Organic Computing
Status and Outlook

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Overview

- Vision
- Status
- Outlook
- Conclusion

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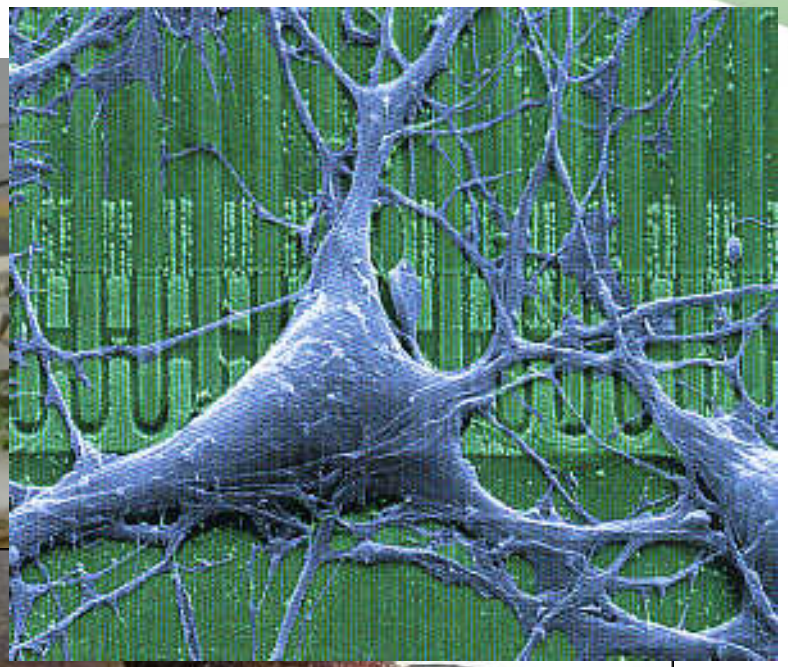
What Organic Computing is *not about*



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So, what is it about?






- Collections of **intelligent (embedded) systems**
  (scenarios like **smart house, car, office, factory, shop, healthcare**,…
  …**ubiquitous, pervasive computing**).
- Potentially **unlimited networks** (large number, mobility)
- **Spontaneous local interaction,** leading to unexpected global behaviour
  (**emergent phenomena** as a result of **self-organisation**)
- **Robust services** in dynamically changing environments
  (e.g. mobile communication).
- **Flexible behaviour** as a reaction to varying external constraints
  (e.g. traffic light control)
- **Design, management and acceptance problems** wrt increasingly **complex systems**
  → **Controllability? Trustworthiness?**

⇒ **We have to come up with good ideas for**

- **designing, managing, and controlling unlimited, dynamical networks of intelligent devices,**
- **utilising the available technology for the utmost benefit to humans.**

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Vision for System Architecture > 2010

- **Organic Computer Systems**
  - will possess lifelike properties.
  - will consist of autonomous and cooperating sub systems and will work, as much as possible, in a self-organised way.
  - will adapt to human needs,
  - will be robust, adaptive, and flexible,
  - will be controlled by objectives (“goal-driven”),
  - will provide customized service in a user-friendly way,
  - will be trustworthy.

- **Self-organisation** allows for adaptive and context aware behaviour:
  - self-configuring
  - self-optimizing
  - self-healing
  - self-protecting
  - self-explaining
  - self-managing
  - …

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Meta-data?

Model-predictive?

Controlled-self-organized?

Model-based?

Organic Computing

You-name-it…

Feedback control?

Policies?

It is not the question,
whether adaptive and self-organising systems will emerge,
but ***how*** they will be designed and controlled.

Self-managing?

Autonomic?

Feedforward control?

Self-adaptive?

Self-organized?

Emergent control?

