# Socio-technical Organisation

Virginia Dignum

# (Agent) Socio-technical Organizations

Develop theory and tools for engineering complex multi-actor systems, integrating artificial and human partners, based on computational models of organization and adaptation

- Engineering socially intelligent systems
- Integrating systems in human organizations

- Taking into account
  - Predictability, Control, Adaptability, Macro / micro behavior...

# Motivation: Theoretical
# Individuals and Organizations

- Individuals → Autonomy
- Organization → Regulation

- Individuals (agents) are motivated by their own objectives
  - May take up role in organization if that serves their purposes
- Organizations have their own purpose
  - Mission exists independently of the agents populating it

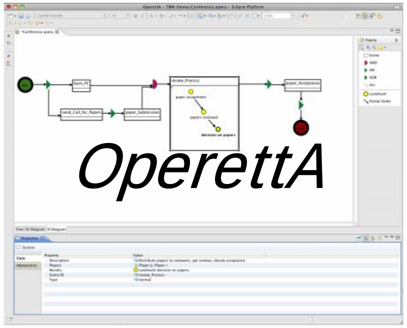
# Motivation: Practical Socio-technical interaction

- Concerns
  - Human-system/agent interaction
  - Individual interests
  - Global goals and requirements
  - Interdependencies
  - Control and monitoring
  - Social features for computer systems
  - Computer as social actor
  - Adaptation
- Domains
  - Transport
  - Governance
  - Energy
  - Inter-organization processes
  - Training and coaching
  - Social-sensor networks
  - Search and rescue
  - Serious games

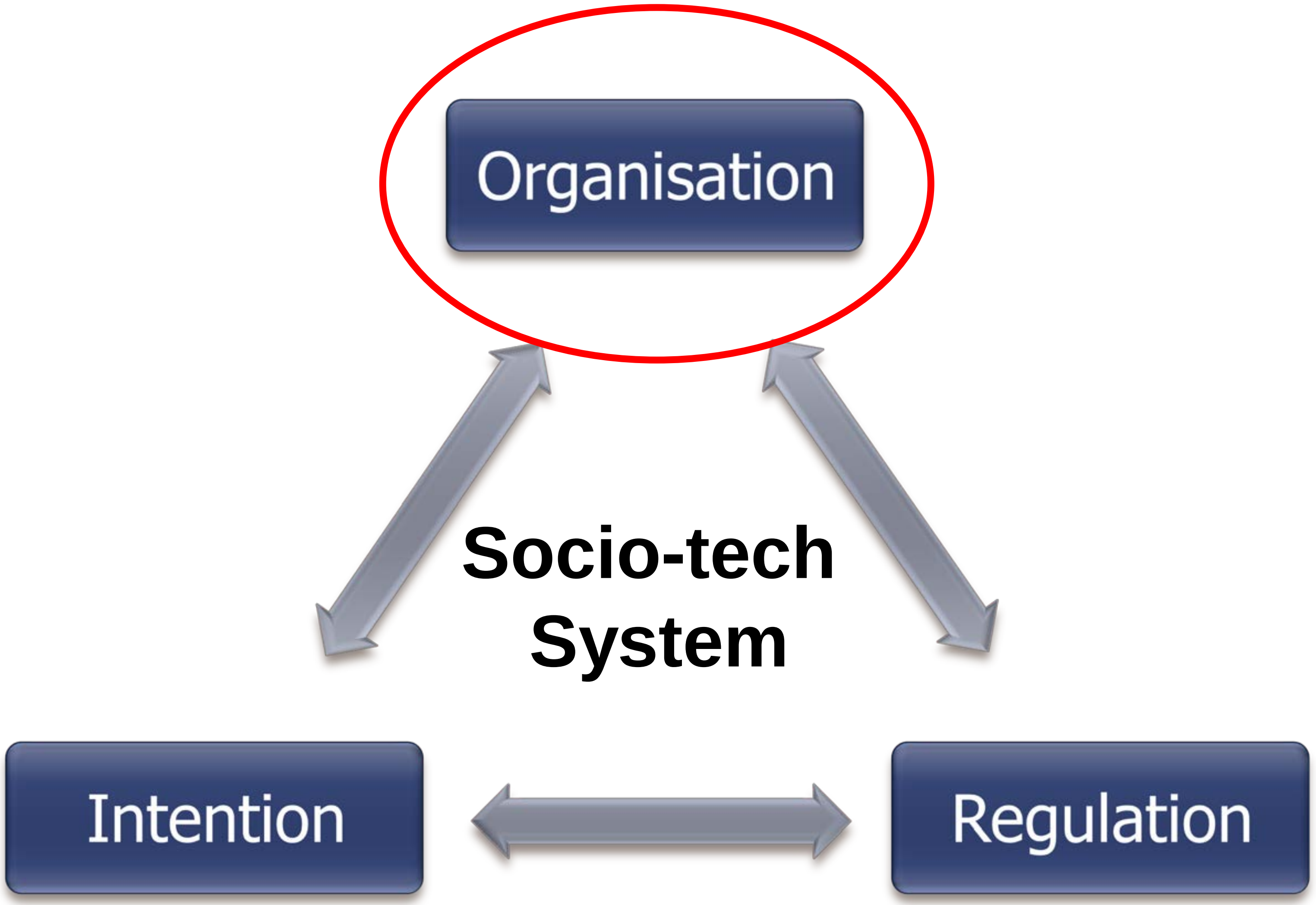
# Our research at TU Delft

- Organization modeling and simulation
  - Analysis, design, redesign
- Formal organization models: modal logics
- Computational models of organization;
- Organizational models of (information) systems

- Applications
  - Service orchestration
  - Business processes / Logistic processes
  - Smart infrastructures




- Tools/Methods: OperA / OperA+ / OperettA /
- Formalisation: LAO


Organisation
Socio-tech
System
Intention
Regulation

# 1. Agent organization: Main features

- Make a clear distinction between description of organization and description of agents
- Agents are
  - dynamic, autonomous entities that evolve within organizations
- Organizations
  - Are regulative environments that constrain the behaviors of the agents
  - or: may appear as the result of agents' activities

# Specific concerns of agent organization

- Interaction among components cannot be completely foreseen at design-time
- Agents, organisation, and environment are ‘independent’ of each other
  - architecture choices
- Explicit representation of the system's inherent organizational structure

# Formalisms for Agent Organization

- 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. deal with resource limitations and the dependency of activity on resources (e.g. costs)
9. Deal with the fact that agent activities are NOT independent
10. distinguish between organizational roles (positions) and agents' functionality
11. deal with normative issues (representation of boundaries for action and the violation thereof)
12. represent organizational dynamics: evolution of organization over time, changes on agent population (reorganization)

# More on LAO

- Journal papers on LAO
  - A logic of agent organizations. (Logic Journal of the IGPL, 2012
  - A formal semantics for agent (re)organization. Journal of Logic and Computation, 2013
- Background
  - 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)

