A generic software framework for role-based Organic Computing systems

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Organic Computing

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- Dedicated research effort in Germany
  - Priority program of the German Research Foundation
  - 18 teams working in different areas: sensor nets, software engineering, embedded systems, swarms, etc.
- Trying to coin a new term encompassing
  - Autonomic Computing
  - Bio-inspired algorithms
  - Self-Organizing and Self-Adaptive Systems

SAVE ORCA – Target Systems

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- Embedded, software intensive applications that are
  - particularly resistant against disturbances and component failures (w.r.t. functional correctness, safety, security)
  - adaptive to changing requirements and modified tasks

- Agent- and role-based systems
  - Each agent has several capabilities
  - Resources with different tasks are processed by the agents
  - Each task needs different processing steps
  - Processing steps are a given sequence of capabilities
  - Roles define which capabilities the agent applies

SAVE ORCA – Goal

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- Goal: Framework for the design and construction of highly reliable Organic Computing applications
  - Top-Down Design Methodology
  - Integrated Software Development Process
  - Formalization of self-x properties
  - Formal analysis and verification to enable behavioural guarantees
  - Extensible generic runtime environment (today)

SAVE ORCA – Adaptive Production Cell

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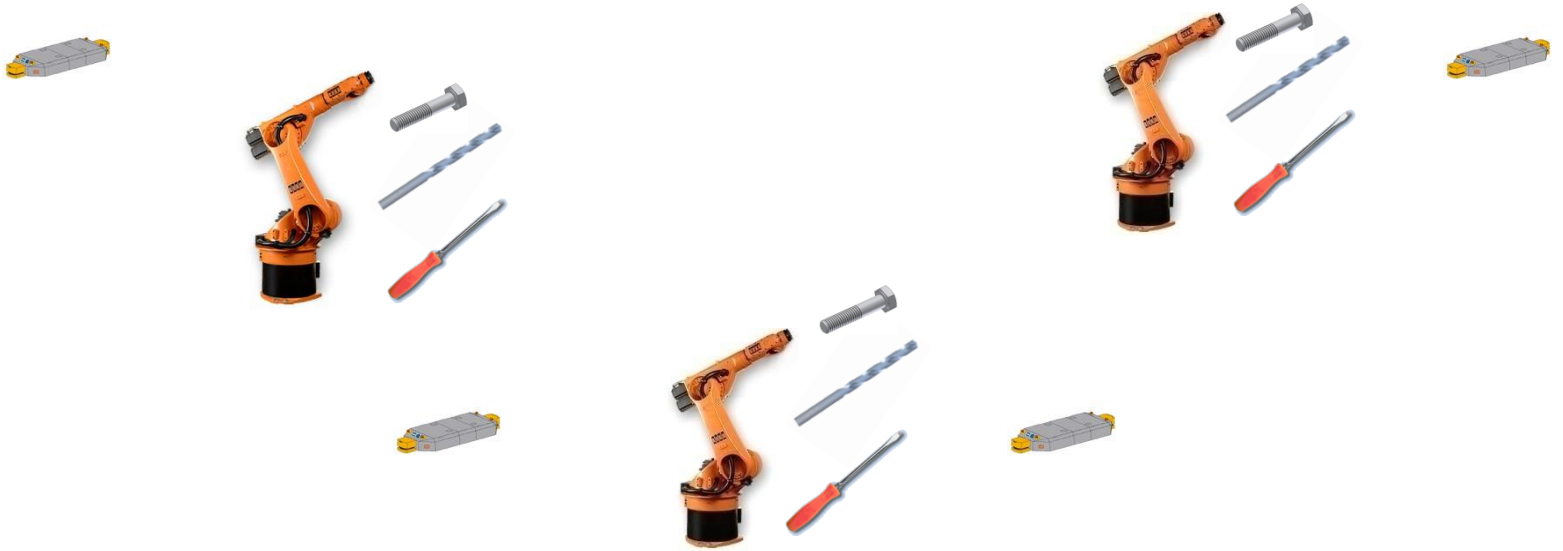
Goal: Process workpieces in a given order!

Unprocessed workpieces

Processed workpieces



SAVE ORCA – Normal Operation

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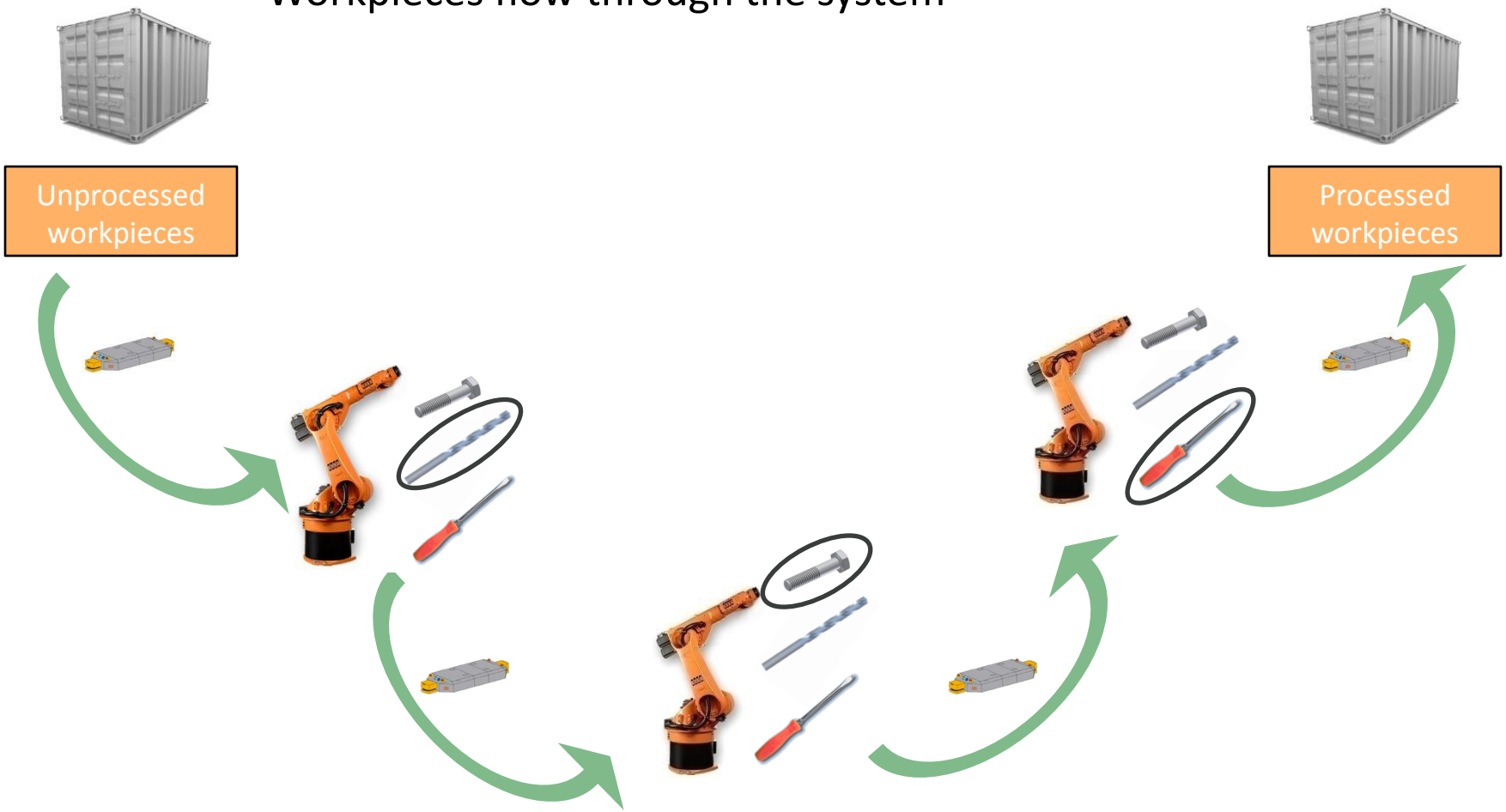
Normal Operation:

