KEY COMPONENTS OF THE ARCHITECTURE OF CYBER-PHYSICAL MANUFACTURING SYSTEMS

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Abstract: *The future of industry contains many challenges. Necessity is to increase the degree of digitization and achieve a new level of productivity. The rise emergence of modern production lines operating in accordance with the concept of Industry 4.0 foresees the creation and implementation of new technologies and the emergence of autonomous production units capable of independent existence within the manufacturing process. They must closely communicate with other elements and cooperate with all the elements in the production process. In this article we describe architecture of theoretical cyber-physical system and give components and technologies necessary to implement a modern enterprise designed according to Industry 4.0 standards.*

Keywords: INDUSTRY 4.0, PROCESS, MANUFACTURE, STANDARDS, ARCHITECTURE

1. Introduction

The result of implementing new technologies and new ways of communicating between industrial facilities is the fact that the boundaries between the real environment and the virtual world are being wiped out. New technologies in industry are well known as Industry 4.0 concept or Cyber-physical production systems. The main target of successful application of the concept of Industry 4.0 into practice is the realization of intelligent, interconnected production systems that can dynamically respond to changing conditions during production and are able to vary their physical and logical structure during the work cycle.

Cyber-physical systems are represented by a set of electronic and mechanical components linked to each other by means of sensors and networks that provide intelligent platform for flow and analysis of data (6).

The complexity of these production systems is significant and essential part of modern equipment in addition to physical facilities and operations are software tools to enable research in integration of information and management systems and solving problems in the field of acquiring knowledge (data mining), simulation of production and service processes and logistics systems with the possibility of their optimization, planning and management of production (ERP systems) and business intelligence tools (BI). Using these technologies, it is possible to create a combination of virtualized production environments to physical - Digital Twins (DT).

2. Architecture of Cyber-Physical systems

Due to the complexity of the industries, design of the structure of intelligent factory must meet a number of criteria and consider the applicability in different sectors and different types of manufacturing processes. There are a number of works dealing with issues of structure and standardization in the area of cyber-physical production systems. The work of the authors (12) describes a method of realization through a five-level architecture, referred to as 5C. The proposed model is based on a standardized model that extends with new features. The core of work of authors in article (6) describe the implementation of intelligent manufacturing systems in the Industry 4.0, and define the modern elements necessary for the existence of such production units. Several different approaches to managing and defining the structure of the CPS is described in article (10), while there are analyzed possibilities of centralized and decentralized management of production processes. In the author's work (1), a categorical and hierarchical framework is proposed in which the Industry 4.0 concept is described as achievable by the continuous and incremental development process, the main parameters of which are automation and intelligence: the intelligent manufacturing system is highly automated at the manufacturing company level and is self-repairing, self-optimizing and self-configuring.

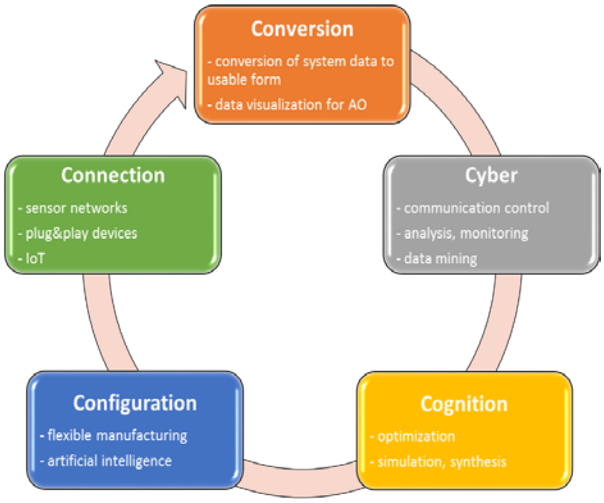

Fig. 1 *Basic parts of CPS architecture 5C*

It is clear that the autonomous intelligent manufacturing subsystems and the relationships between them are too complicated to manage human operators in real time. The solution is to control production process using an intelligent software with artificial intelligence using neural networks technology.

Decisions relevant to management in modern factories will be obtained through a real-time simulation that includes all the states, processes and components of the real world. The technology of digital twins (DT), virtualization and simulation of processes in a virtual environment is an important aspect in the management of production systems. By using DT, it is possible to predict the machine settings and parameters in a simulation environment in the virtual world, whereby switching to a different product (any change in the production process) allows the devices to be set up to configuration based on simulations in the virtual world. This approach significantly reduces machine setup times, improves quality and prevents malfunctions and outages (11).

In the pyramid model (Fig. 2) is assumed architecture of the manufacturing enterprises realized in accordance with the Industry 4.0 concept represented by layers, where the lower level consists of intelligent sensors and regulators interconnected by IoT technology (12). The process of obtaining accurate and reliable data from devices and their components is the first step in the implementation of cyber-physical system. Data can be directly measured by sensors in the production process or obtained from management or enterprise production systems (ERP, MES).

