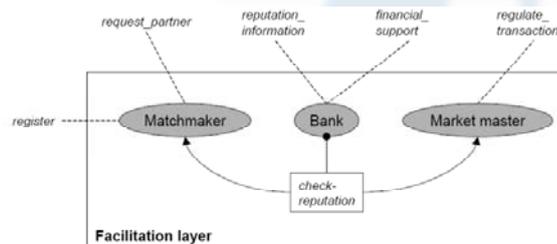
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Social Structures

Organizational classification

- **Market structures** are well-suited for environments where the main purpose is the *exchange* of some goods.
- Three tasks to be performed by facilitator agents:
 - **Matchmaking** facilities to keep track of the agents in the system, their needs and mediate in the matching of demand and supply of services;
 - **Identification** and **Reputation** facilities to build confidence for customers and offer a certain degree of guarantees to all its members despite the openness of the system.

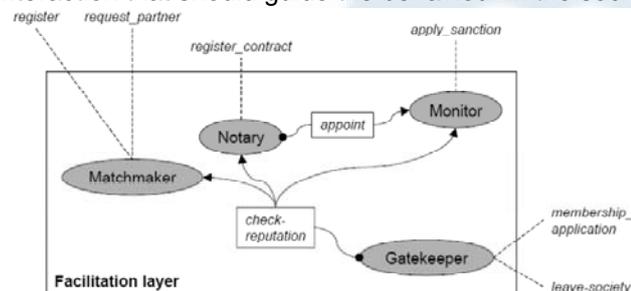


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Social Structures

Organizational classification

- **Network structures** are well-suited for environments where (dynamic) *collaboration* among parties is needed.
- Three tasks to be performed by facilitation agents
 - **Gatekeeper**, which is responsible for accepting and introducing new agents into the society;
 - **Notaries** are facilitator agents which keep track of collaboration contracts settled between agents,
 - **Monitoring agents** can check and enforce the rules of interaction that should guide the behaviour in the society.

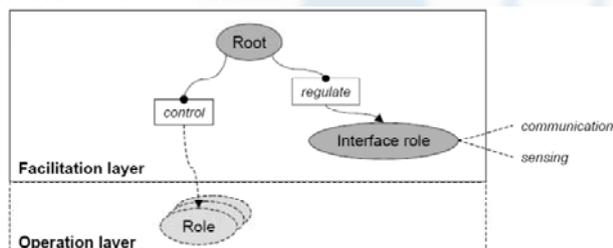


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Social Structures

Organizational classification

- **Hierarchical structures** are well-suited for environments where the society's purpose is the efficient *production* of some kind of results or goods or the control of an external production system.
- In these environments a reliable control of resources and information flow requires central entities that manage local resources and data but also needs quick access to global ones.
- Two main facilitation tasks are identified:
 - **Controllers**, which monitor and orient the overall performance of the system or a part of it;
 - **Interface agents** responsible for the communication between the system and the *outside world*.



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Agent Societies

Social abstractions: Role, Group, Role Dependency

- **Roles** identify activities and services necessary to achieve social objectives and enable to abstract from the specific individuals that will eventually perform them.
 - From the *society design perspective*, roles provide the building blocks for the agent systems that can perform the role,
 - From the *agent design perspective*, roles specify the expectations of the society with respect to the agent's activity in the society.
- In essence, role models deal with collaboration and coordination and specify collaboration relationships between entities without fixing a priori the complete interaction process.

Agent Societies

Social abstractions: Role, Group, Role Dependency

- Roles can be organized into **Groups**.
 - In its most basic form, groups are just a way to refer to a set of roles.
 - Goals and tasks can be assigned to groups.
 - Behavioural or interaction restrictions can be assigned to groups, too
 - For any society, the trivial group of roles is the group that contains all roles in the society.

Agent Societies

Social abstractions: Role, Group, Role Dependency

- Finally, **role dependency** between two roles means that one role is dependent on another role for the realization of its objectives.
 - Societies establish *dependencies* and *power relations* between roles, indicating relationships between roles.
 - These relationships describe how actors can interact and contribute to the realization of the objectives of each other. That is, an objective of a role can be delegated to, or requested from, other roles.

Agent Societies

Characteristics

- **Role models** reflect social competence of agents
 - modelled by rights and obligations
 - influence agent behaviour
 - resulting in typical speech acts and protocols for society build-up
- Role models allow to ensure some global system characteristics while also preserving individual flexibility
 - Explicit rights and obligations allow to commit to specific roles
 - roles guarantee global behaviour
 - role descriptions are represented by formal models
- **Interaction models** reflect workflows and business processes
 - Explicit procedures and access
 - Scenes descriptions are formally specified which allows verification
 - Animation of societies

Electronic Organizations

- Electronic Organizations
- Virtual Organizations
- MOISE+
- OperA



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What is an Organization ?

- Organizations are structured, patterned systems of activity, knowledge, culture, memory, history, and capabilities that are distinct from any single agent [Gasser 01]
 - 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 87]
 - Definition by the designer, or by actors, to achieve a purpose

What is an Organization ?

