The Industry 4.0 net information, measuring and control subsystems

A V Shukalov¹, I O Zharinov¹ and O O Zharinov²

¹ Faculty of Information Security and Computer Technologies, ITMO University, 49, Kronverksky Av., Saint Petersburg, 197101, Russia
² Department of Problem-Oriented Computing Complexes, Saint Petersburg State University of Aerospace Instrumentation, 67, Bolshaya Morskaia str., Saint Petersburg, 190000, Russia

E-mail: aviation78@mail.ru

Abstract. The net information subsystems are for measuring processes application, universal and special cyber-physical production control processes through the calculation and link. The subsystems consist of calculation, technological and telecommunication devices united into open system architecture. The schemes are given of information, measuring and control subsystems, which coordination effort mechanisms are selectively to process a distributed information received through nets of electro and radio connection with a necessary passing through ability. The subsystem structure contains physical and virtual components, which include calculation, electronic and electromechanical elements united with general principles how to construct a communication nets for cyber-physical systems reception and transmission. The main attention is paid to the general data exchange processes as for measurements and control engaging the information vast data processing, which are formed in cyber-physical systems registered in different company local nets.

1. Introduction

The cyber-physical production (CPP) development by implementing base concepts and separate Industry 4.0 innovations for the cyber-physical systems (CPSs) functioning is an innovative transformation of item manufacturing methods and means, which is to increase the control technologies, calculation and connection combined usage efficiency applied in the industrial objects automatizing [1, 2]. The CPP segment progress obstacle is the uniqueness of some technical solutions and the company infrastructure components resource restrictions, which today must be reconsidered and they do not provide the technical rules completion necessary accuracy [3, 4].

The one side way to watch the CPP improvement problem and assets technological renovation bears the creation risks of rigidly organized industrial systems with a potential modernizing limit [5]. The Industry 4.0 actual production option means to aggregate functional subsystems, quality parameters which functionality reflects the balanced indications system collected after some machine equipment condition monitoring [6, 7]. The functional subsystems actions coordination is based on some control organization principles applied in the open type CPP systems [8, 9]:

- the item manufacturing procedures mechanization is done with operational integration, which
is different in CPS control parameters into a single technological environment segment where a lot of parts of different nomenclature are produced;

- the CPS device and technological processes intellectual automatic control is done with the CPP communication information integration among the elements, which are organized in a distributed calculation net structure.

Subsystems to provide a CPP, which correspond its control purposes [10, 11]:

- information and measuring subsystem (IMS), which tracks the CPS functionality parameters and commands and data formation, which are important to control the technological environment;
- information and control subsystem (ICS), which regulates with a group technology (in a discreet or uninterrupted way) the CPS executive mechanisms, which are important for CPP processes to collect the necessary minimal data of equipment functionality deviation.

The intermediary CPSs connection to the subsystem control centers and higher level monitoring systems is based on the net agents subdivision which integral components are equipment unique addresses engaged in technological process [12]. Exterior and interior subsystems connections which periodically transmit the CPS control signals and the necessary CPS settings entering which are used to correct the equipment functionality mode. The CPS and cyber production control end objective is a stabilizing or a regulation the technological parameters plurality with a given law which reflect product manufacturing processes dynamics [13, 14].

2. The CPP information and measuring subsystem

The CPP information and measuring subsystem is a congregation of detectors united with digital connection channels and technological data processing means based on calculation resources integrated in a CPS microcontroller. The first measuring information is registered autonomously with production and engineering CPS sensitive elements, which are transmitted through the net in a multiplexed timed mode in a control loop. The CPP control objects are technological systems and multi-components environments covered with a measuring detector chain compatible in metrological characteristics with edge, fog and cloud calculation means.

The cyclic registration and the real time approximation of the technological data net processing creates a distributed IMS, which integrate the calculation channels in the CPP control loops. The measuring independent procedures of several values based on different physical principles creates a multi-channel control scheme of parallel action, which influence the CPS executive mechanisms. The CPS technological data address collection processes homogeneity let optimize autonomously the surveillance systems of each channel being regulated with methods developed from the automatic control theory for a multi-measure IMS.

The CPP integrated control system specifics are to combine inside a CPS measuring functions closed in the program control technology with processing data functions distributed in an information net. The CPS measurement component registers data automatically from the technological processes sources and the CPS informative component configures the net for the tasks, which completion quality is related closely to the calculation results with a program. By synchronizing the informative, measurement and controlling subsystems they achieve a multi-calculator, which analytical resources are given within the physical and virtual CPS components. The CPP information and measuring subsystem scheme is given in figure 1.

The CPS net interaction parametric and topology organization as an IMS is a solution from the CPP necessity of the necessary control level, technological systems and processes monitor-ability and control-ability. The CPP structure multi-agent property is justified with CPS informative servicing procedures, which unite the message tides on the net (commands and data), which influence the item manufacturing quality and CPS control programmed to complete technological tasks combinations.
To control the message transmission and processing they use a ramified base net (Ethernet, Internet of Things - IoT) uniting information channels and calculation units concentrated in CPS elements. The data processing information process is partially done with CPS calculators and resource consuming calculations are beyond the physical part of the workshop. To unite physical and information CPS processes they use the CPP control system with horizontal and vertical hierarchy levels.

![Figure 1. The CPP information and measuring subsystem scheme.](image-url)

3. The CPP informative and control subsystem
The CPP informative and control subsystem (ICS) is a combination of executive and sensor CPS devices, which self-regulation is done with the mathematical models of the communication and calculation equipment component dynamics. The CPP control group task complex solution requires the disturbances processing and forms the command signals for the technological system elements united into the net connection and transmission data. The technological systems and processes control variables information concord is done with the CPS inter-processing interaction means (CPP regulator), which net connection is done with the feedback principle.