Workpieces flow through the system



SAVE ORCA – Self-Healing

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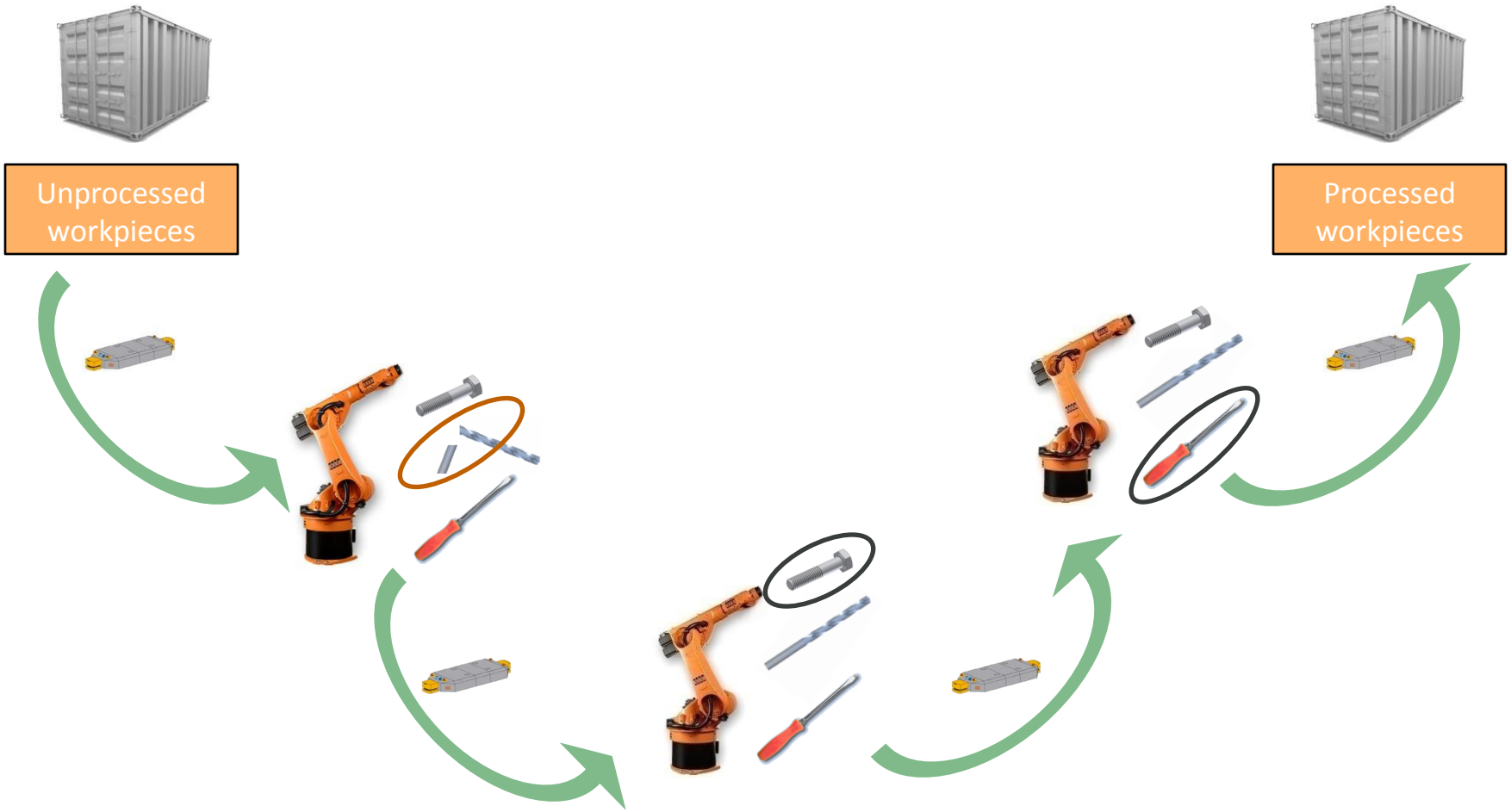
Self-Healing: Resistance to component failures



