Multiagent Organizations

Chapter 2 in G. Weiss (Ed.), Multiagent Systems, MIT Press, 2nd edition, 2012

Virginia Dignum and Julian Padget

May 7, 2012

Contents

Content

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

Content

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

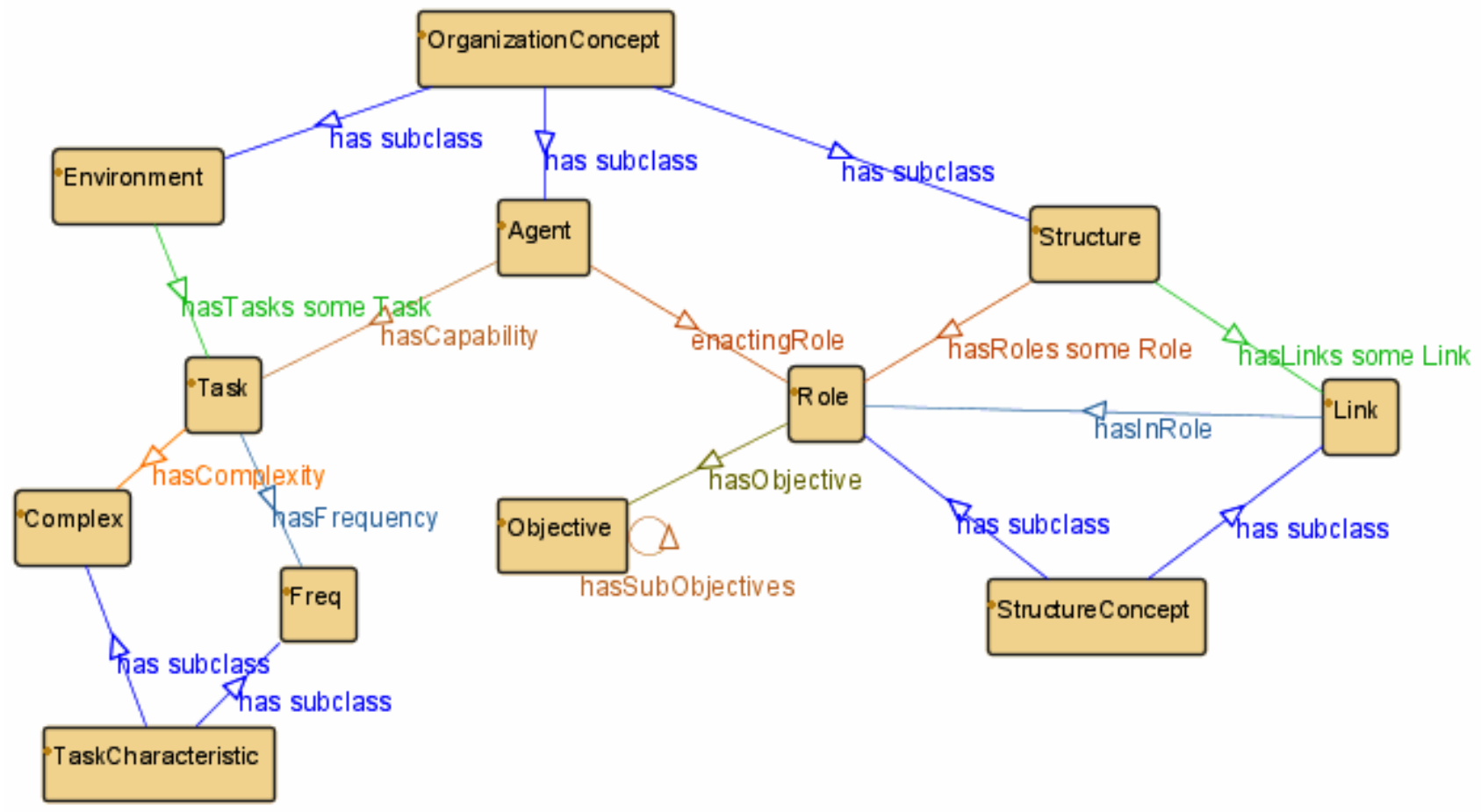
Characteristics of norms

- 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

Ontology


OrganizationConcept
has subclass
has subclass
has subclass
Environment
Agent
Structure
hasTasks some Task
hasCapability
enactingRole
hasRoles some Role
hasLinks some Link
Task
Role
Link
hasInRole
hasComplexity
hasFrequency
hasObjective
Complex
Objective
Freq
hasSubObjectives
has subclass
has subclass
has subclass
has subclass
StructureConcept
has subclass
has subclass
TaskCharacteristic

