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The Scheduling Technology Development of Multi-AGV System in AI Era

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Abstract. As an important intelligent transportation equipment of logistics, Multi-AGV scheduling is a key problem that restricts the operation efficiency and large-scale expansion of AGV system. This paper analyzes and elaborates three key technologies of AGV scheduling, namely Path Planning, Task Scheduling and Traffic Control Management. The method of Time Window modeling based on physical entity is superior to that based on particle motion. Finally, the trend of AGV scheduling intelligentization is illustrated by combining with the current advanced technology.

1. Introduction

With the promotion of Germany's Industry 4.0 high-tech strategic plan and the extensive application of new technologies such as the Internet, the Internet of things, big data, cloud computing and artificial intelligence in various fields, intelligentization has become a new round of industrial revolution in the development of modern logistics industry and manufacturing industry. The robotization level of industry and agriculture will become an important factor to measure the competitiveness of national science and technology. On July 8, 2017, the announcement of the State Council of China on the development of a new generation of artificial intelligence pointed out that it is necessary to accelerate the upgrade of the logistics industry, promote the innovative integration of artificial intelligence and the logistics industry, improve the establishment of a smart logistics public information platform and command system, and build depth-based Perceive logistics system to improve logistics management level and efficiency.

In particular, the catalyst for the outbreak of a new global pandemic COVID-19 in 2020 has made unmanned production and logistics important measures to ensure the normal operation of the economy in the event of a catastrophic emergency.

Therefore, intelligent logistics has ushered in an unprecedented opportunity for development, and can become a strong impetus for the future construction of intelligent factories. The task of intelligent logistics is to use advanced logistics technology to reduce the cost of logistics, so as to improve the efficiency and flexibility of logistics, and reduce resource consumption and environmental costs, which is also an important way to build intelligent factories and intelligent society in the future. As a flexible automatic transport equipment for logistics automation, how to realize the integration of Multi-AGV with the original logistics system and improve the original AGV scheduling technology by combining with the current new technology is a hot issue in the theoretical as well as practical fields. Considering the policy, capital and technology are all pushing AGV scheduling technology onto the fast track. Intelligent AGV system, as an emerging flexible and cost-effective solution, has shown a broad application prospect. In this paper, the key technologies and implementation methods of AGV scheduling are summarized.



2. Definition of AGV

AGV is an automatic transportation device that transports products from one place to another in industry [2]. AGV is an important branch of intelligent mobile robot. The original American Logistics Association's definition of AGV is: equipped with automatic guidance devices such as electromagnetic or optical, capable of traveling along prescribed guidance paths, transportation with safety protection and various transfer functions vehicle. According to the definition of Japanese JISD6801: AGV is a kind of industrial vehicle with automatic operation driven by battery [3].

3. Key Scheduling Technology

The AGV system refers to a system composed of several AGVs, traveling along the guidance path, and operating under the traffic control of the main control computer, which has the functions of handling, control and dispatching. AGV scheduling is the core function of the AGV system. It is mainly refined into three key technologies, namely route planning, task allocation and traffic control. Each key technology is introduced one by one below.

3.1. Path Planning

Path planning refers to an environment with certain obstacles (this environment can be perceived through the interaction between AGV and the environment), given a starting point and a target point, and referring to certain criteria, such as the shortest path factor, the least time spent, and the least number of turns, minimum cost, etc. to search for an optimal collision-free path in your environment. The classification of path planning is as follows:

Table 1. The classification and overview of path planning

Criterion	Category	Overview	Suitability
Changes before or after task execution	Offline path planning	Before the task is executed, the optimal path is generated and does not change until the task is completed	Simple; Stable; Universal
	Online path planning	After the task is executed, the path can be re-planned according to the situation	Complicated; Unstable
Environmental change	Static environmental path planning	Environmental information no longer changes	Simple; Stable; Universal
	Dynamic environmental path planning	Environmental information changes in real time	Complex; Not suitable for structured links
Environmental perception	Global path planning	Planning for global tasks	Overall task
	Local path planning	Planning two-point paths with known local environmental information	Local two points

