

A Review of Scheduling Methods for Multi-AGV Material Handling Systems in Mixed-Model Assembly Workshops

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Abstract

Currently, automobile production in workshops faces demands for multi-variety, small-batch, and rapid delivery. As a key auxiliary link, optimizing the performance of the workshop material scheduling system can enhance production efficiency and economic benefits. With the expansion of enterprise scale and the complexity of production requirements, multi-AGV material handling systems have become an effective solution to optimize production processes and save costs due to their parallel collaboration advantages. However, due to the NP-hard nature of this problem, traditional exact algorithms often perform poorly when dealing with complex large-scale workshop scheduling problems. Therefore, this paper explores the applications of intelligent algorithms such as genetic algorithms, artificial neural networks, and particle swarm optimization, and proposes novel and efficient solutions for scheduling methods of multi-AGV material handling systems in mixed-model assembly workshops. In addition, to address the problem of a large state space in workshop material handling system scheduling schemes, this paper also discusses the potential applications of emerging technologies such as reinforcement learning. Through these studies, it aims to optimize workshop production processes, reduce production costs, and promote the development of the manufacturing industry.

Keywords

Workshop Material Handling System; Multi-AGV Scheduling; Solution Method.

1. Introduction

As the pillar of the national economy, the manufacturing industry profoundly reflects the country's comprehensive strength and core competitiveness. Both 'Made in China 2025' and the report of the 20th National Congress of the Communist Party of China emphasize that technological innovation drives industrial upgrading, especially through intelligent manufacturing and digital technology to empower the real economy. In this context, the automobile industry, as a benchmark field of China's manufacturing industry, is accelerating the transformation of digitalization, automation and intelligence, and has become an important window to observe the high-quality development of China's manufacturing industry.

China's automobile industry has shown strong resilience in multiple challenges. As shown in Figure 1 and Figure 2, production and sales fell by about 7% year-on-year in 2020 due to the epidemic, but recovered in 2022, with annual production and sales reaching 27.02 million and 23.563 million respectively. By 2024, the production and sales volume far exceeded the 30 million mark, reaching 31.282 million and 31.436 million respectively, with a year-on-year increase of 3.7% and 4.5%, marking that the industry has entered a new stage of development. The breakthrough of new energy vehicle technology and the improvement of industrial chain promote the reshaping of market competition pattern. Enterprises should not only cope with the trend of product personalization and customization, but also balance the dual challenges of

cost control and technological innovation. As a mainstream production mode, mixed-model assembly line meets diversified needs through multi-model collinear production, but the accuracy and timeliness requirements of parts distribution are significantly improved. The risk of shutdown caused by shortage of station parts and high cost force the logistics system to upgrade. At present, many automobile manufacturing enterprises have turned to the production mode of multi-variety mixed assembly to meet the diversified needs of the market^[1].

