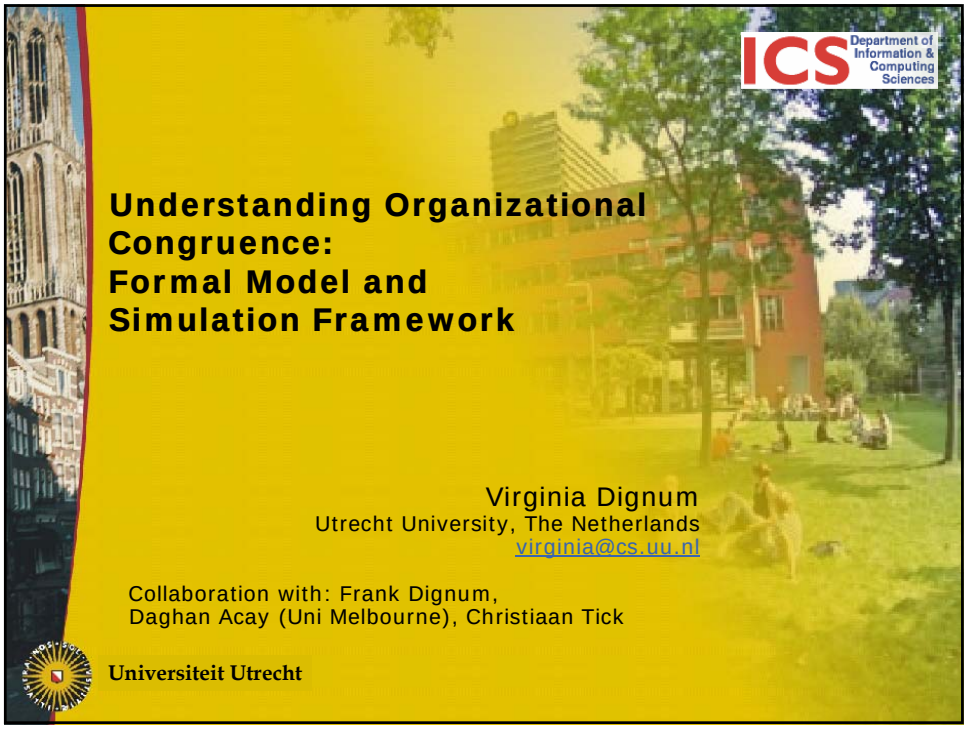


Overview

- Agent Organization and Reorganization
- Requirements for AO formalisms
- AO Formal Model
- Case studies
- Simulation Framework

Agents vs. Organizations

- Agents ➔ Autonomy
- Organization ➔ Regulation

- Agents are motivated by their own objectives, beliefs…
  - May take up role in organization if that serves their purposes
- Organizations have own purpose
  - exist independently of the agents populating it

Agent Organizations

- Coordination in MAS cannot be based on communication alone
- MAS modeling requires high-level abstractions, that are independent of the individual agents

  ➔ Explicit social concepts defining the organization where agents *live*

  - Common purpose
  - Shared 'locality'
  - Order: structure, norms and rules

Dynamics of organization

- Need for reorganization
  - Answer to environment changes
  - Answer to population changes
  - Answer to objective changes
- Need for organization: achieve stability
- Reorganization means loss of stability
- Reorganization decision depends on
  - organizational utility and success.
  - individual utility and success

AO metamodel

- Formal
  - Representation of organization, environment, agents, objectives
    - Partial contribution to performance
  - Representation of dynamics of organization
  - Enable verification of organizational properties
- Realistic
  - Pragmatic issues (time, cost,…)
  - Based on positions/roles, not on specific agents
  - Responsibility vs. action vs. ability

Requirements

1. represent notions of ability and activity of an agent, without requiring knowledge about the specific actions available to a specific agent
   - (open environments)
2. represent ability and activity of a group of agents
3. deal with temporal issues, especially the fact that activity takes time
4. accept limitedness of agent capability
5. represent the notion of responsibility for the achievement of a given state of affairs

Requirements (cont.)

