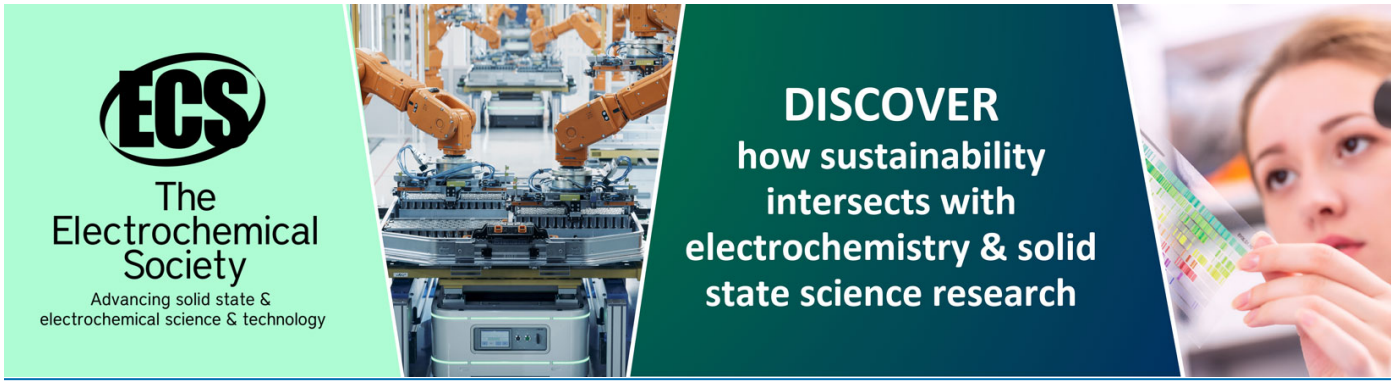
Cyber-physical object tracking system



Cyber-physical object tracking system

A V Shukalov[1], I O Zharinov[1] and O O Zharinov[2]

[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: mpbva@mail.ru

Abstract. There is a task being studied how to control a separate technological aggregate as a regulation object. Information connections between the technological aggregates functions and regulation algorithms are being studied, which are used in the cyber-physical object surveillance systems. There is a two closed loops scheme of electrical-mechanics of the following system given functioning as a mono-aggregate. The stabilizing closed loop is to regulate variables being controlled given with shift and day tasks. The control closed loop is to regulate linear, axis and executive positions of aggregate organs in its coordinates system. The control object is controlled with different regulators influence. The scheme feature is its control object adaptation to the regulating influences with changing in time parameters, which are being translated from the virtual environment to the aggregate with an industrial net. The regulator interface and the aggregate reference model placed in a cloud is done by the Internet of Things. The aggregate regulation is done with settings related to the technological parameters being controlled.

1. Introduction

The ultra-modern approach how to control the technological aggregates requires to translate the control commands and variables through the Internet. To stabilize a separate technological aggregate working process they provide item manufacturing parameters control and industrial installations functioning modes. The control automatizing principle is based on the aggregate condition correction where deviations from the norm are found for the parameters being monitored and controlled.

The remote influence on the item manufacturing process, which is done with the aggregate executive mechanisms, which are controlled with the integrated regulators. The regulator controls the technological modes completion (rules) and send out the aggregate working organs setting signals (control object) into the required positions. The control signals summary tides are sensitive to the aggregate slightest mode deviations from the required values and simultaneously provides multi-parameter object condition regulation with cyclic procedures. The regulation cyclic state has the reverse connection principle by the parameters being controlled and provides some control level dynamic properties to the technological aggregate.

The technological aggregates control parameters space is defined with industrial installation specialty (work and operations types nomenclature) and rules of its exploitation dictated by the manufacturer and in rules. The industrial control objects being applied inconsistency can be seen in aggregate structural features to support executive mechanisms functionality for pneumatic, electrical, hydraulic and other

types of actions. The aggregate functional elements meeting and returning kinematics and dynamics movements defines a control law type being described mathematically and realized as a regulator.

The technological works tide item manufacturing operational pace with some given accuracy characteristics is an aggregate dynamic property, which is reached by solving a particular control task. The production process optimizer provides in the control object work volume the technological modes compliance in the best way, which makes the aggregate application target indications to increase. The aggregate functioning efficiency criterion output for extremum leading role is a combination of control methods, which are made in a production non-interrupted process.