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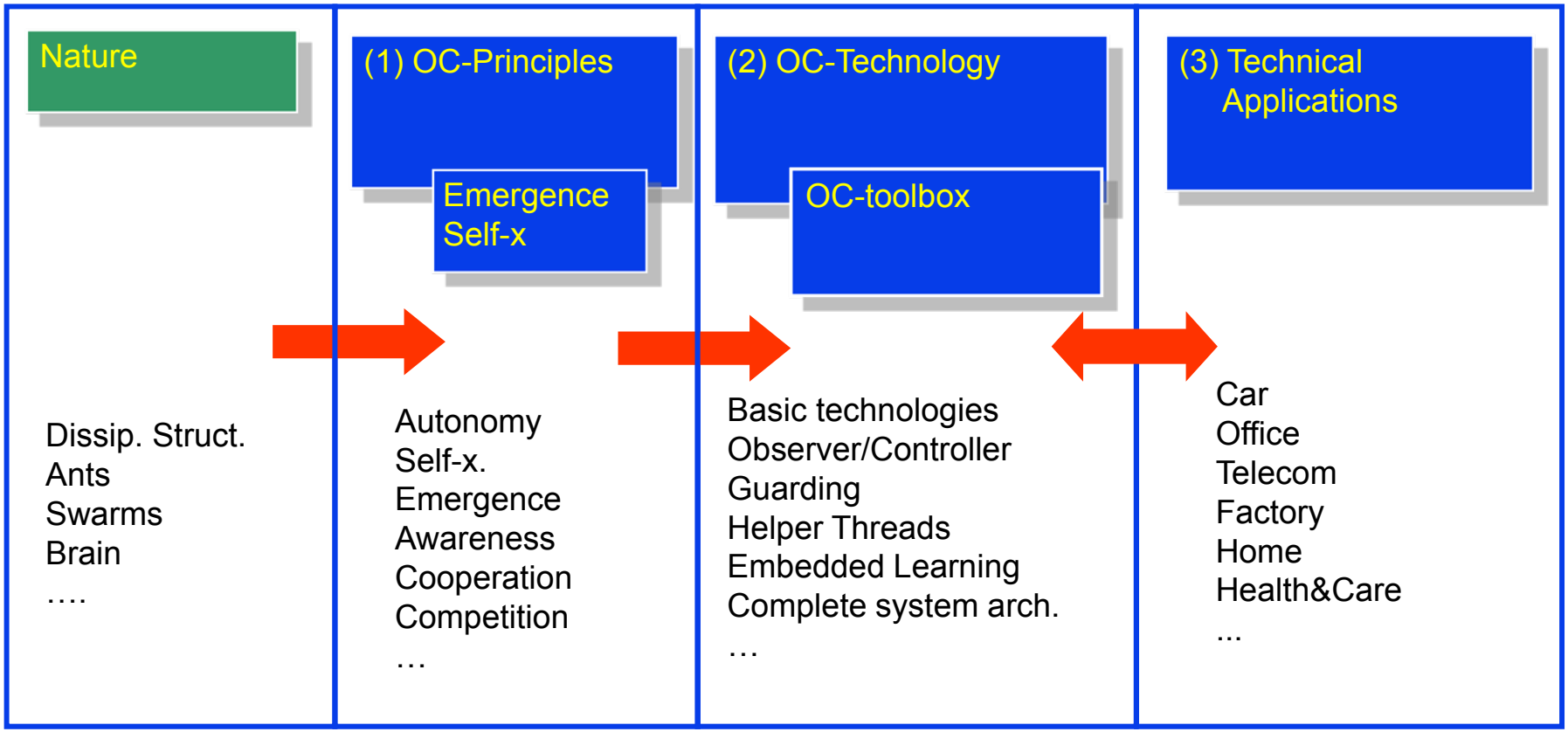
German Framework for Research on OC :

DFG priority program 1183 „Organic Computing“ (2005 – 2011)
currently 19 projects (Phase II), ~2 Mio€ per year
www.organic-computing.de/SPP



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Phase II: 19 Projects

- **Learning to Look at Humans** (Würtz, Uni Bochum)
- **Model-Driven Development of Self-Organizing Control Applications** (Heiß, Mühl, TU Berlin, Weis Uni Duisburg)
- **Organic Fault-Tolerant Control Architecture for Robotic Applications** (Maehle, Brockmann, Uni Lübeck, Großpietsch FhG, St. Augustin)
- **Smart Teams: Local, Distributed Strategies for Self-Organizing Robotic Exploration Teams** (Meyer auf der Heide, Schindelhauer, Uni Paderborn)
- **Formal Modeling, Safety Analysis, and Verification of Organic Computing Applications – SAVE ORCA** (Reif, Uni Augsburg)
- **Embedded Performance Analysis for Organic Computing** (Ernst, TU Braunschweig)
- **OCCS - Observation and Control of Collaborative Systems** (Branke, Schmeck, KIT; Hähner. Müller-Schloer Uni Hannover)
- **OTC^2 - Organic Traffic Control Collaborative** (Hähner, Müller-Schloer, Uni Hannover, Branke, Schmeck Uni Karlsruhe)
- **AUTONOMOS: A distributed and self-regulating approach for organizing a large system of mobile objects** (Fekete, TU Braunschweig, Fischer, Uni Lübeck)
- **Organisation and Control of Self-Organising Systems in Technical Compounds** (Middendorf, Uni Leipzig)
- **Architecture and Design Methodology for Autonomic System on Chip** (Rosenstiel, Uni Tübingen, Herkersdorf, TU München)
- **Multi-Opjective Intrinsic Evolution of Embedded Systems (MOVES)** (Platzner, Uni Paderborn)
- **OCμ - Organic Computing Middleware for Ubiquitous Environment** (Ungerer, Uni Augsburg)
- **The bio-chemical information processing metaphor as a programming paradigm for organic computing** (Dittrich, Uni Jena)
- **Energy Aware Self Organized Communication in Complex Networks** (Timmermann, Uni Rostock)
- **Generic emergent computing in chip architectures** (Fey, Uni Jena)
- **On-line Fusion of Functional Knowledge within Distributed Sensor Networks** (Sick, Uni Passau)
- **A Modular Approach for Evolving Societies of Learning Autonomous Systems** (Rammig. Kleinjohann, Uni Paderborn))
- **Digital On-Demand Computing Organism for Real-Time Systems** (Becker, Brinkschulte, Henkel, Karl, Uni Karlsruhe)