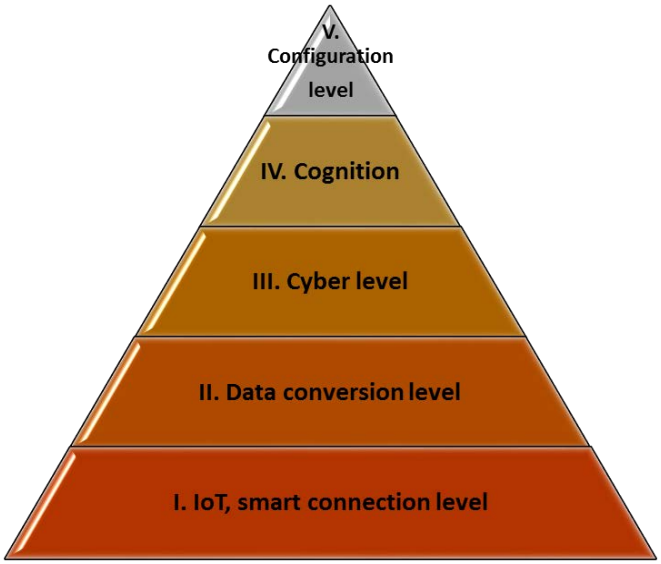

Fig. 2 *CPS – implementation architecture (12)*

Because these are data representing a number of variables of different kinds (time dependent / independent), it is important to choose a suitable method of interpreting the measured data and to select the appropriate form of recording. As a result of the ever increasing use of sensors and machines in the network, it results in the continuous generation of a large data volume (Big Data) (3). For processing of such amount of data are used special techniques and technologies and proper processing and evaluation of these data is very important for softness and quality simulation model twin digital production process.

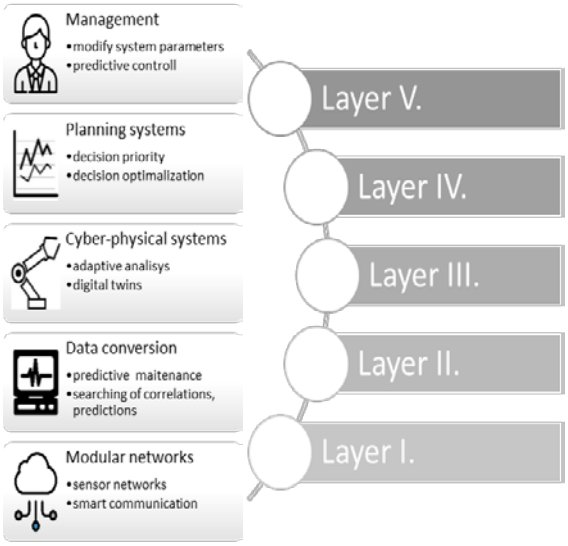

Fig. 3 *Techniques associated to layers in 5C pyramid model*

3. Technology platforms in Cyber-Physical systems

Based on the above information, we can summarize the components and technologies necessary for the implementation of a modern enterprise conceived in accordance with Industry 4.0 and exploiting the potential offered by the proposed technology (6). The future of flexible production and Cyber-physical manufacturing is the use of all modern approaches, communication between all components and the autonomy and intelligence of all elements in production.

- Advanced (autonomous) robotized production lines
  - modern automated and robotized production lines maximize efficiency, modern technology, accuracy and speed of production are an essential element in the implementation of CPS
- Autonomous supervisory/service mobile units (drones with camera system or handlers to carry light objects)
  - drones are easy to use as independent mobile supervisory units (equipped with a camera) or as highly mobile transport units with the appropriate equipment for the transfer of objects
- Industrial 3D printing
  - technology of 3-dimensional printing (additive manufacturing) is able to provide a high degree of efficiency and variability in the production of a wide range of products. By creating 3D objects based on data from materials such as plastic or metal, it is possible to create complex, easily customizable products whose design is impossible to carry out with classic production techniques.
- Autonomous traffic units (autonomous carts and manipulators)
  - ground handlers and vehicles for transporting heavy loads are forming a connection between the individual modules of CPS
- Intelligent management and control system
  - central management and control of all production processes and units must be implemented in such a way as to eliminate the possible errors in the management of complex and time-dependent production processes. This presupposes the exclusion of classical control centers with human service. Manufacturing and manufacturing processes should be managed by an appropriate intelligence management system with an ERP and CRM connection management interface.
- Distributed communication systems – sensor networks + IoT
  - all objects in the production process have to communicate with the control system wirelessly. Together with the sensor system they create an information data network. Based on these data, the central management system is able to analyze production procedures and processes and optimize them to achieve even greater production efficiency.
- Intelligent final inspection - 3D scanner
  - an intelligent control system that accurately identifies the parameters of complex elements and products through a set of cameras camera and 3D scanner.
- Augmented operator
  - in the case of excessively complicated manufacturing processes, the physical capabilities of human staff need to be improved using an additional technical solutions
- Energy-efficient production
  - a modern manufacturing enterprise must use renewable energy sources such as solar panels, energy passive buildings, recycling of raw materials and the like.

4. Conclusion

Modern manufacturing facilities of future are represented by highly automated production lines including sophisticated management and control computing systems. However, the manufacturing process is still dependent on the operators. The future lies in a combination of increasing device autonomy, applying new technologies and improving operators' capabilities, plus increasing the interoperability of all elements.

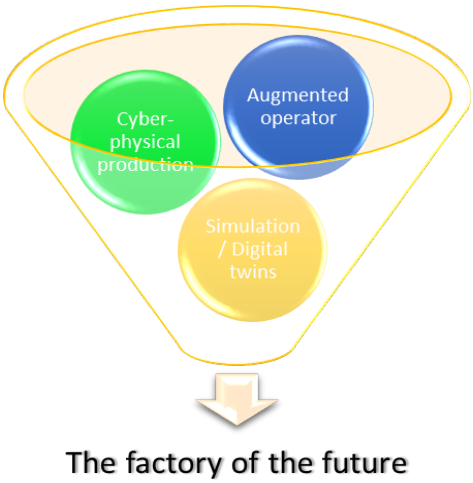

Fig. 4 *New technology in future factories*

In addition, it is necessary to improve interaction in the man-machine context, not only by enhancing and introducing smart technology on the machine side but also by the human abilities, possibly using other electronic specialized circuits implemented directly at the operator. Together with virtualization technologies (predictive simulation), the aforementioned possibilities offer interesting perspectives on the management of production processes in the upcoming period.

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