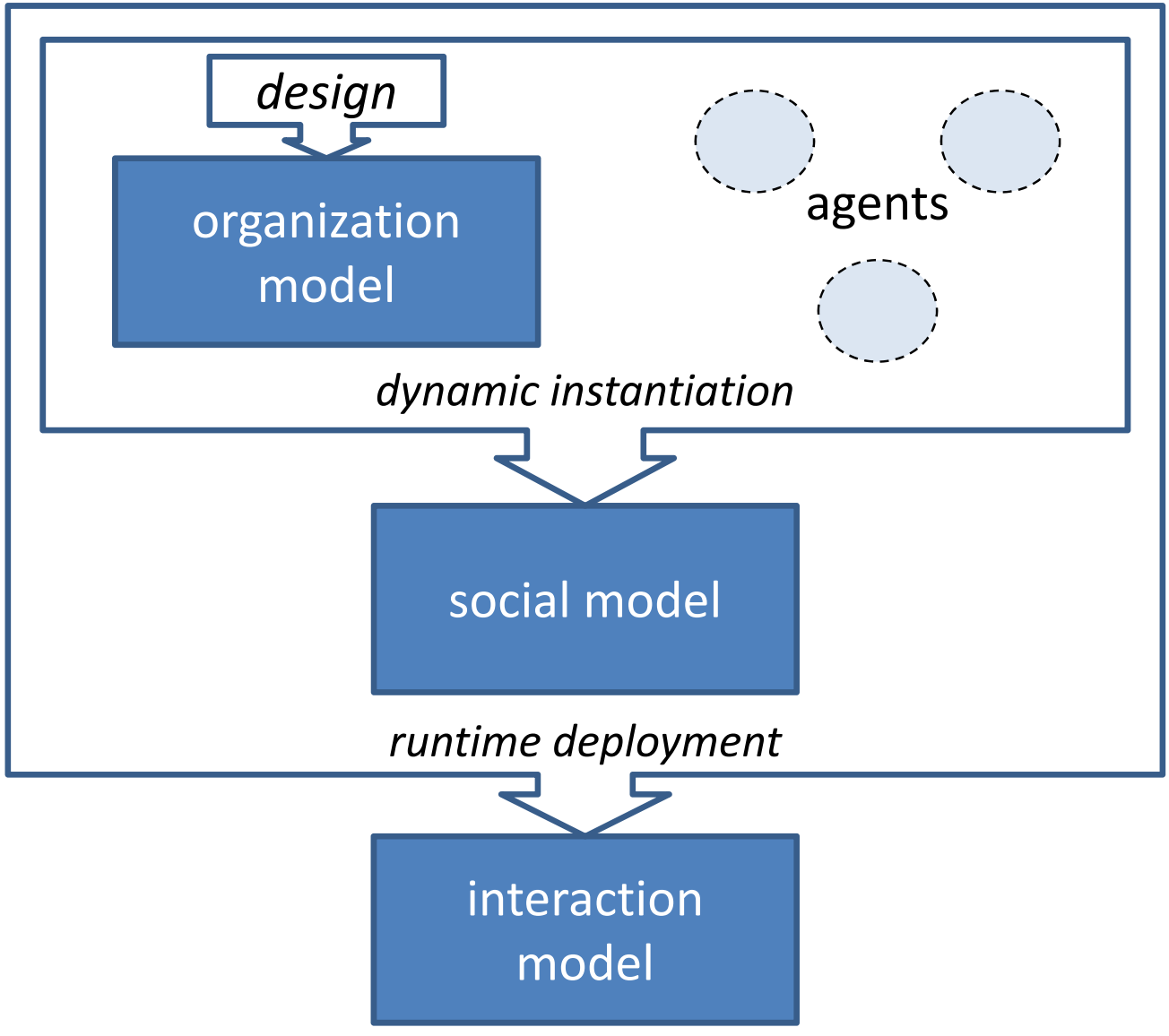
Requirements of Organization Models

- 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



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

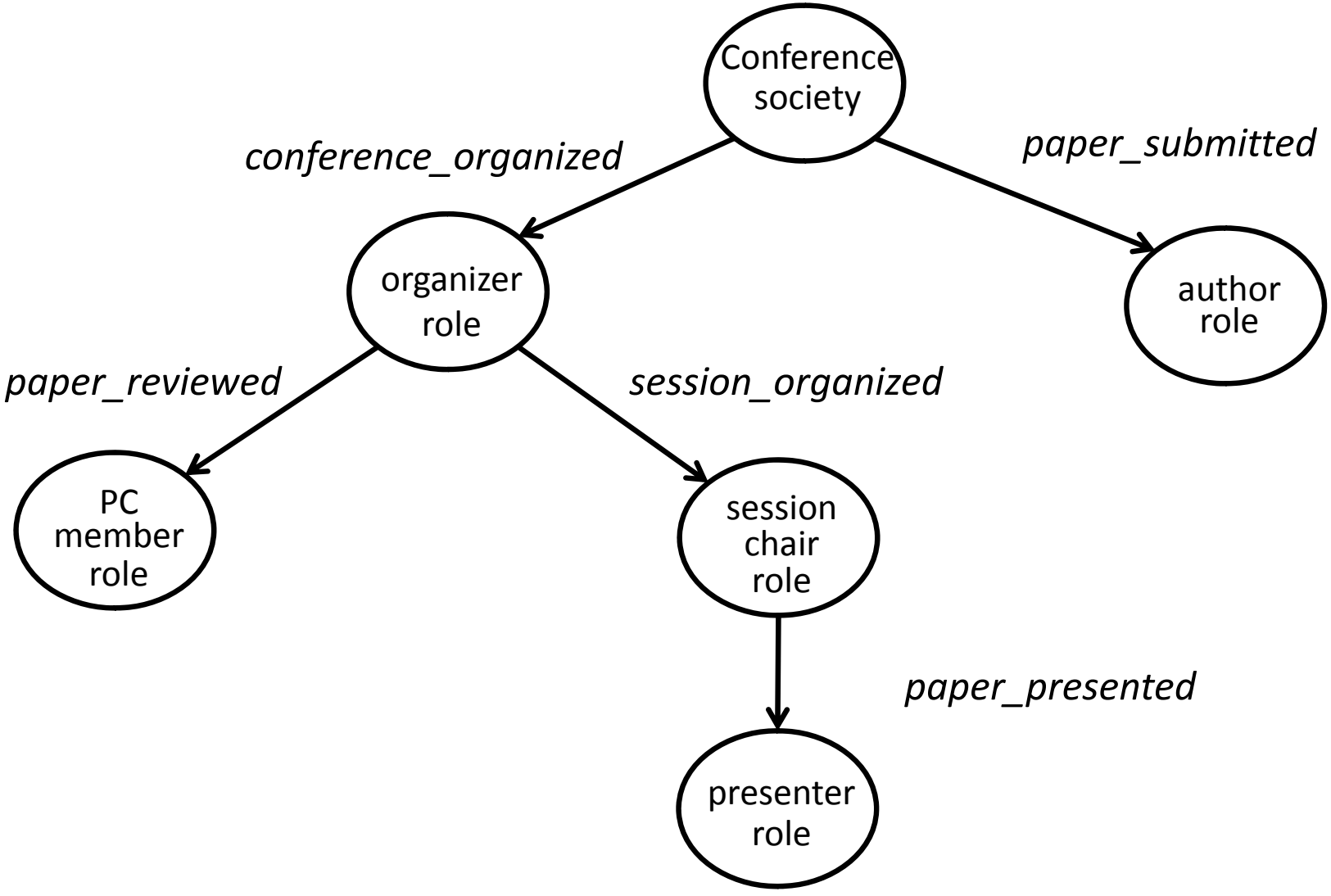
Social Structure

- Role specification

Id	PC_member
Objectives	paper_reviewed(Paper,Report)
Sub-objectives	{read(P), report_written(P, Rep), review_received(Org, P, Rep)}
Rights	access_confmanagement_system(*me*)
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



