An Omnidirectional AGV Path and Attitude Integrated Planning Method

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Abstract

With the continuous development of advanced production technology, Auto Guided Vehicle (AGV) is regarded as an important part of advanced industrial production line, and the types of AGV are increasing. However,the traditional differential steering AGV cannot achieve more flexible movement and turning in narrow warehouse space, so this paper selects omnidirectional AGV as the research object.The omnidirectional AGV is free to change the attitude of the vehicle according to the demand, this brings a lot of convenience in the process of use. However, due to vehicle attitude restrictions in some stations or routes during the vehicle driving, the vehicle is only allowed to pass in a certain attitude. For example, the narrow passage only allows the vehicle to pass parallel to the route on the narrowest side of the vehicle, which brings a lot of inconvenience to the omnidirectional AGV driving.In view of the above problems,this paper proposes a comprehensive planning method for omnidirectional AGV path and attitude, which can plan the attitude adjustment stations of AGVs in the driving process according to the limitation of the AGV's attitude at the station or route in the path planning, so as to help the AGV adjust its attitude and reach the target location smoothly.

Keywords

AGV; Route Planning; Posture control

1 Introduction

In recent years, with the development and progress of intelligent technology, Automated Guided Vehicle (AGV) [1], as a transport tool, has become the main intelligent material transport tool in modern production system and is one of the important means to realize intelligent warehouse [2].

Many AGVs have come into being, but most of these AGVs are differential steering type [3-4], which cannot achieve more flexible movement and turning in narrow warehouses, so AGVs with omnidirectional motion function have become a hot spot in current shop floor logistics research [5].

Conventional differential steering type AGV, when transporting goods, generally choose to make the AGV to move near the storage rack first, lift the lifting mechanism to the specified height, and then, the AGV makes the goods move towards the storage rack through the feed mechanism until they reach the upper part of the storage rack, and finally the lifting mechanism drops to make the goods move in place. However, this method may be risky when transporting heavy products, as the center of gravity of the goods will deviate with the movement of the feeding mechanism, and when the projection of the center of gravity on the plane exceeds the support surface, it will produce the danger of overturning and cause serious safety accidents. Therefore, the safer method of delivery is to use an omnidirectional AGV, which first lifts the goods to a specified height, then causes the AGV to move to the bottom of the shelf and lower the lifting platform, so that the goods stay safely in the shelf position. This method can avoid the risk of overturning due to the change of the position of the center of gravity of the goods in the horizontal direction.

Although omnidirectional AGV brought many convenience in the process of use, it can freely change the body attitude according to demand, but due to the AGV in the process of driving part of the

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station or route have body posture limit, such as the AGV between two shelves, which is a narrow channel, only allows the AGV to the narrowest side of the body parallel to the road through, and when the AGV needs to place the goods into the storage rack below, due to the narrow space does not support the AGV steering, only through the side of the way to enter, which brings a lot of inconvenience for the omnidirectional AGV driving.

Although many scholars have done mature research on path planning of AGVs, few of them have taken into account the constraints of the AGV on the body posture at stations and road sections in the driving process. Therefore, this method proposes an omnidirectional AGV path and posture integrated planning method, which can plan the posture adjustment nodes of the AGV during the driving process according to the restrictions of the AGV on the body posture at the stations or road sections in the path planning process, so as to help the AGV adjust its posture and reach the end point smoothly.

2 Method

2.1 Algorithm Process

In this paper, the depth-first search algorithm is first used to search the topology map, and all the paths from the starting site to the target site are obtained which are sorted according to the driving distance. Subsequently, according to the current planning path, in the case of the vehicle attitude restriction at the passing route, based on the greedy strategy, assuming how far the omnidirectional AGV can travel at the farthest without changing the heading angle. The intersection of the permitted heading angles of passing stations is calculated until the intersection is an empty set, which means that AGV can only travel to this station at the farthest without changing the heading Angle,Then the previous stations are traversed in reverse, and the first station that allows AGV spin is selected as the body attitude adjustment station.Take this site as the new starting point and repeat the process until you reach the destination. In this way, all vehicle attitude adjustment stations in the planned path can be calculated.Finally, the planned path is segmented according to these stations, and the set of heading angles allowed for each section of path is calculated, and the most appropriate heading Angle is selected and sent to AGV.