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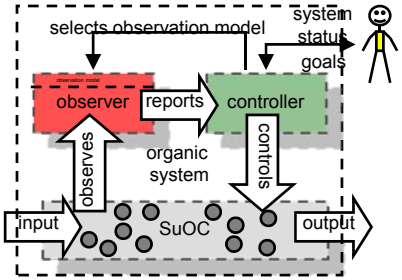
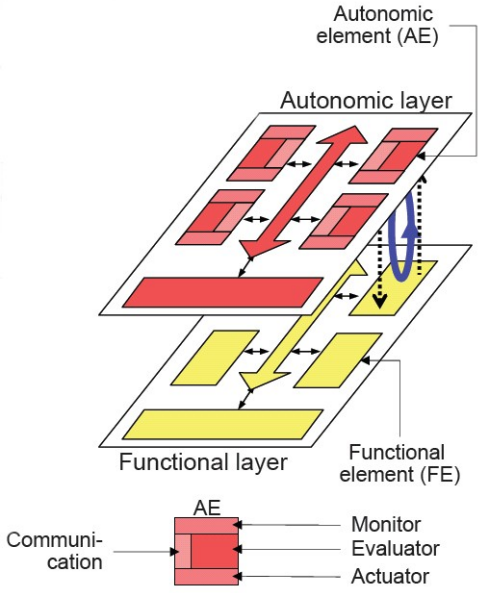
Status:
What did we achieve so far?

- Characterization and classification of emergence in SO-Systems (entropy-based) *(Mnif, Müller-Schloer, Sick)*
- Characterization of basic properties of OC systems (autonomy, controlled self-organisation, adaptivity, robustness, flexibility,…) *(Mühl, Müller-Schloer, Ortmeier, Schmeck, …)*
- Design of a generic O/C-architecture *(Branke, Mnif, Müller-Schloer, Richter, Schmeck,…)*
- Design of generic OC-middleware components (OCμ, Artificial Hormone System – AHS) *(Ungerer et al., Becker, Brinkschulte, Henkel, Karl)*
- Autonomic/Organic Systems on Chip *(Herkersdorf, Rosenstiel et al.)*





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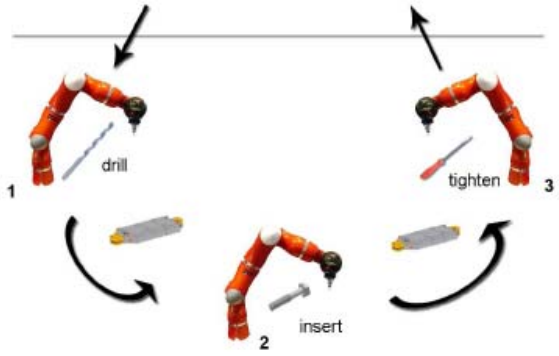
What did we achieve so far?

- Safety analysis and verification of OC-Applications
  (Reif et al.)



- Formal definition and modeling of self-x systems; self-organizing algorithms and development tools for OC applications.
  (Heiß, Mühl, Weis)

- Design of a self-configuring and self-healing robot
  (Brauckmann, Maehle et al.)

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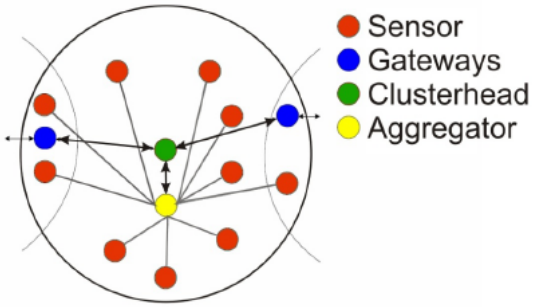
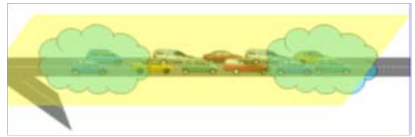
What did we achieve so far?

- Embedded performance analysis of OC-systems using a variant of the O/C-architecture *(Ernst)*
- Energy and resource aware self-organized communication and cooperation (smart teams, sensor networks) *(Timmermann et al., Meyer auf der Heide et al.)*
- Artificial immune systems, self-protection, self-healing *(Trumler et al., Timmermann)*
- Systematic investigation of self-organizing systems in nature (swarms of bees, bio-chemical information processing) *(Middendorf, Dittrich)*
- Application of OC principles in traffic (traffic light control, progressive signal chains, hovering data clouds, organic information complexes, Adaptable Distributed Strategies) *(Branke et al.; Fekete, Fischer)*





