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Modeling of a production system using the multi-agent approach

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Abstract. The method that allows for the analysis of complex systems is a multi-agent simulation. The multi-agent simulation (Agent-based modeling and simulation - ABMS) is modeling of complex systems consisting of independent agents. In the case of the model of the production system agents may be manufactured pieces set apart from other types of agents like machine tools, conveyors or replacements stands. Agents are magazines and buffers. More generally speaking, the agents in the model can be single individuals, but you can also be defined as agents of collective entities. They are allowed hierarchical structures. It means that a single agent could belong to a certain class. Depending on the needs of the agent may also be a natural or physical resource. From a technical point of view, the agent is a bundle of data and rules describing its behavior in different situations. Agents can be autonomous or non-autonomous in making the decision about the types of classes of agents, class sizes and types of connections between elements of the system. Multi-agent modeling is a very flexible technique for modeling and model creating in the convention that could be adapted to any research problem analyzed from different points of views. One of the major problems associated with the organization of production is the spatial organization of the production process. Secondly, it is important to include the optimal scheduling. For this purpose use can approach multi-purposeful. In this regard, the model of the production process will refer to the design and scheduling of production space for four different elements. The program system was developed in the environment NetLogo. It was also used elements of artificial intelligence. The main agent represents the manufactured pieces that, according to previously assumed rules, generate the technological route and allow preprint the schedule of that line. Machine lines, reorientation stands, conveyors and transport devices also represent the other type of agent that are utilized in the described simulation. The article presents the idea of an integrated program approach and shows the resulting production layout as a virtual model. This model was developed in the NetLogo multi-agent program environment.

1. Introduction

One of the most important aspects of modern production systems is the pursuit for excellence through continuous improvement processes within the whole enterprise. Rising customer demand, significant shortening of product lifecycle, fierce competition with other market players, and environmental changes are the result of ubiquitous globalization. It empowers companies to react quickly and flexibly to the changing needs of their customers by taking steps to streamline their production processes at the system modeling stage. Advanced production systems are an intrinsic part of growing businesses, both

small and medium-sized as well as large corporations. The complexity and diversity of the components of the production systems makes it necessary, at the design stage, to develop models presenting various aspects of their structure and operation. An appropriately modeled production system should allow visualizing the processes that take place between the analyzed components of the system. Theoretical research with the use of models provides information and enables a broad qualitative and quantitative assessment of the phenomena occurring inside the analyzed systems. Simulation modeling is one of the methods that can be used to significantly reduce the time at which products appear on the market, as well as to optimize processes within the system such as material flow, inventory reduction, etc. [2-5]. Achieving a certain financial result is not always the goal of system modeling. It is often that the result of simulation is used to improve the system reliability [6-8].

From the point of view of complex systems modeling that provide co-processing and self-organization, it is crucial to create solutions with greater autonomy in terms of reconfiguration and its context. Due to the fact that internal processes are distributed and create a network of mutually interrelated relationships, a change in the configuration of one process can affect the course of others that are interrelated to a greater or lesser degree. It is therefore right to search for solutions with greater autonomy in terms of reconfiguration and its context. For this purpose, simulations based on multi-agent logic could be one of proper approaches. Applying this approach it is much easier to reflect the actual process flow in the production system, and individual components of the process can automatically obtain information to accomplish a specific task [9-17].

2. Methodology of simulating modeling of a robotic workcell

Multi-agent systems (MASs) are not a new solution designated for simulating complex system behavior but they enjoy the interest of scientists. These systems are based on the use of agents as representatives of the system components or other programs. In literature there is no one common definition of an agent although in most of them they are described as the unit which perfectly matches the following characteristics [18-20]:

- **autonomy** - it has some control over his behavior and can act without human intervention or other program one,
- **cooperation** - the ability to interact with other agents to solve a problem,
- **target orientation** - not only to respond to changes in the environment, but also to take the initiative to do so,
- **communicative ability** - both to communicate with other agents as well as with people,
- **reactivity** - reacting to changes in the environment,
- **proactivity** - taking independent actions without waiting for stimuli from the environment,
- **possibility of inference** - decision-making on the basis of acquired and being acquired knowledge (using various artificial intelligence techniques);
- **adaptability** - allows an agent to adapt to changes in the environment basing on the experience gained by this agent.

Of course, some of these characteristics do not only define the distinct properties of an agent, but they could include each other. The agent ability to autonomously act in a group means the ability to participate in high level interactions, such as cooperation or negotiation. Especially important is cooperation, which allows agents to achieve goals beyond their individual capabilities. Collaboration is considered to be one of the most attractive features of a multi-agent approach, and therefore a multi-agent approach opens up great opportunities for implementation in support of the design process [21-23].

