Organization Oriented Coordination in Multi-Agent Systems

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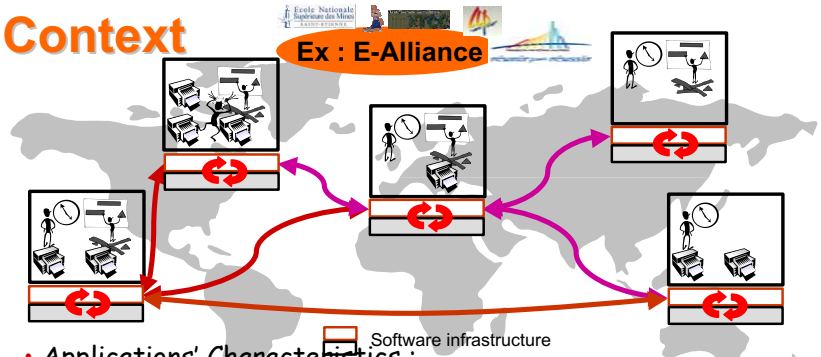
Ouline

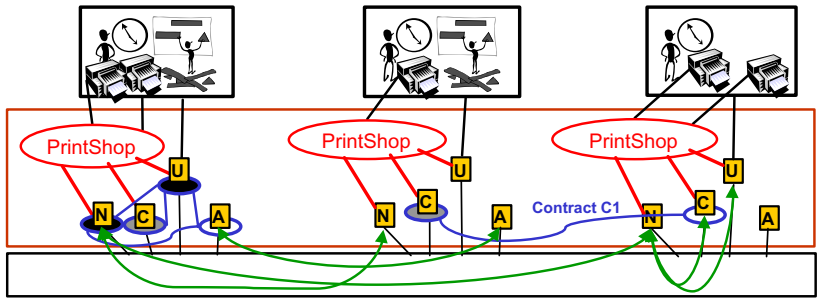
- **Introduction**
  - **Context**
  - **Multi-Agent Systems**
- Organization in MAS
- System Centered Organization Model
- Agent Centered Organization Model
- Reorganization
- Conclusion & Perspectives

Context



- Applications' Characteristics :
  - Multi-* : actors, domains, viewpoints, decisions, …
  - Knowledge intensive tasks,
  - Distribution, Openness, Decentralization.
- Requirements :
  - **Autonomy** at the local level
  - **Cooperation/Competition/Collaboration** at the global level

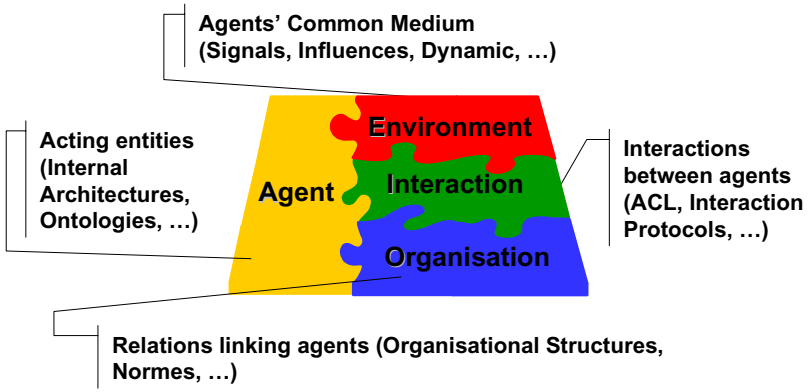
Multi-Agent System



Agent : real or virtual **autonomous** entity, which is,
- **pro-active**,
- **reactive**,
- **social** (interaction with other agents),
- **organised** (management of relations with others).

