Qualitative Modelling of MAS Dynamics:
Using Systemic Modelling to Examine the Intended and Unintended Consequences of Agent Coaction

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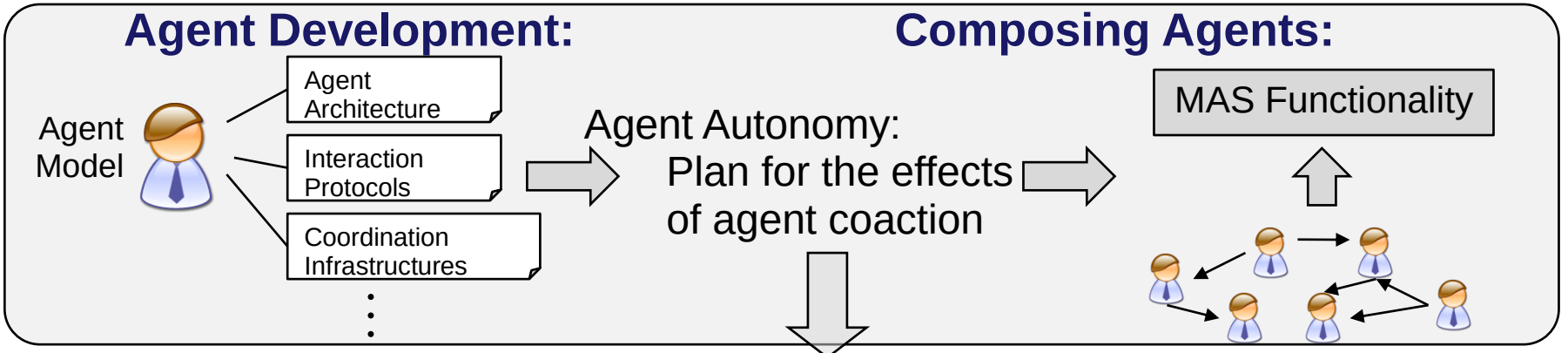
Challenge: “Composability” of Agents

- Agent-Orientation:
  - Approach to the development of complex, distributed systems
- Agent-Oriented Software Engineering:
  - Rich toolset to design agents / interactions



it can make a qualitative difference whether agents (inter-)act in small or large populations

- Intended: Decentralized coordination
  → Self-Organizing MAS
- Unintended: → consequences of coaction, e.g. unwanted synchronizations, oscillations, state swapping,… } e.g.: Parunak 1997, HP, 2005

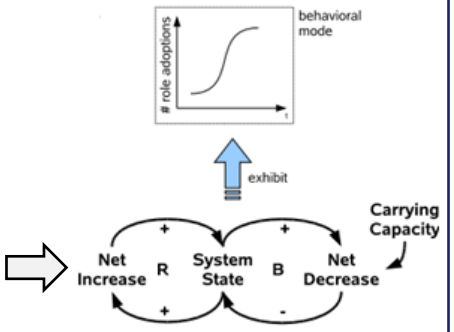
Here:
Design-Time Approach:

- Appropriate abstraction level
- Examine the structure of the interdependencies of system entities

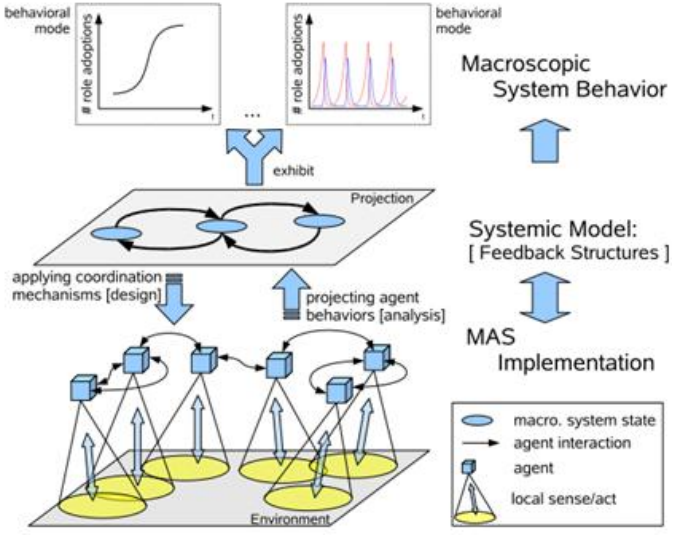
Modeling MAS Dynamics

- Collective Phenomena:
  - mutual interdependencies of system elements
- Approached by System Sciences, e.g. *System Dynamics*
  - Interdisciplinary modelling approach

