A Strategy To Support Bio-Inspired Self-Organization In Smart Manufacturing: Altruism For Collaborative Self-Healing Operations

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INTRODUCTION

In response to market dynamism, and the demand for personalized products, companies are adapting their manufacturing structures for agility and sustainability. New paradigms like Bionic Manufacturing Systems (BMS) emphasize flexibility and reconfigurability, supported by advancements in technologies enabling high connectivity and digitalization. Cyber-Physical Production Systems (CPPS) play a central role, integrating computational units and physical objects, for autonomous and interconnected production. However, the complexity of CPPS necessitates mechanisms for control, adaptation, and self-organization. Self-organization offers benefits such as autonomous task orchestration and resource management, motivating research into bio-inspired solutions for self-healing and governance in intelligent production systems. This dissertation aims to bridge the gap by developing a collaborative healing framework, integrating bio-inspired mechanisms into CPPS for enhanced performance and resilience on the shop floor and automation process levels.

RESEARCH QUESTIONS

To address these challenges, it requires an extensive study of the state of the art in research areas like self-organization in smart manufacturing, bio-inspiration, and self-healing processes. With such ideas, a useful framework to model a self-healing environment can be developed. Thus, this research is guided by the following research questions (RQs).

RQ1. What are the current research trends and challenges in self-organized manufacturing?

RQ2. What benefits can bio-inspiration provide to self-healing operations in a self-organized manufacturing environment?

RQ3. How can a manufacturing framework for healing operations be implemented while denoting self-organized autonomous and collaborative collective behavior?

