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Organization of information exchange between digital companies of Industry 4.0

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Abstract. The paper studies an urgent task of organizing the information exchange between design, production and exploitation companies of Industry 4.0. The information exchange is based on different types and principles of deployment. The access to cloud services for the designer, production operator and exploitation operator is based on wireless technology of industrial Internet of Things. The work suggests the interaction scheme and describes the purpose of the information exchange components between Industry 4.0 companies.

1. Introduction

Information support for design, production and exploitation of equipment parts is based on the implementation of advanced digital technologies at each stage of the article life cycle. The advanced digital technologies of Industry 4.0 include additive manufacturing, cloud technologies, Industrial Internet of Things (IIoT) and other [1-3].

To integrate digital technologies, one needs a unified information space between design, production and exploitation companies. Design and production companies of Industry 4.0 are digital and smart factories that are equipped with cyber-physical systems (CPS) [4, 5]. CPS enable automatic article creation implementing their digital models and digital twins of technological equipment [6, 7].

The exploitation companies of Industry 4.0 involved into item life cycle are united into clusters forming a virtual factory. A virtual factory is to account and control item movement during the exploitation including the information support of logistics (item delivery to the exploitation destination, item installation at the facility), warehouse storage, item sending to the manufacturer for repair and so on [8, 9].

Thus, the task of developing a scheme of information exchange between the companies of the future—digital factories, smart factories and virtual factories—is high on the agenda to guarantee the non-interrupted life cycle of an equipment part.

2. Physical-world components for interaction of Industry 4.0 companies

All infrastructure components that are necessary for Industry 4.0 companies to interact are of two types: physical and virtual. Physical components are hardware equipment of design and production and



exploitation processes of the items [10 ,11]. The physical world components of an Industry 4.0 company are given in Figure 1.

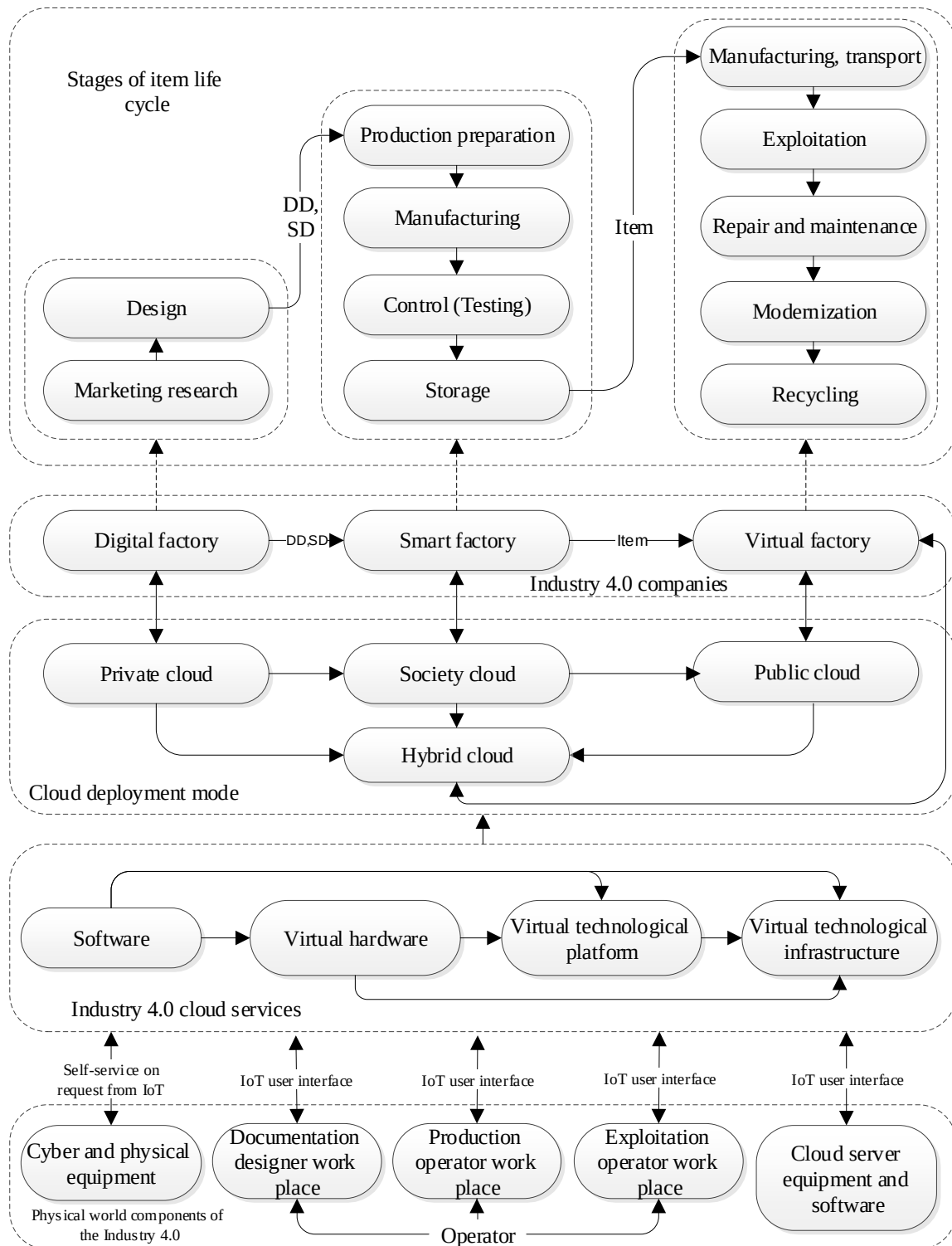


Figure 1. Interaction scheme of information exchange components between Industry 4.0 companies.