System State:	given as a set of system variables
Behaviour:	Characterized by causal relations / rates of variable changes
Circular Structures:	Feedback Loops balancing (-) / reinforcing (+)



- Proposal: Systemic Modelling of MAS
  - Abstracting MAS Designs
  - Modelling the causal structure of entity activities



Describing the Causal Structure of MAS

- Agent Behavior Dependency Graph (ABCG)
- graph-based model: Sudeikat & Renz, 2009

$$ACBG :=< V_{ACBG}, E_{ACBG}>$$

V_{ACBG} : set of nodes

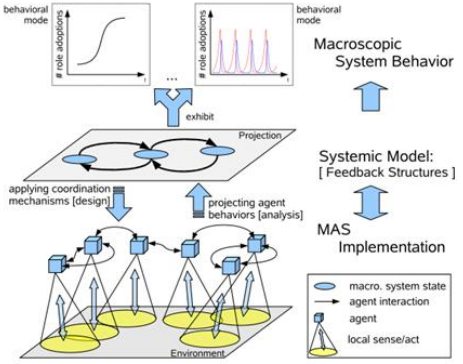
Characterize macroscopic MAS state by abstractions of:

- Agent-Behaviors
  - # of currently activated Roles r(x),
  - # of active Groups g(x),
  - …
- Environment
  - accumulative values of environment-elements e(x)
- …

E_{ACBG} : set of Edges (V_{ACBG} x V_{ACBG})

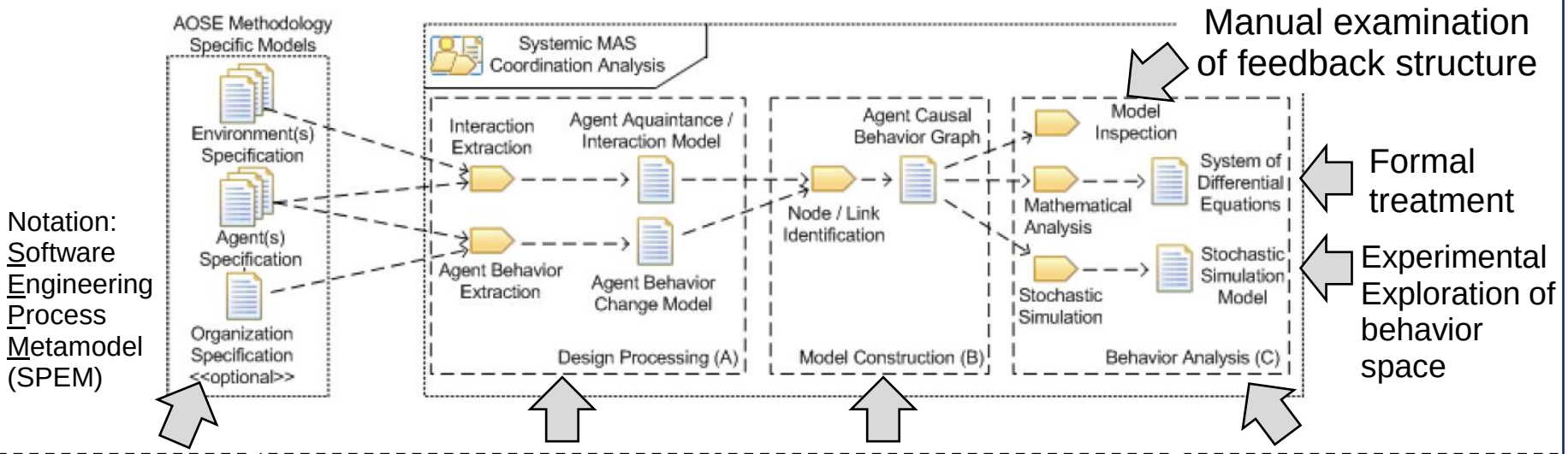
Characterize *causal* influences:

