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Design of robotic work cells using object-oriented and agent-based approaches

A. Sękala* , K. Foit, W. Banaś, G. Kost

Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Polan

* Corresponding e-mail address: agnieszka.sekala@polsl.pl

ABSTRACT

Purpose: of this paper is to present agent-based and object-oriented approaches in the desingning of robotic work cells. The complexity of elements which form the robotic work cells causes that already at the design stage it is necessary to evolve the models that comply with different aspects of the conformation and principles of the operation of the workcell.

Design/methodology/approach: The use of agent-based and object-oriented approaches during the process of robotized workcell's design, allows i.a. to systematize the knowledge about the designed workcell and simplifies the definition and analysis of relationship between its components. Most modern systems CAD/CAM uses object-oriented structure. They do not allow the creation of a direct structure agents. It is therefore necessary to show the relationship between the object and the agent.

Findings: The relationship between object-oriented and agent-based model allow to fill the gap between them. Understanding of them could allow more efficient use of existing systems that are decicated for designing of robotic work cells.

Research limitations/implications: The presented considerations are only the introduction to the further work on developing these methods for the use during the design process of robotic cell, and clearly do not cover all the issues involved, hence there are also other open issues for future research that could generalize the researches or could be a starting point for a new ones. These problems may concern e.g.: development of appropriate methods of communication and cooperation between the agents or the definition of the new agents that can act autonomously according to their own algorithms.

Practical implications: The main objective is to build the base for modular and flexible system that will allow designing of robotic work cells using the methods presented in the paper. Due to high cost of such systems, there is no reason to make it from scratch. The better way is to integrate the existing applications and use the synergetic effect of such approach.

Keywords: Automation engineering processes; Robotic work cells, Agent-based approach; Object-oriented approach

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MANUFACTURING AND PROCESSING

1. Introduction

Today, in the era of globalization, and thus more and more versatile business environment, factories come face to face with new challenges and problems. The increasing demands of customers, shortening the product life cycle, balancing between cost of production, the quality and timeliness of deliveries, eventually coping with the strong competition are just some of the factors that the company must deal with, in order to operate at the volatile market. The company must quickly and flexibly respond to changing needs of the product recipient. Robotized manufacturing systems enable efficient use of human resources as well as the machinery, thus in order to improve the quality and quantity of production and the level of environmental protection. Robots are increasingly replacing human, especially in bad, harmful to health work conditions or during the monotonous work or activities that require enormous precision, which is not attainable for human. The dynamic development of robotics and wider availability of industrial robots has caused their implementation in many branches of industry. Nowadays, the most robotized branches of industry (in quantitative terms) are the automotive industry, electronic industry and production of metal, rubber and plastic parts. In recent years we can see the rapid grow-up of automation and robotics in the food industry.

The high flexibility of industrial robots, reliability and precision of work allows a large variety of implementations. The complexity and diversity of the components used in the robotized workcell causes that already at the design stage it becomes necessary to develop models, which take into consideration various aspects of construction and operation of such cell. Advanced robotic manufacturing systems are the integral part of developing companies, both those operating in the segment of small and medium-sized enterprises as well as large corporations.

Due to the fact that many systems, natural and artificial, is organized in a decentralized manner, the complexity of the problems concerning the robotized production cells requires to find the proper architectural solution of information system that integrates the components of a cell. From the point of view of designing complex systems that provide co-processing and self-organization, the key is to create solutions characterized by greater autonomy, associated with flexibility and contextuability. Some of such solutions that can be applied in a computer aided process of designing of robotized workcells are the object-oriented approach and multi-agent approach (MAS). Such approach enables easy integration of distributed resources of knowledge [1-17].

1.1. Object-oriented approach

The object-oriented approach comes from computer science and is dated back to the mid of 20th century. The beginnings of such method are the implementation of Simula 67 or Smalltalk programming languages and the use of object-oriented databases. Later, this approach has been used also in computer-based modeling, simulation, human-machine interaction devices etc [18].