SAVE ORCA – Self-Healing

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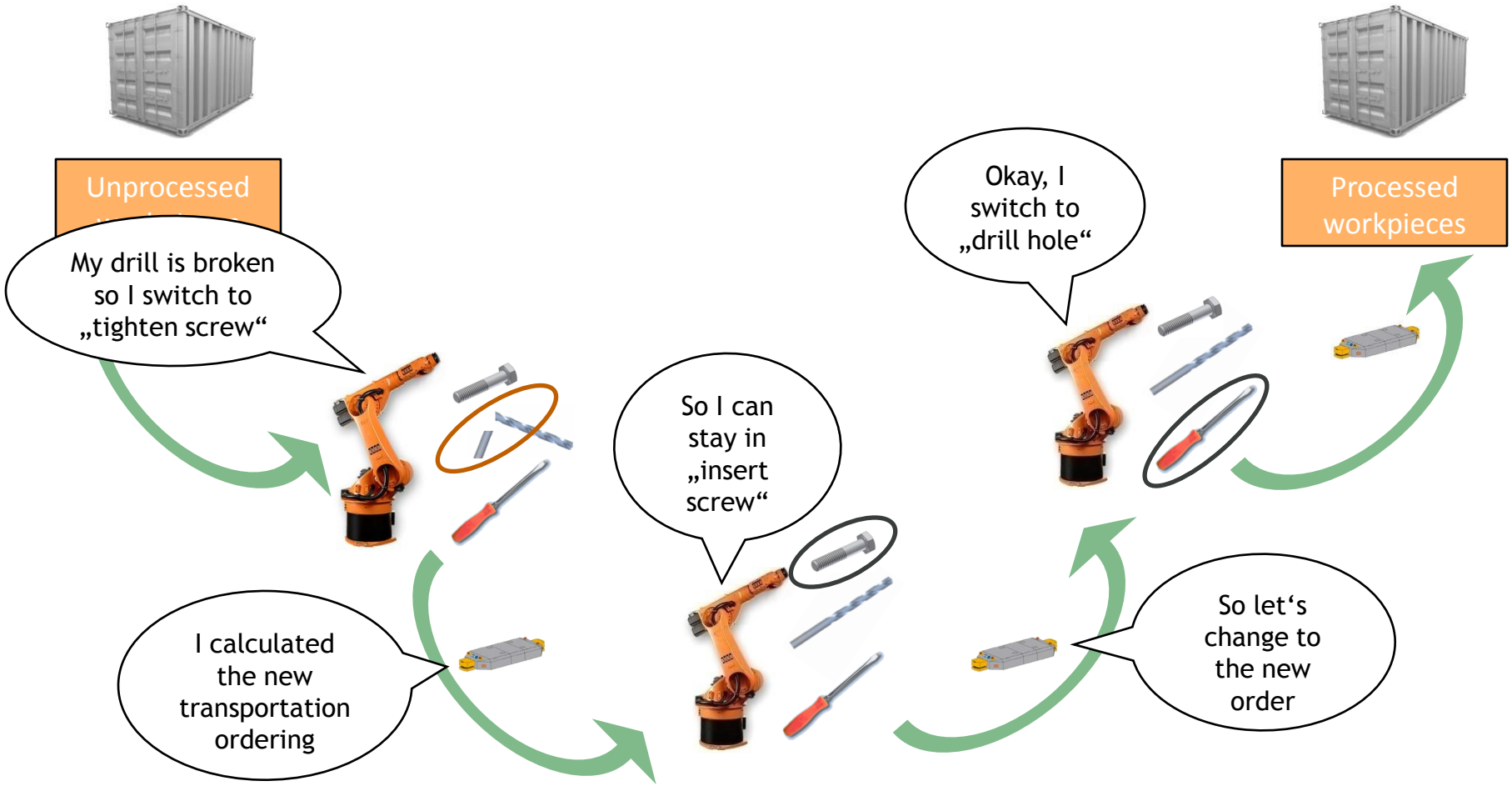
Self-Healing: Resistance to component failures



SAVE ORCA – Self-Healing

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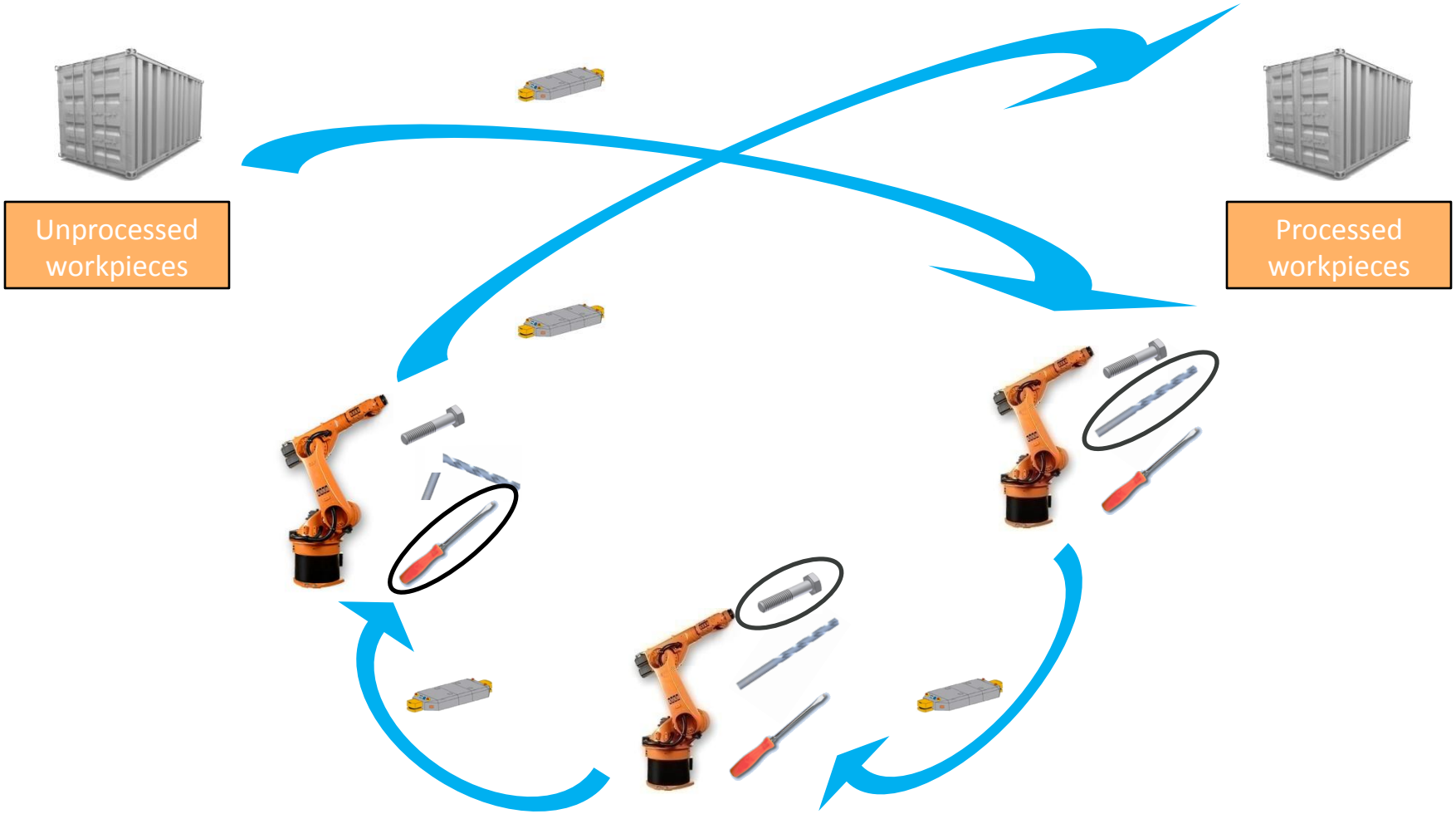
Self-Healing: Resistance to component failures



