Application of the BigData technology for processing manufacturing data at smart factories of the Industry 4.0

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Abstract. The task is being studied to organize the item designing production in smart factories of the Industry 4.0 using the technology of BigData. The BigData technology is necessary to process information about the completion of theme and industrial orders. Theme and industrial orders are the sources of the industrial data at the factory. Theme orders specify the nomenclature of the products manufactured in the factory. Industrial orders specify the schedule of products and separate assembly units manufacturing. The result of the multiproduct digital manufacturing is the large amount of unstructured information that has to be processed. Processing of industrial data is conducted using specialized algorithms of BigData located in the cloud environment of a smart factory. The functional scheme of a smart factory is given to describe the components and their purpose in the level of cloud services. One cycle of a cyber and physical technological line describes the production process of a complicated item designing component.

1. Introduction
The improvement of technological processes and the development of new generation production equipment led to emerging of item designing companies functioning automatically. Those companies are defined as smart factories [1–3] which are companies of the Industry 4.0 [4–6] because those companies are to implement a new digital technology for production processes to create item designing components without an operator.

The practical realization of the ideas of humanless production is based on grouping of cyber and physical systems (CPS) [7, 8] in acceptability for technological operations in digital production sections (workshops, lines) which are to produce a particular item.

In the process of work of a technological line of cyber and physical systems, a vast amount of data is produced, most part of which are:

– the condition of cyber and physical equipment;
– the condition of technological processes completion.

To analyze the vast amount of industrial data, one needs to classify the data and mathematically process them using the algorithms of BigData first [9, 10]. To classify the data, one needs to implement two types of data in a smart factory: a theme order and a production order which are used to evaluate the quality and time required for completing the technological operations in cyber and physical equipment.
2. Materials and methods

The production of item designing components in smart factories of the Industry 4.0 is done with technical documentation being prepared in digital factories. Digital factories specialize in project activity which is to develop construction (CD), program (PD) and technological (TD) documentations. The preparation of documents is done with a group of designers in an automatic workplace and cloud services based on the requirements of the technical task (TT).

The result of an item project is its digital model which is informationally similar to the real physical object. The scheme of the interaction of physical world components and cloud services for project activity of a digital factory is given in figure 1. Figure 1 shows that the project company can develop technical documentation for several items at the same time. The number of automatic workplaces in physical space of a digital factory is equal to the number of designers who carry out their project activity in the company.

![Figure 1. Interaction scheme of components for project activity in the digital factory of the Industry 4.0.](image)

Cloud services with protocols of the Internet of Things (IoT) [11] give informative support to the project activity and are shared within each group of designers. User interface of the services helps the designers to access the resources in a multi-user mode.

The cloud services for project activity in the Industry 4.0 digital factory include:

- services to support virtual machine platforms for the project activity (such services as a program, computer, platform, infrastructure);
- services to access state and branch standards for making methods and scenarios of virtual tests with item digital models and to protocol the results later;
– services of mathematical support in solving project tasks during the modelling, virtual tests and their results;
– services to preserve the results of the project activity (the technical documentation for the item and general technical documentation for projects like a technical task) with cloud storages where the electronic documentation is put from the project company archive.

The technical documentation prepared in digital factories is given to the smart factories of the Industry 4.0 to produce a sample.

3. Theme and production orders in the smart factory of the Industry 4.0
A theme order is an organizational-management document in the company containing information about:
– the source of finance to produce an item designing component;
– the company (digital factory) which is to develop the technical documentation (digital models) for an item designing component to be manufactured later;
– the name and the code of its technical documentation for the item to be produced;
– the company (consumer) which is to receive the produced item designing component to exploit later;
– the names (numbers) of technological workshops (technological lines) engaged in the production of item designing components;
– the names of companies which are to supply the item components produced somewhere else as a part of production cooperation (if any);
– the quantity of item designing components which are to be manufactured;
– the terms of manufacturing (for the items);
– the list of company persons who are responsible for the quality and manufacturing terms of technological operations, availability of CPS, and the theme order works organization in general.

