Multiagent Organizations

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Definitions of Organization

- An organization is a group of people working together with one or more shared goals.
- An instrument of purpose, that is, seen as coordinated by intentions and goals.
- A social system existing in physical and social environments over time.
- An arrangement of relationships between components or individuals which produces a unit, or system, endowed with qualities not apprehended at the level of the components or individuals.

[Morin, 1977]

- An arrangement of relationships between components or individuals which produces a unit, or system, endowed with qualities not apprehended at the level of the components or individuals.

[Olmstead, 2002]
Need for Organization

- Do agents need organizations?
  - Do agents need to know/reason about the organization?
- Do MAS need organizations?
  - Interaction in MAS cannot be based in communication alone
  - MAS engineering require high-level agent independent abstractions
  - Need for explicit social concepts defining the society where agents live
Characteristics of Complex Organizations

- Operate in a changing environment
- Distributed activity
  - Local management, knowledge and data
  - Individual interests and operation
- Global strategy
  - Process integration
  - Culture integration
- Global goals vs. individual goals
- Balance control and independence
Relevance (1)

- From the agents perspective, organizations:
  - Insure a better integration of the agents in the system
  - in order to better adapt themselves to change
  - Delegation of tasks/beliefs between the agents
    - That is, (organizational) structures that need to be represented or exploited
    - such as coalitions, teams, alliances...
Relevance (2)

- From MAS perspective, organizations
  - insure global behavior at the MAS level
    - In terms of cooperation, collaboration, ...
    - To be sure that the global goals of the system or collective instance are achieved
  - represent observed patterns of interaction
Regulation versus Autonomy

- Regulated, or directed, behavior
  - Pre-determined behavior, external to agent:
    - leads to lack of agility
  - Do not consider differences in individual capabilities
  - Strict obedience to rules often does not get work done

- Autonomous behavior
  - Ability to make decisions about own activity
  - Individual rationality is insufficient to deal with social behavior (helpfulness, greater good, )
  - (Informal) structures are necessary for coordinating processes and stability
Regulation and Autonomy

- Can we have the best of both?
- Combination of individual rationality with laws of social interaction
Regulation with Autonomy

- Internal autonomy requirement: Specify organization independently from the internal design of the agent
  - Enables open systems
  - Heterogeneous participation

- Collaboration autonomy requirement: Specify organizations without fixing a priori all structures, interactions and protocols
  - Enables evolving societies
  - Balances organizational needs and agent autonomy
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Components of organizations

- Entities (roles, positions, people, groups, components, )
- Relationships (networks, interactions, coordination )
- Goals (purpose, intention, shared, )
- Norms (culture, rules, )
- Environment (physical, social, open, dynamic, restrictive)
Characteristics of entities

- The entities to be organized are heterogeneous
- The entities to be organized are expected to be rational, cognitive

[Olmstead, 2002]: “The people in this definition are physical organisms and psychological processes [...] [whose] influence is a function of both his or her psychological properties and the properties of the coordination and decision making roles assigned to him or her.”
Characteristics of relationships

- The organization should create order among entities.
- Relationships enable results that cannot be accomplished by any one the individuals alone
  
  [Morin, 1977]: “Endowed with qualities not apprehended at the level of the components or individuals.”

- The organization is responsible for the achievement of the overall goal of the system.
- The organization should create a coherence of the whole.
- Possible relations between entities are:
  - Delegation of tasks
  - Transfer of information
  - Obligation and norms
  - Synchronization of actions
  - Responsibility between agents
  - Access to resources and services
Characteristics of goals

- Organizational goals are not necessarily goals of any of the individuals
- Combined activity is needed to achieve organizational goals
- Global strategy but local decision
Characteristics of norms

- Describe desired organizational states
- Norms as Constraints
  - Cannot be violated: guaranteed fulfilment
- Norms as Regulations
  - Can be violated: agent decides
- Balance between CONTROL and EFFICIENCY
Characteristics of environments

- Organizations need to perceive, reason, and act in relation to the surrounding environment
- Contingent:
  - match among (business) strategy, organizational structure, and the characteristics of the environment is necessary for high performance
- Dynamic:
  - Agents can migrate, behaviour can evolve.
  - Organizational structures change, disappear or grow
  - Organizational objectives change
- Open:
  - Distributed management, knowledge and data
  - Components are not controlled by one entity
Requirements of Organization Models