SAVE ORCA – Self-Configuring

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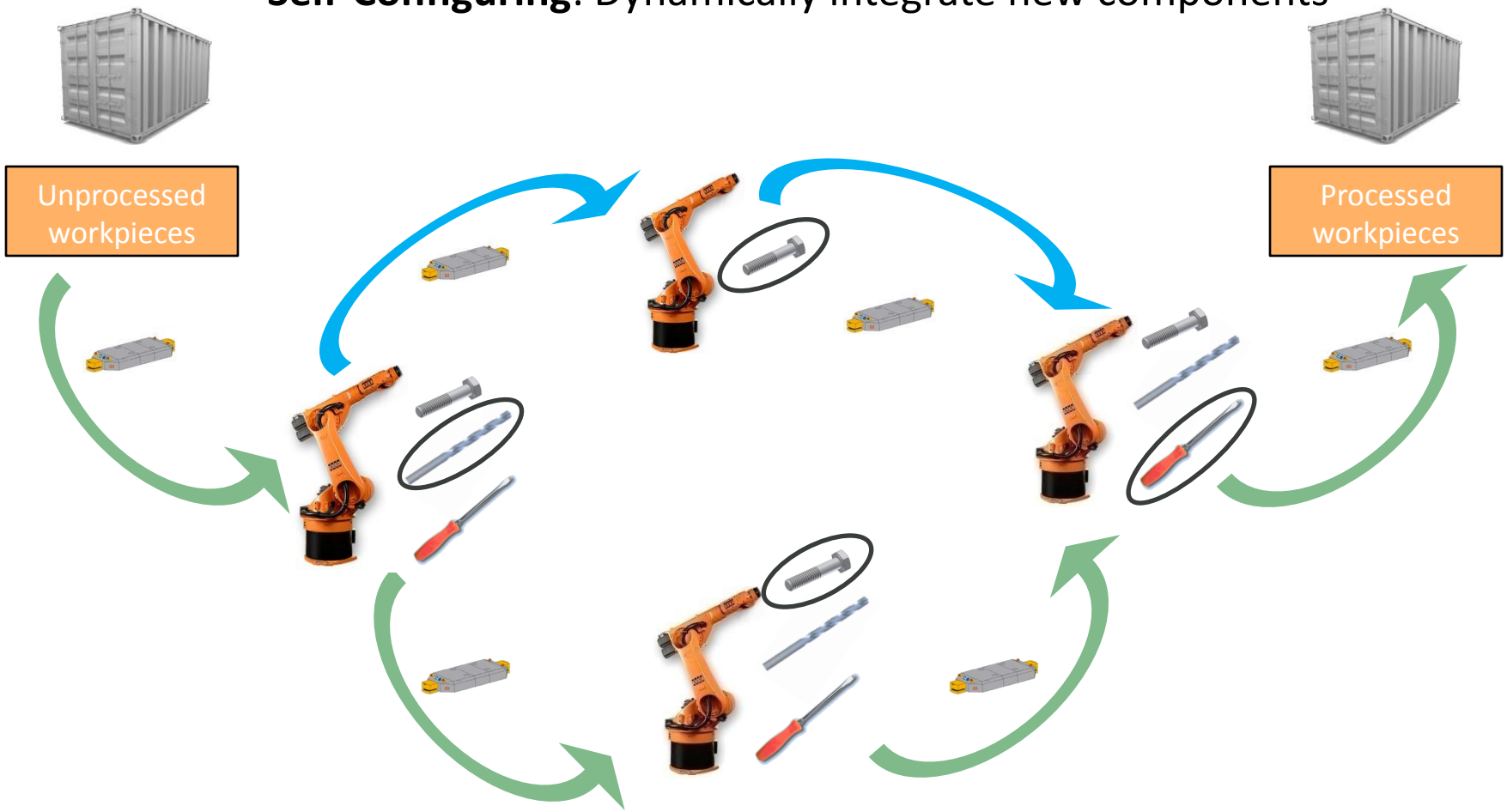
Self-Healing: Resistance to component failures

Self-Configuring: Dynamically integrate new components



SAVE ORCA – Self-Adaptive

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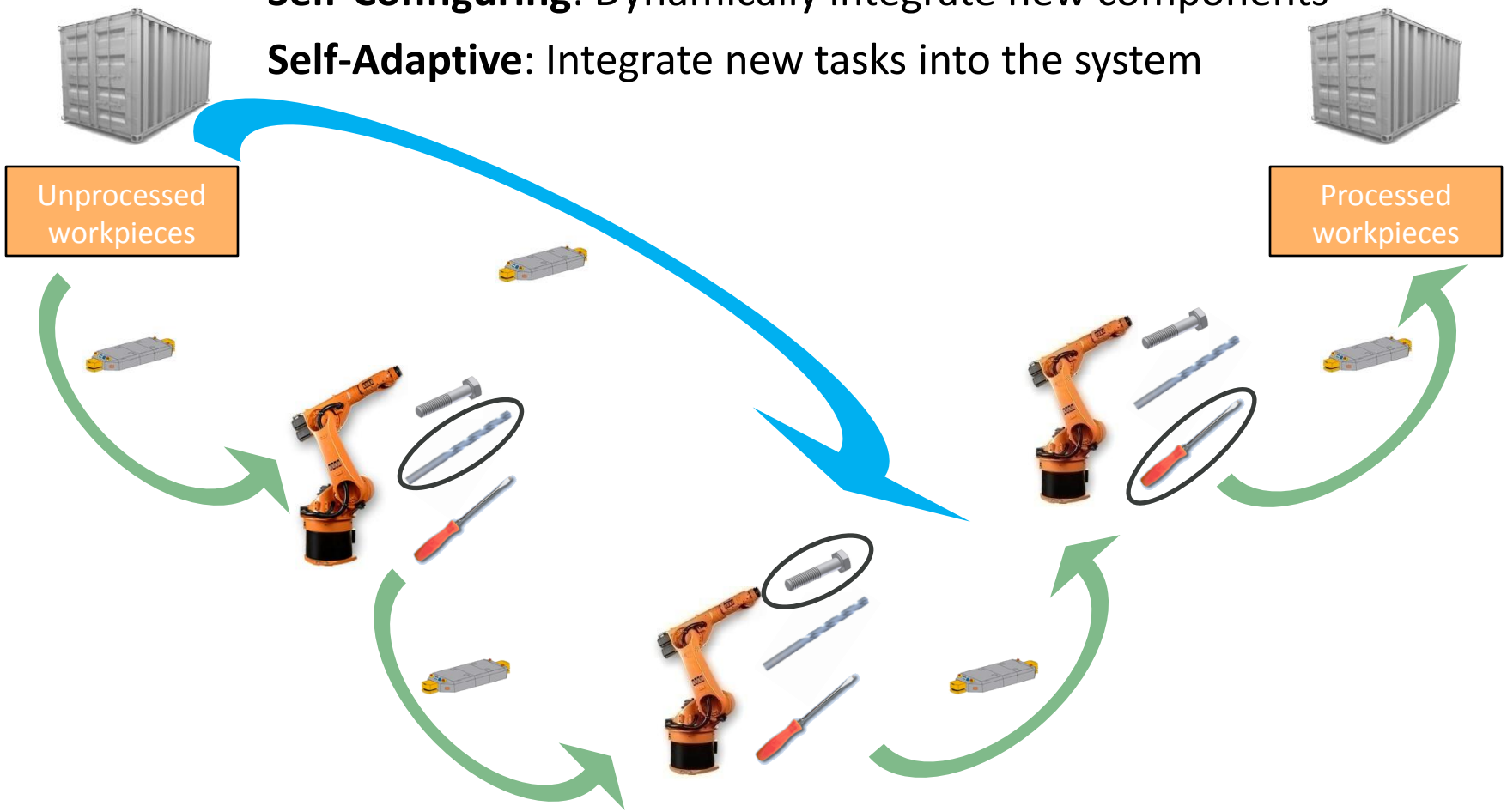
Self-Healing: Resistance to component failures

