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METHOD OF DATA COLLACTION AND IT DISPLAYING IN A GRAPHICAL INTERFACE FROM AUTOMATIC CONTROL UNITS OF COMPLEX OBJECTS

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Abstract

Complex objects, characterized by intricate operations, interconnected components, and dynamic behaviors, pose unique challenges for digital control systems. This article highlights the importance of automated digital control systems in managing these complexities, emphasizing their crucial role in ensuring safety, reliability, and efficiency.

Addressing these challenges involves dealing with system complexity, non-linear dynamics, uncertainties, real-time requirements, data quality, and the need for optimization. Furthermore, ensuring regulatory compliance, safety, scalability, energy efficiency, and cybersecurity adds additional layers of complexity.

This article explores the challenges faced by digital control systems when dealing with complex objects-systems with intricate operations and interconnected components. It emphasizes the vital role of automated digital control in ensuring safety, reliability, and efficiency in such scenarios.

Keywords: complex objects, digital control, automation, reliability, efficiency, system complexity, scalability, industrial processes.

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Introduction

Complex objects refer to systems or structures that have multiple interconnected components, intricate operations, and dynamic behaviors. Examples of complex objects include industrial processes, power grids, transportation systems, and buildings. These objects present unique challenges for digital control due to their complexity, non-linear dynamics, uncertainties, and the need for real-time monitoring and decision-making.

Automated digital control systems play a crucial role in ensuring the safe and reliable operation of complex objects. They provide real-time monitoring, analysis, and control capabilities that enable efficient and optimized operation, improved performance, and reduced energy consumption. These systems help maintain stability, enhance safety, and ensure compliance with regulatory standards. Additionally, automated digital control systems enable predictive maintenance, fault detection, and rapid response to mitigate potential risks and prevent system failures.

Key Challenges in Designing and Implementing Automated Digital Control Systems: [11]

1. Complex objects often entail intricate interconnections and dependencies among components, presenting a challenge in accurately modeling and controlling their behavior. Control algorithms and strategies need to be designed with consideration for these complexities, ensuring robust and adaptive control.

2. Uncertainties and variations in operating conditions, environmental factors, and system parameters are inherent in complex objects. Effective control systems must adeptly handle these uncertainties, adapting to dynamic changes to maintain optimal performance.

3. Real-time monitoring of various sensors and actuators, coupled with swift and accurate decision-making capabilities, is imperative for complex objects. Control systems must rapidly process substantial amounts of data, execute computations, and generate control signals within tight time constraints.

4. Complex objects often encompass multiple subsystems and devices from different manufacturers, each adhering to its communication protocols and interfaces. Designing control systems capable of integrating and communicating with these diverse components is a challenge that necessitates standardization and interoperability.

5. With the increasing connectivity of automated digital control systems to networks, vulnerability to cyber threats rises. Ensuring the security and privacy of data and safeguarding the control system from unauthorized access or malicious attacks becomes paramount.

6. Control systems must exhibit scalability to accommodate the complexity and size of the object being controlled. Additionally, they should demonstrate flexibility to handle modifications, expansions, or changes in the system's requirements without causing significant disruptions or necessitating extensive re-engineering.

Addressing these challenges requires interdisciplinary approaches that combine expertise in control theory, system modeling, data analytics, communication protocols, cybersecurity, and human-machine interaction. Advanced technologies such as artificial intelligence, machine learning, and cloud computing can also play a significant role in designing effective automated digital control systems for complex objects.

Importance of Automated Digital Control Systems: Automated digital control systems are of utmost importance for ensuring the safe and reliable operation of complex objects. Here are some key reasons: [11]

1. Digital control systems enable precise and optimized control of complex objects, leading to improved operational efficiency, reduced energy consumption, and increased productivity.
2. Accurate control ensures that complex objects operate within safe limits, mitigating risks of accidents, equipment damage, or environmental hazards. Control systems can implement safety protocols, alarming, and emergency response mechanisms.
3. Digital control systems can adapt to changing conditions, allowing them to maintain control performance despite variations or disturbances, ensuring stable and reliable operation.
4. Automated systems provide real-time monitoring and diagnostics capabilities, enabling early detection of anomalies, faults, or deviations from desired operating conditions. This facilitates proactive maintenance and prevents potential failures.