One of the areas of implementation such approach is the issue of modeling the robotized production systems. The most common of them is a robotized workcell. The robotized production workcell could be modeled as a multi-agent system in the form of interconnected components. In this conception particular agents represent the individual components of the workcell. The structure of the analyzed workcell could be presented as a dispersed one. The term dispersed means that all elements of the workcell are independent component with their own control systems and programs. Their

cooperation is forced either by time scheduled operation or by signal linking or by the supervising system. In figure 1 is presented a schematic view of a flexible production workcell. The flexibility of this production system is provided through computer control systems allowing dynamic programs exchange and through automated system of tools and tooling exchange.

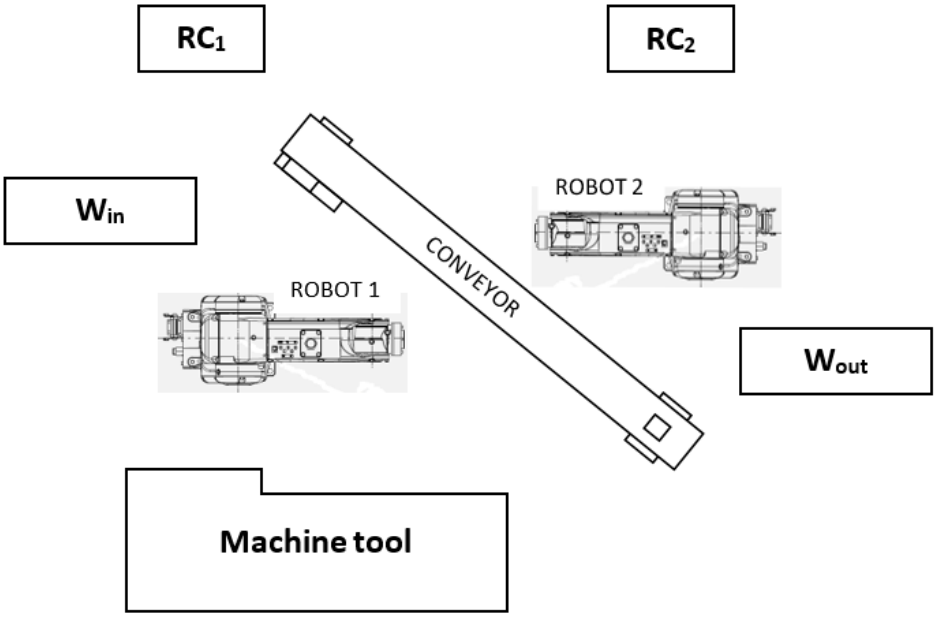

Figure1. Model of a robotized production workcell.

The considered workcell consists of the following elements:

- two industrial robots Fanuc ArcMate 100iB,
- robots control systems (RC_1 and RC_2),
- CNC lathe Emco Concept Turn 155,
- conveyor,
- input buffer (W_{in}),
- output buffer (W_{out}).

All components of the workcell are signal linked and have the ability to communicate with each other. The signal bus transfers the information (0/1) about finishing the realization of particular parts of the control programs of individual components.

Comparing the presented structure of the workcell one could see that it is possibility to make analogy between this system and a multi-agent one. Each component could be represented by an agent corresponding to him. In this case the multi-agent approach ensures full autonomy of individual components of the workcell (machines and equipment) and provides the programmable coordination (integration) of these components (agents). To increase the reliability of the system in the task are divided in such a way that each robot performs its part, but it is also capable to perform the part or all of tasks of the other robot.

3. Model and simulation of a workcell using ant swarm logic

Such described robotized workcell could be modeled as a hierarchical agent-based system. Its holarchy (organization forming the structure of system interdependencies) is presented in figure 2. In comparison with the workcell scheme it is more complex. It is caused by the more sophisticated process of decision making process in such self-organizing system. The organization of the production

process, conducted in that workcell is supervised by the coordinator agent. Basing on the implemented knowledge concerning the process itself this agent coordinates selection of main resources of the process and main components of the workcell. The processes of coordination of resources and components itself are supervised respectively by the resources agent and components agent. They had to coordinate to ensure an efficient operation of the workcell. Of course the operation of each component and each resource is supervised by corresponding to them agents of the lowest level.