# LAO – Logic of Agent Organization

- Given an organization $O_i = (As_i, R_i, rea_i, \leq_i, D_i, Obj_i, K_i)$

1. $\varphi \in \mathcal{L} \Rightarrow \varphi \in \mathcal{L}_{\mathcal{O}}$
2. $a \in As_i, \varphi \in \mathcal{L}_{\mathcal{O}} \Rightarrow C_a\varphi, G_a\varphi, H_a\varphi, E_a\varphi, \in \mathcal{L}_{\mathcal{O}}$
3. $Z \subseteq As_i, \varphi \in \mathcal{L}_{\mathcal{O}} \Rightarrow C_Z\varphi, G_Z\varphi, H_Z\varphi, E_Z\varphi \in \mathcal{L}_{\mathcal{O}}$
4. $a \in As_i, r \in R_i, \varphi \in \mathcal{L}_{\mathcal{O}} \Rightarrow C_{ar}\varphi, G_{ar}\varphi, H_{ar}\varphi, E_{ar}\varphi \in \mathcal{L}_{\mathcal{O}}$
5. $a \in As_i, r, q \in R_i, \varphi \in \mathcal{L}_{\mathcal{O}} \Rightarrow member(a, o_i), role(r, o_i), play(a, r, o_i),$ $dep(o_i, r, q), incharge(o_i, r, q), know(o_i, \varphi), desire(o_i, \varphi) \in \mathcal{L}_{\mathcal{O}}$
6. $r \in R_i, Z \subseteq R_i, \varphi \in \mathcal{L}_{\mathcal{O}} \Rightarrow I_r\varphi, I_Z\varphi \in \mathcal{L}_{\mathcal{O}}$

# Agent activity

- Agent Capability: $C_a\varphi$
    - Based on a 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

# Getting things done

DEFINITION 2.2 (Initiative)
Given an organization $O_i$ in a model $M_O$, $O_i = (As_i, R_i, rea_i, \leq_i, D_i, Obj_i, K_i)$, and a role $r \in R_i(w)$, or a group $Z \subseteq R_i(w)$, initiative $I_r\varphi$, resp. $I_Z\varphi$, is defined informally as: $r$ has the initiative to achieve $\varphi$ iff an agent $a$ playing $r$ will eventually attempt to achieve $\varphi$ or attempt to put another role in charge of $\varphi$. Formally:

$$\begin{array}{lll} w \models I_r\varphi & \textbf{iff} & w \models \exists a : play(a, r, O_i) \wedge \Diamond(H_{ar}\varphi \vee H_{ar} incharge(O_i, q, \varphi)), \\ & & \text{for some } q \in R_i(w) \\ w \models I_Z\varphi & \textbf{iff} & \exists U \subseteq As_i(w) \forall a \in U \exists r \in Z : \\ & & w \models play(a, r, O_i) \wedge \Diamond(H_{UZ}\varphi \vee H_{UZ} incharge(O_i, Z', \varphi)), \\ & & \text{for some } Z' \subseteq R_i(w) \end{array}$$

# Organization properties I

1. Well defined organization (WD):

$$M_O, w \models WD(o_i) \ \textit{iff}$$
$$M_O, w \models desire(o_i, \varphi) \rightarrow \exists r : (role(r, o_i) \wedge I_r\varphi)$$

2. Successful organization (SU):

$$M_O, w \models SU(o_i) \ \textit{iff}$$
$$M_O, w \models desire(o_i, \varphi) \rightarrow C_{o_i}\varphi \wedge \exists r : (role(r, o_i) \wedge I_r\varphi)$$

3. Good organization (GO):

$$M_O, w \models GO(o_i) \ \textit{iff}$$
$$\textit{if } M_O, w \models (C_{o_i}\varphi \wedge I_Z\varphi) \ \textit{then } (\exists U \subseteq R_i(w)$$
$$\textit{and } M_O, w \models dep(o_i, Z, U) \wedge C_V\varphi)$$

# Organization properties II

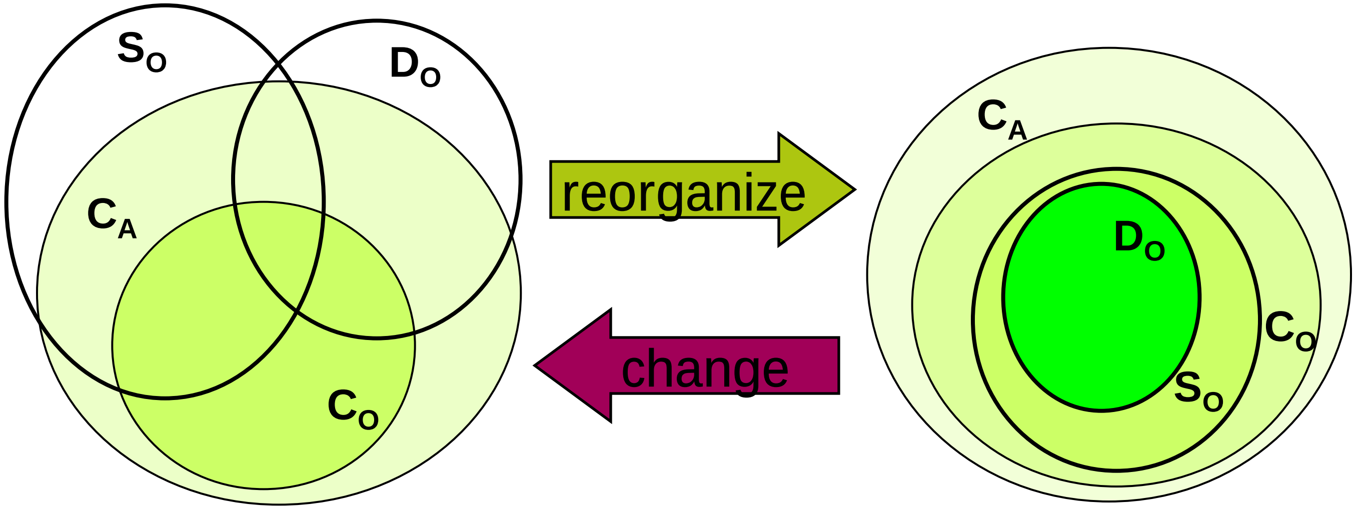
4. Effective organization (EF):

$$M_O, w \models EF(o_i) \;\; \textit{iff}$$
$$M_O, w \models (I_r\varphi \wedge (\neg C_r\varphi) \wedge dep(o_i, r, Q) \wedge$$
$$\exists b, q : q \in Q \wedge play(b, q, o_i) \wedge know(o_i, C_{bq}\varphi)) \rightarrow$$
$$(\exists a : play(a, r, o_i) \wedge E_{ar} incharge(o_i, q', \varphi) \wedge q' \in Q \wedge$$
$$\exists b' : play(b', q', o_i) \wedge know(o_i, C_{b'q'}\varphi))$$

5. Responsible organization (RES):

$$M_O, w \models RES(o_i) \text{ iff}$$
$$M_O, w \models E_Z incharge(o_i, r, \varphi) \wedge X(H_{Vr}\varphi \rightarrow X(\varphi \vee I_Z\varphi).$$

