Path Planning of AGV Based on RFID Localization

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Abstract. In the AGV system, path planning is one of the key problems. In order to improve the efficiency of the task, the paper presents a method of AGV localization and path planning aiming at the existing algorithms. The system structure of the AGV is first designed, including hardware part and software part. The AGV is then localized based on non-contact RFID in real time. The location information, speed information, communication status, video information and other information are sent to the server and monitored remotely. An improved A* algorithm is proposed to achieve real-time path planning of multi-AGV based on the traditional A* algorithm. The simulation proves that the improved A* algorithm performs more efficiently than the traditional A* algorithm, and time-consuming of the improved A* algorithm is reduced dramatically by using the proposed algorithm. Finally, the paper establishes a whole software operation platform of the AGV system, including localization, wireless control and path planning.

Introduction

Recently, automatic stereoscopic warehouse and flexible assembly line have been rapidly developed. Especially, AGV (Automated Guided Vehicle) plays an irreplaceable role between the automatic warehouse and the production workshop, from a station to another station, from a transmission line to another transmission line [1]. It is an autonomous mobile robot, and it is equipped with electromagnetic or optical automatic guiding device. These devices can complete the given various tasks, such as non-contact guidance, driving along the path planned, avoiding obstacles automatically and moving towards target safely [2-3]. RFID is used in AGV to achieve localization of AGV [6]. Compared with the traditional conveyance roller or conveyor belt, AGV transportation route is simple, flexible in structure, takes up less space, and has good mobility and flexibility. Therefore, AGV is widely used in flexible manufacturing system and stereoscopic warehouse. In efficient and reliable automatic production system, the introduction of AGV greatly improves the product quality and efficiency [5-6].

Now, AGV research focuses on the networking of many AGV and the remote wireless scheduling. Some problems need to be solved, such as path planning, localization and intelligent navigation. An autonomous localization method based on panoramic vision sensor is studied in literature [7]. The method can identify the known landmarks of the robot around scenery, and it uses the triangulation method to calculate the coordinates of the robot. The outdoor navigation method of autonomous vehicles or robot is proposed in literature [8], and the method is based on the combination of GPS and visual motion estimation.

Aiming at wireless scheduling problems of AGV, the paper proposes an AGV system, including RFID localization, wireless control and path planning, etc. Furthermore, the paper proposes an improved A* algorithm, and the algorithm improved the efficiency of the whole system.

The System Structure of AGV

The AGV system consists of two parts. There are hardware part and software part. Hardware part includes the overall structure of the AGV and the wireless network, and software part includes the AGV control part and the whole logistics management system. The composition block diagram of the AGVS is shown in Figure 1.
As shown in Figure 2, communication between AGV and AGV is connected with wireless module. There are multi-AGV in the system, an AGV can coordinate with other AGV. AGV communication system is responsible for bidirectional communication between AGV and host computer. Tasks assignment, traffic management, AGV localization, status and load information can be realized by the communication system.

The whole logistics navigation system has the function of path planning and navigation. According to the given start position and end position, an optimal path from the exiting paths can be chosen. AGV can encounter some obstacles and conflict in the process of walking, so the problem on path planning of AGV is not only a simple static planning, but also is a dynamic planning. In order to it can solve the emergency efficiently.\[^9\]
The RFID Localization and Scheduling

RFID technology is used in AGV system; it can provide the information about navigation to overcome the shortage of the visual information. As a reading-writing digital sensors, it can forecast the trajectory of AGV in advance, in order to enhance intelligence of AGV movement. Some RFID are laid out of the range of the AGV route, when AGV passes through the corresponding location, it can transmit the location information of AGV to the back-end server in time.

The working frequency of the RFID reader-writer is 13.56 MHz, and its wavelength is about 22 m. Except from the metal materials, the frequency of wavelength can pass through most materials. It can produce relatively uniform reading-writing area. There are metal objects inevitably in the factory, so anti-metal RFID tag is chosen in this paper. Furthermore the RFID tag is passive and non-contact.

The RFID reader-writer can read multiple tags at the same time, and the rate of data transfer is faster than the RFID reader-writer in low frequency. The distance of reading-writing is within 1m. According to the installation height, the frequency band of RFID reader-writer can be selected. And it conforms to the design requirements of the system.

Information processing flow of RFID is shown in figure 4. Onboard control platform monitors the RFID tag, and it implements read-write operation, once the RFID signal is detected. Read operation refers to reading location and workstation information. Write operation refers the priority, speed and other information of AGV. Finally, all of the information are wirelessly transmitted to server.

Status information of AGV include location, speed, communication and remote operation, etc. And remote operation includes start, reset, stop, calls, etc. These information are all shown on the server efficiently in Figure 5, so that the status of AGV can be remotely monitored.
The Improved A * Algorithm

Path planning can be ultimately boiled down to searching the target path that the total cost is lowest in the specific road network. To find the shortest path, the current popular algorithm, such as Dijkstra algorithm, genetic algorithm, A * algorithm, can solve the problem.