6. represent global goals and its relation to agents' activities
   - (organizational structure)
7. relate activity and organizational structure
8. represent organizational dynamics: evolution of organization over time, changes on agent population
   - (reorganization)
9. deal with resource limitations and the dependency of activity on resources (e.g. costs)
10. distinguish between organizational roles (positions) and agents' functionality
11. deal with normative issues (representation of boundaries for action and the violation thereof)

Formal model for (re)organization

- Logic for agent organizations
  - Contracts and landmarks:
    - LCR (V. Dignum PhD, 2004)
  - Modal logics
    - Branching time: CTL* (Emerson and Halpern, 1990)
    - Deontic: BTLcont (F. Dignum and Kuiper, 1999)
- Stit theories
  - stit operator (Pörn, 1974; Wooldridge, 1996)
  - Agency theory (Elgesem, 1997)
  - Responsibility and delegation (Governatori, 2002), (Santos, Jones, Carmo, 1997)

Semantic model

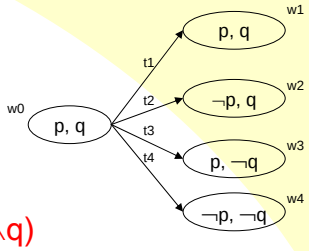
- Given set of atomic propositions, Φ, and set of agents A
- Semantic model M = (W, R, T, π)
  - Kripke model, branching time
  - W: set of worlds
  - R: transitions between worlds
  - T: agent labels on transitions
  - Π: valuation function
- Agent influence on world w
  - Set of transitions from w labeled with a

Agent activity

- Agent Capability: $C_a\varphi$
  - Based o partition of Φ into controllable and not controllable atomic propositions
- Agent Ability: $G_a\varphi$
  - $C_a\varphi$ and a has influence in current world
- Agent Attempt: $H_a\varphi$
  - φ is true in a world reachable under influence of a
- Agent stit: $E_a\varphi$
  - $C_a\varphi$ and φ is true in all worlds reachable from current world

Example

- $\Phi = \{p, q\}$
- $A = \{a,b\}$
- $C_a = \{p\}$ $C_b = \{q\}$



- $\neg C_a(p \wedge q)$ $\neg C_b(p \wedge q)$, $C_{\{a,b\}}(p \wedge q)$
- $\neg G_a(p \wedge q)$ $G_{\{a,b\}}(p \wedge q)$
- $H_a(p \wedge q)$ $H_{\{a,b\}}(p \wedge q)$
  - because $w_1 \vDash p \wedge q$
- Group activity, $S \subseteq A$
  - As for agents
  - Capability: C_S, ability: G_S, attempt: H_S, stit: E_S

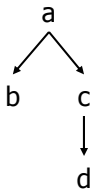
Organization

- Organization model
  - $O = (A_O, \leq_O, D_O, S_O)$
  - $A_O \subseteq A$
  - $\leq_O$: partial order of agents, $a \leq b$
    - a can delegate to b
    - *Note: nothing is said on how delegation is achieved (cf. Dignum, COIN@ECAI'06)*
  - $D_O \subseteq \Phi$, objectives of organization
  - $S_{O,w} \subseteq \Phi$, current state of organization
- Responsibility: $R_a\varphi$ or $R_S\varphi$
  - In charge of achieving a
  - If $a \leq b$ then $C_aR_b\varphi$

Example organization

$$O^w = (A_O^w, \leq_O^w D_O^w, S_O^w)$$

- $A_O = \{a,b,c,d\}$
- $\leq_O$: $a \leq_O b$, $a \leq_O c \leq_O d$
- $D_O = \{\rho\}$, $\rho = (p \wedge q) \vee r$
- $S_O = \{R_a\rho, C_bp, C_dq, C_{\{a,c\}}r\}$

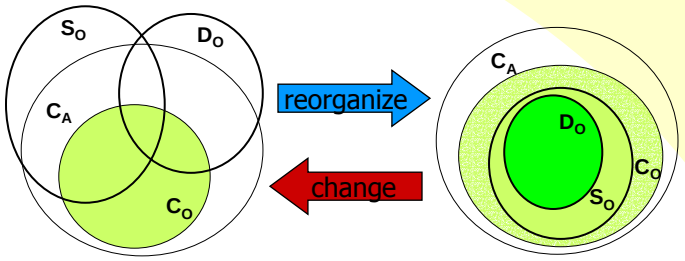


Organizational structure

Possible successful strategy:

w_1: $E_aR_bp \wedge E_aR_cq$
w_2: $R_bp \wedge R_cq$
…
w_i: $R_bp \wedge E_cR_dq$
w_{i+1}: $R_bp \wedge R_dq$
…
w_j: $E_bp \wedge E_dq$
w_{j+1}: $p \wedge q \rightarrow \rho$

