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The Application of Microcomputer Systems in Automatic Control Systems

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Abstract: With the continuous advancement and innovation of computer system technologies, the performance of microcomputers has improved significantly. The enhanced computing power of microcomputer hardware provides greater flexibility for the development of various intelligent optimization algorithms. Integrating microcomputers into automatic control systems effectively addresses the system's demands for signal stability, sensitivity, response speed, and manufacturing cost, thereby significantly advancing the practical application of automatic control systems. This paper comprehensively explores the current state and challenges of applying microcomputers in automatic control systems, while providing an in-depth analysis of development trends in this field. It systematically explains the specific improvements microcomputers bring to control systems and how to select appropriate algorithms based on different types of automatic control systems. Moreover, the review highlights the impact of hardware performance limitations of microcomputers on algorithm implementation and discusses potential solutions and directions for future technological advancements. It also examines successful applications and existing issues in representative automatic control systems employing microcomputers. Finally, the study anticipates the development trends of intelligent optimization algorithms for microcomputers in automatic control systems, as well as the emerging challenges and research directions.

Keywords: microcomputers, automatic control systems ,optimization algorithms

1. Introduction

Currently, with the continuous improvement and innovation of computer system technologies in China, the performance of microcomputers, especially micro-controllers, has significantly advanced. The variety of micro-controllers has rapidly increased, and their processing speed and accuracy have expanded their applications to broader domains. Modern control systems demand high stability in digital signals, and the powerful data processing and computational capabilities of microcomputer systems effectively ensure control precision and effectiveness while maintaining relatively low costs [1].

At present, the application of microcomputers has been developed in numerous fields, such as smart homes, transportation, and industrial production. Micro-controller systems have made significant contributions to balancing system precision and cost, offering advantages like easy expansion, convenient debugging, and stable performance [2]. By reviewing literature in related fields,

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the development trends in the integration of micro-controllers and intelligent control can be summarized.

Research on the role of microcomputers in automation will provide robust support for innovation and optimization in automation technology from both hardware and software perspectives. This will drive the development and application of automatic control across various industries and in daily life, bringing greater convenience to people's lives.

2. Literature Review

2.1. Overview of Microcomputers

Microcomputers are cost-effective, compact, and powerful computing systems that are widely applied in various automatic control systems. Using very-large-scale integration (VLSI) technology, microcomputers integrate the main components of a complete computer system into a hardware chip, such as integrating the central processing unit (CPU), memory, including Random Access Memory (RAM) and Read Only Memory (ROM), multiple interfaces, interrupt systems, and timers. Compared to traditional mainframes and large-scale computers, microcomputers are smaller, cheaper, and offer greater flexibility and programmability. In practical applications, these advantages enable microcomputers to excel in data processing and real-time control tasks. Currently, the advanced processing capabilities of microcomputers rely heavily on cutting-edge microprocessors. Architectures like RISC-V and Advanced RISC Machine (ARM) often feature multi-core designs and high-frequency processing capabilities, providing computational power for complex algorithms while ensuring data accuracy and processing speed [3-4].

The widespread application of microcomputers, such as micro-controllers, in automatic control systems is primarily driven by intelligent optimization algorithms that rely on real-time data processing. Intelligent optimization algorithms are a class of methods that leverage modern computational capabilities and intelligent technologies to seek optimal or near-optimal solutions to problems. These algorithms, utilizing randomness, heuristic searches, and adaptive mechanisms, are extensively applied in automatic control systems to support real-time decision-making and performance enhancement. The performance of an automatic control system largely depends on its precision and response speed. Intelligent optimization algorithms, such as genetic algorithms, particle swarm optimization, and fuzzy control, effectively improve data processing accuracy and responsiveness to external disturbances, significantly enhancing system performance [5].

In practical applications, automatic control systems centered on microcomputers are often embedded in smart homes, autonomous vehicles, and industrial automation equipment. For example, in autonomous driving technology, the integration of microcomputers with sensors enables efficient processing of sensor-detected data. This allows real-time handling of environmental inputs and the application of intelligent optimization algorithms for path planning and dynamic adjustments, ensuring the safety and stability of vehicle operation. In conclusion, microcomputers provide robust technical support for intelligent optimization in automatic control systems. Their extensive applications highlight the future development trends in industrial control and smart products.

2.2. Research Status

In recent years, with the development of computer technology, the application of microcomputers in automatic control has become increasingly widespread, making them an essential component of modern automatic control systems. With their powerful data processing capabilities and flexible programmability, microcomputers excel in real-time monitoring, data processing and analysis, and control logic execution.

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Real-time monitoring involves microcomputers receiving real-time data from system sensors and processing the signals using efficient algorithms, such as filtering, demodulation, and feature extraction. These processed signals serve as the basis for system control decisions. For example, in PID control algorithms, microcomputers can achieve precise control of relevant variables through rapid sampling and control output.

In practical applications, systems and their associated data are often highly complex. Microcomputers, through the use of optimization algorithms, can efficiently handle complex nonlinear systems, significantly enhancing their optimization capabilities in sophisticated control scenarios. For instance, in a micro-controller-based temperature control system, fuzzy logic can be used to fuzzify temperature errors and error rate changes. Based on fuzzy rules and reasoning mechanisms, fuzzy control values are derived. These values are then defuzzified to obtain the parameters for the PID controller, enabling precise temperature control of the micro-controller [6].