The CPP informative and controlling subsystem scheme is given in figure 2. The CPP basic tasks completion is done in informative and operation control levels, which technological process parameters depends on the current and prognosticated CPS conditions being monitored in real time scale. The dominating principles to construct the CPP informative and controlling subsystem architecture are [15, 16]:

- the production and engineer CPSs being controlled space distribution equipped with integrated control system of application purpose, which interaction effect is done through traffic net exchange;
- regulation parameters multi-measurement being realized in vector form and which reflects a lot of sections chain character of static and dynamic CPP structures, which are set adaptively to complete a particular set of technological functions;
- the CPP optimal control multi-criteria task, which indications depend on the item being produced quality and technological processes complexity (an industrial object in general);
- the CPS net centering configuration, which requires a continuous exchange and data processing being circulated among technological systems and the CPP controlling part (a regulator) and other.

The CPP information model based on the CPS set description and their common relations got some instrument features, which are [17, 18]:
• the technological data processing distributive function among CPS calculation means and fog or cloud environment server equipment, which regulate some separated industrial object control processes;
• by using open initial software codes for CPS controllers, which are integrated with operation systems net services codes to automatize the CPP control processes;
• by implementing the artificial intelligence elements into adaptive control laws, which are used to form influence on the technological processes and systems, which parameters are inconstant.

![Figure 2. The CPP information and controlling subsystem scheme.](image)

The CPS control applicable functional systems range is based on resources when local nets are combined and based on computer and information technologies. Separate CPSs control tasks and CPP sections are done through the IoT net with some temporal restrictions in regulating parameters vector transmission. To organize the tides and optimize the CPS net load they use the CPP controlling part, which fast reaction acceptable parameters depend on the volume or the aggregating technological data type, which are being processed. The CPS control target function completion is done with priority servicing mechanisms, which are supported in standard net protocols level. The influence synchronizing of informative and controlling CPS subsystem is done with package multiplying tools, which are transmitted by the net agents from the calculation unit [19, 20].

4. Conclusion
The informative, measuring and controlling CPP subsystems functional limits are not defined until now. The solutions proposed by specialists are full of omissions and hardly applicable under real industrial object conditions. A completely new approach to organize a production means to combine the control hierarchy system inside a digital plant in general where the processes are automatized and optimized because of information connectivity and data processing received from CPSs in digital channels.

The advanced solutions reflecting the CPP net control meaning requires simpler CPS parameters regulation laws with a low process inertia and frequent being measured values pulsating as much as calculations beyond physical CPS devices. In the CPP net control paradigm it is a completely independent object with some automatics elements (a pair of controlling devices and control objects) among which there is no significant respective influence.

The project components and CPS connection scheme, which are part of the disturbing influences controlling and work-out requires some technological systems net interaction with a close relation to physical and logical equipment addresses. The information tides scheme to provide CPS simultaneous usage of commands and data create closed regulation loops of IMS and ICS, which automatizes the CPP.
processes. The control variables being calculated periodically within the given intervals are being translated in a CPS through the message being transmitted settings, which put in order the technological system interaction.

The CPS capabilities base functions set list must have the technological processes different control algorithms and priority message processing including physical values measuring delays of traffic transmission in low speed connection channels (without disturbances resistance). The traffic output beyond the data transmission reliability must be accompanied with duplicating packages sending with repeated messages. The CPS net calculation capabilities, which are a part of IMS and ICS could be compatible with connection channel equipment (commutators, routers and other) in the standardized connection level, which simplify CPP technologies and equipment interoperability problem.

References
[1] Lv Z, Lloret J and Xiang W 2020 Computers & electrical engineering 87 106869
[2] Suzuki A, Masutomi K, Ono I, Ishii H and Onoda T 2018 IFAC-PapersOnLine 51(23) 70-5
[3] Yang Y, Wang S, Wen M and Xu W 2021 Journal of the Franklin Institute 358(1) 1-16
[4] Wang W, Zhang Y and Zhong R Y 2020 Robotics and computer-integrated manufacturing 61 101849
[5] Fumagalli L, Negri E, Severa O, Balda P and Rondi E 2018 IFAC-PapersOnLine 51(11) 803-8
[6] Liu R, Xu H, Zheng E, Jiang Y and Chang S 2020 Computer communications 157 179-86
[7] Zakoldaev D A, Korobeynikov A G, Shukalov A V and Zharinov I O 2019 IOP Conference Series: Materials Science and Engineering 665(1) 012015
[8] Xiong J and Wu J 2020 Computer communications 155 197-204
[9] Zhao J and Dong Q 2020 Computer communications 160 63-70
[10] Wang H 2020 Computer communications 157 336-42
[11] Vara J L, Ruiz A and Blondelle G 2021 Journal of systems and software 171 110812
[12] Mohamed M A, Challenger M and Kardas G 2020 Journal of computer languages 59 100972
[13] Attarzadeh-Niaki S-H, Sander I and Ahmadi M 2021 Integration 77 48-58
[14] Lv Z, Chen D, Lou R and Alazab A 2021 Future generation computer systems 117 291-8
[15] Villar E, Merino J, Posadas H, Henia R and Rioux L 2020 Microprocessors and Microsystems 78 103244
[16] Hu T, Bertolotti I C, Navet N and Havet L 2020 Computer standards & interfaces 70 103424
[17] Chen L, Dui H and Zhang C 2020 Reliability engineering & system safety 199 106869
[18] Lass S and Gronau N 2020 Computers in industry 115 103128
[19] Gurjanov A V, Zakoldaev D A, Shukalov A V and Zharinov I O 2018 Journal of Physics: Conference Series 1059(1) 012010
[20] Napoleone A, Macchi M and Pozzetti A 2020 Journal of manufacturing systems 54 305-35