Mechatronics function simulation of complex technical systems using advanced design environment

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Abstract. The current stage of design methodology development and the development of a specific approach of Industry 4.0 enforces new solutions in the field of design heuristics and new solutions in the field of their integration. In the first case, this applies in particular to the development of new design methods, aimed at creating unconventional structural solutions of systems with complex performance characteristics. In the second case, this concerns the search for tools and methods of IT for combining partial solutions into integrated, synergistic construction solutions. One of the elements characterizing Industry 4.0 is the integration of approaches in the field of automation and data processing and exchange as well as manufacturing. This type of integration fits into the implementation of the mechatronic function, the aim of which is not only to learn about the kinematics and dynamics of the system under study, but also its behaviour during controlled work. The first stage of the technical system research process understood in this way is to design a new system. The developed integration method will minimize the risk of malfunctioning of the actual control system.

1. Introduction

Nowadays the accelerated development of different embedded systems leads to creation complex mechatronics solutions. They base on synergetic composition of different subsystems constituting the new whole in a form a composite technical means. This process is associated with the development the most important element of a mechatronics solution, and namely the control system. Its development is based on the development of the IoT (Internet of Things) [1]. It is a concept achieved by establishing digital interconnections between every component of a control systems using Internet. Internet in this case replaces various data buses. This technology evolves from the simply busses technology and RFID (Radio-Frequency IDentification) devices allowing to track object in different localizations [2].

Thanks to different tags elements of a control system could be identified and managed through Internet from different localizations and by different managers. Such solutions allow developing mechatronics and buildtronics systems on the base of commonly used devices and technologies [3, 4]. Because of wide spreading of Internet technology, it is possible to create also dissipated systems that can operate with the same efficiency like traditional compact systems. The capacity of systems based on IoT reaches over one hundred million devices being controlled [1].
According the above figure, it is needed the cooperation on 8 levels to provide proper operation of systems based on the concept of IoT. It is also related with ensuring security in the network and the certainty of its operation. Especially it is true in the case of technical system of very large scale.

2. Theory of design complex systems
Theory of design of complex technical means must include some important features. First of all it is significant to determine main component subsystems of such technical means. It is not unequivocal in the case of composed system like the system of a mining support presented in figure 2.

Figure 1. Reference model of IoT [5].

Figure 2. Example of a model of a complex technical system (mechanical one).
Investigations within the methodology of design of complex systems let creating the outline of main subsystems constituting any technical means. One could distinguish three main subsystems: structural one, drive one and control one (figure 3).

![Diagram of three main subsystems: structural, drive, and control.](image)

**Figure 3.** Example of a model of a complex technical system (mechanical one).

Each of these subsystems characterize by a special set of attributes. In the case of the control one its attributes are represented by settings of the control devices and mainly by the control program. The proper work of the control system could be verified by the analysis of the mechatronics function of the system in a virtual environment.

3. **Mechanical systems mechatronics function analysis**

The analysis of the mechatronic function of mechanical complex systems is conducted in CAD/CAE environments using proper prepared virtual models. In figure 4 is presented an example of such system in the form of a complex workcell. Such analyses are conducted on the base of properly structured virtual models. They are structured with the using appropriate joints linking individual parts. Base system models (like robots) could be used to build more sophisticated ones (like below).

![Virtual model of a manufacturing mechanical system.](image)

**Figure 4.** Virtual model of a manufacturing mechanical system [6].
Moreover, one should state that linking together CAD/CAE environments with programs for modelling control systems one can obtain the overall system for investigating the mechatronics function of different composed mechanical systems [7-9].

4. Architectural complex systems design
The problem becomes even more complex in the case of buildings design. It is particularly difficult for smart buildings designs. The term smart building means a building with complex automation of all its subsystems. It applies to lighting, heating, ventilation, air conditioning, and security subsystems as well as to different home appliances. Basic features of a smart home are: monitoring, controlling, efficiency and intelligence. A scheme of smart home is presented in figure 5.

![Smart home concept based on IoT](image1)

Figure 5. Smart home concept based on IoT [10].

Frequently the concept of a smart home is realized basing on the idea of IoT. Such solution is presented in figure 6. It is based on the Ethernet standard as the central data bus. All devices of the control system are connected to this bus. Communication is realized basing on a protocol, common for all devices and programs.

![Smart home concept based on IoT](image2)

Figure 6. Smart home concept based on IoT [11].
The analysed concept was applied for the planned design process of a smart home and next investigations of its mechatronics function. The aim of these investigations was to determine whether the designed control system and algorithms operate properly.

5. Project of a smart home
The objective of investigations is to elaborate a model of a sophisticated system that allows analysing the mechatronics function of a building. For this purpose, was designed a concept of a building together with outline of all control and energetic subsystems what is presented in figures 7 and 8. Basing on the design an actual model was prepared.

Figure 7. Elaborated model of a smart home.

Figure 8. Scheme of the electric system of the smart home.
The elaborated model was connected to the control system based on the Ethernet standard and PLC controllers (figure 9). The control system was designed in the PC SCHEMATIC program. The monitoring and controlling of the system was done using HMI panel which was connected to the Ethernet. In figure 10 is presented the view of one of control windows.

![PLC control system of the smart home](image)

**Figure 9.** PLC control system of the smart home.

![Control panel of the system](image)

**Figure 10.** Control panel of the system.

The elaborated system is presently modelled in a virtual environment to obtain the possibility to virtual verification of the mechatronic function of a building. Secondly it allows to creating a hybrid system linking virtual environment and actual PLC control system. Such hybrid approach allows test operation of a PLC control system using virtual models.
6. Conclusions
The presented solution is the application of some concepts that allow creating sophisticated, contemporary technical means of complex structure. It is particular important in the area called buildtronics that means in the area of mechatronics function of a contemporary building. In the paper it was shown that at the present stage it is possible to create real-virtual cooperating systems allowing modelling mechatronics function of complex technical means. The development towards mechatronics function of a building (buildtronics function) is realized basing on the experience and knowledge of mechatronics function of mechanical complex systems. The objective of present investigations is also towards the development of fully virtual models allowing conducting investigations of the mechatronics function.

One should note that the development of the presented complex approach to designing of sophisticated technical means is the smallest in the area of the material function. This is the challenge for the future advanced studies. Nowadays are conducted investigations aimed to develop the description of special materials [12, 13]. They should allow developing the models of material characteristics to design material for special applications.

7. References
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