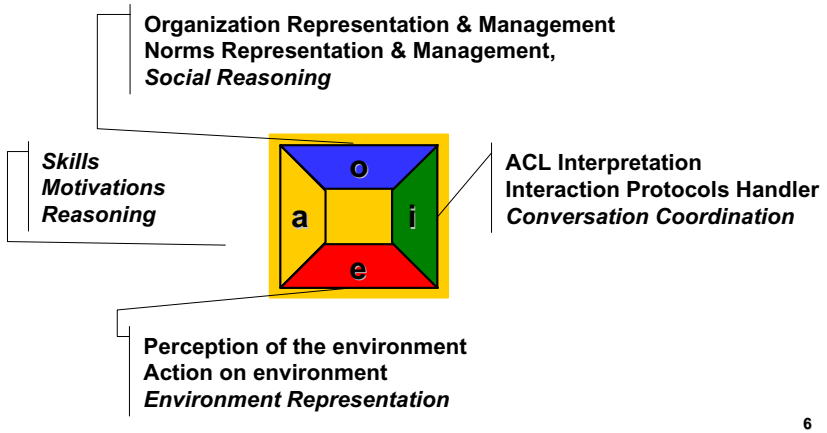
System Centered Models (SCM)

- MAS = <A,E,I,O> "Vowels" [Demazeau]



Agent Centered Models (ACM)

- Agent = <a,e,i,o>



Outline

- Introduction
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  - Multi-Agent Systems
- **Organization in MAS**
- System Centered Organization Model
- Agent Centered Organization Model
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Definitions of Organizations

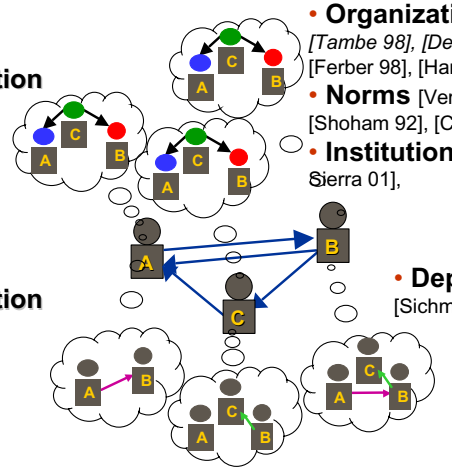
a) A decision and communication schema which is applied to a set of actors that together fulfill a set of tasks in order to satisfy goals while guarantying a global coherent state [Malone 87]
→ **definition by the designer, or by actors**

b) An organisation is characterized by : a division of tasks, a distribution of roles, authority systems, communication systems, contribution-retribution systems [Bernoux 85]
→ **normative** system

c) 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]
→ **emergence**

Organization Models in MAS

System Centered Organization Models



- **Organizational Structures** *[Tambe 98], [Decker 95],* [Ferber 98], [Hannoun 99]
- **Norms** [Verhagen 00], [Dignum 96], [Shoham 92], [Conte 99]
- **Institutions** [Sergot 99], [Esteva, Sierra 01],

Agent Centered Organization Models

- **Dependence Networks** [Sichman 95]

Organization Processes in MAS (1)

- Enactment of SCO Models on Agents' behavior
  - SCO Models aim at controling the local behavior of Agents to coordinate the resolution process taking place in the agents,
  - *Agents' architectures with respect to Autonomy (O-Autonomy)*
- Computation of ACO Models in Agents
  - Representation and computation of ACO Models in the local behavior of Agents,
  - *Agents' architectures with respect to Autonomy (I-Autonomy)*

Organization Processes in MAS (2)

- Reorganization = definition of new SCO Models by Agents
  - When, How, Why to reorganize
  - Coordination of this reorganization process
- Enforcing SCO Models in Agents
  - When, How, Why to enforce a SCO Model
  - Coordination of this enforcement process

Plan

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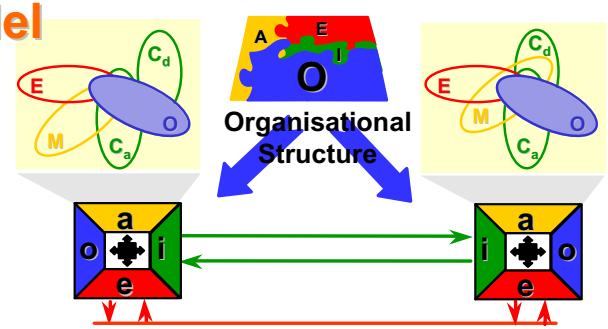
System Centered Organization Model

