Cyber-physical and human control of technological process and equipment sensitive to failures

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Abstract. The cyber-physical production automatizing way being studied based on ergative component implementation in the control system to regulate technological processes and equipment. The ergative component has a function of human control correcting cyber-physical systems behavior when being controlled parameters deviation is detected. Human control is necessary to ensure the technological safety of the facility and is used in the event of equipment failure to prevent emergencies and man-made catastrophes. Human control commands are realized through the man information action over the regulator mathematical model (digital twin) controlling cyber-physical systems functionality from the virtual environment. The human control parameters are defined after the cyber-physical production current situation intellectual analysis engaging expert and advising systems and providing a quality increase of the item being manufactured because of control errors operative compensation. The automatic mode requires an ergative component of supervisor function excluding human direct interaction to the processes. The ergative component automatized mode requires target marking function done by a human, which results in several actions on the control object. The control loop human temporal absence possibility is reached by solving the task of the control function distribution between the technical system ergative part and the automatics. There is a scheme given of cyber-physical production control containing an ergative component.

1. Introduction
The cyber-physical production (CPP) as an automatic control object is a complicated dynamic system uniting a lot of heterogeneous in nomenclature cyber-physical systems (CPSSs) of technological purpose placed within a single company [1, 2]. The CPS control model under the CPP determined functioning states based on net communications creating closed and perplexed loops of the information and material product tides movements but sometimes a mathematical analysis in details and maintaining of given stability resource are required. The CPP systems could be [3, 4]:

- CPS technological connections defining industrial equipment physical devices intersystem interaction order in the automatic item manufacturing conveyor process;
- CPS functional connections defining the enclosed automatic loops interaction parametric level degree with closed chains of local and main feedbacks.

The combination of technological, information and functional connections being formed with the
dynamic control system realizing in parallel rapid and slow cycles of item manufacturing in CPS groups, which leads to a hardly predictable CPP behavior and hardly formalizing CPS actions in the machine language algorithms, which potentially could be even an industrial object emergency situation [5]. The human centering approach to organize CPP control reflect an human directed action over technological processes and equipment means to develop and implement in the industrial automatics loops an ergative automatizing system part, which has a function of multichannel collection, data processing and regulating signals appearance correcting initial start states and all workshop CPSs subsequent functionality [6, 7].

The CPP automatizing system ergative part where the most important executive section is a human is a control subject segregating the CPS actions, which are relevant to the technological situation and take out the reason number one violations of the industrial object established rules how to complete the processes [8, 9]. The human intervention to the fully automatic CPP is in most cases a force major circumstance, which is a serious violation of item manufacturing technology. The CPP technological safety against processes violations could be a result of some CPS equipment (machines) failure and random software glitches, which lead to being controlled parameters deviations in automatic loops and sometimes to the conveyor full stoppage [10, 11].

Control commands division, which in emergency cases and according to the plan are sent by a human or an automatic technical system correspond the CPP autonomous CPS functionality level is a project task to solve, which they define the ergative section actions in industrial automatics closed loop [12, 13]. The target pointing function done by human creates information (signal) actions on the control system, which is clearly to be synthesized in a plurality of events each of which is a possibility of human intervention in the CPS technological processes being manufactured. The complex dynamic system human and machine smooth cooperation is provided if the function human roles (the ergative component) who monitor the continuous technological cycle are in-scripted with some restrictions to the CPP automatic control technical system [14, 15].

2. CPP safety incidents
The control object of the CPP man-machine interaction system is CPS machines and mechanisms to which the materials and parts are loaded to complete different technological process operations. The functioning CPS state violation is provoked with random failures contains some changes of the process technological parameters to be monitored. CPS exploitation consequences being in a broken state are an immediate and prolonged damage of equipment components constructive destruction and negative actions of potentially hazardous for environment factors.

The CPP functionality loss and associated with it ecological danger is viewed by the control system as a hazardous techno-genic accident with a potential risk of being an emergency. The probability quality evaluation of an emergency appearance after a CPS failure is calculated through the CPS reliability indications and its accidents statistics collected in the CPP data base. The CPP control system actions are directed to correct CPS characteristics parameters of which contain some deviations, which is to evaluate technological processes fact state and to work out actions for CPSs to minimize the failure probability.