There is a company order to initiate a theme order based on the stipulated contract to manufacture and deliver the items (sets). A theme order has a unique name of the items being produced. A theme order has a number in format of AAA, which refers to the year and month when the theme order was initiated and the theme order ordinary number within the company. For a serial item designing company, the annual number of simultaneously fulfilled theme orders is about 100 units.

A production order is a specification of a theme order which is prepared by:
- an automatic translating program to process the text document with grids (tags);
- an automatic operator in production (for the item designing companies of the Industry 3.0) based on the analysis of technical specification from construction documentation for an item.

The item specification contains the full list of parts and units, components which are parts of the item, a list of the program and construct documents nomenclature created for the item. Therefore, each unit of the item can have a unique number which is the number of the production order for the manufacturer. A production order has the number in the format of AAA/BBB, where AAA is the number of the theme order to produce the items; BBB is the number of the production order to characterize a particular unit as a part of the theme order.

For a complicated item designing component which has some radio elements and optical units, the average number of production orders is about 100 units. Therefore, the preparation for production of about 1000 production orders for about 100 item designing components (theme orders) with different calendar production terms and for different consumers (exploitation companies) is conducted simultaneously in a smart factory.

To process the condition and quality of technological operations completion with such a vast number of items (units) in digital production, special technologies including BigData should be used.

4. Organization of automatic production in a smart factory of the Industry 4.0
The component scheme of the production section in a smart factory of the Industry 4.0 is given in figure 2. All components of a smart factory can be divided into physical components and cloud service
components.

The physical components of a production section include:
– cyber and physical equipment, namely production machines to manufacture the parts (units, items) as a technological line without operator;
– robotized transport equipment (robots-controllers) which is to transport blanks, parts, units, and some other things among production machines to continuously support the item manufacturing process;
– a computerized control system to generally coordinate the technological lines with the algorithms of BigData to process vast amounts of production data.

![Diagram](image)

**Figure 2.** Interaction scheme of components for production activity in a smart factory of the Industry 4.0.

Cloud services components of the production section include:
– CPS digital twins which are mathematical models of physical devices with full information similarity of the original;
– BigData algorithms to process vast amount of industrial data to make the mathematical analysis of the conditions and quality of completion of theme and production orders in an item designing company.

Figure 3a shows an example of a time chart of the cyber and physical production equipment cycle to produce the item D. There are subsections of the item D (units B, F and parts A, C, E, G) which are shown in figure 3b.

The simple lines with the filled circles show the stages of the CPS work which are a part of the production of parts (units). The dot-and-dash lines with the empty circles show the stages of the CPS work when it waits for a new production order. The lines with spaces and arrows show the transportation stages of parts (units) by a robotized transport system among cyber and physical systems within one technological line.

The figure 3a shows one time cycle of a technological line. Therefore, for the continuous production of items, one needs to give new production orders to cyber and physical systems awaiting for them. This distribution is done in a smart factory with computerized control systems of cyber and physical systems.
based on the algorithms of BigData to process the information of completion of the theme and production orders.

![Diagram of technological line](image)

**Figure 3.** Characteristics of production process: a) a time cycle of CPS functioning, b) the components of item D.

5. Conclusion

The modern item designing companies of the Industry 4.0 are a difficult thing to create where one needs to unite physical and virtual components. For the harmony of this integration for the purpose of creating innovative production sections, one needs to apply new information technologies.

As figure 2 shows, the technologies of the item designing companies are cyber and physical systems, cloud technologies, industrial IoT technologies, technologies of BigData, and other. Cyber and physical systems produce physical items. Cloud technologies and industrial IoT technologies are a production mean of cyber and physical level (virtual). The technology of BigData based on cloud services is to process vast amounts of production data generated in the work process of a smart factory to control the condition and quality of completion of item designing component technological operations.

All industrial data generated in a smart factory can be divided into the information about cyber and physical system condition which can be processed without statistics and the information about technological operations completion conditions which is processed statistically. The mathematical programs to control the quality of completion of technological operations as part of theme and production orders are the base for the BigData algorithms technology.

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