- An organization is characterized by: a division of tasks, a distribution of roles, authority systems, communication systems, contribution-retribution systems [Bernoux 85]
 - 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 77]
 - Pattern of emergent cooperation

Electronic Organizations

Definition

- An **Organization** is a supra-agent pattern of **emergent** cooperation or **predefined** cooperation of the agents in the system, that could be defined by the designer or by the agents themselves, for a purpose.
 - Pattern of emergent/potential cooperation
 - *Organizational entity, institution, social relations, commitments*
 - Pattern of predefined cooperation
 - *Organizational structure, norms, ...*

Electronic Organizations

Historical Remarks

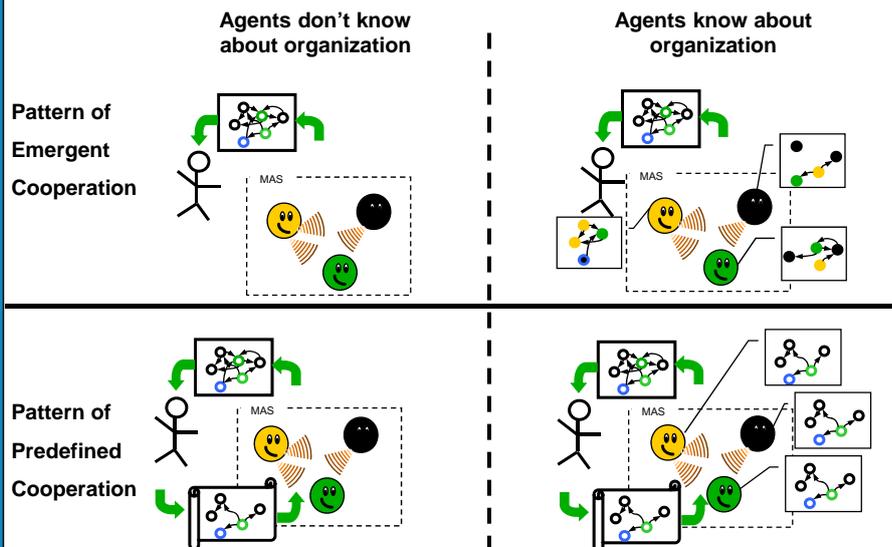
- **70 → 90** : Beginnings
 - Area of Interest in Distributed Hearsay-II [Lesser 80]
 - An Organizational View on Distributed Systems [Fox 81]
 - DVMT [Corkill 83, Pattison 87]
 - MACE [Gasser 89], Roles [Werner 89]
- **90 → 00** : Maturation
 - Dependence Theory [Castelfranchi 92]
 - CASSIOPEE [Collinot 96], MARSO [MARCIA 97]
 - AGR [Ferber 98], TAEMS [Decker 96], TEAMS [Tambe 98]
 - Computational Organization Research [Carley 99]
- **00 → now** : “Golden Age”
 - MAAMAW 01 “Organizations in MAS”
 - Workshops on Norms, Institutions, Organizations in ICMAS, AAI , AAMAS
 - **COIN** (Coordination, Organizations, Institutions and Norms in MAS)
<http://www.pcs.usp.br/~coin>