Designing and implementing effective automated digital control systems for complex objects involve several challenges: [11]

1. Complex objects often have intricate structures and numerous interacting components, making it challenging to model the system accurately and design appropriate control strategies.
2. Integrating different control components, such as sensors, actuators, controllers, and communication networks, into a cohesive system can be complex. Compatibility, data exchange, and synchronization issues need to be addressed.
3. Determining optimal control parameters for complex objects is challenging due to non-linearity, multi-variable interactions, and uncertainties. Controller tuning methods and optimization algorithms need to be developed and applied effectively.
4. Complex objects generate vast amounts of data, requiring efficient data acquisition, processing, and decision-making algorithms for real-time control. Ensuring timely and accurate data acquisition and processing is crucial.
5. Control systems need to be robust against uncertainties, variations, and faults. Designing fault detection, isolation, and recovery mechanisms, as well as implementing redundancy strategies, are essential for reliable operation.
6. With increased connectivity, complex objects are susceptible to cyber threats. Designing secure control systems with authentication, encryption, intrusion detection, and prevention mechanisms is critical for protecting against cyber attacks.

Conflict Setting

In the dynamic landscape of automated control systems (ACS), the path to achieving optimal efficiency, reliability, and user interaction is fraught with challenges.

ACSs hold the promise of making operations more efficient and reliable. But, in the real world, it’s not always going smoothly. We delve into a common struggle faced in various industries as ACS innovation meets the complexities of different sectors. This conflict lies at the heart of our exploration.

Materials and methods

Automated Control Systems: ACS implements an automated process of collecting, storing and processing information necessary to make comprehensive decisions about the object. The operation of the ACS must be justified, that is, it must lead to useful techno-economic, social or other results. In particular, the use of ACS makes it possible to increase efficiency or reduce errors caused by the human factor, improve the quality of the control object and control itself, etc. The most important task of the ACS is to increase the efficiency of facility management based on the increase in labor productivity and the improvement of management process planning methods. ACS consists of various elements and devices that are interconnected to carry out a certain process.

Let's highlight a number of general requirements for ACS, according to which they should have or provide:

- Means of ensuring compatibility with each other.

The components of the ACS must be compatible with each other, as this helps ensure effective communication and coordination between the component parts. ACSs are often designed to perform specific tasks within a larger system or process, such as those associated with a residential home, such as water, gas, smoke venting, vehicle speed control, or traffic flow control. In many cases, multiple control systems may be needed to work together to achieve a desired result, such as controlling building deformation. Compatibility of control systems can facilitate the integration of new systems or the upgrading of existing ones. For example, if a company wants to add a new management system to its manufacturing process, it will be much easier to do so if the new system can be easily integrated with existing systems. In general, compatibility between ACSs is important to achieve the efficient operation of complex systems, as well as to facilitate the integration and modernization of these systems.

- A sufficient degree of reliability to achieve the stated objectives.

ACSs must have a sufficient degree of reliability to achieve their stated objectives. ACS reliability refers to its ability to perform its intended functions consistently and accurately over time. If the ACS is not reliable, it can lead to real-time system failures and other negative outcomes.

Achieving a satisfactory degree of reliability for an ACS requires careful design, testing and maintenance. Some of the main factors that can affect the reliability of the ACS include:

1. Selection of components: choosing high-quality, reliable components is essential to ensure the reliability of the ACS. Components that are prone to failure or have short lifetimes can significantly reduce overall system reliability.

2. Additional components include: Incorporating additional components or subsystems into the design of the ACS can ensure that the system continues to function even in the event of a failure or malfunction.
3. Testing: the ACS testing according to the test methodology is necessary to ensure that it functions properly under different conditions.
4. Service: regular maintenance and inspection of the ACS can help identify potential problems and prevent breakdowns before they happen.