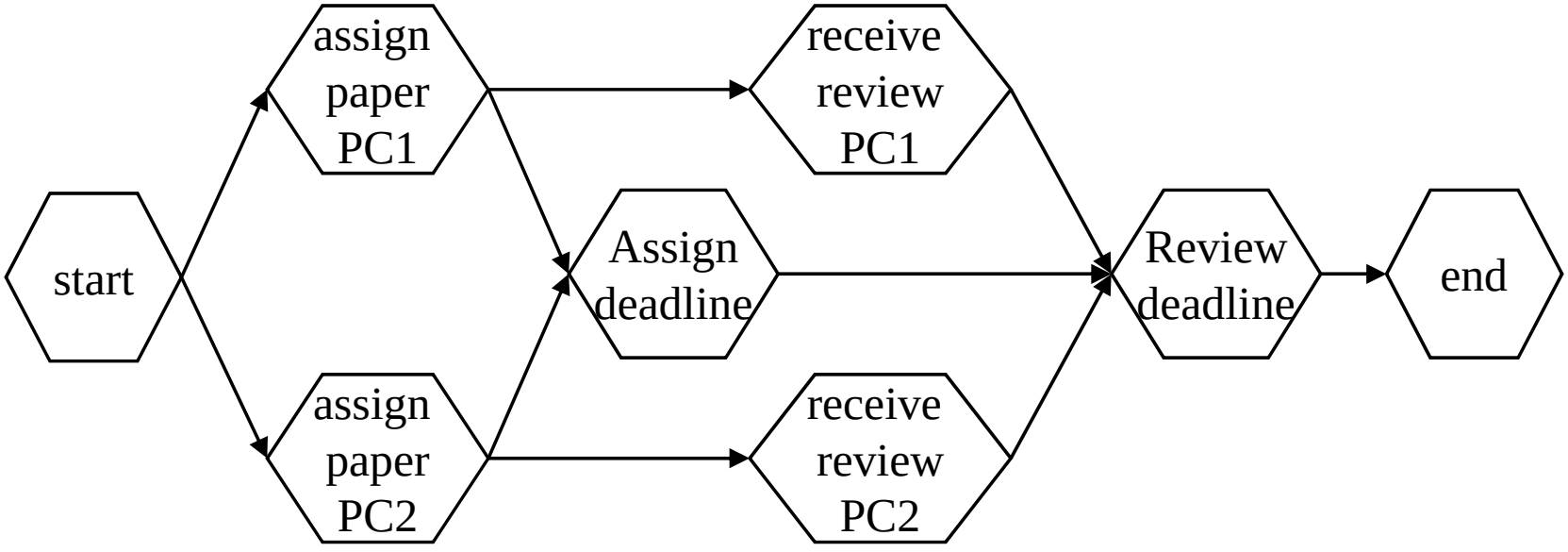
Interaction Structure

- Scene specification

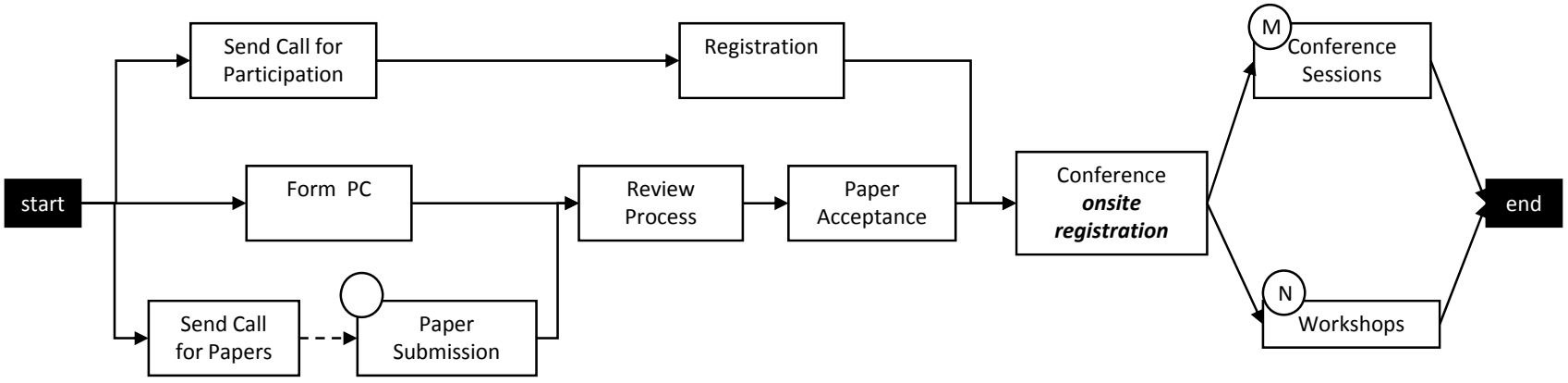
Scene	Review Process
Roles	Program-Chair (1), PC-member(2)
Results	$r_1 = \forall$ P $\in$ Papers: reviews_done(P, rev1, rev2)
Interaction Pattern	PATTERN(r_1): *see figure* **??**
Norms & Rules	Program-Chair PERMITTED assign_papers IF paper_assigned THEN PC_member OBLIGED review_paper BEFORE deadline

Table: Script for the *Review Process* scene.

Landmarks


start
assign paper PC1
assign paper PC2
receive review PC1
receive review PC2
Assign deadline
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