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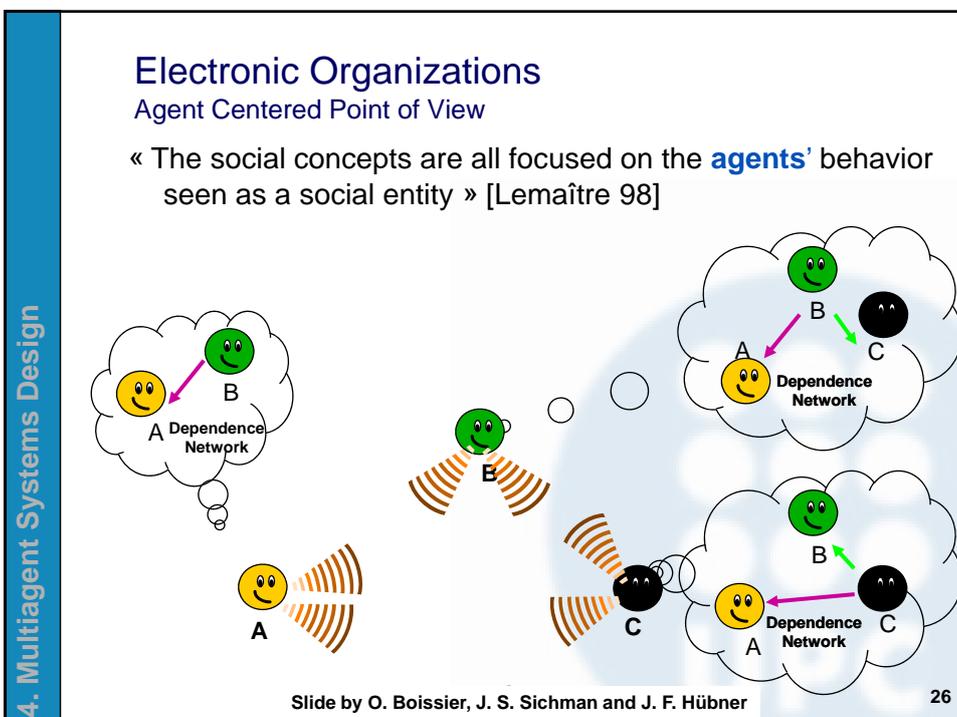
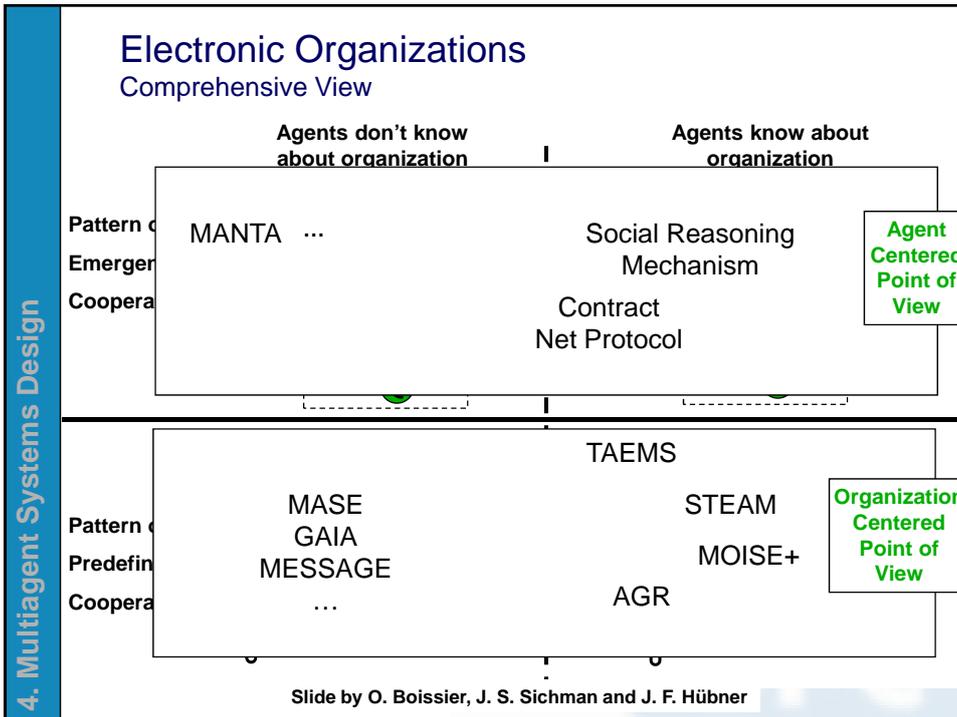
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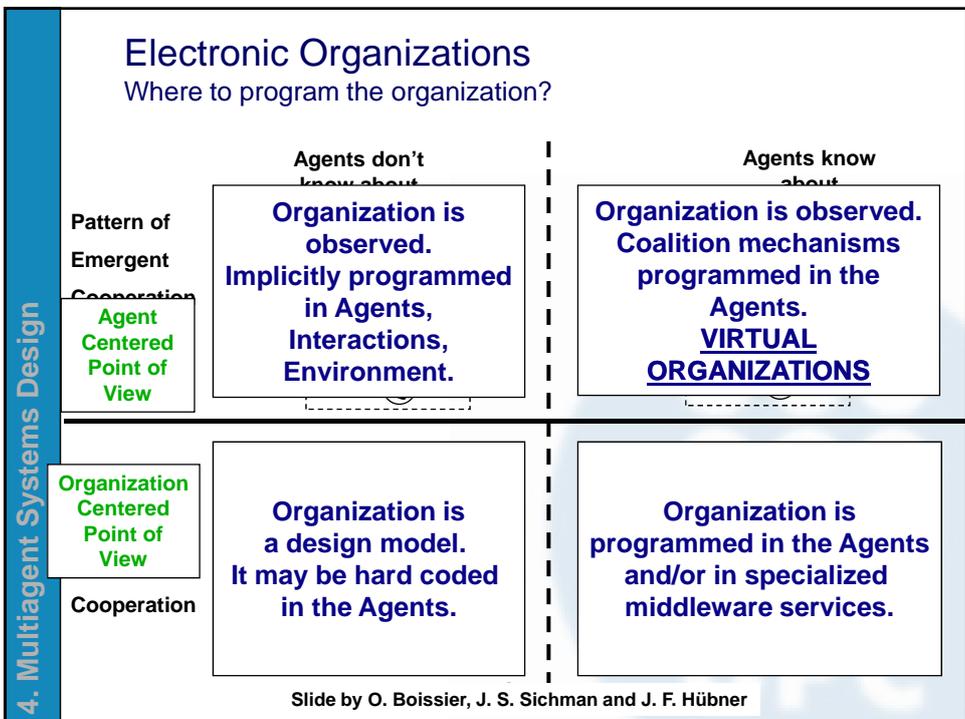
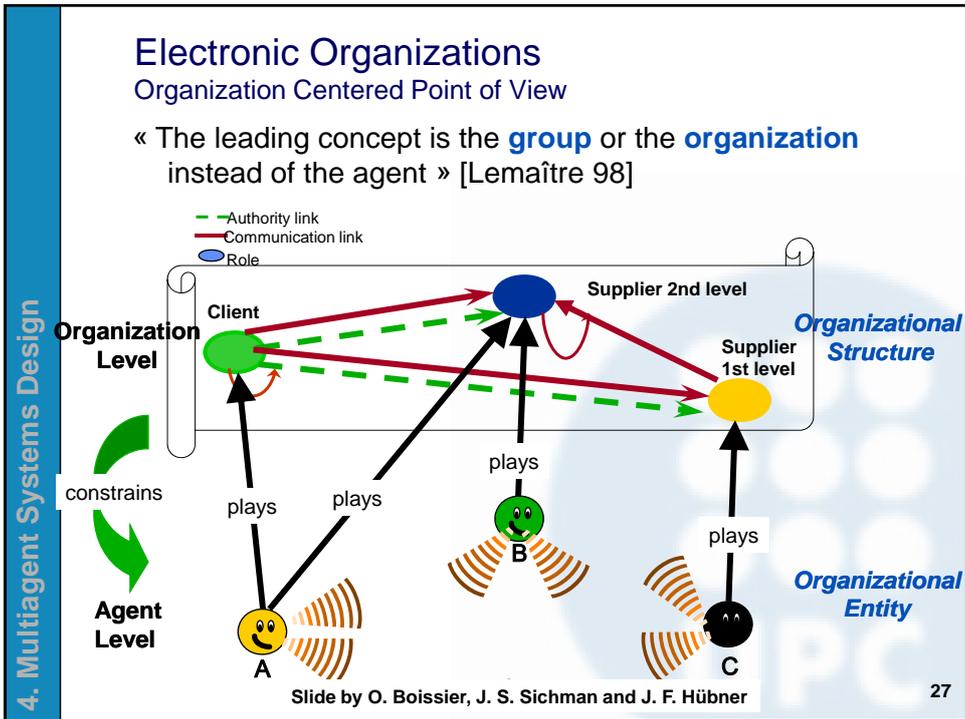
Electronic Organizations