   Generally, achieving a sufficient degree of reliability for an ACS is important to ensure that it can achieve its stated objectives and perform intended functions consistently and accurately over time. This requires great attention to design, testing and maintenance, as well as the use of high-quality, reliable and, where necessary, additional components.

- Sufficient adaptability to changes in the conditions of its use.

ACS must have sufficient adaptability to changes in the conditions of its use. The ability of an ACS to adapt to changing conditions is known as its "flexibility" or "adaptability". This is important because the operating conditions of the system may change over time, and the system must be able to adapt to each change in order to continue to function effectively.

There are several factors that can affect the adaptation of ACS, including:

1. Scalability: The ACS should be designed with scalability in mind, meaning that it can be easily expanded or modified to meet changing conditions or requirements.
2. Integration of sensors. ACS must be able to integrate with a wide range of sensors and other input devices to be able to collect and analyze data from various sources to adapt to changing conditions.
3. Flexibility of the management algorithm. The control algorithms used by the ACS must be flexible enough to adapt to changes in the controlled process or system. This may involve adjusting set points, changing control strategies, or introducing new control algorithms altogether.
4. User interface. The ACS should have a user-friendly interface that allows operators to change settings easily, adjust parameters, and monitor system performance.

   In general, the adaptability of the ACS is important to ensure that it can continue to function effectively and achieve its objectives under changing conditions. By embracing scalability, sensor integration, flexible control algorithms, and a user-friendly interface, engineers can help ensure that ACS remains adaptable and efficient over time.

- Monitoring and diagnosis of the correct execution of automated functions, indicating the location, type and cause of violations of the system’s correct operation.

The ACS must have monitoring and diagnostic capabilities to ensure the correct performance of automated functions. This is necessary to detect any deviations or malfunctions in the system’s operation, that may have significant consequences on the operation, security and efficiency of the system. Monitoring and diagnostic capabilities should provide information about the location, type, and cause of any system malfunction. This information can help to the system operators quickly identify and correct any problems that may occur, thereby minimizing any negative impact on system performance and ensuring that it operates safely and reliably. Furthermore, the ability to monitor and diagnose system performance can help identify any patterns or trends that may indicate underlying problems or areas for improvement in system design or performance. This can help optimize system performance and prevent future occurring problems. In summary, monitoring and diagnosing automated control system performance is essential to ensure safe, reliable, and efficient operation.

- Measures to protect personnel from wrong actions that lead to an emergency state of the facility or control system, as well as from unauthorized interference and leakage of information.

The ACS should provide means to protect personnel from wrong actions that could lead to emergency situations in the control system, as well as from unauthorized interference and leakage of information. These measures are essential to ensure the safety of personnel.

Some of the activities that ACS can provide include:

1. User access control. A system can implement a strict user access control policy, where users are granted only the privileges necessary to perform their job functions. This can prevent unauthorized access to the system and help protect against accidental or intentional actions that could lead to an emergency.
2. Authentication and authorization. The system may require strong authentication and authorization procedures for users to access the system. This can prevent unauthorized access to the system and ensure that only authorized personnel can make changes to system configuration and operation.
3. Additional safe mechanisms. The system can be designed with additional components to prevent emergencies in case of component failure or malfunction.
4. Training and knowledges. Personnel can be trained and informed of the potential risks and consequences of wrongdoing or unauthorized intervention. This can help prevent accidental or intentional actions that could lead to an emergency.

   In summary, the ACS must provide means to protect personnel from wrongdoing and unauthorized interference to ensure the security of the system and its personnel.

Components of automated control systems

Automated control systems usually consist of several components that work together to achieve their goals. Here are some of the key ingredients.

- Sensors

Devices that measure physical variables such as temperature, pressure or flow rate. They provide input to the control system.

- Actuators

Devices that can be controlled by the system to control physical processes or devices. Examples are motors, valves and relays.

- Management algorithms

Sets of instructions that control system behavior based on inputs from sensors. They define how the system should respond to changes in measured physical variables.