Organizational change



S_O: current state of organization O
D_O: desired state of organization O
C_O: scope of control of agents in O
C_A: scope of control of all agents

Monitoring for change

- There is not one best way to organize, but not all structures are equally effective
- Performance: measure to which objectives are achieved in a given state
  - function *perform*: $W \times \mathcal{P}(A_{\leq}) \times \Phi \rightarrow \Re$
  - *perform* represents the cost associated with activity in W
  - *perform*$(w, G_{\leq}, p) = c$
    - (fixed for $\forall w \in W, G \in A, p \in \Phi$)

Properties of *perform*

Intuitively:

- *perform*(w, $G_{\leq}$,p) + *perform*(w, $G_{\leq}$,q) ≤ *perform*(w, $G_{\leq}$,p∧q)
  - Tired!
- $\neg C_{G_{\leq}}\varphi \rightarrow$ (*perform*(w, $G_{\leq}$, φ) = ∞)
- *perform*(w, $G_{\leq}$, φ) ≤ *perform*(w, $G_{\leq}$, φ∧ψ)
- (φ→ψ) → (*perform*(w, $G_{\leq}$, ψ) ≤ *perform*(w, $G_{\leq}$, φ))

Acting for change

- Planned reorganization
  - Endogenous: due to activity of agents in organization; organization controllable
  - Exogenous: due to activities outside the scope of control of the organization
- Types of reorganization operations (from human organizations):
  - Staffing: hire, fire, train (add capabilities)
  - Structuring: positions, departments, groups
  - Strategic: mission, vision, objectives

Reorganization operations

Given semantic model ε and organization $O=(A,\leq,D,S)$:

- $a \notin A$, *staff+*(O,a): $O' = (A \cup \{a\},\leq,D,S \cup C_a)$
- $a \in A$, *staff-*(O,a): $O' = (A/\{a\},\leq,D,S/C_a)$
- $a,b \in A$, *struct+*$(O,a \leq b)$: $O' = (A,\leq \cup \{a \leq b\}, D,S)$
- $a \leq b \in A_{\leq}$, *struct-*$(O,a \leq b)$: $O' = (A,\leq/\{a \leq b\}, D,S)$
- $\neg(d \wedge D) \rightarrow \perp$, *strateg+*$(O,d)$: $O' = (A,\leq,D \cup \{d\},S)$
- $d \in D$, *strateg-*(O,d): $O' = (A,\leq,D/\{d\},S)$

Deciding about change

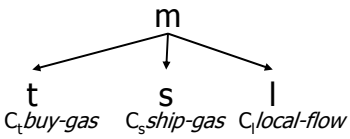
- Reorganization operations are just as any other predicate
  - Thus e.g.: C_a*staff+*(O,b) or C_G*strateg+*(O,d)
- Reorganization decisions based on
  - Current performance
  - Cost of reorganization
  - E.g. *perform*(w, O,σ) + *perform*$(w', O',D_{O'}) \leq$ *perform*(w, O, D_O) where σ is some reorganization operation
  - Compare costs of different possible reorganization operations; performance of resulting organizations

Cases studies in reorganization

- Organizational congruence in C2 situations
  - Adaptive Architectures for Command and Control (Entin et al, 2003, 2004)
- RoboSoccer
  - Team allocation (Hubner et al, 2004)
- Gas Supply Chain
  - Liberalization of Dutch market (Pelletier et al, 2005)
- Sensor networks
  - Sensing 360° environment (Matson, Deloach, 2005)

The original gas market

- Monopolist organized all parties: trader, shipper, local manager:



- O = ({m,t,s,l}, ≤, D, S)
  D = {d} = {*buy-gas* ∧ *ship-gas* ∧ *local-flow*}
  S = {R_md, C_t*buy-gas,* C_s*ship-gas,* C_l*local-flow}*
  perform(w, O, d) = v
- Exogenous change (by government decision):
  staff-(O,m) resulting in O′ = ({t,s,l}, ≤, D, S)
  perform(w, O, d) = ∞