- Reflect and Support Organizational Design
  - Structure: roles, norms, interaction
  - Global goals and requirements

- Specify interaction independently from the internal design of the agent (internal autonomy requirement)
  - Interaction structures are not completely fixed in advance
  - Enables open systems
  - Heterogeneous participation
  - in OperA: separation between agent and role

- Balance organizational design and agent autonomy (collaboration autonomy requirement)
  - Explicit agreements concerning individual performance
  - Explicit agreements concerning interaction
  - Enables evolving societies
  - Balances organizational needs and agent autonomy
  - in OperA: landmarks
Example Organization Model: OperA

- 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)
Opera development

- design
- organization model
- dynamic instantiation
- social model
- runtime deployment
- interaction model

agents
OperA Organizational Model

- Social Structure
  - roles, groups, dependencies
- Interaction Structure
  - scene scripts, connections, transitions
- Normative Structure
  - role, scene and transition norms
- Communication Structure
  - communicative acts, domain ontology
Social Structure

- Role specification

<table>
<thead>
<tr>
<th>Id</th>
<th>PC_member</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objectives</td>
<td>paper_reviewed(Paper,Report)</td>
</tr>
<tr>
<td>Sub-objectives</td>
<td>{read(P), report_written(P, Rep), review_received(Org, P, Rep)}</td>
</tr>
<tr>
<td>Rights</td>
<td>access_confmanagement_system(me)</td>
</tr>
</tbody>
</table>
| Norms & Rules | PC_member OBLIGED understand_english  
PC_member OBLIGED review_paper BEFORE deadline  
IF paper_by_colleague THEN PC_member  
FORBIDDEN review_paper |

Table: *PC member* role description.
Roles and dependencies

Conferece society
- organizer role
  - conference_organized
  - paper_submitted
- session chair role
  - session_organized
- presenter role
  - paper_presented

Paper reviewed
- PC member role

Author role
Interaction Structure

- Scene specification

<table>
<thead>
<tr>
<th>Scene</th>
<th>Review Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roles</td>
<td>Program-Chair (1), PC-member(2)</td>
</tr>
<tr>
<td>Results</td>
<td>$r_1 = \forall P \in \text{Papers}: \text{reviews_done}(P, \text{rev1, rev2})$</td>
</tr>
<tr>
<td>Interaction Pattern</td>
<td>PATTERN($r_1$): see figure ??</td>
</tr>
<tr>
<td>Norms &amp; Rules</td>
<td>Program-Chair PERMITTED assign_papers</td>
</tr>
<tr>
<td></td>
<td>IF paper_assigned THEN PC_member</td>
</tr>
<tr>
<td></td>
<td>OBLIGED review_paper BEFORE deadline</td>
</tr>
</tbody>
</table>

Table: Script for the *Review Process* scene.
Landmarks

start
assign paper PC1
assign paper PC2
Assign deadline
receive review PC1
receive review PC1
receive review PC2
Review deadline
end
Interaction Scenes
Normative structure

► Abstract norms
  ▶ Statutes, vision and mission of the organization
  ▶ Values that direct the fulfilling of organization objectives
  ▶ Context

► Concrete norms
  ▶ Protocols and Rules: enable agents to comply with organizational norms
  ▶ Constraints: cannot be violated
  ▶ Regulations: agent can decide
Communication structure

- Abstract level
  - Generic Terms
    - Incontextual concepts
  - Model Ontology
    - concepts of the framework itself
    - e.g. norm, rule, role, group, violation, landmark

- Concrete level
  - Concrete domain ontology
  - Generic communication acts
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Evolution of Organizations
Institutions

- Institutions facilitate and enforce the normative character of organizations
- Describe exchange mechanisms
- Specify coordination structures
- Determine interaction and communication forms within the organization
- Connect organizational and individual perspectives
- Make explicit the social norms governing behaviour, external to the agents
What is an Institution?

- A set of rules:
  - capable of describing correct
  - and incorrect action,
  - obligations acquired through correct action
  - and sanctions levied for incorrect action
  - while maintaining a record through its internal state.