Because of the technological aggregates remote control automatizing idea relatively new state excluding human interruption to the industrial object condition it is an actual task to design the regulation technology, which requires a bunch of equipment settings to be translated (control parameters) through the Internet. In this case, technologically actual aggregate configurations could be achieved with discrete control mechanisms based on message transportation service into a computerized net. The production object control discrete regulation technology designing today is for an advanced engineering center specialized in the Industry 4.0 automatizing.

2. The technological aggregates regulation principles

A huge number of the technological aggregates control laws is defined by the production tasks difficulty, the control objects construction features and parameter space size, properties, which characterize the processes being regulated. The combination of all regulator elementary influences on the control object means only to maintain the given parameters number conditions within the accepted quality criteria limits. The technological parameters limits completion is provided with closed control chains, which approximate the aggregate indications being controlled to the optimal limits (exploitation).

To calculate control object regulating influences values they of course use microelectronics program means made as a machine. The control object discrete conditions change work cycle is characterized with parameters, which are typical for each technological stage ending. Within a stage regulator controls one or several being controlled parameters values and makes a decision of dissonance nullifying, which means that the necessary technological aggregate balance is violated.

Technological processes parameter values processing and their stability maintaining is based on production data with some statistic properties aggregation by a control system. Technological parameters division into independent data blocks requires some optimization sub-tasks to be notified, which regulation laws depend on the aggregate construction. To regulate the control object within each parameter independently creates the control system scheme, which is a combination of one-loop closed chains, which production processes are fully or partially automatized. A generalized scheme of a multi-loop automatic control system for a technological aggregate is shown in figure 1.

The multi-parameter control lets view a technological aggregate as an independent information source, which functioning parameters must be constantly evaluated. To form control signals is based on regulator reaction of different events, which characterize being controlled processes. The processes automatic regulation and aggregate discrete control provide the necessary laws of being controlled parameters changes and generates the necessary product material tides structures into the production environment.

To control technical means aggregates sets let happen the inter-connected parameters regulation using a net. Depending on production situation the aggregate level net provides control signal translation to the industrial equipment end elements from any controlling influence and for any parameter being regulated. In this case, a general industrial regulator provides the controlling signals correction by the parameter values with a cross influence. The precision regulators integrated in technological aggregates support in local level the necessary stabilization mode of separate processes.

The multi-connection control system gives a fuller industrial object regulation function coverage by realizing with adaptation mechanisms a plurality of controlling loops, which are formed dynamically. The multi-connection control technology application in a cyber-production is based on closed loops for processes main indications with a variable structure with non-stationary dynamic parameters.

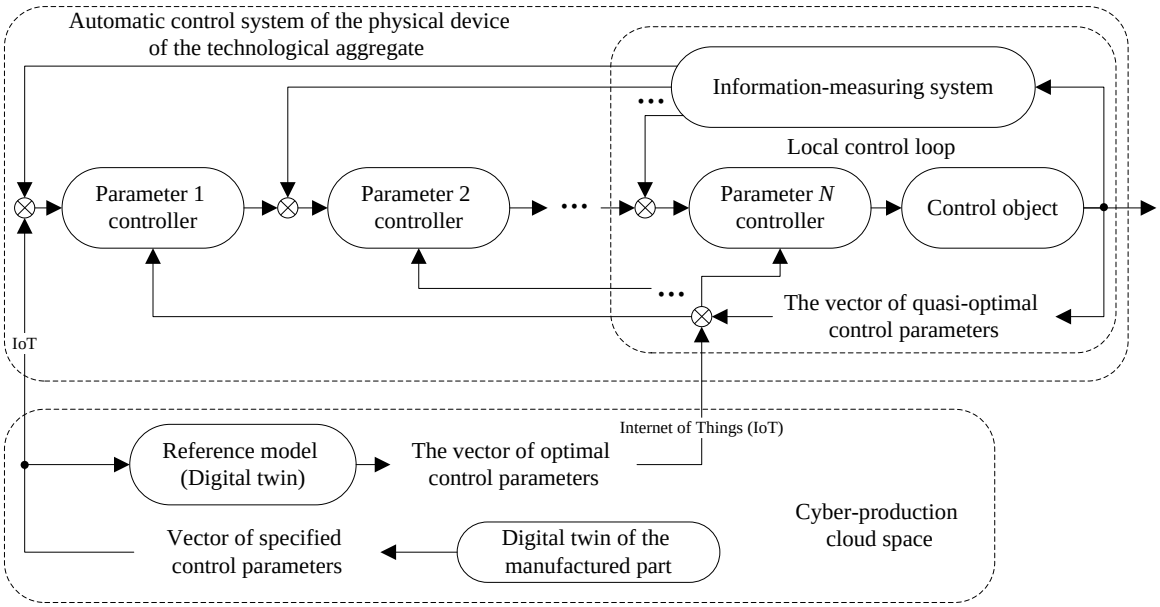


Figure 1. A generalized scheme of a multi-loop automatic control system for a technological aggregate.