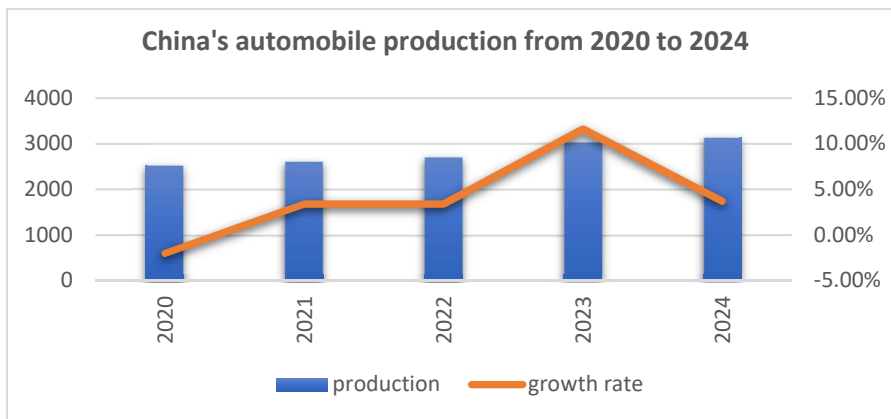


Figure 1. China's automobile production from 2020 to 2024

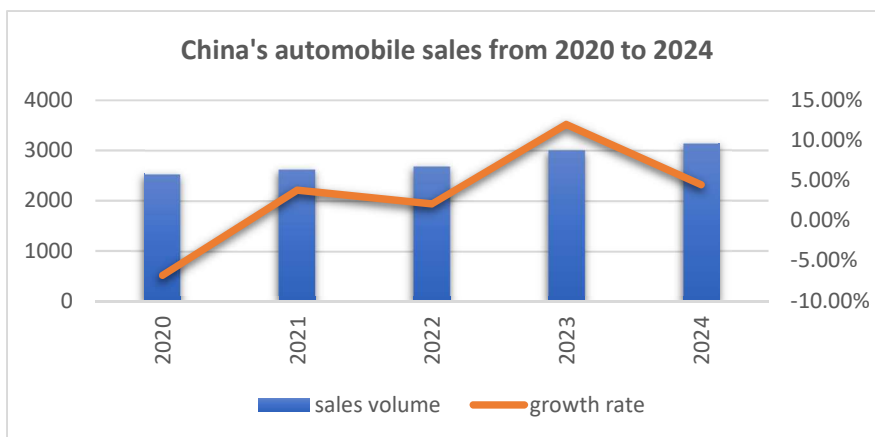


Figure 2. China's automobile sales from 2020 to 2024

At present, China 's automobile logistics cost accounts for as high as 15 %, far exceeding developed countries such as Europe, America and Japan. Among them, the material distribution cost of mixed-model assembly line accounts for 15 % -30 % of the total cost, which has become a key bottleneck restricting competitiveness^[2]. The frequent occurrence of dynamic events in the workshop, such as equipment failure and emergency order insertion, requires the material system to be highly flexible. The traditional single AGV system has been insufficient in dealing with complex logistics scenarios. The multi-AGV collaborative operation system can improve the handling efficiency by more than 30 % through parallel task processing and intelligent scheduling. The optimization of material distribution needs to take into account the characteristics of limited material box capacity and multi-load transportation equipment. It is necessary to prevent the stagnation of the production line and reduce the hidden cost caused by frequent replenishment. The academic community focuses on building a highly flexible material handling system and exploring the optimal scheduling strategy in a dynamic environment. This is not only a difficult point in theoretical research, but also an urgent need for industrial upgrading.

Artificial intelligence technology provides new ideas for solving logistics dilemma. Reinforcement learning technology can realize intelligent scheduling in dynamic environment through independent decision-making and continuous optimization. The system can respond to changes in the state of the workshop in real time, quickly generate emergency plans in emergencies such as machine failure and order adjustment, and continuously improve the quality of decision-making through historical data learning. Multi-AGV system combined with intelligent algorithm can effectively balance task allocation, path planning and conflict resolution, and improve material distribution efficiency by 20 % -40 %. With the deep integration of manufacturing industry and AI technology, this intelligent logistics system with self-learning ability is becoming the core competitiveness of automobile enterprises to reduce costs and increase efficiency. In the future, achieving the proportion of logistics costs to the international advanced level through technological innovation will be an important breakthrough direction for China 's automobile industry to shift from scale expansion to quality improvement.

2. Research Objectives and Significance

At present, the automobile manufacturing industry is facing the dual pressure of product iteration acceleration and demand diversification. Although the mixed-model assembly line can balance flexible production and resource efficiency, the traditional material distribution system has bottlenecks such as supply delay, line-side inventory backlog, and high logistics costs, which frequently leads to production line stagnation. Multi-AGV system realizes accurate material distribution and inventory optimization through intelligent collaborative scheduling, dynamic path planning and real-time data interaction, which has become the core solution to break through the bottleneck of production efficiency and reduce operating costs. Therefore, it is of great research background and research value to study the scheduling method of multi-truck material handling system in mixed-model assembly workshop.