The CPP dangerous state identification is done through the virtual environment program tools to send a message to the man-machine interaction system with the CPS control rules, which correspond to the equipment exploitation modes with the lowest risk of technological safety. The hazardous situation created after a CPS failure is regulated with the man-machine control system to prevent or hold-up the techno-genic damage not only for the equipment but also for the environment. To solve situation tasks how to provide emergency CPP activity they apply control technologies combining into a single scheme the automatics technical part components and the ergative part components to control safety accidents and their consequences.

3. The CPS control system ergative component
The man and machine system is a CPP element to complete the technological processes and CPS devices
control functions. Human and technical system actions are for minimizing the control function value because a CPS is not ideal in software or hardware means or because of random factors. In state CPS functionality mode (nominal) the control functions are done automatically and the human controls the errors in a supervisor way where the human action is excluded from the automatics loop and the errors values are not higher than the limits. The CPS integrated blocking or safety machine activation shows that a control error value is excessive accompanying a violation with the technological processes established rules transmits the automatics loop into semiautomatic functionality mode where the CPS operations completion is continued with the human monitoring control [16].

The CPS technological processes violation correction is a part of CPP human service obligations and is done by the CPS control functions settings changing of the given regulator information model (digital twin). The CPP control system machine models are implemented in the industrial automatics as a new class of information actions, which in parallel action the digital and analogue signals of the CPS being completed technological processes indications. A non-conflict temporal absence of the automatics loop human action in the CPS functionality state modes are provided with special scheme solution shown in figure 1 and the CPS physical and virtual environment regulator control system integrating ergative component. To change the control priority (automatics or automatized control) defining CPP autonomous functionality level they use gadget regulating organs supporting man and machine interface.

![Figure 1](image_url) Figure 1. The industrial automatics closed loop scheme with the CPS control system ergative component.

The CPS automatized control gadget is an end technical device (a single block of a single user connected to a multiuser work place) in industrial design (protected one), which is used by human to navigate through the man-machine interface system and to complete functions to program the
algorithms. Constructive and ergonomic solutions make this thing to be an option of a portable gadget (like a sensor panel, a graph web-terminal or an industrial display) supporting the non-breakable CPS control function. The gadget calculation functions are defined with CPP technological specifics task (target) are to support net technologies for thin or universal client being done from the human side.

The CPS group actions correction using the gadget connected to the Internet of Things (IoT) net let create local regulation loops, measuring and technological control channels engaging multi-tide sensors technologies to solve the CPP main technological task. The CPP human professional competences should provide delay characteristics into one or multilevel CPS control channels, which do not make significant delays of the error competences in the equipment regulation processes. The control latent period characterizing human actions form the moment of the CPP technological situation changing to the moment of correcting action appearance, which is a parameter of automatized model system «situation-action», which is to minimize the ergative component machine learning means and systematic personnel trainings in realistic simulators [17].

The CPP human control automatized work place gadget provides being monitored CPS parameters screen indication (information and control area), which functional interface are mnemonic images and immersive elements being projected using the augmented reality technology. The technological processes continuous monitoring functions and automatics situation control are done by a human with the current CPP situation intellectual analysis characterized with a tide of information control errors depending on properties and states of the CPS being regulated. Events oriented human inclusions (ergative parts of technical system) in the automatics loop provide the CPP control diversity, which is significantly more complicated than an enclosed CPS hierarchy structure.

Among all possible options of incoming information (signal) actions and random disturbances affecting a CPS the CPP behavior as a dynamic system is unpredictable because the human gadget should be connected to the analytical data bases and to machine expert and advising components proposing to a human control commands. The intellectual hints are results of the being controlled control objects states diagnostic information vast data amount mathematical processing and events classification (CPS identification with a violated technological process), which requires automatic system ergative part participation. The expert advising systems focus human attention on discrepancies (control errors) of a particular CPS, which reduces the vector scaling of the data received by human and the control accuracy is increased justified with human actions based directly on the information being displayed in a particular moment of time.

To minimize the nomenclature requirements of the CPP parameters being indicated is a feature of man and machine interface adequate to capabilities of the human sensor system subjective perception and technological information processing under the states of the CPS control errors continuous vector changing. To maintain human awareness with technological signaling tools shown in the gadget screen protects the human from information over-charge and let delegate the most part of the automatic control functions to the servers forming the company virtual environment [18].

4. The man and machine CPP control

The man and machine technology is a CPP component being applied in the technological processes partial automatizing and which requires an human as the control system ergative element providing industrial equipment smooth operation. The CPP control human content participation is to realize human intellectual potential, which has the technological processes information control functions (service ones), which include sensor measurements, distributed computing, CPS net communications and other.