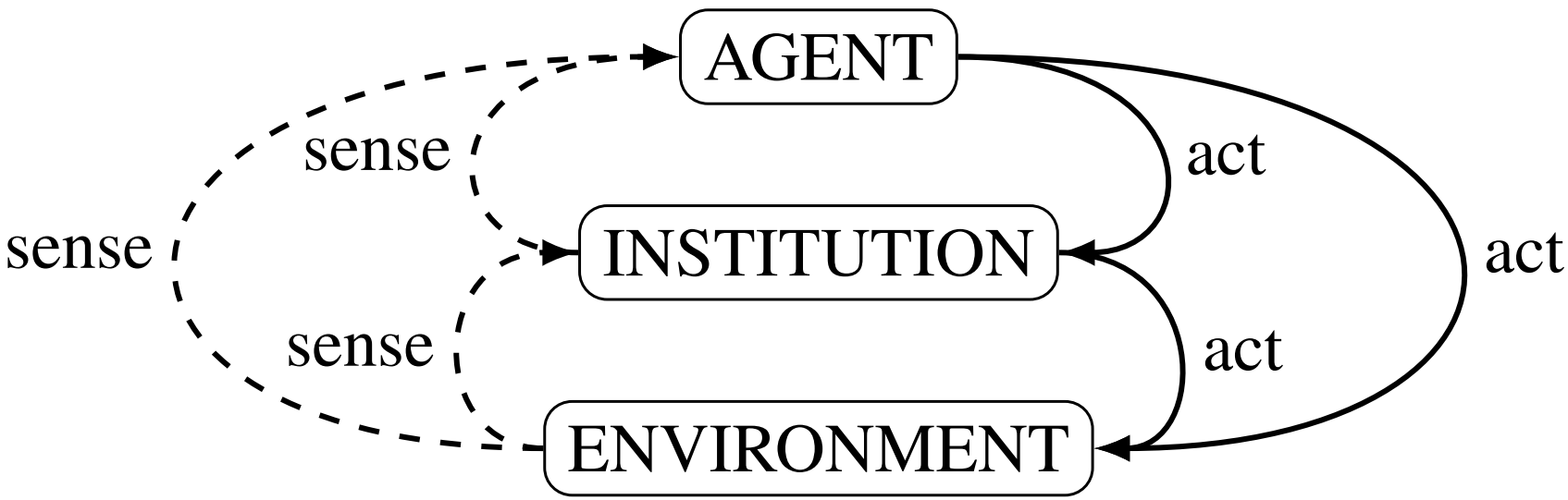
Content

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

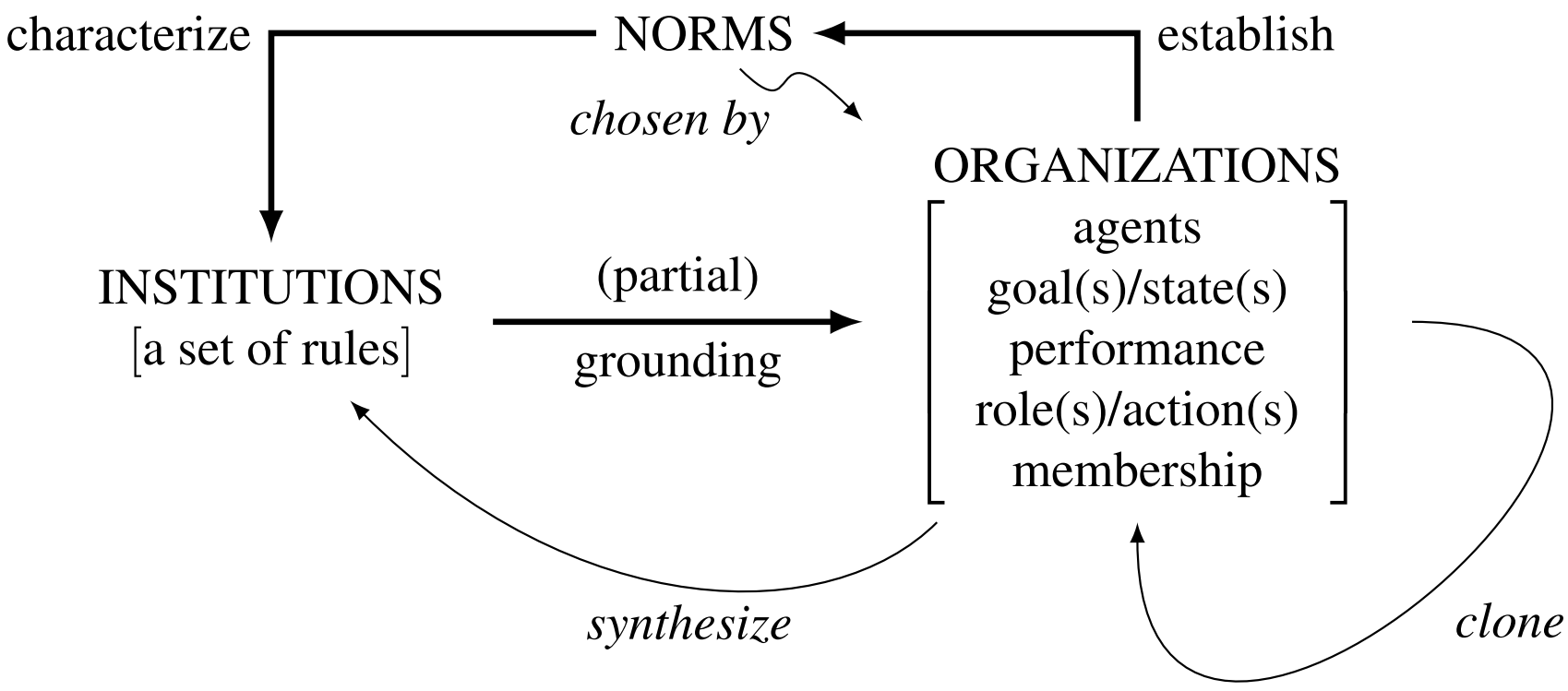
- Organizations derive from [Mintzberg, 1993]:
  - Organizational structure,
  - management and
  - business
- Contend that: institutions underpin organizations

