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Modelling of a production system using the multi-agent network approach

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Abstract. Since robotic systems become increasingly widespread in manufacturing environments, the need for improving production efficiency is the key factor for applying robots in industry. There are many different reasons involving robots application for manufacturing task realization. The most common reasons include their reliability, high quality of work, flexibility, inherent accuracy and repeatability. The approach to the problem of manufacturing processes robotization has changed a lot over several last years. In this article is presented the approach based on multi-agent systems approach resulting in the application for supporting functioning of the system of robotized manufacturing workcells. Complexity of the components created robotized workcells causes, that already at the design phase, it is necessary to develop models presenting various aspects of their structure and functioning. These models are simplified representation of real systems, allowing predicting some behaviour or responses what leads to systematize knowledge about the designed workcell. All of these factors involve, as the consequence, the additional difficulties associated with the process of decision-making. They concern, among other, on the coordination of components of such distributed system like a workcell and on providing the access to the required information, thereby generating unnecessary costs. The aim of this approach is determining the method for a flexible response and preventing situations that might contribute to delay of the robot task. The virtual system was modelled and simulated in common robot offline programming software.

1. Introduction

The current technological progress determined to a large extent the dynamic development of industrial robotics, which is one of the main directions of economic development in the industrialized countries. The approach to the problem of robotization, over several years, has changed a lot. The increased awareness of the competitive advantage offered by the use of robotic production systems meant that industrial robotization ceased to be perceived as a future solution, albeit somewhat abstract. Robotic production systems enable effective use of both human resources and the machine park, thus contributing to the improvement of quality and quantity of production and environmental protection [1].

Despite considerable improvement in the efficiency of production processes which has occurred in recent years, adapting production to the changing environment is very difficult, especially that the changes currently underway are just the beginning of a long-lasting process of adapting to the growing demands of the market. The concept of “Industrie 4.0” (original German form), enabling the connection of machines and devices within digital ecosystems, plays an increasingly important role in global production. The gradual evolution of production processes (see figure 1), and in particular the introduction of new technologies for a wide range of applications in the enterprise, unifies the real world of production machines with the virtual world of the Internet and information technology. Currently the rate of observed changes increases rapidly. It is related with development of electronic industry, computer science industry and informatics industry [2-8].

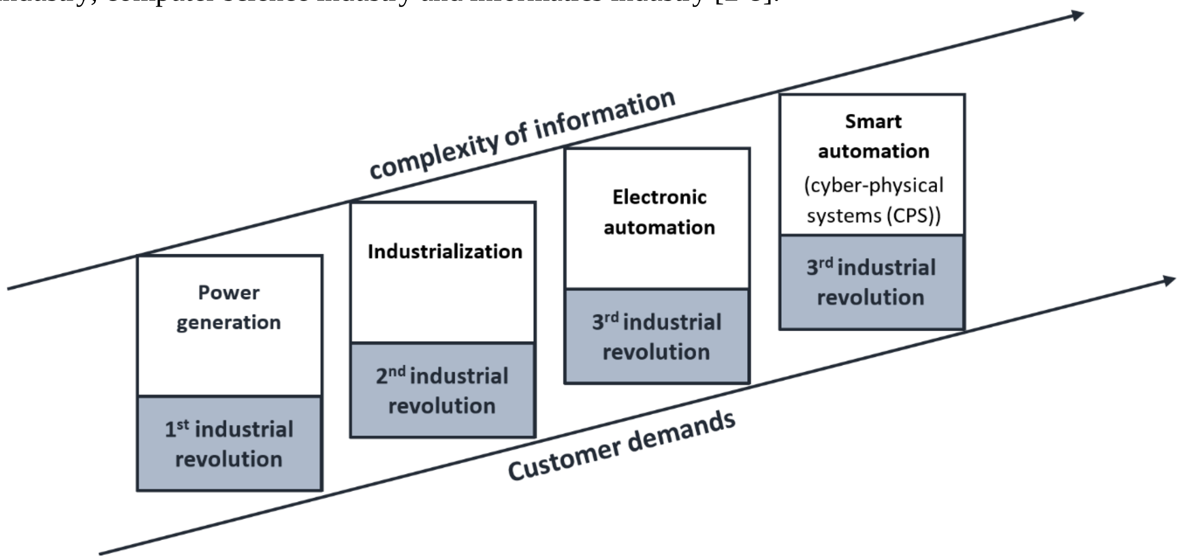

Figure 1. Industrial revolutions.

