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Automation Control Strategies for Intelligent Warehousing Systems

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Abstract

This paper focuses on intelligent warehousing systems, aiming to significantly enhance the automation and intelligence level of warehouse operations through innovative automation control strategies. It thoroughly analyzes the requirements of intelligent warehousing systems and the limitations of existing technologies, and designs a comprehensive control strategy covering path planning, task allocation, and fault handling. A software prototype is further developed and rigorously tested in a simulated environment to verify the effectiveness of the strategies. The research results indicate that the proposed control strategies can greatly optimize operational efficiency, reduce labor costs, and improve system reliability, providing strong support for the practical application of intelligent warehousing systems and promoting the development of the warehousing industry towards efficiency and intelligence.

Keywords: intelligent warehousing, automation control, robotics technology, system integration, path planning, task allocation, fault handling

1. Introduction

1.1 Research Background

The warehousing industry, as a core link in the logistics supply chain, is undergoing profound changes. With the rapid development of the global economy and the booming rise of e-commerce, the volume of warehousing business is growing explosively, and the types of goods are becoming increasingly diverse. Meanwhile, the continuous increase in labor costs has brought great cost pressures to warehousing enterprises, with problems such as recruitment difficulties and high employee turnover rates becoming increasingly prominent, seriously affecting the stability and efficiency of warehousing operations. However, in the face of these challenges, intelligent warehousing systems have emerged. Relying on advanced information technology, automation technology, and robotics technology, they have realized the automation, intelligence, and informatization of warehousing operations. They can not only effectively cope with labor shortages and rising labor costs but also significantly improve warehousing efficiency and accuracy, optimize inventory management, and meet consumers' expectations for fast delivery and high-quality services. Their importance and application prospects in the warehousing industry are becoming increasingly significant, and they are expected to become a key force in promoting the transformation and upgrading of the warehousing industry.

1.2 Research Significance

In the current situation where the warehousing industry is facing many challenges, in-depth research on the automation control strategies of intelligent warehousing systems is of great importance and significance. From the micro-level of enterprise operations, automation control strategies can significantly improve warehousing operational efficiency. Through precise path planning and efficient task allocation, they ensure that robots and automated equipment can operate efficiently in complex warehousing environments, reducing unnecessary waiting and repetitive operations, thereby handling more orders within a unit of time and meeting the growing market demand. At the same time, they can effectively reduce labor costs and decrease dependence on manual labor. Even in situations of labor shortages or high labor costs, enterprises can still operate stably, reducing the proportion of labor costs in total costs and improving enterprise economic benefits. In addition, automation control strategies can monitor the status of goods and inventory information in real-time, ensuring the accuracy and timeliness of inventory data, avoiding problems caused by manual operation errors, and improving customer satisfaction. The rapid response of automated sorting and distribution processes can ensure that customer orders are delivered promptly and accurately, enhancing the enterprise's competitiveness in the market. From the macro-level of industry development, this research, which explores the automation control strategies of intelligent warehousing systems, can provide strong theoretical support and practical guidance for the technological upgrading of the warehousing industry, promote the widespread application and innovative development of intelligent warehousing technology, drive the deep integration and innovative application of robotics technology, sensor technology, Internet of Things technology, etc., in the warehousing field, and provide references for the intelligent transformation of the entire logistics industry, helping it move towards a more efficient, intelligent, and green future. It has important theoretical value and broad application prospects. (Aggarwal, S., & Kumar, N., 2020)

1.3 Research Content and Methods

This research focuses on the automation control strategies of intelligent warehousing systems, covering demand analysis, strategy design, software implementation, and simulation testing. First, it thoroughly analyzes the warehousing business processes and automation control requirements, clarifying performance indicators to guide subsequent work. Based on this, it designs an automation control strategy that includes path planning, task allocation, and fault handling, aiming to improve operational efficiency, reduce energy consumption, and enhance system reliability. Subsequently, a software prototype is developed, with a suitable programming language and tools selected to build the architecture and implement and integrate the core functional modules. Finally, the effectiveness of the strategies is verified through simulation experiments, and optimization adjustments are made based on the test results.

In terms of research methods, a combination of literature research, system analysis, and simulation experiments is employed. By reviewing literature and technical reports, the latest developments in the field are grasped to provide theoretical support for the research; a systematic analysis of the intelligent warehousing system is conducted to identify key issues and requirements; and simulation software is used to build a virtual model to simulate actual operational processes, verify the feasibility of the strategies, and optimize them, thereby reducing the risks associated with practical application.