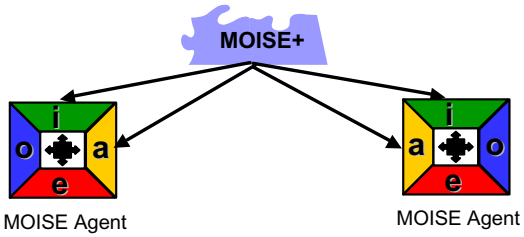


MOISE+[Hannoun 00, Hubner 02]
Temporal **O**rg. **S**truct. **L**anguage [Carron 01],
DMOISE+ [Hubner 03]
Dependance in **Org**anization [Hannoun 98]

SCOM : MOISE+

[Hannoun 00, Hubner 02]

- MOISE +
  - Structural Specification : Roles, Links, Groups
  - Functional Specification : Goals, Plans
  - Interaction Specficiation : Protocols, Speech Acts
  - Deontic Specification : Obligation, Permission

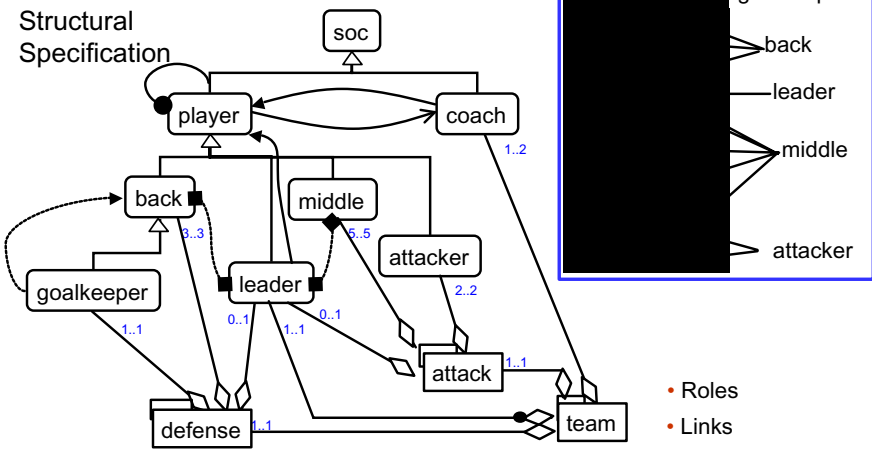


- Applied to RobotSoccer

SCOM : MOISE + (1) Structural Specification

- Individual level
  - organizational roles and role inheritance
- Social level
  - role links (authority, communication, . . .)
  - representing the social role's relational aspect
- Collective level
  - groups and sub-groups
  - well-formation rules (roles' cardinalities and compatibilities)

SCOM : MOISE + (2)