Liberalized gas market

- *staff+*(O',t'), *staff+*(O',s'), *staff+*(O',l') such that:
- O' = ({t',s',l'}, ≤', D', S')

  Where:

  D' = D = {d} = {*buy-gas* ∧ *ship-gas* ∧ *local-flow*}

  S' = {$R_{t'}$d, $R_{s'}$d, $R_{l'}$d, $C_{t'}$*buy-gas,* $C_{s'}$*ship-gas,* $C_{l'}$*local-flow*}

S` = {…, $C_{t'}$struct(O,t'≤s'), $C_{t'}$struct(O,t'≤l'), $C_{s'}$struct(O,s'≤t'), $C_{s'}$struct(O,s'≤l'), $C_{l'}$struct(O,l'≤s'), $C_{l'}$struct(O,l'≤t')}

Reorganization of gas market

- Endogenous activity: by action of agents
- In liberalized situation, each has interest (responsibility) to get market going
  - someone has to start it!
  - More knowledge, decision power necessary for each agent
- Possible activity (local manager takes lead):

  $R_{l'}$d

  $E_{l'}$struct(O,l'≤s')

  $E_{l'}$struct(O,l'≤t')

  $E_{l'}$ $R_{t'}$*buy-gas*

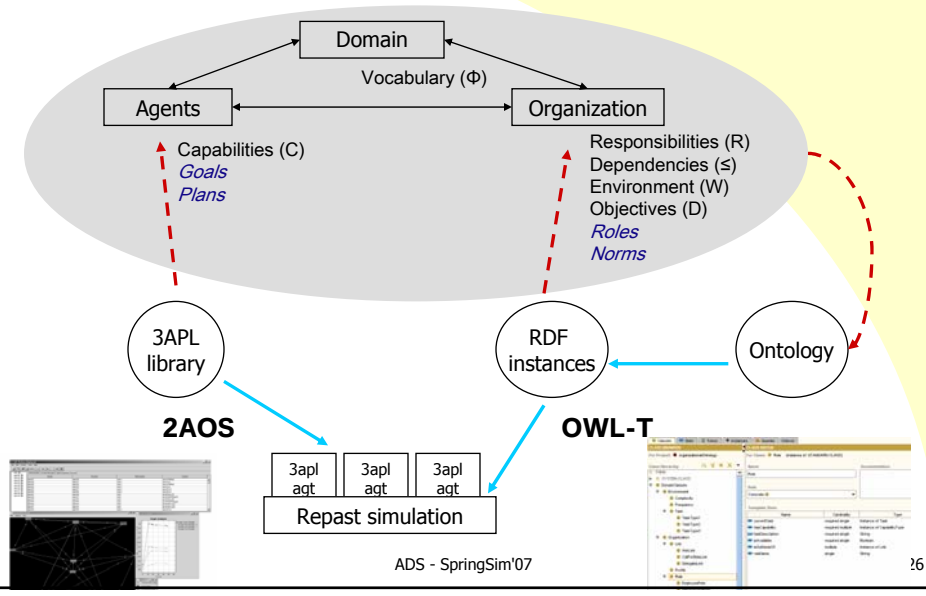
  $E_{l'}$ $R_{t'}$*ship-gas*

  $E_{l'}$ *local-flow*

Simulation tool

- Organizational ontology
  - Organizational concepts
- Cognitive agent library (3APL)
  - Goals and capabilities
- Simulation platform
  - Flexible environment, scheduling, visualization
- Conversion of ontology instances (specific organization) into Repast model
- Plugin 3APL – Repast
- Acknowledgements:
  - Daghan Acay, Christian Tick

Simulation framework



Conclusions

- Formal model for (re)organization
  - Realistic organizations (time, costs, structure,…)
  - Semantics based on temporal logic (…)
- Towards a theory for reorganization
  - Analyze, compare, investigate different (pragmatic) approaches
- Simulation framework
  - Ontologies serve interoperability and flexibility
  - Cognitive agents provide realistic behavior
  - Simulation tool (repast) provides environment model
- Future work
  - Full axiomatization
  - Further development of tool
  - Applications:
    - Human-agent networks
    - Micro-credit/local currencies
    - Crisis management
    - Adaptive gaming