Research of Intelligent Dynamic Dispathcing System of High Speed and High Precision AGV

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Abstract: In order to improve the working efficiency of high speed and high precision AGV, the method of path planning in dispatching system is studied, and an improved Astar algorithm is proposed, which can reduce the number of inflection points needed in path planning. The weight ratio of AGV going straight and turning is raised. The improved algorithm is applied to AGV path planning, which improves the efficiency of the algorithm. Experimental results show that the efficiency of this algorithm is higher than that of traditional Astar algorithm in the application of specific enterprise projects.

1 INTRODUCTION

As a kind of automation equipment, AGV is currently used in such process steps as material transfer and parcel sorting in the workshop. During the shopping festival, manual sorting cannot meet the processing needs of a large number of orders, and it is necessary to replace the manual with automatic equipment [1]. Shi Jian Feng and Yang Yong Sheng et al. (Shi Jianfeng, Yang Yongsheng, 2016) proposed an improved Dijkstra algorithm which added parameters such as turning cost, energy consumption cost, path patency and so on, reducing the number of turns in path planning and improving the effectiveness. Cao You Hui, Wang Liang Xi et al. (Cao Youhui, Wang Liangxi, 2009) have made the orientation of the target point dynamic, made the combined force of gravitational repulsion is not equal to zero, and avoided the defect that traditional artificial potential field method is easy to fall into the local minimum, and the good path planning of AGV is realized. Wang Ding et al. (Wang Ding, 2008) used Astar algorithm to carry out the path planning of AGV and modularized the scheduling system, which reduced the cost of software maintenance.

The research on scheduling strategy of AGV mainly includes task assignment and path planning (Lu Xinhua, Zhang Guilin, 2003; Huang Yuqing, LIANG Liang, 2006; Huang Jiansheng, 2008). At present, the research on path planning at home and abroad mainly use algorithms such as Astar algorithm, artificial potential field method, Dijkstra algorithm (Ammar A, Bennaceur H, Chaari I, et al, 2016).

Most of the research focuses on the theoretical innovation and the improvement of the algorithm structure, whereas does not consider the actual AGV projects. The project R&D, maintenance cost and the R&D cycle are supposed to be considered for AGV in the actual project research. Therefore, based on the existing research of AGV, future research on AGV are suggested to combine with specific projects, to be tested in practical applications, and to be examined regarding the efficiency as the ultimate goal. In this paper, an AGV path planning method based on the improved Astar algorithm is proposed. Combined with specific projects, the turning cost of AGV is added to the evaluation function, and the artificial potential field method is used to effectively reduce the number of turns, from which the efficiency of AGV in actual (Yang Lianchang, 2012).

2 MODEL ESTABLISHMENT

2.1 Map Construction

Figure 1 shows the actual workshop map of a project. According to the actual project task book, the size of the material in the drawing is 1100*1100

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(mm), and the size of each sorting line is 5600*742 (mm). Each shipping port can accommodate no more than 6 skips, the size of the delivery port area is 3300*3300 (mm).

Figure 1. Layout of workshop.

The project is a typical medical material distribution logistics system. The layout plan is shown in Figure 2, and the map is rasterized to facilitate the task assignment and the path to the AGV. Planning.

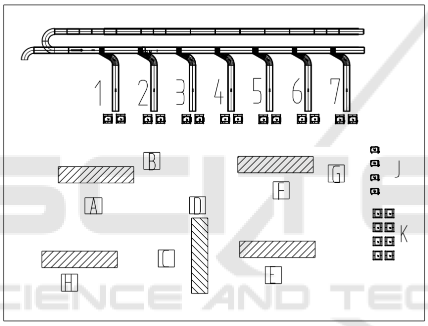


Figure 2. CAD layout of workshop

In this figure, 1~7 are sorting lines. Each sorting line corresponds to two picking points, A~H is the delivery point. K is the empty storage area. J is the charging pile and AGV waiting area. It makes full use of idle time for charging and improve efficiency. In this project, the work task of each AGV is to transport the parcels of every sorting line from 1 to 7 to the designated position A~H. The task assignment and path planning of the AGV are handled by the on-site central dispatch system.

2.2 AGV Status Description

(1) As shown in the figure, the AGV comes with a jacking device, therefore it can be transported from the four directions of the skip to the bottom of the skip. AGV's movement will not be affected because of its own universal wheels.

(2) Each time the AGV starts working in a point-to-point state, the same car is not allowed to be sent to different delivery points. The delivery port can temporarily store the skip truck. If a temporary storage area of a delivery port was full, no new task would be sent to the delivery port.

