Organic Fault-Tolerant Control Architecture for Robotic Applications

E. Maehle,
F. Mösch, M. Litza

University of Lübeck
Institute of Computer Engineering

W. Brockmann,
D.M. Meyer

Institute of Computer Science
Computer Engineering Group

K.-E. Großpietsch

Institut
Autonome Intelligente
Systeme

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Sankt Augustin

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Overview

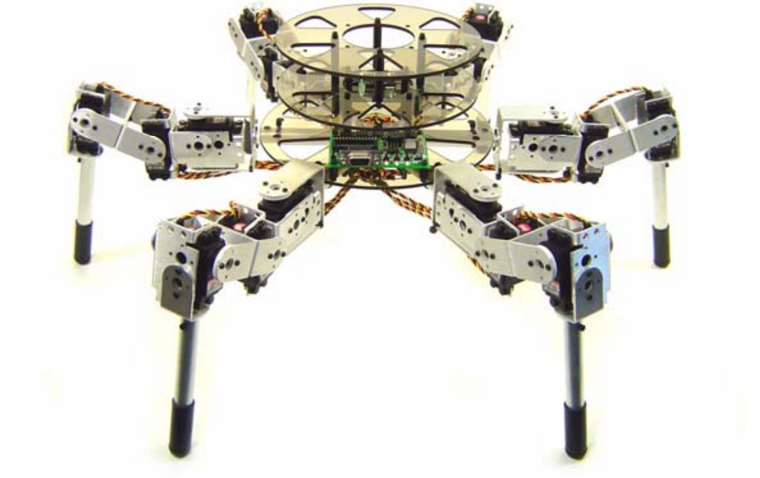
Aim:

- detect, react, and adapt to malfunctions (uncertainties, unforeseen situations, errors, faults)
- avoid critical system states at any time
- low cost implementation

Approaches:

- self-monitoring, self-organization
- specific control architecture
- specific neuro-fuzzy learning methods
- adaptive filters

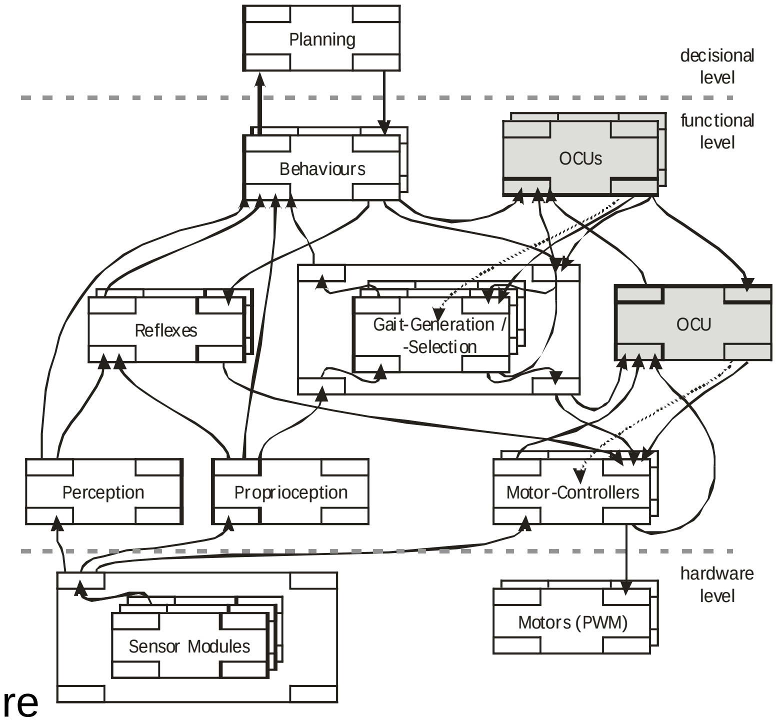
Application: real-world robots as demonstrational systems



Concepts and Requirements

<u>Requirements:</u>

- hard real-time requirements
- avoid critical system states at any time
- learning
  - fast
  - in-situ, online
  - closed loop
- avoid potentially chaotic learning behavior