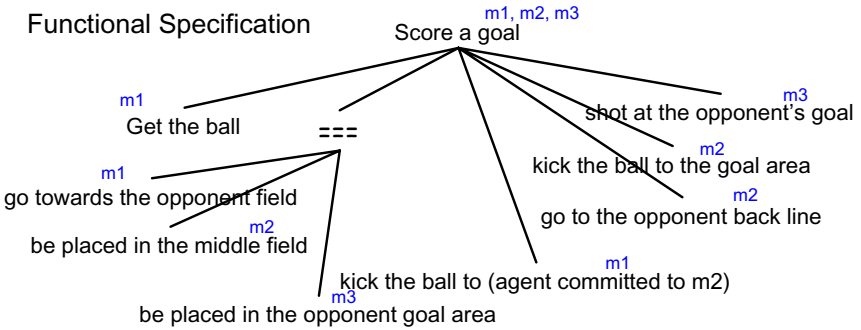


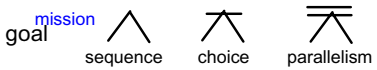
- Roles
- Links
- Groups

SCOM : MOISE+ (3)
Functional Specification

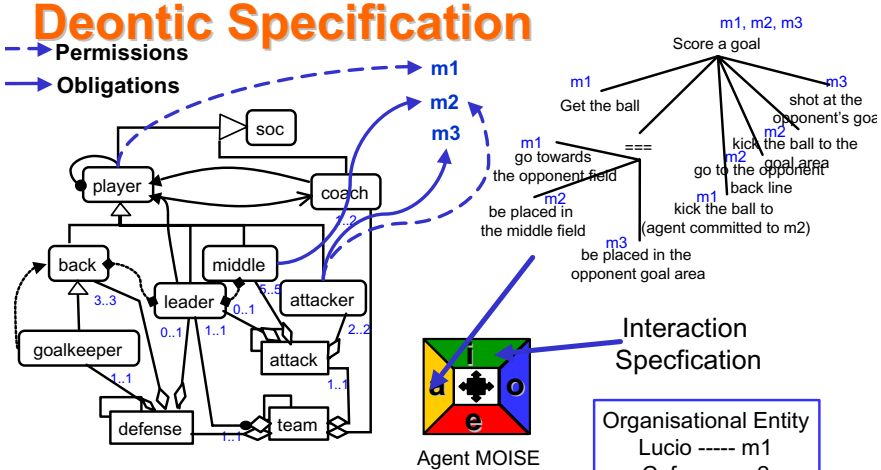
- Describes how the global goals are decomposed by plans and distributed to the agents by missions
- Collective level
  - schemes: a global plan decomposition
- Individual level
  - missions: a set of scheme's global goals that an agent may be committed to

SCOM : MOISE+ (4)

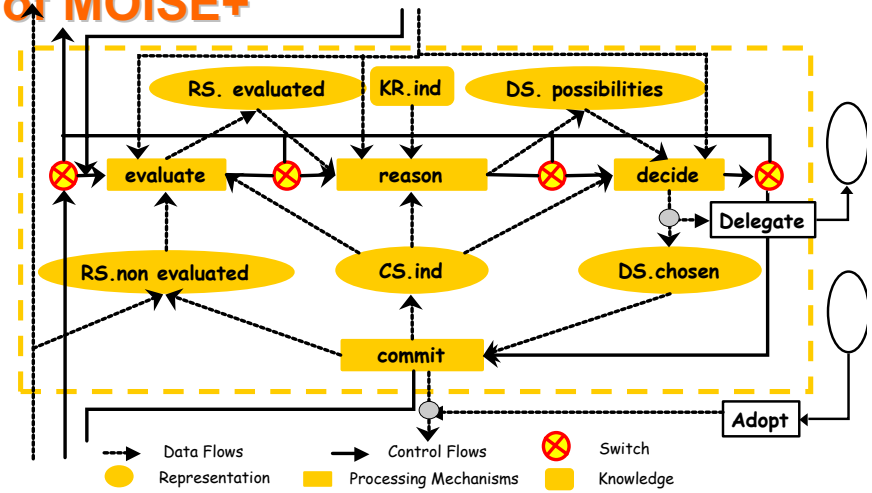




SCOM : MOISE+ (5)
Deontic Specification



Agent Centered Programmation of MOISE+



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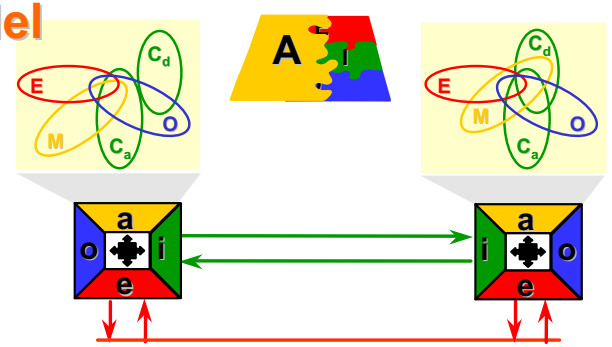
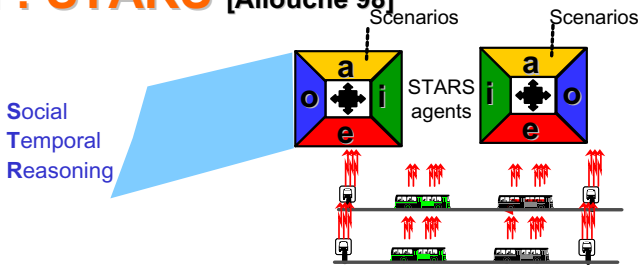
Agent Centered Organization Model