- Programmable logic controllers (PLC)

Specialized computers that control actuators based on inputs from sensors and control algorithms.

- Human Machine Interface (HMI)

It is an interface through which a operator can interact with the system. It usually includes a display screen, buttons, and other controls.

- Communication networks

Communication networks play a pivotal role in the functioning of automated control systems. They are the arteries through which data flows, connecting different components and enabling real-time control and monitoring. These networks can be broadly categorized into two main types: wired and wireless. In the system we designed (In our developed system), data is sent over a wired network.Wired networks are characterized by the use of physical cables to transmit data. They are known for their reliability and stability, making them well-suited for applications where data integrity is primary important. In industrial settings, Ethernet-based wired networks are often the backbone of ACS infrastructure, ensuring that critical data reaches its destination without interference.

- Power sources

They provide the power needed to operate various system components such as sensors, motors and PLCs.

System health check

- Checking sensor parameters and making a decision.

The information received from the sensors is processed according to table 1, where the limit values of the sensors are included:

Table 1

Table of limit values of sensors available in automated control system

Sensor name	Minimum value	Maximum value
Temperature sensor 1	-50	500
Humidity sensor 1	0	95
Pressure sensor 1	0	160
…	…	…

Based on table 1, the system makes decisions, and the graphic interface displays information about the given device, whether the device is in a state or not, errors and warnings about the given device are also displayed.

- Sequential execution of actions. The various activities of the ACS process occur in a specific order. A management system involves the sequential execution of clearly defined actions.
- Displaying the states of devices in the system and preparing for actions.

  Data rendering is carried out through a computer with a graphical interface, which represents the current data of the ACS. Based on the data of the devices represented by the graphical interface, certain actions are performed. In other words, the purpose of WHO is not only to collect data, but also to perform actions based on the collected data.

Based on the above, a program has been developed and offered for the ACS, which allows not only to collect and display the data of all the devices in the system in a graphical interface, but also to manage the system. As a result, two programs were developed, one for the server and the other for the client. The server receives the data from the system's devices through the CAN highway, analyzes them and sends to the user (client) using the UDP protocol. And for the user, in the graphical interface, the data is displayed.

Considering the complexity of such systems, we have presented in our article a method of data collection and monitoring software, the description of the server part that is given below.

Server side

The server program is a console application (Console Application) designed to collect data from the devices of the automatic control system using the Canopen protocol and the Can bus. It then sends this data to the user via the UDP protocol and displays it in the program interface.

The program is developed in the Qt environment, which provides a number of advantages for developers. For example, Qt offers a wide variety of prebuilt widgets and tools that can be used to build cross-platform applications. Qt also provides an integrated development environment (IDE) that simplifies the development process and makes it easy to write, debug, and test code.

The software uses the Canopen protocol, that is a communication protocol used in industrial automation systems to exchange data between devices. CanOpen supports a variety of data types and allows for real-time data exchange, making it ideal for use in ACSs.
Additionally, the program uses the UDP protocol to send data to the user. UDP is a lightweight protocol suitable for applications requiring fast and efficient data transfer. It is often used in applications that require real-time communication. Overall, the combination of Qt, Canopen, and UDP provides a powerful set of tools for building applications that require real-time data exchange and efficient communication. Using these technologies, the server software is able to collect data from the devices and send it to the user in a fast, efficient and reliable way.

Note: UDP (User Datagram Protocol) and TCP (Transmission Control Protocol) are two of the most common transport layer protocols in computer networks. TCP is a connection-based protocol, which means that it establishes a connection between two devices before transferring data. This connection is maintained throughout the data transfer, and the two devices exchange data in a sequential and reliable manner. In contrast, UDP is a connectionless protocol, meaning that data is sent without first establishing a connection. This makes UDP faster and simpler than TCP, but also less reliable because packets can be lost or dropped. The main difference between TCP and UDP is speed, as TCP is comparatively slower than UDP. In general, UDP is a much faster, simpler and more efficient protocol, however, retransmission of lost data packets is possible using TCP. It should be taken into account that if data reliability is important in any case, then you should not use the UDP protocol, it is unreliable, but provides a fast connection between the server and the user.