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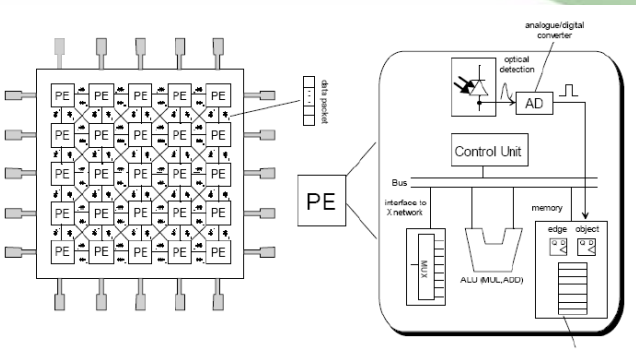
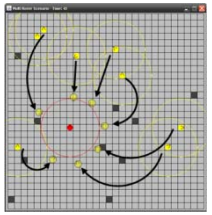
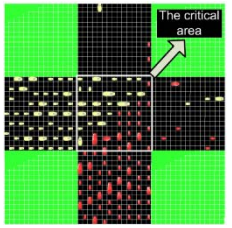
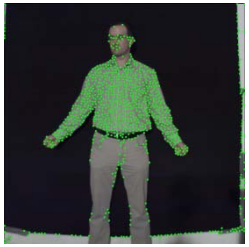
What did we achieve so far?

- Concept of Marching Pixels (MP), emergent algorithms, emergent computing *(Fey)*
- Principles, methods, and architectures for evolutionary self-adaptation to real-world problems *(Platzner)*
- Principles of collaboration, coordination and learning in multi-agent systems *(Branke, Hähner, Müller-Schloer, Schmeck,…)*
- Use of Classifier Systems for online learning *(Prothmann, Richter, Rochner, Zeppenfeld)*
- Analysis of emerging behaviour in evolving societies of learning autonomous systems *(Rammig et al.)*
- Autonomic learning of functional knowledge in sensor systems *(Sick)*
- Learning to find and track humans in video sequences and to recognize individuals *(Würtz)*









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What did we achieve so far?

Joint work:

- Mini Workshops (13 so far)
- SPP working groups on
  - Architectures *(T. Ungerer)*
  - Applications *(W. Reif)*
  - Bio-inspired methods *(M. Middendorf)*
  - Design methods *(H.-U. Heiß)*
  - Self-organization and emergence *(C. Müller-Schloer)*

Work done?

Do we need new topics?

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What did we achieve so far?

Impact , visibility of Organic Computing:

- Book on Organic Computing (ed. Rolf Würtz), Springer
- IEEE CIS Task Force on Organic Computing
- Dagstuhl Seminars on Organic Computing (next one end of 2010 or beginning of 2011)
- Workshops, special tracks, or thematical focus at conferences
  - GI Annual Conference
  - International Conference on Architecture of Computer Systems (ARCS)
  - ACM International Conference on Computing Frontiers
  - IFIP Conference on Biologically Inspired Cooperative Computing (BICC)
  - International Conference on Autonomic and Trusted Computing (ATC)
  - IEEE Congress on Evolutionary Computation (CEC)
  - IEEE International Conference on Self-Adaptive and Self-Organizing Systems (SASO)

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Outlook:
Who will be in Phase III?

- Nobody knows so far, current situation:
  - 23 project proposals
    - 19 proposals for project continuation
    - 1 OC testbed proposal
    - 1 coordinator proposal
    - 3 new proposals
  - 1 additional proposal which might get associated
- Reviewer meeting **March 26, 2009**
  (8 reviewers: 3 from Germany, 4 new reviewers)
- Hopefully, official decision by May or June, 2009

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Outlook:
Where do we go beyond SPP 1183?

- **Topics of our working groups on Friday**
  - Lasting contributions of OC
  - Challenging topics that should be addressed based on the results of this SPP (Robustness, Trust,…)
  - Potential funding mechanisms/programs for future research on OC.
- Typical application areas for OC:
  - Traffic, automotive systems, machine management (→ program autonomik, BMWi)
  - Energy system, electro mobility
  - Logistics, production systems
  - Communication
  - Surveillance
  - ….

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Conclusion

- SPP OC has produced a solid basis for further research and development projects
- OC technologies are applicable to a range of interesting application areas
- Research programs may be focused on application scenarios where OC is an enabling technology
  - Energy system
  - Machine management
  - Virtualisation (Cloud Computing,…)
  - …
- We should cooperate to identify potential scenarios for further joint projects or research programs based on OC techniques.

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Backup Slides:
Challenges for research on OC systems

- Learning:
  - Potential of online- and offline learning
  - Collaborative learning
- Coordination and collaboration
  - Typical patterns of c & c in OC systems
  - Benefits, necessity of c & c
- Design
  - Finding the right balance between explicit design and degrees of freedom
  - Finding the right separation of concerns in hierarchical OC systems
- Cognition
  - Finding out “the needs of human users” (or, of the environment).
  - Detecting anomalies, distinguishing the “good” from the “bad”.