The physical-world components of an Industry 4.0 company are:

- cyber-physical systems, engaged in the production process at smart factories;
- automated work places of the developers of design documentation (DD), software documentation (SD) and technological documentation of items designed at digital factories;
- automated work places of production operator for quality assessment and to control the stages of equipment part manufacturing at smart factories;
- automated work places of exploitation operator at a virtual factory to monitor and control the movement of equipment part during exploitation;
- server equipment (computers, switches, routers, data storages and other) and software which on the physical level creates cloud services with remote access.

The operators of the automated work places interact with cloud services via user interface software by IoT protocols. The means of human-to-machine communication are as follows: personal computer, tablet, phone or other equipment with a screen, browser and access to internet. An Industry 4.0 company includes many automated work places synchronized with each other to perform design and production operations in line with the part development of or its manufacturing algorithm.

Cyber-physical systems [4, 5] enable automatic information exchange with cloud services components with *self-service on request* access provided by IoT components. Each component of a cyber-physical system has personal software-supported internet access port in a unified channel of cloud information exchange for the mechanical assembly line.

3. Virtual-world components for interacting Industry 4.0 companies

Software services create virtual components with remote user access through an automated work place. The cloud services necessary for information exchange between the Industry 4.0 companies are given in Figure 1.

Cloud services of Industry 4.0 are [1-3]:

- program-type service which provides a digital factory designer with the final piece of software to design an item and automatically create template-based technical documentation;
- computer-type service which gives a digital factory designer and smart (virtual) factory operator the final piece of hardware for computation, technical calculations, modelling, rendering, user software installation and other. Virtual calculation machine is a software server available to user as a resource;
- platform-type service which gives a digital factory designer and smart (virtual) factory operator a means to develop special user applications destined for particular design and production operations. Consequently, the ready-to-use components of user applications can be regarded by a user as a program-type cloud service;
- infrastructure-type service which gives a digital factory designer and smart (virtual) factory operator a means to manage digital engineering and financial data about company activity, digital models of manufactured equipment components, company digital twins and its technological equipment (cyber-physical systems).

Obviously, the infrastructure-type service is the most efficient service and is created after the integration of lower-tier services: program, computer, and platform. The integration of services (pooling of cloud services) can be done by several means (deployment models) in a single cloud that is available to the personnel of the factories of the future.

Cloud deployment models are defined by the tasks of a particular Industry 4.0 company and can be:

- a private cloud which corresponds to the activities of a single company which performs a particular set of life stages of an equipment part. Such company is an Industry 4.0 digital factory which carries out some design tasks to create technical documentation for an equipment part;
- a community cloud which corresponds to the activities of a group of *supplier-consumer* companies and unified document workflow within the production cooperation. Such group of companies is called smart factory, which manufactures items of equipment and their components (materials, parts);
- public cloud which corresponds to the activities of a group of companies (virtual factory) which personnel is to monitor the condition of an equipment item during its life cycle (from the stage of marketing research until the stage of recycling);

- hybrid cloud that in terms of the user access type unites hardware and software solutions and services used in a private cloud, community cloud or public cloud.

Thus, the cloud service deployment model defines the means and right of access for an Industry 4.0 company personnel to different cloud services.

The data storages of a private cloud contain the following components as ready-to-use Computer-Aided Design (CAD) solutions:

- archive of design solutions generated automatically by the developers as a part of a digital factory operation. The archive of digital factory project solutions includes newly developed and already existing solutions with high unification and standardization. The design solutions are digital models of equipment items;
- archive of tasks for the development of an item of equipment and its parts (private development tasks);
- archive of company standards which regulates the processes of design and electronic document flow in the company;
- archive of reference and technical regulation documentation which is necessary to develop technical documentation for equipment items according to the industrial and state standards;
- archive of technical documentation for standard items and materials (resistors, capacitors, metals, rubber, paint and other) used as raw materials and components to design new equipment;
- mathematical models of environment (externalities) necessary for certain stages of virtual tests on digital models of equipment items performed at a design company. Virtual tests are done to evaluate the compliance of an item under development with the technical task (technical solutions suggested by designers are validated using mathematical models, while the design results are rendered on the computer screen of an automated work place).

The cloud storage of contains the smart factory data as library services:

- archive of company standards which regulate the production operations and electronic documentation flow in the company;
- workflow charts and technical documentation for equipment item provided to a company for its mass production;
- algorithms of technological processes and operations which consequently are used to compose a workflow chart equipment item production;
- digital twins of technological equipment (cyber-physical systems) installed at a production company and enabling automatic production of equipment items;
- models of components and materials which are used in the company to create an equipment item;
- network models and charts of equipment item manufacturing at a company, including production data of both primary manufacturer and suppliers of components working within the production cooperation.

The cloud data storage of a virtual factory contains the library services of:

- archive of the standards regulating the electronic document flow in the company;
- data on the operation of the item and its operation documentation;
- list of contractors that contribute to the item life cycle (development, production, transportation, maintenance, repair, and other).

In Figure 1, the dashed arrows show the connection between Industry 4.0 companies and the item life cycle stages implemented via cloud services.

4. Conclusion

The development of modern item design industry inherently includes the improvement of technological basis of design and production companies and organizational support of companies that use the item. The united information space is made available to the personnel of the factories of the future through a set of services deployed in a cloud.

The cloud service contains a set of data that corresponds to mathematical, software, information, linguistic, methodical and technical support which interaction is regulated via organizational support.

The organizational support application by the personnel of the factories of the future enables the information exchange between Industry 4.0 companies at each stage of equipment item design.

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