The CAN (Controller Area Network) bus is a popular industrial network standard that focuses on connecting different devices and sensors in the same network[6]. The CAN interface is actively used in industrial automation, where the CAN standard CiA (CAN in Automation) is used very often [7].

The main features of the CAN protocol are:

- Very high reliability and security,
- Each message has its own priority,
- There is an error detection mechanism,
- Re-sending messages sent in error,
- Data transmission is broadcast,
- There can be several master devices in the same network,
- Wide range of data rates [7].

CANopen is designed as a high-level network protocol that runs on top of the physical CAN protocol. The CANopen protocol contains 8 protocols, but as a rule, different applications use some of them. In particular, only two of them were used in the AKS software: SDO (Service Data Object) and PDO (Process Data Object). SDO and PDO are the 2 main ways of transferring data using the CANopen protocol, which are different from each other. SDO is a slow data transfer method compared to the second major data exchange method PDO.

Qt is a cross-platform environment, where the system was programmed in C++ language [1]. Qt CAN Bus is a simple API for connecting to the CAN bus, sending and receiving CAN frames[8].

In order to receive and send CAN frames, several actions are first performed in the program:

1. A CAN highway device has been created.
2. Checked whether our desired software module is provided by QCanBus or not. QCanBus is one of the Qt classes that provides registration and creation of software modules.
3. It was checked which interface of the selected software module is free.
4. A connection has been established with that interface.
5. After these steps, the device is opened to write and read CAN frames.

We receive the data on the server in the form of SDO or PDO. PDO consists of COB-ID and data. Using COB-ID, we determine from which device the data came and with what protocol. The length of the PDO data packet is limited to 8 bytes.

Data is transferred from the server to the user using the UDP protocol[2]. The data is stored in the server in structures, and depending on the change of one of them, the data is sent to the user (client). The minimum size of the transferred data is 16 bytes, and the maximum size cannot exceed 2400 bytes.

In order to send the data using the UDP protocol, several operations were performed in the program.

1. We need to know the IP address to which we need to send the data, in this case it is the IP address of the user's (client) computer.
2. We need to know the address with which we should send
3. We have integrated the IP address and the protocol in the program for sending data[9]

Client side

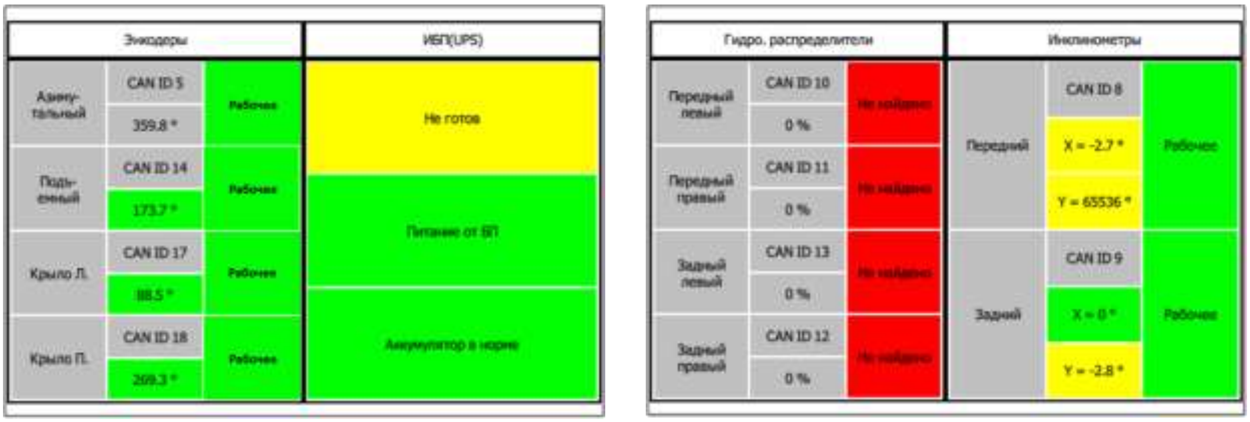

Fig 1. Display of some data received by UDP in the client program

This program is a graphical interface that displays the data of all the devices in the ACS. The program's function is to receive data and display it.