METHODS (1): State of the art analysis

Contribution to RQ1 and RQ2

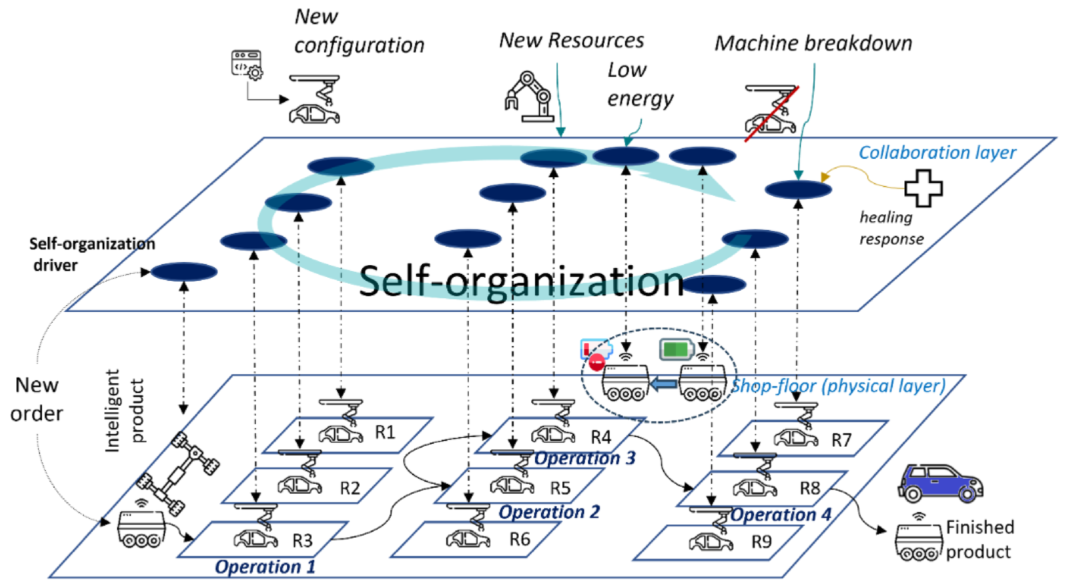

Figure 1. Self-organized Smart Manufacturing

PRISMA analysis: 52 papers

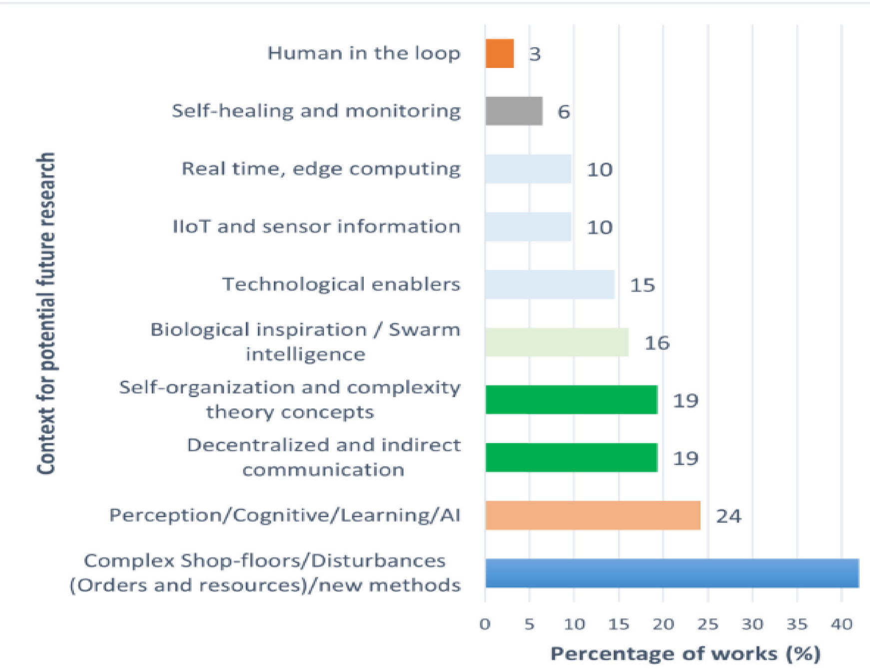

Figure 2. Potential future research direction after PRISMA

METHODS (2): Framework Development

Contribution to RQ3

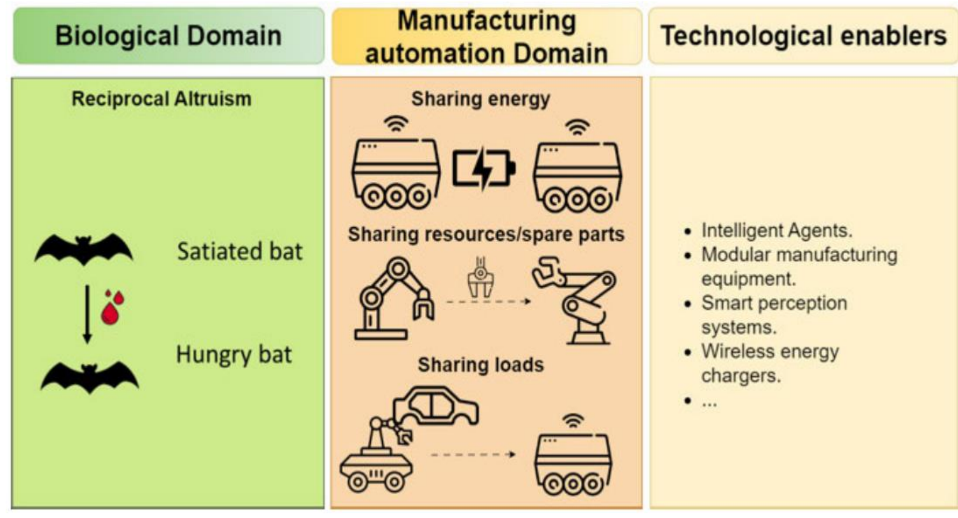

