Structure of digital and smart factories of the Industry 4.0

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Abstract. The current task of creating digital factories of the Industry 4.0 through the example of digital factories and smart factories engaged in the item designing is considered. The scheme of competences for the Industry 4.0 company is presented, based on the experience and the performance of the existing companies of the Industry 3.0. The digital factory scheme with project components and its informative support is presented. The smart factory scheme with production components is also given. Based on the results of the analysis of the digital design and manufacturing processes, the set of unique components providing information support to the project and production activity of enterprises is proposed. Implementing general components in the form of ready-to-use services deployed in the community cloud is proposed. Unification of the cloud services components is efficient for the Industry 4.0 companies which are parts of one virtual factory.

1. Introduction

Synthesizing the structure of a project and production company is an important step of the company projection. For the Industry 4.0 [1, 2], such synthesis is the combining of components and technologies to support its functionality in the virtual space (the cloud level) and its physical level.

For the company structure synthesis, it is needed to display the technologies and options from the company into the project solution space that includes technical and program support for the company activity [3, 4]. Mathematically, this procedure conforms the procedure of dividing some pluralities into subsets. Each one of them complies with the criteria. Some subsets of technical and program means provide support for separate divisions [5, 6] which function according to some mathematical criteria.

On the other hand, technological stages and procedures can be described as mathematical graphs, and the item manufacturing technological route [7, 8] could be presented as an oriented graph. Graph tops correspond to technological operations, and graph branches correspond to transportation directions in a workshop. Therefore, a subset of technological and program means of production can be assigned to the oriented sub-graph, which collectively conforms to the description of the company divisions and their functionality.

To synthesize the structure of smart [9, 10] and digital [11, 12] factories, the following should be defined:
– types of project and production operations being done in the Industry 4.0 company;
– technologies and components which are necessary to complete project and production activity, including informative and program support, and to display the defined spaces.

2. The principles of forming the competence of digital and smart factories
Creating companies of the future [13] functioning on the basis of paperless and humanless technologies is an industry development task that should be solved at a global scale. Today, no single country can separately make the full life cycle of an item based only on national technologies and components. The internationalization of production leads to emerging of transnational companies where the projection is done in one country, the item manufacturing is done in another one, and the item consumer can be located in a third country. In the setting of the fourth industrial revolution, such logistics should be done on the basis of virtual factories of the Industry 4.0.

The main know-hows of virtual factories are concentrated in the project and production environment which is divided into a digital factory and a smart factory of the Industry 4.0. The principle of competence formation of smart and digital factories is given in figure 1. The main resources of the factories activities are [14]:
– technologies of projection and manufacturing of the items (components) which are being developed today at research and development and manufacturing companies of the Industry 3.0;
– new materials, technologies and industrial standards which are being developed today at the research institutes of the Industry 3.0;
– education standards and professional specialists which are being prepared today to work in education institutes in the setting of digital economy. They are a part of national development programs, national technological initiatives, state standards, etc.

Figure 1. The scheme of the competence formation of digital and smart factories of the Industry 4.0.

The synergy effect from using the Industry 3.0 resources for creating the companies of the Industry 4.0 should lead to the following expected results:
– an item digital model which can be the item designing component, machine component (cyber and physical system), etc.;
– a process digital model, i.e. the item digital route of projection or production being done in the company virtual space;
– a digital model of the result which is the digital quality certificate prepared according to the industrial standards of new generation.

3. The structure of the Industry 4.0 digital factory

The structure of the Industry 4.0 digital factory is given in figure 2. In the scheme, the divisions and informative support types are presented which are necessary for the company project activity (item technical documentation preparation).

![Figure 2](image_url)

**Figure 2.** The structure of project divisions of the Industry 4.0 digital factory and informative support of projection activity (IaaS – Infrastructure as a Service).

The main project divisions of a digital factory are:
– a science and research division which is specialized in finding out the perspective construction types and innovative solutions to ensure the item (technologies) projected has high quality and newness;
– a research and development division which is specialized in preparation of technical (construction, program) documentation for the item, using CAD (Computer Aided Design) designing systems installed in the designer automatic workplace (AWP);
– a senior supervisor division where the designer prepares the technological documentation for the item and equipment which is necessary for manufacturing at the smart factory of the Industry 4.0.

Unlike at the companies of the Industry 3.0, where the information exchange is done with a local data bus and one standard for the files exchanged, at the Industry 4.0 companies it is done with cloud technologies. The Industry 4.0 factory cloud service is of type of the private cloud and has some infrastructure type resources. The processing of the item engineering data from the digital factory is done with the algorithms of BigData for the vast amount of the project data.

