Self-organization in Manufacturing Systems: Challenges and Opportunities

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Agenda

- Introduction and motivation
- Self-organization in manufacturing systems
- Foundations of a biological-Inspired control solution
- Why are not yet adopted by industry?
- Challenges and opportunities
- Conclusions

Motivation for this Work

- Re-configurability and responsiveness are key roles to a company stay in the business,

  exhibiting an agile response to the changing conditions through their dynamic re-configuration on the fly.

- Reconfigurable manufacturing control systems are based on emergent technologies and impose:

  modularity, integrability, customization, scalability, convertibility and diagnosability.

- Biology and nature are suitable sources of inspiration for the development of RMS and evolvable systems.
- Applicability of bio-inspired theories to build RMS.

What can Bio-inspired Theories Offer

- Simple individual entities possessing simple behaviors,
  - A small number of rules can generate complex systems.
  - Depending of intelligence and learning skills.
- Swarm intelligence:
  - Emergent collective intelligence of groups of simple and single entities.
  - Alternative way of designing intelligent systems, in which autonomy, emergence and distribution replace centralized control.
- These systems operate in a very flexible and robust way.
- Self-organization, chaos and complexity theories support the operation of non-linear and dynamic processes.

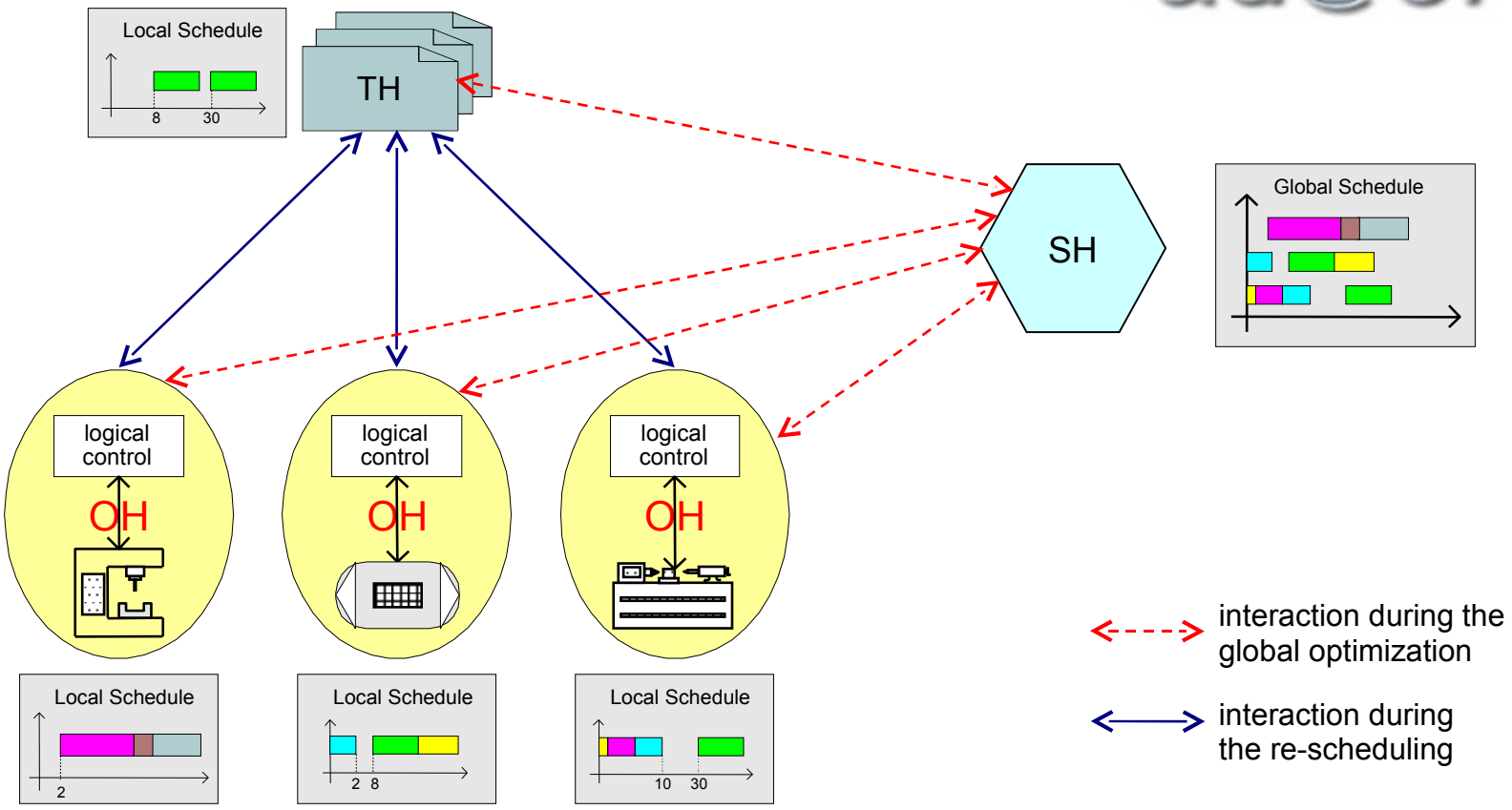
The Self-Organization Concept

- Definition: *Ability of an entity/system to adapt dynamically its behavior to external conditions without external intervention.*
- The application of self-organization allows the dynamic:
  - Self-configuration (i.e. adaptation to changing conditions by changing their own configuration without service disruption);
  - Self-optimization (i.e. tuning itself in a pro-active way);
  - Self-healing (i.e. capacity to diagnose deviations and take proactive actions to normalize them).
- The emergence of the global control is based on:
  - Capability of individuals to change dynamically their properties.
  - Evaluation if the evolved solution is better than the previous one.
  - Important to achieve order and stability.

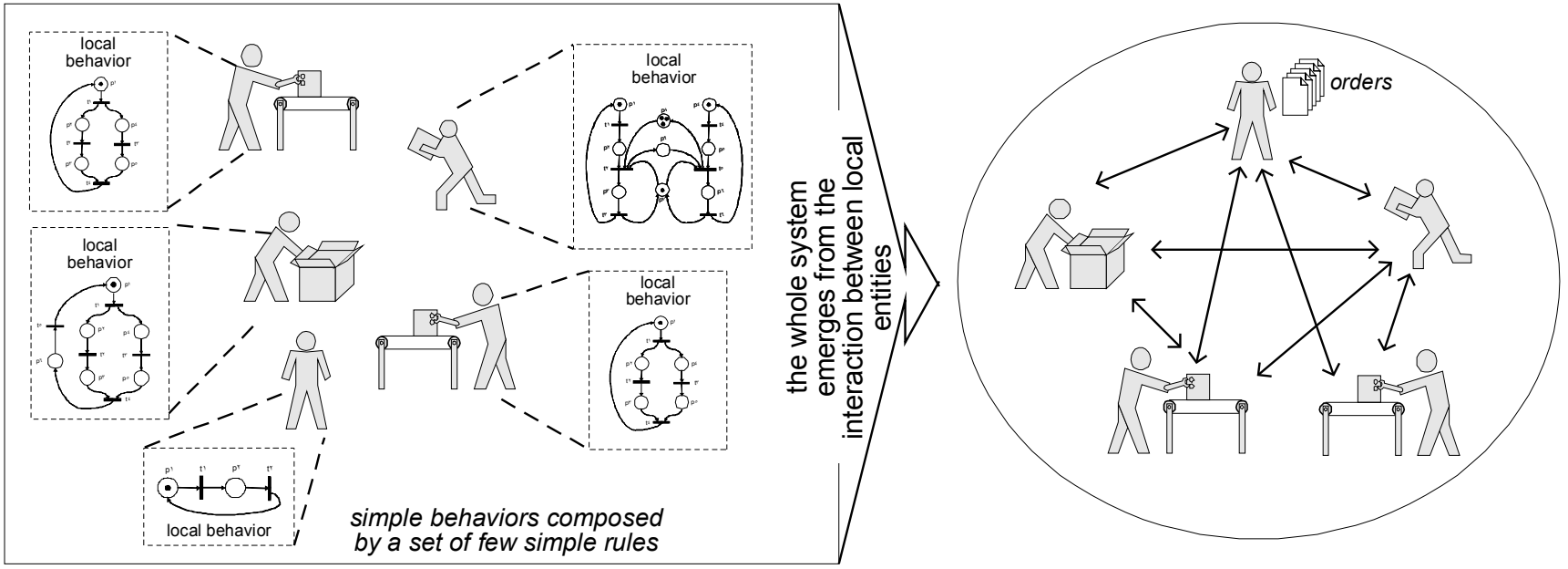
Bio-Inspired Manufacturing Paradigms

- Some manufacturing paradigms:
  - Holonic Manufacturing Systems (HMS).
  - Bionic Manufacturing Systems (BMS).
  - Reconfigurable Manufacturing Systems (RMS).
- Propose distributed, autonomous and adaptive manufacturing systems.
- Differ in their inherent capability to adapt to changes without external interventions.

