Designing technologies for the interaction of cyber-physical systems in smart factories of the Industry 4.0

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D A Zakoldaev[1], A V Shukalov[1], I O Zharinov[1] and O O Zharinov[2]

[1] Faculty of Information Security and Computer Technologies, ITMO University, 49, Kronverksky Av., Saint Petersburg, 197101, Russia
[2] Department of Problem-Oriented Computing Complexes, Saint Petersburg State University of Aerospace Instrumentation, 67, Bolshaya Morskaia str., Saint Petersburg, 190000, Russia

E-mail: mpbva@mail.ru

Abstract. An actual task is to project industrial purposes cyber and physical systems interaction technologies in the Industry 4.0 smart factories. Three cyber and physical systems interaction options are described (mechanical, informative and man and machine) which are applied in the item designing components manufacturing technological process. A scheme of system projection route is proposed for the cyber and physical interaction technologies. A scheme of system projection route is proposed for digital production cloud resources (services and applications) which are applied to realize automatic informative interaction for cyber and physical systems digital twins.

1. Introduction

Modern industry development is directed today to create companies, which implement the advanced industrial technologies and cyber and physical systems of technological purpose to manufacture high-tech product [1, 2]. Such companies (the Industry 4.0 smart factories) apply digital production technologies and components oriented to process production data electronically. Production digitalizing helps to automatize significantly the completion of key technological operations and manufacture the items, which have the parts manufactured with additive technologies [3, 4].

The Industry 4.0 smart factories characterize the plurality of cyber and physical systems (CPS) types, which they have and CPS structural complexity with functional, machine and informative production resources redundancy [5].

To project cyber and physical systems of different purposes today is done by different specialized companies, which use different methods and means to generate project solutions, which created [6, 7] duplication of several types of design and unnecessarily wide CPS nomenclature, which are proposed to be implemented in a digital production.

Machine base of cyber and physical production based on CPS must be viewed as a plurality of production elements with a limited pair compatibility based on the principles of several technological operations completion results acceptability [8, 9].

Technologies [10, 11] being implemented today in production is oriented to distribute functions among separate CPSs and to create an invariable production core — a computerized control system of technological operations and productions functioning with artificial intelligence. In the Industry 4.0

smart factories the artificial intelligence technology requires the production transition to use multi-operational components and calculation environments placed in CPSs and in the digital company virtual environment [12].

Smart factories projection must be done using methods of structural and parametric synthesis based on the system links analysis among all components of cyber and physical production. Available for the smart factories designers today science and technical archive helps to create and research project solutions to select digital production technological appearance keeping in mind the influence of the automatic production functioning different aspects [13, 14].

To solve the digital production projection problems in the project solutions synthesis initial state it is an important task to describe mathematically the projection object and its components, components and technologies interaction order which are used in the Industry 4.0 smart factories. Smart factory model representation as a projection object helps to transit the most part of project procedures to the level of mathematical abstractions and initiate the search for the best project solution automatically.

2. CPS interaction technologies projection

Cyber and physical production division item manufacturing technological processes are based on the multi-operational cyber and physical systems interaction technologies. CPS interaction technologies are realized in the CPS physical devices level and in the CPS digital twins level. CPS physical devices interaction is done cinematically which makes the part being manufactured to be transported from one CPS to another. CPS digital twins interaction is done in the company cloud environment and requires the technological operations completion data results production data exchange among CPSs or between CPS and computerized control system. The projection route of inter-machine CPS interaction technologies is given in figure 1.

CPS inter-machine interaction technology projection for the Industry 4.0 automatic production is done step by step. The CPS interaction technology first projection step is to design the ways of the CPS physical parts mechanical interaction. Mechanical ways of CPS interaction is done technically with a robotized transport system after which functioning the manipulator robot transports parts between receiving and sending boxes of the production machine. CPS mechanical ways of interaction is based on the group of Machine-to-Machine technologies and sensors applications and additive technologies production.