The philosophy of an object is based on everyday experience. When a thing is considered-for example a table-then some observations could be made, like the shape of tabletop, the number of legs, the kind of finish, whether it could be folded or not, etc. This concerns to the particular table that somebody could see. Assuming that this person is in a furniture store, he could compare many tables by comparing mentioned properties one by one. In this way, describing some properties that may have different values for different tables, a "general model" of a table could be created. This abstract entity is a class. In other words, a class is description of the common properties of a set of objects-is a concept. The class could also contain methods that describes the actions performed with the use of objects. For example a class of office chairs (*OfficeChair*) could have the method for setting the height of seat (*SetSeatHeight*). The object is derived from the class and basically inherits the same properties and methods. In general we could define object as a set of properties (P) and methods (M) (Eq. 1).

$$O = \{P, M\} \tag{1}$$

The object relates with the real thing that is unambiguously determined-it is a phenomenon. The characteristic of the real thing is encapsulated inside the object as a set of data (properties and methods). Generally, the data are not visible in the object's environment and can be accessed by using methods. In order to communicate with the outer world, the object delegates some method and properties to be visible for other objects-creates the client interface (Figure 1) [2]. In such way, the risk of data damage is significantly reduced.

One of the very important property of the object-oriented approach is the inheritance [19]. It means that the object (child) could be derived from the other object (parent) and automatically inherits all methods and properties that are defined in parent object. The child object could have also implemented some additional properties and methods that are inherited by its child objects, and so on. The example of inheritance is shown in Figure 2. The class of milling machines could have defined some parameters like the size of workspace, maximum table load etc. Every particular milling machine, derived from this class will have implemented the same parameters.

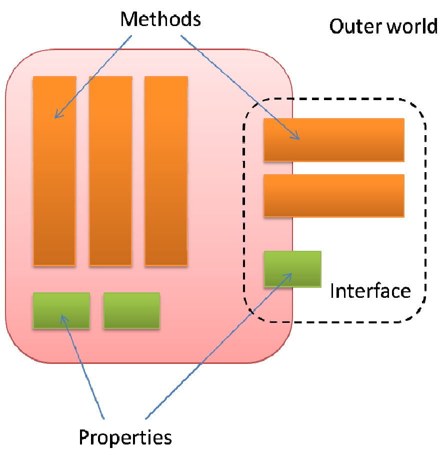

Fig. 1. The object with client interface

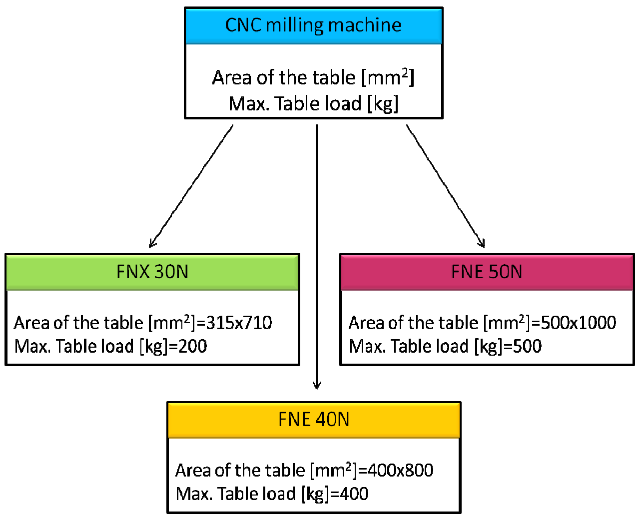

Fig. 2. The simplified idea of properties inheritance

The other important property of object-oriented approach is polymorphism [19]. In the simply words, the polymorphism means “one thing in many, different forms”. In the nature, polymorphism manifests itself i.a. by different colouring of individuals belonging to the same species.