A * algorithm is one of the most efficient algorithms to solve the shortest path in static network. Compared with the traditional shortest path algorithm, the key to A * algorithm is its evaluation function, it is shown in formula (1).

\[ f(n) = g(n) + h(n) \]  

where
\( f(n) \) -- The evaluation function from the initial point through the point n to the target point;
\( g(n) \) -- The actual cost in the state space from the initial point to the point n;
\( h(n) \) -- The estimated cost of optimal path from point n to the target point.

Therefore, designing a reasonable evaluation function is the key to using the A * algorithm. And the more reasonable evaluation function is, the more efficiently the algorithm processes.

Generally, \( h(n) \) of the traditional A * algorithm is shown in formula (2).

\[ h_{\text{traditional}}(n) = D(n, i) \]  

\( D(n, i) \) -- Manhattan distance from point n to the target point i.

In this paper, the evaluation function is mainly focused on the direction and distance. But the unit of the direction and distance are different, and the weight of the function is difficult to distinguish. So it needs normalized processing. Specific functions is described in formula (3).

\[ h(n) = a \times D + b \times W \]  

where
\( h(n) \)-- The estimated cost of optimal path from point n to the target point.
\( D \) -- Manhattan distance from point n to the target point;
\( W \)-- The angle between a segment and the other segment, the first segment is from the starting point to point n, the second segment is from point n to the target point;
a-- The weighted value of distance, the unit is meter;
b-- The weighted value of angle, the unit is radian.

When \( D \gg w \), the unit is not uniform affects the planning result, and the influence is obvious.
Especially in a wide range of path planning, the direction is no longer binding, so that the evaluation function is unreliable.

First, it needs to compute distance and angle from point \( n \) to all associated points with point \( n \), and compute the average. The formulas are shown as follows:

\[
\bar{D} = \frac{1}{m} \sum_{n=1}^{m} D_n \tag{4}
\]

\[
\bar{W} = \frac{1}{m} \sum_{n=1}^{m} W_n \tag{5}
\]

where

\( m \) -- The total number of associated points with point \( n \).

Finally, the corresponding distance and angle are normalized, the improved evaluation function is shown in formula (6).

\[
h_{\text{improved}}(n) = a \left( \frac{D}{\bar{D}} \right) + b \left( \frac{W}{\bar{W}} \right) \tag{6}
\]

After normalized processing, it only considers the impact of the distance and angle on path planning. Regardless of the size of the distance and angle, it can avoid the problem that the unit of distance and angle are not unified. The improved \( A^* \) algorithm effectively avoids repeatedly searching for some points, greatly reduces the search space and improves the efficiency of the algorithm.

Simulation

Efficiency of Algorithm

Efficiency is the most important evaluation index in path planning, mainly includes computation time and quality. For the quality of path planning, finding the shortest distance path is the key. It can be realized by all of the popular path planning algorithms, but the differences among the more computation time.

The basic hardware conditions in the paper are CPU: dual core 1.6 GHz, Memory: 2G. Considering the precision of the algorithm, a high precision timer is used. It is different from the general timer. Timing accuracy of the high precision timer can reach microsecond.

![The algorithm simulation.](image)

The map used in the test is a topological map. The starting point is point 1, and the target point is point 15. The dashed lines represent the planned path with algorithm, the solid lines represent searched points by using the algorithm. The shortest path simulations with improved \( A^* \) algorithm and \( A^* \) algorithm are respectively shown as Figure 6. As can be seen from the roadmaps, searching paths of improved \( A^* \) algorithm and \( A^* \) algorithm are same, but the number of searching points with improved \( A^* \) algorithm is less than that with \( A^* \) algorithm.

Path planning abilities of different algorithm are compared with the average consuming time that...
AGV spends on the shortest path, and the average consuming time is represented with the average of 100 times. As shown in the Table 1, the searching speed of improved A* algorithm is faster than the A* algorithm.

Table 1. Consuming time contrast with two algorithms (ms).

<table>
<thead>
<tr>
<th></th>
<th>Improved A*</th>
<th>A*</th>
</tr>
</thead>
<tbody>
<tr>
<td>The average of the front 50 times</td>
<td>24.781</td>
<td>307.220</td>
</tr>
<tr>
<td>The average of the latter 50 times</td>
<td>25.822</td>
<td>303.978</td>
</tr>
<tr>
<td>The average of 100 times</td>
<td>25.302</td>
<td>305.599</td>
</tr>
</tbody>
</table>

Software

Floor plan of Logistics plant can be drawn by CAD or drawing board. The imported electronic map data mainly includes information of each point, weights, coordinates, etc. All data will be imported into the database so that it can facilitate AGV scheduling. As long as selecting the starting point and end point on the background server, it can automatically calculate the shortest path and realize the dynamic path planning of AGV.

Conclusion

An AGV system based on RFID localization is proposed in this paper, and it mainly combines RFID technology, path planning, wireless communication, etc. According to simulations, monitoring software on the background can successfully monitor AGV position, realize path planning dynamically, etc. Compared with previous algorithm, the improved A* algorithm can effectively improve the speed of planning on the map with larger area. Although the speed is improved, the amount of data storage is still large. Therefore, it needs to further study how to reduce the amount of storage with high computation speed in future work.

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References