The basis of path planning is the establishment of an environmental model, which directly affects the choice of algorithms. Environmental modeling mainly includes grid models, geometric models, topological models, and three-dimensional models[8]. Among them, the grid model is a common environment modeling method. The grid model can intuitively express a two-dimensional map model, but the grid size needs to be determined in advance during the map model establishment process. The grid density directly affects the accuracy and speed of the solution. The higher the grid density, the higher the accuracy of the solution, but the slower the solution speed. The smaller the grid density, the lower the accuracy of the solution, but the faster the solution speed. The geometric model relies on the visual sensors on the AGV, extracts the collected environmental information, identifies the

environment in the form of geometric points, lines, and planes, and performs path planning. The topological graph model represents a map with a topological structure and is suitable for the representation of large-scale environmental graphs. Compared with the two-dimensional model, the three-dimensional model can more realistically and intuitively express the site environment, but requires a lot of data, so related applications and research are less.

3.2. Task Scheduling

Task scheduling refers to determining how to assign these tasks to the AGVs in the system to complete the transportation tasks when the system generates transportation tasks so as to minimize the sum of the transportation losses of all tasks[4].

There are two main types of task scheduling: task-finding and vehicle-finding tasks. AGV optimal scheduling is to first perform path planning, and based on the planned AGV path, according to certain scheduling rules and constraints, reasonably and efficiently assign tasks to AGV in the system[5]. Task scheduling is generally implemented using heuristic algorithms[6]. Among them, the scheduling goal is to minimize the number of AGVs, minimize the total transportation time, or minimize the total transportation distance, etc.[7]. The scheduling task at a certain time is interpreted as: selecting the best task set and the best route for an AGV, or selecting the appropriate AGV and transportation route for a transport task.

Task scheduling is a combinatorial optimization problem. When the number of assigned tasks is large, the solution space of the problem increases geometrically, which results in a combined explosion problem, which is a NP-hard problem. In practical manufacturing systems, there are many NP-hard combinatorial optimization problems similar to the unmanned transportation task scheduling problem. Among them, there are single-objective optimization problems and multi-objective optimization problems. Because exact algorithms are difficult to solve, in order to solve the optimal solution or a satisfactory suboptimal solution in a short time, heuristic evolutionary algorithms are usually used to solve it in actual manufacturing systems. Genetic algorithms have been widely used in solving various combinatorial optimization problems. At present, the application of genetic algorithms is quite mature, and the performance is relatively stable. Similarly, genetic algorithms and their improvements have also been widely used in unmanned transportation task scheduling.

3.3. Traffic Control

The core of traffic control is to resolve AGV conflicts[9]. In a Multi-AGV scheduling system, conflicts are defined as conflicts on resources, including time resources and space resources. No pair of objects can occupy the same common area at the same time. There are three types of conflicts: opposite conflicts, intersection conflicts, and occupation conflicts. Occupation conflict mainly refers to occupation of roads, occupation of target nodes, and inconsistencies in speed.

The solution to conflict resolution is to develop a series of rules. Common rules are priority rules (tasks or cars), detour rules, and traffic rules for other lanes. With different path planning techniques and task scheduling techniques, the incidence of system conflicts is also different. Therefore, the three key technologies of AGV scheduling are essentially interrelated and mutually reinforcing.

4. Related Implementation of AGV Scheduling

AGV scheduling is a multi-objective comprehensive optimization problem, which requires multiple factors to be considered as a whole and three major sub-problems to be solved cooperatively, so as to achieve the optimal efficiency of AGV system scheduling. In the implementation of AGV scheduling, the common method is the time window prediction method.

4.1. Time Window Based Prediction Method

Multi-AGV path planning and conflict processing generally use time window-based prediction methods[10]. The time window method refers to establishing a time window for resource occupation based on the start time and end time of the space occupied by the AGV. When the time windows of resources occupied by different AGVs do not overlap, it indicates that no collision has occurred. If a

potential collision occurs, adjust the original time window to avoid collision. Multiple cars adjust the time windows in order to avoid collisions in accordance with the priority rules.

The traditional modeling method based on Time Window prediction generally adopts the AGV particle as the modeling mechanism, which refers to the time period from AGV vehicle entering a path to leaving the path, during which the vehicle is given the right to use a certain direction of the path. The Time Window property does not take into account the boundaries of the AGV entity vehicle.