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Challenges for research on OC systems (2)

- Control
  - Finding the right balance between “SO” and “control” phases.
  - Does “control by objectives” work?
- Trust
  - Can OC-systems be trustworthy?
  - Trust engineering?
- Assessment
  - Can there be “service level agreements” with guaranteed performance for OC-systems?
  - Benefits of OC versus “standard” designs?
  - Benchmark applications for OC
- …

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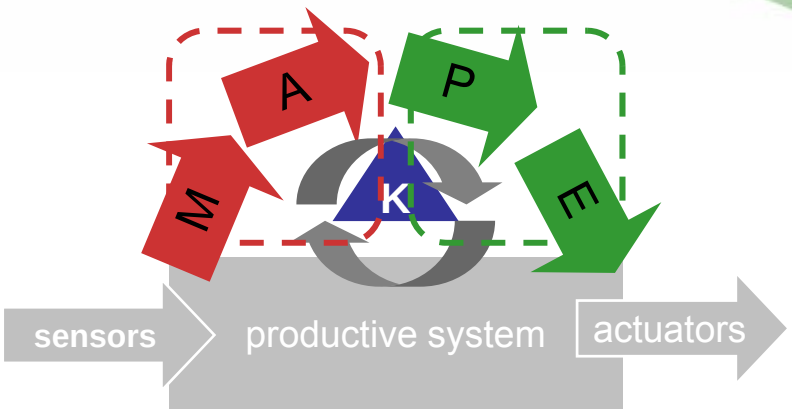
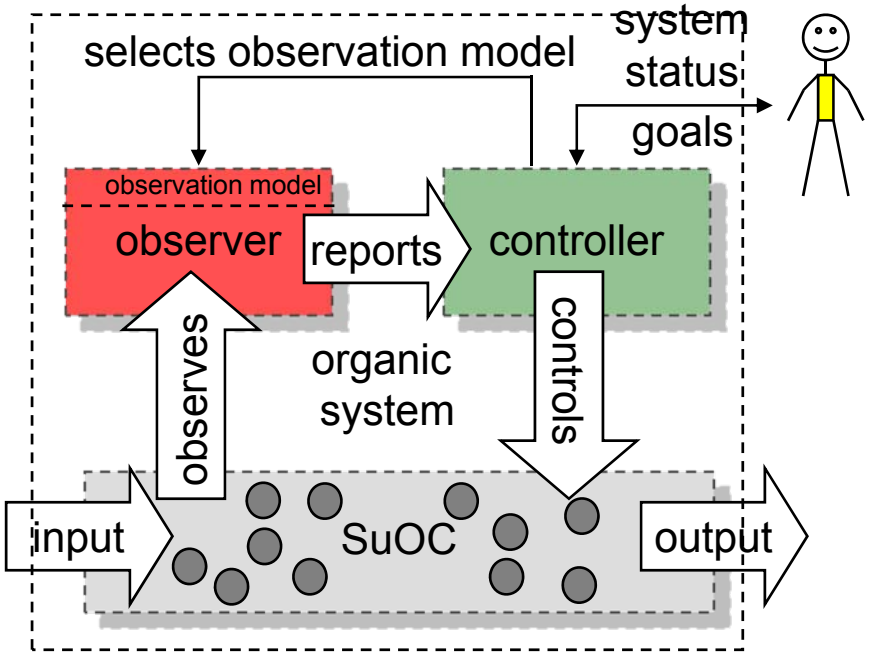
(Generic) Concepts for Control of SO-Systems

- IBM's **MAPE cycle** for autonomic computing
  - Monitor
  - Analyze
  - Plan
  - Execute
  - Knowledge

  (called "autonomic element")
- System under observation and control (SuOC)
  - A set of interacting elements/agents.
  - Does not depend on the existence of observer/controller.
- Distributed and/or central **observer/controller-architecture**
  - Driven by external goals
- Multilevel organization





