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The distributed agent-based approach in the e-manufacturing environment

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Abstract. The deficiency of a coherent flow of information from a production department causes unplanned downtime and failures of machines and their equipment, which in turn results in production planning process based on incorrect and out-of-date information. All of these factors entail, as the consequence, the additional difficulties associated with the process of decision-making. They concern, among other, the coordination of components of a distributed system and providing the access to the required information, thereby generating unnecessary costs. The use of agent technology significantly speeds up the flow of information within the virtual enterprise. This paper includes the proposal of a multi-agent approach for the integration of processes within the virtual enterprise concept. The presented concept was elaborated to investigate the possible solutions of the ways of transmission of information in the production system taking into account the self-organization of constituent components. Thus it implicated the linking of the concept of multi-agent system with the system of managing the production information, based on the idea of e-manufacturing. The paper presents resulting scheme that should be the base for elaborating an informatics model of the target virtual system. The computer system itself is intended to be developed next.

1. Introduction

The complexity of the processes taking place within an enterprise causes that nowadays, in the conditions of global and most of all competitive economy, the efficient information flow between the enterprise components could have the decisive influence on its survival and development. The overriding goal of any enterprise should be the ability to adapt to the rapidly changing conditions of a competitive environment. Enterprises, which do not work comprehensively and put on the development of only certain areas of their activity, for example they focus only on costs decreasing, are on a hiding to nothing. Industrial practice shows that the much more effective strategy is to ensure the enterprise, as a whole, the possibility of rapid adaptation to function in changeable market conditions. This purpose could be achieved by integrating with each other manufacturing processes, technology, data about manufacturing resource and production systems, so that they cooperate together executing specified tasks. This integration should take place with the use of network solutions, treating as the priority to establish a closer relationship with the customer. This forces enterprises to better integrate systems in order to improve cooperation between the spheres of management, designing, production/manufacturing, engineering, supplying and distribution of a product [1, 3, 10-15].
This method of system functioning is possible only if there is a suitable system for information exchange between existing levels of the enterprise organization and the resources existing at these levels. Nowadays, in the area of process control, the most frequently is performed the division of information systems in an enterprise on the so-called classes, in accordance with the role they perform [1, 4-7]. In classical organizational schemes it could be distinguished three basic levels that could be related with three management systems: strategic one, tactical and operational one. These systems, in the form of an organizational triangle are presented in figure 1.

![Figure 1. Classification of enterprise layers.](image)

According to the presented classification it could be distinguished the following levels:

- **Corporate management layer** – layer concerning planning and enterprise resources management, and also relations with suppliers and customers (ERP-enterprise resource planning, CRM-customer relationship management, SCM-supply chain management).

- **Manufacturing management layer** - layer acting as an agent of information transferring between the operation layer and the corporate management layer (MES-manufacturing execution system, SCADA-supervisory control and data acquisition, HMI-human–machine interface).

- **Operation layer** – automatics systems responsible for controlling production units (PLC-programmable logic controller, DCS-distributed control system).

In the presented division it is not included the corporate layer, which is responsible for the laying out the direction of development of an enterprise. Modern business is a hybrid system in which coexist different solutions, as there are many different types of data sources concerning the state of a production system. The key element of the integration success of all or nearly all areas of an enterprise is the initial diagnosis and in-depth analysis of processes occurring in its interior, as well as their constituent elements and their proper modeling. Integration of the areas needs adequate distribution of tasks to dispersed subsystems cooperating with each other to collaborate together executing specified tasks [1].

2. E-manufacturing

The e-manufacturing philosophy is the concept of producing in accordance with changeable market needs. It was created as the response to current market needs, related with the dynamic development of the e-business strategy and the prevalent need for integration of activities within an enterprise, which
are necessary for effective decisions making. The e-manufacturing consists of performing complete integration of production and business layers, basing on communication with the use of advanced information technology, using intelligent computer techniques (figure 2)[2, 8-9, 19]. Integration of the production layer and business one consists of creating a possibly rapid data transfer system from the production layer to the highest layers of enterprise management and transferring the decision from the management layer to the production one. The information exchange, in real time, enables dynamic making and implementation of strategic decisions. Therefore, the e-manufacturing environment could be defined as the system that integrates, in real time, production resources with suppliers and customers, using for this purpose the network-oriented computational tools and wireless technologies [16-21].