- An institution is a set of rules that interprets some but not necessarily all of an agent’s actions as correct or incorrect within that context: the norm-regulated agent.
Origins of Institutions

▶ Economics [North, 1991]
  “the rules of the game in a society, or more formally, the humanly devised constraints that shape social interaction.”

▶ Social science [Harré and Secord, 1972]
  “that part of the act-action structure produced by the subset of the rules followed by a particular category of individual.”
  “Role is a normative concept, focusing on what is proper for a person in a particular category to do”

▶ also [Ostrom, 1990]
  “the prescriptions that humans use to organize all forms of repetitive and structured interaction... at all scales”
  “individuals... face choices regarding the actions and strategies they take, leading to consequences for themselves and for others.”
Organizations

- Organizations derive from [Mintzberg, 1993]:
  - Organizational structure,
  - management and
  - business

- Contend that: institutions underpin organizations

Institution

An established law, custom, usage, practice, organization, or other element in the political or social life of a people; a regulative principle or convention subservient to the needs of an organized community or the general ends of civilization. [Oxford English Dictionary, WWW]
Institutions, norms and organizations

- Institutional rules are called norms
- A norm is an informal or formal constraint on action

**Norm** A standard or pattern of social behaviour that is accepted in or expected of a group. [Oxford English Dictionary, WWW]
An informal model

To satisfy the statement of requirements, that:

- An institution is a set of rules that interprets *some* but not necessarily all of an agent’s actions as correct or incorrect within that context: the norm-regulated agent.
- We identify
  - A (partially) observable environment
  - where agents actions are events: $e_i$
  - that cause environmental state transitions
  - but *some* events map to institutional events: $e'_j$
  - that cause institutional state transitions
  - by adding/deleting institutional facts
Conventional generation

Interpreting a physical action as an institutional action is called *conventional generation* (see speech acts [Searle, 1969], action theory [Goldman, 1970] and [Davis, 1984])
Traces

A simple formalization uses traces to capture sequences of actions:

▷ Let $s_i \in S$ denote a state of a system (model)
▷ Let $e_i \in E$ denote an event that affects a system (model)
▷ Let $\tau : S \times E \rightarrow 2^S$, denote a state transformer function
▷ Hence, an actor interacting with a system generates a trace:

$$s_0 \xrightarrow{e_0} s_1 \xrightarrow{e_1} s_2 \xrightarrow{e_2} s_3 \ldots s_n \in T$$

▷ And induces a corresponding institutional trace:

$$s'_0 \xrightarrow{e'_0} s'_1 \xrightarrow{e'_1} s'_2 \xrightarrow{e'_2} s'_3 \ldots s'_m \in T$$

Now need to define:

▷ How to express constraints on institutional behaviour
▷ How to map external actions to institutional actions
Constraints on action

- One convenient way is through the combination of
- Obligation, where
  - an actor must take actions resulting in a particular institutional state that satisfies the obligation
  - such as a reviewer submitting a review by the end of the review period
- Permission, that
  - indicates whether some action is permitted for some actor in the current state of the institution
  - such as the program committee chair closing submission of papers
- Power, that
  - indicates whether some action by some actor has an effect on the institutional state [Jones and Sergot, 1996]
  - such as only the program chair being able to extend the paper submission deadline
Event mapping and state changing

- Some external events are related to institutional events:
  \[ e_i \rightarrow e'_j \]
  - Defined by the *generation* relation \( G \)
  - The institutional state is a set of facts: \( \mathcal{F} \)
  - When there is an institutional event:
    - add facts to, or
    - delete facts from
    the institutional state
  - Defined by the *consequence* relation \( C \)
  - Hence, the institutional state transformer function:
    \[ \tau : S \times E \rightarrow 2^S \]

may be realized by \( C \circ \text{TC}(G) \), where TC denotes the transitive closure.
A formal model

