Cyber and Physical Systems Technology Classification for Production Activity of the Industry 4.0 Smart Factory

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Abstract. The task is to create a company of new type (a smart factory) for the Industry 4.0. A smart factory is for production cycle of the item designing manufacturing. A smart factory is equipped with cyber and physical equipment controlled with computerized system which is a part of the company digital infrastructure. Cyber and physical production apply innovative production technologies for the item life cycle supported in a smart factory. There is a scheme of informative technologies classification in automatic production of the Industry 4.0. The classification is done with technological operation done in the company with the technology of each type. There is a scheme of informative technologies distribution in the Industry 4.0 smart factory by components of production infrastructure. The role and place of each informative technology of the Industry 4.0 smart factory is described.

1. Introduction
To digitalize the industrial economy is a development direction of state science and technical politics. Digital economy elements [1-3] are informative technologies and means of industrial production, standards of digital certification and other. United components of digital economy implemented in production infrastructure of item designing companies created smart factories [4, 5] of the Industry 4.0 to conduct their activity with minimum part of humans.

Smart factories of the Industry 4.0 are a new type of company [6, 7] equipped with cyber and physical systems which function automatically. Cyber and physical systems (CPS) united into a production line is a deep automatizing to manufacture the item designing components.

Cyber and physical systems function automatically without humans to make technological operations. The primary human role [8, 9] in cyber and physical production is to monitor the item manufacturing process and maintenance and service of cyber and physical technological equipment.

To control cyber and physical systems in production they require [10, 11] to integrate program and technological solutions which base is digital informative technologies. Informative technologies are to support production processes completion and to form the smart factory digital infrastructure.

The Industry 4.0 smart factory digital infrastructure also permits:
- to organize joint function of cyber and physical systems which results will be the completion of the company production plans with optimal (quasi-optimal) criteria;
- to provide production process flexibility in automatic mode by implementing self-organization technologies of cyber and physical systems which is operative and adaptive resetting of technological equipment;
- to provide the system of electronic documents in company with electronic exchange of technological documentation components for the item and production data which are made after the item is done;
- to provide informative support of user (exploiter) of the item and repair services and the maintenance;
2. Progressive informative technologies of the Industry 4.0

The composition of the Industry 4.0 production company requires to implement into smart factory infrastructure (serial plants) some progressive informative technologies with item digital models and twins of cyber and physical systems [10, 11]. Informative technologies in production are to support the technological operation completion of the item manufacturing being done in physical machines level and cyber-level.

Classification scheme of progressive informative technologies of the Industry 4.0 is given in figure 1.

- to organize distributed system of control in company with minimal expenses after the personnel made some mistakes.

**Figure 1.** Classification of informative technologies being implemented in the production activity of the Industry 4.0 smart factory (IoT – Internet of Things).

Informative technologies classification of the Industry 4.0 smart factory is given in technology groups to support the following technological operations:

- to organize informative exchange (communication environment in production) based on production data transferring net protocols;
- to organize technological operations completion with cyber and physical systems;
- to storage and process vast amounts of industrial data after the technological operations;
- to organize inter-machine cooperation (cooperation of cyber and physical systems) when the technological operation is being done in production section;
- to organize human and machine interface [5] (interaction of operator in production and cyber and physical system) after the monitoring of production activity in a smart factory and the solution of the tasks of production process situation control.

These production operations are the closed loop cycle of the item designing component manufacturing with technical documentation given to the designers of the Industry 4.0 digital factory electronically (digital model).
Informative progressive technologies distribution scheme by components of cyber and physical production of the Industry 4.0 smart factory is given in figure 2. Line with spaces are objects to define the technology type and simple lines is a place of application of those technologies in production. Having analyzed the scheme in figure 2 we see that each technology of cyber and physical production can be divided into two groups:
- technologies of direct application in cyber and physical production (for example, additive technologies being used in work chambers of cyber and physical systems);
- technologies of interaction to complete the production tasks of a smart factory (for example, technologies of IoT are being applied with cloud technologies and cyber and physical systems security technologies).