Figure 3. Bio-inspired approach

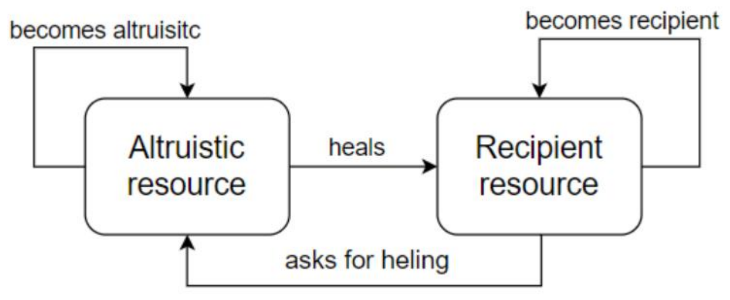

Figure 4. Vision of an altruistic manufacturing environment

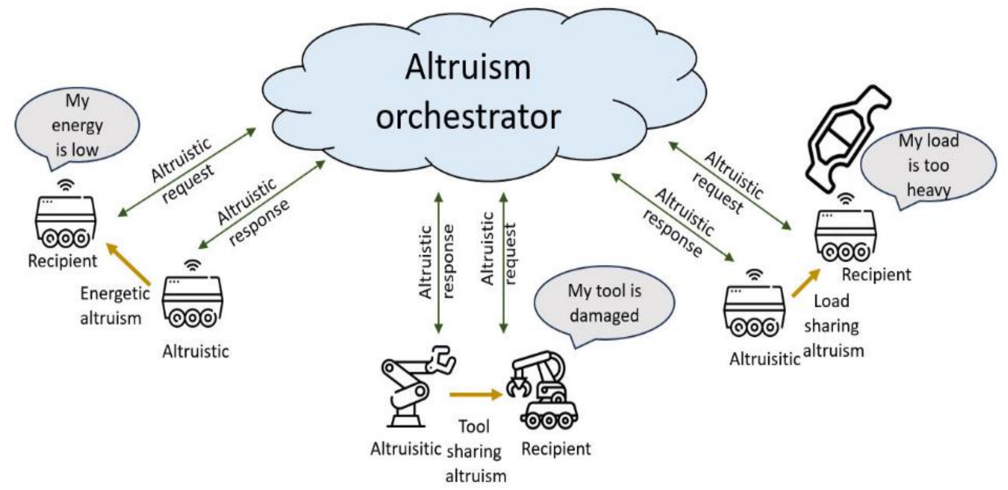

Figure 5. Collaborative altruistic behavior based on an orchestrator

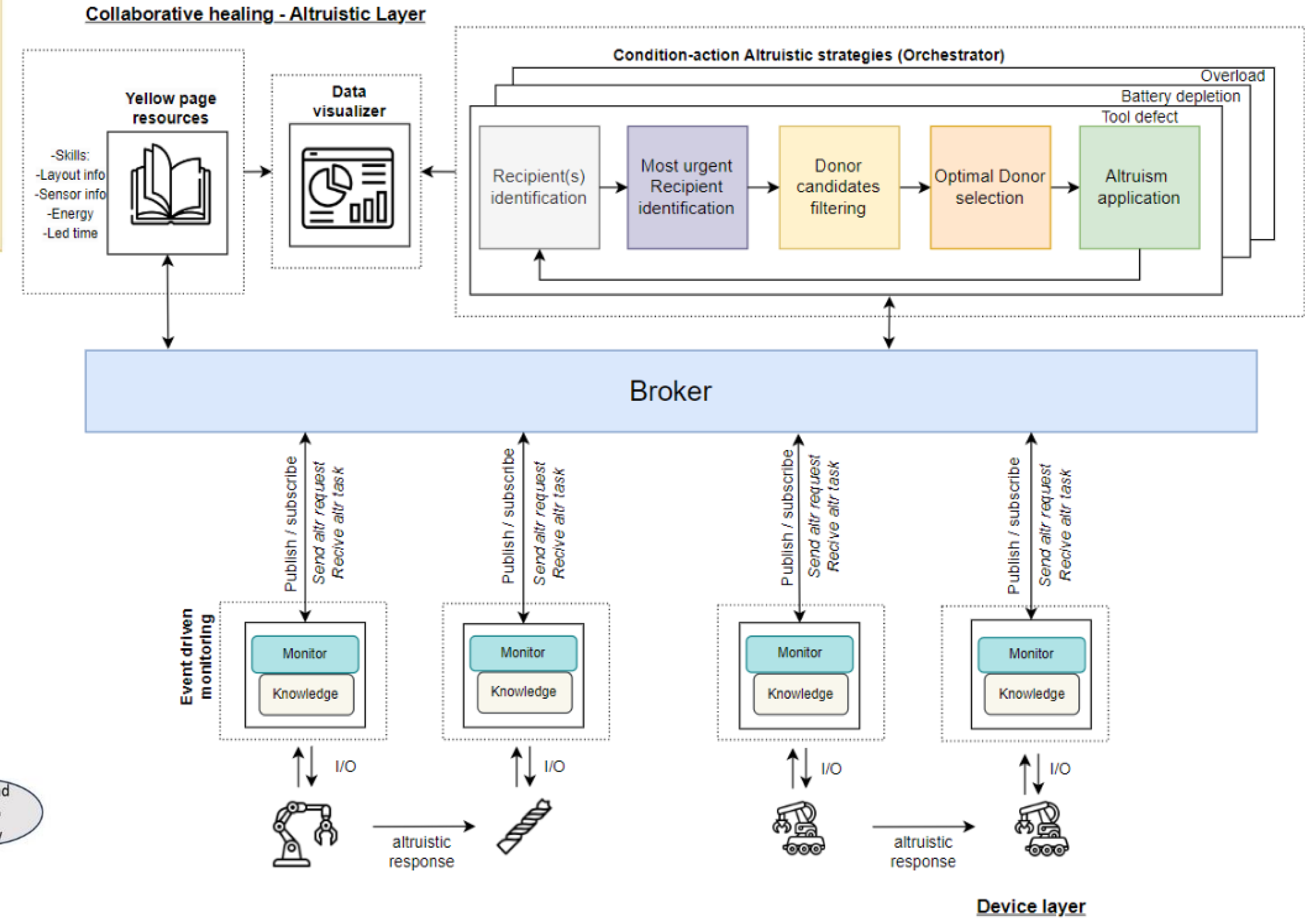

Figure 6. Altruistic-based framework for collaborative healing operations

RESULTS