<table>
<thead>
<tr>
<th>Normative system</th>
<th>( \mathcal{N} := \langle \mathcal{E}, \mathcal{F}, \mathcal{G}, \mathcal{C}, \Delta \rangle )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Events, comprising exogenous, (normative) actions and (normative) violations</td>
<td>( \mathcal{E} = \mathcal{E}<em>{\text{ex}} \cup \mathcal{E}</em>{\text{inst}} ) with ( \mathcal{E}<em>{\text{inst}} = \mathcal{E}</em>{\text{act}} \cup \mathcal{E}_{\text{viol}} )</td>
</tr>
<tr>
<td>Normative facts (fluents): power, permission, obligations and domain-specific facts</td>
<td>( \mathcal{F} = \mathcal{W} \cup \mathcal{P} \cup \mathcal{O} \cup \mathcal{D} )</td>
</tr>
<tr>
<td>Generation relation: maps state and event to a set of events</td>
<td>( \mathcal{G} : \mathcal{X} \times \mathcal{E} \rightarrow 2^{\mathcal{E}_{\text{inst}}} )</td>
</tr>
<tr>
<td>State formula: the set of positive and negative fluents comprising the current normative state</td>
<td>( \mathcal{X} = 2^{\mathcal{F} \cup \neg \mathcal{F}} )</td>
</tr>
<tr>
<td>Consequence relation: maps state and event to a pair (additions, deletions) of sets of fluents</td>
<td>( \mathcal{C} : \mathcal{X} \times \mathcal{E} \rightarrow 2^{\mathcal{F}} \times 2^{\mathcal{F}} ) where ( \mathcal{C}(X, e) = (\mathcal{C}^{\uparrow}(\phi, e), \mathcal{C}^{\downarrow}(\phi, e)) ) where ( \mathcal{C}^{\uparrow}(\phi, e) ) initiates a fluent, and ( \mathcal{C}^{\downarrow}(\phi, e) ) terminates a fluent</td>
</tr>
<tr>
<td>The initial set of fluents</td>
<td>( \Delta )</td>
</tr>
</tbody>
</table>
The conference scenario

- Entities: person, paper
- Roles: reviewer, chair, author
- Properties: listed author, is in English
- External events: submit paper, open submission, close submission, open review, close review
- Institutional events: corresponding to above
- Two scenarios:
  - opening of submission
  - review assignment
Some of the actors are identified:

- Frank is PC chair
- Gerhard is a reviewer

These are institutional facts. As is the power and the permission from Frank to declare submission is open.
Conference scenario: submissions opens

- **exogenous event**
  - openSubmission(Person);
  - inst event iopenSubmission;
  - openSubmission(A) generates
    - iopenSubmission(A)
    - if isChair(A);

- **iopenSubmission(A) initiates**
  - perm(icloseSubmission(A)),
  - pow(icloseSubmission(A));

- **iopenSubmission(A) terminates**
  - pow(iopenSubmission(A)),
  - perm(iopenSubmission(A)),

- **External event is recognized, generating institutional event, iff A is the PC chair. This is part of the \( G \) relation**

- **The institutional event causes the addition of some powers and permissions to the institutional state so that papers can be submitted and submission can be closed. This is part of the \( C \) relation.**

- **...and the deletion of powers and permissions associated with opening submission. This is also part of the \( C \) relation.**

- **Submission opens, which adds the facts that Frank is permitted and empowered to close submission**

- **At the same time, the permission and power to open submission are deleted: it cannot be done twice**
**Conference scenario: reviewer assignment**

assignReviewer(P,R,A) generates
iassignReviewer(P,R)
if isChair(A),
 isReviewer(R), not listedAuthor(P,R);

iassignReviewer(P,R) initiates
obl(review(P,R,Report) reviewClosed, badRev(R)),
perm(isendReview(P,R,Report)),
pow(isendReview(P,R,Report));

- The institutional event is only generated if the principal is the PC chair, if R is on the PC and not an author of the paper.
- The assignment establishes an obligation for reviewer R to deliver the review by the close of the review period, or the violation event badRev occurs.
- Review delivery now permitted and empowered

▶ A reviewer can be assigned to a paper, as long as the roles are correct and the reviewer is not listed as an author on the paper
▶ The corresponding institutional event adds
  ▶ An obligation on the reviewer to produce a review by the end of the review period
  ▶ The permission and the power for the reviewer to send a review
A possible trace

Identified events are:

- Person: virginia registers Paper: paper01
- Person: virginia uploads Paper: paper01
- Person: frank closes submission
- Person: frank assigns reviewer Paper: paper01, Person: gerhard
- Person: gerhard sends review Paper: paper01

These events cause changes in the institutional state (next slide):

- The addition and deletion of various powers and permissions
- The creation of obligations at $i_k$ and $i_m$
Multiple Institutions

- A **single institution** can capture the full normative behaviour, but a monolithic structure may be undesirable:
  - Single institutions with a limited range of interaction can be analysed and re-used more easily — institution libraries
  - Institutions are situated in a social and legal framework with whose norms they must interoperate, so institutional workflows are unavoidable

- **Institutional composition** is a different process in which a *single* internally consistent institution is synthesized from several institutional specifications.

- A **multi-institution** is a workflow of several connected institutions, each with their own identity and probably with conflicting norms.
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Agents and Organizations

- Agents $\Rightarrow$ Autonomy
  - Agents are motivated by their own objectives, beliefs...
  - may take up organizational role if it serves their purposes

- Organization $\Rightarrow$ Regulation
  - Organizations (too) have their own purpose
  - Exist independently of the agents populating it
Roles and Agents

- **Role**
  - Abstract representation of a function, service or identification within a group/society
  - Desired activity and behavior, from society perspective

- **Agent**
  - is capable of flexible, autonomous action in order to meet its design objectives.
  - Agents act, roles not
Role enacting agents

- the execution of the functions defined by the role or imposed by role relationships, including the ability to use resources available to the role.
- the ability to communicate, as a proxy for its role, with players of other roles.
- the ability to reason about which of its plans and activities can be used to achieve role objectives.
Matching agents and roles

- How to integrate agent goals and role goals?
- How to integrate agent norms and role norms?
- If conflicting: which to choose?
- How to order role and agent goals/norms?
- What about sub-goals?
- Intuitively, a role enacting agent will
  - Achieve role goals,
  - Behave according to role norms, and
  - Interact using role interaction rules
Role enactment styles

- **Selfish enactment**
  - agent includes as many own goals and rules and gives priority to those

- **Social enactment**
  - agent includes as many own goals and rules but gives priority to goals and rules of role

- **Maximal social enactment**
  - agent only uses goals and rules of role and according to priorities of role
Role enactment 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
  - Roles to be played (social contracts)
  - Scene performance (interaction contracts)
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Organizations and change

- Organizational objective: provide stability
- Environment changes
- Organizational objectives change
- $\Rightarrow$ need for re-organization:
  - internal stimulus: implement revised organizational objectives
  - external stimulus: react to environmental changes
- Depending on scale, adaptation can be:
  - agent behavioural change
  - changes in internal agreements
  - revision of the social structure
(R)Evolution in organizations

- A dynamic tradeoff between
  - regulation: the norms that bring about the organizational objectives
  - autonomy: exploration of alternative behaviours that
    - may not be norm-compliant
    - provide a degree of agility

- Cycle moves from
  - explicit rules, where compliance is shaded by autonomy, to
  - implicit rules, where autonomy establishes what is newly compliant,
  - leading to explicit statement of the implicit rules
  - etc.

Diagram:

```
  implicit organization
  ▶ evolution

  explicit organization
  ▶ revolution
```


When to reorganize?

- Organizational utility:
  - Measure in which organizational objectives are met
  - Reorganization good if utility increases
  - But must account for cost of reorganization

- Organizational performance based on three factors [So and Durfee, 1998]:
  - task-environmental factors
  - structure
  - behaviour
Emergent organizations

- Bottom-up creation instead of top-down definition
- Often occur in the context of “tragedies of the commons” [Hardin, 1968]
- Use cases analyzed by Ostrom [Ostrom, 1990]
- Resulting in the Institutional Analysis and Development (IAD) framework [Ostrom, 2005]
- Addresses real-world (human) scenarios:
  - Many and complex interacting variables
  - Contexts within contexts (c.f. multi-institutions)
- But is it applicable to MAS?
  - Approach encourages unconventional solutions for “messy” common-pool resource problems
  - Solutions are derived from actor preferences resulting in high stability and resilience
  - Approach takes account of a range of factors and discourages simplistic re-use
Bibliography I


