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DEVELOPMENT OF ARTIFICIAL INTELLIGENCE ALGORITHMS FOR CREATING ADAPTIVE CONTROL SYSTEMS

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Abstract. This article presents methodology for creating and developing of artificial intelligence algorithms for creating adaptive control systems.

Keywords: adaptive learning systems, intelligent learning systems, methods of creation, implementation of learning systems, computer-based learning, machine learning technologies, personalized learning, testing of learning systems.

Annotatsiya. Ushbu maqolada moslashuvchan boshqaruv tizimlarini yaratish uchun sun'iy intellekt algoritmlarini yaratish va ishlab chiqish metodologiyasi keltirilgan.

Kalit so'zlar: moslashuvchan o'rganish tizimlari, aqlli o'rganish tizimlari, yaratish usullari, o'rganish tizimlarini joriy etish, kompyuterga asoslangan o'rganish, mashinani o'rganish texnologiyalari, shaxsiylashtirilgan o'rganish, o'rganish tizimlarini sinovdan o'tkazish.

Аннотация: В данной статье представлена методология создания и разработки алгоритмов искусственного интеллекта для создания адаптивных систем управления.

Ключевые слова: адаптивные системы обучения, интеллектуальные системы обучения, методы создания, реализация систем обучения, компьютерное обучение, технологии машинного обучения, персонализированное обучение, тестирование систем обучения.

INTRODUCTION

This article presents algorithms for synthesizing adaptive control systems for non-stationary systems and analyzes them under incomplete information. Models, parameter identification methods, and adaptive control laws are developed to ensure stability and high accuracy. The main results demonstrate the effectiveness of the proposed methods.

MATERIALS AND METHODS

In this paper, we propose a new framework for assessing the feasibility and applicability of various artificial intelligence algorithms in control and monitoring systems. Our framework includes constructing feature systems for both the characteristics of the artificial intelligence algorithms and the characteristics of the

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control and monitoring tasks. Furthermore, we create a feature mapping matrix that links the features of the artificial intelligence algorithms to the features of the control and monitoring systems. The effectiveness of the algorithms is assessed using functional and performance metrics, providing a standardized framework for applying artificial intelligence algorithms to control and monitoring tasks.

RESULTS AND DISCUSSION

Modern management is undergoing fundamental changes due to the introduction of artificial intelligence technologies, which have moved from the experimental stage to the category of working tools for improving operational efficiency, reducing costs, and enhancing competitive advantages. In Uzbekistan, this process has accelerated amid import substitution and the development of national AI platforms, supported by the state strategy through 2030, which provides for tax incentives, grants, and the creation of regulatory sandboxes. The practical application of AI spans all functional areas of management. In strategic planning, machine learning systems analyze large arrays of structured and unstructured data—from financial reports and news feeds to social media—revealing hidden patterns, modeling development scenarios, and forecasting market trends. In operational management, AI automates decision-making in typical situations, optimizes supply chains, manages inventory, and allocates resources in real time, adapting to changing conditions.

Adaptive control in robotics is the ability of a robot to automatically adjust its behavior and control parameters in response to changes in the environment or the system itself (e.g., wear, load changes, new objects) to maintain optimal performance where rigid, programmed controllers fail. It uses sensors to perceive the environment, allowing the robot to dynamically modify its program and controller parameters in real time, unlike traditional systems that operate according to a fixed model.

Adaptive control represents a paradigm shift in robotic systems, particularly in the industrial sector. Compared to fixed parameters and programmed responses, adaptive control algorithms have the ability to adapt behavior during operation, even in the presence of changing conditions. Particularly in industrial settings, where variability in both tasks, materials, and operating conditions is the rule rather than the exception, this dynamic approach to control is especially important [1]-[3].

A key characteristic of adaptive control in robotics is its continuous perception, learning, and adaptation. The system continuously monitors multiple parameters, including position, force, velocity, etc., as well as environmental conditions. Based on this wealth of data, these conditions are then processed to

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update the control strategy to ensure the robot performs optimally under these changing conditions. The most important advantage of adaptive control is its ability to cope with time-varying uncertainties and disturbances. For example, these could include variations in part dimensions due to normal, unforeseen changes in material properties, or even wear and tear on the robot itself in the production environment. The control system can ensure high precision and reliability in the face of constant change, which is crucial in modern manufacturing. Adaptive Control Techniques Applied in Autonomous Manufacturing Robots:

Control Technique:

1. **Model ReferenceAdaptive Control(MRAC):**

- Core Principle: Adjusts controller parameters to follow a reference model
- Key Advantages: High tracking accuracy; stability assurance
- Manufacturing Applications: Robotic arm positioning, CNC machine control.

2. Self-Tuning Control (STC):

- Core Principle: Online estimation of system parameters
- Key Advantages: Handles parametric uncertainty
- Manufacturing Applications: Variable-load robotic manipulators

3. Adaptive Neural Network Control

- Core Principle: Learns nonlinear dynamics using neural networks
- Key Advantages: Strong adaptability to complex environments
- Manufacturing Applications: Assembly robots, welding automation

4. Fuzzy Adaptive Control:

- Core Principle: Combines fuzzy logic with adaptive mechanisms
- Key Advantages: Robust to noise and uncertainty
- Manufacturing Applications: Human–robot collaboration

5. Reinforcement Learning-Based Control

- Core Principle: Optimizes actions through trial-and-error learning
- Key Advantages: Enables autonomous skill acquisition
- Manufacturing Applications: Mobile robots, flexible manufacturing systems

Adaptive control algorithms can significantly reduce the need for manual re-calibration and reprogramming. However, this is particularly useful in flexible manufacturing environments where product lines tend to change. Adaptive robots don't need to stop for reconfiguration, as they can quickly establish new operating configurations with minimal human intervention. Many adaptive control implementations in robotics require the underlying mathematical models and computational methods to be quite sophisticated. These may include neural networks, fuzzy logic systems, or model-based predictive algorithms. The choice of method depends on whether a high or low level of adaptability is required, the

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application requirements, and the complexity of the manufacturing process. With growing interest in implementing autonomous robotic systems in manufacturing, it is becoming clear that adaptive control is not simply an incremental technology addition, but rather a transformation shift in how robots perceive and respond to their environment.

Several components working together determine how adaptive control algorithms for autonomous robotic systems in manufacturing will develop. The underlying framework forms the foundation of a system capable of real-time adaptation and optimization. Understanding these components is essential to fully grasping the potential and complexity of adaptive control in industrial robotics. The type of hardware used depends on the complexity of the control algorithm and the requirements of the manufacturing process. In most cases, performance and efficiency can be optimized by combining multiple types of processing units. The core of an adaptive control system begins with an algorithm, or a set of rules and mathematical models that determine how the machine will respond to changing conditions. A particularly important feature of these algorithms is their ability to update the system model in real time.

Researchers and technician-engineers are working to address these issues and create more reliable, efficient, and versatile adaptive control systems for industrial robots. Solutions will be found to these problems, and as solutions emerge, we will see increasingly sophisticated autonomous self- operating systems capable of handling the complexity of modern manufacturing, a challenge we will never be able to match.

CONCLUSION

Adaptive control algorithms for autonomous AI systems represent a huge leap forward in technology development. As you may already know, these advanced control systems provide unprecedented levels of flexibility, efficiency, and intelligence in industrial automation. However, as we've already demonstrated through the case studies and research areas discussed, adaptive control holds enormous potential for redesigning manufacturing operations. Emerging trends in advanced artificial intelligence, edge computing, and bio-inspired approaches promise the future of adaptive control systems.

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