In order to receive the data using the UDP protocol, several operations were performed in the program:

1. Determining which server the server sends the data to.
2. Establishing a connection with the server

After that, the user program displays the data of all the devices in the system.

The graphical user interface is written in QML, a programming language for developing graphical interfaces[3][10]. In figure 1 shows the display of device data in the user program in the ACS.

Research results

In the field of automated control systems (ACS), where data collection and display are instrumental for optimizing efficiency and system performance, research results offer valuable insights into how these systems can be enhanced.

1. Research results indicate that the integration of the CANopen protocol and the UDP protocol within ACSs leads to significant improvements in data collection and transfer, ultimately enhancing the overall system efficiency. Researches have shown that this combination ensures the seamless flow of data from server to user, resulting in a more responsive and streamlined ACS.
2. Research has provided insights into the reliability and precision of data collected using the CANopen protocol in ACSs. It has been demonstrated that the CANopen protocol offers a high degree of accuracy and dependability, outperforming alternative data collection methods and contributing to the overall reliability of the system.
3. Results indicate that advanced graphical interfaces developed in the Qt environment play a pivotal role in user interaction and experience within ACSs. Researches show that such interfaces significantly improve user engagement and make data collection and system operation more intuitive and user-friendly.

4. Research in the realm of complex object control systems highlights the specific challenges faced in implementing digital control systems. These results underscore the significance of addressing system complexity, non-linear dynamics, uncertainties, and other factors unique to complex objects to ensure optimal system performance.
5. Research underscores the critical importance of interdisciplinary collaboration in the development and improvement of digital control systems, particularly when managing complex objects. Studies indicate that interdisciplinary teams can effectively address the multifaceted challenges of these systems.
6. Recent investigations have explored the cybersecurity measures necessary to safeguard data collection and transfer processes within ACSs, especially when advanced protocols like CANopen and UDP are utilized. These researches emphasize the need for robust cybersecurity solutions.
7. Research highlights the significance of designing digital control systems that comply with industry-specific regulations and standards. These results provide insights into how compliance can be achieved without compromising system performance or operation.
8. Research results point to the critical role of real-time data collection and analysis in complex objects. Recent researches have delved into the technologies and strategies required to achieve effective real-time data processing within ACSs.

Conclusion

In the ever-evolving landscape of automated control systems (ACS), our exploration of the integration of advanced protocols, versatile programming environments, and interdisciplinary collaboration has revealed a promising path towards ACS optimization. Through research results, it becomes evident that the integration of the CANopen and UDP protocols can significantly enhance data collection, while the use of user-friendly interfaces in the Qt environment fosters improved user interaction. These advancements are important in ACS efficiency and reliability. Additionally, our investigation into complex object control systems emphasizes the importance of tackling unique challenges within such environments, thus making ACSs more adaptable and capable.

Furthermore, exploration has highlighted the critical relevance of interdisciplinary collaboration in navigating the intricacies of ACSs. Effective cybersecurity measures have proven to be indispensable, as they safeguard data integrity and system stability. Simultaneously, achieving regulatory compliance, ensuring real-time data processing, and promoting energy efficiency all contribute to the holistic improvement of ACSs.

The case studies further affirmed their impact in real-world scenarios. Collectively, these research results underscore the potential for ACSs to not only meet but also exceed expectations in terms of efficiency, reliability, and user experience.

