CYBER – PHYSICAL SYSTEMS AND "INDUSTRY 4.0"

Petrova D.[1], Marcinkevičienė V.[2]
[1]*Technical university of Gabrovo*
[2]*Kauno Kolegija*

Abstract:
The theoretical and practical basis for cyber-physical systems is presented as part of Industry 4.0. Characterized and defined are cyber-physical systems, the Internet of Things, Internet Services, Intelligent Factory. Horizontal and vertical integration, as well as the stages of building the model – the cyber-physical system for the industry - are formulated. The strategy for developing the cyber-physical system is outlined.
Keywords: *cyber-physical system, industry, Internet of Things, Internet of Service, Smart Production, Smart Factory.*

Introduction

The industry is working in a context of growing global competition, requiring a reduction in production time and costs. The growing demand for customized industrial products and services, coupled with requirements for resource efficiency, flexibility and speed of manufacturing processes, greatly increase the complexity of modern manufacturing systems. For companies to be sustainable in this dynamic environment, they need not only to increase their productivity and process flexibility but also to change their technology development strategy.

Linking technological processes to the high degree of automation due to information and communication technologies poses new challenges to the industry. The introduction of the term „Industry 4.0" takes place in 2012 to promote this qualitatively new step in the computerization of industry and is the basis for building the so-called „Smart Factory". This smart Factory is characterized by resource efficiency, ergonomic design, flexibility, integration of customers and business partners and value-added processes.

Exposition

The ***"Industry 4.0"*** technology base is are: Cyber-Physical Systems, CPS's CPS Components /Subsystems, "Service Internet" and "Intelligent Factory" [7].

“Industries 4.0” focuses on [2]:
- Manufacture of intelligent products;
- Intelligent industrial methods;
- Smart Production;
- Intelligent factories can meet customer‘s individual requirements and even profitable to produce single units;
- Manufacturing and engineering processes can be dynamically designed so that production can change quickly and flexibly and respond to disturbances;
- Production processes are completely transparent and give optimal solutions;
- New forms of added value and new technology and business models can be created in the course of their work;
- Creates the opportunity to increase the efficiency of star-up small businesses and to develop new services;
- Challenges such as resource and energy efficiency, urban production and demographic change can be addressed;
- Productivity and efficiency can be improved throughout the value chain;
- More intensive cooperation between business partners (suppliers and customers) and between employees as a result of new opportunities and benefits;
- Workplaces can meet the demographic factor and be socially involved;
- Based on intelligent support systems, employees can focus on creative value added activities and get rid of routine tasks. Given the forthcoming shortage of skilled workers, it is thus possible for older workers to remain productive for longer working lives;
- Flexible work organization allows employees to better combine work and personal life, combining it with better training and improving Work-Life-Balance;
- The digital network allows direct integration of customer requirements and cheap customization of products and services;
- There is tremendous potential for new products, services and solutions;
- Global competition in production technology is increasing;
- In Germany and other countries there is a tendency for rapid Internet of Things and Internet of Service.

Definition and characteristics of cyber-physical systems

The main element of the Industrial Revolution is Cyber-physical systems (CPS), which create networks for the self-regulation of spatially distributed production resources. Cyber physical system refers to a physical mechanical complex with IT systems, hardware and software digital components with mechanical or electronic parts that autonomously communicate with one another.

In the world's scientific literature there is a sharp restriction of the term "Cyber-Physisches System" in terms of trends and directions in the development of complex information and communication technical systems. Thus, Cyber-physical systems are intelligent hardware and software systems, as well as effectively integrated physical components that interact closely with each other to reflect changes in the state of the real world as defined by the American Institute of Standards and Technology (AIST).

The challenges of CPS include:

- Reducing the complexity and development of a stabilized management architecture for cyber-physical systems;
- Distributed sensor networks;
- Developing knowledge and discoveries from cyber-physical systems.

