Cyber-control of groups of technological aggregates

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Abstract. Groups of technological aggregates creates a production cyber-segment being controlled autonomously. Electrical automatics aggregate elements are described as some control theory terms with kinematics and dynamics tasks laws being completed. Cyber-control system of groups of machines in production is built as a multi closed-loop scheme with typical two or three loops tracking channels. There is a multi-loop production cyber-control scheme given. The cyber-control specifics include the additional virtual and traditional physical tracking system. The aggregate virtual tracking system control signals are registered in parametric settings of physical tracking system regulators. The aggregate situation cyber-control is done with a digital production avatar.

1. Introduction

Multi-agent cyber-control of groups of mobile robots is an interdisciplinary scientific task of the industry automatizing, which solution includes the developed countries innovations prioritized list [1, 2]. Proved in practice industrial structure architecture with smooth and unchangeable technological processes is highly unsuitable for the modern market defiance, where the mechanized equipment automatic rearrangement ability is additionally actual under the conditions of uncertain production environment [3, 4].

The general problem of operational cyber-control of groups of mobile robots, made in the class of cyber-physical objects, is the absence of the independent agents smooth algorithms defined algorithm united by a variable (multi-link) mobile connection net topology [5, 6]. The production agent architecture is based on multi-mode connection with net objects complicated identification system, which is to control the objects and industrial automatics agents [7, 8].

The super modern solution to provide the robotized agents behavior co-ligation as a group are formed in the Industry 4.0 program documents, which understanding by an author could be approximately used as the poorly organized system optimal cyber-control strategy to manufacture a non-imported product [9, 10]. The industrial objects control and identification ability are formalized by the relationship complicated resources as a group of mobile robots, which are equal to independent technological aggregates, which may highly load the equipment [11, 12].

The robotic systems cyber-control is a part of the newest technological history and virtual agents must be implemented to the hierarchy production system (cyber-components) and partially the calculation load will be transferred from cyber-physical objects to the cloud [13, 14]. The cloud
environment smart net unites technological aggregates, physical processes and mathematical calculations to coordinate the agents into a robotic group. The machine groups received the artificial intelligence create multi control closed-loops functioning with industrial automations laws based on adaptation and learning principles [15].

The Industry 4.0 strategies as an innovation preserve the human analytical abilities in the virtual and physical robotic systems control closed-loop. The discrete production digital avatar is an ergative component with functions of relationships situation regulations to formalize cyber-physical objects group interaction [16, 17]. The discrete production avatar harmonically implemented into general control plant system realizes eristic schemes of independent production operations synchronization.

Cyber-physical understanding of the Industry 4.0 strategy requires a detailed scientific development to construct new virtual control models for a group of mobile robots adapted for the conditions of uncertain production environment [18, 19]. When the active cyber-physical objects are appeared the central net cyber-control idea significance increases clearly but the solution available today are nothing more than private academic researches and one unit laboratory replicas [20].

2. Cyber-production control system decomposition

The cyber-production control system solves the organizational and technical problem of ensuring the coordinated interaction of technological automations, consisting of a large number of interconnected aggregates. Depending on the requirements of different production sub-technologies the industrial object control system makes some deliberate influences on the corresponding technological aggregates to realize a set of rules and prescriptions to rule the product manufacturing procedure. The cyber-production technological object control general scheme is given in figure 1.

![Technological cyber-production object control general scheme.](image)

The cyber-production control system informative capacity supports the dynamic state indication intellectual regulations:

- single technological operations and production processes conditions in the control objects working volume (the processes physical parameters stabilization);
- a set of technical means to complete the combined (the subsequent and parallel) scheme of some production functions according to the given program (the control object working modes end plurality control).

To reconfigure the technological equipment and control objects regulators parameter settings includes the machine designing different production processes aspects to provide the combined safe and economical functioning of aggregates. The industrial objects automations system in practice is done with several control levels accorded with parameters, which apply the closed-loop feedback in the regulation and control loop of the cyber-production. The functional completeness automatic system property is reached through the technological aggregates provision with different types of controlling and regulating nodes, which are in direct contact with the cyber-production environment.

