Engineering and manufacturing methodology of multi-robots collaboration model synthesis

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Abstract. The theoretical problem of the synthesis methodology for the collaboration of multi-robot facilities is investigated. The analysis is presented and the basic hardware and software of multi-robot facilities are determined. Multi-robotic industry can be implemented within the intelligent mechatronic systems (IRS). A methodology has been developed and procedures for technical collaboration of the intelligent robotic components of the multi-robotic industry have been defined. The emerging technologies of collaboration between IRS are determined. The analysis is presented and the results are determined for each intelligent robotic component of the engineering and manufacturing mechatronic facilities. The function and specialization of each IRS resources for the implementation of the multi-robotic reliable facilities is determined.

1. Introduction

Robotization of mechatronic factories has identified new business strategies for the implementation of procedures for the engineering and manufacturing of technical devices [1, 2]. A specific feature of the new industrial structure is the integrated nature of engineering and manufacturing. The problems of educating specialists, developing a new type of robotic elements (intelligent robotic systems — IRS) [3, 4], developing the emerging high technologies, etc., are not of a separate nature today and are being solved in parallel [5, 6].

Within the framework of Industry 4.0 technologies, new robotic facilities are being formed integrating the most critical phases of the technical product life-cycle [7]. As a result of this interaction, the costs of engineering and manufacturing will be significantly cheaper.

Changes in the methodology for engineering and manufacturing are reflected in new forms of innovative interaction of robotic factories and in the synthesis of new types of mechatronic robotic structures [8, 9]. An additional component inherent in mechatronic robotic enterprises is a cloud, in the resources of which relevant components serving engineering and manufacturing are located [10, 11].

The cloud is a digital resource for engineering and manufacturing, duplicating the mechatronic structure of real robotic facilities with a brainware model [11, 12]. Brainware models of robotic facilities provide in cloud parallel modeling of robotic processes. Simulation results are optimal business strategies for humanless mechatronic engineering and manufacturing [13, 14].

New types of robotic facilities and the high emerging technologies for their interaction have identified the developers of mechatronic factories [15, 16] new strategies for ensuring synchronous
parallel function of IRS, which are installed on remote production sites. Such strategies are intended to be used as part of distributed engineering and manufacturing tools.

2. Engineering and manufacturing resources classification
To organize industrial factories as the Industry 4.0 conception is done in the direction of three types of mechatronic robotic facilities creation [17, 18]:
- the mechatronic robotic facilities as an engineering company;
- the mechatronic robotic facilities as a manufacturing company;
- the mechatronic robotic facilities as an exploitation company.

The mechatronic robotic facilities as an engineering resource includes [19]:
- a manufacturing facility;
- a modelling and visualization facility;
- a facility of cloud.

The mechatronic robotic facilities as a manufacturing resource includes [20]:
- a manufacturing facility;
- a test facility;
- a facility of cloud.

The mechatronic robotic facilities as an exploitation resource:
- a logistics facility;
- an exploitation facility;
- a facility of cloud.

The sustainable engineering and manufacturing scheme is shown in figure 1. The most general for all three types of factories are human resources (specialists) and cloud resources. Cloud resources could be united into a single virtual facility for mechatronic factory with the principles of cloud different type. IRS and specialists access to the mechatronic factories cloud resources is done by means of Ethernet and IoT, which let the engineering and manufacturing IRS out to the global Internet [21].

![Figure 1](image_url)
3. Collaboration of the computer-integrated engineering and manufacturing components

A result of the mechatronic robotic facilities interaction is engineering and manufacturing of product. The collaboration of the computer-integrated engineering and manufacturing components in the product life-cycle are shown in figure 2.

Mechatronic robotic factories designers provide device projection with hardware and software concentrated in a facility. Hardware of engineering include industrial computers in which automatic work places are deployed. The engineering software is placed in the mechatronic facility cloud and is used by the designers to prepare the device electronic models (copies).

The digital copy has the stages of model tests being executed by the designers in the modelling and visualization facility. The results of copy model tests are used by the designers to verify the electronic manual quality. The innovate final representation version of device is a digital twin, which positively passed all types of model tests in a mechatronic robotic facility. The digital twin for device is transmitted to the mechatronic robotic facility server, which is done as a cloud storage.

The device digital copy availability in a smart mechatronic robotic server storage is a necessary condition to put a device into mechatronic manufacturing. Manufacture hardware is placed in the smart robotic facility and executed by intelligent robotic systems of industrial purpose. The manufacturing in the robotic facilities is done with the robotic data and the control system software for IRS placed in the cloud. The manufacturing humane control the quality of the mechatronic processes completion.

Device automatic manufacturing result using intelligent robotic systems is a real device. Each real device is transmitted to the mechatronic robotic test facility in which automatic intelligent robotic test hardware and software are placed. Real devices passed all tests positively are given to the exploitation.

The device exploitation is done in the virtual mechatronic facility, which unites service centers of device repair and maintenance, exploitation points, transport logistics, etc. Device exploitation accompanying is done by specialists of virtual mechatronic facilities who coordinate the device movements in cloud.

Each device exploitation results data are transmitted to the virtual mechatronic facility cloud and to the robotic engineering factory cloud to evaluate parameters of device exploitation reliability. Besides, device exploitation data is the base to correct the device digital copies tests methods so electronic manual and the methods of its verification is being continuously improved.

Figure 2. Computer-integrated engineering and manufacturing systems in the product life-cycle (ED - exploitation documentation).
4. Conclusion
Created in last 70 years practice how to organize engineering and manufacturing for industrial factories is done today in the existing technologies. The existing technologies requires to implement in the mechatronic robotic facility electronic and computer-integrated resources. The primary resource components of engineering and manufacturing today are highly productive personal computers, IRS with computer numeric control, etc. equipped with a special software:

- systems of engineering;
- systems of manufacturing;
- systems of device life-cycle automatic control, etc.

The current requirements of world industry defined new methods to organize engineering and manufacturing, which hardware and software a significant increase in engineering automatizing and executing transition to fully robotic facilities. The substantive part of the automatizing principles for engineering and manufacturing defined in the high emerging technologies. Emerging high technologies are to create mechatronic robotic facilities and IRS of new type and to implement it in all stages of the devices life-cycle [22, 23]:

- progressive intelligent machines, which is multi-materials IRS of mechatronic;
- perspective high emerging technologies based on cloud, wireless connection, artificial intelligence methods, etc.

Emerging technologies diversity and multi-material of intelligent robotic systems requires from the mechatronic facility designer to make some solutions, which define [24]:

- role and place of all type mechatronic robotic facilities in the device life-cycle;
- intelligent robotic system types and emerging technologies being used in the mechatronic facility;
- ways of synchronous interaction organization for sets of IRS.

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