Multi-criteria Process Optimization for Mass Customization

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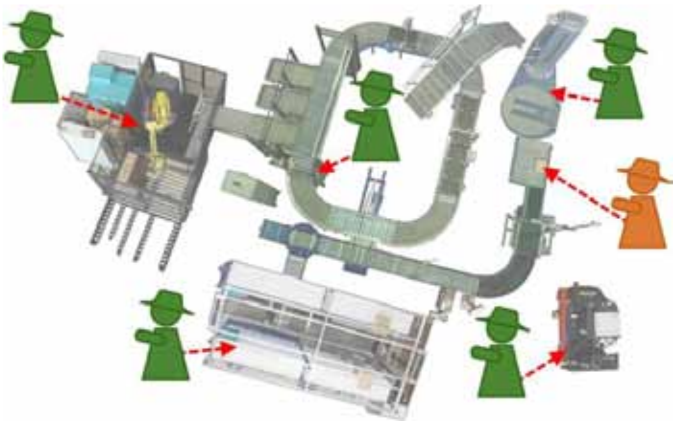
Since it was first introduced in 1987, the concept of Mass Customization gained favourable interest by several authors and quickly turned into a wide spread research area. Mass Customization is defined as an approach to manufacture customized products for individual consumers with means of mass production without significantly increasing production costs or selling prices. The implementation of Mass Customization in the real world is restrained by the limits of assembly segmentation and lack of autonomy in supply chains. Hence, Future Project Industry 4.0 suggests, that loosening those limitations and implementing autonomy in supply chains by applying Cyber Physical Systems and the Internet of Things will be the key enabler for the fourth industrial revolution.

Before autonomy can be implemented in production facilities and in-house logistics, several aspects have to be taken into consideration. Some researchers already emphasized, that a trade-off between costs and benefits has to be managed. Others suggest the consideration of energy consumption and costs of active and idle machines. Another factor that may be relevant is the speed of each station and the synchronisation of production steps. It is likely that parameters and their weights vary between different facilities. Additionally, synergetic effects may emerge between the various factors. It has to be determined which factors can be generalized and which factors depend on the given facility. In any case, a multi-criteria optimization problem must be solved to maintain and improve efficiency.

An Agent-based Approach

Currently, Computer-aided Production Planning (CAPP) is considered a valid solution to realize Mass Customization efficiently. However, centralized CAPP does not allow autonomy of any machine during the overall production process. When decentralizing the planning process, decisions will be made locally by the various machines. To further maintain efficiency, the multi-criteria optimization problem must be solved in a decentralized way. Common knowledge (e.g. goals and policies) has to be shared between the various machines. Therefore, application of agent technology is a promising approach.



In context of Artificial Intelligence, an agent is a software program which is defined as an autonomous entity with the capability of reacting upon changes in its environment. For a more detailed definition of a specific agent, four components have to be considered: Performance, Environment, Actuators, Sensors. Performance describes the goals the agent wants to reach and the rules it has to follow. Environment describes the agent's world model, including static and dynamic factors, which may include other agents. Additionally, every agent has two sets of interfaces: One set to perceive the environment (Sensors) and one set to manipulate and interact with the environment (Actuators). Additionally, agents can be divided in four different classes: Simple reflex agents which only react upon recent events without a concurrent world model or any knowledge about previous decisions; model based reflex agents which have an internal model of the current state of the environment; goal based agents which are working towards reaching specific goals; utility-based agents which apply a utility function to choose

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the most efficient way to reach their goals. Furthermore, machine learning methods can be applied to refine the decision making process of an agent.

Multi-Agent Technology in Logistics

Multi-Agent Systems (MAS) are suitable for real-world application and simulation of systems where local decision making and dynamic reactions on events are focused. During the last decade, MAS have been used to solve various problems of the logistics domain. Developing an appropriate agent model is crucial for this research. Therefore, it is useful to consider several questions regarding the given scenario to decide if MAS can be applied and how the agent-model should be designed. Amongst these questions, you will find the following: What is the purpose of the model? What will the agents be in the model? Who will be making decisions? What is the environment? How do the agents interact with the environment and/or other agents?

As stated above, the purpose of the model is to find a decentralized solution for a multi-criteria optimization problem. Even though the model will be developed for simulation purposes, it should be easily applicable to real-world systems like the Log*Dynamics* Lab. Within this model, every machine (and probably every product) will be represented by a dedicated agent.
Three different strategies for decision making could be applied, because decisions could be made by machines, products or both of them. It has to be determined which approach is the most promising. While interaction with the environment strongly depends on the type of machine, all interaction between agents will be handled by exchanging messages using a standardized state-of-the-art communication language (FIPA-ACL).

Considering that solving the multi-criteria optimization problem is a global goal within the facility, all agents should be at least utility based-agents. The application of machine learning is not necessarily required but should be considered anyway.

Real World Application

Within this research project, an agent model will be developed and implemented in simulation software and a real world testbed provided by the LogDynamics Lab. While large-scale simulation requires a dedicated supercomputer, the software for a single agent will run on conventional hardware products like Personal Computers (PCs) and Programmable Logic Controllers (PLCs). Therefore, the agent model could be adapted to PLC-controlled machines at reasonable cost.

As stated before, the decentralized agent-based approach will increase flexibility and robustness of inhouse logistics in production facilities or warehouses. The results of this research will answer the question how agent-based technology can be used to decentralize planning within a given facility while maintaining or even improving the overall performance. By answering this question, this research project will provide valuable insights for the development of future facilities and therefore take another step towards autonomous logistics.