The required influence of the technological automatic elements great number is provided with adaptive regulation algorithms to make a comparison between the being received production processes quality and the reference processes, which are being calculated with the equipment digital twins in the different levels of abstraction. The first cyber-production control system structuring requires the
regulation dynamic models separation with item manufacturing physical processes in three levels:

- the cyber-production automatics low level contains the sensitive elements (measuring detectors) to regulate the technological parameters, which are to be controlled and regulated including the executive devices, which influence the aggregates conditions;
- the cyber-production automatics medium level contains the microcontrollers, which integrated in the aggregates electronic components and to make real the object being regulated control laws according to the controlling technological parameter type (the 3D (Dimensional)-printer material consumption, the printed circuit boards washing baths liquid level, the solder reflow temperature in the convection oven profile and other) and to establish its stabilization quality;
- the cyber-production automatics high level contains the computer equipment servers, which evaluate technical aggregates static and dynamic properties of the processes being engaged for each control channel and parameter being monitored.

Controlling influences accordance with low-levels and high-levels automatics elements including the technological process being controlled part details or for aggregates (a group of aggregates), which provides typical regulation laws including mechanisms of remote transferring for the message register unit (measuring results) to characterize the cyber-production activity definite aspect.

3. Cyber-control of groups of robotic object

Cyber-control of groups of robotic object in production is done with robust and adaptive methods to provide the smooth interaction of physical and virtual plant components. The digital production physical layer is formed with some mechanized machines (the low-level automatics integrative system). The digital production virtual layer is formed with (a quality new system of high-level automatics) different aspects of cyber-control which is the artificial intelligence. The secured inter-machine data exchange is done through interaction interfaces of the cyber-physical objects multi-agents full functional integration constructed in different types. The Industry 4.0 production cyber-control multi-loop system is given in figure 2.

The robotic system virtual and physical cyber-control is done with functioning and stability supporting of each automatics closed-loops with their own quality parameters in the given restriction system. The cyber-control strategy under production environment uncertainty requires one type principle to construct each closed-loop, which together is a multi-loop system. The component specifics of private tracking systems and its dynamic indications registration are defined with kinematics and dynamics laws done with a particular technological aggregate.

Cyber-physical objects group interaction is based on expert systems technologies to provide a non-failure production functioning. The artificial intelligence controlling the production has the following functions:

- the semantic structuring of data tides being translated to a multi-agent environment by the message transport service;
- to find out critical points and to calculate non-blocking transportation routes by a smart transport machine of the product being manufactured;
- to calculate a dynamic massive of topology and kinematics technological aggregates interaction schemes;
- optimal cyber-control informatively and mechanically connected groups of technological aggregates;
- the cyber-physical objects executive organs movement time and space coordination and calculation metrics processes;
- informing the responsible specialists about the happened production rules;
- operative modification of the cyber-production algorithm platform, robotic agents behavior specifics, a set of program utilities and other;
deviation detection of technological aggregates working modes with established by the manufacturer resource restrictions;
several times correction (balancing) of time table (loading chart) of technical aggregates under oscillation of the production orders incoming tides conditions;
inner materials part tides optimization and insured tools orders (materials);
grouping of shifts and days tasks synchronized with all following related production operations and other.

The item being manufactured digital twin

Cyber-production digital twin

Figure 2. The Industry 4.0 production cyber-control multi-loop system.

The secured information exchange protocols provides the message queue mechanism inter-machine interaction service. The machine and program technological aggregates junction equipping support the message sender and receiver functions. A table of agents (agent identifiers) is formed by a decentralized communication scheme, where each receiver may support a radio connection in the group with neighboring equipment within the mobile connection coverage. The messages being circulated content is different up to the message significance and functioning for technological aggregate in a group.

The robotic agent message receiver for cyber-control task has the following internal resources functions:

the production tasks detection, controlling variables and information of attributive matter available through the Internet for technological aggregate;
autonomous in implemented software (the item digital model) of the product manufacturing in optimal and close to optimal modes with minimal planning self-cost;
the data copies storage and technological aggregate conditions protocoling;
the correct finishing of production operation when the cyber-physical object alarm working mode happens;
regulation with disturbance control transportation and position stabilization process factors of the technological aggregate executive organs;
blocking of the last received message if a time connection loss is detected into digital company Internet channel;
tracking of controlling parameters and minimizing of dynamics errors of the product manufacturing depending on situation being monitored in stochastic production environment.
with temporary technological load and other.