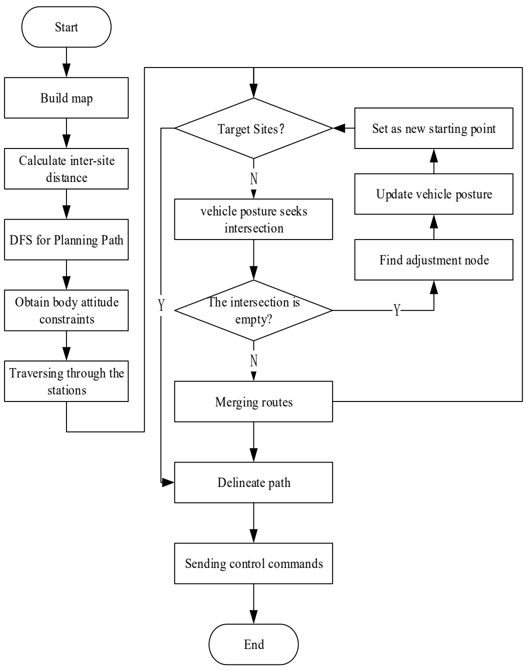

Figure 1 Method flow chart

2.2 Map Environment Modeling

Topological map method is used to construct indoor map model. The topological map method is to represent some important areas of the environment by a node, and the nodes are connected by line segments to represent paths [6]. As shown in Figure 2, Figure 2 is a schematic of a warehouse for a particular type of product, which has a heavy mass and a long length. The map model contains two main aspects, which are site information and route information. The sites are generally classified based on road bifurcations or turning points and the starting and ending points of road sections where road conditions change.

In addition to the location of the site in the map, since omnidirectional AGV is used in this paper, the site information also needs to represent which sites allow cart spins and which sites have restrictions on the inbound attitude of the AGV. Take site 10 in the figure1 as an example, the site is located between two shelves, the space is narrow, and the delivery length is long, so the AGV is not allowed to spin at this site; then take site 9 as an example, because the AGV can not spin at site 10, so it can only be allowed to move sideways from site 10 into site 9.

Road information needs to divide all the accessible roads into several basic sections, which are used to describe the starting and ending stops of the road, the attitude restriction of the vehicle body passing through the road, and the narrow condition of the road. Take section 18-10 as an example, because this section is located between two shelves, the space is narrow, so the AGV can only be allowed to pass parallel to the road with the narrowest side of the body.

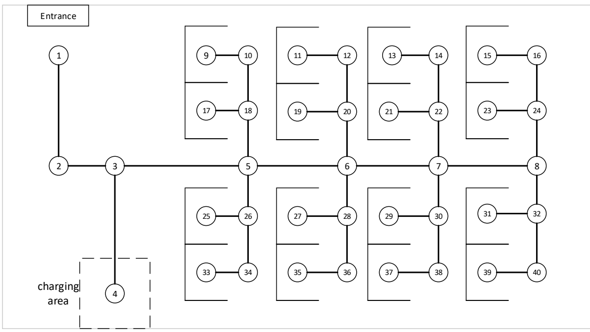

Figure 2 Warehouse Diagram

2.3 Route Planning

In this paper, we use depth-first search algorithm to perform path planning under the body pose constraint of each road segment. Since this paper uses the topological map method to construct the map model, the stations in the topological map can be regarded as the vertices of the graph in graph theory, and the connecting lines between the stations, which are also the routes, can be regarded as the edges in the graph, and the depth-first search algorithm, as one of the commonly used algorithms in graph theory [7], can find out the path between two nodes that meets the requirements, and then calculate the sum of the distances of the edges that make up the path, which can obtain each path's distance, which meets the need of this method. The body attitude constraint described in this method generally refers to the body direction allowed for the cart to pass a certain section.

To calculate the distance matrix, if there are n stations in the map, then define an $n \cdot n$ two-dimensional matrix e in advance. $e[i, j]$ denotes the distance between station i and station j. If station i to station j can be reached directly without going through any other station, then $e[i, j]$ is equal to the value of the distance between station to station, and if station i to station j cannot be reached directly or i is equal to j then $e[i, j]$ can be equal to a extremely large fixed value.

Input the starting station and target station. From the starting station, iterate through the unvisited station along the planning path.Before visiting, first determine whether the current station allows the adjustment of the vehicle attitude, if the current station allows the adjustment of the vehicle attitude means that regardless of the previous vehicle attitude, the car can be adjusted at the current station , so that the car can arrive from the current station to the station to be visited; if the vehicle attitude can not be adjusted, the set of vehicle attitude allowed by the previous section and the set of vehicle attitude of the section to be visited to find the intersection, if the intersection is empty, the car can not arrive, give up the station , if the intersection is not empty, the car can arrive, visit the station .When there is no unvisited station , it goes back to the previous station and continues to try to visit other stations until all stations have been visited.During the access, if the target station is visited, all nodes passed are recorded and stored in the backup path, and the sum of all distances is recorded.After the access, the path with the shortest distance is selected as the current path, and the remaining paths are stored in the backup queue in order according to the distance, and the paths are switched from the backup queue in order when the current path is unreachable.

2.4 Calculate Attitude Adjustment Nodes

First make a hypothesis about the farthest the car can travel from the starting point without changing its vehicle posture.Suppose the planning path is a-b-c-d-e-f , then derive from station a.With 2.2 it is possible to obtain the set P_{end} of vehicle attitudes that allow the vehicle to pass each basic section (end indicates the identification of the end station of that basic section).The set P_b of vehicle postures of route segment a-b is intersected with the set P_c of vehicle postures of route segment b-c. The result is S . If S is non-empty, then it means that the car can drive from station a to station c without changing its vehicle posture.At this point, and then the intersection of S and the set P_d of route segment c-d , if the result is empty, it means that the vehicle from station a to station d need to change the vehicle attitude at least 1 time, if station d allows the vehicle to adjust the vehicle attitude, then allow the vehicle to adjust the vehicle attitude of the station can be at station d , If vehicle attitude adjustment is not allowed, then each station from station d to station a needs to be traversed in reverse, where the first station that allows vehicle attitude adjustment is the cart at the current adjustment station.Then this adjust vehicle attitude station is considered as the current new starting point and repeat the above process until all stations are traversed to get all vehicle attitude adjustment stations, if all stations are not adjustable vehicle attitude, it means the path is not reachable, jump out of section 2.4 and switch the path from the backup queue in section 2.3.