Figure 2. The e-manufacturing philosophy [19].

The most important element of the e-manufacturing concept is the common, multidimensional database that, in real time, gathers all necessary information, and which provides quick access to data and to various analyses. All operations carried out at the production level are referred to the management one.

The other reason for developing the e-manufacturing concept was the concept of a virtual enterprise or dynamic virtual manufacturing nets. In such production system the department organization exists only in the virtual reality. The real manufacturing departments are located in different factories, even in different countries. So the cooperation of such distributed production units is difficult and the profits of introducing and utilization of the informatics concept of e-manufacturing is the highest.

3. Application of multi-agent systems in an enterprise

The accessibility of a variety of technologically advanced equipment, computer applications while contributing to the technological progress, causes a number of inconveniences for an enterprise, both technical and business. Not always the communication between all levels/layers of an enterprise is well defined, with clearly designated borders of competency, but there is always a need for vertical communication with the process layer. This communication requires the solution of many problems, such as: lack of feedback in real time between the enterprise layers, costs associated with process implementation (employees hiring, tools and resources unification), existence of distortions in a data flow and the duration of each operation. Due to the universal and very general character the agent systems could be used in various scientific fields. Because of their ability to autonomously react to changes occurring in the environment, in which they are embedded, these systems are a convenient tool for analyzing, designing, and using in decentralized systems. In other words, multi-agent systems could be used wherever it operates a distributed resource of knowledge [22-27]. The complexity of the processes taking place in the e-manufacturing environment could be modeled as a multi-agent system, with generally defined objectives, which detailed specification may succeed during the process of
system decomposition into smaller agent systems, which are, in some sense, independent. In figure 3 is shown the architecture of the proposed system, which is an extension of the approach proposed in [17].

![Figure 3. Architecture of the proposed system.](image)

The proposed approach consists of a user interface, databases (local and global) and agents cooperating with each other. In the structure of the proposed system it could be observed the division on the so-called coordinating agents, which are responsible for the individual layers of an enterprise. The coordinators supervise the correct execution of the tasks by agent or group of agents assigned to them, plan tasks to perform and assign them to individual constituent elements (agents) within its own structure, communicate with the enterprise management system, as well as interact with each other. The global database collects information about the process state and the resources, whereas the agents have the ability to receive and analyze data, and to influence on the environment for example by reporting: the execution and/or the order of tasks, the current state of a process, the consumption of materials, the encountered problems, etc. Each of the agents contains detailed information on the tasks assigned to them. In addition, between all agents group there is cooperation, which is regarded as one of the most attractive features of the multi-agent approach and therefore, this approach opens up great opportunities related to the implementation of these systems in an e-manufacturing environment through direct data and information exchange between the
components of the manufacturing process. The open structure of the system makes it possible to reconfigure the system, as well as add new control functions and modules.

4. Conclusions
The proposed approach is an extension of the concept presented in the work [17]. Multi-agent systems should be regarded as one of the tools supporting the activities of an enterprise, and not as an element necessary for its functioning. The main advantage of the MAS application is elimination of manual data processing, thereby reducing the cost of information acquisition. Through the use of multi-agent systems, it is possible to automate and optimize many processes that formerly required human intervention (e.g. equipment arrangement and equipment cooperation). These systems could aid or even replace a man first and foremost in many functions considered with decision making. They could decide faster and more accurately through taking into consideration more complex sets of data. Moreover, the open architecture provides data capturing, management of them and their comprehensive analysis in real time. The further stage of works will be determining the communication protocol between cooperating agents.

The elaborated concept could be characterized by some essential advantages. Firstly it is possible to use the existing, licensed software that is applied by our Institute. Secondly the integration process, in this approach, is based on the common data representation (in a global one and in local ones). The databases are the fundamental link allowing binding the system of separate program tools. It is however needed to elaborate proper interfaces for data format transferring. And finally the third advantage is related with the possibility of self-organization that could be conducted on the uniform data stored in the common databases.

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