The traditional single AGV system is difficult to support the dynamic production environment due to lack of flexibility, and multi-AGV collaborative handling can significantly improve handling efficiency and reduce line-side inventory and logistics costs through task allocation optimization and parallel operations. Multi-AGV scheduling needs to solve multi-objective optimization in dynamic environment, which is a NP-Hard level complex problem. At the same time, it is more complex than single AGV scheduling problem in judging handling time, assigning handling tasks and selecting handling trolleys. It is very limited to use the traditional exact algorithm to solve the problem. Therefore, it is necessary to use intelligent algorithms such as genetic algorithm, artificial neural network and particle swarm optimization to solve the problem. At the same time, reinforcement learning provides an important solution to solve the problem of large state space in the scheduling scheme of workshop material handling system. In short, how to use intelligent algorithms and reinforcement learning algorithms to reduce production costs under the premise of ensuring timely material handling and production efficiency in multi-AGV material handling operations has very important research significance.

3. Review of Domestic and International Research

The scheduling optimization of material handling system in mixed-flow workshop aims to achieve the dual goals of efficient handling task execution and low-cost material replenishment. The scientific and reasonable scheduling scheme needs to clearly plan the handling task elements, specifically covering the core parameters such as the type and quantity of materials selected for handling, the priority order of transportation, and the AGV selection criteria. The academic community has carried out multi-dimensional research on such production optimization problems, aiming to fully release the operational potential of manufacturing

systems through technological innovation. The workshop material handling scheduling strategy can be divided into two categories : static scheduling and dynamic scheduling according to the difference of environmental adaptability. The static scheduling mode relies on the implementation of the formulated production plan, and the input parameters are deterministic and non-time-varying, which is suitable for task allocation in a stable production environment. Dynamic scheduling emphasizes the immediate response ability to the real-time operation data of the workshop. It is necessary to construct an adaptive mechanism to cope with external disturbances and generate a dynamic optimal decision-making scheme. From the dimension of transportation carrier, the existing research mainly focuses on two directions : single automatic guided vehicle scheduling and multi-automatic guided vehicle scheduling. In static scheduling scenarios, single AGV systems usually adopt fixed route planning and periodic delivery strategies, while multi-AGV systems need to solve path conflict avoidance and load balancing optimization problems. The single AGV operation under the dynamic scheduling system emphasizes the real-time path re-planning ability, and the multi-AGV collaboration realizes autonomous collaboration by constructing a distributed decision-making mechanism. The following will start from the two aspects of static scheduling and dynamic scheduling, and introduce the current research status of single AGV and multi AGV respectively.

3.1. Static Scheduling

The static scheduling method is a way to treat the scheduling problem of the workshop material handling system as a deterministic problem. It assumes that all material handling requirements are known before scheduling, and then establishes a mathematical programming model based on this information, and uses integer programming, dynamic programming and other operational research methods to solve the problem of scheduling optimization. The scheduling scheme aims to efficiently and energy-efficiently supply materials to the production system, ensure that parts are delivered on time to maintain the stable operation of the manufacturing system, and minimize unnecessary parts distribution, thereby reducing line-side inventory costs. Through reasonable scheduling, it can improve efficiency, reduce logistics costs, and give full play to the production and manufacturing potential of enterprises. The static scheduling method is suitable for the case of a given fixed production plan arrangement, and provides important theoretical and practical guidance for solving the scheduling problem of the workshop material handling system.

3.1.1. Single-AGV Problems

Aiming at the problem of on-time delivery of materials in automobile mixed-model assembly lines, Emde and Gendreau et al. ^[3]focused on the single-point optimization of scheduling and transportation links, and took the lead in constructing a mixed integer programming model for multi-load trolley scheduling and loading under fixed routes. The tabu search algorithm achieves the balance between on-time supply of parts and in-process inventory, which provides an effective method for solving the NP-hard problem. On this basis, Emde et al. ^[4]further introduced the assembly line sequencing problem, and significantly improved the synchronization and timeliness of material supply by dynamically adjusting the synergy between production sequence and logistics supply.

In terms of effective integrated scheduling of AGVs with other resources, Yuan Minghai et al. ^[5]expanded the research scope to the dual-resource integrated scheduling problem of AGVs and machines. They comprehensively considered multiple constraints of machines, workpieces, and AGVs and established a dual-resource integrated mathematical model, providing new ideas for solving resource coordination problems in complex manufacturing systems.

3.1.2. Multi-AGV Problems

With the development of manufacturing and the expansion of production scale, material flow in workshops has become more complex and diverse. Single AGVs can no longer fully meet the

complex material transportation and handling needs of workshops. Multi-AGV systems can achieve rapid and accurate material transportation through collaborative work and intelligent scheduling. Therefore, researching and applying multi-AGV systems has become an inevitable choice.