The most part of informative progressive technologies are for consolidative interaction with each other as a part of cyber and physical production of a smart factory.

3. Communication technologies of cyber and physical systems in production

Communication environment of the Industry 4.0 smart factory can be done with wired and wireless nets which user are operators in production (through the terminals) and cyber and physical systems. The most important information being circulated in the communication environment of a smart factory is:
- data of technological operations completion state in cyber and physical systems;
- material and parts consumption data which is necessary for the production;
- data of well functionality of cyber and physical systems and other.

This data through the wired Ethernet channels or wireless of Bluetooth helps the computerized control system [3] to plan the production process operatively for each cyber and physical system which is a production active agent [8, 9] connected to the Internet. This is the hybrid automatic production in a smart factory which is a single net based on the IoT technology for different cyber and physical equipment.

The IoT industrial net helps the computerized control system to control cyber and physical systems in a central way. Active properties of the agent makes the cyber and physical system to be the correction initiator of operative production plans if any emergency should arise. So IoT cyber and physical systems can be control agents which makes the system to be a non-central one. If combined central and non-central control they create the dynamic production where the technological operation are done
automatically.

Quick development of technical and program communication means requires the informative security of automatic production. Your industrial data is a vital information today for a competitive company of the same activity field. To make sure the safe functionality of automatic technological equipment in a smart factory the factory communication environment [12] must have cyber and physical systems security components. Those components are machine and software solutions to cut out any unauthorized access to the production infrastructure including the remote access to the cyber and physical systems through the IoT channels.

4. Storage and processing technologies of the industrial data vast amounts

To process the vast amount of industrial data generated after the work in a smart factory there must be some new technologies of statistical analysis of the work quality criteria after given criteria. Those are technical and economic criteria (production rent, production rhythm, technological operation completion automatizing signs, cost of the item being manufactured). Technologies of informative support for production statistical analysis are BigData and cloud technologies.

The technology of Big Data is a set of horizontal program means for high-speed machine processing of non-structural data to find out their statistical value. In the Industry 4.0 the BigData technology is for mass and parallel processing of production information after some narrow production operations are completed in different cyber and physical systems to give the smart factory operator the condition completion of technological routes (for example, in the SQL (Structured Query Language) data base format of industrial processes).

Cloud technologies of the Industry 4.0 is a set of calculation resources (virtual machines, remote software, industrial data storage servers) available for automatic production operator and cyber and physical systems. Cloud technologies is for working with data amounts after the first industrial information from sensors and executive machines and from cyber and physical systems controllers is being processed with the technologies of BigData.

Implementation of cloud technologies in production infrastructure of the Industry 4.0 smart factory transferred some components and algorithms of control and data storage means from the physical world to the virtual environment to which users may access remotely. Projecting of smart factories has no restriction in territorial locations as a technological line of cyber and physical system and environments which are necessary for their application (information resources). If necessary the cyber and physical system controller through the wireless channel of Bluetooth and IoT means always may access the cloud data storage on a distant virtual server.

5. Technological operation completion in cyber and physical systems

They apply sensor and additive technologies to complete the operations with cyber and physical systems.

Sensor technologies implement in a cyber and physical system intellectual sensors for first processing the data of technological operations completion in the work chambers of technological equipment. Intellectual sensor is an advanced form of simple sensors which creates the sensor nets in a smart factory where the data is being processed with complexing mathematical algorithms. Sensor nets of cyber and physical production helps the smart factory operators who monitor the situation to receive the actual production information in each moment of time about the completion of technological operations.