Comprehensive View



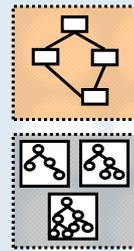
Slide by O. Boissier, J. S. Sichman and J. F. Hübner





MOISE+

- **M**odel of **O**rganization for multi-agent **S**yst**E**ms [4],[5]
- <http://www.lti.pcs.usp.br/moise>
- Distinguishes three main dimensions in the organization of a Multi-Agent System:
 - Structural Specification
 - Groups, links, roles
 - Compatibilities, multiplicities
 - inheritance
 - Functional Specification
 - Global goals, plans,
 - Missions, schemas,
 - preferences
 - Deontic Specification
 - Permissions, Obligations



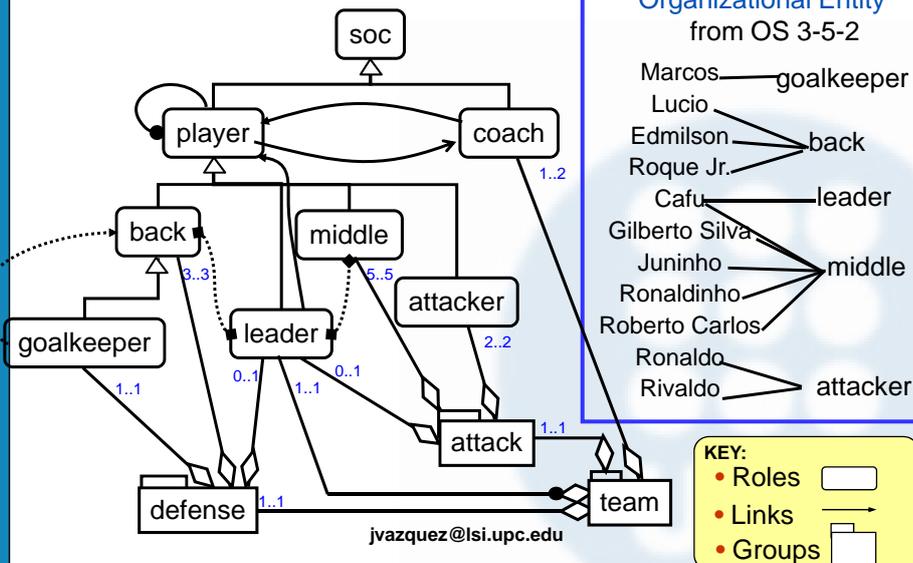
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MOISE+

