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Faster than Dijkstra and A* Methods for the Mobile Robot Path Planning Problem Using Four Movement Directions: The Dhouib-Matrix-SPP-4

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Abstract. Planning the shortest path for a mobile robot is a hard task. It consists in quickly finding the shortest distance from the starting to the target positions with obstacles collision-free. The performance of the robot mobile will be increased if the optimal shortest path is rapidly planned. Therefore, in this paper the novel optimal method entitled Dhouib-Matrix-SPP (DM-SPP) is enhanced for this problem with four movement directions (namely DM-SPP-4) for an environment represented as a grid map with fixed obstacles. The simulation results on several 41x41 grid maps and the comparison of DM-SPP-4 to different methods (Basic Dijkstra, Modified Dijkstra, Basic A*, Modified A*, Best First Search Algorithm, Breadth First Search, Depth First Search algorithms) show that DM-SPP-4 can realize the path planning more rapidly and accuracy.

Keywords. Mobile Robot; Shortest Path Problem; Artificial Intelligence; Optimization; Dijkstra, A*; Best First Search Algorithm; Breadth First Search; Depth First Search; Dhouib-Matrix-SPP.

1. Introduction

The Mobile Robot Path Planning Problem aims to plan the shortest trajectory of a mobile robot from its current position to the target position with obstacles collision-free. In order to solve this problem several methods were developed: A hybrid method based on the A* Algorithm with a bio-inspired method is developed in[1] for a mobile robot in static and dynamic environments; a Multi-objective Genetic Algorithm with three criteria (length, security and energy consumption paths) is dedicated for the mobile robot path planning in[2]; an integrated Genetic Algorithm with the Ant Colony Optimization method is proposed for the mobile robot path planning[3]. In this paper the novel optimal method Dhouib-Matrix-SPP (DM-SPP) is enhanced with four movement directions (entitled DM-SPP-4) in order to plan the shortest trajectory for a mobile robot (see figure 1). Actually, we designed and developed the DM-SPP method in[4] to solve the general shortest path problem. Hence, we adapted the DM-SPP with eight movement directions to unravel the autonomous mobile robot path planning problem in [5]. Whereas, in this paper DM-SPP is investigated with four movement

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directions (namely DM-SPP-4) and compared to several other methods (Basic Dijkstra, Modified Dijkstra, Basic A*, Modified A*, Best First Search Algorithm, Breadth First Search, Depth First Search algorithms) developed in the literature (using four movement directions).

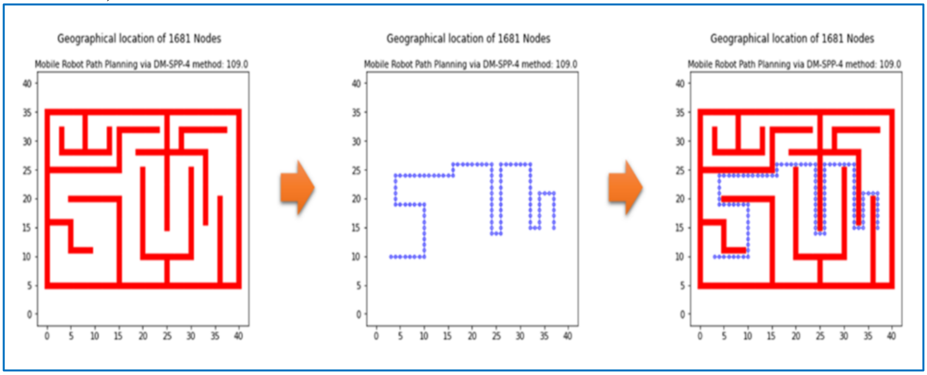

Figure 1. The trajectory plan generated by DM-SPP-4 method**.**

The reminder of this paper is structed as follows: In the next section the novel DM-SPP-4 method is introduced; in the third section the simulation comparisons are made under different environments and finally a conclusion is presented with perspectives for further research directions.