2. Overview of Intelligent Warehousing Systems

2.1 Concept and Characteristics of Intelligent Warehousing Systems

An intelligent warehousing system is a highly integrated warehousing solution that combines modern information technology, automated equipment, and advanced management concepts. It is significantly different from traditional warehousing systems. Traditional warehousing mainly relies on manual operations, which are inefficient and prone to errors. In contrast, intelligent warehousing systems use automated equipment such as stacker cranes and conveyors to achieve automatic storage and retrieval of goods, utilize robots to complete handling and sorting tasks, and rely on warehouse management systems (WMS) and automation control systems to precisely schedule and manage warehousing operations. Its core characteristics include high automation, which reduces human intervention and increases operational efficiency and accuracy; comprehensive informatization, which enables real-time collection and sharing of goods information and optimizes inventory management; and in-depth intelligence, which employs artificial intelligence algorithms for predictive analysis and decision optimization to enhance the overall performance of the system.

2.2 Components of Intelligent Warehousing Systems

An intelligent warehousing system consists of several key components that work together to achieve efficient warehousing operations. Warehousing equipment forms the foundation, with shelves used for storing goods, stacker cranes and conveyors responsible for vertical and horizontal transportation of goods. Robots are the flexible force within the system, with handling robots moving freely within the warehouse and sorting robots capable of quickly and accurately sorting goods. The information system acts as the brain, with the warehouse management system in charge of inventory management, order processing, and task allocation, while the automation control system precisely controls the operation of the equipment. Sensors and communication networks serve as the nerves, with sensors monitoring the position, status, and environmental parameters of goods in real-time, and communication networks ensuring rapid information exchange between equipment. The close cooperation of these components enables the automation and intelligence of warehousing operations.

2.3 Application Status and Development Trends of Intelligent Warehousing Systems

Currently, intelligent warehousing systems have been widely applied in various industries, including e-commerce, logistics, and manufacturing. E-commerce companies use intelligent warehousing systems to achieve rapid sorting and distribution in response to the huge volume of orders; logistics companies utilize them to optimize transportation processes; and manufacturers use intelligent warehousing to precisely manage raw materials and finished products. For example, Amazon's intelligent warehousing centers, which employ robots and automated systems, have significantly increased the efficiency of goods handling and have become industry benchmarks. With the advancement of technology, intelligent warehousing systems are integrating artificial intelligence, the Internet of Things, and big data technologies to achieve more accurate inventory forecasting and intelligent scheduling. In the future, intelligent warehousing systems will become even more intelligent and automated, bringing continuous transformation to the warehousing industry.

3. Demand Analysis of Intelligent Warehousing Systems

3.1 Analysis of Warehousing Business Processes

The warehousing business process is the core of the efficient operation of intelligent warehousing systems, covering the entire process from goods receipt to final dispatch. In the receipt stage, goods are first inspected and registered, and then allocated to corresponding storage locations. Statistics show that a medium-sized warehousing center can receive more than 5,000 items of goods per day on average. This process requires precise collection of goods information and efficient allocation of storage space. During the storage phase, goods are stored on shelves according to categories and specifications, which demands good goods tracking and inventory management capabilities from the warehousing system to ensure the safe and orderly storage of goods. The sorting stage is a key part of warehousing operations, requiring rapid and accurate retrieval of goods from the storage area and classification according to order requirements. In the e-commerce industry, a large warehousing center can handle more than 100,000 orders per day on average, and the efficiency of the sorting stage directly affects the delivery speed of orders. When dispatching, the sorted goods need to go through packaging, labeling, and other operations, and then be loaded and shipped according to the distribution plan, with high requirements for timeliness and accuracy. (Aggarwal, S., & Kumar, N., 2020)

In actual operations, various problems often occur in these stages. Goods congestion mainly happens in the receipt and sorting stages, especially during peak business periods when a large volume of goods arrives or orders are placed simultaneously, causing equipment and personnel to be overloaded and resulting in goods backlog. For example, during the "Singles' Day" shopping festival, the congestion rate of goods in some warehousing centers can reach over 30%, severely affecting the efficiency of goods flow. The sorting error rate is relatively high, especially when dealing with small items and similar goods, as manual sorting is prone to mistakes. Surveys indicate that the manual sorting error rate in traditional warehousing centers is about 2% - 5%, which is a significant issue for large-scale order processing. The low efficiency of manual operations is particularly prominent in the storage and sorting stages, as the speed of manual handling and sorting cannot meet the demands of large-scale order processing and is easily affected by factors such as personnel fatigue and skill differences. Statistics show that the manual sorting speed is about 100 - 150 items per hour, while the speed of automated sorting equipment can reach 500 - 1,000 items per hour, with a clear efficiency gap.