In the aspect of scheduling problem considering AGV path planning, SAIDI-MEHRABAD et al. [6] first constructed a multi-AGV integrated job shop scheduling model considering conflict-free path planning, and minimized the total completion time by two-stage ant colony algorithm. On this basis, Ham [7] proposed a constraint programming method, which realized the multi-AGV synchronous scheduling of production process and material transfer, broke through the limitation of traditional single link optimization, and promoted the transformation of resource scheduling from independent operation to collaborative management.

Regarding task allocation for multi-load vehicles, Zhou et al. [8] added the distribution of storage locations for incoming and outgoing goods to the task allocation problem and achieved balanced task allocation for multi-AGVs through the proposed heuristic rules. This research provides an optimization framework for AGV task allocation in static storage location environments but does not fully consider the impact of order dynamics and time constraints on scheduling strategies. On this basis, Liang et al. [9] further focused on the problem of order picking and multi-AGV collaborative scheduling, proposed a hybrid time window and order batching strategy, and constructed a comprehensive scheduling model including moving time, queuing time, and picking time. By deeply coupling order processing with AGV path planning, this research broke through the limitations of traditional static task allocation optimization and achieved efficient matching between dynamic order demands and AGV resources, thereby improving task completion efficiency while reducing system operating costs.

3.2. Dynamic Scheduling

Dynamic scheduling, also known as real-time scheduling, is a method of scheduling tasks in a real-time environment. It can dynamically generate optimal task scheduling schemes based on current situations and available information, including real-time information such as workstation status, multi-load vehicle status, production tasks, and line-side inventory status. Different from static scheduling methods, dynamic scheduling continuously functions during the production process, schedules tasks in real-time according to system status, does not interfere with the operation of manufacturing and processing activities, and can make decisions without requiring all information in advance. Dynamic scheduling is usually triggered at fixed time intervals^[10] or after specific events^[11], such as the generation of new material handling tasks or the change of vehicle status from busy to idle.

3.2.1. Single-AGV Problems

In the evolution of theoretical research in the field of workshop AGV scheduling, scholars have gradually deepened the problem model and solution method for different levels of constraints. Tang^[12] focused on the dynamic scheduling scenario under the constraints of transportation resources. By constructing a flexible job shop model, the transportation capacity limitation of AGV is combined with the dynamic task response mechanism for the first time, which provides a theoretical framework for solving the problem of basic resource constraints. However, with the increase of the complexity of the problem, the traditional dynamic scheduling method exposes the defects of solution space explosion and insufficient real-time performance when dealing with multi-load AGV cooperative operation. In response to this limitation, scholars such as Feige^[13] further expanded the research boundary and innovatively proposed a history-guided region partitioning algorithm (HRPEO) to solve the scheduling problem of AGV flexible job shop with limited multi-load.

3.2.2. Multi-AGV Problems

In modern intelligent manufacturing systems, frequent changes in production requirements and operating environments have spawned complex dynamic scheduling problems. Due to many uncertain factors in the manufacturing workshop, including the random disturbance of the production environment and the dynamic change of the order demand, the traditional static scheduling strategy is difficult to adapt to the real-time changing production scene. As the core component of intelligent manufacturing, multi-AGV cooperative scheduling system needs to respond to emergencies in the system through dynamic adjustment strategies. By introducing a dynamic scheduling mechanism, the material handling path planning and task allocation of multi-AGV system can be effectively optimized, the no-load time of equipment can be reduced, the resource utilization rate can be improved, and the workshop production efficiency can be significantly improved.