Self-Configuring: Dynamically integrate new components

Self-Adaptive: Integrate new tasks into the system



SAVE ORCA – Self-Optimizing

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Self-Healing: Resistance to component failures

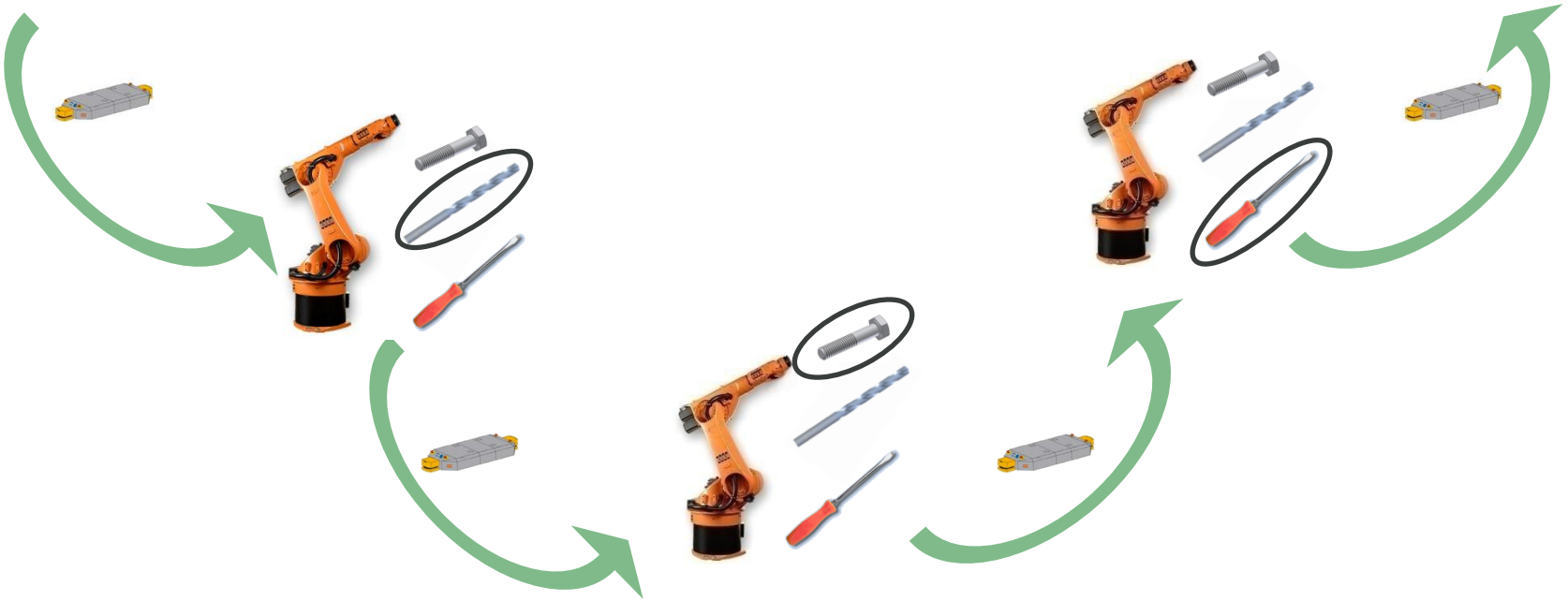
Self-Configuring: Dynamically integrate new components

Self-Adaptive: Integrate new tasks into the system

Self-Optimizing: Improve configuration fitness

Unprocessed workpieces

Processed workpieces



SAVE ORCA – Restore Invariant Approach

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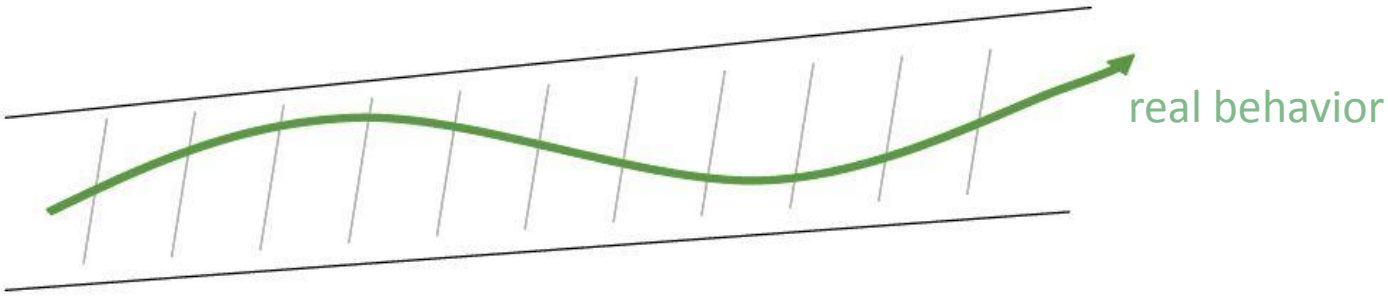
- Formally model a system‘s intended behaviour with invariants
- Invariants establish corridor of acceptable behaviour
- Whenever system leaves corridor, reconfigure to restore invariants