The Time Window modeling method based on the actual physical model of vehicles refers to adding the actual size of AGV vehicles into the time window attribute. In the dynamic Multi-AGV scheduling process, the time window implementation mode can effectively predict the actual position of vehicles and more effectively avoid the collision problem. It is especially suitable for dynamic scheduling of vehicles in narrow space.

4.2. Task Flow Process

The basic process of online Multi-AGV scheduling is generally based on newly arrived tasks, vehicle standby positions, path topology maps, and task priority rules, using a heuristic algorithm to calculate the task allocation table[11]; according to the path topology map, traffic rules, and task allocation The table priority uses the time window method to sequentially calculate the online vehicle routing table. The time calculation uses the traditional TSP method; in special cases, such as updating the online routing table before a conflict occurs.

5. Intelligent Trend of AGV Scheduling Technology

Realizing large-scale AGV cluster scheduling and control based on various advanced intelligent algorithms, and improving the AGVS system's cooperative handling capability are the current directions for the development of AGV scheduling technology. The scheduling algorithm based on modern intelligence technology blending of traditional methods realize optimal assignment of tasks, multi-AGV path planning, and traffic control, so that AGV clusters can coordinate operations, cooperate with each other without interfering with each other, and exert optimal efficiency.

5.1. Neural Network Method

The neural network method[12] detects the environment through sensors and inputs the sensor data into the network to train the self-organizing neural network to improve the cognitive ability of AGV in the environment and pass the AGV's motion information through the network Output. The limitation of the neural network method is that it takes a long time to learn and train and lacks real-time performance.

5.2. Fuzzy Logic Method

The fuzzy logic method[13]blurs the state space of the AGV. The mapping relationship between the sensor input state space and the AGV action space is represented by constructing a fuzzy rule base. AGV path planning without environment model usually adopts this method to promote the development of free path AGV . The fuzzy logic method has a certain real-time nature. This method overcomes the problem of local optimization.

5.3. Reinforcement Learning Methods

As an important one of machine learning methods, reinforcement learning methods are applicable to the fields of process control, task scheduling, robotics, etc., and find the optimal strategy through the interaction between the agent and the environment. Millan proposed a connectionist reinforcement learning method[14], which is a learning method from environmental state to behavior mapping. Its advantage is that it can learn online through trial and error and environmental interaction to obtain environmental information, thereby optimizing the robot's behavior strategy, which is completely different from supervised learning methods such as neural networks. Research shows that reinforcement learning methods can effectively make up for the shortcomings of previous methods, and can improve the adaptability and self-learning ability of mobile robots, and thus perform better in a location environment.

Learning from environmental states to behavioral mapping requires that behaviors obtain the greatest cumulative return from the environment. If the environment is Markov, reinforcement learning problems can be modeled using Markov decision processes. According to whether an accurate environment model is required in the learning process, it can be divided into a model-based method and a model-independent method. The model-based approach requires accurate state transition probabilities to evaluate the current state. In reinforcement learning problems, environmental models are often unknown, so the applicability of model-based methods is limited. According to the time when the agent updates knowledge in an unknown environment, the model-independent methods are divided into time difference (TD) method and Monte Carlo (MC) method. The MC method does not update knowledge until the end of the event. If the event is too long, the update delay is large; the TD method is to update the currently acquired knowledge immediately after completing a time step, and to solve the problem of time reliability allocation by iteration[15]. This rapid update method makes the TD method and its improvements widely used in reinforcement learning. The TD method can be divided into on-policy and off-policy according to whether the same strategy is followed in value prediction and behavior selection. They correspond to Q-learning and sarsa (state actionreward state action) algorithms, respectively. Q-learning and off-policy make learning data more diverse.

6. Summary

Automatic guided vehicle systems (AGVs) are complex systems that integrate software and hardware. It is a combination of computer technology, automatic control technology, management technology, manufacturing technology, and artificial intelligence technology. With the deepening of research in the field of artificial intelligence, there will be more and more advanced artificial intelligence technologies applied to AGV. This paper describes three key technologies and related scheduling methods of AGV scheduling, and introduces three major artificial intelligence methods: neural network method, fuzzy logic method, and reinforcement learning method. It is foreseeable that in the future, artificial intelligence technology will be more integrated into AGV dispatching, enabling AGV to collaborative operation more accurately and efficiently in path planning, task allocation, and traffic management and control.

7. References

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