In the scheduling scheme allocation of multi-load vehicles, scholars have gradually improved the adaptability and algorithm efficiency of the scheduling model through progressive innovation. Early research represented by Meng et al.^[14], aiming at the multi-objective integrated scheduling problem of flexible assembly workshop, a heuristic strategy based on the principle of first processing first handling and nearest handling is constructed, and an improved genetic algorithm is developed to optimize the transportation path, which provides a basic decision-making framework for multi-AGV system. On this basis, the research trend has gradually shifted to refined modeling under multi-dimensional constraints. For example, Zhao^[15] focused on the EMU maintenance scenario, broke through the limitations of traditional single-factor optimization, and incorporated industrial actual constraints such as AGV load capacity, battery life and task time window into the mathematical model. Through multi-population genetic algorithm, the collaborative improvement of resource utilization efficiency and task completion timeliness is realized. With the upgrading of the complexity of application scenarios, scholars have further focused on the robust scheduling mechanism under dynamic disturbances. Wang^[16] proposed a solution to the multi-AGV scheduling problem (MASP-SF). The core model of task allocation is constructed by mixed integer linear programming, and the group-based variable neighborhood search (PVNS) algorithm is innovatively integrated to enhance the global optimization ability. At the same time, the fast repair mechanism and the improved NNH rescheduling strategy are introduced to form a closed-loop decision-making system from normal scheduling to fault emergency response.

On the issue of sustainable development of multi-AGV scheduling research, Zhou^[17] took the lead in introducing carbon footprint accounting and machine load balancing into the flexible job shop scenario, and constructed a green low-carbon scheduling framework for multi-AGV collaborative transportation. The Pareto optimization of AGV path planning and energy consumption control is realized by improving the NSGA-II algorithm, which lays a methodological foundation for low-carbon scheduling. Since then, the research focus has shifted to the innovation of intelligent decision-making mechanism in dynamic environment. Zhang^[18] broke through the limitations of traditional heuristic algorithms and proposed a memetic algorithm based on deep Q network. Through the adaptive characteristics of reinforcement learning, the multi-objective trade-off in green manufacturing and logistics scheduling is optimized in real time, which significantly improves the dynamic response ability under complex working conditions. On this basis, Yao^[19] further strengthened the algorithm architecture. The developed deep Q network multi-objective memetic algorithm synchronously compresses the completion cycle and energy consumption through a two-layer optimization mechanism, and achieves a breakthrough in time-energy consumption dual-dimensional collaborative consumption reduction in dynamic scheduling. As the application scenario extends to the field of precision manufacturing with high safety requirements, Zou^[20] innovatively combined mixed integer programming with group-based iterative greedy

algorithm (PIG) to solve the time series conflict problem caused by AGV unloading safety detection in matrix workshop. By balancing local search and global exploration through a multi-stage perturbation strategy, the total cost control range is extended to all-factor dimensions such as equipment depreciation, energy consumption monitoring and safety risks while avoiding local optimization.

In terms of path planning problems, early research such as Du^[21] focused on basic algorithm innovations for single-AGV path optimization. The proposed hybrid genetic particle swarm optimization algorithm (GA-PSO) combined the global search ability of genetic algorithms with the local optimization characteristics of particle swarm algorithms, and achieved a dual improvement in path efficiency and robustness in discretized workshop maps through feasible path topology construction and the Warshall-Floyd shortest path algorithm, laying an algorithmic foundation for multi-AGV path planning in static environments. However, with the increasing demand for multi-AGV collaborative operations, simple shortest path generation can no longer meet the complexity requirements of actual workshop dynamic scheduling. In response, Shan^[22] established a time-window-based conflict prediction model, upgraded the traditional path search problem to a space-time coupled collision-free path planning framework. The proposed general algorithm not only reconstructed the time-dimensional constraint mechanism for AGV movement trajectories but also designed a phased conflict detection and dynamic re-planning strategy, enabling multi-AGV systems to real-time avoid deadlocks and collision risks when sharing path resources, further improving path planning and conflict resolution strategies.

3.3. Applications of Different Algorithms in Workshop Scheduling

Currently, methods for solving dynamic workshop scheduling problems mainly include fuzzy logic algorithms, intelligent optimization algorithms, and machine learning algorithms. Among them, intelligent optimization algorithms are classic methods in the field of workshop scheduling and are widely used in production scheduling. In recent years, with the rapid development of information technology and artificial intelligence, various machine learning algorithms have begun to be applied in workshop scheduling. This section will discuss common scheduling algorithms, and the mainstream algorithms are as follows:

3.3.1. Fuzzy Logic Algorithms

Sudiarso^[23] proposed a fuzzy logic-based scheduling algorithm that uses failure frequency and the average number of required parts as inputs to determine the best production system control strategy and batch size. For dynamic uncertainties such as machine failures and uncertain job arrivals, Bilkay^[24] proposed a two-stage algorithm where the first stage assigns part processing priorities based on fuzzy logic. Ramkumar^[25] proposed a system based on triangular fuzzy membership functions and fuzzy rules for multi-objective job shop scheduling problems, transforming the problem into a three-objective optimization problem by considering factors such as job size, workshop workload, and job priority.