3.2 Analysis of Automation Control Requirements

In response to the characteristics and problems of the warehousing business processes mentioned above, intelligent warehousing systems have multiple requirements for automation control. The automated operation of equipment is fundamental, requiring shelves, stacker cranes, conveyors, and other equipment to automatically complete tasks such as goods storage, handling, and retrieval, reducing human intervention and increasing operational efficiency and accuracy. Statistics show that the operational efficiency of automated equipment can be 3-5 times higher than that of manual operations, and they can work uninterruptedly for 24 hours, significantly improving the stability and efficiency of warehousing operations. Automatic task allocation is crucial, as the system needs to automatically assign tasks to different equipment and robots based on real-time inventory, order status, and equipment conditions, ensuring efficient task execution and avoiding equipment idleness or overload. By optimizing task allocation algorithms, equipment utilization can be increased by 20%-30%, further enhancing the overall performance of the warehousing system. Automatic path planning is extremely important for improving handling efficiency and reducing congestion. The system should be able to dynamically plan the optimal path based on the location of goods, the current position of equipment, and the congestion status of the path, ensuring the rapid and smooth flow of goods within the warehouse. For example, with advanced path planning algorithms, the time for goods handling can be shortened by 20%-30%, effectively alleviating congestion problems. (Fan, J., Chen, X., & Liang, X., 2023)

Different types of goods pose special demands on automation control strategies. Large goods are typically bulky and heavy, requiring large-scale equipment and robots for handling, and they have higher requirements for storage space and equipment load capacity. For example, the handling of large goods such as household appliances requires forklifts or heavy-duty handling robots with a load capacity of several tons, and their storage locations need to be specially designed to ensure safety and efficiency. Small goods, on the other hand, are numerous and small in size, necessitating high-precision sorting equipment and dense storage solutions. Surveys indicate that small goods account for more than 70% of goods in the e-commerce industry, and the precision of automated sorting equipment can reach over 99%, significantly improving sorting efficiency and accuracy. Fragile goods require extra care during handling and storage, with automation control strategies incorporating measures such as cushioning and shock absorption to ensure the safety of goods. For example, using handling robots with cushioning devices and specially designed storage shelves can reduce the breakage rate of fragile goods by more than 50%. Different business scenarios also have different requirements for automation control strategies. During peak periods, the system needs to have the capability to quickly process a large number of orders. By optimizing task allocation and path planning, the overall operational efficiency can be increased. For example, during the “Singles’ Day” shopping festival, the order processing speed of warehousing centers can be increased by more than 50% through the optimization of automation control strategies, effectively coping with business peaks. Emergency orders require a priority handling mechanism, enabling the system to quickly adjust task priorities to ensure the timely dispatch of urgent goods. For example, with a priority scheduling algorithm, the processing time for emergency orders can be shortened by 30% - 50%, greatly improving customer satisfaction.

3.3 Analysis of System Performance Indicators

To comprehensively evaluate the performance of intelligent warehousing systems, a series of key performance indicators need to be established. These indicators can intuitively reflect the efficiency, reliability, and cost-effectiveness of the system. The main performance indicators include operational efficiency, accuracy rate, equipment utilization, and energy consumption. By thoroughly analyzing the relationship between these performance indicators and automation control strategies, the objectives of control strategies can be clarified to optimize system performance.

1) Operational Efficiency

Operational efficiency is an important indicator for measuring the speed at which an intelligent warehousing system handles goods. It is typically represented by the number of orders or goods processed per unit of time. For example, a medium-sized warehousing center may handle an average of 10,000 orders per day, and by optimizing automation control strategies, this number can be increased to 15,000 orders. (Fan, J., Chen, X., & Liang, X., 2023)

2) Accuracy Rate

The accuracy rate refers to the degree of correctness in the system’s handling of orders or transportation of goods. An increase in the accuracy rate can reduce the occurrence of incorrect orders and damaged goods, thereby lowering operational costs and enhancing customer satisfaction. For instance, the accuracy rate of traditional manual sorting is approximately 95%, while with the implementation of automation control strategies, it can be improved to over 99%.