Structural Specification

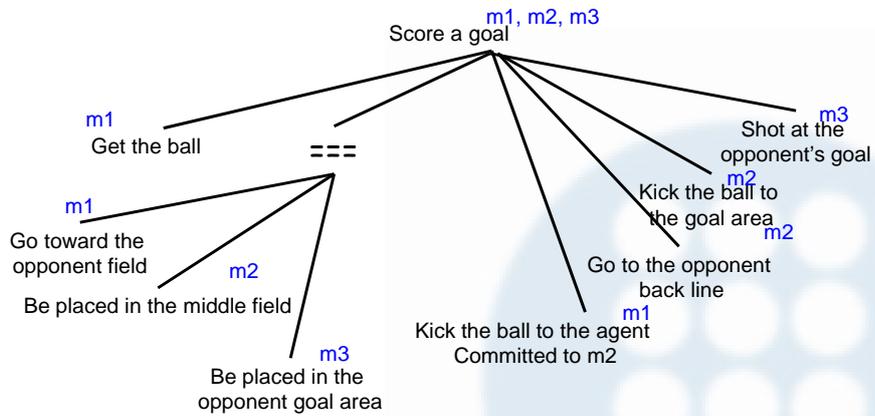
Organizational Structure : 3-5-2



MOISE+

Functional Specification

Functional Schema : side_attack



KEY:

mission Goal: sequence choice parallelisme

MOISE+

Deontic Specification

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

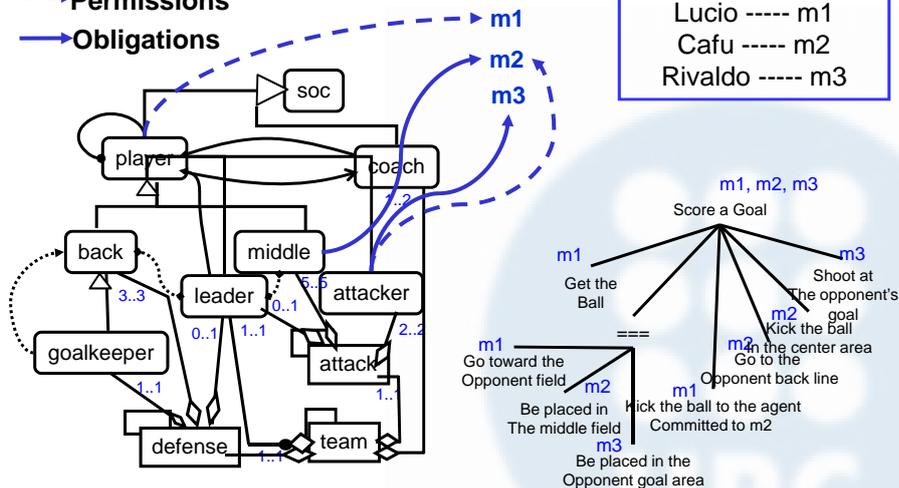
Role	Deontic Relation	Mission	Temporal Constraint (cf. [carron 01])
Back	Permission	m1	In [0 30]
Middle	Obligation	m2	during [Attacker]
Attacker	Obligation	m3	Any

MOISE+

Deontic Specification

- - - - - Permissions

- - - - - Obligations



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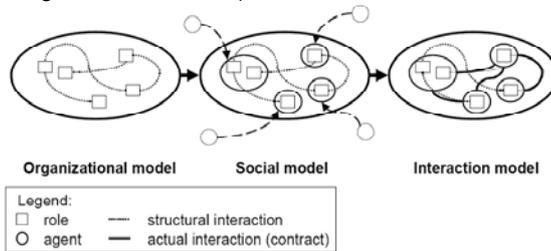
OperA

- OperA is a framework for the specification of multi-agent systems. It distinguishes between
 - the mechanisms through which the structure and global behavior of the model is described and coordinated, and
 - the aims and behavior of the service-providers (agents) that populate the model
- It is based on formal semantics that make verification possible.
- The OperA framework represents interaction between agents in a way that:
 - is independent of the internal design of the agents
 - distinguishes organizational characteristics from agents' own goals
 - creates dynamic links between organizational design and agent populations
 - allows for the adaptation of interaction patterns to the characteristics of specific populations.

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OperA Models

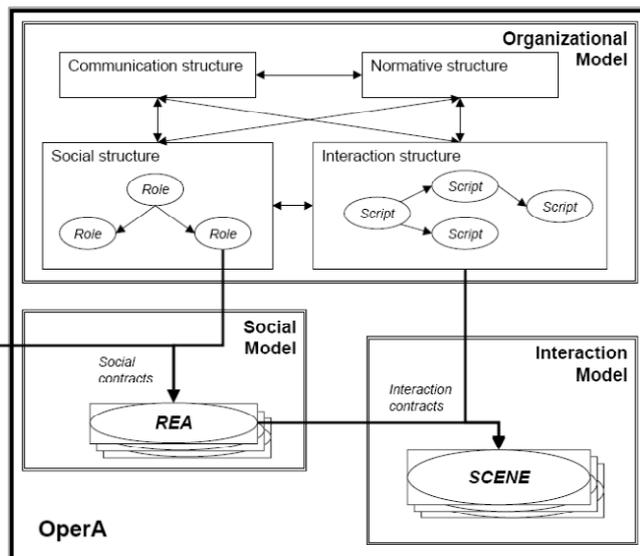
- 3 models:
 - **Organizational Model**
 - represents organizational aims and requirements
 - roles, interaction structures, scene scripts, norms
 - **Social Model**
 - represents agreements concerning participation of individual agents ('job' contracts for agents)
 - rea = role enacting agent
 - **Interaction Model**
 - represents agreements concerning interaction between the agents themselves ('trade' contracts between reas)