(3) After the AGV delivery is completed, the empty car leaves. Each delivery port sends an empty vehicle recovery task request after the delivery is completed. If it was less than two picking line picking trucks, AGV would give priority to the empty picking line to the picking line; otherwise, the AGV would send the empty picking cart to the staging area.

(4) Task assignment is divided into two ways. 1. After the skip is full, the transport request is sent. After the dispatch system acquires the mission information, it assigns the corresponding AGV to execute. 2. The caller manually calls to avoid the cargo accumulation.

(5) If the number of empty pick-up trucks in a sorting line was less than two, the dispatching system would automatically deliver the empty-car transport task.

(6) Set the charging post in the AGV waiting area. If there was no task at a certain moment, the AGV would automatically return to the waiting area for charging. At any time during the waiting process, only the voltage was not lower than the protection voltage, and new tasks could be accepted.

(7) If the AGV voltage was lower than the protection voltage, the charging task was automatically executed after completing its own task, and the AGV does not perform other tasks during this process.

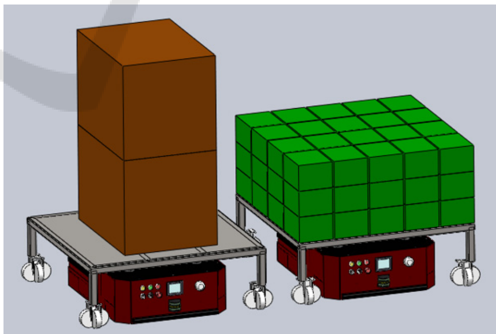


Figure 3. Schematic diagram of AGV transport skip.

2.3 AGV Mathematical Model

As shown in figure 4, the travel speed of the AGV can be expressed as:

$$V_C = \frac{1}{2}(V_L + V_R) \tag{1}$$

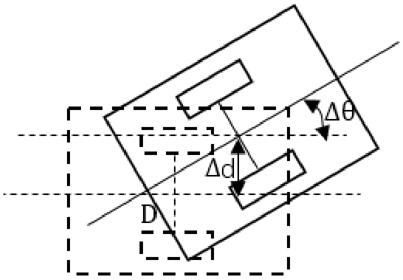


Figure 4. Model diagram of AGV.

The yaw angle $\Delta\theta$ can be expressed as:

$$\Delta\theta \approx tan\,\Delta\theta = \frac{(V_R - V_L)\cdot\Delta t}{D} \quad (2)$$

The lateral offset distance Δd is:

$$\begin{aligned}\Delta d &= V_C \cdot \Delta t \cdot sin\,\Delta\theta \\ &= \tfrac{1}{2}(V_L + V_R)\cdot \Delta t \cdot sin\,\Delta\theta \end{aligned} \quad (3)$$

Among them, the interval time between the two gestures is Δt. The left drive wheel velocity is V_L, The right drive wheel velocity is V_R, The centre velocity is V_C, and the drive wheel pitch is D.

Differentiate via time, get:

$$d\Delta\theta = \frac{1}{D}(V_R - V_L)dt \quad (4)$$

$$d\Delta d = \frac{1}{2}(V_L + V_R)\ sin\,\Delta\theta\, dt \quad (5)$$

To integrate by t can get the equation of motion of the AGV during driving:

$$\theta = \frac{1}{D}(V_R - V_L)t \quad (6)$$

$$d = \frac{1}{2}(V_L + V_R)\,sin\,\Delta\theta \cdot t \quad (7)$$

Finally, the Laplace transform is performed on the time:

$$\theta(S) = \frac{1}{DS}(V_R - V_L) \quad (8)$$

$$d(S) = \frac{1}{2S}(V_L + V_R)\ sin\,\theta \quad (9)$$

2.4 System Mathematical Model

Suppose that m tasks are performed by n AGVs in a certain period of time, the time taken for each AGV to complete its task is $t_i(i = 1 \dots n)$. In order to make the task assignment more uniform and the system more efficient, $t_{max} = \{t_i\}$ must be the smallest.

The number of AGVs is N, the total number of tasks is M (s). The number of sorting lines is c (strips). The number of delivery ports is b (several). Each delivery port temporary storage area can be stocked by e (s). The AGV rated load is W (kg). The actual load of task i is w_i(kg). The time of AGV from the sorting line to the delivery port in task i is t_i(s).