> 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 norms 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]*



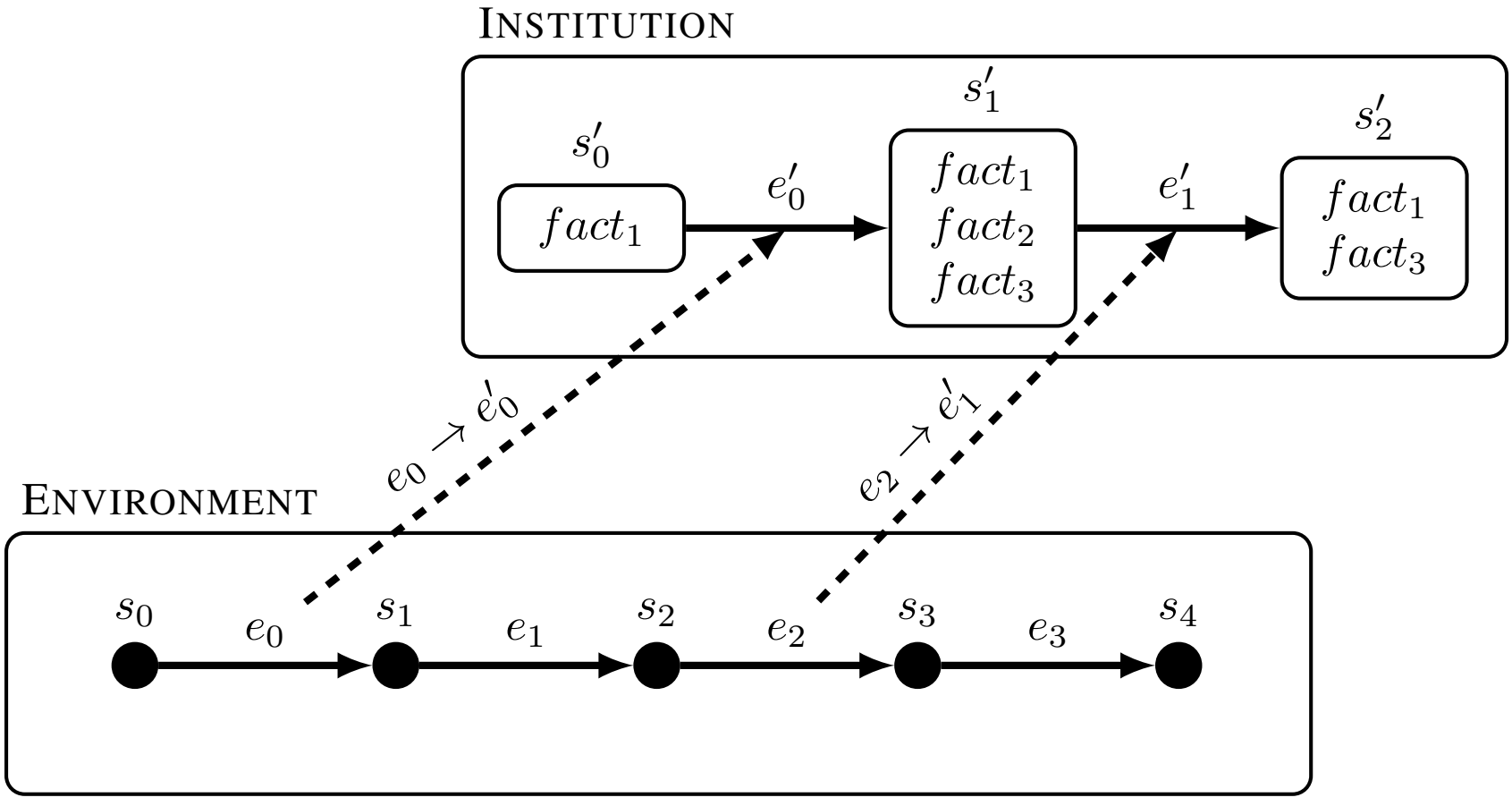
An informal model

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 $s_i \in \mathcal{S}$ denote a state of a system (model)
- Let $e_i \in \mathcal{E}$ denote an event that affects a system (model)
- Let $\tau : \mathcal{S} \times \mathcal{E} \rightarrow 2^{\mathcal{S}}$, denote a state transformer function
- Hence, an actor interacting with a system generates a *trace*:
  $s_0 \xrightarrow{e_0} s_1 \xrightarrow{e_1} s_2 \xrightarrow{e_2} s_3 \ldots s_n \in \mathcal{T}$
- And induces a corresponding institutional trace:
  $s'_0 \xrightarrow{e'_0} s'_1 \xrightarrow{e'_1} s'_2 \xrightarrow{e'_2} s'_3 \ldots s_m \in \mathcal{T}$