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OperA Models

AGENT
goals
beliefs
(norms)



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OperA

Organization Model Design Steps

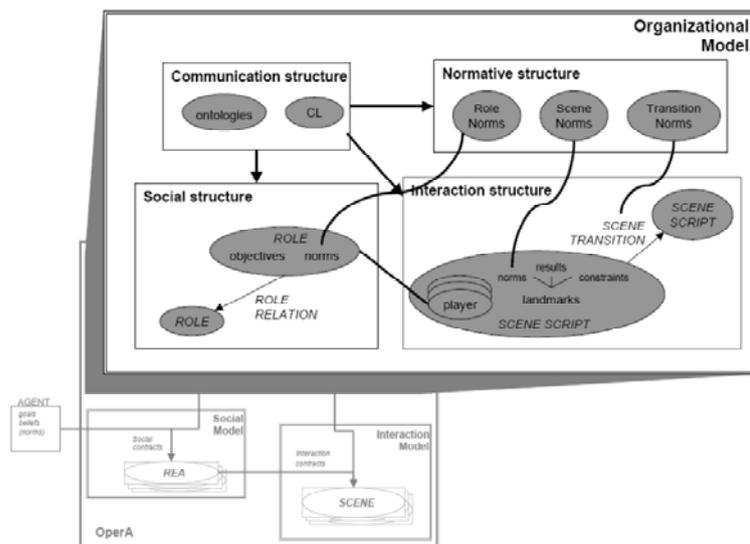
- Identify
 - Stakeholders (internal, external)
 - Coordination types
 - Requirements and objectives
 - Global
 - Per stakeholder
 - Role dependencies
 - Norms
- Describe domain ontologies
 - Concepts (and possible relations)
- Specify Social Structure
- Identify partial order of role objectives / dependencies
- Describe scene scripts
- Identify scene transition requirements / consequences
- Specify Interaction Structure

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OperA

Organization Model Architecture



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OperA

Organizational Model: designing the Environment Level - I

- Organization
 - Global objectives and requirements
 - Functional (what)
 - Interaction (how)
 - Objective decomposition (to roles)
- Stakeholders
 - Objectives
 - Dependencies
 - Requirements
 - **Role tables**: relation to stakeholders

Role	Relation to society	Objectives	Dependencies
Role 1	Stakeholder X	...	Role N
Role M	From coordination model	...	Role P, Role 1

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OperA

Organizational Model: Designing the Environment Level - II

- Identify organizational norms
 - Responsibility analysis
 - Resource analysis
 - Trigger analysis
 - Norm specification
 - Sanction specification
- **Norm tables**

Description	Norm Analysis	
Type (O, F, P)	Responsibilities	Initiator: <i>role</i> Action: <i>role</i>
Textual description	Triggers	Pre condition: <i>state</i> Post condition: <i>state</i>
	Specification	whenever <i>state</i> then <i>role</i> is O,F,P to achieve <i>state</i> otherwise <i>sanction</i>

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Organizational Model: designing the Behavior Level - I

- Social Structure
 - Roles
 - Sub-objectives are identified by means-ends analysis
 - Role dependencies identify interaction between roles -> scenes

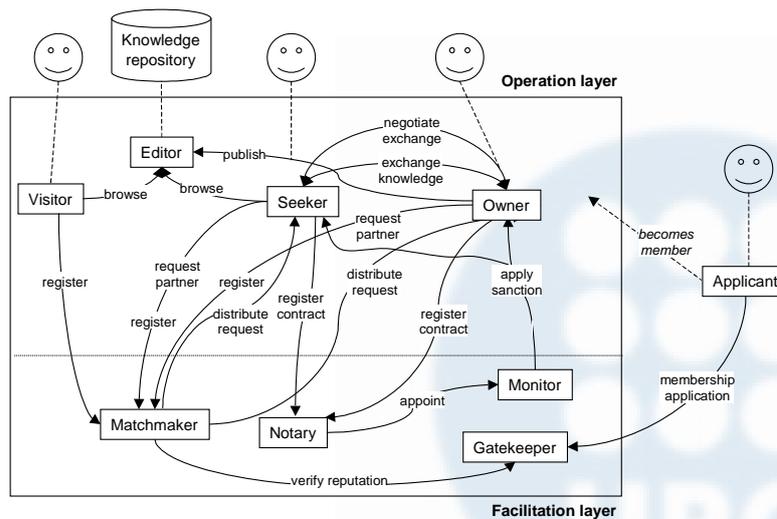
ROLE DEFINITION	
Role id	Identified in Environment Level
Objectives	Formalization of objectives identified in the role table
Sub-objectives	Result of means-end analysis for each role objective
Rights	From means-end analysis and norm analysis
Norms	From the Norm analysis in Environment Level
Type	Roles associated with the coordination model are institutional, and operational roles are in principle external.