At the same time, the decision variable is defined as x_{ijk}: When the AGV k executing the task i after the task j, the value is 1, otherwise it is 0; y_{ik}: When the task i is executed by the AGV k, the value is 1, otherwise it is 0. According to the project description, a mathematical model of the multi-AGV scheduling system is established as:

$$min\,t_k = min\sum_{i=0}^{m}\sum_{j=0}^{m} x_{ijk}\left(t_{ij} + t_i\right)$$
$$k \in (1, 2, \cdots n) \quad (10)$$

$s.t.$

$$w_i \leq W, i \in (1, 2, \cdots n) \quad (11)$$

$$\sum_{k=1}^{n} y_{ik} = \begin{cases} n, & i = 0 \\ 1, & i = 1,2,,,m \end{cases} \quad (12)$$

$$\sum_{i=0}^{m} x_{ijk} = y_{ik}, j \in (0,1,,,m), k \in (0,1,,,n) \quad (13)$$

The constraint conditions combine the mission status and travel of the AGV: 1. The AGV load must not exceed the rated load; 2. A task can only be executed by one AGV; 3. The AGV performs only one task before performing the current task.

3 IMPROVED ASTAR ALGORITHM

3.1 Artificial Potential Field Method

The artificial potential field method can predict obstacles in advance. It is assumed that the obstacle generates a repulsive force to the moving object, and the target point generates gravity to the moving object in the artificial potential field method, thereby it will avoid the situation that the AGV hits the obstacle and then turns to effectively reduce the number of inflection point.

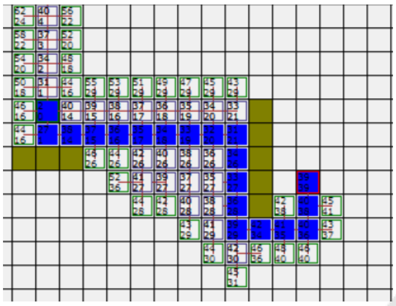
In order to combine the Astar algorithm, this paper makes the following changes:

(1) Only the repulsive field is retained, and the heuristic function h(n) in Astar replaces the role of the gravitational field.

(2) By classifying the repulsion and the extended, only the direction in which the nodes are extended is opposite to the repulsion is reserved.

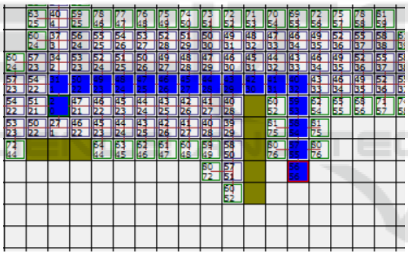
Table 1. Comparison between traditional algorithm and improved with the artificial potential field method.

Case 1



Walking path length: 18 nodes
Turning times: 4

Case 2



Walking path length: 16 nodes
Turning times: 2

Case 1 is the path planning of the traditional Astar algorithm, and case 2 is the path obtained by adding the artificial potential field method. It can be seen that the traditional Astar may increase the number of inflection points toward the obstacle movement, and if the obstacle can be bypassed at the start, the inflection points' number is reduced.

3.2 The Turn Cost

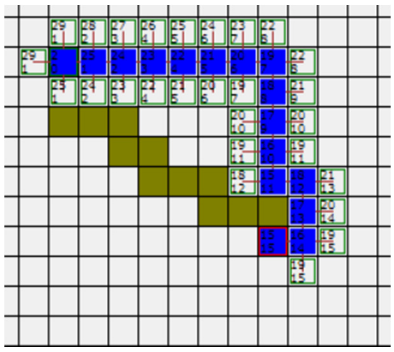
Add the turn cost in the actual cost, assuming that the cost of rotating in situ at a node is α times to the straight walk, so there are:

$$g(n) = g_l(n) + g_t(n)$$
$$= g_l(n) + \alpha g_l(n) = (1+\alpha) g_l(n) \qquad (14)$$

The path obtained by improved Astar algorithm with the turning cost is as shown in the table 2:

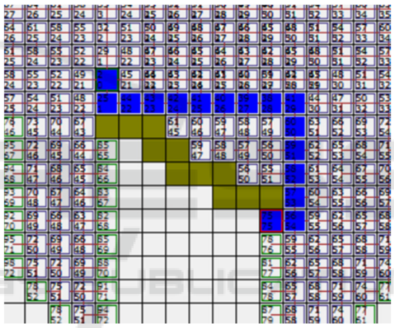
Table 2. Comparison between traditional algorithm and improved with the turn cost.

Case 1



Walking path length: 15 nodes
Turning times: 4

Case 2



Walking path length: 15 nodes
Turning times: 3

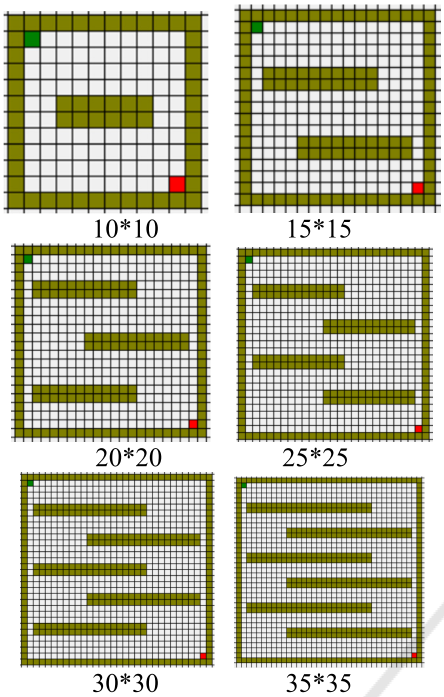
The traditional Astar algorithm has a large number of inflection points. After adding the turning cost and the number of inflection points to the evaluation function, it will effectively reduce the number of turns and improve the efficiency.