# Organizational dynamics




$S_O$: 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

# Reorganization operation

- **Staffing**: changes to the set of agents
  - *staff+, staff-*
- **Restaffing**: assigning agents to different roles
  - *enact, deact, move*
- **Structuring**: change to organization's structure
  - *position+, position-, struct+, struct-*
- **Strategy**: change to organization's objectives
  - *strateg+, strateg-*
- **Duty**: change to organization's initiative (*incharge* relations)
  - *duty+, duty=*
- **Learn**: change to organization's knowledge
  - *learn+, learn-*

**Definition 9 (Reorganization Operations).** *Given an organization* $O_i = (As_i, R_i, rea_i, \leq_i, D_i, Obj_i, K_i)$*, in a model* $M_O$*, the reorganization operations over* $O_i$ *in* $M_O$ *are:*

1. $w \models staff^+(o_i, a, U)$ iff $w \models \neg member(a, o_i) \wedge \mathcal{X}(member(a, o_i) \wedge \forall r \in U : play(a, r, o_i) \wedge \forall \varphi : C_{ar}\varphi \rightarrow know(o_i, C_{ar}\varphi))$, where $U \subseteq R_i(w)$
2. $w \models staff^-(o_i, a)$ iff $w \models member(a, o_i) \wedge \mathcal{X}(\neg member(a, o_i) \wedge \neg\exists r \in R_i : play(a, r, o_i))$,
3. $w \models enact(o_i, a, r)$ iff $w \models \neg play(a, r, o_i) \wedge \mathcal{X}(member(o_i, a) \wedge play(a, r, o_i))$
4. $w \models deact(o_i, a, r)$ iff $w \models play(a, r, o_i) \wedge \mathcal{X}\neg play(a, r, o_i)$,
5. $w \models move(o_i, a, r, q)$ iff $w \models play(a, r, o_i) \wedge \neg play(a, q, o_i) \wedge \mathcal{X}(play(a, q, o_i) \wedge \neg play(a, r, o_i))$
6. $w \models position^+(o_i, r)$ iff $w \models \neg role(r, o_i) \wedge \mathcal{X} role(r, o_i)$
7. $w \models position^-(o_i, r)$ iff $w \models role(r, o_i) \wedge \neg\exists a \in As_i : play(a, r, o_i) \wedge \neg\exists q \in R_i : (dep(q, r, o_i) \vee dep(r, q, o_i)) \wedge \mathcal{X}\neg role(r, o_i)$,
8. $w \models struct^+(o_i, (r \leq q))$ iff $w \models role(r, o_i) \wedge role(q, o_i) \wedge \mathcal{X} dep(o_i, r, q)$,
9. $w \models struct^-(o_i, (r \leq q))$ iff $w \models role(r, o_i) \wedge role(q, o_i) \wedge \mathcal{X}\neg dep(o_i, r, q)$,
10. For $d : \neg(d \wedge D) \rightarrow \bot$, $w \models strateg^+(o_i, d)$ iff $w \models \mathcal{X} desire(o_i, d)$
11. $w \models strateg^-(o_i, d)$ iff $w \models \mathcal{X}\neg desire(o_i, d)$
12. $w \models duty^+(o_i, r, \varphi)$ iff $w \models \mathcal{X} incharge(o_i, r, \varphi)$
13. $w \models duty^-(o_i, r, \varphi)$ iff $w \models \mathcal{X}\neg incharge(o_i, r, \varphi)$
14. $w \models learn^+(o_i, \varphi)$ iff $w \models \mathcal{X} know(o_i, \varphi)$
15. $w \models learn^-(o_i, \varphi)$ iff $w \models \mathcal{X}\neg know(o_i, \varphi)$

**Definition 10 (Safe Reorganization).** *For a semantic model $M_O$, given an organization $O_i = (As_i, R_i, rea_i, \leq_i, D_i, Obj_i, K_i)$, the reorganization operations over $O_i$ in $M_O$ are safe if the following properties hold:*

1. $\models I_r\varphi \wedge staff^-(o_i, a) \rightarrow \mathcal{X} I_r\varphi$
2. $\models C_Z\varphi \wedge staff^-(o_i, a) \rightarrow \mathcal{X} C_Z\varphi$
3. $\models (I_r\varphi \wedge (\forall a : play(a, r, o_i) \rightarrow \neg C_{ar}\varphi) \wedge staff^-(O_i, a)) \rightarrow \neg E_{ar} incharge(o_i, q, \varphi)$
4. $\models I_r\varphi \wedge deact(o_i, a, r) \rightarrow \mathcal{X} I_r\varphi$
5. $\models C_Z\varphi \wedge deact(o_i, a, r) \rightarrow \mathcal{X} C_Z\varphi$
6. $\models (I_r\varphi \wedge (\forall a : play(a, r, o_i) \rightarrow \neg C_{ar}\varphi) \wedge deact(o_i, a, r)) \rightarrow \neg E_{ar} incharge(o_i, q, \varphi)$
7. $\models I_r\varphi \wedge move(o_i, a, r, q) \rightarrow \mathcal{X}(I_r\varphi \vee I_q)$
8. $\models C_Z\varphi \wedge move(o_i, a, r, q) \rightarrow \mathcal{X} C_Z\varphi$
9. $\models (I_r\varphi \wedge (\forall a : play(a, r, o_i) \rightarrow \neg C_{ar}\varphi) \wedge move(o_i, a, r, q)) \rightarrow \neg E_{ar} incharge(o_i, t, \varphi)$
10. $\models (C_{o_i}\varphi \wedge I_r\varphi \wedge struct^-(o_i, (r \leq q)) \wedge \exists U \subseteq R_i(w) :$ $(dep(o_i, r, U) \wedge C_U\varphi) \rightarrow \mathcal{X}(\exists W \subseteq R_i(w) : (dep(o_i, r, W) \wedge C_W\varphi))$
11. $\models strateg^+(o_i, \varphi) \rightarrow \mathcal{X}(C_{o_i}\varphi \wedge \exists r : (role(r, o_i) \wedge I_r\varphi))$
12. $\models C_{o_i}\varphi \wedge duty^+(o_i, r, \varphi) \rightarrow \mathcal{X} \exists U \subseteq R_i(w) : (dep(o_i, r, U) \wedge C_U\varphi)$
13. $\models (duty^+(o_i, r, \varphi) \wedge (\forall a : play(a, r, o_i) \rightarrow \neg C_{ar}\varphi) \wedge dep(o_i, r, q) \wedge play(b, q, o_i) \wedge$ $know(C_{bq}\varphi)) \rightarrow \mathcal{X}(\exists a : play(a, r, o_i) \wedge E_{ar} incharge(o_i, q, \varphi))$
14. $\models desire(o_i, \varphi) \rightarrow \exists r : (role(r, o_i) \wedge I_r\varphi) \wedge duty^-(o_i, t, \psi)$ $\rightarrow \mathcal{X}(desire(o_i, \varphi) \rightarrow \exists r : (role(r, o_i) \wedge I_r\varphi))$
15. $\models I_r \wedge (\forall a : play(a, r, o_i) \rightarrow \neg C_{ar}\varphi) \wedge dep(o_i, r, q) \wedge play(b, q, o_i) \wedge learn^+(o_i, \varphi)) \rightarrow$ $\mathcal{X}(\exists a : play(a, r, o_i) \wedge E_{ar} incharge(o_i, q, \varphi))$