The fourth industrial revolution that is currently carried out concerns the comprehensive digitization and automation of industrial production. There is no one generalized definition of "Industrie 4.0". It can be assumed that the fourth industrial revolution is a kind of concept of production digitization, and thus a full autonomy of the production system, based on close connections and communication between its various elements. In other words, "Industrie 4.0" means the integration of intelligent machines, systems and the introduction of changes in production processes aimed at increasing production efficiency and introducing the possibility of flexible product changes. The development of new digital technologies such as the Internet of Things, Cloud Computing and Big Data contributes to the creation of so-called production cyber-physical systems (Cyber-Physical Production Systems - CPPS). Production, cyber-physical systems are complete structures, including machines and devices with built-in sensors and actuators, along with the appropriate software for collecting, analysing and storing data. The CPPS systems make decisions autonomously and have the possibility for global communication through standardized communication interfaces with other CPPS systems. Advanced robotics based on a new generation of robots that are capable of learning, working and interacting with other robots and people is one of the main pillars of "Industrie 4.0". Such systems could be fully realized in the form of a multiple agent's system.

2. An agent technology

Multi-agent systems (MAS) could be describes as a system of cooperating, individual agents. Due to ability of MAS to autonomously respond to changes occurring in the environment in which they are embedded, they are a convenient tool for analysing, designing and applying in decentralized systems. An agent is an abstract concept of individual, independent unit being a part of the system. It is a unit embedded in a certain environment, which it perceives by means of sensors and with which it can interact with the help of effectors [12, 13]. Figure 2 shows the general form of an agent and its interaction with the external environment.

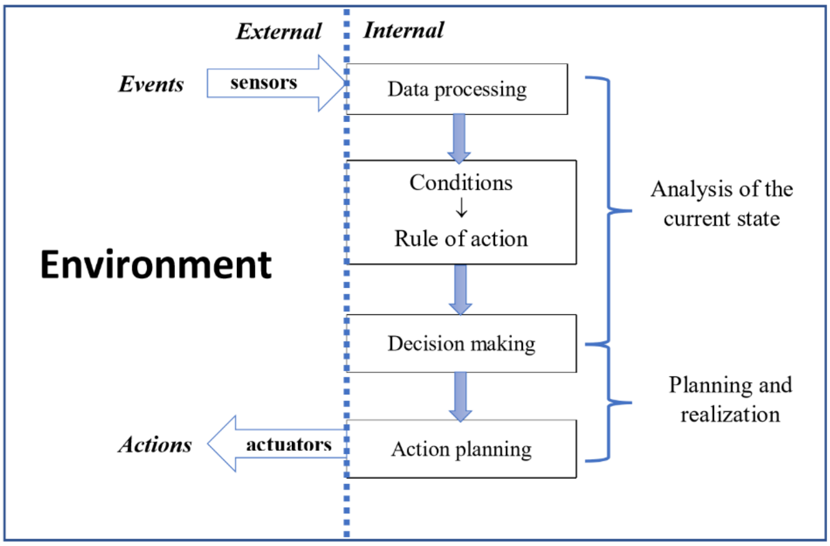

Figure 2. General form of an agent [14].

In addition, the agent is able to communicate with other agents (or users), to receive and process information, as well as to make autonomous decisions which are optimized to achieve specific objectives. In literature, an agent is described as a unit that should be characterized by the following features listed in table 1.

Table 1. Properties of an agent [14].

Feature	*Comment*
Autonomy	It has some degree of control over his behaviour and can operate without human intervention or other program.
Communication	Both with other agents as well as with people.
Cooperation	Ability to interact with other agents to solve a given problem of the whole system.
Reactivity	Responding to changes in the environment.
Goal attainment	Not only responding to changes in the environment, but also taking initiatives to cause them.
Adaptability	Allows to adapt to changes in the environment based on the experience gained by the agent.
Proactivity	Undertaking independent actions without waiting for stimuli from the environment.
Possibility of inference	Making decisions based on possessed and acquired knowledge (application of artificial intelligence techniques).

By connecting several agents together, MAS is created. It is important that in such system agents cooperate with each other in order to accomplish the earlier defined task.

3. The proposed architecture

The presented approach, in the form of hierarchical MAS is a very good solution to model contemporary production system that acquired the characteristics of the “Industrie 4.0” concept. In the paper is presented the system based on the model of a production robotised workcell. Designing a robotised production workcell is the process of combining components into groups, combining these groups into larger workcells or dividing large workcells into smaller ones. Combining or dividing take place from the point of view of the needs of the assumed tasks which should be implemented in these designed workcells [15].

A robotic cell can be represented by the form α|β|γ [16], where α is a vector defining the environment of machines and devices (machine environment), β – is a code characterising conducted processes (processing characteristics), and γ id the function of the system objective [17].

- α – machine environment, can be classified, equation (1), as:

$$\propto = RC_{m,r}^{g}(W_{s1}, \dots, W_{sm}) \tag{1}$$

where:
RC – Robot Cell,
W_s – Work station
g – gripper (single: g =1 or dual g = 2),
m – number of machine at each stage,
r - number of robots.