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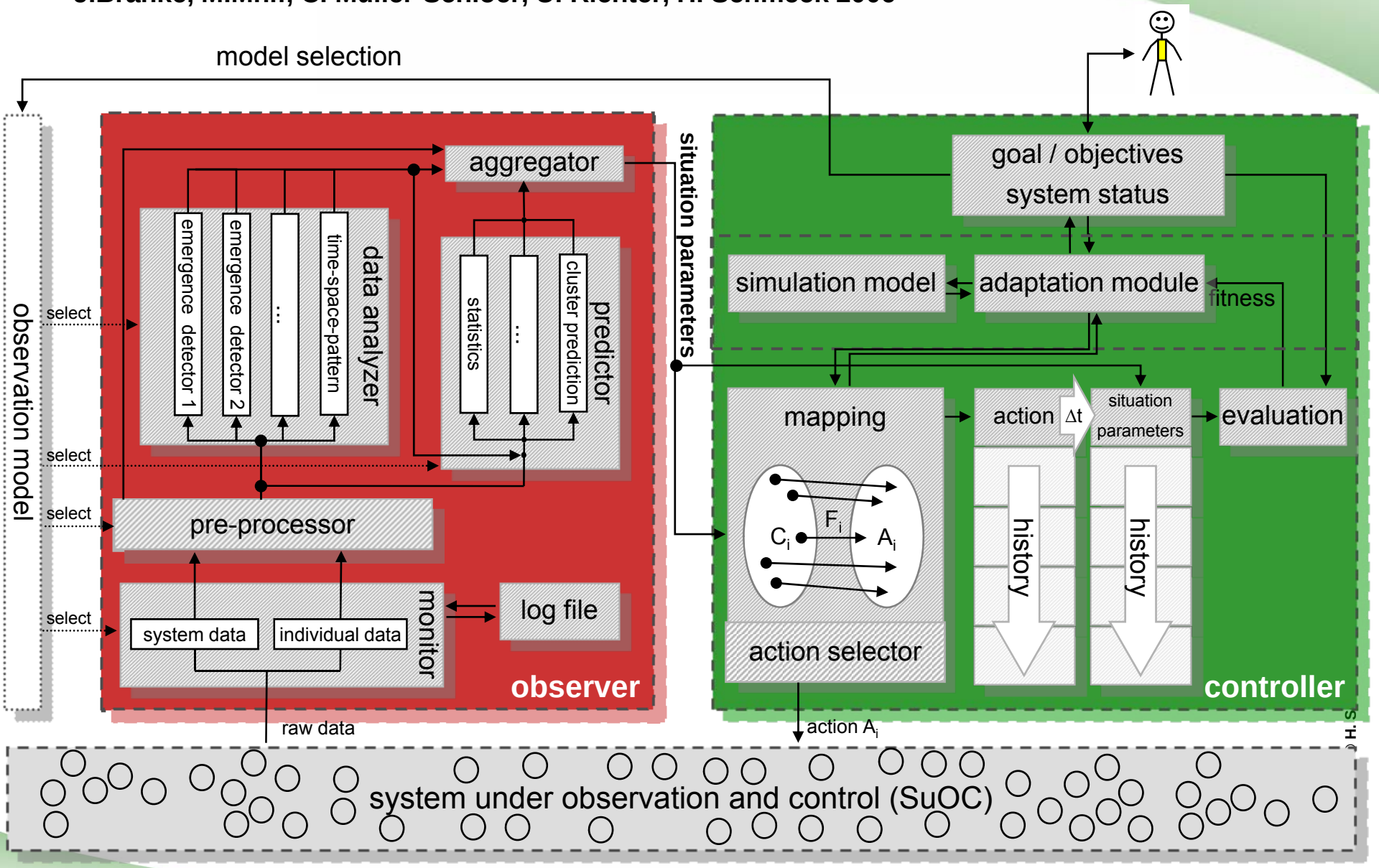
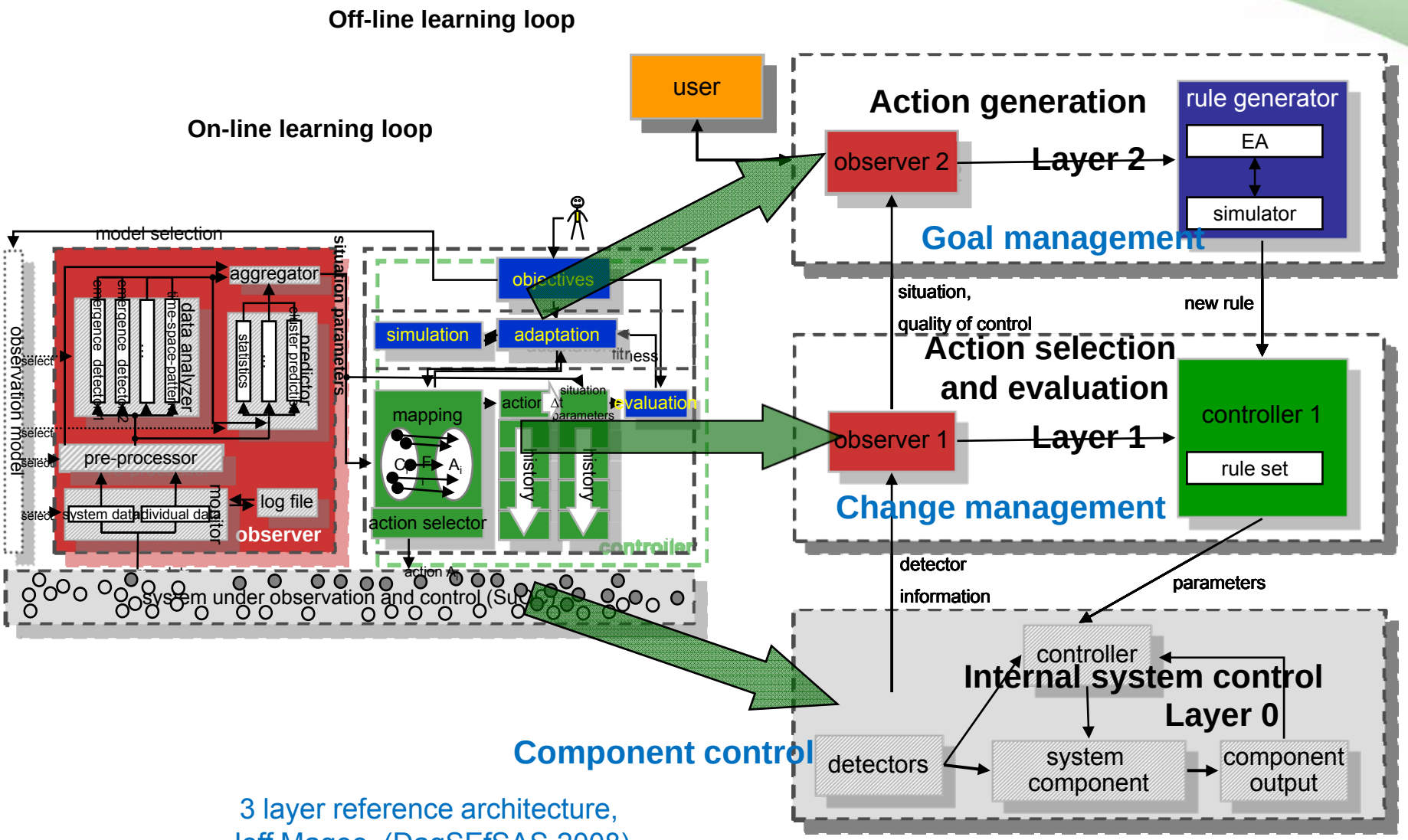
Generic O/C-Architecture

