Université Grenoble Alpes

PhD Subject
Ecole Doctorale MSTII

A collective intelligence approach for reuse-oriented decision support in circular design and remanufacturing

Projet IDEX CDP
CIRCULAR

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Subject Description :

Context

Circular Economy Creating circular industrial systems able to transform post-used products into new products require reuse-oriented strategies, resulting in component remanufacture that leads to the manufacture of totally new products from the transformation of post-used components [Brissaud and Zwolinski, 2017].
The reuse strategy is a manufacturing strategy driven by market conditions, both customer wishes and material procurements. The new product differs from previous products. Repurposed products are products that are built for a different purpose and belong to a different product family. Upgraded products are products of the initial family that get different functions and performances. Re-purposing and upgrading a product implies the interaction of multiple areas of expertise from all along the value chain to integrate the different constraints related to the product, the process and its resources, or the business model [Bauer et al., 2017]. In many cases, the customer also acts as a stakeholder.

Internet of Things and Multi-Agent Systems In general, the Internet of Things (IoT) can be defined as : “A global network infrastructure, linking physical and virtual

objects through the exploitation of data capture and communication capabilities. This infrastructure includes existing and evolving Internet and network developments. It will offer specific object-identification, sensor, actuator and connection capability as the basis for the development of independent federated services and applications. These will be characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability [Moisescu et al., 2010]."
IoT is a potential way of providing real-world entities with certain degree of "intelligence" so that the required level of context awareness can be achieved. Using IoT in manufacturing make then possible to consider the different systems involved in manufacturing as multi-agent systems. [Xing et al., 2011, Wang et al., 2016]
By using a social metaphor, the multi-agent paradigm offers a powerful framework for autonomous behaviors, social, organizational and cooperative exchanges needed for these kinds of artificial complex systems [Jamont and Occello, 2015]. Autonomy is one of the main concepts in the multi-agent issue : it is the ability of agents to control their actions and their internal states. Adaptation allows an agent to reason about the quality of its work according to constraints or incomplete data. The autonomy of agents implies no centralized control at a system level. An agent can be endowed with communication capabilities. Multi-agent systems aim to build collective intelligence systems. Nodes are not only autonomous but rather social entities. Agents are able to communicate, but also to interact adapting dynamically their interaction mode. The objective is not only to manage a system or to make a system adaptive but also to produce a collective emergent behavior [Wood and Galton, 2009].
Designing a Multi-Agent System (MAS) leads to find a way to build local agents structures and behaviors to drive the system of agents produces a particular global structure or a particular global functionality.

Manufacturing and Multi-Agent Systems Multi-agent systems have addressed with success manufacturing problems for a long time [Shen et al., 2003, Wang et al., 2016]. In the field of circular economy, we can find recent multi-agent contributions to the global process modeling [Gómez et al., 2017, Xing et al., 2017] or on particular steps like disassembly [Sathish et al., 2015] or product collection [Xing et al., 2011]. Our objective is to demonstrate the relevance of multi-agent systems on human-centred design and manufacturing.

Expected Contribution

Theoretical contribution We propose to focus on the re-purposing phase of the re-use oriented process. The aim of this thesis is to study a multi-agent model for a re-purposing-oriented manufacturing system (Figure 1). Taking benefit of the collective intelligence capabilities, it will be a decision making support system able to integrate variability of inputs availability and uncertainty (openness), highly adaptation to market, humans (high-level knowledge like business, values, personnal preferences) and to very diverse technical constraints (quality, processing, storage constraints ...) and able to integrate multiple areas of expertise required interactions.
We argue in favor of an agentification of collected components, material, parts, production resources by means of IoT techniques. Agents will be avatars of physical objects representing them and enriching them on a virtual level. Agents will be able to interact directly or indirectly with them through information systems, machines or human operators.