3. Cyber-physical object double-loop tracking system

The cyber-physical object control task is an automatic tracking system, which includes:

- the stabilizing closed loop to provide the necessary level regulation of technological parameters (powder melting temperature in the 3D-printing, sucker transferring speed having a radio element in the component automatic placer and other);
- the control closed loop to track down the necessary technological processes with given parameter laws (the 3D-printer nozzle position space angle, the turning mechanism junctions of the mobile transport manipulator grasp and other).

The machine park cyber-control with technological parameters in real production conditions is done through digital connection channels of subjugation and regulation algorithms. The control parameters variation for cyber-physical objects executive organs is translated through the Internet and solves the task of accurate part and tool positioning in the technological aggregate basic coordinates system and also the task how to control the necessary dynamic indications of technological processes. The automatic tracking control system double-loop scheme functioning with electric and mechanical principle, which is a part of technological cyber-physical object is given in figure 2.

The cyber-control itself of electrical and mechanical cyber-physical object is an executor of the production operations end plurality with more or less defined work conditions. Each production operation has its unique identifier corresponding to a format table designed by the technological aggregate manufacturer. The cyber-control technology gives to the machine the necessary directives through computer connection channels containing parameters and types of production operations. The part production is done through linear, axis and angle transportations of the part and tool with the classical laws of kinematics and dynamics.

The trajectory calculation dynamic accuracy of the components being transported in some moments of time (tact), which is done through regulator made with on-board technological aggregate microcontroller. The microcontroller additional functions are:

- to register cyber-physical object basic conditions (switched on, switched off, executing a task, being idle, searching for the equipment failures, error code identification in the condition table

and other);

- to note the machine itself functioning parameters (speed and coordinates of executive mechanisms transportation and tools, the being executed operation identifier to load or unload the parts from the chamber and other).

The tracking system parameters being controlled are cyber-physical object system variables to compensate a dissonance after a production operation completion. The closed loop cyber-control of all executive mechanisms (coordinate system position, servo axis momentum and speed and other) is done through a speed regulator (stabilizing closed loop) and position regulator (control closed loop). Time quantizing of separate loops is done with synchronizing tact generator.

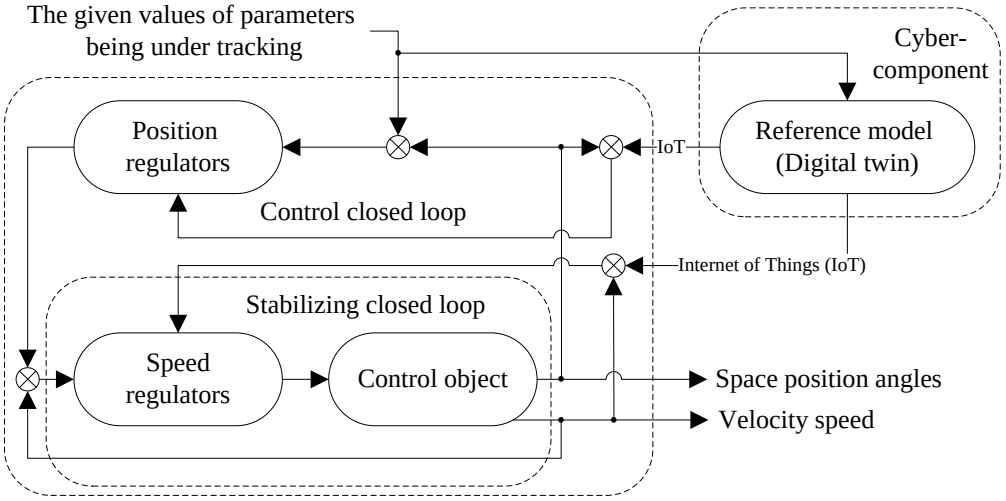


Figure 2. The automatic tracking control system double-loop type scheme functioning with electric and mechanical principle as a part of technological cyber-physical object.