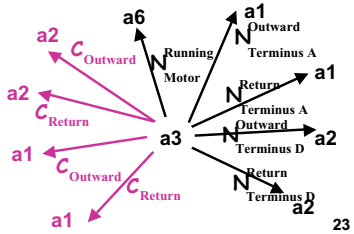
Social Temporal Reasoning [Allouche 98]

ACOM : STARS [Allouche 98]



- Temporal Dependence Network

$$needs(a_u, a_v, p_i, p_j) \equiv p_i \in resp(a_u) \wedge p_j \in resp(a_v) \cap subtask(p_i) \wedge p_j \notin resp(a_u)$$



Dependence Network

- **Dependence relations between agents**
  - **needs (N)**

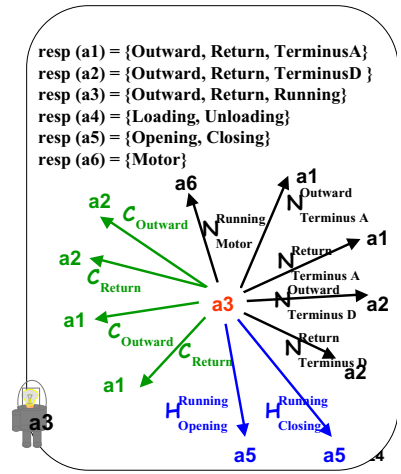
$$needs(a_u, a_v, p_i, p_j) \equiv p_i \in resp(a_u) \wedge p_j \in resp(a_v) \cap subtask(p_i) \wedge p_j \notin resp(a_u)$$

  - **helps (H)**

$$helps(a_u, a_v, p_i, p_j) \equiv opp(p_i, p_j) \wedge p_j \in resp(a_u) - resp(a_v) \wedge p_j \in resp(a_v) - resp(a_u)$$

  - **competes (C)**

$$competes(a_u, a_v, p_i) \equiv p_j \in resp(a_u) \cap resp(a_v)$$



Temporal dependence network (Needs dependence)

- Execution of a task

$do_I(a_u, p_i) \equiv \forall J \;\; J \; \textbf{\textit{esfd}} \; I, \; do_J(a_u, p_i)$

(***esfd*** = ***e***qual or ***s***tart or ***f***inish or ***d***uring)

$done_t(a_u, p_i) \equiv do_{[d(p_i),t]}(a_u, p_i) \wedge \forall I \;\; [d(p_i), t] \; \textbf{\textit{sfd}} \; I, \neg (do_I(a_u, p_i))$

- Activation :

$needs_I(a_u,a_v,p_i,p_j) \Leftrightarrow \exists J, K \; needs(a_u,a_v,p_i,p_j) \wedge do_J(a_v,p_j) \wedge do_K(a_u,p_i) \wedge I = J \cap K$

- Continuity rule :

$needs_I(a_u,a_v,p_i,p_j) \wedge do_J(a_u,p_i) \wedge do_K(a_v,p_j) \wedge I \; \textbf{\textit{d}} \; J \cap K \Rightarrow needs_{J \cap K}(a_u,a_v,p_i,p_j)$

- Deactivation :

$needs_I(a_u,a_v,p_i,p_j) \wedge done_t(a_v,p_j) \Rightarrow (\forall J \; needs_J(a_u,a_v,p_i,p_j) \Rightarrow J \; \textbf{\textit{esfd}} \; [I^-,t])$

Temporal dependence network (Help dependence)

- Activation :

$helps_I(a_u,a_v,p_i,p_j) \Leftrightarrow \exists J \mid helps(a_u,a_v,p_i,p_j) \wedge (do_J(a_u,p_i) \vee do_J(a_v,p_j)) \wedge I \; \textbf{\textit{esfd}} \; J$

- Continuity rule :

$helps_I(a_u,a_v,p_i,p_j) \wedge (do_J(a_u,p_i) \vee do_J(a_v,p_j)) \wedge I \; \textbf{\textit{esfd}} \; J \Rightarrow helps_J(a_u,a_v,p_i,p_j)$