Biological-Inspired Control Solution



Complex Systems from the Individuals

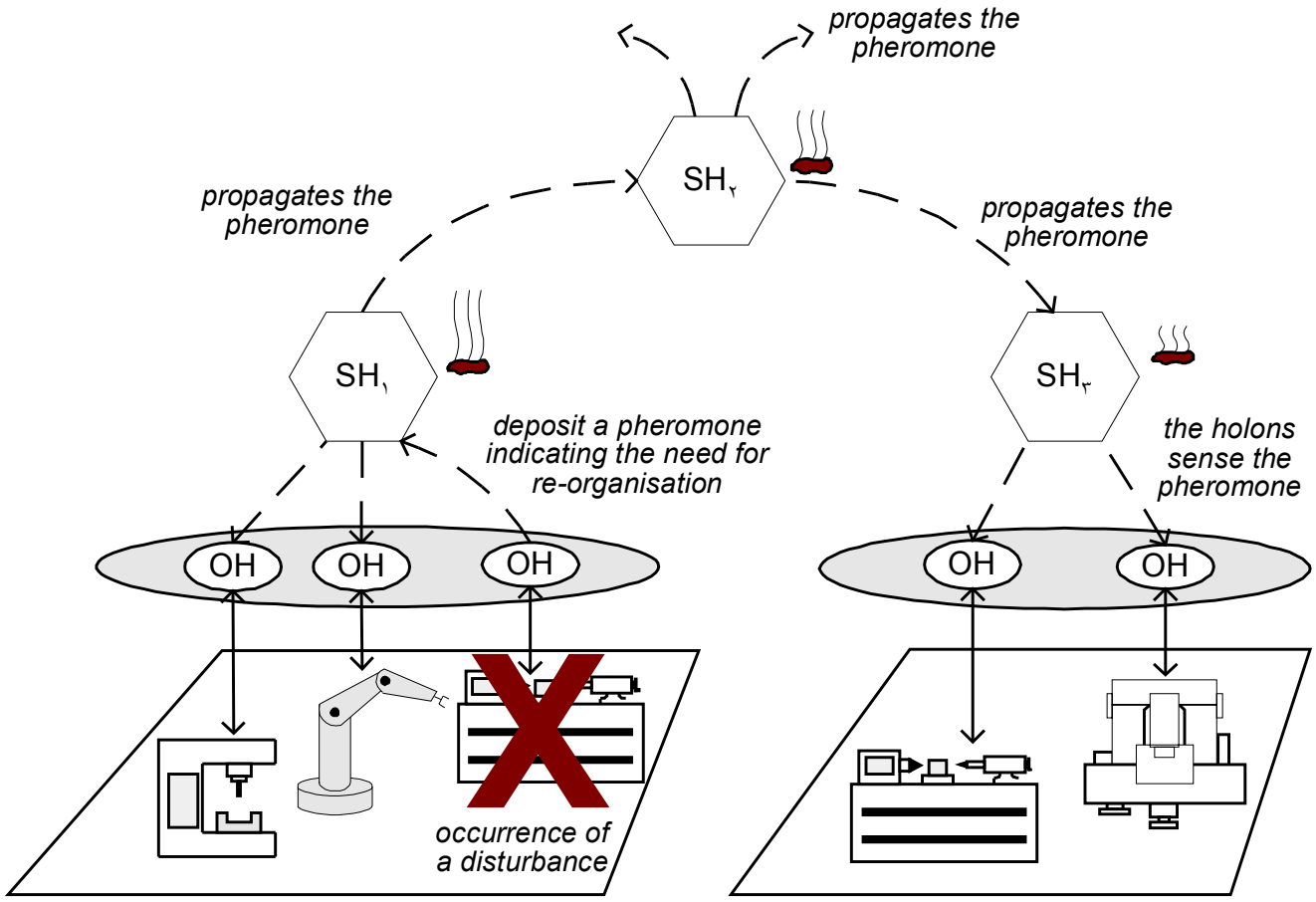


Individual Driving Forces: Autonomy Factor

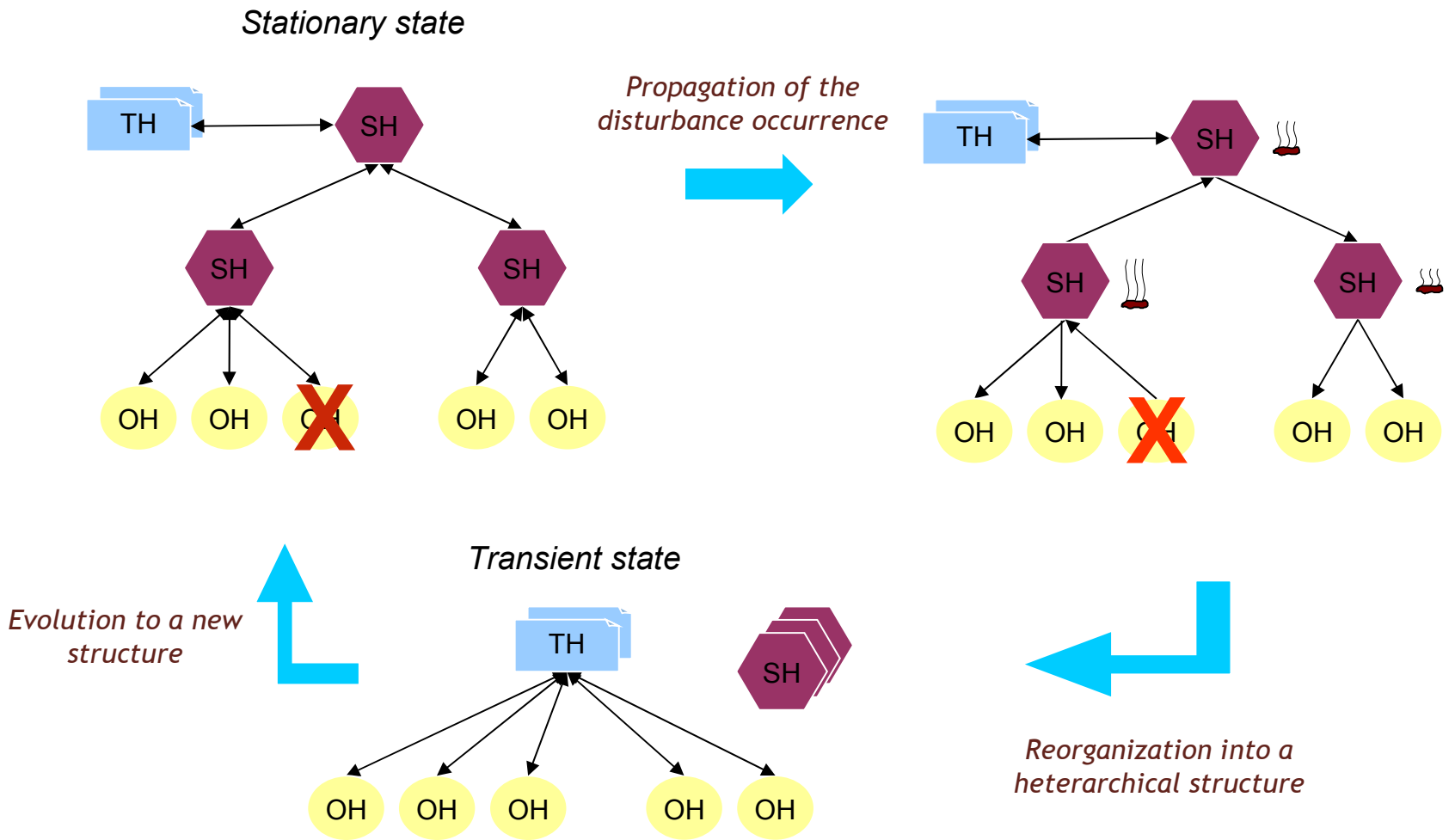
- An intrinsic parameter reflecting the degree of autonomy of a holon.
- Evolves dynamically in order to adapt the holon behavior to changes in the environment where it is placed.
- Regulated by a fuzzy rule-based engine that considers:
  - the reestablishment time (τ),
  - the pheromone parameter (ρ).

```
IF ρ == High AND α == Low
   THEN α = High AND ReorganiseIntoNewStructure

IF ρ == High AND α == High AND τ == Elapsed
   THEN α = High AND Reload τ

IF ρ==Low AND α==High AND τ == Elapsed
   THEN α = Low AND ReorganiseIntoNewStructure
```

