Modelling and simulation of a robotic work cell

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Abstract. The subject of considerations presented in this work concerns the designing and simulation of a robotic work cell. The designing of robotic cells is the process of synergistic combining the components in the group, combining this groups into specific, larger work units or dividing the large work units into small ones. Combinations or divisions are carried out in the terms of the needs of realization the assumed objectives to be performed in these unit. The designing process bases on the integrated approach what lets to take into consideration all needed elements of this process. Each of the elements of a design process could be an independent design agent which could tend to obtain its objectives.

1. Introduction

In recent decades the technical, economic and social factors have largely determined the dynamic development of industrial robotics, which is one of the main directions of economic development in industrialized countries. The changing business environment in which production plants must operate makes new and unknown challenges and problems. Product lifecycle shortening, production costs minimization, ensuring the adequate quality and timeliness of orders, and acting in fierce competition with other subjects are just some of the factors with which must face companies operating in the global market[1,2]. It forces companies to respond quickly and flexibly to changing customer needs by installing capital-intensive machinery. From the economic point of view these machines should be used 24 hours a day, seven days a week. This is practically possible only with the use of manipulators and industrial robots. Robotized production systems enable efficient use of both human resources and stock of machinery, thus they contribute to improve the quality and quantity of production. The increasing importance of robotics in industry is primarily determined by the measurable benefits of its implementation. Robots are increasingly replacing humans in monotonous jobs, or requiring huge, unmanageable precision - modern industrial robots achieve the accuracy up to 1,000-ths of a millimeter. The increase in availability and the dynamic development of industrial robots have led to their implementation in almost every field of industry. Increasingly, systems with high levels of flexibility, automation, and reconfiguration possibility are emerging in place of classic manufacturing systems. The intensive development of industrial robotics is, obviously, a challenge for modern robotic engineers. Appropriate design and modeling of the manufacturing system is essential for the efficient integration of the workcell components and the proper operation maintenance of robotic production systems. The complexity and diversity of the components being the part of the robotized production workcells make it necessary to develop, already at the stage of designing, models representing various aspects of their construction and operation. For each production plant, there are a

large number of subsystems and factors that directly or indirectly affect the productivity, efficiency and synchronization of a production process at that plant [3-15]. The complexity of the issues involved in robotized production workcells designing requires searching the proper architectural solutions in the processes of designing, modeling and simulating these systems. From the point of view of designing complex systems that provide co-processing and self-organization, it is crucial to create solutions with greater autonomy concerning its reconfiguration ability and context. The solutions that can be used for aiding the process of robotized manufacturing workcells designing could be found in the area of multi-agent approaches. Among others it allows integrating distributed knowledge resources[16-18].

2. Multi-agent methodology of robotized workcells designing

A multi-agent system can be defined as a set of independent (autonomous) agents that occupy a certain place in the system and cooperate one with another. It should be noted, however, that in the literature there is no single, generalized definition of an agent or a multi-agent system. It is generally assumed that an agent is an abstract concept embedded in a certain environment that can benefit from certain knowledge resources, which is primarily characterized by its autonomy, reactivity, communicativeness, and collaboration with other agents. The agent acts on the basis of observations that reach him from the environment, and on which it could, to a certain extent, influence [19-23].

In the context of the methodology of technical means designing there is a great variety of approaches, both in terms of the structure of the designing process and the general principles for defining the design requirements for which the quality of the design action is determined [24]. The general scheme of designing of the constructional form of technical means according to integrative approach [24] is shown in Figure 1.
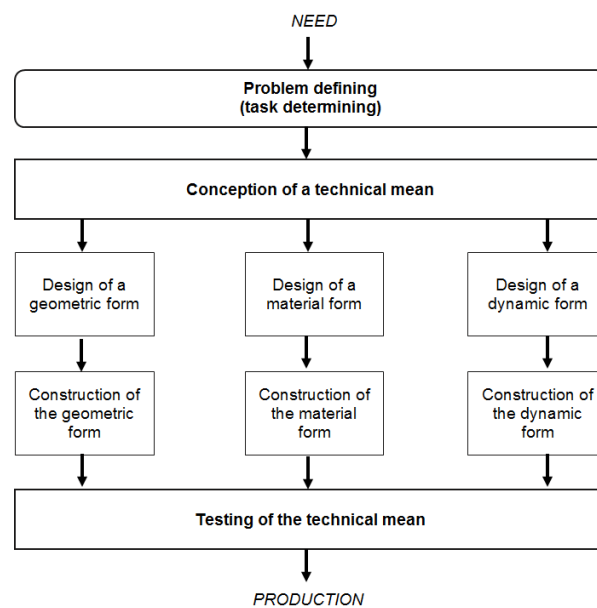

Figure 1. Process of technical means designing [24].