# Safe reorganization

**Theorem 1.** *Given* $O_i = (As_i, R_i, rea_i, \leq_i, D_i, Obj_i, K_i)$ *and a semantic model* $M_O$*, a safe reorganization* $Reorg$*, is such that:*

$$M_O, w \models WD(o_i) \wedge Reorg \rightarrow \mathcal{X}WD(o_i)$$
$$M_O, w \models SU(o_i) \wedge Reorg \rightarrow \mathcal{X}SU(o_i)$$
$$M_O, w \models GO(o_i) \wedge Reorg \rightarrow \mathcal{X}GO(o_i)$$
$$M_O, w \models EF(o_i) \wedge Reorg \rightarrow \mathcal{X}EF(o_i)$$
$$M_O, w \models RES(o_i) \wedge Reorg \rightarrow \mathcal{X}RES(o_i)$$

# Implementing Organization

- ‘Balancing’ agents and organizations
- Assuming agents to be heterogeneous entities
  - Different architectures
  - Independent from social design
  - Joining organization as means to fulfill own goals
  - No guarantee on truthfulness, cooperation, ...
- Means are needed to ascertain organizational operation
  - Negotiation scenes
  - Contracts

# Approaches to AOS design

- Implicit:
  - organization emerges (is observable) from the agents' behaviour
- Explicit:
  - Organization model is first order entity, independent from agents
- Internal
  - organization model is embedded in the agents
- External
  - Shared representation of organization model, outside agents

# Our Approach: External – Explicit
## Integrating 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

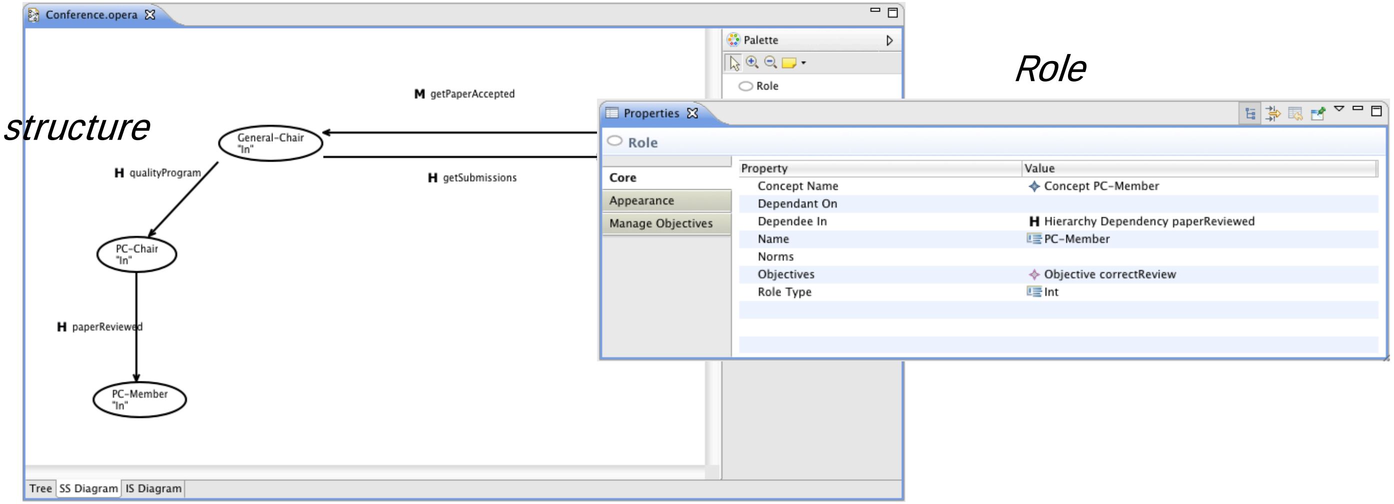
# OperA Model

- Components for organization specification
  - 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)
  - Interaction Model
    - represents agreements concerning interaction between the agents themselves ('trade' contracts between reas)

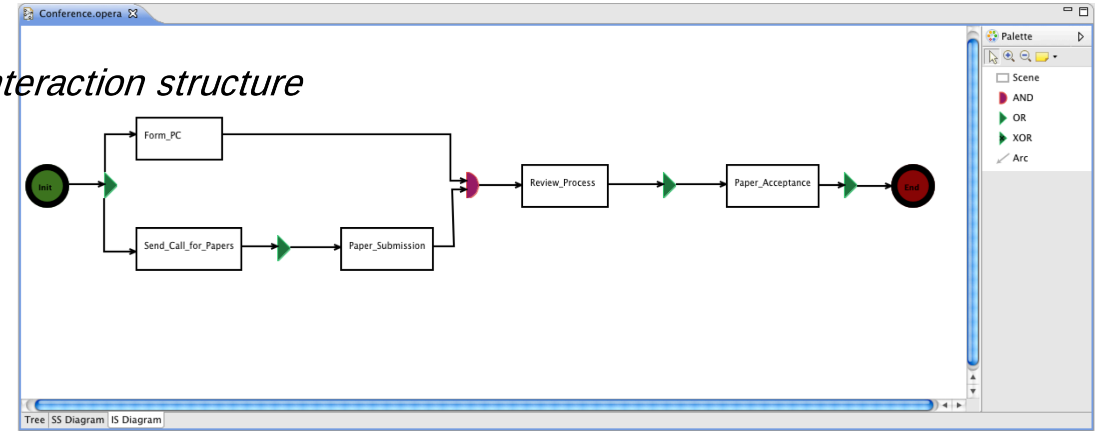
# OperettA: Organisation model specification and verification