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Organizational Model: Role dependencies



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Organizational Model: Role example

Role: Knowledge Seeker	
Role id	k-seeker
Objectives	o ₁ := request-knowledge o ₂ := browse-repository
Sub-objectives	$\Pi o_1 = \{ \text{get-potential-partners}(\text{question}, \text{partner-list}), \text{choose-best-partner}(\text{partner-list}, \text{partner}), \text{get-answer}(\text{question}, \text{partner}, \text{answer}) \}$
Rights	access-repository
Norms	IF agreed-share(partner) THEN OBLIGED publish-repository(answer)
Type	external

OperA

Organizational Model: designing the Behavior Level - II

- Interaction Structure
 - Scene scripts
 - Interaction structure
 - Partial ordering of scenes
 - Relationships between scenes
 - Causal dependency: Sequence of scenes
 - Synchronization: AND relation between scenes
 - Parallelism: OR relation between scenes
 - Instantiation: new scene instances

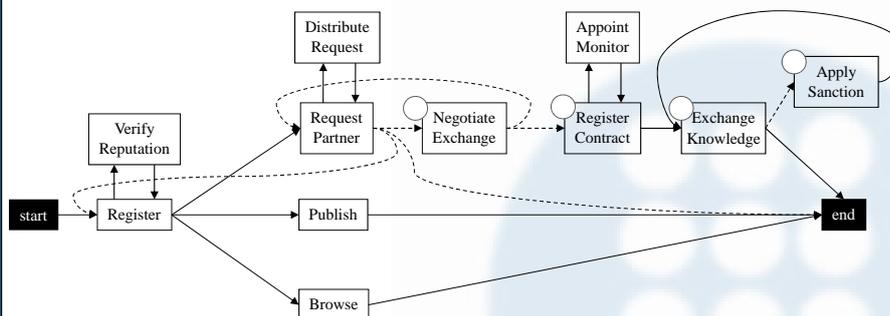
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Organizational Model: Scene script

SCENE TABLE	
Scene identifier	From role dependency
Roles	Participants in scene
Description	Textual description
Results	Objectives of scene -> relate to role dependency
Patterns	Partial ordering of landmarks to achieve result, for each scene result
Norms	From norm analysis
Rationale	Further information

OperA

Organizational Model: Interaction Structure



OperA

Organizational Model: Scene example

Interaction Scene: Partner Request	
Description	Seeker requests possible partners that can answer knowledge need
Roles	S: Knowledge-seeker(1), M: Matchmaker (1)
Results	DONE receive-partners(S, M, question, ListPartners)
Patterns	
Norms	OBLIGED request-knowledge(M, knowledge-owners, answer-deadline) BEFORE deadline IF request-knowledge(matchmaker, P, question, deadline) THEN OBLIGED answer-request(P, M, YN, question) BEFORE deadline

OperA

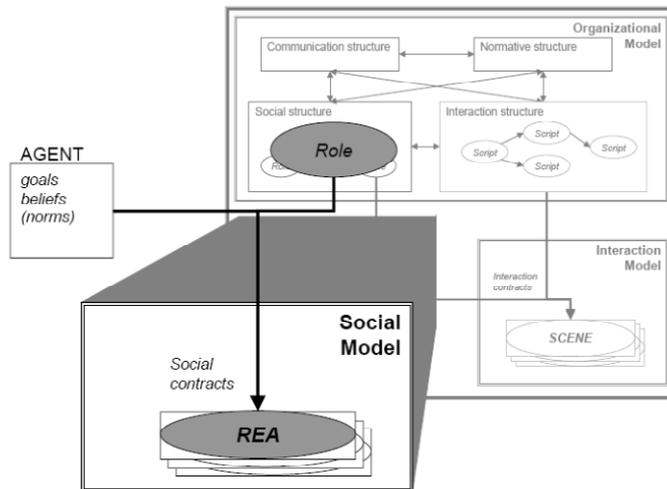
Social Model design

- Specification of **role negotiation scenes**
- Specification of negotiator agent

- Based on the **role descriptions** specified in the OM
 - minimum requirements
 - negotiable characteristics, and their range

Role Negotiation Scene: Role R	
Roles	Negotiator (N), applicant (A)
Results	$\rho = \text{contract}(A, R, \text{SocialContract})$
Plans	$\Pi\rho = \{ \text{agreed}(\text{char}1) \text{ AND } \dots \text{ AND } \text{agreed}(\text{char}N) \text{ BEFORE } \text{contract-agreed}(N, A, \text{social-contract}(A, R, CC)) \}$
Norms	PERMITTED(N, negotiate-social-contract(A, R)). OBLIGED (N, propose-range(char1, min, MAX))...

