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METROLOGICAL VERIFICATION OF CYBER-PHYSICAL SYSTEMS

This article presents the features of functioning the cyber-physical systems and their components. The possibility to connect measuring devices of electrical quantities, measuring devices of non-electrical quantities, and sensors with data interface to cyber-physical systems components is considered. The analysis opportunity of sensors possible accession to embedded system control is examined. The classification by the sensors output signal type is considered. On the basis of the sensors classification concluded that the cyber-physical systems is most expedient to use intelligent sensors. According to the results of the analysis of the cyber-physical system characteristics and components a multilevel remote metrological verification of cyber-physical systems is proposed. With the proposed algorithm the cyber-physical system components can be verified at the request of any component, subsystem or system as a whole. Also a person can initiate a metrological testing process, if there is suspicion of incorrect operation or its time for cyber-physical system routine verification.

Keywords: measuring instrument, software, metrological verification, cyber-physical system, embedded system control, intelligent sensor

1. Introduction

At present time informational technologies cover almost all spheres of human activity and they are the most important factor in innovation. Facilities with the embedded system control (ESC), which are combined with each other via global network, perform many new functions and actions that can partially or completely eliminate human from the process activity. Every year the real and virtual worlds are becoming closer to each other forming technical base of cyber-physical systems (CPS). CPS usually are complex systems which components may be located at great distance from one another.

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They combine information, software, electronic, optical, mechanical and other physical components that "communicate" via the Internet in real time [1, 2]. CPS performs processing of information and functions of monitoring and control equipment. CPS infrastructure mainly consists of subsystems, which electronic components are implemented through ESC [3] and get information about the environment through sensors and measuring device (MD) and can influence it through actuators (Fig. 1).

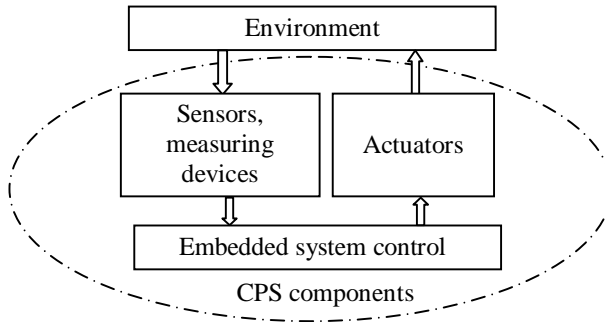


Fig. 1. Block diagram of CPS components

Rys. 1. Schemat blokowy komponentów CPS

With the widespread use of microprocessor and microcontroller technology the basic processing of measurement results such as averaging, approximation, filtering, interpolation, Fourier transform, etc. are implemented mainly by software.

If measuring information incorrectly displays the characteristics of the object of the environment (error measurement results exceed acceptable values), the effect of the actuators on the object may be incorrect. This can lead to incorrect functioning of CPS and undesirable consequences and sometimes can be dangerous to human life. Therefore, to ensure the proper functioning of CPS important components, the development of methods, techniques and remote metrological verification of sensors, measuring devices and software is important.

2. Analysis possibility of metrological verification of sensors and measuring devices of cyber-physical systems

Figure 2 shows the block diagram to connect measuring devices of electrical quantities, measuring devices of non-electrical quantities, and sensors with data interface to CPS components. For metrological verification of MD electrical quantities (voltmeters, ammeters, etc.) is necessary to submit

exemplary input signal. There are a number of exemplary means of voltage, current and frequency reproduction, etc. [4], which are small and can be integrated into the CPS. If the sensor is verified then the appropriate physical quantity of known value should be submitted for input. In most cases this requires complex and bulky equipment, for example, the verification of temperature sensor requires reference temperature points, high-precision thermostats and so on.

That's why the remote metrological verification of MD electrical quantities is much easier compared to sensors. Besides sensors metrological verification is not always possible verify remotely.

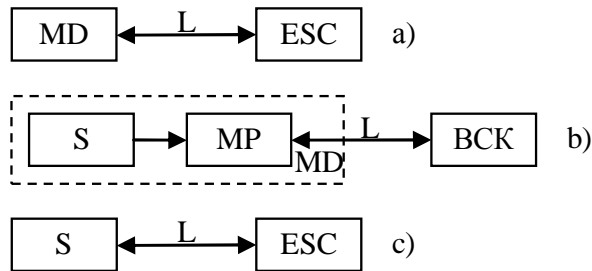


Fig. 2. Block diagrams of connection: a) MD electrical quantities, b) MD non-electrical quantities and c) sensors to CPS components, where MD - measuring device; L- link; ESC - embedded system control; S - sensor; MP - measuring part

Rys. 2. Schemat blokowy połączenia: a) MD wielkości elektrycznych, b) MD wielkości nieelektrycznych i c) czujniki do elementów CPS, gdzie MD - urządzenia pomiarowe; L- połączenie; ESC - wbudowany system sterowania; S - czujnik; MP - część pomiarowa

For remote verifying of software the cyber-physical systems are the best because they are connected to the Internet and access to them and to the software that serves them are available. It is only necessary to provide a software service that allows starting the review process.

On the other hand the analysis opportunity of sensors possible accession to ESC is interesting, which made it possible to significantly simplify measurement of CPS. Classification by the sensors output signal type: analog sensors; digital sensors; binary sensors; impulsive sensors, intellectual sensors.

The output signal of analog sensors is a continuous physical quantity (preferably electric). The advantage of analog sensors is the simplicity of their implementation. The disadvantage is that the connection of such sensors to the measuring system must use additional measuring equipment [4].

Digital, binary and impulse sensors can be directly connected to ESC if they have a digital and frequency input. Intelligent sensors easily connected to ESC using industrial networking protocols Profibus, Foundation Fieldbus and others.