J.Branke, M.Mnif, C. Müller-Schloer, U. Richter, H. Schmeck 2006



Different view on O/C-architecture



3 layer reference architecture,
Jeff Magee, (DagSEfSAS 2008)

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Example Application: Organic Traffic Control

User
user
Rule generator
Rule generation
rule generator
EA
simulator
observer 2
Layer 2
Situation
Quality of contro
situation,
quality of control
Controller 1
"LCS"
new rule
Obs
Rule selection
and evaluation
controller 1
rule set
observer 1
Layer 1
Detecto
information
Detectors
detector
information
parameters
Layer 0
Internal
system control
Layer 0
controller
detectors
system
component
component
output

Recall:
car waiting?
minimum
green
extension
(secs. per actuation)
max. initial
green

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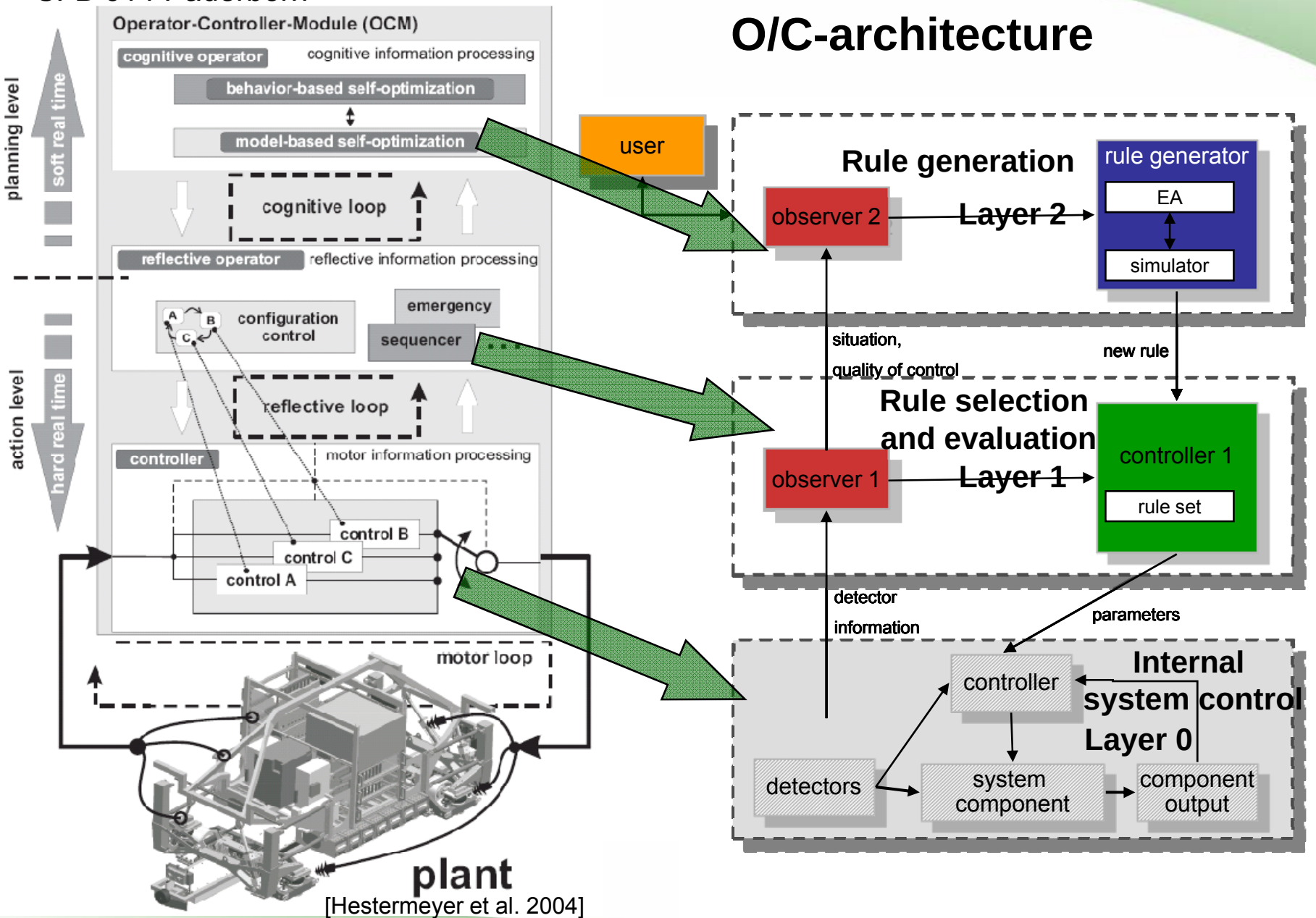
Operator-Controller Module