- direct ($e_{(d+/-)}$),
  e.g. inter-agent communication, …
- mediated ($e_{(m+/-)}$),
  e.g. shared environments, …
- …



Systematic Procedure

- Optional Development Activity:
  - Describe the conceived application design as a dynamical system and examine the space of possible behaviors.



Application design
- Methodology specific

(Pre-) processing
- Identification of :
  - Interactions
  - Behavior Space
    - of system elements

ACBG Construction
- iterate Models
  - Identify nodes
  - Identify links

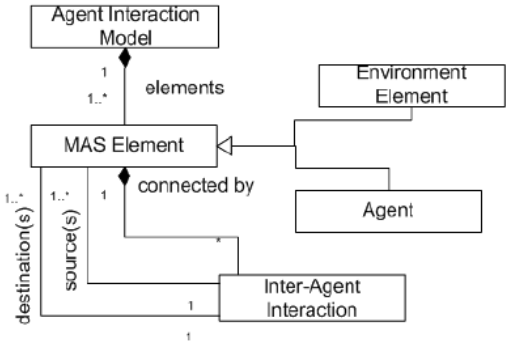
Analysis
- Behavior Animation → Simulation models
- Understanding of the causal structure guides sys. simulation

ACBG Construction

Derivation of Interaction Model

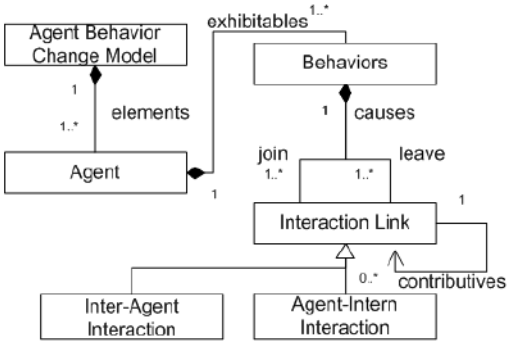
- Search designs for Interactions between system elements
  - Agent / Agent
  - Agent / Environment
  - Environment [2]

⇨ Abstraction guidelines: depend on the modeling notation



Derivation of Behavior Model

- Identification of agent behaviors
  - e.g. for BDI agents, Sudeikat et al. 2006
- Identification of causes for behavior adjustments
  - Adoption
  - Termination

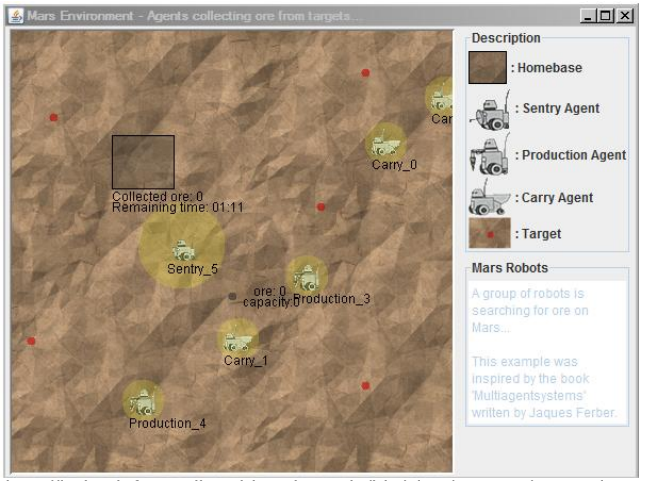


Systemic model (ACBG):
Mapping the identified inter-agent interactions
to the causes of behavior changes

Case Study : Marsworld Dynamics

- Hypothetical Scenario: e.g. Ferber, 1999
  - Agent teams mine ore on a far distant planet
  - Agent types:
    - Sentry: Equipped with sensors to find/examine ore locations
    - Producer: Equipped with mining devices to mine ore
    - Transporter: Moving ore to home base
    - Default behavior: search the environment
- Small scale implementation available
  - E.g. in the Jadex system
  - Fluctuating exploitation of resources

⇨ Examine the dynamic properties of larger systems (is more different?)