- Deactivation :

$helps_I(a_u,a_v,p_i,p_j) \wedge (done_t(a_u,p_i) \vee done_t(a_v,p_j)) \Rightarrow (\forall J \mid helps(a_u,a_v,p_i,p_j) \Rightarrow J \; \textbf{\textit{bomsdfe}} \; [I^-,t])$

Temporal dependence network (Competition dependence)

- Activation :

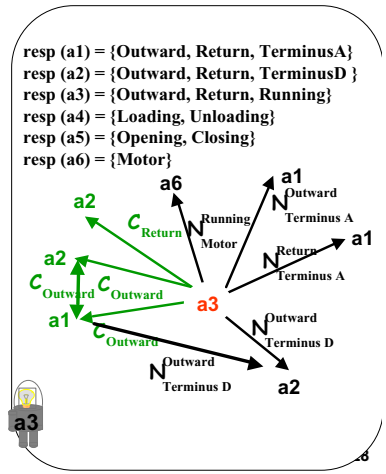
$competes_I(a_u,a_v,p_i) \Leftrightarrow \exists J \mid competes(a_u,a_v,p_i) \wedge (do_J(a_u,p_i) \oplus do_J(a_v,p_i)) \wedge I \; \textbf{\textit{esfd}} \; J$

- Continuity rule :

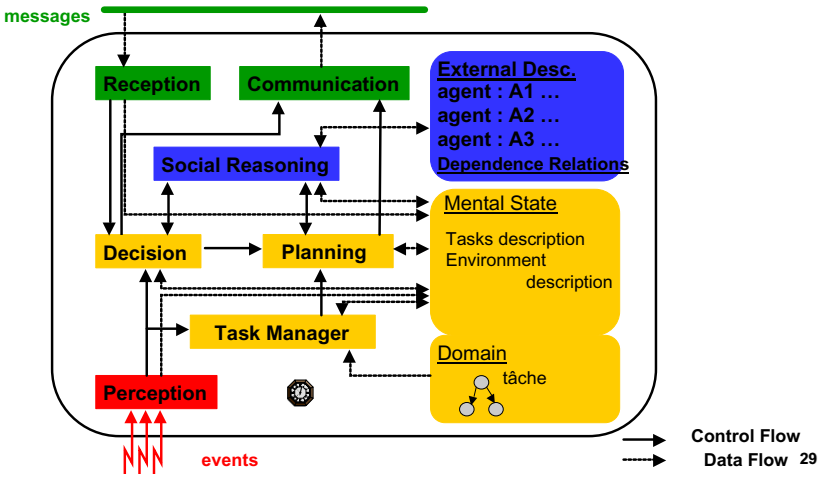
$competes_I(a_u,a_v,p_i) \wedge (do_J(a_u,p_i) \oplus do_J(a_v,p_i)) \wedge I \; \textbf{\textit{sfd}} \; J \Rightarrow competes_J(a_u,a_v,p_i)$

Conjonction of Dependence Network

- **Reasoning on its own dependence to deduce dependence relations that exist between the other agents**

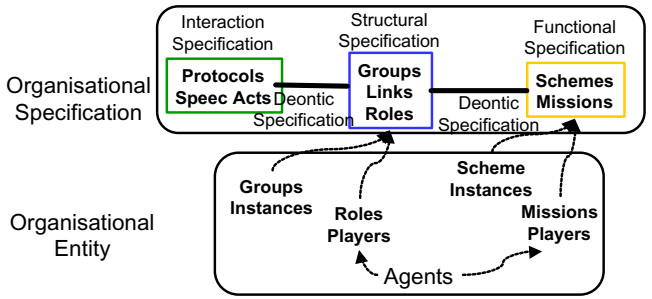


STAx Agent



Reorganisation within MOISE+

A rich panel of possible reorganizations :