The application of microcomputers in automatic control not only improves the intelligence and efficiency of systems but also significantly optimizes resource utilization. With advancements in embedded chip technology, the cost of microcomputers is expected to continue decreasing, leading to their increasing adoption in automatic control systems. This trend provides strong technical support for achieving more precise and efficient automation across various industries.

The significant progress in intelligent optimization algorithms has facilitated their widespread application in automatic control, particularly in improving system performance and ensuring stability. In recent years, intelligent optimization algorithms such as Genetic Algorithms (GA) and fuzzy control have become essential tools for designing and optimizing automatic control systems. The main principle of Genetic Algorithms is to simulate natural selection and genetic mechanisms to find near-global optimal solutions for complex multi-modal optimization problems. In fuzzy control, fuzzy rules are introduced as inputs, and intelligent optimization algorithms are used to adjust parameters in real time, enabling effective control of complex nonlinear systems.

The development and application of microcomputer technology and algorithms have opened new possibilities for modern automatic control systems in terms of intelligence, real-time performance, and adaptability. These advancements drive innovation in intelligent control technologies, promoting progress and opening new avenues for smarter and more efficient systems in various industries.

2.3. Issues and Challenges

In the integration process with automatic control systems, the application of microcomputers and corresponding intelligent optimization algorithms still faces many problems and challenges. One of them is the limitation of computing resources. In microcomputers, the limited computational power and memory capacity make the algorithm's computational burden heavier when dealing with complex optimization problems. The second is the balance between adaptability and real-time performance. To meet the real-time requirements of the system in practical applications, it is necessary to reduce resource consumption while ensuring performance. At the same time, in rapidly changing environments, the control system needs to have good adaptability to cope with external disturbances. To balance these two relationships and maximize system performance, microcomputers must have intelligent adjustment functions, dynamically adjusting and adapting to changes while ensuring real-time performance.

On the other hand, there are still some gaps in current research in related fields. The performance of automatic control systems is not only affected by the hardware of the microcomputer itself but also largely depends on the software algorithms carried by the computer. The former can be evaluated using simple and intuitive standards such as computing power and energy consumption, while the latter can be evaluated from aspects such as convergence rate and robustness. However, there is currently a lack of a widely recognized standardized evaluation system that combines the two, making

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it difficult to comprehensively and objectively assess the advantages and disadvantages of different application schemes. This has, to some extent, restricted comparative studies between software-hardware combination schemes and the direction of performance optimization choices.

3. Case Analysis

3.1. Case Study: Home Automation Control System

The home environment is the primary place for everyone to rest and relax. A comfortable and convenient home environment can effectively enhance people's work efficiency, mental health, and sense of well-being, among other things. The development of modern smart home systems has brought many conveniences and support to people's lives and spirits. Automatic control systems play an important role in modern smart homes, enabling efficient management and optimization of the home environment. In recent years, the widespread application of microcomputers has promoted the intelligence of home automatic control systems, improving the system's response speed and control precision, and significantly enhancing the performance of smart home systems.

One case is the use of the STM32 chip to control home sensors as well as doors, lights, etc. [7]. The alarm system mainly includes sensors such as the smoke gas-sensitive sensor MQ2, temperature and humidity sensor DHT11, flame sensor, and voice sensor LD3320. When the system is working, it sends the environmental data collected by these sensors to the STM32F103C8T6 chip, which processes the data and displays the environmental information on the screen. The voice sensor can collect voice information, then parse the collected voice commands and send them to STM32 via the serial port, which then controls operations such as "open the door" and "turn on the light". This system fully utilizes the advantages of micro-controllers in data processing and hardware interaction, while incorporating voice recognition functionality, enhancing the system's practicality and better meeting people's living needs.

Another case is the smart home curtain automatic control system based on STC89C51 [8]. It uses a photo-resistor to detect the ambient light intensity and sends the data to the MCU, which then controls the motor to move the curtains after processing the data. The system also includes a manual remote control module, adopting a design scheme that combines light control, infrared, and manual operation to achieve the intelligence and humanization of the curtain system.

Smart home systems have introduced a self-learning mechanism based on neural networks to adapt to residents' living habits. By collecting and analyzing residents' daily behavior data, such as the time they go out and the frequency of their activities, the system can intelligently adjust its working modes to improve the comfort and convenience of living. Smart home systems can also achieve energy-saving goals and enhance the level of intelligence in the living environment. With continuous technological advancements, smart home systems will continue to optimize and upgrade, providing users with a more efficient and secure living experience.

3.2. Case Study: Traffic Automatic Control System

With the advancement of technology, traffic systems are gradually becoming more intelligent and automated. In today's fast-paced society, public transportation systems, as the lifeline of urban stability and order, have their operational efficiency directly impact the quality of life for residents and the pace of urban development. Traffic automatic control systems, as an essential part of modern traffic management, are increasingly being applied in urban transportation, railway transport, and aviation management.