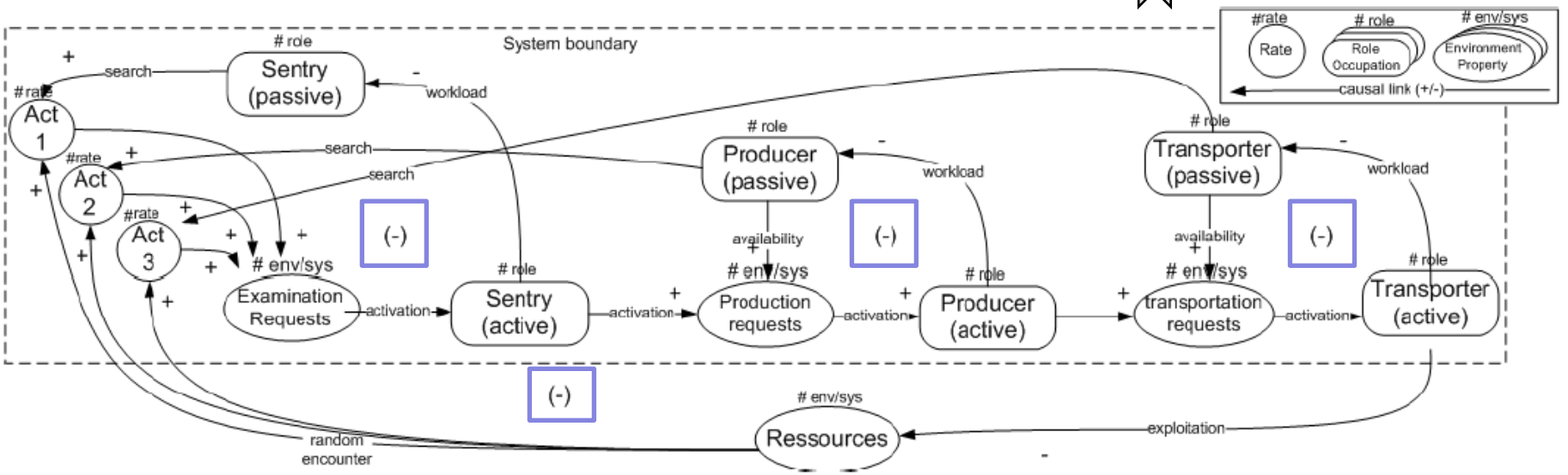


http://jadex.informatik.uni-hamburg.de/bin/view/Usages/Examples

Dynamical Structure

- Agent types are described by two role nodes
  - activated
  - searching
- Environment:
  - # of unexploited resources

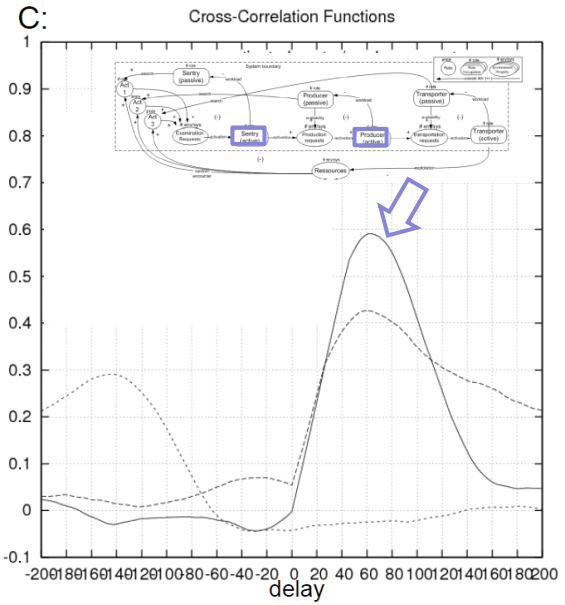
4 balancing feedback-loops:
- continuous removal of resources
- Activation of Sentries
- Handling Production Requests
- Handling Transport Requests