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 $\mathcal{G}$
- 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 $\mathcal{C}$
- Hence, the institutional state transformer function:

$$\tau : \mathcal{S} \times \mathcal{E} \rightarrow 2^{\mathcal{S}}$$

may be realized by $\mathcal{C} \circ \mathrm{TC}(\mathcal{G})$, where TC denotes the transitive closure

A formal model

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

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

Conference scenario: entities, roles and events

```
type Person;
type Paper;

static isReviewer(Person);
static isChair(Person);
static isAuthor(Person);
static listedAuthor(Paper,Person);
static isInEnglish(Paper);

initially isChair(frank),
   isReviewer(gerhard);

exogenous event submitPaper(Paper);
exogenous event openSubmission(Person);
exogenous event closeSubmission(Person);
exogenous event openReview(Person);
exogenous event sendReview(Paper,Person,Review);
```

These are some of the objects that appear in the model. This is a simple monomorphic type system

Associates a `Person` with a particular role

Associates a `Person` and a `Paper`

Uses the above to set up some roles

Some of the events that identify key transition points in the scenario

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 $\mathcal{G}$ 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 $\mathcal{C}$ relation.

...and the deletion of powers and permissions associated with opening submission. This is also part of the $\mathcal{C}$ 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

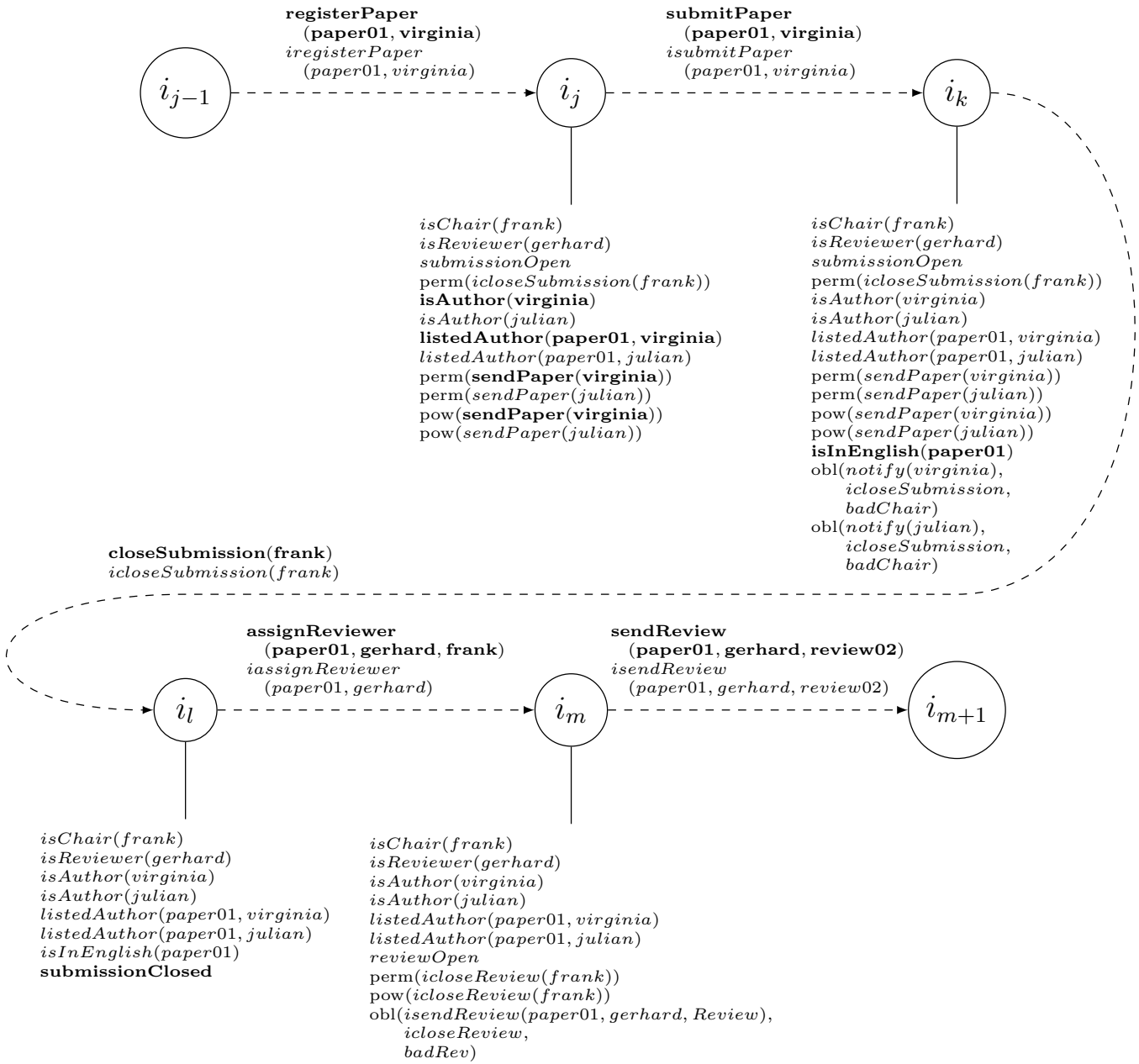
Identified events are:

- 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

Conference scenario trace



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.