SAVE ORCA – Architecture

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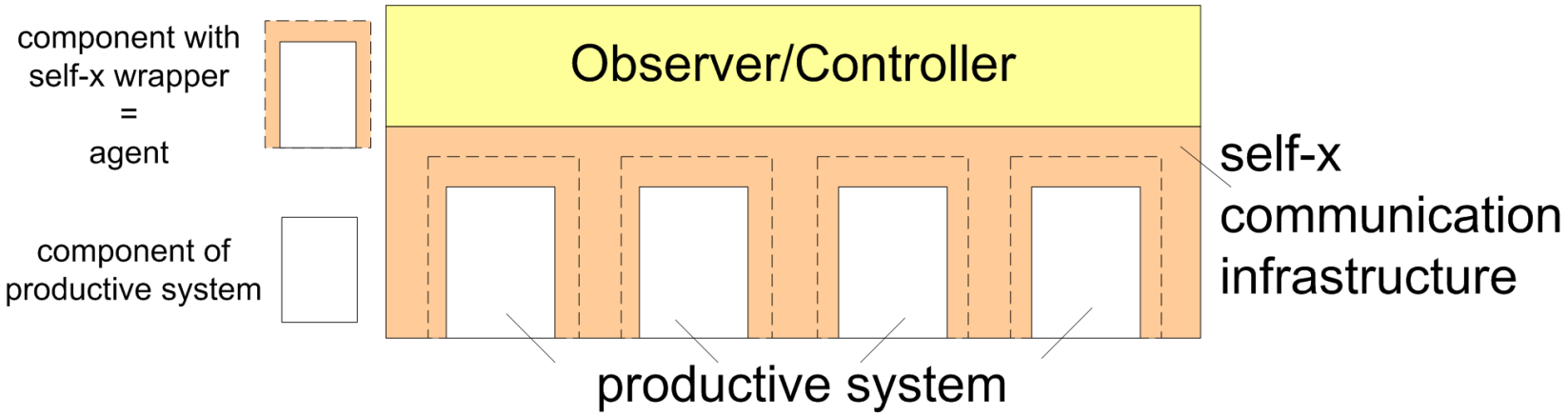
- Invariants are observed at runtime by centralized or distributed Observer/Controller
- Reconfiguration can be formulated as a constraint satisfaction problem



SAVE ORCA – Organic Design Pattern

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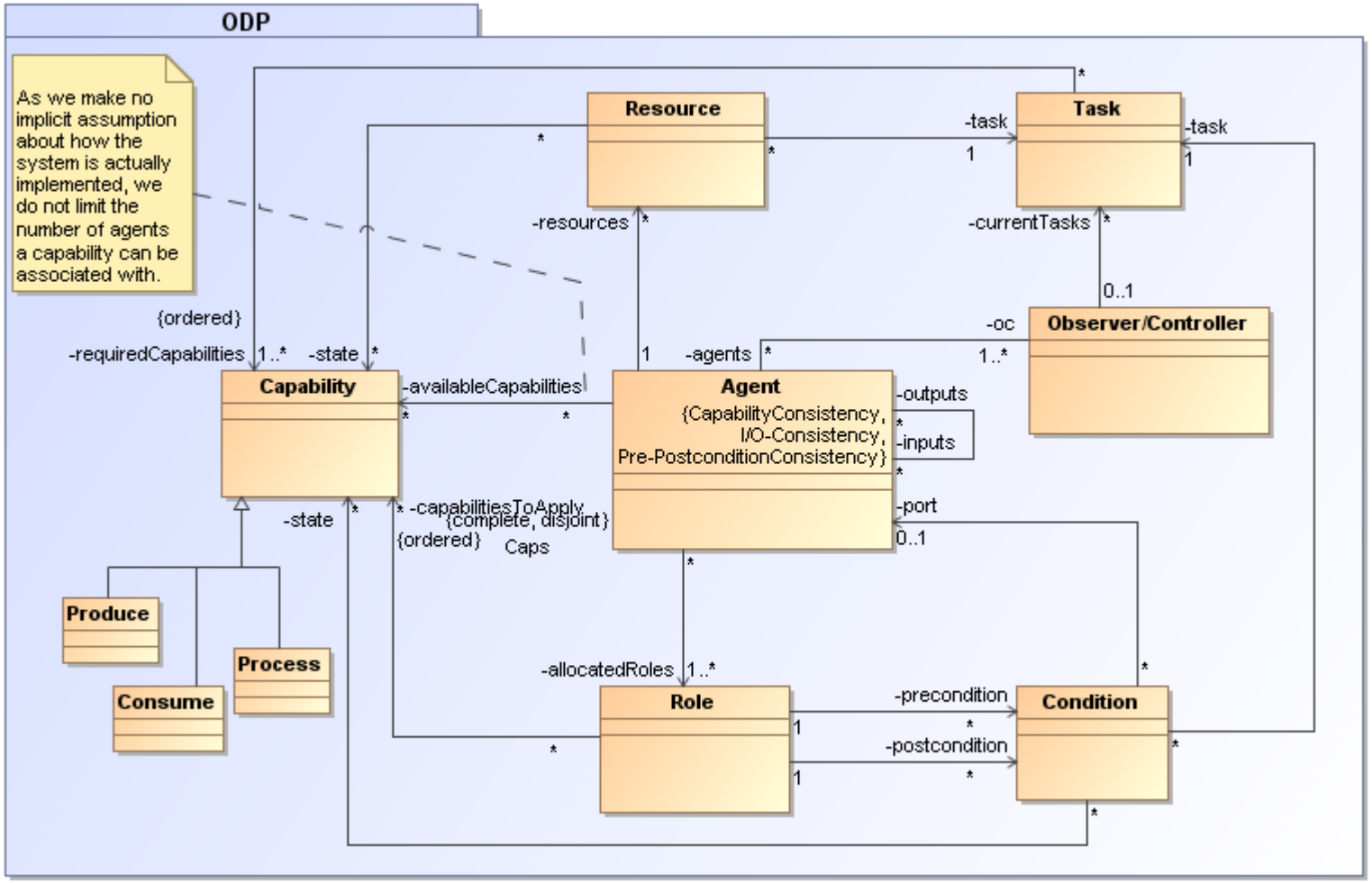