The vehicle pose set described in this method, as shown in Figure 2, is set to v in the actual direction corresponding to the top of the map, assuming that the car needs to drive from station 2 to station 1 at this time, which is a road in the map from the bottom up, assuming that this section of the road allows the car to move longitudinally and laterally, then the vehicle pose set allowed in the map for this section of the road is $\{v,u,-v,-u\}$,Where v means allow the front end of the cart to go up in the map, which in this section of the road means going straight ahead, u means allow the front end of the cart to go right in the map, which in this section of the road means moving sideways, $-u$ means allow the front end of the cart to go left in the map, which in this section of the road means moving sideways, and $-v$ means allow the front end of the cart to go down in the map, which in this section of the road means driving in reverse, where $v,u,-v,-u$, instead of requiring the front end of the cart to always maintain that angle, allows the cart to adjust its direction without deviating from the road in that direction.

2.5 Calculated posture

Using each vehicle attitude adjustment station as a segmentation point, the entire path is divided into segments, and each segment of the route is noted as $Road_i$ (i is the serial number of each segment of the route).Each section of the route $Road_i$ in turn consists of a number of basic sections, and the set of vehicle postures allowed in each basic section of $Road_i$ is intersected to obtain the set $Status_i$. $Status_i$ is the set of body attitudes that allow the cart to pass the route, and if the body attitudes allowed by $Road_i$ are not unique, You can choose a body attitude from $Status_i$ that best suits the current direction of travel. If $Status_i$ is empty, it means the current path is not reachable and switch the route, if there is no other route to switch, it means the path is not reachable and the method ends.

3 Experiments and analysis of results

In order to verify the effectiveness of the method proposed in this paper, simulation experiments are conducted under QT/C++ platform to test whether the omnidirectional AGV can adjust its attitude flexibly and reach the end point smoothly under different tasks with the map shown in Figure 2 as an example.

Table 1 lists several types of tasks that need to be performed by omnidirectional AGVs in the warehouse logistics process, with input starting sites and target sites, and gives the planning paths generated according to the method in Section 2.3.

Table1 Omni-directional AGV task list

Task Type	Starting Site	Target Sites	Planning Path
Charging task	1	4	1-2-3-4
Inbound task	1	9	1-2-3-5-18-10-9
Outbound task	9	1	9-10-18-5-3-2-1

When the AGV is performing charging tasks, it is stipulated that the charging interface of the AGV is located at the rear of the vehicle, therefore, in order to facilitate charging, it is stipulated that when the AGV drives into the charging station, i.e. station 4 point, it needs to reverse into the station. The task execution flow is shown in Table 2.

Table2 Charging task flow

step	Starting Site	Target Sites	Heading angle	action
1	1	2	180°	Straight ahead
2	2	3	180°	Move to the right
3	3	3	0°	Rotate 180° clockwise
4	3	4	0°	Reverse the car

When the AGV performs the task of entering the warehouse, because site 10 and site 18 are located between two shelves, the space is narrow, so the vehicle is not allowed to spin, and site 9 is also limited because of the space, the vehicle needs to move sideways to enter. The task execution flow is shown in Table 3.

Table3 Inbound Task Flow

step	Starting Site	Target Sites	Heading angle	action
1	1	2	180°	Straight ahead
2	2	5	180°	Move to the right
3	5	5	0°	Rotate 180° clockwise
4	5	10	0°	Straight ahead
5	10	9	0°	Move to the left

The outbound task flow is shown in Table 4.

Table4 Outbound task flow

step	Starting Site	Target Sites	Heading angle	action
1	9	10	0°	Move to the right
2	10	5	0°	Reverse the car
3	5	2	0°	Move to the left
4	2	1	0°	Straight ahead

According to the experimental results, it can be found that the method proposed in this paper can, on the basis of path planning, plan the body posture adjustment nodes of the car for the body posture restriction conditions that may be encountered in the driving process, so as to avoid the situation that the car cannot pass smoothly due to the body posture restriction in the driving process, and thus help the car adjust its body posture and reach the end point smoothly.

4 Conclusion

This paper proposes a comprehensive planning method for omnidirectional AGV path and attitude, which addresses the problem that the traditional AGV path planning method cannot flexibly adjust the heading angle according to the body attitude restriction of omnidirectional AGVs at passing stations and road sections. This method can plan the vehicle's attitude adjustment node for the body attitude restriction conditions that may be encountered in the driving process, so as to give full play to the advantages of omnidirectional AGVs and avoid the situation that the vehicle cannot pass smoothly due to the body attitude restriction in the driving process, thus helping the vehicle to adjust its attitude and reach the end point smoothly.

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