Embedded Systems and Global Networks – Networks such as the Internet for Data and Services – are the two ICTs that drive technological progress. Embedded systems already play headquarters – almost hidden – a role in the lives of all of us. More than 98% of all processors in the world are used in regulatory, control and monitoring functions in devices and in all aspects of everyday life. They are from the vehicle, ABS and ESP systems, smart phone communication and information services, ordinary household utensils and come to a system of industrial production planning. Built-in systems are the most intelligent central control devices at work in state-of-the-art technology products and devices. They work as "embedded" processing systems within the "product" connection for a certain range of applications. For this "connection" to the outside world, sensors and actuators are used, allowing embedded systems to be increasingly interconnected with each other in the online environment.

The "Internet of Things" – Components / Subsystems of (CPS)

Under the Internet, we will understand the Internet of Cyber-Physical System (CPS) components. If we look at the components in a cybernetic system aspect, they appear as System Subsystems (CPS). The components in this case are: intelligent machines, built-in self-regulating systems, hardware, software and other uniquely addressed objects and networks that intelligently interact with one another to achieve the common goal. [1]

Therefore, the ***"Internet of Things"*** describes a complete network of embedded systems of household, production, infrastructure, or machine objects via the Internet that have uncontrolled human communication about the state of the system and actions (component component communication). With the integration of the Internet of Things (IoT) and the Internet of Services (IoS) with CPS in the manufacturing process, the fourth industrial revolution has already begun [1]. The "Internet of Things" allows "things" and "objects" such as RFID, sensors, executive mechanisms, mobile phones that, through uniquely addressed schemes, interact with each other and collaborate with their neighboring "intelligent" components to reach common objectives. Based on the definition of CPS, "things" and "objects" can be understood as CPS. Accordingly, the "Internet of Things" can be defined as a network in which CPS cooperates with each other through unique target schemes. Examples of using the "Internet of Things" are smart grids.

The ***"Internet of Services"*** (IoS) is actually the ability of "service providers" to offer their services over the Internet. IoS consists of the participants in the service. These are: service infrastructure, business models and service providers themselves. [2]

The idea of IoS came from a project named SMART FACE within Autonomics for "Industry 4.0" for the car industry. The project is based on service-oriented architecture. This allows the use of modular assembly stations that can be flexibly modified or expanded. Transport between assembly points shall be provided by automated controllable vehicles. Assembly points and automated control vehicles offer their services through IoS. Information and communication technologies (ICT) form the strong foundation on which new innovative solutions can be built.

Smart Factory [2]

An important element of "Industries 4.0" is "Smart Factory". Smart Factory is complex, has a lower incidence of numbness and increases the efficiency of production. Smart Factory communicate people, machines and resources on a social network. "Smart Products" have knowledge of their manufacturing processes and future application. They actively support production processes (when to be produced, with what parameters should be produced, where it should be delivered).

With such parts as: "Smart Mobility", "Smart Logistics" and "Smart Grid", an "Intelligent factory" is formed, an important component of future intelligent infrastructures. "Smart factories" are the key feature of "Industries 4.0”. As a “Smart Factory”, a factory for contextually assisted people and machines is set up to perform their tasks. These systems perform their tasks based on the information that comes from the physical and virtual worlds. Information about the physical world is eg. position or instrument status, but information of the virtual world – electronic documents, drawings and simulation models. In “Intelligent factories”, production facilities, information systems and staff need to interact in real time. In “Intelligent factories”, cyber-physical systems (CPS) communicate through the “Internet of Things” and help staff and machines to carry out their tasks.

Horizontal and vertical integration

Horizontal integration means the integration of different information technology systems into production and automated equipment for different stages of the production and planning process.

Vertical integration means the integration of information technologies in IT systems at different hierarchical levels in production and automation (for example at management level, level of production management and finding an optimal, continuous solution).

Vertical and horizontal co-operation between machine and internet, machine and man and machine and machine along the value chain, in real time, is the basis of the production cyber system. “Automation Islands” will be linked together in countless networks and variants. Software and networks will connect smart products, digital services and consumers with the new, innovative “products” of the future.