In the computer science, the polymorphism is very often equated with subtype polymorphism [20]. In the Figure 3, there is the example of subtyping, where the supertype is *Dog* class and subtypes are objects, which describes the specific breed.

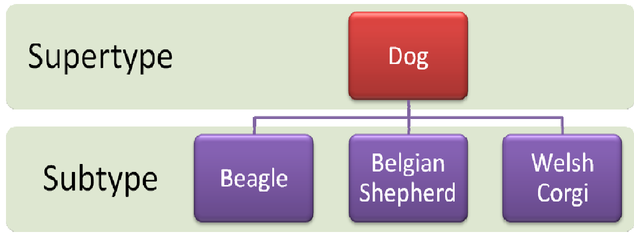

Fig. 3. Polymorphism-subtyping

Such approach allows to manage different objects using the same methods. For example, the method of use of steering wheel, brakes or transmission (manual or automatic) is (more or less) the same in almost any type of car-so it is enough to learn how to drive the particular car in order to manage to drive (almost) any car.

The object-oriented approach is widely used in computer-driven simulation systems as well as in CAD/CAM/CAE programs or databases. Concerning the robotized workcells, the objects could be used as description of the whole system and relation between machines, manipulated objects, storages etc. For example, a part of the object’s interface that represents the robot could be the set of inputs and outputs connected to sensors or effectors, the machine tool could be turned on or off using interface methods etc. Besides modeling (as it is used in computer simulation software), such approach also allows managing and programming of the whole system [21]. It is very important, because contemporary flexible manufacturing systems have distributed control systems that could “talk” to each other using industrial data networks.

Objects have a lots in common with agents and sometimes it is difficult to distinguish them. The matter is additionally complicated by the existence of many different definitions of the agent. Generally speaking, the agents constitute conceptually higher level of abstraction, being the “specialized” objects, embedded in the particular environment. In contrast to agent, objects are related to and have not autonomy to make an independent decision [22, 23]. Agents will be characterized in details in the further part of this paper.

1.2. Multi Agent Systems

Multi Agent Systems, due to its decentralized character, could be suitable approach during the design of robotized workcell. In such system, the basic entity is an agent that are embedded in certain environment. The agent could examine the environment using sensors and modify it using effectors (Figure 4).

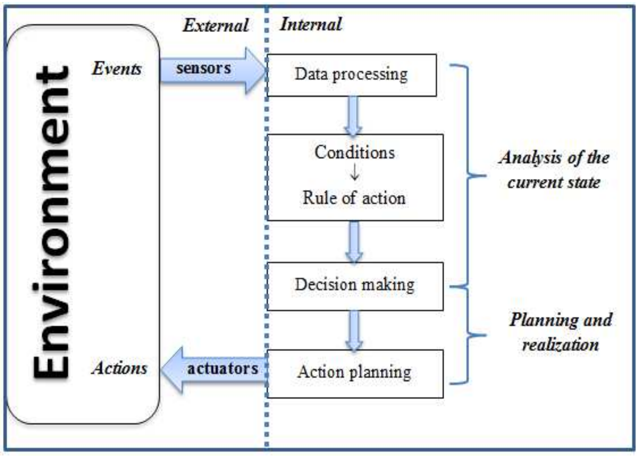

Fig. 4. General structure of the agent system

The analysis of the literature gives no strict definition of an agent. The agent is often described as an entity that should have following properties [24-32]:

- autonomy – agents controls itself in a limited way and could act without the intervention of a human or master program,
- cooperation – it is the ability of interaction with the other agents in order to find the solution of a given problem,
- communication – it is the ability to communicate with the other agents by using data interfaces and with the humans, using the HMI,
- reactivity – an agent reacts to the changes in the environment,
- goal orientation – an agent not only reacts to the changes in the environment, but also initiates some changes,
- proactivity – an agent acts independently, without the signals from the environment,
- ability of inference – it is the ability of making the decision on the basis of own knowledge or the information acquired from the environment,
- adaptivity – it is the ability to adapt itself in the environment on the basis of agent's experience.