*Social structure*

*Role*



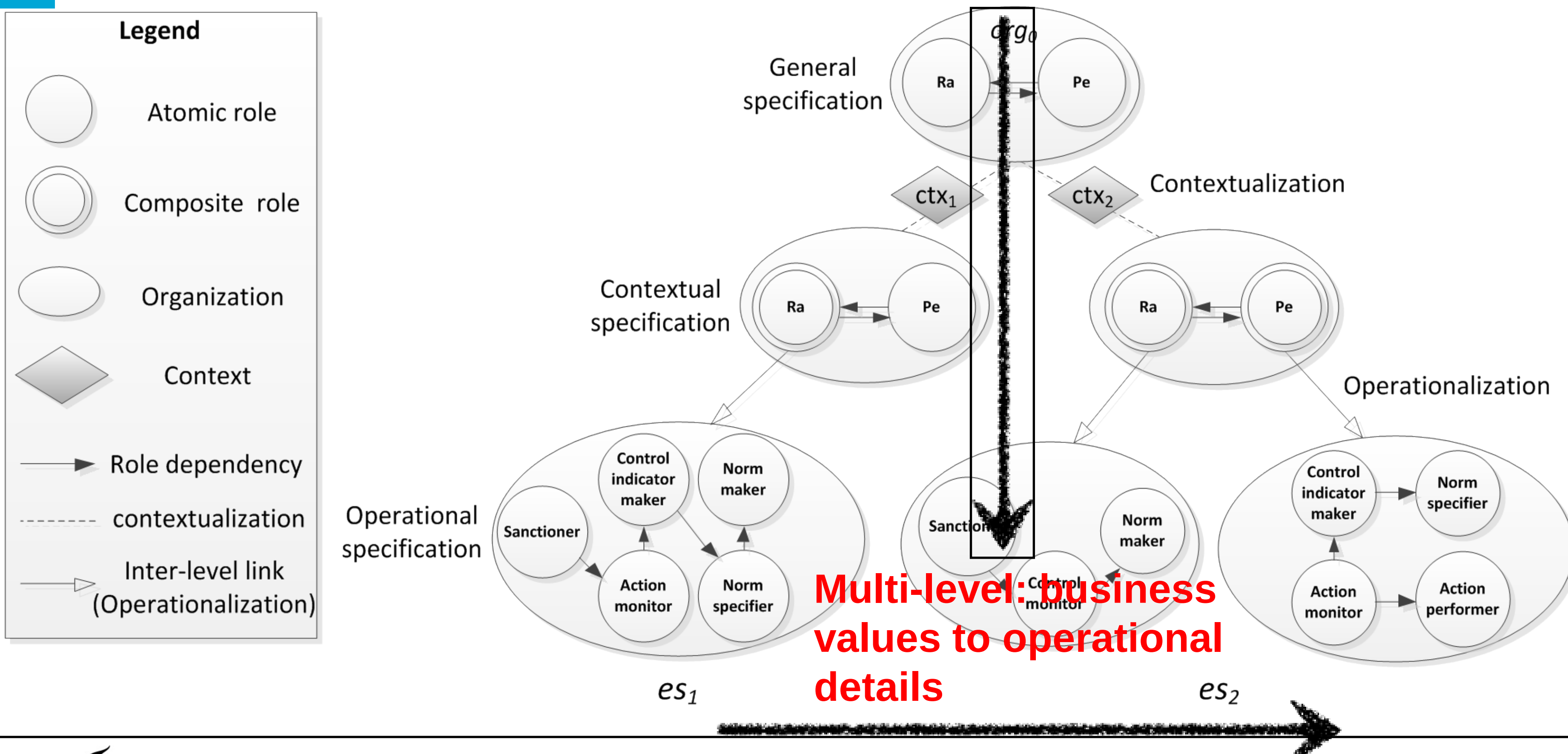

*Interaction structure*



# OperA+

- Work of Jie Jiang (2009-present)
  - Agent organization modeling framework
  - Addresses different aspects
    - Organizational model
    - Social model
    - Interaction model
- Aimed at multi-organizational collaboration (OperA+)
  - Multi-level: business values to operational details
  - Multi-context: different application environments

# Organisation contextualisation and refinement




**Multi-level: business values to operational details**

**Multi-context: different application environments**

# 2. Regulation

- Formal / computational social reasoning
  - Socially intelligent agents (norms, emotions, culture...)
  - Institutional analysis and design
- Value-sensitive Software Engineering Systems and Services
  - Norms engineering: from abstract values to implemented rules