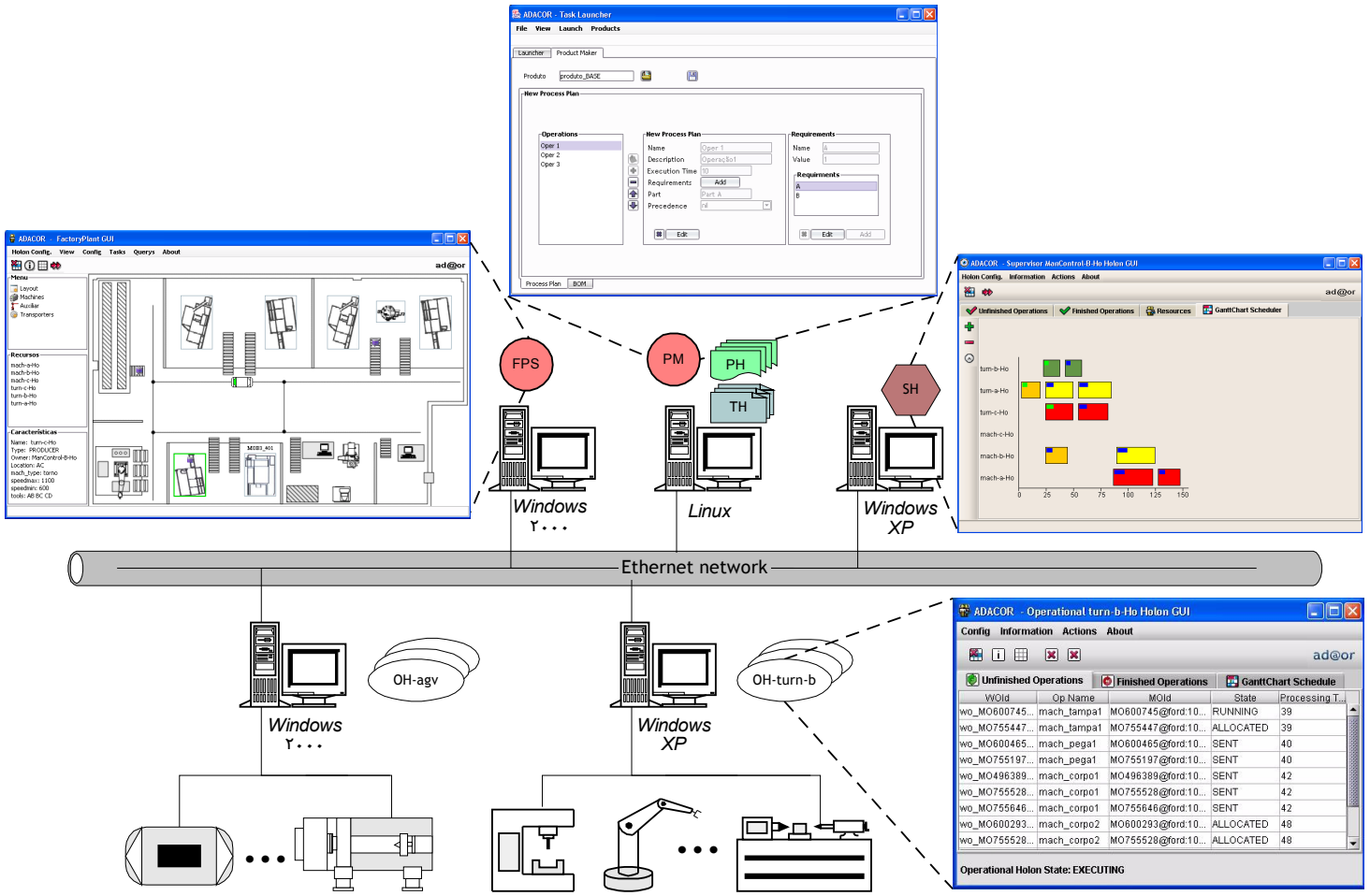
Global Driving Forces: Spreading Mechanism



Adaptive Control Working in Practice



Prototype Operation



Why Are Not Yet Adopted by Industry?

- New way of thinking.
- Customers and industry want to use proven technology.
- Industry is afraid of the usage of emergent terminology usually associated to these new technologies.
- Investment to implement these emergent approaches.
- Restrictions of some technical issues.
- Use of limited features offered by the bio-inspired theories.

Challenges and Opportunities

- Convincement of people to believe in the concepts,
  - using mature demonstrations to proof that they work as desired, even in severe scenarios.
  - Indicators illustrating the benefits of these approaches.
- Presence of modularity, embodied intelligence, re-configurability mechanisms and interoperability.
- Stability: identify reconfiguration opportunities, while maintaining the system behavior predictable and stable.
- Interoperability in heterogeneous environments.
  - Semantics and ontologies seem to be the answers to this challenge.

Conclusions

- Manufacturing systems are addressing the challenge for reconfigurable and evolvable systems.
- Biological and nature inspired concepts and theories seem suitable for the design of RMS.
- Bio-inspired solution using concepts derived from HMS, swarm intelligence and self-organization, supported by the use of multi-agent principles.
- Some possible reasons for the weak adoption by industry were pointed out.

Thank you!

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