The agent's ability to act autonomously as a part of group means the ability to participate in the high-level interactions, like cooperation or negotiations. The cooperation is particularly important, because allows the agents to aim the goals that are beyond their individual abilities. Thus the multi-agent approach gives the new possibilities that concerns the implementation during the process of robotized work-cells design [11].

1.3. Case Base Reasoning (CBR)

Case Base Reasoning (CBR) is the one of artificial intelligence method that can be used to solve the problems through modification and adaptation of solutions worked out in the past, during solving the same or similar issue. In this manner, the aim is to develop a predictive model characterized by decreased uncertainty about the future. The CBR method is based on the knowledge and experience. It consists in searching of analogies between the current situation and the past problems. All of the issues – properly described – are gathered in the computer memory. In other words, the CBR method is a cyclic process of problem solving and learning on the basis of gathered knowledge and experience (Figure 5) [34, 36].

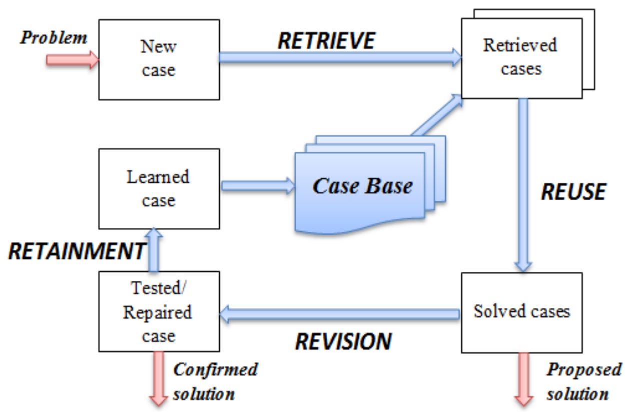

Fig. 5. The CBR cycle [36]

Solving of the problem, using the described method, consists in the analysis of the current situation, formulation of the new problem and – as a consequence – browsing the database in order to find the same or similar case. The important advantage of the CBR method is that the solved problem is immediately added to the database and could be used during the next session, solving another problem [33-36].

The use of the CBR method in the designing process is very suitable tool, especially when we concern the possibility of collecting the information about successfully finalized tasks.

2. The outline of the system dedicated for computer aided design of robotized workcell

The main task of agents is the proper reaction for events that take place in the environment. In order to realize the goal, agents must take the initiative, interact with the others and use own experience based on the past events. Such approach supports the solving of the new problems. There is many descriptions of synergistic use of CBR and MAS methods in the literature [36].

The process of design of robotized workcell consists in organizing of component elements in groups that can be joined, making large cells. It is also possible to do the opposite and split the large group of cells into smaller one. Using one of the described methods depends on needs, kinds of tasks that will be realized in particular workcell. Robotized workcell could be therefore defined as a set of programmable machines D (machine $d \in D$) - so called Workstation, that could be NC/CNC machines-and the storage units M (storage $m \in M$), which are handled by robots R [37].

In the present case it was assumed that design of the robotized workcell will consist in the choice of components and-implicitly-the agents representing these elements. The use of agent-based approach can generalize complex problems-in the other words it introduces the alternate levels of abstraction. The complex manufacturing systems can be modeled as a agent-based system, with generally defined objectives, while exact goals can be refined during the process of decomposition of the considered system into smaller, agent-based systems that exist-in some way-independently. Figure 6 shows the concept of the proposed system. It consists of user interface, database and cooperating agents. In the structure of the system can be distinguished small, decentralized and partly independent modules that are focused only on key tasks. Such system could be reconfigured and extended by new modules and control functions. The database keep the information about process status and resources, while agents receive and analyze data and interact with the environment, for example by selecting the proper materials, components etc.