- Application areas
  - Compliance Engineering
  - Security and trust

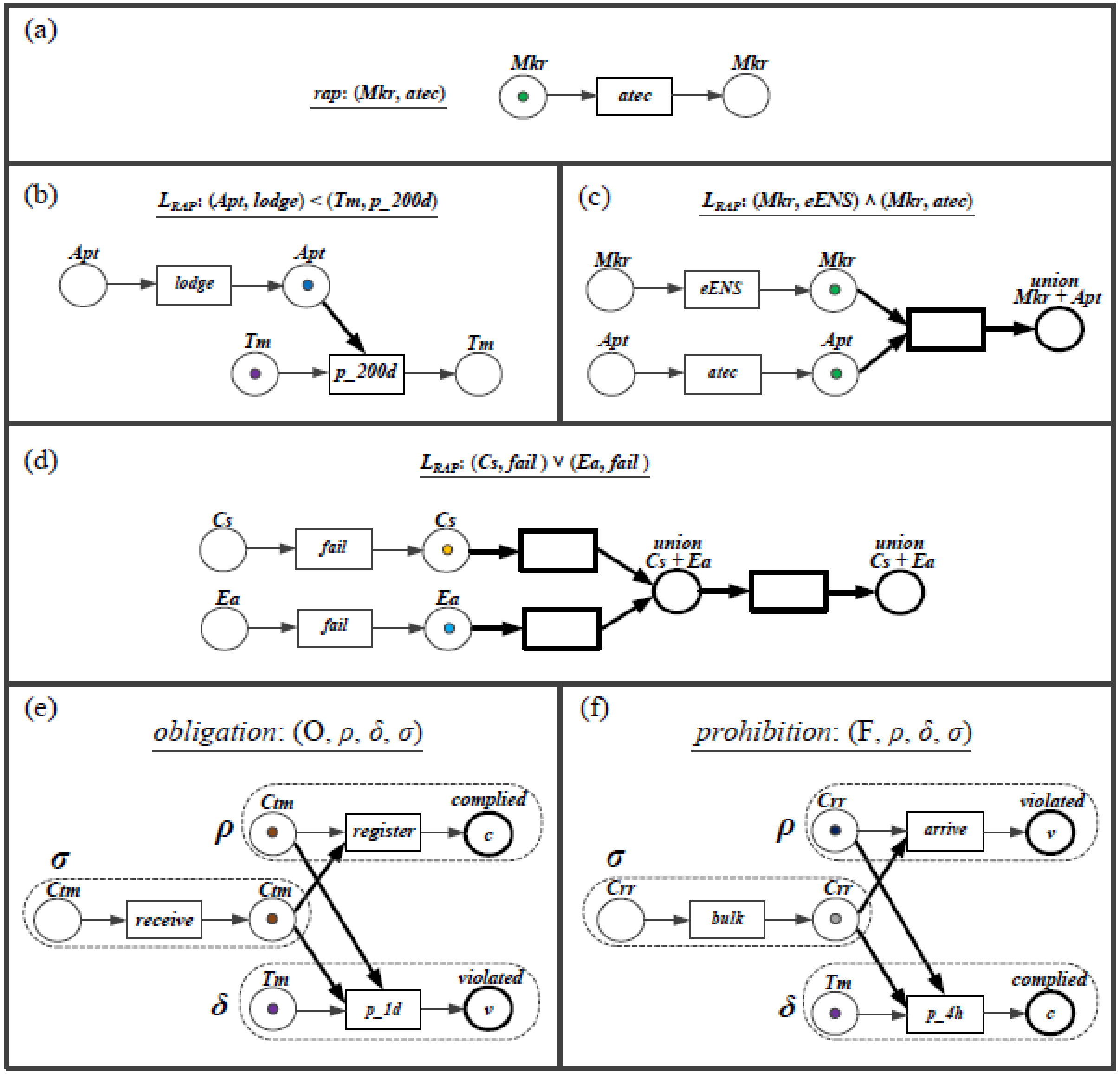
- Tools/Methods: OperA+ / VSSD

# Norms in OperA+

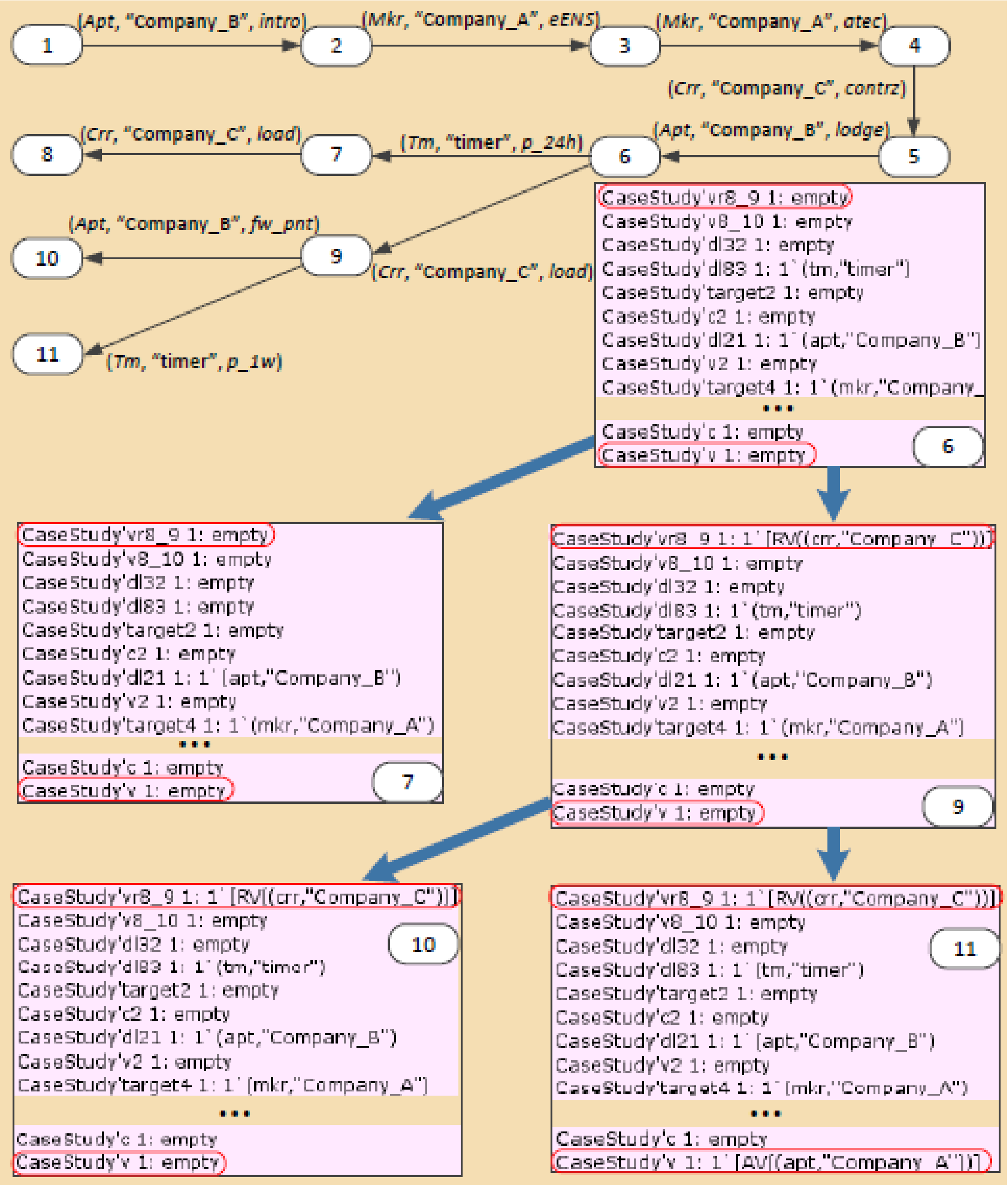
- Norm definition based on ADICO (Elinor Ostrom)
- Formally anorm is defined as a tuple n = (D; rap; d; p) where:
- D = {O;F;P} indicates the deontic type of the norm, i.e., Obliged, Forbidden, and Permitted;
- rap = (r, a), the target, a role action pair;
- d $\in$ RAP , describing the deadline;
- p $\in$ LRAP , describing the precondition;