Content

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)

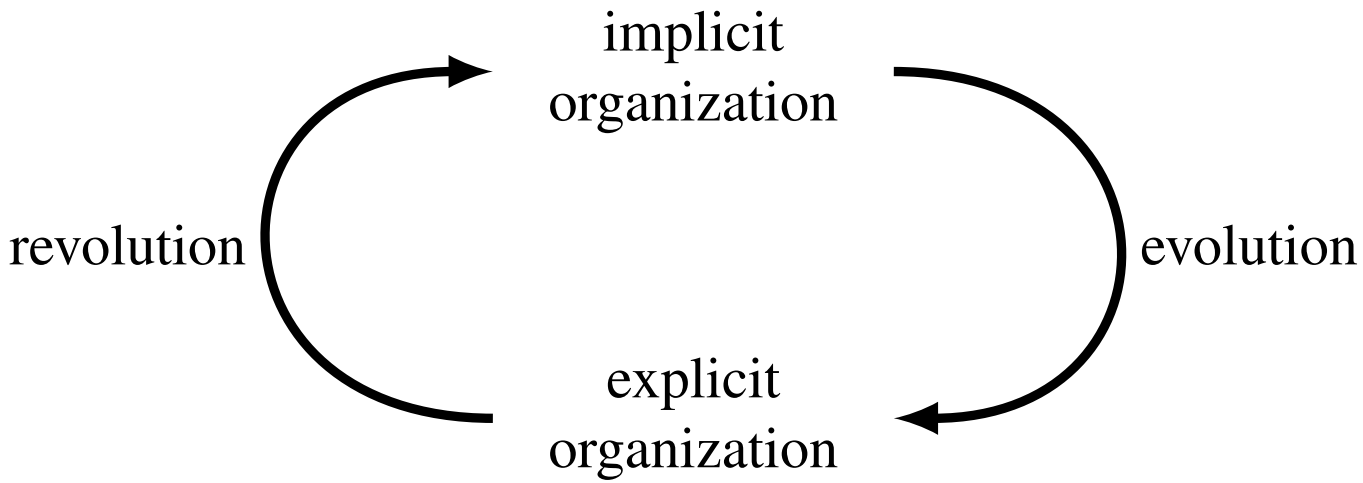
Content

Organizations and change

- Organizational objective: provide stability
- Environment changes
- Orgnizational 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.



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
- Ofter 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 resrouce 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


Davis, S. (1984).
Speech acts and action theory.
Journal of Pragmatics, 8(4):469 – 487.


Goldman, A. (1970).
A Theory of Human Action.
Prentice-Hall.


Hardin, G. (1968).
The Tragedy of the Commons.
Science, 162:1243–8.


Harré, R. and Secord, P. (1972).
The Explanation of Social Behaviour.
Blackwells.
ISBN 0 631 14220 7.

Bibliography II


Jones, A. J. I. and Sergot, M. (1996).
A formal characterisation of institutionalised power.
Logic Journal of IGPL, 4(3):427–443.


Mintzberg, H. (1993).
Structures in Fives: Designing Effective Organizations.
Prentice Hall.


Morin, E. (1977).
La Methode I: la Nature de la Nature.
Seuil.


North, D. (1991).
Institutions, Institutional Change and Economic Performance.
Cambridge University Press.

Bibliography III


Olmstead, J. (2002).
Creating the Functionally Competent Organization: An Open Systems Approach.
Quorum Books.


Ostrom, E. (1990).
Governing the Commons. The Evolutions of Institutions for Collective Action.
Cambridge University Press, Cambridge.


Ostrom, E. (2005).
Understanding Institutional Diversity.
Princeton Universiy Press.
ISBN: 9780691122380.


Oxford English Dictionary (WWW).
Oxford english dictionary.
`http://www.oed.com`, retrieved March 2011.

Bibliography IV


Searle, J. R. (1969).
Speech Acts: An Essay in the Philosophy of Language.
Cambridge University Press.


So, Y. and Durfee, E. (1998).
Designing organizations for computational agents.
In Carley, K., Pritula, M., and Gasser, L., editors, *Simulating Organizations*, pages 47–64.