- β – processing characteristic refers to the list of system limitations, e.g. pickup criterion (free, no-wait, interval), part-type and so on,
- γ – objective function, for which e.g. the notation γ = μ means efficiency maximization.

The graphical representation of layers of a robotised workcell is shown in figure 3.

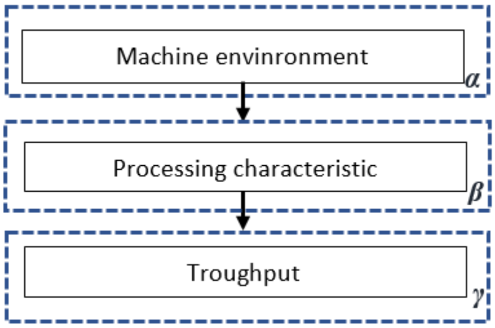

Figure 3. Robotic flow-shops [16].

In the case under consideration, the problem was limited to designing robotised workcells as representatives of a production system. It was assumed that the design of a robotised production workcell consists in selection of appropriate components, and indirectly agents representing the individual layers the α and β of a workcell. The γ layer is omitted, it is not considered. The structure of the proposed system is a holonic one [13], which consists of small, decentralized and, partially independent, modules concentrating around each other only key duties.

In addition, the system could be reconfigured, as well as equipped with new features (control functions) and modules. The system consists of a user interface, a database and cooperating agents of a holon structure. The database gathers information about the process and resources status, while agents have the option of receiving and analysing data and influencing the environment, e.g. selecting appropriate workcell components.

The structure of the proposed system is distinguished by four basic groups of independent holons, and namely:

- a group of holons representing the environment of machines and devices, otherwise responsible for available resources, which include:
  - holon of work station,
  - holon of robots,
  - holon of grippers,
  - holon of space requirements

- a group of holons representing the processing characteristic, which include:
  - holon of task relation,
  - holon of time-metric,
  - holon of pickup criterion
  - holon of part -time

Each of the holons (agents) contains detailed information on the tasks assigned to them. Agents combine with each other to form a structure of elements of the general form shown in figure 4. Connections between agents are conditioned by the need to exchange messages in specific situations and at a specific time. The presented connection structure should be treated as a set of relations contained in the workcell, and the information contained in the sent messages as information about the state of the object.

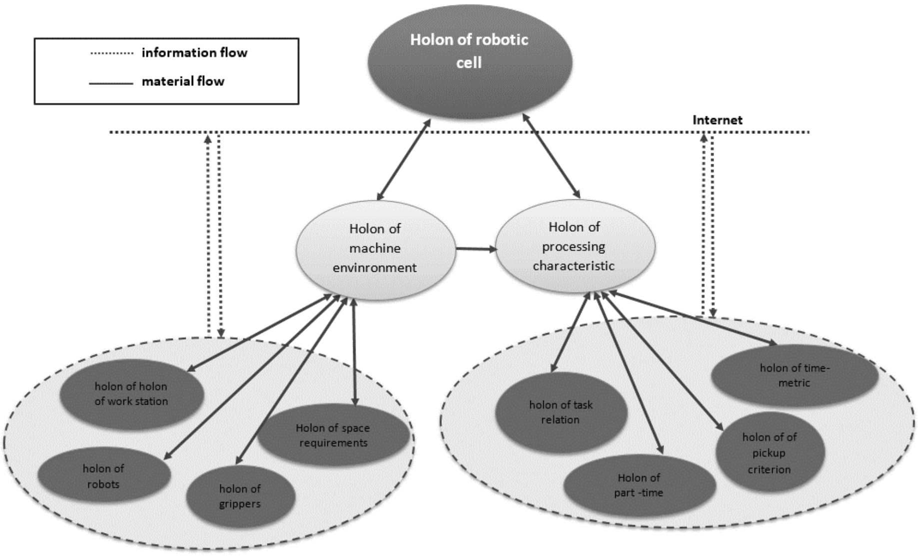

Figure 4. The holon-based model of the considered system

4. Conclusions

The paper discusses the possibility of utilizing multi-agent systems in supporting the designing process of a robotised production workcell. The presented considerations should be treated as a conception of the future solution of a functional advisory system supporting the completion of components of a designed workcell.

The concept itself of using MAS approach in designing is not new. Agent systems can replace human beings primarily in many decision functions making decisions faster and more accurately. The presented in the work considerations are only an introduction to further work related to the development of these systems and obviously do not exhaust all issues related to them, which require recognition of many problems and limitations, such as communication and interaction between agents. This is also the source of other, open problems of future research, which these considerations may generalize or constitute an incentive to take on new ones. However, it was shown that the MAS approach should be successfully applied in future systems of "Inductrie 4.0" concept.

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