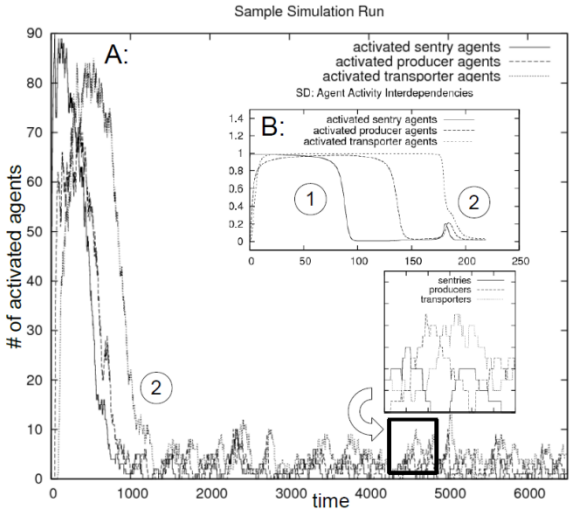
Marsworld Analysis

- Validate Systemic Model:
  - Causalities in the systemic model
    → (cross-)correlations of agent activities
    - Agent-based simulation (Netlogo)

  → highly fluctuating, stationary regime: system characteristics can be observed



- Anticipate MAS Characteristics:
  - Comparing
    - ACBG animation
    - MAS simulation
  - Characteristic Initialization behavior:
    - Initial overload of Sentries



Conclusions

- Systematic Development of MAS has to plan for collective phenomena!
- Proposal: Systemic Modeling level
  - examine the qualitative characteristics of MAS
    - E.g. oscillations / state swapping, steady states, …
  - Anticipate collective phenomena in MAS designs
- Structured process to derive systemic models
  - Interface AOSE design models
  - Optional activity in MAS development

End

Thank you for your Attention!

Questions / Suggestions are welcome!

References

- Anderson, P. More is Different, *Science,* 1972*, 177*, 393-396
- Ferber, J.; Gutknecht, O. & Michel, F. From Agents to Organizations: An Organizational View of Multi-agent Systems *Agent-Oriented Software Engineering IV, 4th International Workshop, AOSE 2003,* 2003
- Ferber, J. Multi-Agent Systems, *Addison Wesley,* 1999
- Gardelli, L.; Viroli, M. & Omicini, A. On the Role of Simulations in Engineering Self-organising MAS: The Case of an Intrusion Detection System in TuCSoN *Engineering Self-Organising Systems, Springer,* 2006
- Mogul, J. C. Emergent (Mis)behavior vs. Complex Software Systems *HP Laboratories Palo Alto,* 2005
- Parunak, H. & VanderBok, R. Managing Emergent Behavior in Distributed Control Systems *Proc. of ISA Tech '97,* 1997
- Renz, W. & Sudeikat, J. Modeling Feedback within MAS: A Systemic Approach to Organizational Dynamics *Proceedings of the International Workshop on Organised Adaptation in Multi-Agent Systems,* 2008
- Sudeikat, J. & Renz, W., MASDynamics: Toward Systemic Modeling of Decentralized Agent Coordination *Kommunikation in Verteilten Systemen,* 2009, 79-90
- Sudeikat, J. & Renz, W. On Simulations in MAS Development, *KIVS 2007 Kommunikation in Verteilten Systemen -- Industriebeiträge, Kurzbeiträge und Workshops, VDE-Verlag,* 2007
- Sudeikat, J. & Renz, W. Monitoring Group Behavior in Goal-Directed Agents using Co-Efficient Plan Observation, *Agent-Oriented Software Engineering VII, AOSE 2006,* 2007