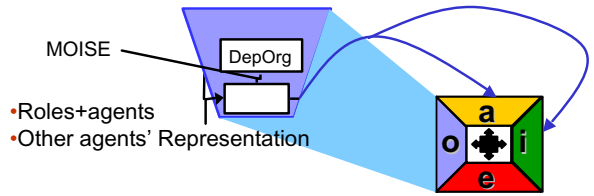


A multi-step process : detection, design, selection, enactment

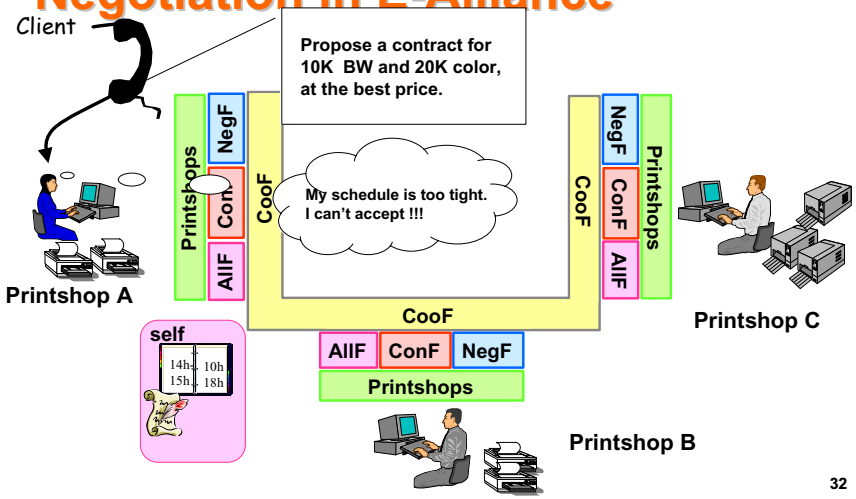
Exogeneous (Designers) vs
Endogeneous (Centralized vs Decentralized)

Agent Centered Reorganisation
[Hannoun 98]

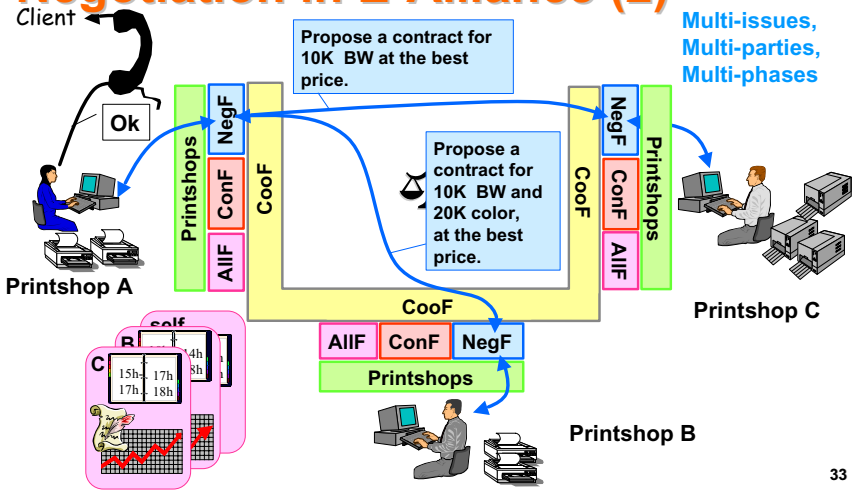
- **Dep**endence in **Org**anization (DepOrg)
  - Computing dependence networks within the Organizational Structure
  - Computing dependence networks within the Organizational Entity