- Norm Net
  - NN ::= norm | NN AND NN | NN OR NN | NN OE NN

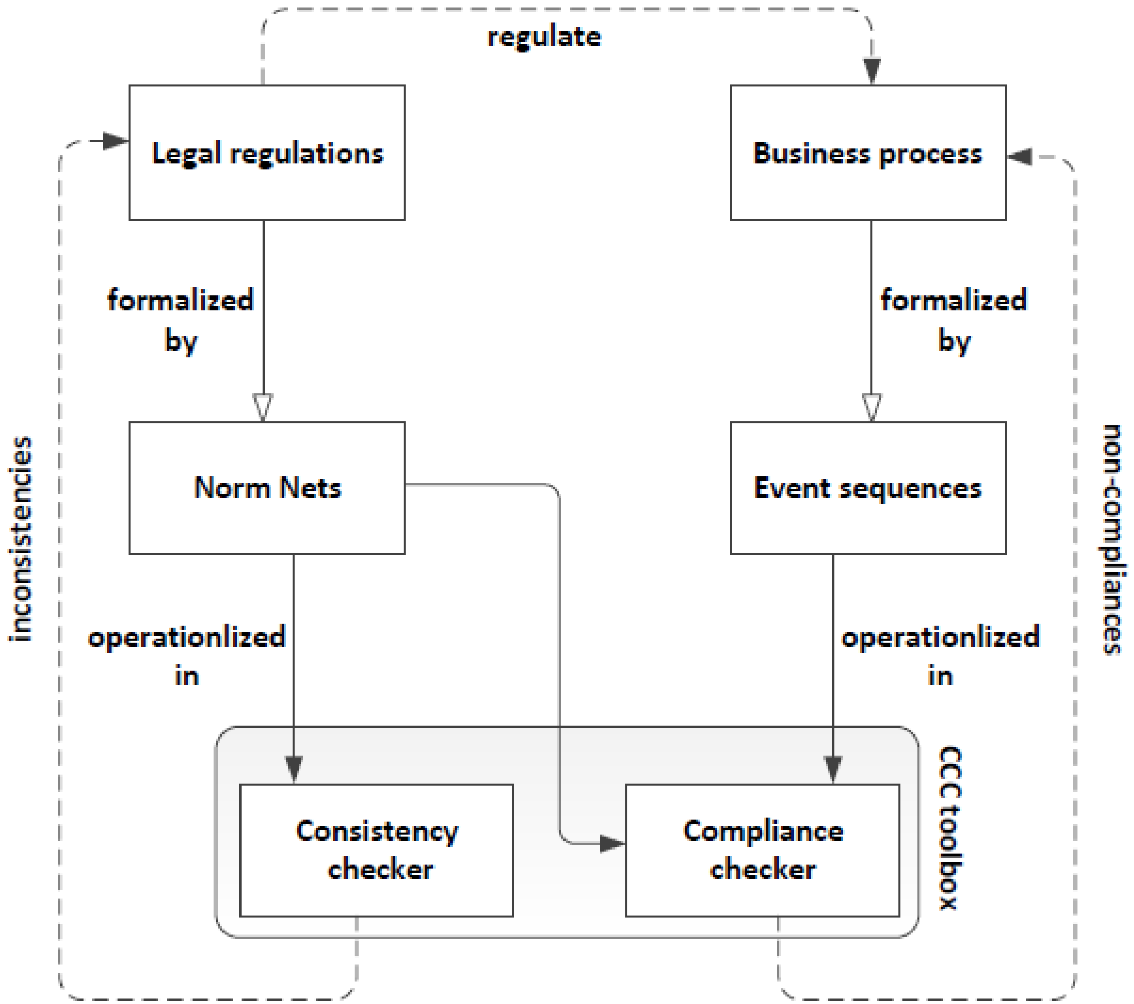
# Operational semantics: CPN

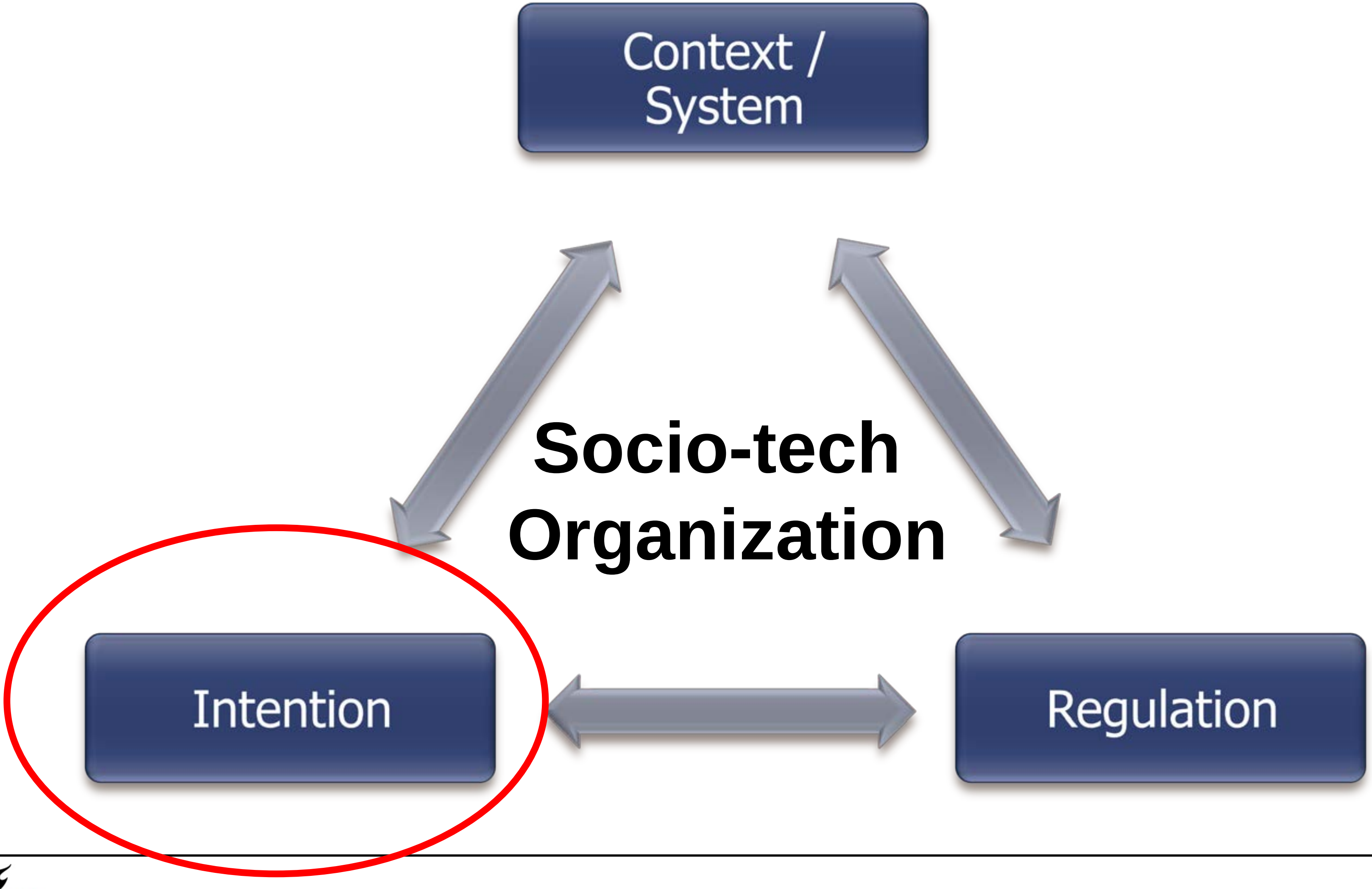


# Compliance Query



# Normative Compliance



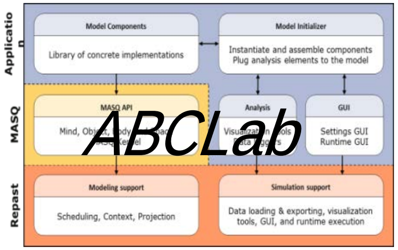

Context /
System
Socio-tech
Organization
Intention
Regulation

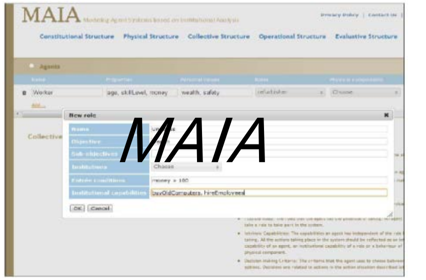
# 3. Intention

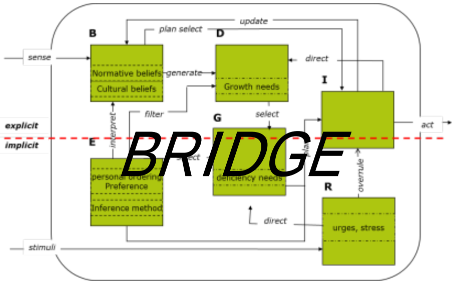
- Intelligent agents
  - Social interaction and coordination
  - Reason about own role / others role
- Rich cognitive models
  - culture, norms, personality effect on reasoning

- Applications
  - Human-agent-robot teams;
  - Healthy Lifestyle solutions / Coaching systems
  - Gaming
  - Social Simulation

- Tools/Methods: BRIDGE / ABCLab / MAIA



# The people in the loop

- **Participatory design**
  - Value-sensitive design
  - Engineering with stakeholders
    - Rapid prototyping
    - User-friendly development environments

- **HA(R)T (human-agent-robot teamwork)**
  - Hybrid teams
  - Human-agent collaboration within MAS
  - Ethical / responsibility issues