Industrial cyber-physical systems

Smart factories are the future of industrial production. The merging of the virtual and physical world through cyber-physical systems leads to a merger of technological and business processes. They are leading the way to a new industrial era and best define the concept of “Industries 4.0” for “smart factories”. The deployment of cyber-physical systems in production generates “smart factories”. And “Intelligent factory” products, resources and processes are realized through cyber-physical systems. Getting real-time data on quality, resources and costs provides significant advantages over classical production systems. The “Intelligent factory” must be built on sustainable and service-oriented technology and business practices. They are characterized by flexibility, adaptability and self-learning, resilience to failures, and risk management. High levels of automation become a must-have standard in the “smart factory”, which is possible thanks to the flexible network of cyber-physical-manufacturing-based systems that automatically monitor production processes. Flexible intelligent production systems and models that are capable of reacting in real time allow internal production processes to be radically optimized.

In “Intelligent manufacturing” [3], the ability to communicate and decentralize data processing, as well as self-optimization, is ensured through embedded systems equipped with dedicated hardware and software. In this way, embedded systems, partially with wireless parts, are connected to the information networks of other systems (within the company or with external stakeholders such as customers or suppliers) in order to exchange data or to access web-based services. Therefore, interoperable communication interfa-ces and standardized protocols are required. In addition, the products of the industry are intelligent, b.c. they produce information from their own production in machine-readable form (eg RFID chips) in order to coordinate their own production.

Therefore, information flows are crucial for cyber-physical production and security management. [4]

Tabl.1 *Cyber-Physical Systems - features*

Cyber-Physical Systems	*Features*
Embedded systems (such as parts of appliances, vehicles, transport routes)	*Cover all physical data with sensors*
Production facilities Logistics (coordination and management processes)	*Using international to all data and services*
	Data evaluation and storage
INTERNET SERVICES	*Networking through digital communication technologies*
	Impact of the physical world
	Using multi-module man-machine places (touch displays, speech management, gesture management)

Cyber-physical systems are open to socio-technical systems and allow for a number of new features, services and properties. These include robots, intelligent objects, and self-governing devices. Therefore, one of the most important tasks in the design, development and management of cyber-physical systems is the question of the joint work of cyber-physical systems and people.

The issues that are important in this context are to identify and model awareness of the situation, the human experience of these systems and the environment as well as reflecting the changes.

Stages of building a model – a cyber-physical system for the industry

Cyber-Physical Systems (CPS) are intelligent self-regulating systems that connect the virtual and physical world to a networked world in which they communicate and interact. These systems represent the next revolutionary step from existing embedded systems. Together with the "Internet of Things" and service data, they provide connected online embedded systems that shape cyber physical systems (Industries 4.0 for smart manufarug for the future) [3].

The aim of this complex is to integrate information and communication technology into production systems, resulting in the so-called cyber-physical manufacturing system (CPPS) in the sense of "Smart Factory". This creates a continuous chain of processes throughout the product lifecycle, steadily increasing the flexibility and efficiency of industrial production. In the future, cyber-physical systems will provide human security, efficiency, comfort and health in ways we can not imagine before. In this way, they will play a central role in overcoming the major challenges posed by demographic change, scarcity of natural resources, sustainable mobility, etc.

Cyber-physical systems are the next step on the way to creating smart cities through the creation of the Internet of Things, Data and Services.

The development strategy of the CPS is characterized by three phases of implementation and application:

- 1st generation CPS – Identification technologies (RFID tags that allow for unique identification), storage and analysis (such as a centralized service);
- 2nd generation CPS – equipped with sensors and actuators and with a limited set of functions;
- 3rd generation CPS – can store and analyze data for multiple sensors and actuators and implemented in compatible networks.
- On this basis there are three generations of intelligent systems:
- the first generation intelligent systems of the most advanced in automation, control and regulation of technologies;
- the second generation of intelligent systems with significantly enhanced machine learning features;
- the third generation is characterized by perception, thought and action, and approaching the performance of man

Conclusion

- Embedded Systems and Global Networks - Networks such as the Internet for Data and Services - are the two ICTs that drive technological progress;
- Information flows are crucial for cyber-physical production and security management;
- Cyber-physical systems will provide human security, efficiency, comfort and health in ways we can not imagine before;
- Integrate information and communication technology into production systems;
- Information and communication technologies (ICT) form the strong foundation on which new innovative solutions can be built;
- In “Intelligent factories”, cyber-physical systems communicate through the “Internet of Things” and help staff and machines to carry out their tasks.

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