In the presented design process there are five stages:
➢ determining the problem arising from the emerging need,
➢ conception elaboration,
➢ designing process,
➢ constructing process,
➢ testing process.

The versatility of the presented method makes it possible to extend it to other fields of designing of complex technical means, including robotized production workcells.
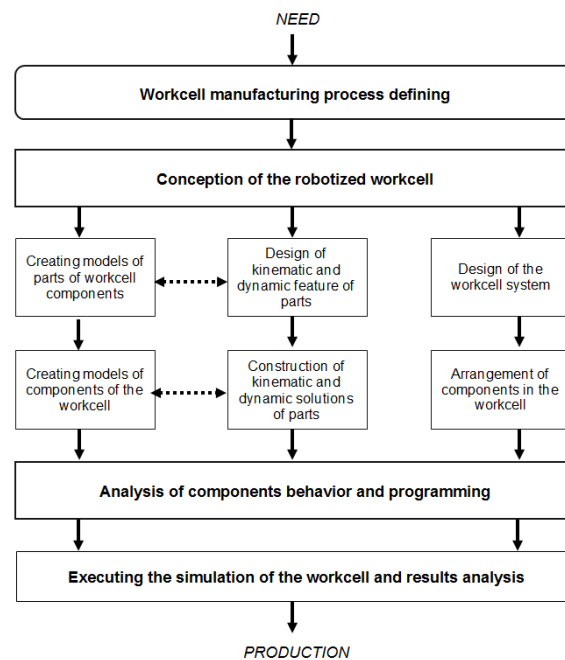
Figure 2. Proposed conception of a design process.

Regarding the designing and simulating the robotized production workcells the scheme, shown in Figure 1, takes the form shown in Figure 2, in which it could be distinguished several subsystems creating the system of a robotized production workcell. In the presented approach, the robotized production system is defined as the assembly of three subsystems of which the first two are mutually conjugated (operating simultaneously), and namely:

- ➤ the system of main components of a workcell (industrial robots, cooperating devices, interoperable buffers, system etc.),
- ➤ the system of kinematic and dynamic dependencies of elements (ranges of configuration variable, velocities of individual components, type of motion etc.),
- ➤ the system of arrangement of elements in a workcell - spatial organization.

It should be taken into account that all activities, conducted within the designing process had to meet one basic requirement – the integrity. The presented design process which includes the partial design processes could be expressed as multi-agent optimization in which each component (geometrical form designing, material design and dynamic feature designing) is an independent, collaborative agent whose primary purpose is to create the additive constructional form (robotized workcell design). This process is modeled as an agent system with broadly defined purposes, which exact formulation could be achieved during the process of system decomposition into smaller agent-based subsystems that exist - in a sense - independently. In other words, the design of a robotized production workcell consists in selecting the appropriate components of the workcell and indirectly the agents representing these components. The cooperation of system agents is aimed at achieving a poly-optimal solution.

The ability to split tasks into smaller items (subtasks) and their parallel execution by many units represented by agents could contribute to increasing the efficiency of the design process. Moreover it could be conducted partially in an autonomy way.

3. Methodology of simulating modeling of a robotized work cell

There is no one accepted definition of computer simulation in the literature. It is generally assumed that simulation is a method that involves performing numerical experiments on dynamic models

describing existing or planned systems. The main purpose of the simulation is to provide the user with knowledge about the behavior of the studied system or system over time [25].

The analyzed designing process of a robotized workcell could be more precisely defined as the mechatronic design process. It objective is to obtain very complicated output information about the modeled system. In this approach mechanical components of the mechatronic system are extended by actuators, sensors and modern digital online information processing systems [26]. To optimize the functional dynamic features of the mechatronic system one should take into account such factors as: geometrical, physical-topological, and mathematical relation linking components. The mechatronic design process includes the next simulation processes: the kinematic simulation, the dynamic one and the mechatronic function one [27].

