Distribution of software between reconfigurable manufacturing systems

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Abstract. The scientific-technical problem is to organize the device manufacturing process using reconfigurable manufacturing systems software. Controlled with a software machines are the unit of reconfigurable plant. It is received to classify the machine software according to its place in a reconfigurable plant. Autonomous, remote, virtual and distributed software for reconfigurable manufacturing systems (RMS) is described. Autonomous component software is placed inside the RMS itself. Remote component software is placed in the RMS physical server. Virtual component software is placed the RMS cloud server. Distributed component software is placed simultaneously in all infrastructure components of a RMS with its own hardware. The functional schemes are received for the hardware and software RMS in the two level: physical and virtual.

1. Introduction

The reconfigurable plant constitution principles have the flexible and advanced technologies [1, 2]. Reconfigurable manufacturing system (RMS) in plant is a computer system, which controls the device production process, which takes place inside the machine. Manufacturing process organization in a RMS is done in the physical devices level and in the cloud twins of the RMS, which permits to classify a RMS as a multi-processing computer system with a multiple tide of commands and a multiple tide of data [3, 4].

A reconfigurable manufacturing systems are united in a reconfigurable plant with the principle of completion results acceptability into separate technological sections, which together create a workshop of plant [5, 6]. From the computer process organization point of view such schemes of RMS unification may allow to create in a reconfigurable plant a multi-level hierarchy computer structure, which control is done in the software. Each RMS in this case is viewed as a reconfigurable plant agent in a multi-agent reconfigurable structure [7, 8].

RMS resources availability allow to place in the plant infrastructure a software, which is used by the reconfigurable distributed manufacturing control system to plan [9, 10]. The plant infrastructure consists of distributed in a physical devices and plant cloud models, which does not allow to place the plant software directly with a base of a single computer core [11, 12]. So to project a reconfigurable plant it is necessary to design and implement into infrastructure the RMS, which use the software as a tool [13,
Reconfigurable plant is a combination of autonomous RMS, which control is realized in the software. By the components the plant infrastructure within which RMS software are placed all machines can be classified as [15, 16]:

- RMSs with autonomous functional software;
- RMSs with remote functional software;
- RMSs with virtual functional software;
- RMSs with distributed functional software.

2. **RMS with autonomous components software**

Software components functional scheme for RMSs with autonomous component software is shown in figure 1.

![Figure 1. Autonomous software components functional scheme in the RMSs.](image)

Software autonomous components are placed directly in the RMSs static memory and are executed by the controller. The autonomous components software include:

- operational system;
- functional software;
- testing software.

which are installed to the RMS in the reconfigurable plant. The autonomous software is the RMS software base set which defines the probability of the RMS universal application in a reconfigurable plant. A RMS with autonomous software is a unit of reconfigurable plant oriented to manufacture a multi-material of the devises.

A RMS with autonomous software is a universal computer, which setting is being done by the additional software components with the requirements of a particular production placed within the servers of the reconfigurable plant. All RMSs being used in a reconfigurable plant are equipped with autonomous software, which supports the data exchange functions in different formats through the interfaces of Ethernet, Bluetooth and other.

3. **RMS with remote components software**

RMSs remote software components are placed in a server, which is located in the reconfigurable plant. RMS server equipment software access is done with wireless channels of Ethernet. Autonomous server with software does not have any connection to the internet and is placed within a section or within a workshop to service a limited number of RMSs which manufacture the device.

The remote software does not contain the components of functional and testing software, which are used to control RMS functionality and to specialize each RMS oriented within a industrial line to complete a given number of operations. The remote software is installed to the RMS static memory from
the server after each RMS power-up or RMS reloading after a failure of device manufacturing.

Remote software components are narrowly specialized in relation to the device being manufactured in a particular plants section and are different from the neighboring sections. Remote software components define inside the workshop technologies of RMS interaction. Software components functional scheme for RMS with a remote software is shown in figure 2.

![Figure 2. Remote software components functional scheme in the RMSs.](image-url)

4. **RMS with virtual components software**

RMS virtual software components are placed in the server, which are located inside the reconfigurable plant or beyond it. RMS server with virtual software provides the plant cloud environment access to which for each RMS is done with the interfaces of Internet-of-Things.

RMS virtual software is general for each RMS, which are placed in different reconfigurable plant sections and are necessary to organize synchronous RMS interaction, which manufacture the device in a plant with different theme and production orders. Virtual software supports RMS flexible technology in the inter-workshop level.

Virtual software has the components of the RMS functional software executed in a virtual machine deployed in the reconfigurable plant cloud resources. Software components functional scheme in a RMS with virtual software is shown in figure 3.

![Figure 3. Software virtual components functional scheme in the RMSs.](image-url)

5. **RMS with distributed components software**

Distributed software components are placed simultaneously in each RMS, in the plant servers and external ones, which provide plant cloud environment. Distributed software is used to organize RMS synchronous interaction, which executes simultaneously testing (background) and functional software in the physical RMS and in the virtual RMS.
The distributed software contains operational system components placed in different computers (RMS, server and other) of plant, which interact. Distributed software in plant a parallel completion of autonomous, remote and virtual software components inside the RMS in multi-task mode, which supports the production data exchange among RMSs with the interfaces of Ethernet, IoT, Bluetooth.

The distributed software is the base for the distributed manufacturing control system software, which supports as well man-machine interface of humane and RMS interaction in a reconfigurable plant. The distributed software functions with methods of artificial intelligence, which is to self-reconfigurable the RMS in plant. The distributed software components helps to plan the plants processes, which is done in the cloud platforms or in the cloud infrastructure of the reconfigurable plant. The software components functional scheme in a RMS with the distributed software is shown in figure 4.

![Figure 4. Distributed software components functional scheme in the RMSs.](image)

6. Conclusion
The projection of RMS plants based on automatic reconfigurable robotic workcells helps to show a number of properties among, which the most important for the project solution are:

- multi-processing, which means each component of the reconfigurable plant engaged in the device manufacturing completion has a calculation platform functioning with a software;
- multi-link, which means all RMSs, server and cloud, the plant warehouse and mobile RMS are united with communication calculation environment of the plant data transition;
- multi-devices, which means all RMSs are narrowly specialized and to organize a manufacturing of device it is required several autonomous RMSs;
- multi-image, which means that all RMS elements have an image in the physical RMS and an equivalent image in the cloud RMS.

So reconfigurable plant is a complex of physical RMSs and software RMSs for technological and computer components with open architecture. RMS highly-productive computer resources, high-level RMS programming languages, high-speed channels of information data exchange among RMSs and plants cloud are key components and necessary methods to create a perspective reconfigurable plant.

To organize plants process of a device manufacturing the most perspective scheme of software placement in a RMS is a distributed scheme. The distributed software helps to create exchange of plant data and to organize a computer process in a plant with the rules of open specifications, which gives the
projection perspective of scaled automatic reconfigurable factory. A scaled reconfigurable plant may integrate new RMSs or entire industrial lines without significant change of the existing plant in the company, in the hardware and in the software level.

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