To correct dissonances of automatic closed loops is done in physical and software levels with reverse connections to restrict the regulation. Within each work cycle the control variables values are compared with the reference values calculated from the cyber-physical object digital twin (model). The system data free exchange between the technological aggregate and its virtual copy is done through the message transportation service non-synchronically delivered from the cloud environment into the physical device microcontroller. The cyber-physical object electrical automatics are connected to the production company general and local nets. The important cyber-control task is to concord the physical device time tact with its digital twin to adapt the regulator settings.

4. Conclusion

Technological aggregates automatic regulation is done with full mechanization of main operations completion processes. The aggregate parameters constant control is done with end and automaton models, which is a single set of control loops, which evaluate in uninterrupted way the industrial object deviations from equally weighted conditions balance. The control object current state tracking is supported with some electrical and mechanical systems measuring detectors to transform a technological parameter into an electric signal, which is to be translated the being monitored variables values into the regulator controller with information reverse connection channels.

The control system machine part, which is a technological object and is done with programmable logic microcontrollers with some automatizing technological algorithms and which are capable to calculate the required aggregate control. The control loops units are different technical devices (automatics executive elements, speed and angle movement detectors, step engines, redactors and other), which influence the aggregate condition under the regulator control, which manufacture the product

with some definite technologies.

The existing control methods of particular technological aggregates are classified, according to its connection scheme among automatic elements complexity and different industry branches specifics. Separate control functions completion and their quality indications research are based on the machine units and mechanisms mathematical description unified approach, which participates in all technological processes phases. The aggregate dynamic processes evaluation analytical model is the base to distribute the technological load and to support automatized equipment optimal work modes.

The discrete control method some technological features to control the objects through the Internet they require some new methods of aggregates distributed regulation through the controlling and disturbing influences channels. The discrete control modes solutions group is expected to provide mechanisms work coordination:

- the equipment primary loop, which includes the processes technological parameters regulation sub-system for the value being controlled from the required one;
- the equipment auxiliary loop, which includes the sub-system to control the assembly units material tides and their configuration change.

To synchronize the primary and auxiliary local loops interaction requires from the aggregate regulator the corresponding control actions to preserve the production process control. The aggregate discrete control method engages a stationary computer and industrial net to transmit the parameters being regulated. The control loops hierarchy (local in an aggregate and global for the production) creates a multi-level distributed structure with reconfigurable parameters where autonomously machines and machine systems function.

References

[1] Rocher G, Tigli J-Y, Lavirotte S and Le Thanh N 2020 *International journal of approximate reasoning* **118** 112-32
[2] Schleinkofer U, Klopfer K, Schneider M and Bauernhansl T 2019 *Procedia CIRP* **81** 264-9
[3] Bonci A, Carbonari A, Cucchiarelli A, Messi L, Pirani M and Vaccarini M 2019 *Automation in construction* **102** 68-85
[4] Oks S J, Jalowski M, Fritzsche A and Möslein K M 2019 *Procedia CIRP* **84** 257-64
[5] Jing L and Jinlong L 2019 *Journal of systems architecture* **97** 168-84
[6] Cao Y, Huang Z, Ke C, Xie J and Wang J 2019 *Computers & security* **87** 101478
[7] O'Donovan P, Gallagher C, Leahy K and O'Sullivan D T 2019 *Computers in industry* **110** 12-35
[8] Kajati E, Papcun P, Liu C, Zhong R Y, Koziorek J and Zolotova I 2019 *Advanced engineering informatics* **42** 100988
[9] Gurjanov A V, Zakoldaev D A, Shukalov A V and Zharinov I O 2018 *IOP Conference Series: Materials Science and Engineering* **327(2)** 022111
[10] Gnidenko A, Sobolevsky V, Potriasaev S and Sokolov B 2019 *IFAC-PapersOnLine* **52(13)** 642-7
[11] Regal T and Pereira C E 2019 *IFAC-PapersOnLine* **52(13)** 863-8
[12] Nguyen V H, Nguyen T L, Tran Q T and Besanger Y 2019 *Sustainable energy, grids and networks* **20** 100252
[13] Krueger V, Rovida F, Grossmann B, Petrick R, Crosby M, Charzoule A, Garcia G M, Behnke S, Toscano C and Veiga G 2019 *Robotics and computer-integrated manufacturing* **57** 213-29
[14] Gurjanov A V, Zakoldaev D A, Shukalov A V and Zharinov I O 2018 *IOP Conference Series: Materials Science and Engineering* **450(3)** 032046