Robotic message sender agent for cyber-control tasks has the following internal resources functions:

- forming and displaying through the digital connection channel a robotic objects group message or to a particular independent production aggregate registered on net;
- informing the production control artificial intelligence about a non-planned event, which is critically important for cyber-physical objects exploitation to reflect the meaning of what is happening while the machine is functioning (for example, equipment and tool wearing out);
- informing the production control artificial intelligence about a period of planned maintenance of technological aggregate synchronized with primary and secondary production processes, which directly influence the object interaction in an industrial robots group and other.

The general production net infrastructure with synchronization means to provide communication message exchange environment in the separation in time mode. A non-synchronous technological aggregate connection and group structures cyber-control into mobile configurations, which is done with the following net functions:

- IP (Internet Protocol)-address identification of each cyber-physical object (machine) registered in general and local company nets and equipped with Bluetooth, Wi-Fi, GPS (Global Positioning System) or 4G (Generation) modules by the manufacturer;
- to support message receiving function (sending) among agents with a transport protocol, which may export and import the end consumer production data;
- saving production messages in a queue and their context duplicating with block chain technologies to cyber-control remotely the technological aggregates with necessary indications of quality;
- the personal digital identified avatar communication with a central mobile control of collective monitoring and cyber-physical objects and other.

A digital production avatar may solve some cyber-control tasks with a single operator stand (monitoring electronic block) and machine means like a terminal or a separate gadget software, which is a tablet computer form-factor. The digital production author function who is personally responsible for technological processes coordination as a remote cyber-control task is:

- to prepare tasks and change scenarios of manufacturing for necessary production planning depth in group interaction technological aggregates algorithms;
- to connect a reserve super computer resource into a digital production cyber-segment, which is maximum-ly loaded with orders and engages the calculation resources;
- operative perception and reaction of different situations in the production conditions out of permitted limits dictated with digital twins (models) of robotic mobile groups;
- initial data or separate parameters restrictions changing corresponding to external production orders resonance conserving the control accuracy with industrial automatics elements;
- technological aggregate parameter settings if the avatar manufacturer granted it this function;
- the contra-agents information actual state of some time moments participating in inner and external production cooperation and other.

The station control face-panel (terminal) or a wireless remote (gadget) are made with fully size sensor screen collecting discrete technological aggregates control signals and their status (description attribute: without a load, order completing and other). General and detailed dynamic quality analysis of the items being manufactured is done with a cloud service with an effective data semantic structuring mechanism using a recursive mathematical operation.
4. Conclusion
A group of robotic cyber-physical objects is an actual research direction including scientific cyber-control tasks and information processing. The production key element is the calculation environment uniting into a single information field all available cyber-physical components engaged in technological operations. Regulator virtual models implementation functioning in parallel with technological aggregates and physical loops creates a new type of control process maximum-ly approximated to an advanced production.

The national interests to realize cyber-physical technologies potential is an influence dominating factor, which proves the State technological independence. The cyber-control task central position is to formalize principle combos how a multi-agent system functions, which is used in the Industry 4.0. To overcome several fundamental and secondary scientific problems of cyber-control they use profile academic centers to improve system theory, automatic regulation theory and information security theory.

The goal of the Industry 4.0 cyber-control, which makes it different from the modern production with its automatizing is to create automatic system capable to function autonomously in real world by adapting to the disturbances being controlled. To create a completely new production requires to design a set of science and technical solutions within which the primary one is the data processing cloud centers based on industrial metrology systems. The cyber-control of robotic groups is an orientation to design a discrete automatic production model necessary to work out the Industry 4.0 advanced industrial solutions. An intellectual production engaging virtual cyber-control technologies combining with cyber-physical robots and technics soon enough will define the forthcoming informative era technological base. Technical and economic reasons of such industrial approach are proved by specialists now.

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