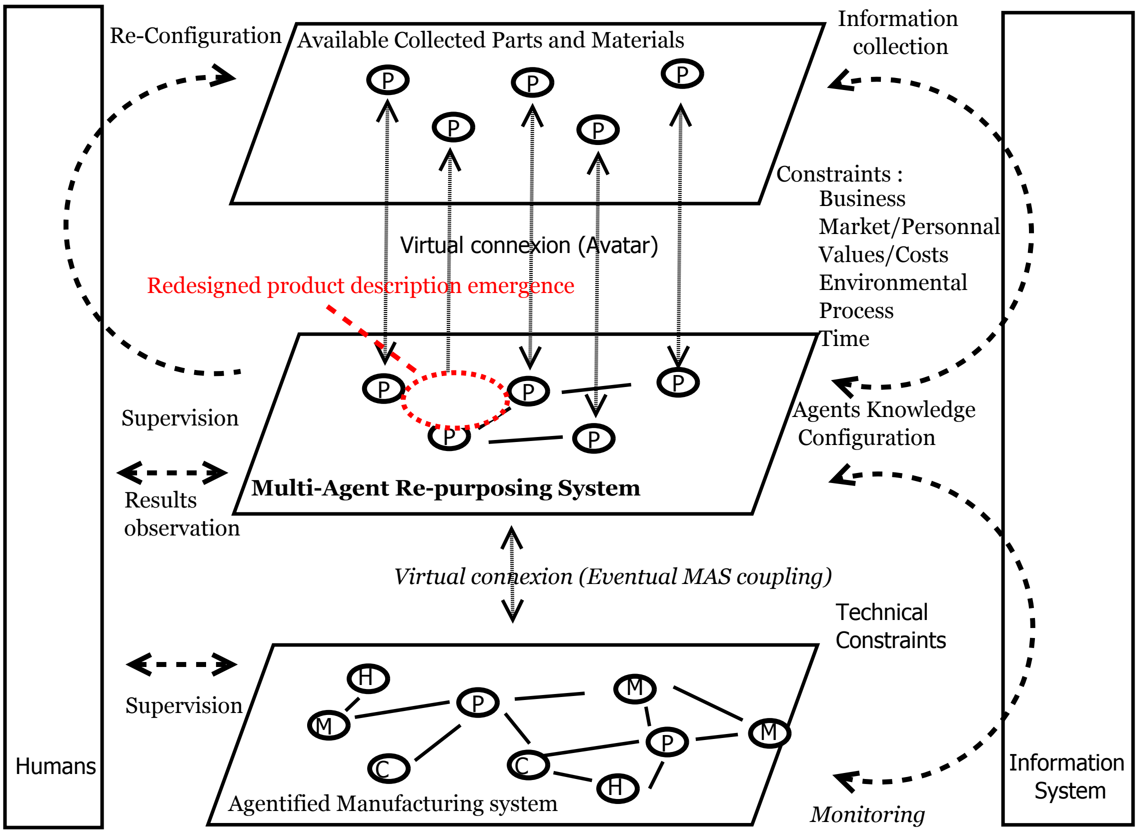

FIGURE 1 – Overview of the model

In order to achieve collective intelligent behaviors for agents, we will have to define :
- local knowledge (components constraints)
- global constraints as social norms and obligations [Conte and Paolucci, 2014] (process constraints)

At a virtual level, they will implement strategies of negotiation to build dynamic coalitions (organizational structures) corresponding to new proposed assemblies. The choice of the best suited assemblies will be ensured through a social attraction mechanism inspired from social sciences, like models issued from small groups dynamics [Lavy et al., 2015, Puurtinen et al., 2015].
Supervision mechanisms will be introduced to make possible interaction between the system and humans [Hoang et al., 2012].
The multi-agent system able to achieve a real socialization of the remanufacturing process [Tao et al., 2017].

Practical contribution The multi-agent model will be simulated using MASH. MASH is a tool to develop multi-agent systems able to interact with physical devices or connected environments [Jamont and Occello, 2015]. Experiments will be made using real world credible data. The development will be guided, for example, by the following use case :

1. CC, the Circular Company, is specialized in designing specific personalized products and in manufacturing it from post-used components that were collected. CC owns its own production system to re-manufacture components and assemble the new product.
2. A customer asks for a product A to the circular company. The engineer of the circular company must design both the product A* that cover the product A demand and the whole manufacturing process to get it. The resources available to manufacture the new product are those of the CC production system and the set of collected products, parts and components. The engineer drives and mediates the proposals of the design system. When appropriate, the engineer and the customer negotiate some elements of the final product regarding the initial wish.

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