3.3.2. Intelligent Optimization Algorithms

The application of intelligent computing methods in workshop scheduling has been a research hotspot in recent years, mainly using intelligent computing technologies such as genetic algorithms, artificial neural networks, and particle swarm optimization to solve workshop scheduling problems. These methods can effectively improve scheduling efficiency, reduce solution complexity, and contribute to the overall optimization of workshop logistics.

Xiaoqin^[26] et al. proposed a mixed-integer linear programming model and a dual-population collaborative genetic algorithm (DCGA) to provide an accurate solution framework for AGV path planning problems, achieving collaborative optimization of machine selection and operation sequencing through a two-layer coding strategy. However, with the exponential

growth of problem scale, the computational complexity of traditional exact methods has increased sharply, making it difficult to meet actual production needs. Against this background, Belabid^[27] innovatively proposed a fire and maneuver optimizer (FMA), which combines greedy strategies with multi-neighborhood search by simulating the suppression-push-attack mechanism in military tactics, significantly improving the solution efficiency for large-scale flow shop scheduling problems.

3.3.3. Reinforcement Learning Algorithms

Reinforcement learning (RL) focuses on how an intelligent agent (Agent) can learn and maximize the rewards it receives in a complex and uncertain environment. The agent interacts with the environment, observes the environment's feedback, accumulates experience through continuous attempts, and gradually optimizes its behavioral strategy to achieve the optimal cumulative reward. In dynamic scheduling problems, the application of reinforcement learning algorithms enables the agent to flexibly adjust its scheduling rule usage strategy according to changing scheduling states, thereby achieving more intelligent and effective task scheduling.

Among traditional reinforcement learning algorithms, Q-learning, as a classic value iteration-based method, has shown good convergence characteristics in discrete and finite state-action spaces, but its algorithm efficiency is limited by the curse of dimensionality in the state space and is difficult to predict unobserved states. To break through this limitation, academia has proposed integrating deep neural networks into the reinforcement learning framework to form the innovative paradigm of deep reinforcement learning (DRL). This technical path combines the representation learning ability of deep learning with the decision-making mechanism of reinforcement learning, successfully achieving generalized processing of high-dimensional state spaces, and its applications have expanded to multiple industrial fields requiring real-time decision-making, such as smart manufacturing and logistics optimization. Empirical analysis shows that DRL algorithms can effectively capture nonlinear features in complex scheduling scenarios by constructing deep value networks, demonstrating significantly better performance than traditional methods in typical problems such as dynamic task allocation and path planning. Hu et al. ^[28] took the lead in constructing an AGV dynamic scheduling system based on adaptive DRL, realized real-time decision-making through a hybrid rule optimization mechanism, and made significant breakthroughs in minimizing the process completion time and delay rate indicators, which provided feasibility verification for the application of DRL in industrial scheduling. Aiming at the scalability bottleneck of traditional models in complex workshop scenarios, Zhao^[29] 's research forms key technical iterations. Through the dual-framework system, the collaborative optimization of deep reinforcement learning and iterative greedy algorithm, as well as the reconstruction of coding network based on DQN and deep neural network, effectively solve the problem of high-dimensional state space modeling and multi-task parallel scheduling. In order to further expand the multi-objective optimization capability, Wu^[30] designed a double-layer DQN (DDQN) architecture, introduced a dual-agent cooperation mechanism between target selector and actuator, and successfully realized the dynamic trade-off optimization between the total delay time and the longest process time. With the deepening of industrial big data application scenarios, the Actor-critic fusion framework developed by Zhao^[31] significantly improves the generalization ability and convergence efficiency of the algorithm under large-scale data sets by jointly optimizing the policy gradient and the value function. These studies have shown that deep reinforcement learning has great potential and application value in solving job shop scheduling problems.