OperA Social Model architecture



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OperA Social Model: Contracts

- A **contract** is a statement of intent that regulates behavior among organizations and individuals
 - **Specific norms**
 - Time period
 - Terms and conditions
 - Sanctions
- Focus of contracts in OperA
 - **Roles to be played** (social contracts)
 - **Scene performance** (interaction contracts)

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OperA

Social Model: Social Contracts

- The Social Model results in:
 - Role enacting agent
 - Enactment contract

Social Contract	
Agent	Anne
Role	Knowledge seeker
Clauses	<ol style="list-style-type: none"> 1. PERMITTED(Anne, access-kb([KB1, KB3, KB7]) 2. OBLIGED(Anne, publish-received-knowledge(item, KB3) allows(KO, publish)) 3. $\forall p: \text{contract}(p, \text{Anne}) \rightarrow \text{PERMITTED}(p, \text{publish}(p, \text{Anne's-item}, \text{kb}))$

OperA

Social Model Design Steps

- For external roles:
 - Identify minimum requirements
 - Identify negotiable characteristics, and their range
- Specify role enactment scripts
 - Negotiator (internal) agent
 - Negotiation pattern for role characteristics

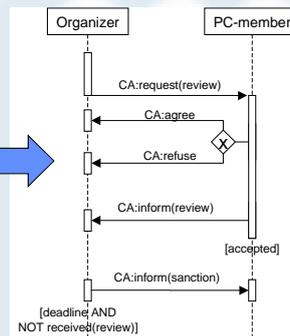
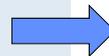
Example:

- Seller agent:
 - Minimum reqs: provide (email) address, allow reference check
 - Negotiable: fee and percs, volume, marketing info,...
- Results in role enacting agent design and contract

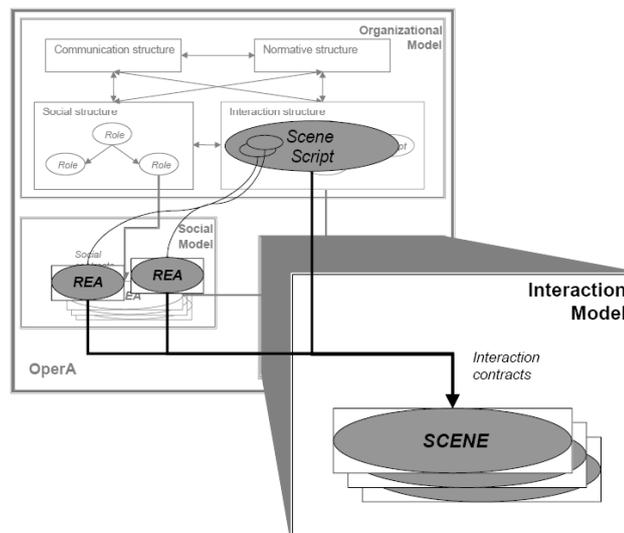
OperA Interaction Model

- Based on script interaction scenes
- Depending on the **characteristics of the agents** that apply for society roles
- Results in
 - Specific **protocols** for the scenes, that are supported by the agents

Interaction Scene: PC-member role enactment	
Roles	Society keeper (SK), applicant (A), society register (R)
Results	$\rho = \text{contract}(A, \text{PCmember}, \text{SocialContract})$
Plans	$\Pi \rho = \{ \text{agreed}(\text{max-papers}(M)) \text{ AND } \text{agreed}(\text{review-deadline}(D)) \text{ BEFORE}$ $\text{contract-agreed}(\text{SK}, A, \text{social-contract}(A, \text{PCmember}, \text{CC})) \text{ BEFORE}$ $\text{contract-registered}(R, \text{social-contract}(A, \text{PCmember}, \text{CC})) \}$
Norms	PERMITTED(SK, negotiate-social-contract(A, PCmember)). OBLIGED (SK, role-description-announced(role(PCmember))).



OperA Interaction Model architecture



OperA

Interaction Model Design Steps

- For each scene:
 - Identify negotiable landmark range
- Specify script negotiation scripts
 - Negotiator (internal) agent
 - Negotiation pattern for landmarks
 - Other protocol requirements

Example:

- Payment scene:
 - Fixed Landmarks: check credit card, check email identification
 - Negotiable: payment deadline, delivery deadline, fees,...
- Results in interaction protocols and contracts

References

- [1] J. Vázquez Salceda. “The Role of Norms and Electronic Institutions in Multiagent Systems”, Birkhauser-Verlag, 2004
- [2] Virginia Dignum, “A Model for Organizational Interaction: Based on Agents, Founded in Logic”. PhD dissertation, 2004
- [3] N.V. Findler and R. Malyankar. “Social structures and the problem of coordination in intelligent agent societies”. 2000.
- [4] J.F. Hübner, J.S. Sichman and O. Boissier. “A Model for the Structural, Functional, and Deontic Specification of Organizations in Multiagent Systems”. Proceedings of SBIA'02.
- [5] J.F. Hübner, J.S. Sichman and O. Boissier. “S-Moise+: A Middleware for developing Organised Multi-Agent Systems”. In Proceedings of OOP'05 Workshop.