The Industry 4.0 digital factory private cloud has a cloud data storage with the components of:
– construction, program, and technological documentation which is the item digital twin;
– some branch and state industrial standards and company standards to provide information support for the company specialists of the project activity;
– some technical tasks, methods, scenarios, and protocols to control the procedure and results of the item virtual tests (virtual tests are an analogue of the physical ones and are done with the item...
mathematical model with the means of CAD designing);

– mathematical models of the item, its components, and technologies used to describe its physical and chemical properties with some formal descriptions (differential and integral equations and other);

– technical documentation for automatic workplaces for designers and technological equipment used at the digital factory as the project activity of the company.

The components of data cloud storages can be the projection results (digital models) and also types of informative support or services for projection. The Internet of Things (IoT) grants the access for the company staff members to the cloud resources.

Technical documentation for the item is the result of the digital factory project activity. The item life cycle suggests that technical documentation will be given to the smart factory to manufacture the item. The interaction between a digital factory and a smart factory for the electronic documentation can be done with the specialists of the company electronic archive which is a community cloud with infrastructure type resources. The documentation given to the smart factory has to pass virtual tests that prove the quality and adequacy of the digital twin to the actual item.

4. The structure of the Industry 4.0 smart factory
The structure of the Industry 4.0 smart factory is given in figure 3. The company divisions and types of informative and technical support for the company manufacturing activity (item manufacturing) are presented.

The main divisions of the Industry 4.0 smart factory are:

– a digital production division equipped with cyber and physical (CPS) systems functioning automatically where the stages of the item manufacturing are conducted;

– a test division equipped with cyber and physical technological equipment for the physical item testing which results will confirm the item quantity of the item being manufactured.

Cyber and physical testing and technological equipment are united in a single production line where
the item is produced. Informative support of the production process is done with cloud technologies of private cloud type and with infrastructure type services.

The smart factory private cloud has the following components of informative support of the production process:

– CAD systems which are used by the serial construction division for preparation of technological documentation and digital factory documentation (suggestions on how to change documentation);
– automatic systems of process control which are used to self-organize the functionality of cyber and physical systems. The base for self-organization process is BigData algorithms for processing the industrial data;
– automatic systems for preparing the production technically. With their help, the serial construction division and engineering support conduct the setting and field running of cyber and physical technological equipment.

The Industry 4.0 smart factory private cloud has a cloud data storage which has:
– branch and state industrial standards and company standards for information support of the production activity of the serial construction division;
– technical documentation for automatic workplaces, technological equipment, and cyber and physical systems which are used in the production activities of a smart factory;
– item technological documentation which is used in production and test divisions for manufacturing the item. Technical documentation describes the routes of item manufacturing and how to complete some technological operations;
– mathematical models of materials and components for the company virtual space to calculate the quality of technological operations completion with digital twins of cyber and physical systems;
– methods, scenarios, and protocols of real tests which are used to control the quality of the item produced in the smart factory.

The access of company staff members and cyber and physical equipment to the cloud data storage is provided with the means of the industrial Internet of Things. Figures 2 and 3 show that the digital and smart factories of the Industry 4.0 infrastructure contains some components of same-type information. Those components are marked with grey color (background).

Uniting a digital and a smart factory into a single line as a part of the Industry 4.0 virtual factory allows to exclude the clone components of information support. For that, the unified components should be taken away from the cloud storage which is a part of private clouds and transferred to the community cloud to unite the informative space of two companies. Thus, the technical documentation will be successive. In other words, it can be developed in one company and used in the production process of the other company as the part of the united item life cycle.

The technical documentation succession is due to:
– unified formats of preparation, storage and transfer of the item information;
– unified mathematical models of materials and components as a part of the item digital models;
– standards and methods for documentation execution and test organizing;
– unified digital twins of cyber and physical systems which are a part of the company virtual space.

It is important that cloud services of infrastructure type are unified and deployed in the community cloud to support project and production activity of the company.

5. Conclusion
The project and production company structure is a way to describe how the components interact. The company structure is transformed according to technical means and information support types used.

In figures 2 and 3, the most important components for creating of smart and digital factories of first generation are given. The technologies and algorithms of artificial intelligence (AI) can improve the self-organization algorithms for cyber and physical systems and project solutions generation ways. Such project and production activity can lead to the cyber and physical systems of a new type oriented for the project activity.

The creation of robotized machines at digital factories will change the designer’s functions
significantly. In the future, a designer will make concepts and methods of projection (idea generation), and the preparation of all documents will be made by digital twins of cyber and physical systems. Today, this ideology is partly realized in automatizing of construction documents preparation, where some documents are created automatically based on specifications and 3D drawings. These types of documents are based on the project engineering data that are connected to each other. Today, developing these technologies is a current task.

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