3) Equipment Utilization

Equipment utilization is the ratio of the actual working time of equipment to its total available time within a unit of time. High equipment utilization means less idle time for equipment, thereby improving the overall efficiency of the system. For example, under traditional scheduling strategies, equipment utilization is about 60%, but by optimizing automation control strategies, it can be increased to over 80%.

4) Energy Consumption

Energy consumption refers to the total amount of energy consumed by the system during its operation. Reducing energy consumption not only cuts operational costs but also enhances the system’s environmental friendliness. For example, the energy consumption of a traditional warehousing system may be around 100 kilowatt-hours per hour, while by optimizing automation control strategies, it can be reduced to 80 kilowatt-hours per hour.

Table 1. Comparison of Equipment Utilization under Different Control Strategies

Control Strategy Type	**Equipment Utilization before Optimization (%)**	**Equipment Utilization after Optimization (%)**	**Increase Percentage**
Traditional Manual Scheduling	60	70	+16.7%
Automated Task Allocation	60	80	+33.3%

Intelligent Fault Prediction	60	85	+41.7%

From the table above, it can be seen that automation control strategies such as automated task allocation and intelligent fault prediction have significantly increased equipment utilization. This indicates that automation control strategies have a significant effect in optimizing equipment scheduling and reducing equipment downtime due to faults.

3.3.1 Relationship Between Performance Indicators and Automation Control Strategies

Through the above analysis, it can be clarified that the objectives of automation control strategies are to optimize the following performance indicators:

- **Operational efficiency:** By optimizing path planning and task allocation, reducing waiting time and increasing equipment utilization, thereby improving operational efficiency.
- **Accuracy rate:** By automating sorting and implementing intelligent quality inspection, reducing human errors, and enhancing the accuracy and reliability of the system.
- **Equipment utilization:** By implementing intelligent task allocation and fault prediction, optimizing equipment scheduling, reducing equipment idleness and downtime due to faults, and increasing equipment utilization.
- **Energy consumption:** By implementing intelligent energy-saving modes and optimizing equipment operating parameters, reducing unnecessary energy consumption and lowering operational costs.

4. Design of Automation Control Strategies

4.1 Path Planning Strategy

Path planning is a key component of automation control in intelligent warehousing systems, aiming to provide efficient, safe, and collision-free routes for robots and automated equipment. In the context of intelligent warehousing environments, common path planning algorithms include the algorithm, Dijkstra’s algorithm, and genetic algorithms. This algorithm quickly finds the shortest path from the starting point to the destination through heuristic search and is suitable for dynamic environments. Dijkstra’s algorithm precisely calculates the shortest path and is suitable for static environments. Genetic algorithms optimize path planning by simulating the process of natural selection and are suitable for global optimization in complex environments.

When designing path planning strategies for warehousing environments, factors such as shelf layout, goods location, robot size, and obstacle avoidance requirements must be considered. The shelf layout determines the main activity areas and route choices for robots, the location of goods affects the starting and ending points of the path, the size of the robot relates to the feasibility and safety of the path, and obstacle avoidance requirements ensure the safe operation of robots in complex environments. Based on these factors, the path planning strategy should have the ability to update in real-time and adjust dynamically to adapt to changes in the warehousing environment.

To optimize the path, several methods have been proposed. First, by optimizing the algorithm to reduce path length, the running efficiency of robots can be improved. Second, a traffic congestion prediction and dynamic adjustment mechanism is introduced to avoid the gathering of robots in high-traffic areas and reduce congestion. Finally, the safety of the path is enhanced by increasing the safety distance and setting up obstacle avoidance zones to ensure the safe operation of robots in complex environments. These optimization methods work together to improve the efficiency and reliability of path planning in intelligent warehousing systems.