A simulated based shop-floor has been developed in Netlogo to understand the preliminary implications of the proposed concept.

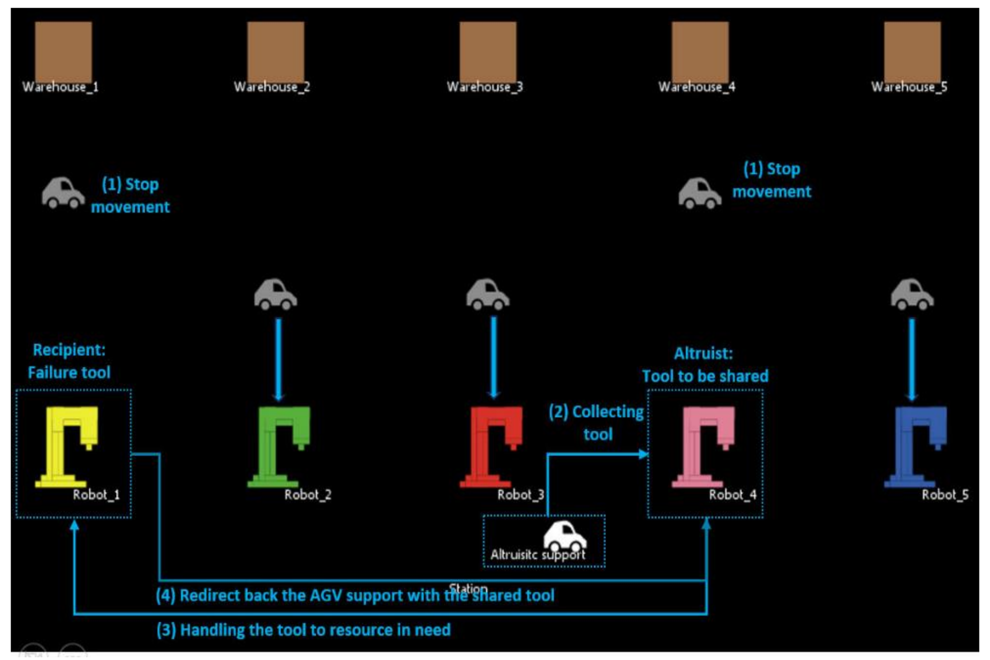

Figure 7. Simulated shop-floor in Netlogo

Requirements for R1	
Application	pick & place
Payload	> 1
Allowed tool condition	> 80%

Robot	Payload (u)	Tool condition(%)	Due time(u)	dist (u)
R2	1.2	93	5	18
R3	1.5	89	5	10
R4	2.0	92	5	18