The CPS interaction technology second projection step is to design the ways to describe the order of man and machine interaction in automatic production. Man and machine interaction is based on the Humane-to-Machine technologies group and application of augmented reality technologies and cyber and physical systems security technologies. CPS and operator interaction in production is done technically with a smart factory computerized control system and CPS integrated means to support man and machine interface.

The CPS interaction technology third projection step is to design the ways of CPS digital twins informative interaction. CPS informative interaction provides self-organization processes of CPS physical devices in production to manufacture a bunch of items automatically. CPS informative interaction system core is the artificial intelligence placed inside the automatic production computerized control system. CPS informative interaction is based on Systems-to-Systems technologies group and uses cloud technologies, Big-Data technologies, CPS security technologies and industrial internet of things technologies.

CPS inter-machine interaction technologies projection is a directed process which is done according to the cyber and physical production development technical task (TT) requirements prepared with production technologies knowledge base and the Industry 4.0 information exchange data base technologies.

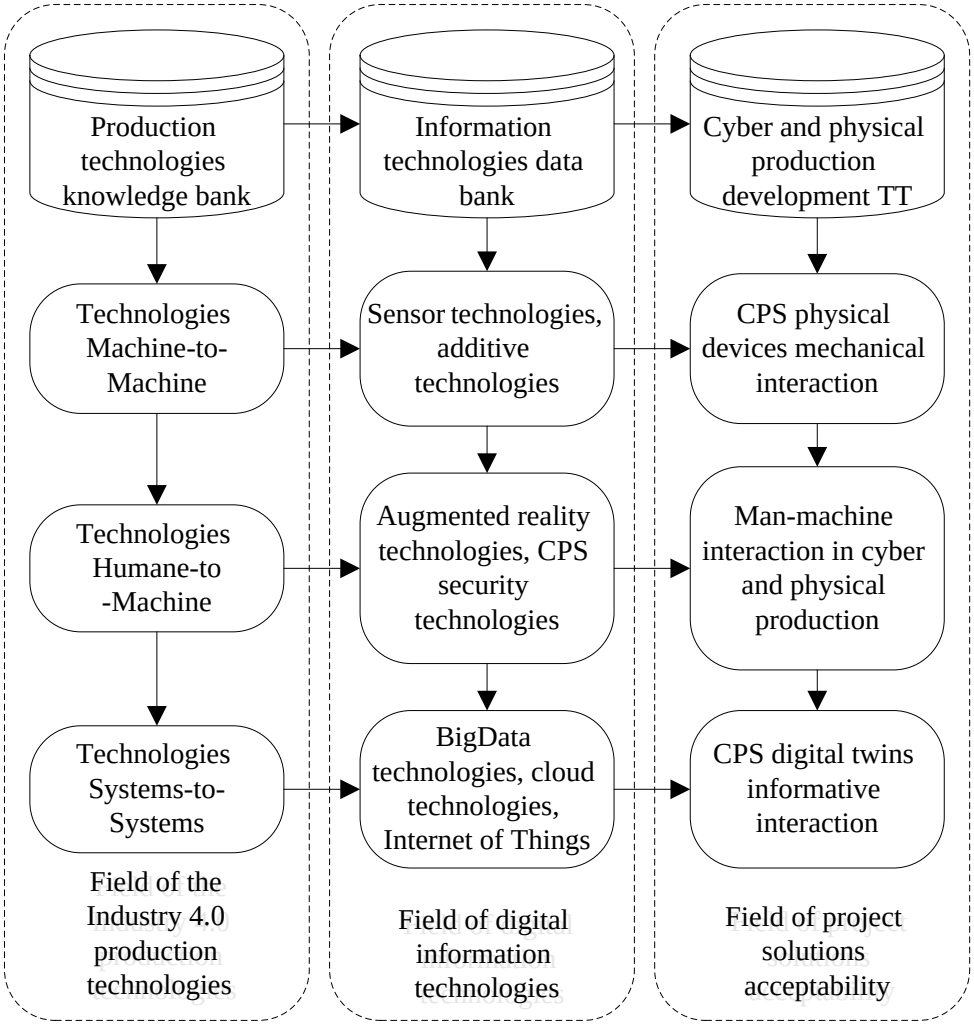

Figure 1. CPS inter-machine interaction technology system projection route.

