Research on Collision Avoidance Strategy of AGV

Jian Rong

Abstract:
In order to avoid the phenomenon of collision between automatic guidance in unidirectional guidance route network, an automatic guided vehicle system based on one-way guidance path network is proposed to avoid the problem of automatic navigation touch strategy.

Keywords: automatic guided vehicle system, collision avoidance, one-way guidance path

Introduction
The automatic guided vehicle system composed of multiple automatic guided vehicles (shorted name by AGV) is widely used in logistics automation of many industries. In the AGV control process, need to solve the task scheduling, path planning and collision avoidance and other issues. Thus, the AGV collision avoidance problem is a difficult problem in AGV research field; in order to solve this problem, we may adopt a method that is based on a unidirectional pilot path network (shorted name by UGN). It is unlike the BGN, in the UGN, the AGV has the same direction of operation on each path segment, and it thus facilitating the implementation of decentralized path planning (AGV autonomous path planning), reducing the burden of AGV central system, improving system integration and scalability[1], therefore, and this paper is based on UGN AGV as the research object. Because of all AGVs share the same boot path, so the mutual interference between AGV is inevitable, in order to avoid collisions, we adopt two methods:

Jian Rong, Hangzhou Cigarette Factory of China Tobacco Zhejiang Industrial Co., Ltd. Zhejiang Hangzhou 310024 China
1. Centralized collision avoidance for planning method

Domestic use of such methods to solve AGV collision avoidance problems, however, because AGV is a discrete event dynamic system, once a AGV delay occurs, cannot be planned in accordance with the time window of the established path, it may affect that other AGV has been planning a good path, we need to dynamically adjust the AGVs order[2].

2. Combining the decentralized path and centralized traffic management

In UGN, the path planning can adopt the classical optimal path algorithm, this paper only considers the traffic management method. In generally, traditional traffic management methods divide the path-network into a series of non-overlapping regions based on regional control, for avoiding collision between AGV, each area allows only one AGV to run at any time. However, this condition is too harsh, may reduce the system operating efficiency[3]. This paper based on the UGN characteristic, to proposed a avoid collision method, each path segment can accommodate multiple AGVs at its capacity, this paper established the running state model based on directed graph of AGV, based on this model, we propose a loop search method.

1 Description of AGV collision avoidance problem based on UGN

The AGV based on UGN consists of UGN and several AGVs, \( N_G \) is the number of AGVs in the system, UGN can be described with the weighted graph \((G(V,E,D))\), thereinto, \( V = \{v_i \in N \text{ and } s \leq i \leq N \} \) represents the set of nodes, the nodes consist of path intersections and loading and unloading points, \( N_v \) is the number of nodes in the path network, \( E = \{e_{ij} | v_i = (v, v_j), v, v_j \in V \text{ and } v_i \neq v_j \} \), \( N_E \) is the number of path segments, \( v_i \) is called the starting point of \( e_{ij} \)-edge, \( v_j \) is called the end point of \( e_{ij} \)-edge, \( D = \{d_{ij} | e_{ij} \in E \} \) expresses the right collection, \( d_{ij} \) expresses the length of \( e_{ij} \)-edge. The AGV layout based on UGN is shown in Figure 1, the direction on the path segment indicates the direction in which the AGV is permitted on the current path segment, the number on the path-segment indicates the length. In the UGN, the common collisions are shown in Figure 2 that it may cause collisions between AGVs. In Figure 2a, when an AGV is running at the target station, another AGV is parked on its path (such as the AGV is idling or unloading), in Figure 2b, two AGVs are traveling at the same intersection, in Figure 2c, since 1#AGV is about to enter the path segment without the remaining capacity, so it will take a long time to tie up the intersection, it bring on 4#AGV is blocked in a long time, it reduces the operating efficiency of the system.
In the actual conditions, each AGV is installed in front of the collision avoidance sensor, when the AGV on running detects an obstruction in front, it will decelerate immediately until it stops, and this approach avoids collision of two conflicting AGVs as shown in Figure 2a. However, the sensor's lateral obstruction to the AGV is often undetectable and cannot guarantee that other types of collisions AGV does not collide, so we must design the corresponding collision avoidance strategy, but no matter what kind of collision avoidance strategy, there will be an AGV blocked by another AGV and it temporarily unable to move the situation. For simplify the model, the system assumed to be as follows:

(1) Once AGV receives the handling task, it immediately plan a shortest path from the docking position to the task station, and once AGV start running, it will not replace the path autonomously.

(2) Assume that the idle AGV’s docking position does not affect other AGV runs. In the UGN, each AGV adopts adopt autonomous path panning method based on global static map, as long as the optimization target (the shortest, the shortest time or through the intersection of the least, etc) unchanged, AGV can only obtain an optimal path by Dijkstra algorithm, therefore, it is assumed that the first assume is generally established in UGN. For example, we set up specifically for the storage of idle AGV in the path network, so we do not need to consider the impact of idle AGV in traffic management.
2 The control method of collision avoidance

Figure 2 shows the corresponding collision avoidance strategy. Figure 2a shows the conflict can be autonomously resolved by AGV, without traffic management to coordinate. Other types of conflict coordination strategies are as follows:

The Figure 2b shows the two AGVs competing for the same intersection. To avoid collisions between two cars, we define a lock for each intersection. We set a lock point at all entries at the intersection, when the AGV entered the intersection, the AGV would stop at the locking point at first, and then AGV applies to enter the intersection for high-level traffic management unit. If the traffic management unit queries that the intersection is not locked, it is allowed to enter and lock the intersection. AGV immediately went into the intersection until it received the access signal, and when it has get across the intersection, it would unlock this junction. Therefore, all export locations need to set an unlock point at the intersection, as shown Figure 3. If the AGV does not have access to the signal, then it will stay at the lock point and will delay after a period of time to reapply. In order to avoid the conflict as shown in Figure 2c, when the AGV enters the intersection, we may to check that the system whether if any remaining capacity of incoming path segment in addition to detect. The remaining capacity of the path segment (e_ij):

\[ R(e_{ij}) = C(e_{ij}) - I(e_{ij}) = \text{Round}(\frac{d_{ij}}{L_{AGV} + F}) - I(e_{ij}) \]  

(eq.1)

In this formula, \( C(e_{ij}) \) is the maximum numbers of AGV on the path-segment of \( e_{ij} \), \( I(e_{ij}) \) is the minimum, \( \text{Round()} \) is a round-down function, \( d_{ij} \) is the length of \( e_{ij} \), \( L_{AGV} \) is the length of AGV, \( F \) is minimum and safe distance between AGV. When the remaining capacity of \( e_{ij} \) by AGV is zero, it shall be temporarily forbidden to enter the intersection, to avoid the intersection is occupied on long time.

As shown in Figure 2d, due to industrial field space constraints, the two-lead mark line is closed, resulting in 2# AGV turn will interfere with the operation of 1# AGV, to avoid collisions, you can think of it as a virtual intersection (as shown Figure 4), to ensure that when an AGV in the turn, the other section of the interference position without AGV, although AGV may have other types of conflicts in special circumstances, it can be solved by adding virtual intersections.
3 Simulation Experiment and Analysis

3.1 Experimental method

In order to verify the effect of collision avoidance method, we carry out the following simulation experiments. Assume that a UGN-based AGV layout is shown in Fig.1, assuming the length of AGV is 1.5 meter, the safety distance is 0.5 meter, run speed is 1 meter, acceleration is 0.5 m/s, do not consider loading and unloading time. It can be seen from the calculation that the smallest loop in the layout can accommodate eight AGVs, in order to ensure that AGV will not appear to collide, assuming sever AGVs running at the same time. AGV and the guide path are represented by Transporter and Track objects, the station and the lock position are added by adding the sensor object to the track object, AGV involved in a variety of control algorithms can be prepared in the Method object SimTalk program implementation, compare two methods of collision avoidance:

1) The collision avoidance method in this paper

Add a virtual intersection after each loading and unloading site, and set up a reduction and subtraction point for each intersection. The simulation interface is shown in Fig.5.

2) Traditional regional control method

In the area control method, each zone can only accommodate one AGV at any time, however, the regional control method is more flexible in the division of the region. In the UGN, each path-segment can accommodate multiple AGVs\(^4\). Therefore, it is necessary to accommodate the number of AGVs per path-segment, and multiple partitions on each path-segment, with a total of 24

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Figure 3. Lock and unlock the location settings. Figure 4. Virtual intersection.

Figure 5. Experimental interface of the method proposed in this paper.
partitions. Each exit location of the partition is set to a temporary stop, when the AGV needs to enter other partitions, at first, in the temporary stop braking, and then apply to the AGV traffic management unit into the next partition, and access to traffic management unit allows, then it access to the next partition, the simulation interface shown in Figure 6. Simulation time is 48h, the two methods in the 24h ~ 48h between the simulation data shown in Tab.1. The meanings of the parameters in the table are as follows: ① the average number of interactions refers to the number of times and AGV averages a request to send an access request to the AGV traffic management unit for each carrying task. ② The average number of task interactions refers to the average execution time of the task.

![Figure 6. Experimental interface of traditional regional control.](image)

3.2 Experimental data analysis

Traditional zone controls methods need to set multiple partitions on the same path-segment, AGV is paused at the exit location of each partition and interacts with the AGV traffic management unit, and interact with the AGV traffic management unit. As shown in Tab.1, compared with the method proposed in this paper, the average number of times of regional control law doubles, thus increasing the system traffic, is not conducive to the implementation of large-scale AGV, and the temporary docking of the AGV at each outlet location also increases the execution time of the handling task. In this paper, the method of collision avoidance is only necessary to set the lock point in the necessary position, so the average number of tasks and the execution time of task are less than the traditional regional control method. Although the regional control can reduce the number of stops by reducing the number of stops and the number of interactions, each area can only accommodate one AGV.

4 Concluding remarks

This paper presents a traffic management method for AGV based on UGN, aiming at the several conflicts that may occur during the operation of AGV, the corresponding collision avoidance strategy is put forward. Simulation results show that compared with the traditional regional control method, the collision avoidance strategy proposed in this paper is more suitable for UGN.
The traffic management method mentioned in this paper is only applicable to AGV based on UGN, however, in some practical applications, if the path-segment is set to unidirectional path-segment, it cannot guarantee the strong connection of the path network due to the limitation of the site. Therefore, a single bidirectional hybrid navigation path network has appeared, this paper presents a traffic management method for AGV based on UGN.

References