GENERALIZATION OF THE MATHEMATICAL MODEL OF ENERGY CONSUMPTION VERIFICATION AND REMOTE CONTROL

1Ismanova Klara Do'lanboyevna
2Akhmadaliyev Anvarbek Alijon o'g'li
1Namangan Institute of Engineering and Technology, Associate Professor
2Namangan Institute of Engineering and Technology, Basic Doctoral Student
E-mail: anvarbek19932627@gmail.com

Abstract
Mathematical models for remote control optimize instrument performance, calibration, and measurement error minimization. The measurement system includes all devices and methods that implement the measurement process. In the mathematical model, the role of the structure of the system, the methods of operation and the error model is important.

Keywords: Remote control, Manipulators, Robot technologies, Automation, Sensors, Control system, Real-time mode, IoT (Internet of Things), Software, Remote communications, Digital control systems.

Introduction

Remote manipulator control model is a system that plays an important role in the field of automation and modern technologies. This model is designed to facilitate the control of the manipulators, that is, a mechanical arm or a robot, by means of remote control and automation. Remote control manipulators are used in various industries, including industrial manufacturing, medicine, cybernetics, and many more. Remote manipulator control aims to achieve high precision and efficiency, further expanding with the development of robotic technology. The main task of the system is to remotely control the movements of manipulators, to communicate with them and to successfully conduct operations. In remote control, technologies such as computer systems, sensors, communication channels, and artificial intelligence are integrated. With the help of these systems, the manipulators will be able to work even in dangerous or adverse conditions, for example, in space stations, nuclear power plants or in environments that may be hazardous to humans. The main task of the remote control model is to ensure the interaction between the manipulators and the control system, to ensure efficient and real-time data transfer between them. At the same time, remotely controlled manipulator systems allow not only to perform certain tasks, but also to effectively manage them, taking into account the person's specific needs.

The use of digital systems in adjusting the energy consumption of remotely controlled manipulators is critical to increasing efficiency and reducing costs. The following methods can be considered: The use of digital systems in adjusting the energy consumption of remote control manipulators is critical to increasing efficiency and reducing costs. A few of the following methods can be considered:

Method 1. Energy Monitoring Systems (EMS) Real-time monitoring- using digital systems to monitor the energy consumption of manipulators in real time. To do this, sensors and measuring devices are installed on manipulator systems that accurately measure energy consumption and send it to a central control system. Energy Analysis & Optimization These systems analyze energy consumption and show the energy consumption of each manipulator or action step. Through this, necessary changes can be made to improve energy efficiency.

Method 2. Sensors and IoT (Internet of Things) technologies Through IoT, manipulator systems are connected to other devices and systems and can be controlled remotely. These systems monitor in real time all energy parameters related to manipulators and give recommendations for energy consumption optimization. Smart sensors Sensors installed in each manipulator compartment measure energy consumption during movement and transmit data to a central system for analysis. With the help of the sensors, it is possible to measure the indicators of voltage, current, heat and other energy consumption.

Method 3. With Supervisory Control and Data Acquisition (SCADA) Systems it is possible to control the remote manipulators and control their energy consumption. These systems allow you to monitor all operations and energy consumption, stopping or optimizing movements if necessary.

The optimal mathematical model is used in energy monitoring systems, remote control manipulators or other technological systems in order to increase energy efficiency and optimize energy consumption. With the help of mathematical models, it is possible to calculate, manage and optimize the energy consumption and efficiency of systems. Here's an overview of a mathematical model aimed at minimizing optimal energy consumption, and we'll look at some of the basic principles for building it. Energy Consumption Minimization Model The following optimization function is used to minimize the optimal energy consumption:

Generalization of model

$$\min_{u(t)} \int_0^T C\big(u(t)\big)dt \quad (1)$$

Here: u(t) is the control variables of the system (e.g., motor speed, energy consumption, or manipulator movements).

C(u(t) is a cost function that represents energy consumption, which indicates the energy consumption of the movement or the operating efficiency of the system.

T is the time frame for making decisions (e.g., time interval).

In addition to the limitations related to energy consumption, the restrictions for energy monitoring systems and manipulator systems are expressed as follows:

$$P_{min} \le P(t) \le P_{max} \quad (2)$$

Here:

P(t) — the energy consumption of a system depends on time.

P_{min} and — minimum and maximum limits of energy consumption.P_{max}

Energy Efficiency Maximization Model If the goal is to maximize energy efficiency, then the following model can be used. Maximize efficiency

$$\max_{u(t)} \int_0^T \eta\big(u(t)\big)dt \quad (3)$$

Here:

$\eta(u(t))$ - a function that represents the effectiveness of the system. The efficiency function depends on energy consumption and system performance outcome (e.g. reduce energy consumption or increase production capacity). T- Term for decision-making. When improving system efficiency, there might be limitations regarding the system performance:

$$f_{min} \leq f(t) \leq f_{max} \quad (4)$$

Here:

$f(t) -$ the output of the system performance, e.g. the output or the system utility.

and minimum and maximum performance limitations of the system.$f_{min} f_{max} -$

Management rules also play an important role in creating an optimal model. For example, in the problem of optimality in the remote control of the manipulator, the speed and moment of the manipulator can be the control variables.

The optimal governance model can be summed up as follows:

$$\min_{u(t)} \int_0^T L(x(t), u(t))dt \quad (5)$$

Here:

$L(x(t), u(t)) -$ the cost function of the system based on the energy consumption and rules of action.

x(t) is the state variable of the system (e.g., the position or velocity of the manipulator).

u(t) is a control variable (e.g., manipulator's motion or energy consumption).

Energy Recovery and Recuperation Model It is possible to use the Recycling and Energy Recuperation (energy recovery) model in energy monitoring systems. For example, converting kinetic energy into electricity:

$$E_{qayta} = \eta_{rek} P_{boshqaruv}(t) \quad (6)$$

Here:

$E_{qayta} -$ Recycled Energy.

η_{rek} $-$recuperation efficiency.

$P_{boshqaruv}(t)$ $-$management energy.

In this model, power recovery and recovery systems play an important role in improving system efficiency. With the help of machine learning and artificial intelligence algorithms, it is possible to find the optimal management strategies of the system. For example, by creating training and forecasting models for an energy monitoring system, it is possible to identify relationships between system variables and make optimal decisions. Machine Learning Model Using machine learning algorithms, it is possible to generate the following model to predict a system's energy consumption and determine optimal control:

$$u(t) = f(historical\ data) \quad (7)$$

Here:

$u(t) -$ control variable (e.g., energy consumption).

$f(\cdot)$-a model learned using a machine learning algorithm.

Historical data - learned historical data.

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Conclusion

The use of digital systems to adjust the energy consumption of remotely controlled manipulators not only saves energy, but also helps to improve the efficiency of systems, optimize operations and reduce technological errors. With the help of digital systems, IoT, SCADA, and automated control algorithms, the performance of the manipulators can be improved, resulting in reduced energy consumption and improved system efficiency. The optimal mathematical model includes various formulas and constraints to improve the efficiency of energy monitoring systems, minimize energy consumption, and reduce carbon emissions. With the help of this model, it is possible to calculate, optimize all system parameters and make management decisions. Optimization of constraints and control variables in the model help improve system efficiency.

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