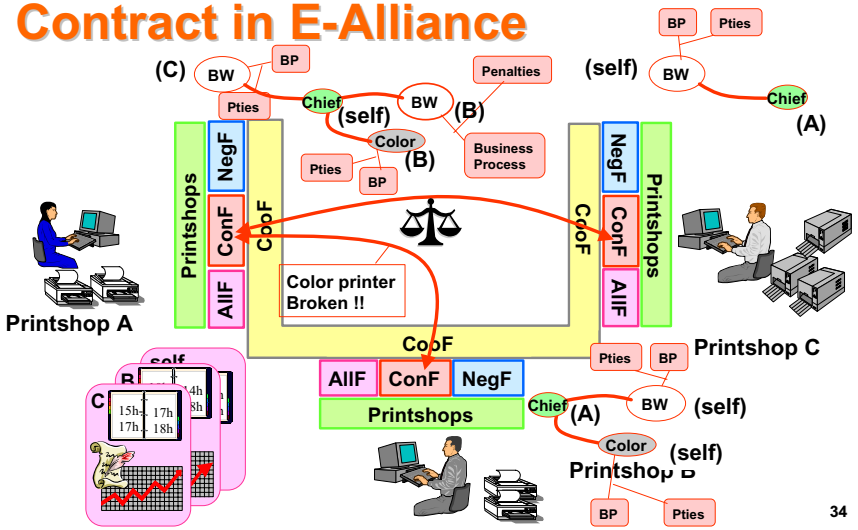
Agent Centered Reorganization Negotiation in E-Alliance



Agent Centered Reorganization Negotiation in E-Alliance (2)



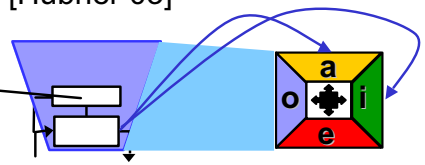
Agent Centered Reorganization Contract in E-Alliance



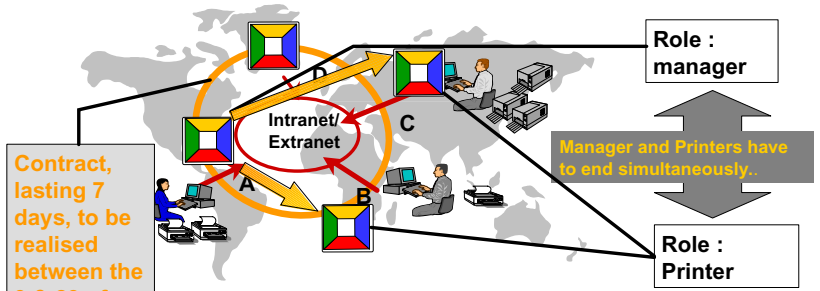
System Centered Reorganisation

- Temporal Organisational Structure Language (TOSL) [Carron 01]
  - MOISE+(t)
  - TAG Agent
  - *Application : SimuEnt*
- DMOISE+ : use of MOISE+ to control the reorganisation process [Hubner 03]

Organisational Structure dedicated to the reorganisation :
-Reorganisation roles (detection, history, design, …)
-Reorganisation groups



System Centered Reorganisation TOSL [Carron 01]



- Temporal Properties (tp): relative or absolute temporal anchor of organizational terms.
- Temporal Constraints (tc): temporal positioning of organizational terms.

System Centered Reorganisation TOSL [Carron 01]

(tos *:name* Contract

:roles (manager, printer) :links Lm_p

:tp (self **=** [1week] ∧ self **in** [03/12/01, 23/12/01])

:tc ([manager] **f** [printer])

(role :name manager :missions ((O mm)) :tp () :tc (self **f** [IM_P]))

(link :name IM_P :type authority :source Manager :target Imprimeur

....

:tp (self **d** [8:00am, 8:00pm]) :tc (self **s** [imprimeur]))

....**)**

Conclusion & Perspectives

- Models :
  - System Centered Organization Models : MOISE+, TOSL
  - Agent Centered Organization Models : STR, DEPORG
- Organization Processes
  - Enactment exists BUT too rigid
  - Dependence Computation
  - Reorganization : example of detection, of design
  - Enforcement has to be done → needs of penalty, policies

➔ Define a global framework for reorganization of SCO Models based on ACO Models (ACO Models provide reorganization indices)

Perspectives

- Normative aspects in SCO Models in relation to Autonomy of the agents
  - Enrich MOISE+ with interaction and environment specification to constrain Interaction and Environment components of each agent
  - Define more precisely Obligations and Permissions : add penalties so that agents may reason on it.
  - Equip MOISE+ with norms at different levels
    - Roles, links, groups
  - Define an agent's architecture to exhibit adjustable autonomy with respect to organization in which it executes