# Social Actors Development: From Agents to Partners

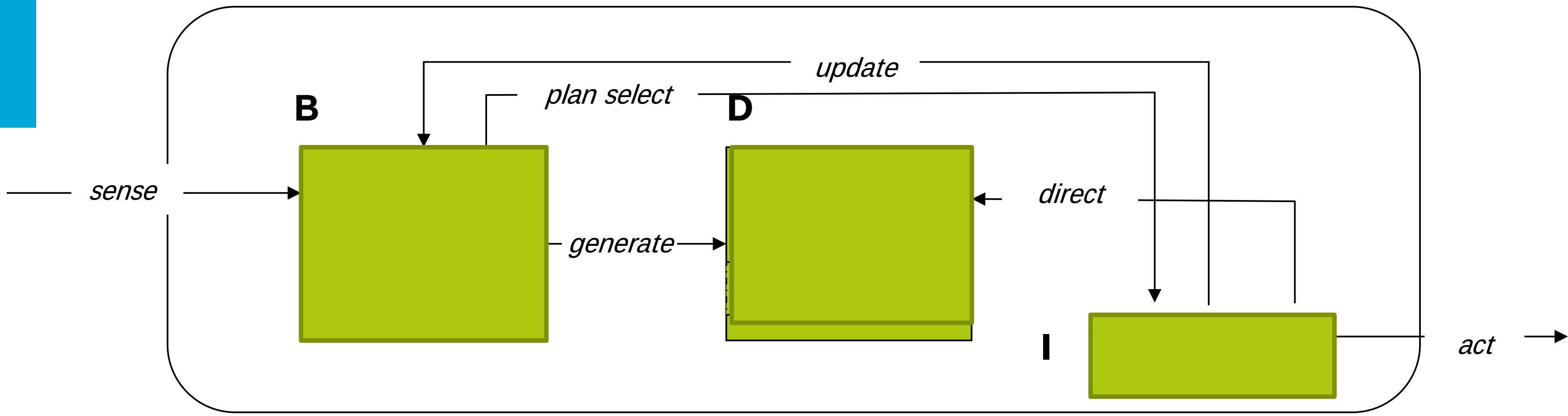
- Intentionality
  - Purpose, autonomy
- Social awareness
  - With others, despite others, for others, using others
- Values as basic ‘constructs’
- Culture, personality, context as ‘modifiers’

# Elements of rich agent models

- Rational: Goal-directed
- Social: Culture and norms
- Personality: Individual differences
- Physiological: Hierarchy of needs/urges
- Emotional: reaction to a perceived situation

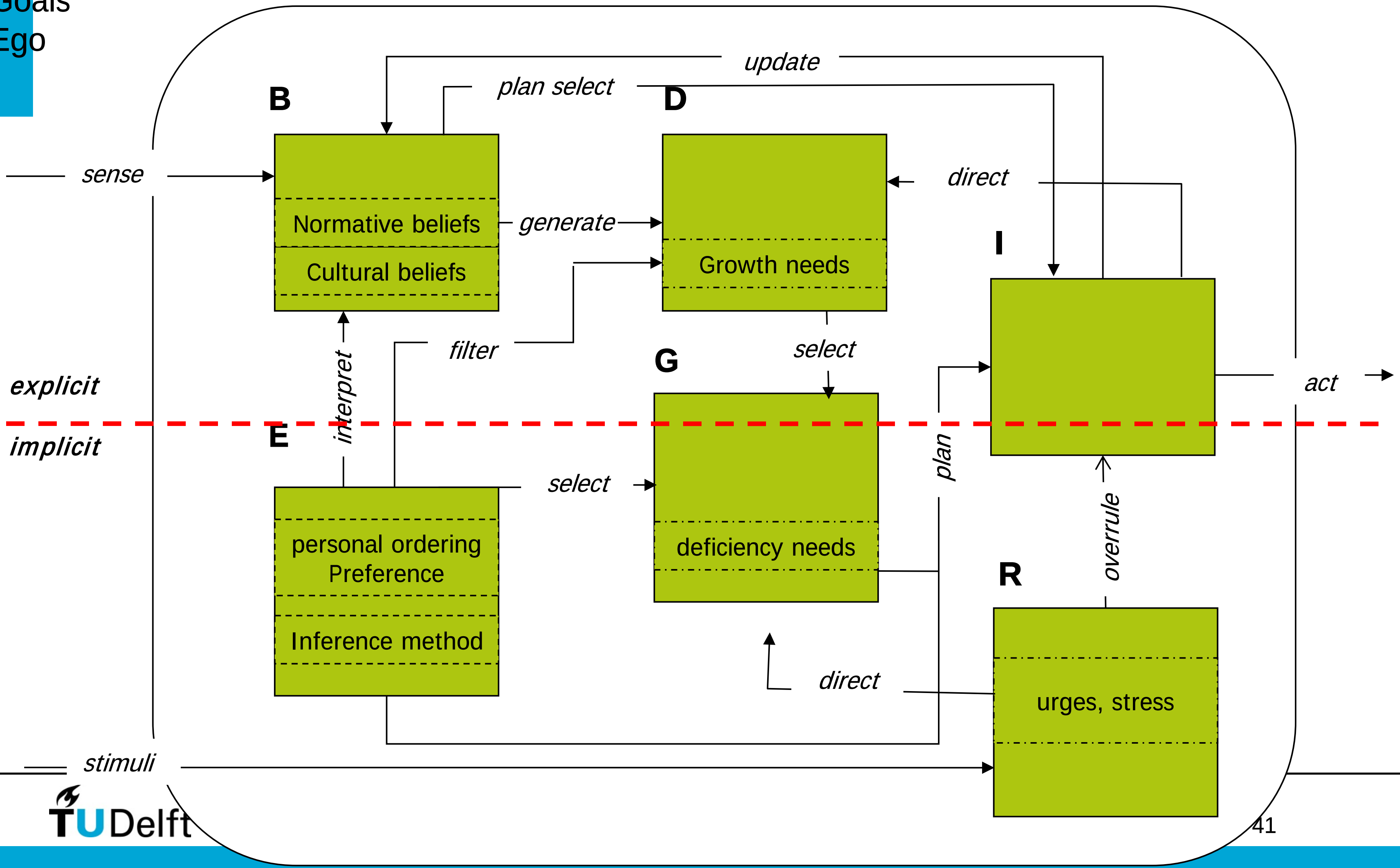
- Resulting behaviour
  - Perceived social environment
  - Possible worlds foreseen
  - Emotions and goals drive decision making and perception of current state

# Extending BDI



Beliefs
Response
Intentions
Desires
Goals
Ego

# The BRIDGE architecture



# Conclusion

- Interaction of (intelligent) autonomous entities
  - Common goals / Shared resources
  - Own reasoning
- Separation of concerns
  - Global vs. individual (organisation vs. agent)
  - Design vs. simulation vs. deployment
- Human-agent collaboration
  - Norms, values
  - Communication / understanding
- Open, dynamic environments
  - Co-evolution
- Cost-benefit: Not ‘one size fits all’