Jadex BDI Agent System

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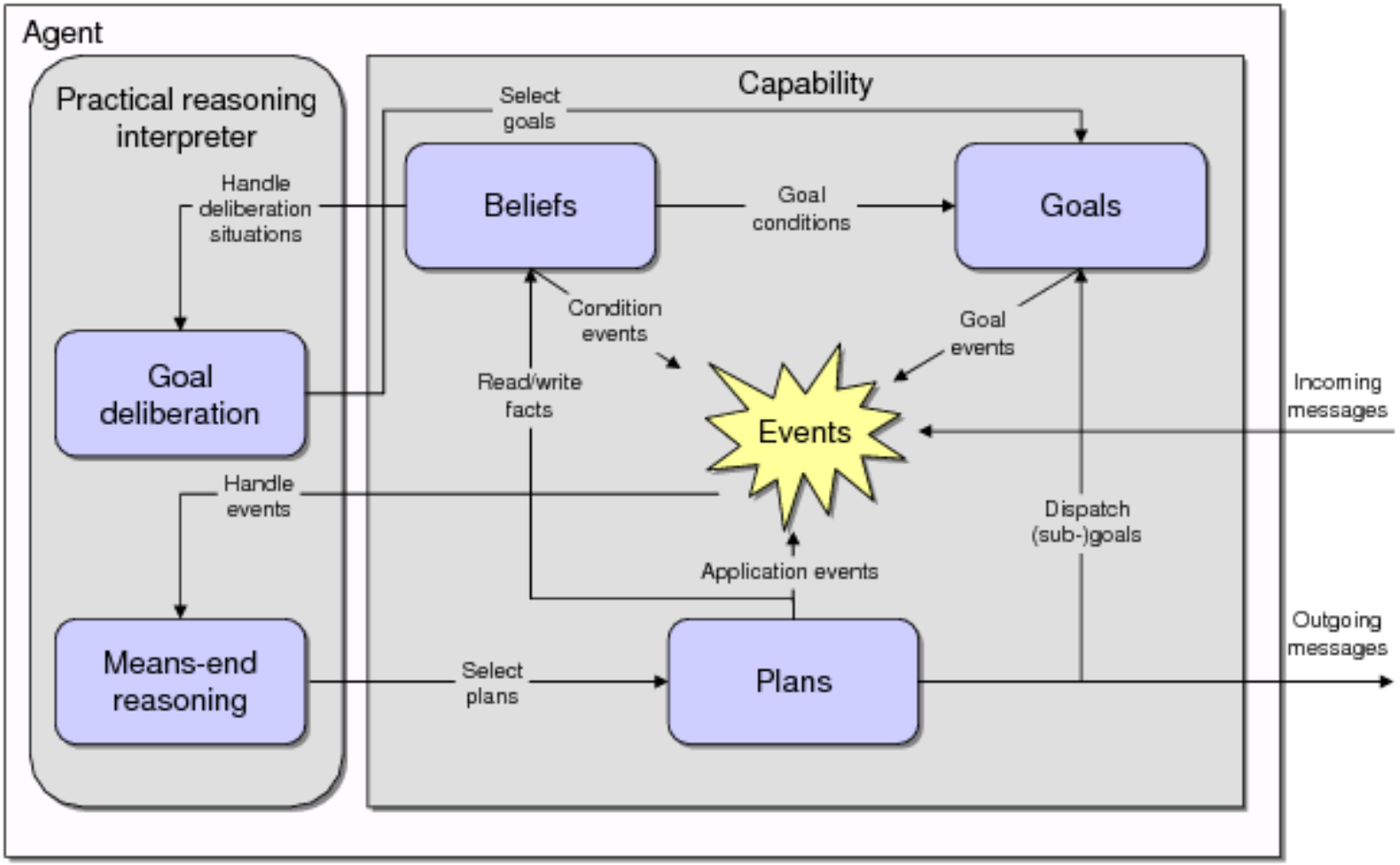

Graphic from [Jadex User Guide]

The ODP Runtime Environment

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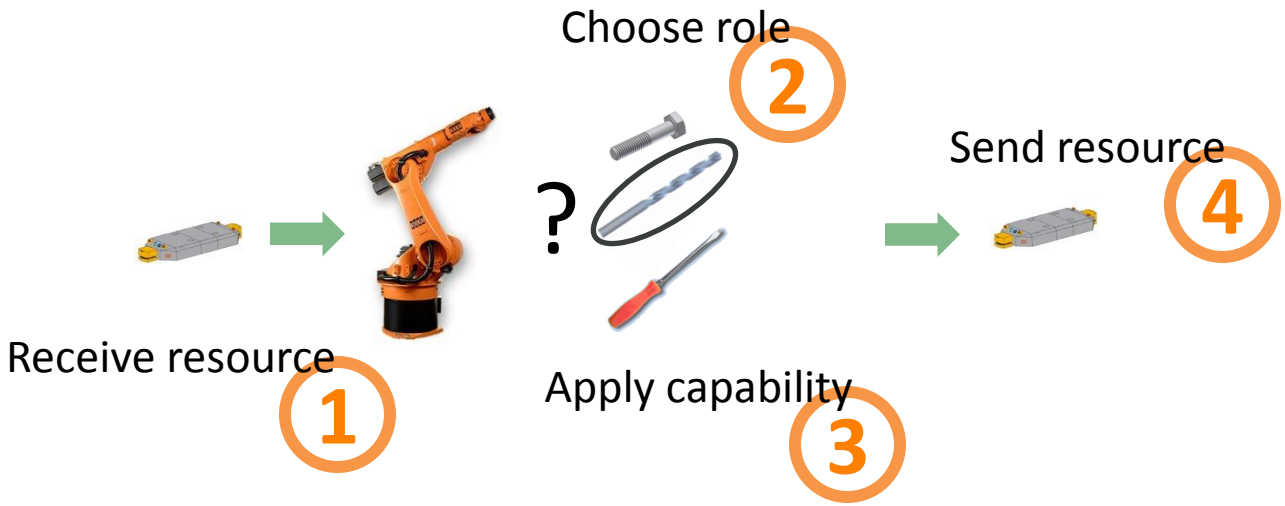
- ODP concepts can be mapped to Jadex concepts
- Generic infrastructure is provided as Jadex capabilities:
  - Communication
  - Role selection and execution
  - Reconfiguration
  - Data models and messages
- Domain and application-specific extension points

ODP	Jadex
Agent	Agent
Observer/Controller	Agent
Capability	Plan
Role	Belief
Condition	Belief
Resource Task State	Belief

Generic role execution

Role: Precondition (Input agent, resource state)
Capability to apply
Postcondition (new resource state, output agent)