3. Company cloud resources projection

Digital production cloud resources are production infrastructure components placed in the smart factory virtual space. The cloud resources primary purpose is to support informatively production operations being done in a CPS. Cloud resources functioning is done remotely for a CPS and for a production operator. The route of digital production cloud resources projection is given in figure 2.

Automatic production cloud resources are divided into:

- technical and program means of server equipment which can be used for the production cloud resources functioning;
- cloud services which grant cyber and physical systems and production operators the function of production process informative provision;
- cloud applications which grant cyber and physical systems and production operators calculation and analytical functions of the production processes provision.

Cloud resources projection is done with strict consequence logic (First the server parts components than the cloud services and at the end the program applications) which is explained with the project solution influence accepted in the previous stages of projection to the following project solutions.

The selection of technical and program means for server equipment are defined by the company cloud environment deployment type and its information exchange channels pass through capabilities which connect to each other the production process participants. Company cloud environment realization is defined significantly by the cyber and physical dynamic properties and reliability of cyber and physical production in general.

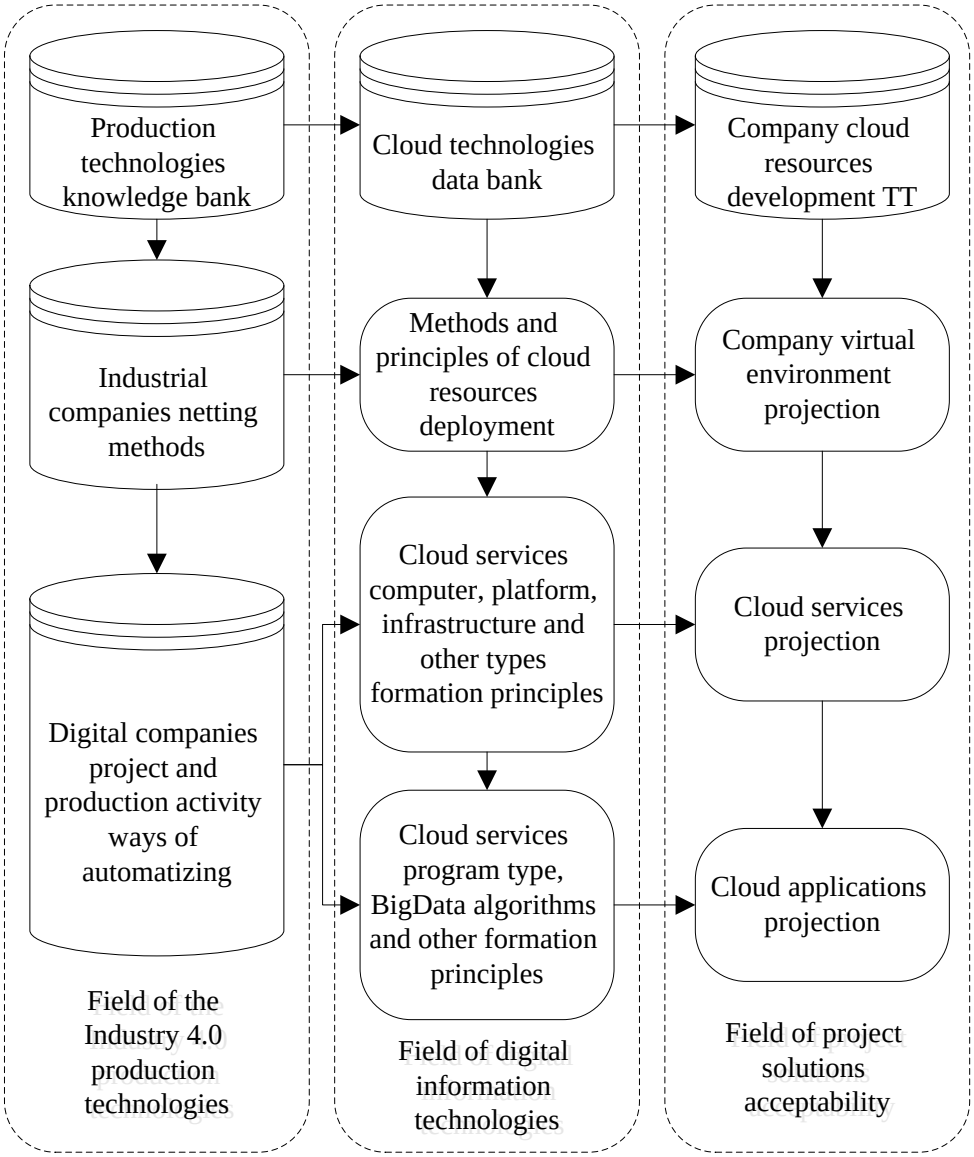

Figure 2. System projection route of the Industry 4.0 smart factory cloud resources.

Cloud services projection is done with the tasks being solved in an automatic production and requires to create in the company virtual space the components (cloud computer, cloud platform, cloud infrastructure and other) which provides the necessary calculation functioning for a smart factory. Cloud infrastructure as a service helps to deploy in the company cloud environment an automatic production digital twin and to model with the cloud applications the production operations to control their quality. A cloud computer has a limited functionality and together with cloud application helps to deploy in the company virtual space only a digital twin of a separate multi-operational CPS.

To project cloud applications is a practice oriented procedure which purpose is to automatize some technological operations using mathematical calculations or which represent CPS production activity results as a visual graph for a production operator.

4. Conclusion