In the urban transportation sector, microcomputers are primarily used in information transmission devices, such as traffic lights, warning signals, and stop notifications. In one case, researchers designed an automatic bus station announcement system[9]. This system uses the STM32F103C8T6

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micro-controller as the main control chip, an RFID module for signal transmission, the DHT11 sensor module to collect temperature and humidity information, and the JQ8400 voice module to announce station information. The system not only replaces the bus driver in making stop announcements but also displays station and temperature/humidity information on an OLED LCD screen. This system fully utilizes the capabilities of various micro-controller modules, effectively improving the efficiency of public transportation systems in daily life, while also enhancing convenience for passengers and drivers, reducing safety hazards, and alleviating the driver's workload.

In railway transport, microcomputer-based automatic control systems can improve the safety and stability of railway operations. Currently, at the intersections of highways and railways, manual management of crossings is common, with safety often influenced by human factors such as psychological state and fatigue. In one case, an unmanned railway crossing control system[10]was designed. This system monitors vehicles, uses wireless communication, and controls barriers. The system uses the STC12C5A32S2 microcontroller as the control chip to achieve these functionalities.

In aviation, microcomputer-based automatic control systems are used to ensure the normal operation of various aircraft components. In one case, a DC monitoring system for aviation based on the AD7888 chip[11]was designed, with the primary application of real-time monitoring of the aircraft's DC systems during flight. The microcontroller analyzes and calculates input values, and the output values drive the control circuitry to manage related components. This system is used for high-power equipment on aircraft, providing detailed real-time monitoring of their power supply to ensure the normal operation of the aircraft's power system.

Overall, the integration of microcomputers with intelligent optimization algorithms not only enhances the efficiency of traffic automatic control systems but also significantly improves the overall safety and reliability of traffic management. These application cases demonstrate the broad prospects of intelligent technology in modern transportation systems and provide strong support for future traffic management.

4. Prediction of Development Trends

In practical applications, research in the field of microcomputers is driving the rapid development of modern automatic control systems. In terms of hardware, the development trend is moving toward higher integration, miniaturization, and low power consumption. The development of FPGA and embedded technologies has also brought more opportunities to enhance computer performance and system practicality. Through these hardware platforms, real-time data processing and rapid algorithm implementation have become possible, thereby improving the flexibility and real-time response capabilities of control systems.

In terms of diversity, research on microcomputers and their associated algorithms is gradually expanding to more application scenarios. From traditional industrial equipment automation to intelligent manufacturing, robotics, and unmanned systems, the intelligent optimization algorithms embedded in microcomputers are quickly adapting to the needs of various complex systems. For dynamic and nonlinear systems, algorithms need to have self-learning and self-optimization capabilities, adjusting control strategies in real-time to respond to environmental changes and system disturbances.

Looking ahead, advancements in quantum computing technology may bring new transformations to the development of automatic control systems. Quantum computers show great potential in solving combinatorial optimization problems and large-scale computational tasks, and their application in the field of automatic control holds great promise. By combining quantum technology, intelligent optimization algorithms in microcomputers are expected to achieve faster computation speeds and higher optimization accuracy.

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Overall, the application of microcomputers in automatic control systems is undergoing rapid evolutionary development. Facing the challenges and opportunities of new technologies, future research in this field will focus more on the intelligence and adaptability of algorithms, as well as the improvement of hardware conditions.

5. Conclusion

With the continuous development of computer technology and automatic control theory, research on the application of microcomputers in automatic control systems has made significant progress. The core of this research lies in exploring the combined application of various microcomputer hardware and algorithm software to enhance the control capability and response efficiency of automatic control systems in complex control environments. In recent years, the development of hardware technologies such as microcontrollers, embedded systems, and FPGAs, along with the widespread application of intelligent optimization algorithms like genetic algorithms, fuzzy control, and neural networks, have become the main research directions in this field.

From the perspective of system performance, control systems centered around microcomputers exhibit stronger adaptability and stability when handling nonlinear systems and complex environments. These systems are able to maintain stable operation in various working environments, with particularly excellent performance in fields like industrial automation, smart homes, and robotics.

On the other hand, the application of microcomputers in automatic control still faces many limitations in both software and hardware aspects. In terms of hardware, the computational resources of microcomputers are still insufficient to handle large-scale computations of complex algorithms. Additionally, microcomputers lack the adaptability to the environment and cannot balance the demands of real-time performance and stability effectively. From the software perspective, there is currently a lack of a comprehensive and objective standard evaluation system for the integration of software and hardware systems, making it difficult to fully and objectively assess the advantages and disadvantages of different application schemes. In future research, a key direction will be to organically integrate traditional control theories with emerging intelligent optimization algorithms to promote the intelligent development of microcomputers in automatic control systems. Meanwhile, for specific application scenarios, advancing the optimization and integrated development of different algorithms will be an effective way to further improve the overall performance of control systems. Researchers need to focus on the applicability of algorithms and their performance in real-world applications in order to achieve the best control outcomes. Through continuous development and innovation, microcomputers will demonstrate even greater potential in the field of automatic control, driving sustained progress in related technologies.

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