Additive technologies of the Industry 4.0 smart factories is a set of technical and technological solutions to automatize production processes of part manufacturing (item) with stage by stage increasing of material on the prepared base. Unlike the CNC (computer numerical control) machines of the Industry 3.0 companies where the metal was out step by step with a cutting tool («subtractive technology»), additive production of the Industry 4.0 is more economic with raw materials (plastic, metallic, ceramic powders) when item is created and without additional mechanical treatment (soon electrotyping will be applied with additive technologies and 3D-printing).

6. Technologies of inter-machine interaction of cyber and physical systems

Conveyor manufacturing of complicated technical parts requires interaction among machines in automatic mode. Cyber and physical equipment of the Industry 4.0 use the technologies of Machine-to-Machine and Systems-to-Systems to interact. Technologies of M2M is an informative and mechanical way of data exchange and components of the item being manufactured supported with physical machines
(machines) of cyber and physical systems. For cyber and physical systems of digital twins there is the technology of S2S which helps the technological equipment to transmit to each other or to computerized system the production data which include:

- information about conditions of technological operations completion;
- information about material and parts availability which are used to manufacture the items.

In production with wireless communication nets the technologies of M2M and S2M must be done in the mobile version. Mobile production net provides data information exchange between stationed cyber and physical systems and mobile robotized transport system of a smart factory which transport blanks (parts) among work positions of cyber and physical system.

7. Human and machine interaction for cyber and physical production

Human and machine interface is necessary to organize information interaction among production operators and technological equipment (cyber and physical system). This interface has two options to be organized:

- through the cyber and physical system terminal where the operator controls directly the work modes of technological equipment (influence to the terminal itself);
- through interface of software when operator could control the working mode of cyber and physical systems remotely using the technologies of IoT and cloud services.

Cyber and physical systems control through terminal (technology of Humane-to-Machine) are used normally for repair and maintenance and during put into operation to synchronize the equipment in a single technological line.

To control cyber and physical system through the software they may use a computer of automatic work place or with a gadget of communication (tablet, phone and other). Sometimes they apply special means of communication like: virtual reality helmet or augmented reality glasses. Augmented (virtual) reality is a technology to be applied in the Industry 4.0 [6, 7] to organize the interaction of operator and cyber and physical system. In practice the augmented reality gives the user the production graphical data of cyber and physical equipment functionality.

A part of image which operator see in visual means (special glasses) is formed with the software and is applied over what the operator could really see. So operator watch the cyber and physical equipment (for example, to repair) and at the same time receives some hints of the gear being repaired which could be seen with glasses of augmented reality. Hints may include technical schemes, user instructions, recommended list of tools and other information which is necessary for the operator of the Industry 4.0 to make its job description.

Augmented reality technology is an informative support of operator activity to interact with the technologies of IoT, cloud technologies and the technologies of BigData. The place where the hint is displayed is automatically calculated according to the human position inside the cyber and physical production and the infrastructure component being watched. The hints itself are formed with artificial intelligence from the smart factory cloud environment.

8. Conclusion

To integrate informative technologies into a single infrastructure of the item designing company is a necessary condition to make the economy work with digital standards. Standards of digital economy require unique approach to organize business processes to accompany each step of the item life cycle.

Smart factory of the Industry 4.0 makes the stage of the item life cycle from production preparation, supply, item manufacturing and its quality control and later delivery of item to the exploitation point (consumer). Informative support of those stages requires from the smart factories the electronic system of control of the item engineering data with some subsystems to provide:

- to control the material purchase and parts which are necessary to manufacture the item and maintain the functionality of cyber and physical equipment;
- to control the finished product selling which are according to the technical and norm documentation (branch and state standards);
- to prepare the production technologically and processes of technological operation completion in the work chambers of cyber and physical systems;
- production planning (operative, tactical, strategical) in a smart factory and to plan the timing of the finished product delivery (graphs);
- to budget material and technical resources of the smart factory to make the manufacturing of production processes and to develop the company;
- to control the repair and maintenance of the item being manufactured in a smart factory and the items being exploited and other.

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