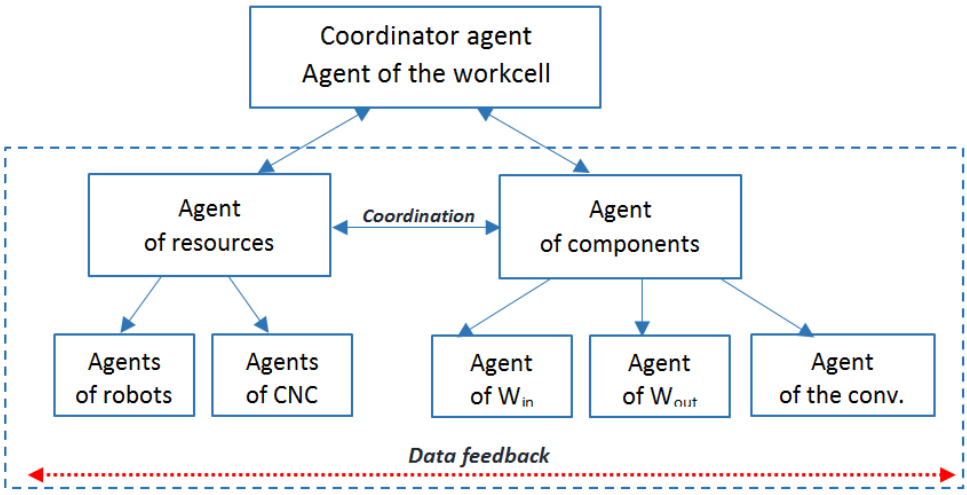

Figure 2. Proposed holarchy of the system.

The system in such structure has been implemented in the NetLogo environment. It is presented in figure 3. NetLogo is special environment designated to model and simulate the behavior of different natural and artificial systems. It could be also used to study the influence of different parameter on the changings in the systems responses. It is designated as an environment utilizing the concept of self-operating agents.

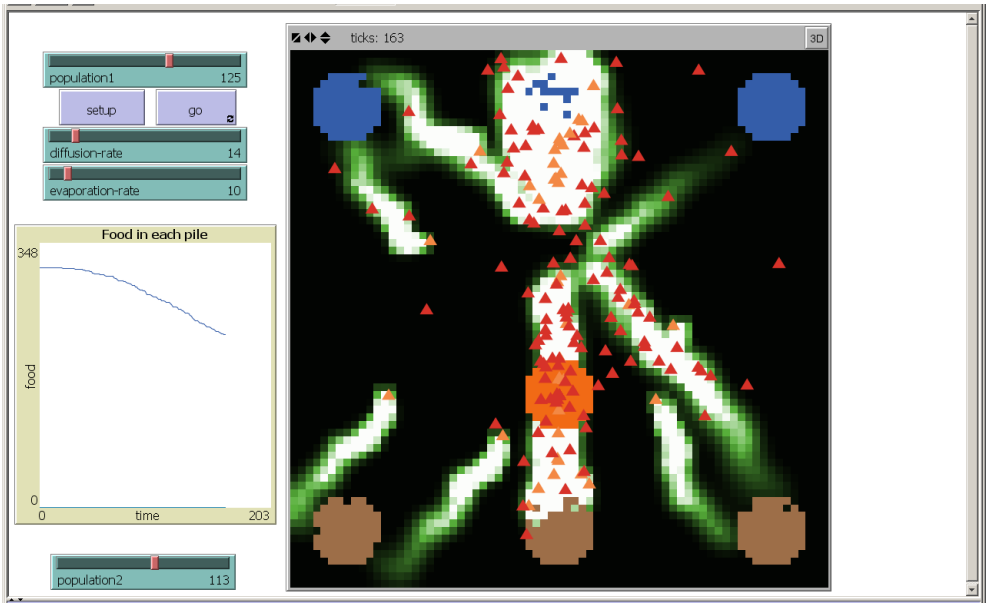

Figure 3. Conception of the agent-based manufacturing system.

The idea of the system work was based on the utilization of multiple ant colony (MAC) approach as the tool for multiple objective optimizations [24]. The hierarchy of MAC is similar to the holarchy presented in figure 2. In MAC, each group of agents corresponds to a colony of ants, and routes defined by agents correspond to the pheromone routes marked by particular ant. In presented example ants are represented by triangles which correspond to the manufactured items and transport routes are marked in white. Adopting this approach it is expected to reduce the likelihood that all mobile agents establish connections using only the optimal path.

4. Conclusions

Modeling and simulation as a special approach to the design process allow determining essential parameters of the created technical system. In the presented paper the idea was consider with modelling the system of components in the robotized workcell and related with this issue planning production routes. The proposed conception of system designing bases on utilization the NetLogo environment. It is used to utilize the multi-agent approach. The swarm logic is used as the tool of self-organizing of this system. Initial results show that it is possible to determine the general structure of the designed system of the robotized workcell and the general scheme of functioning in the form of simplified schedule of its operation. Utilization of the NetLogo environment allows as well conducting different simulation tests, to study the influence of different disturbances on its behavior. Secondly it becomes visible that utilization of the artificial intelligence solution in the form of an ant algorithm let to obtain a certain extent of the autonomy of the design process.

The presented solutions are preliminary ones. They could include in next investigations other constructional features like material or dynamic ones. But on the other hand the allow identifying problems and solutions that erases in the proposed approach. The issue that should be particularly investigated is the mechanism and conditions of knowledge exchange between the independent agents of the analyzed system as well as between them and supervising agents. It is related with the assumption concerning the limited knowledge of the agents of the lowest level of operation.

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