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ԲԱՐԴ ՕԲՅԵԿՏՆԵՐԻ ԱՎՏՈՄԱՏ ԿԱՌԱՎԱՐՄԱՆ ՀԱՆԳՈՒՅՑՆԵՐԻՑ ՏՎՅԱԼՆԵՐԻ ՀԱՎԱՔԱԳՐՄԱՆ ԵՎ ԴՐԱՆՔ ԳՐԱՖԻԿԱԿԱՆ ԻՆՏԵՐՖԵՅՍՈՒՄ ԱՐՏԱՊԱՏԿԵՐՄԱՆ ՄԵԹՈԴ

Շահվերդյան Ա.Ա[1,2], **Սմբատյան Ա.Լ.**[1,2]
[1] ***Երևանի Կապի Միջոցների Գիտահետազոտական Ինստիտուտ ՓԲԸ***
[2] ***Ճարտարապետության և Շինարարության Հայաստանի Ազգային Համալսարան***

Բարդ օբյեկտները, որոնք բնութագրվում են բարդ գործառնություններով, փոխկապակցված բաղադրիչներով և դինամիկ վարքագծով, յուրահատուկ մարտահրավերներ են ներկայացնում թվային կառավարման համակարգերի համար: Այս հոդվածը ընդգծում է ավտոմատացված թվային կառավարման համակարգերի կարևորությունը այս բարդությունները կառավարելու համար՝ ընդգծելով դրանց կարևոր դերը անվտանգության, հուսալիության և արդյունավետության ապահովման գործում:

Այս մարտահրավերների լուծումը ներառում է համակարգի բարդության, ոչ գծային դինամիկայի, անորոշությունների, իրական ժամանակի պահանջների, տվյալների որակի և օպտիմալացման անհրաժեշտության հետ գործ ունենալը: Ավելին, կանոնակարգային համապատասխանության, անվտանգության, մասշտաբայնության, էներգաարդյունավետության և կիբերանվտանգության ապահովումն ավելացնում է բարդության լրացուցիչ շերտեր:

Այս հոդվածը ուսումնասիրում է թվային կառավարման համակարգերի առջև ծառացած մարտահրավերները, երբ գործ ունենք բարդ օբյեկտների՝ բարդ գործառնություններով և փոխկապակցված բաղադրիչներով համակարգերի հետ: Այն ընդգծում է ավտոմատացված թվային կառավարման կենսական դերը նման սցենարներում՝ անվտանգության, հուսալիության և արդյունավետության ապահովման գործում:

Բանալի բառեր. բարդ օբյեկտներ, թվային կառավարում, ավտոմատացում, հուսալիություն, արդյունավետություն, համակարգի բարդություն, մասշտաբայնություն, արդյունաբերական գործընթացներ:

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INFORMATION AND COMMUNICATION TECHNOLOGIES

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METHOD OF DATA COLLACTION AND IT DISPLAYING IN A GRAPHICAL INTERFACE FROM AUTOMATIC CONTROL UNITS OF COMPLEX OBJECTS

МЕТОД СБОРА ДАННЫХ ИЗ УЗЛОВ АВТОМАТИЧЕСКОГО УПРАВЛЕНИЯ СЛОЖНЫХ ОБЪЕКТОВ И ИХ ОТОБРАЖЕНИЯ В ГРАФИЧЕСКОМ ИНТЕРФЕЙСЕ

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Сложные объекты, характеризующиеся сложными операциями, взаимосвязанными компонентами и динамическим поведением, создают уникальные проблемы для цифровых систем управления. В этой статье подчеркивается важность автоматизированных цифровых систем управления в управлении этими сложностями, подчеркивая их решающую роль в обеспечении безопасности, надежности и эффективности.

Решение этих проблем включает в себя решение проблем сложности системы, нелинейной динамики, неопределенностей, требований реального времени, качества данных и необходимости оптимизации. Кроме того, обеспечение соответствия нормативным требованиям, безопасности, масштабируемости, энергоэффективности и кибербезопасности усложняет ситуацию.

В этой статье исследуются проблемы, с которыми сталкиваются цифровые системы управления при работе со сложными объектами — системами со сложными операциями и взаимосвязанными компонентами. В нем подчеркивается жизненно важная роль автоматизированного цифрового управления в обеспечении безопасности, надежности и эффективности в таких сценариях.

Ключевые слова: сложные объекты, цифровое управление, автоматизация, надежность, эффективность, сложность системы, масштабируемость, производственные процессы.

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