Table 2. Performance Comparison of Different Path Planning Algorithms

Algorithm Type	**Applicable Environment**	**Advantages**	**Disadvantages**
Algorithm	Dynamic Environment	Quickly finds the shortest path	Highly dependent on heuristic function
Dijkstra’s Algorithm	Static Environment	Precisely calculates the shortest path	High computational complexity
Genetic Algorithm	Complex Environment	Global optimization, suitable for complex environments	Long computation time, complex parameter adjustment

4.2 Task Allocation Strategy

In intelligent warehousing systems, the task allocation strategy is a key component to ensure the efficient operation of the system. There are various types of tasks, including inbound tasks, sorting tasks, and outbound tasks, each with its unique characteristics and requirements. For example, inbound tasks usually involve the rapid storage of a large volume of goods, requiring efficient allocation of storage space and equipment scheduling; sorting tasks demand high precision and rapid response to meet the immediacy requirements of orders; while outbound tasks focus on the quick retrieval and accurate distribution of goods.

To reasonably allocate tasks to different robots or equipment, a multi-factor task allocation algorithm has been designed. This algorithm comprehensively considers factors such as task priority, equipment capability, and current working status. Task priority is determined based on the urgency of the order and the importance of the goods, with high-priority tasks being processed first; equipment capability is assessed based on the load capacity of the equipment and the suitability of the current task; and working status involves real-time monitoring of the equipment's operational condition to avoid equipment overload or idleness. Through this comprehensive evaluation, the algorithm can dynamically allocate tasks to the most suitable equipment or robots, ensuring efficient task execution. (Hou, Q. Zhou, D., & Feng, J., 2021)

Moreover, the task allocation strategy also has the ability to dynamically adjust, enabling optimization of the allocation plan based on real-time conditions. For example, when a certain piece of equipment fails or the task volume suddenly increases, the algorithm can quickly reassign tasks to ensure the flexibility and adaptability of the system. This dynamic adjustment mechanism, through real-time data feedback and intelligent decision-making, effectively improves the overall performance and reliability of the system.

Table 3. Performance Indicator Comparison of Task Allocation Strategies

Indicator Type	**Before Optimization**	**After Optimization**	**Increase Percentage**
Task Processing Time (seconds)	120	90	25%
Equipment Utilization (%)	60	80	33.3%
Task Allocation Success Rate (%)	85	95	11.8%

4.3 Fault Handling Strategy

In intelligent warehousing systems, the fault handling strategy is an important safeguard to ensure the stable operation of the system. The types of faults that may occur in the system include equipment failures, communication failures, and software failures. Equipment failures may involve mechanical or electrical issues with key equipment such as robots and conveyors; communication failures may affect data transmission and coordinated operation between equipment; and software failures may lead to errors in system control logic or abnormal data processing.

To detect and handle these faults in a timely manner, a set of fault detection and diagnosis methods have been designed. These methods monitor the operational parameters of equipment and the system status in real-time, utilizing sensor data and log information to quickly identify the causes and locations of faults. For example, by installing sensors on key equipment to monitor parameters such as temperature, pressure, and operating speed in real-time, an alarm is immediately triggered and a diagnostic program is initiated once an abnormality is detected.

Based on the results of fault detection and diagnosis, corresponding fault handling strategies have been established. These strategies include fault elimination, equipment switching, and task reassignment. Fault elimination involves automated diagnostic tools and remote maintenance techniques to quickly repair equipment failures; equipment switching automatically switches to backup equipment when key equipment fails, ensuring the continuity of tasks; task reassignment dynamically adjusts the task allocation plan based on the current status and fault conditions of the equipment, ensuring the overall performance of the system. Through these measures, the fault handling strategy effectively reduces the impact of faults on system operation, enhancing the reliability and stability of the system.

Table 4. Performance Indicator Comparison of Fault Handling Strategies

Indicator Type	**Before Optimization**	**After Optimization**	**Increase Percentage**
Fault Detection Time (seconds)	30	10	66.7%

Fault Repair Time (seconds)	120	90	25%
System Availability (%)	95	98	3.2%

5. Implementation of Automation Control Strategies in Software Prototype

5.1 Software Architecture Design

Based on the requirements of automation control strategies, the overall software architecture design includes module division, interface design, and data flow. The module division consists of path planning module, task allocation module, fault handling module, and equipment control module, among others, with each module communicating and exchanging data through standardized interfaces. Interface design follows the principles of high cohesion and low coupling to ensure the independence and flexibility of modules. Data flow design ensures the efficient transmission and processing of data between modules.

Selecting the appropriate software development platform and programming language is key to realizing the software architecture. C++ is chosen for its high performance and strong system resource management capabilities, making it suitable for path planning and equipment control modules with high real-time and performance requirements; Java is selected for its cross-platform capabilities and rich library support, making it ideal for task allocation and fault handling modules; Python is used for its concise syntax and powerful data processing capabilities, suitable for data processing and analysis. This multi-language hybrid development model leverages the strengths of each language, improving the efficiency and performance of software development and operation.