Development and research of project solutions in how to create a digital automatic cyber and physical production is an actual direction of economy industrial sector development which are being done today as the Industry 4.0 concept. The Industry 4.0 concept means to create new types of item designing companies, which function with digital production and informative technologies to make a high-quality product automatically.

Today some methods how to project the robotized companies are known and the designers pay the most attention to the Industry 3.0 workshop technological arrangement problem. Unlike the Industry 4.0 digital companies which function automatically the Industry 3.0 companies function autonomously (with humans participating). So the existing methods of the digital companies projection cannot be used to develop architecture of the Industry 4.0 digital factories, smart factories and virtual factories.

For such companies they need to develop new methods and means based on cyber and physical production technology application including industrial internet of things, cloud technologies, augmented reality technologies and other because those production infrastructure components were never used in the Industry 3.0 companies.

Science and technical progress in different industry branches led today to the creation of different informative and production technologies, which have a narrow specialty of practical application significance. To organize a digital production it is necessary to define the types of technologies, which have the inter-operability property combined with an application, which may allow the designer to solve the task of the Industry 4.0 smart factories theoretical synthesis. So, this task which is to synthesize a smart factory is rounded down to explain mathematically the technical solutions in selection of digital production and components interaction technology for cyber and physical systems.

Absolutely new for the Industry 4.0 digital production in comparison with the Industry 3.0 companies is the application of cloud technologies, which is used as the base for production company virtual environment creation. Smart factory virtual environment contains the necessary cloud services and applications which access for user and cyber and physical system is realized through the industrial internet of things interfaces. So, the Industry 4.0 digital companies have an absolutely new project task which is to synthesize the cloud resources and interaction order for the smart factory production components.

Structural complexity of projection object and diversity of cyber and physical systems classes, the Industry 4.0 production and informative technologies is explained by the application of methods and means, which automatize the key project procedures of smart factory synthesis. The task to project automatizing means to complete project works is necessary to be solved in parallel of projection tasks of smart factories themselves.

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