3.3.4. Multi-Agent Deep Reinforcement Learning Algorithms

In the technological evolution of multi-agent reinforcement learning-driven shop scheduling, the research content has undergone a transitional development from the construction of basic collaborative framework to the integration of complex network structure. Zhang^[32] took the

lead in constructing a multi-agent manufacturing system based on deep reinforcement learning. Through the collaborative design of self-organization mechanism and online learning strategy, the feasibility of collaborative decision-making of distributed agents in dynamic environment is preliminarily verified, which lays a methodological foundation for multi-agent collaborative scheduling. On this basis, the DeepMAG model proposed by Zhang^[33] achieves a key breakthrough, innovatively integrates the multi-agent graph with the deep reinforcement learning framework, and characterizes the topological relationship between workshop devices through the graph structure, which significantly improves the state modeling accuracy of the flexible shop scheduling problem. In order to strengthen the real-time decision-making ability, the dual-depth Q network architecture developed by Liu^[34] enables the multi-agent system to achieve near-real-time response in dynamic job scheduling through enhancement mechanisms such as experience playback and priority sampling, and improves the algorithm execution efficiency to the industrial application threshold. The MAS-RL system constructed by Inal^[35] shows paradigm advantages under heavy load conditions. Its reinforcement learning framework based on multi-agent collaboration comprehensively surpasses traditional rule scheduling in five core indicators such as late job ratio and flow time, which confirms the robustness of the technical path in high-pressure production scenarios. With the penetration of graph neural network technology, the focus of research has shifted to the spatial relationship mining of workshop state. Jing^[36] introduced graph convolutional network to construct information transmission channels between agents, and optimized the global scheduling strategy of flexible workshop through topological feature extraction. The distributed multi-agent architecture (DMASA) developed by LPu^[37] realizes the deep embedding of device-task correlation through heterogeneous graph neural network, and combines the strategy optimization mechanism of reinforcement learning to achieve a coordinated leap in scheduling decision accuracy and computational efficiency in intelligent manufacturing scenarios.

4. Summary

After in-depth analysis of numerous studies, it is found that current research on multi-AGV scheduling in workshops mainly focuses on resource allocation, task sequencing, scheduling considering different practical factors, and path planning. The paths for AGV material scheduling are roughly divided into three types. One is that AGVs are responsible for transporting parts from the material supermarket to each workstation, with each AGV handling all parts without regional division, meaning each AGV's possible handling paths include all workstations. The second is that each workstation has input and output areas, and AGVs are responsible for material transportation between workstations and loading/unloading stations. The third is in matrix manufacturing workshops, where there are fixed transportation channels for AGVs to travel. Currently, no scholar has studied the division of part handling tasks for different workstations in assembly line manufacturing workshops, where some parts are transported by specific AGVs and others can be transported by multiple AGVs.

The diversity of research methods for multi-AGV scheduling in workshops provides a certain degree of applicability for solving specific problems, including technologies such as fuzzy logic, intelligent optimization, and machine learning. However, these methods may not be fully applicable to all situations and are still limited by universality. Traditional intelligent optimization algorithms such as genetic algorithms, artificial neural networks, and particle swarm optimization require the design of heuristic rules for specific problems, which may be limited in terms of algorithm generality and adaptability when facing large-scale or dynamically changing scheduling problems. The application of machine learning in workshop material handling system scheduling, by imitating the human learning process, can adapt to changes in system states and environmental parameters. This algorithm consists of two parts: offline

training and online scheduling. It uses historical data to train the model to guide real-time scheduling decisions. However, the effectiveness of the model highly depends on the quality of training data and the rationality of hyperparameter settings. High-quality training data is the basis for ensuring effective model learning, and hyperparameter adjustment directly affects the model's prediction accuracy and learning efficiency. Although automated hyperparameter adjustment techniques such as grid search and Bayesian optimization can assist in finding appropriate parameters, they may require significant computational resources and time. Therefore, important factors to consider include how to establish a dynamic scheduling model that adapts to actual production processes, select optimization goals to reduce costs, and obtain the best scheduling strategy through appropriate solution methods to respond to real-time changes in the production system environment.

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