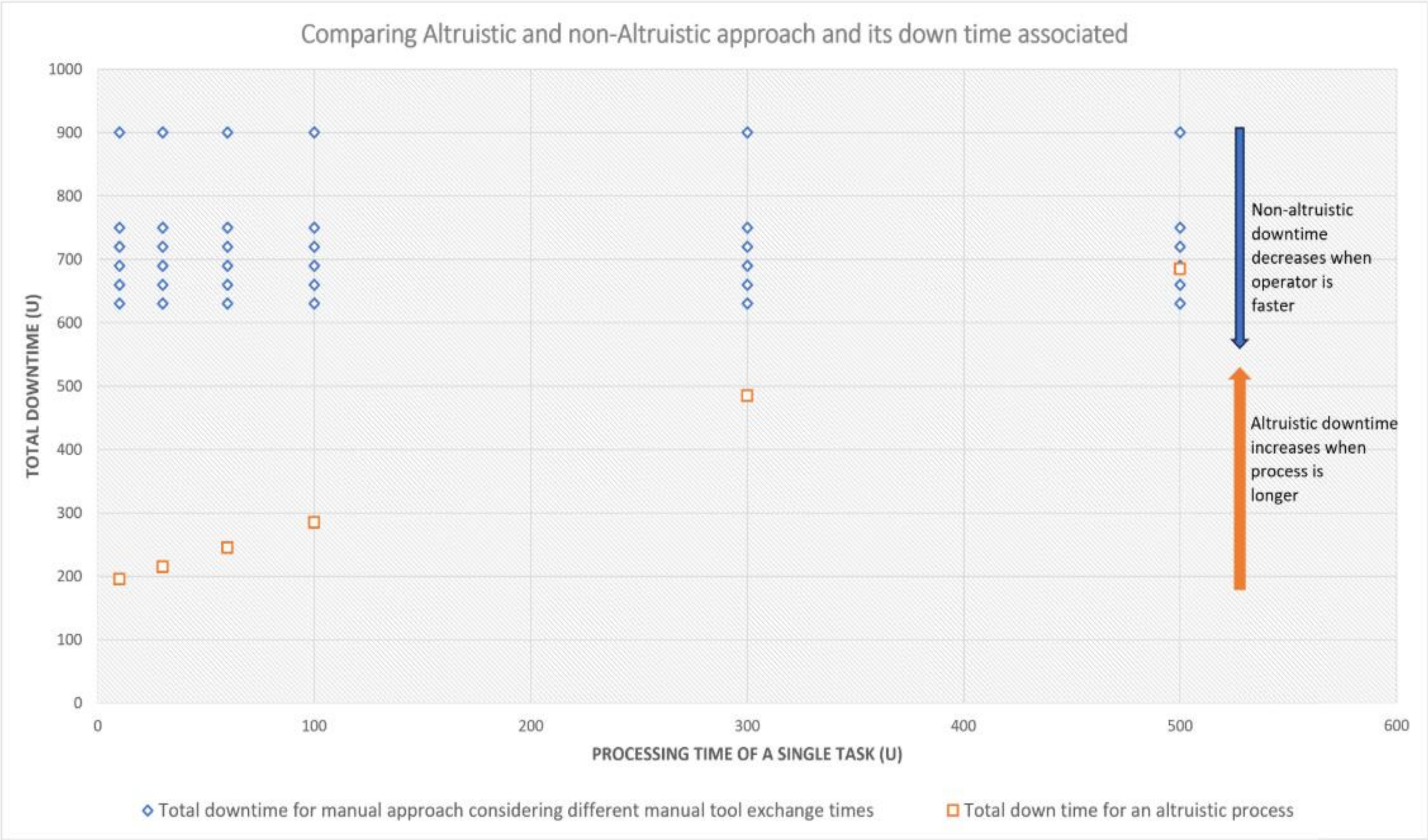

Figure 8. Comparing Altruistic and non-Altruistic approaches and its downtime-associated

CONCLUSIONS

(RQ1) There are several challenges in the line of self-organized smart manufacturing, especially in the field of biologicalisation, complexity engineering, and integration of other self-x ideas, i.e., self-healing.

(RQ2) Collaboration and self-organization can provide several benefits for a self-healing approach, i.e., continuous operation, entities that can cure each other are some examples.

(RQ3) This work explores a novel approach for collaborative healing behavior among manufacturing resources, inspired by altruism observed in animal species, i.e., vampire bats. The approach involves assigning two roles: Altruistic/Donors and Recipients and utilizes a broker and publish-subscribe mechanism for information exchange.

(RQ3) Multi-criteria decision-making is incorporated to determine the optimal donor candidate for support, showcasing the potential for self-organized healing and maintenance tasks.

(RQ3) When applying a non-altruistic (manual) and an altruistic (automatic) approach, it was possible to observe that generally, the altruistic outperforms the non-altruistic one. For a minimum processing time, the downtime is drastically reduced when having an altruistic approach (almost 3 times)

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