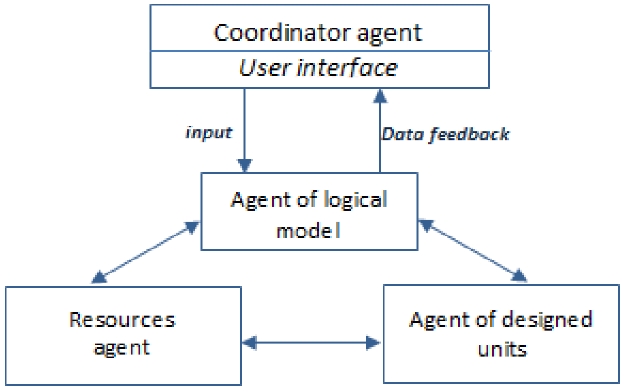

Fig. 6. The proposed architecture of the system

The analysis of the presented architecture of the system allows to distinguish several basic units, that compose the multi-agent system. These include:

Coordinator agent – its task is to coordinate and monitor of the whole robotic workcell.

Agent of logical model – its task is the presentation and monitoring of logical structure of the workcell during the process of design [37].

$$Cell_{Logic} = \left(D \cup M, R, \{Group(r) | \, r \in R\}\right) \tag{2}$$

In the assumed structure of workcell, the group of machines M is divided into subgroups called machine centers $m \in M$, which are handled by particular robots r, where $r \in R$. The robot r may handle only the machine that is located in its range (workspace):

$$Serv\_space(r) \subset E_o \tag{3}$$

where: E_o – Cartesian Base Frame.

The set of devices D, located in the workspace of the particular robot is denoted as:

$$group(r) \subset D \cup M \tag{4}$$

Resources agent – is the agent which is responsible for proper utilization of available resources, like technological tooling of a robot, machine tools, tools, buffers, auxiliary equipment, transport equipment and reorientation stands. Moreover, the agent controls the flow of elements that are manufactured using mentioned resources. In the process of selection of the right components of the workcell, the *resources agent* is supported by the inference module and the database of cases (Figure 7).

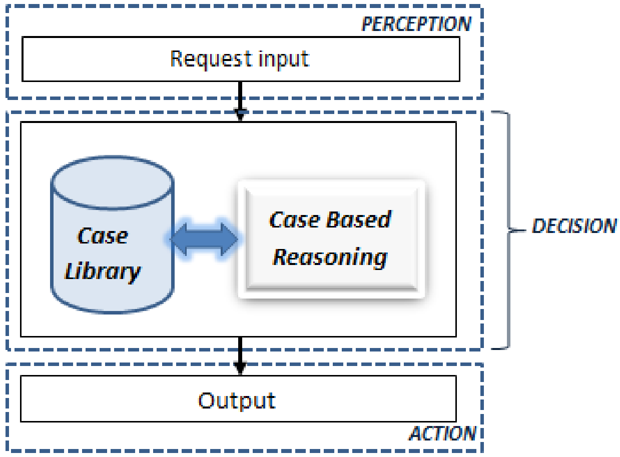

Fig. 7. Resources agent structure

Agent of designed unit – it is responsible for selection and suitable work of a particular robot and/or machine.

3. Conclusions

The paper discusses the possibility of use agent-based and object-oriented methods in the process of robotized workcell design. Such systems could significantly reduce the effort of the engineer during the whole process. The object-oriented approach allows to distinguish smaller parts of the system and treat them independently, but in relation to the whole system. The agent-based approach is a development of object-oriented method. Agents are more specialized than objects and may have the ability of inference. Such systems could be considered as labour-saving due decision making process. In some circumstances they could make decision quicker and more accurately than the engineer.

The issues considered in the paper are only the introduction to further work related to the development of systems dedicated to computer-based design of robotized workcells. Clearly, not all the problems were described here-many of them require further, detailed study and experiments, like eg. communication and cooperation between agents. The open questions involves intense research in the field of artificial intelligence and computer science that in the future will lead to the creation of test version of the complete system.

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