4 THEORETICAL VERIFICATION

Intuitively using the presentation software to demonstrate the performance of improved algorithms, analyze the number of inflection points, path lengths, and analyze the final path of the traditional Astar algorithm and its improved algorithm and compare the validity and correctness of the final path results.

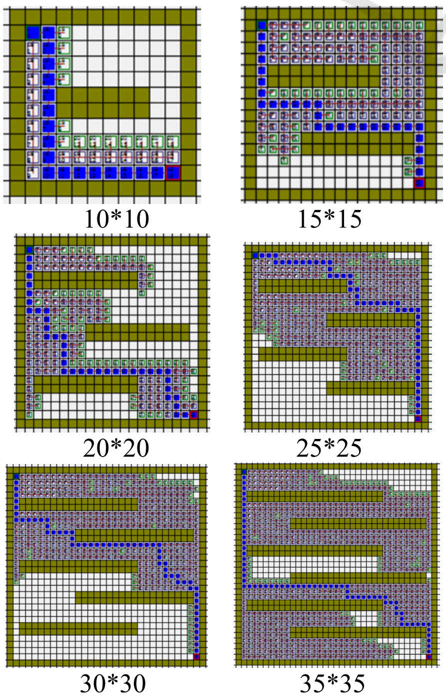
The six experimental maps followed are used for verification:

Table 3. Experimental maps.



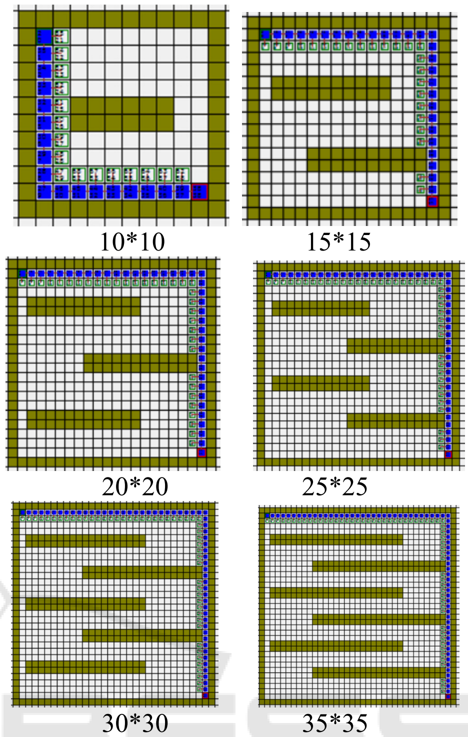
After testing the feasibility of the improved algorithm with different number of nodes, the path plan obtained by the traditional Astar algorithm is shown in the table 4:

Table 4. The path obtained by traditional algorithm.



The improved algorithm gets the path as shown:

Table 5. The path obtained by improved algorithm.



By comparing the path length and the number of inflection points, the analysis results are shown in the table 6:

5 CONCLUSIONS

(1) The traditional Astar algorithm is based on the grid map, with the evaluation function as the core, and the shortest path is foreseen. However, it cannot predict the location of obstacles in advance. It has low predictability, and does not recognize the cost of turning in actual projects.

(2) Adding the artificial potential field method to predict the position of obstacles can greatly improve the predictability of the algorithm, reduce the number of inflection points in the path, and improve efficiency in the actual project.

(3) Adding the turning cost is more suitable for the path planning in the actual project, the operation and path planning simulation of the mobile robot. The number of inflection points in the path can be stably reduced and the work efficiency can be greatly improved.

Table 6. Path analysis of traditional algorithm and improved algorithm.

Map	Project	Traditional Astar	Improved Astar
Map 1 (10*10)	Turning times	2	1
	Walking path length	18	18
Map 2 (15*15)	Turning times	4	1
	Walking path length	28	28
Map 3 (20*20)	Turning times	9	1
	Walking path length	38	38
Map 4 (25*25)	Turning times	11	1
	Walking path length	48	48
Map 5 (30*30)	Turning times	14	1
	Walking path length	58	58
Map 6 (35*35)	Turning times	10	1
	Walking path length	68	68

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