The rivalry between constantly improved off-line and on-line programs contributes to the increased efficiency of robotic systems. Simulation is currently one of the most important techniques for modeling robotized workcells. Currently, almost all robots manufacturers offer virtual environments, where it is a possibility not only to program robots, but also to run full 3D simulations, taking into account the real work cycles of the controllers. Successively, the following stages are distinguished in the robot modeling and simulation process [28-30]:

➢ Stage 1. Modeling of a robot and components of a workcell,
➢ Stage 2. Arrangement of components in a workcell,
➢ Stage 3. Defining the kinematics of machines and devices,
➢ Stage 4. Defining the paths of a robot,
➢ Stage 5. Testing and verification of the created model.

The stages, presented above, should be preceded by a description of the set of characteristics of the system components and their interrelations. The stages 1, 2 and 3 relate to modeling a virtual workcell, i.e. selection, from the available set of models, the corresponding elements, their location in the system, and the kinematics of machines and devices. The step 4 includes defining robot paths, as well as collisions testing and their possibly corrections. Information from these stages is the input data to an internal preprocessor by which it is possible to visualize the processes taking place in the modeled workcell. If the process is not satisfactory, one can correct the placement of components in the workcell or change the paths (trajectories) of the robot. If the simulation meets the initial assumptions, the postprocessor generates the corresponding program for the robot. In the last step, after uploading the program to the robot, it is tested and calibrated. If the results are satisfactory, the end of the task is completed, otherwise the entire process must be repeated from the beginning.

4. Methodology of simulating modeling of a robotized work cell

The NetLogo environment has been used to analyze the problem of agent-based robotized workcell designing. NetLogo is a dedicated multi-agent environment that allows modeling and simulating operations of systems of different level of complexity. It is as well is a multi-agent programming language and it was designed for multiple audiences. Agents in NetLogo environment are one of the next forms (objects - turtles, patches, links and the observer). According to the programed rules they can operate cooperatively or competitive. Agents in NetLogo could operate concurrently, in order to explore connections between micro-level behaviors of individuals and macro-level patterns that emerge from their interactions.

The presented idea of the robotized workcell designing and the proposed its holarchy (the proposed structure of the workcell) were implemented in the NetLogo environment to test the possibility of the analyzed concept of agent-based workcell designing. For the analysis has been chosen the system of virtual stands linked together with transport routes (figure 3).
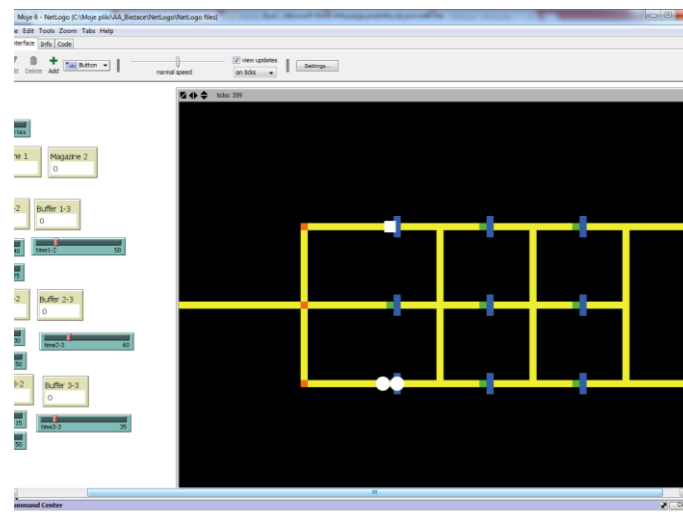
Figure 3. Conception of the agent-based manufacturing system.

The presented above virtual system consists of two types of agents. The first I represented by manufactured item (objects – turtle). There are two types of these agents representing two different processes being conducted in this production system. Patches are the second type of agents. They represent devices (blue), buffers (green) and transport route (yellow) in the system. The objective of the system is to terminate both two processes with the shortest worktime. It should be stated that this is the beginning phase of the system testing.

5. Conclusions

The main goal of modeling and simulation tests, within the designing process of robotized manufacturing workcells is investigation of the structure and functioning of created objects and to developing appropriate algorithms to optimize the work of the entire system. In this paper is discussed the possibility of utilization of multi-agent systems for aiding the process of designing, modeling and simulating of a robotized workcell. These systems can replace humans primarily in decisional functions allowing making decisions more quickly and accurately.

The considerations presented here are an introduction to the further development of this approach to the designing process. They obviously do not cover all the issues linked with the analyzed problem, as it requires identifying many other questions and limitations, such as communication and interaction between agents. Moreover, there are also other open problems of future researches, which could generalize these considerations or be incentive to undertake new researches in this area.

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