SFB 614 Paderborn



[Hestermeyer et al. 2004]

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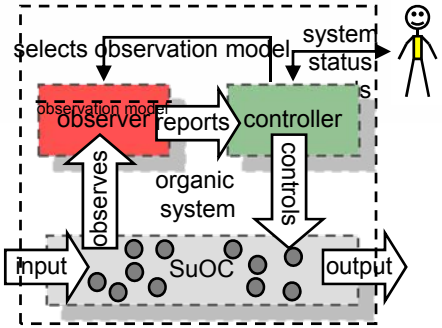
Remarks on O/C architecture



- Flexible template for observing, analysing, and influencing system behaviour.
- The potential of online and offline learning (Layers 1 and 2) should be explored in more application scenarios.
- The potential of modifying the model of observation and its consequences for controlling the system should be explored.
- There will be a roadmap of O/C architectures with growing capabilities, so far, only rather simple versions have been investigated.
- There is a need for more explicit support of communication and cooperation on the O/C-level(s).

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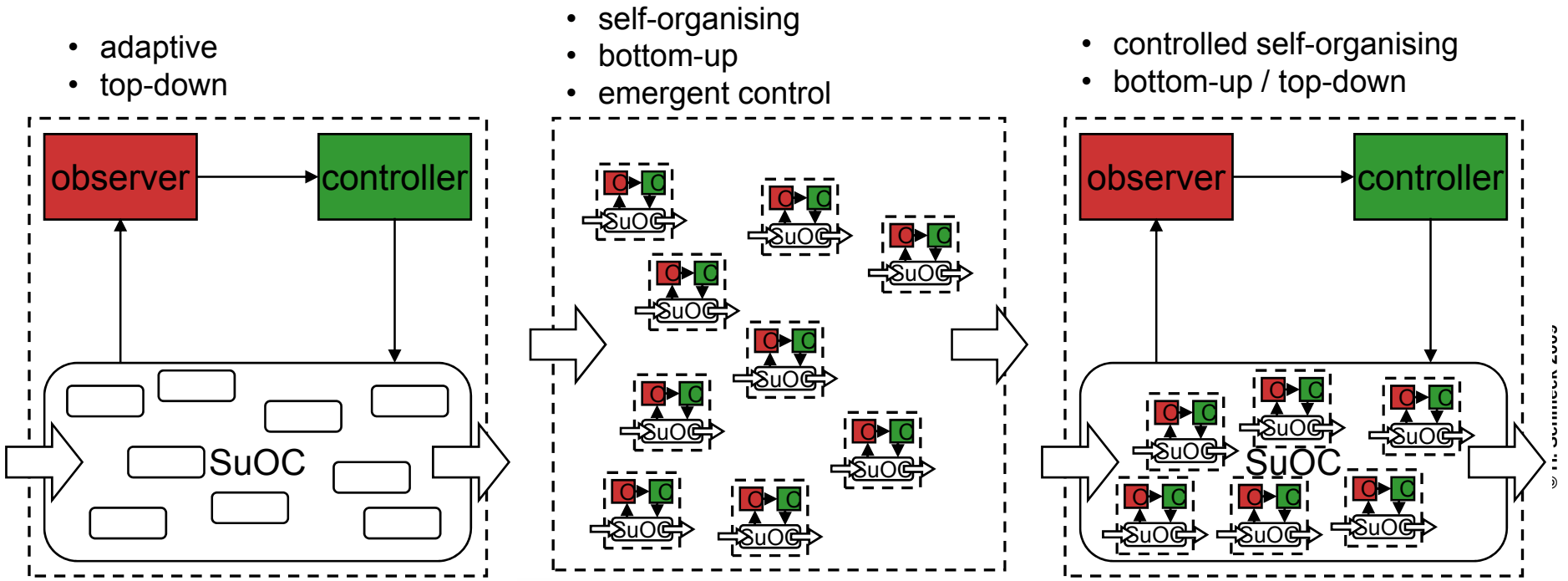
Realisation of OC systems

1. **Central**: One observer/controller for the whole system.
2. **Distributed**: An observer/controller on each system component.
3. **Multi-level**: An observer/controller on each system element as well as one for the whole system.



Types of control actions

1. **Control the environment** (e.g. speed limit in traffic)
2. **Control the communication** (messages, addresses, neighborhoods,…)
3. **Control the local behavior of components** (reconfigure HW, update software, modify skills, set new local objectives,..)