The man and machine system collects automatically and analyzes the technological data necessary to optimize the control process and change the CPP dynamics in the given by human direction (the necessary one). The control system ergative part information and regulation properties are engaged for [19, 20]:

- the distance monitoring of product material tides movement through a mechanized conveyor line equipped with automatic CPSs;
- the remote control of parametric deviations (errors) appeared in a closed loop of man and
machine control after a comparison of process parameters current values with the given one;
- an indirect action on CPS executive mechanism or the technological process being realized with it through the control functions parameters changing defining as a digital twin the CPS regulator information model;
- the forced conveyor line stoppages (a direct intervention to the CPP infrastructure) when an emergency situation is detected and switching means of being regulated processes net commutation change for CPS control reserve schemes and other.

The CPP ergative component control commands are received by the automatics closed loop through a man and machine interface realized in the base of human automatized working place supporting parameter indication functions, visualization (animation) and technological processes monitoring. The remote control (gadget) connecting through the IoT human net a separate CPS and CPP hierarchy structure may be included into control loop and be integrated with the program automatizing means (algorithmic) based on edge, fog and cloud calculations. The technical and ergative CPP control system parts interaction scheme is given in figure 2.

![Figure 2](image)

**Figure 2.** The technical and ergative CPP control system parts interaction scheme (ECVL – Edge computing virtual loop).

The industrial object functioning special dynamic parameters characterizing ergative part action on the CPP control system is a time interval defined by subtraction between the item manufacturing technological process violation appearance moment and the moment of the human regulator intervention. The action priorities given by human and the control system to the CPS and also their
numeric relationships and combining are subject of scientific researches and mathematical calculations defining properties of the CPP infrastructure stability and control-ability.

5. Conclusion

The logic and dynamic model of the control system ergative part interaction with the main technical system requires the mathematical control function parameters adaptive change providing criterion extremum characterizing CPS automatic regulation quality. Separate CPSs local regulation heterogeneous in parallel technological processes specifics lead to dynamic properties change of the entire CPP control closed loop, which indirectly action the end item quality (being manufactured).

The separate CPSs parameters local loop control is formed in the IoT-connection session mode during, which the object being regulated data is automatically collected and analyzed and some CPS actions are transmitted automatically. The CPP direct manual control mode of the Industry 4.0 industrial automatic system is fully excluded because of being regulated parameters complexity and features of their interdependent structural organization (hierarchy). The ergative system part automatized control provides regulation of all technological aggregates, CPS mechanisms and their inside processes in situation when the qualified and in-time human intervention is necessary.

To issue some recommendations for man to make a decision how to control the CPP is done through a machine expert advisor (avatar), which synthesized information is of consultative character. The anti-emergency and restoration (correcting the processes) control system ergative part intervention is done to the equipment (transport machines, manipulators, CPSs), which interaction break-down may lead to an infrastructure object break-down or even to an ecological catastrophe.

The man functionality specifics in the CPP control system is related to the inertia character of the control action appearance justified with individual features of psychic and physical human perception and his intellectual capabilities to process the technological data. The system ergative part control channel process delays are for the following: the screen parametric information reading by human, intellectual analysis and making a decision in the industrial environment and also human finger movements (touching) over the gadget sensor elements are viewed as taking-out organs of CPS regulating action.

In the Industry 4.0 paradigm the technical system ergative part receives the properties of controlling agent forming action instruction for executors, which could be several groups of subordinate CPSs. Interconnected CPS control algorithms define the rules of intersystem technological equipment interaction are placed in edge computing platforms and corresponds to the software tools solution of classical physical processes control task. The technological section CPS is viewed as an inner consumer of the production processes results with information and measuring and controlling functions providing integrated quality control of the item being manufactured.

The being regulated processes or items parameters deviations are events to initiate the control system ergative part. The man actions in the information interaction process with the CPP technical infrastructure after receiving a warning message with his gadget are done through a number of operations, which interpretation is to correct the control function and to correct the CPS behavior logic within a conveyor line. The CPS control functions correspond to periodically initiated processes, which setting depend on CPP specialty and define the industrial equipment control-ability (CPS sensitivity to actions) for a particular technological task. The means to describe a technological process are a type of provision necessary to develop CPS control model and the machine expert advisor intellectual component being realized in the company virtual environment.

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