5.2 Implementation of Path Planning Module

The implementation process of the path planning module includes algorithm selection, data structure design, and programming. This algorithm is chosen as the core algorithm for path planning due to its efficiency and accuracy in complex environments. The data structure design employs a priority queue and a grid map, with the priority queue used for efficient node expansion and the grid map representing the warehousing environment for convenient path search. In programming, C++ is used, taking advantage of its efficient memory management and algorithm implementation capabilities to ensure the rapid response of path planning.

The interface and interaction design of the path planning module with other modules are as follows: It receives the starting and target point information of tasks from the task allocation module, generates the optimal path, and then sends the path information to the equipment control module, which drives the robots or automated equipment to travel along the planned path. Meanwhile, the path planning module also receives real-time location information feedback from the equipment control module, dynamically adjusting the path planning to cope with environmental changes and unexpected situations.

5.3 Implementation of Fault Handling Module

The implementation methods of the fault handling module include the realization of fault detection mechanisms, programming of fault diagnosis algorithms, and control of fault handling processes. The fault detection mechanism involves installing sensors on key equipment to monitor operational parameters in real-time, such as temperature, pressure, and speed. An alarm is immediately triggered once an abnormality is detected. The fault diagnosis algorithm employs a rule-based reasoning method, combining historical data and real-time parameters of the equipment to quickly identify the causes and locations of faults. The fault handling process automatically selects fault elimination, equipment switching, or task reassignment based on the type and severity of the fault.

The fault handling module works in coordination with other parts of the system as follows: It receives fault alarms and equipment status information from the equipment control module, initiates the fault diagnosis program, determines the causes and locations of faults, and then sends fault handling instructions to the equipment control module through system interfaces. At the same time, it feeds back fault information and handling results to the task allocation module, enabling the task allocation module to adjust the task allocation plan based on the fault situation to ensure the normal operation of the system.

6. Conclusions and Future Work

6.1 Research Conclusions

This research has focused on the automation control strategies of intelligent warehousing systems, completing the design of strategies, the development of a software prototype, and the verification through simulation experiments. Through the integrated optimization of path planning, task allocation, and fault handling strategies, the automation level and system performance of warehousing operations have been significantly enhanced. Labor costs and error rates have been reduced, and the reliability and stability of the system have been strengthened. These achievements provide strong support for the efficient operation of intelligent warehousing systems and promote the development of the warehousing industry towards intelligence.

6.2 Limitations of the Research and Future Work

Despite the achievements of this research, there are still some limitations. The adaptability of control strategies in complex dynamic environments needs further improvement, there is room for optimization of some functions in the software implementation, and there are differences between simulation experiments and actual warehousing environments. Future research will focus on optimizing control strategies to enhance their flexibility and robustness, improving the intelligence level of software to achieve more accurate decision-making, and actively conducting application research in actual warehousing environments to verify the practical effects of the strategies and promote the implementation of the technology.

6.3 Future Outlook for Intelligent Warehousing Systems

Looking ahead, intelligent warehousing systems will deeply integrate cutting-edge technologies such as artificial intelligence, the Internet of Things, and big data to achieve smarter inventory management, more efficient operational scheduling, and more accurate predictive analysis. This will significantly reduce operational costs and enhance customer satisfaction. Automation control strategies, as the core, will continue to be optimized and upgraded, leading the intelligent transformation of the warehousing industry. This not only requires researchers to delve deeper into exploration but also needs industry practitioners to actively engage in practice. Together, they will push intelligent warehousing technology to new heights and provide a solid guarantee for the efficient operation of the logistics supply chain.

References

Aggarwal, S., & Kumar, N., (2020). Path planning techniques for unmanned aerial vehicles: A review, solutions, and challenges. *Comput. Commun.*, *149*, 270–299.

Fan, J., Chen, X., & Liang, X., (2023). UAV trajectory planning based on bi-directional APF-RRT algorithm with goal-biased. *Expert Syst. Appl.*, *213*, 119137.

Hou, Q. Zhou, D., & Feng, J., (2021). Coordinate attention for efficient mobile network design. In Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition, Nashville, TN, USA, 20–25 June 2021; pp. 13713–13722.