Generic role execution

Role: Precondition (Input agent, resource state)
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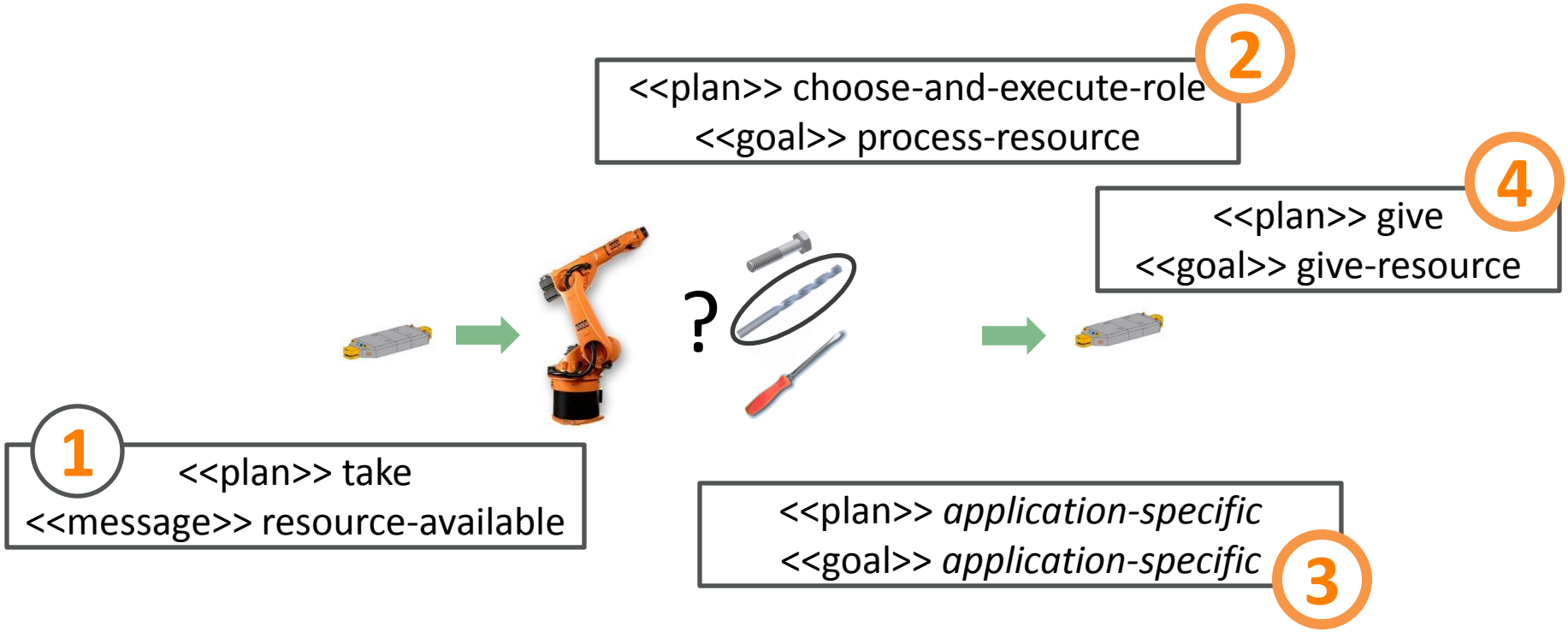

ODP‘s reconfiguration process

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Observer Controller

O/C uses global knowledge to calculate role allocation that satisfies global invariants 4

Agent informs O/C 2
Global invariant is violated

O/C sends new configuration to agents which adopt it 5
Local invariants are satisfied again

O/C asks all agents for their current configuration 3

Agent discovers something is wrong
Local invariant is violated 1

ODP reconfiguration process

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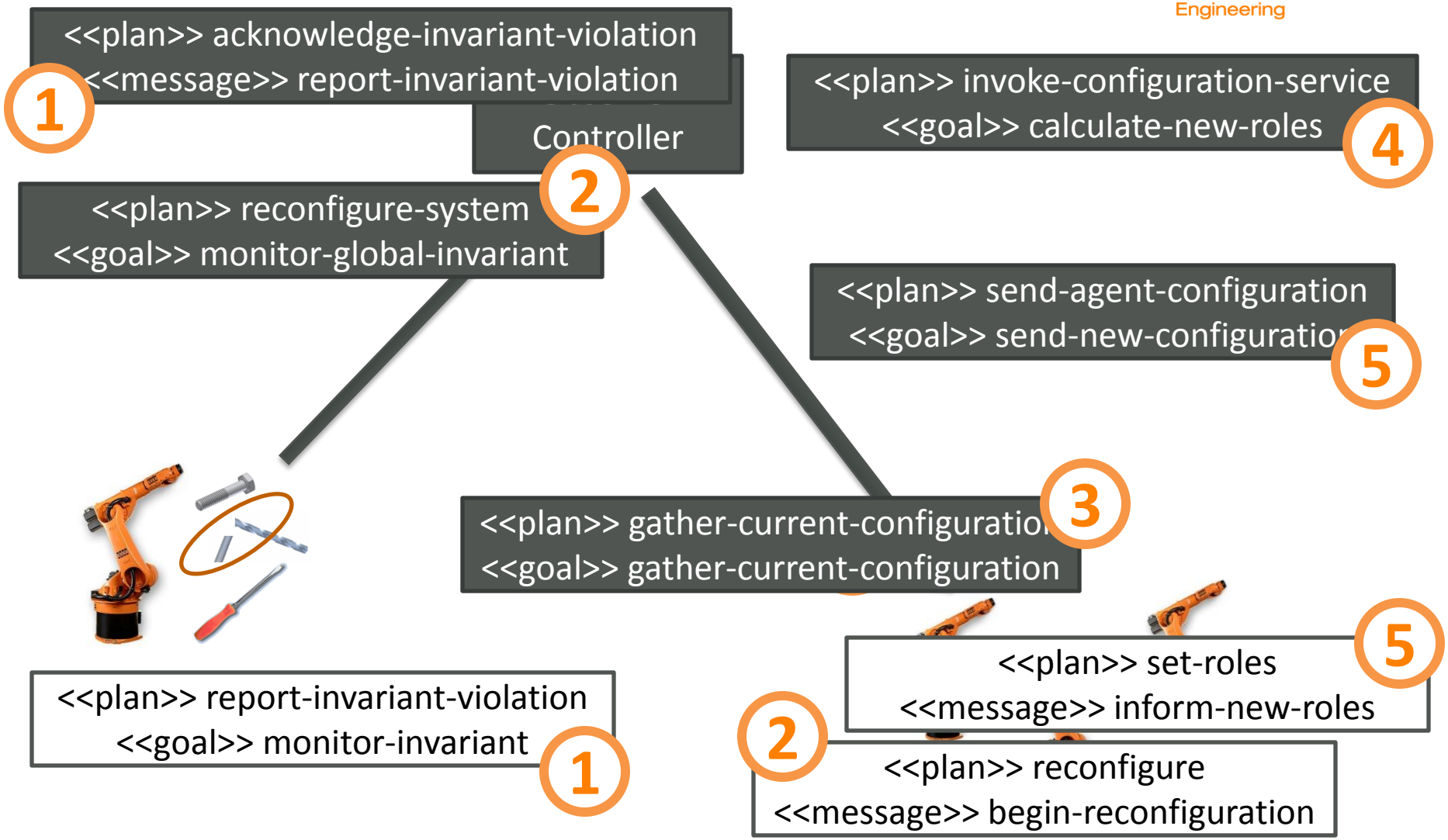

Extension points for actual implementations

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- **Application of capabilities**: What should the agents do with the workpieces
- **Domain-specific invariants**: Specify the behavioural corridor of the application domain
- **Reconfiguration algorithm**: Optimize the algorithm for the domain or application
- **Resource Flow**: Adapt the framework to specific resource handling requirements

Contributions

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- SAVE ORCA provides guideline and process for reliable, secure Organic Computing systems
- ODP Runtime Environment provides the means for short design-implementation turnaround times
- Many features implemented in a generic fashion
- Clearly defined extension points
- Built on top of a reliable and well-documented platform