Intelligent sensors (IS) have a number of properties that significantly distinguish them from other types of sensors. They can automatically choose measuring range, carry out algorithmic correction of the measurement results, operate in a dialogue with the central control system, take decisions, transfer measurement results in digital form, as well as alarms and others. IS can conduct self-tuning, self-testing and self-examination [5, 6].

IS performing necessary conversion of measurement data and mathematical processing of measurement results. Therefore, the use of IS enables to release ESC from storage and processing of a large number of intermediate data. Given the above information allows considering the optimal use of IS in CPS.

3. Multilevel metrological verification of cyber-physical systems

Metrological verification of CPS is a fairly complicated procedure, given the fact that cyber-physical components combined into one system for pursuing a particular task and can be located in any corner of the globe. Taking into consideration such a specificity of CPS as "measuring device" the multilevel metrological verification of CPS is proposed. Metrological verification of CPS should occur at all stages of operation starting with verification of sensors by controlling components of CPS, self-testing of intelligent sensors and finishing with a total test of CPS which is given by the controlling person, if there are doubts about the correctness or CPS functioning or its time for CPS routine verification. Based on the analysis the multi-process verification of CPS is proposed (Fig. 3).

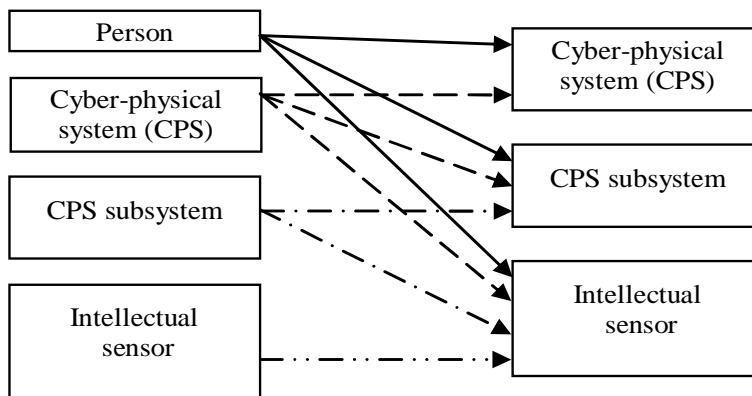


Fig. 3. Multilevel metrological verification of CPS

Rys. 3. Wielopoziomowa weryfikacja metrologiczna CPS

Metrological verification of CPS takes place at all levels: system; subsystem; intelligent sensors. At the system level initiation metrological verification is run by the system itself. If metrological verification of lower level elements(subsystems, intelligent sensors) is performed at the same time , it will be suspended, because the priority belongs to the system level. If the metrological verification of CPS error is not detected, the system will conduct further work as usual until the next verification. If the verification errors are found, the CPS will try to correct them. In case of a successful error correction CPS will continue its work in a normal mode. Otherwise, the information about place and time of error will be transferred to the user interface. CPS will turn on safe mode and staff will take care of correcting errors. After that CPS will be restored in a normal mode.

CPS subsystem controls and distributes tasks between ISs and actuators. Initiating verification subsystem can take place in CPS or subsystem. If the metrological verification of lower level elements (intelligent sensors), is being performed it will be suspended. If the verification has already started there is no need to perform another one. Initiation of metrological verification of ISs can take place in CPS, subsystem or ISs itself. The staff will be involved in verifying CPS elements only when CPS can not correct the errors encountered during the inspection. In other cases, the metrological verification will be performed automatically.

4. Conclusions

On the basis of the sensors classification concluded that CPS is most expedient to use intelligent sensors as they do not require the use of additional measuring devices; they are able to conduct basic processing of measurement results, self-tuning and self-diagnostics, they work with a variety of data interfaces and etc. IS can conduct periodic metrological verification of its sensors using the built extent of physical quantities.

The software verification of CPS can be implemented remotely, as CPS is connected to the Internet. It is only necessary to provide a software service that allows starting the review process.

According to the results of the analysis of CPS characteristics and components a multi remote metrological verification of CPS is proposed. With the proposed algorithm the CPS components can be verified at the request of any component, subsystem or system as a whole. Also a person can initiate a metrological testing process, if there is suspicion of incorrect operation or its time for CPS routine verification.

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METROLOGICZNA WERYFIKACJA SYSTEMÓW CYBER-FIZYCZNYCH

Streszczenie

W artykule opisano specyfikę systemów cyber-fizycznych i ich komponentów. Przedstawiono schemat blokowy, łączący przyrząd pomiarowy wielkości elektrycznych, przyrząd pomiarowy wielkości nieelektrycznych oraz czujniki z interfejsem danych z systemem cyber-fizycznym. Przedstawiono klasyfikację systemów według typu sygnału wyjściowego czujników. Na podstawie klasyfikacji czujników autorzy doszli do wniosku, że systemy cyber-fizyczne najlepiej współpracują z czujnikami inteligentnymi. Biorąc pod uwagę wyniki analizy cech systemów cyber-fizycznych i ich komponentów, zaproponowano wielopoziomą weryfikację metrologiczną tych systemów. Zgodnie z proponowanym algorytmem elementy systemów cyber-fizycznych mogą być weryfikowane na wniosek jakiegokolwiek komponentu, podsystemu lub systemu jako całości. Również człowiek może zainicjować proces testowania metrologicznego, jeśli istnieje podejrzenie nieprawidłowej pracy lub nadszedł okres rutynowej kontroli systemów cyber-fizycznych.

Słowa kluczowe: przyrząd pomiarowy, oprogramowanie, kontrola metrologiczna, system cyber-fizyczny, wbudowany system sterowania, czujnik inteligentny.

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