<u>Concepts:</u>

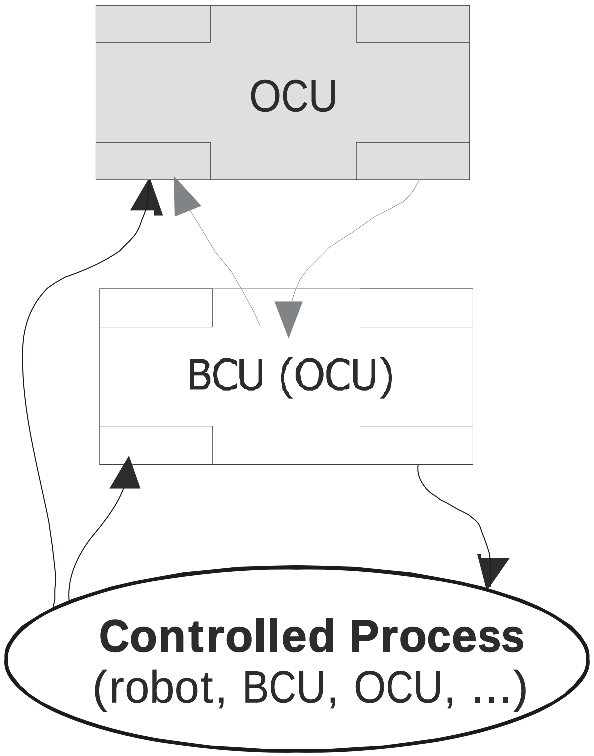
- ORCA – Organic Robot Control Architecture
  - generic, modular, hierarchical systems architecture
  - BCUs = Basic Control Units
  - OCUs = Organic Control Units
- hybrid crisp-fuzzy systems (HCFS) for guarded self-organization
- adaptive filters for high-dimensional problems
- smart action selection
- signals reflecting the ´health´-state

Self-Organization

Aim:
- improve the systems behaviour
- adapt to malfunctions without a formal model even in safety-critical applications

Solutions:
* controlled self-organization
  - supervised adaptive online-learning
  - a priori knowledge + tagging mechanism -> safety warranty
* adaptive action selection
* SILKE-approach (System to Immunize Learning Knowledge-based Elements)

Issues:
goal-directed learning
- in interacting subsystems
- at different system levels
- at OCU-level, e. g. to improve
  - learning speed
  - accuracy



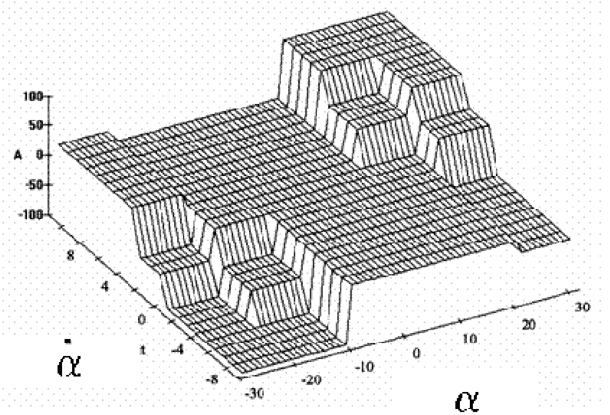
Definition from systems sciences:

Emergence is a property of a complex system which is of no relevance on the level of an individual and cannot be described by summing their properties, but results from the behavior of interacting (adaptive) individuals.

Applicable at two granularity levels:

individuals at - parameter level
- module level

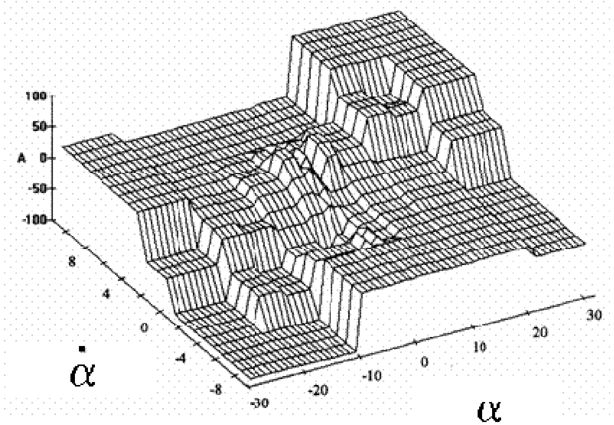
Our focus: Controlled self-organization (at systems and at module level)



Generation of more diverse systems behavior by

- splitting more general rules (parameter level)
- generation of new behaviors (module level)

e. g. - copy an existing behavior
- modify both behaviors separately



Autonomic nervous system: **ORCA**

fast, local, but simple reflexes at lower systems levels

versus complex, global, but slow actions on higher levels

Hormones: ´**health**´-signal

Local and global influence of the ´health´-state

Immune system: **rules**

Granularity (nature)	ORCA-level	adapt. filter	HCFS	SILKE
- cell	parameter	weight	rule	T-cell*)
- organ	module	filter module	HCFS module	= organ-specific
- body	system	interacting modules		= immune system

*) T-cell: - monitors and controls an organ at cell level

-> detects and eliminates local anomalies

-> avoids uninitialised learning situations