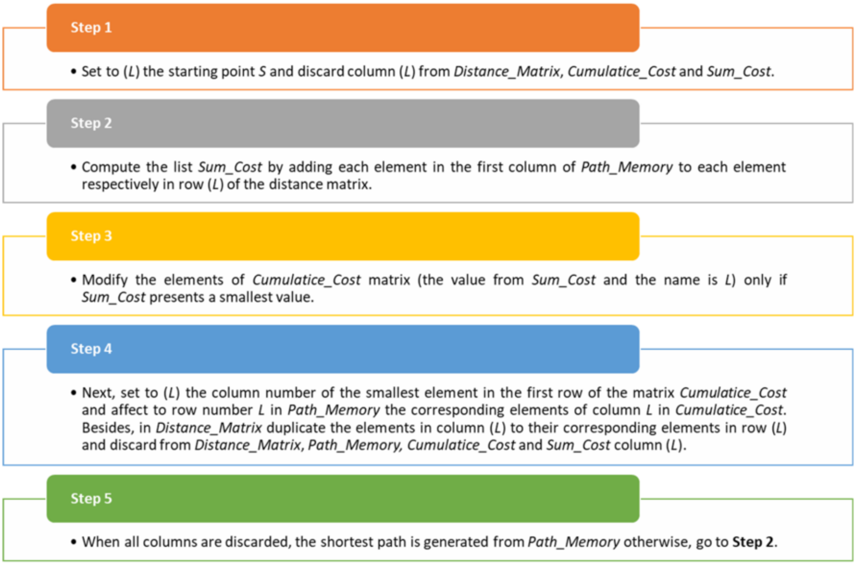

Figure 2. The general structure of DM-SPP-4 method.

2. The Novel Optimal DM-SPP Method

The DM-SPP method is developed under the general concept of Dhouib-Matrix (DM) where several heuristics (DM-TSP1 in[6-11], DM-AP1 in[12-15] and DM-TP1 in[16-

17]), Metaheuristics (DM3 in [18-21], DM4 [22-26] and FtN in[27]) and optimal methods (DM-MSTP in [28] and DM-SPP in [4, 5]) are developed.

Basically, DM-SPP-4 is based on four movement directions to create the contingency matrix and composed of five steps (see figure 2). Besides, DM-SPP-4 exploits one list (*Sum_Cost*) and three matrices (1- the *Distance_Matrix*: used to archive the distance between nodes 2- the *Cumulative_Cost*: Indicate the best cost and successor for the preselected nodes 3- *Path_Memory*: where the best connections between nodes is archived).

3. The Results

Based on the representation of the environment as a grid map, the modeling and simulation analyses are carried out under a DELL Laptop using an Intel® Core™ i7-1255U 1.7 GHz processor, 16 Go RAM, Windows 10 operating system and Python platform. The performance of the proposed DM-SPP-4 method is tested on three environments (Easy, Medium and Hard maps represented by a 41x41 grid model) and compared to six methods developed by [29]: Basic Dijkstra (B-Dijkstra), Modified Dijkstra (M-Dijkstra), A*, Modified A* (M-A*), Best First Search Algorithm (BFS), Breadth First Search (BRFS), Depth First Search (DFS).

3.1. Easy Map

First In the first case study (Easy map) a 41x41 grid map is used. As you can see in Figure 3, the optimal path plan (55) is engendered via the DM-SPP-4 method (the blue pathways) with collision-free (where all the obstacles are avoided: the red squares) in just (0.05 second).

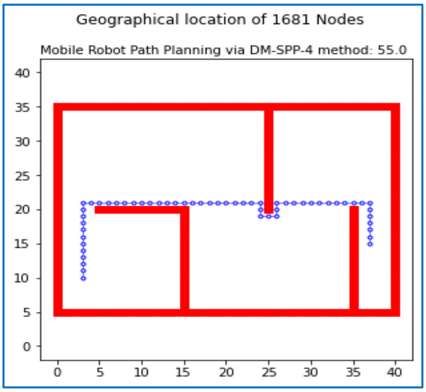

Figure 3. The planning path generated by DM-SPP-4 for an Easy Map (41*41 grid model).

As it can be seen from table 1, the required computational time for DM-SPP-4 is very reduced (0.05 second) compared to the other methods developed in the literature.

Table 1. Performance comparison between the proposed DM-SPP-4 method and seven different methods on an Easy map (41x41 grid map)

Column1	Column2	Column3
–10.2	10.2	10.2
5.36	6.32	6.32
–5.7	5.7	0.326

3.2. Medium Map

In order to further verify the rapidity of the DM-SPP-4 method, a simulation comparison is conducted in a second environment. Figure 4 illustrates the optimal path planned by DM-SPP-4 where the red squares are the obstacles to be avoided. As you can see, this solution generated by DM-SPP-4 is not collided with the edge of all obstacles: This solution (75) is rapidly generated in just (0.05 second).

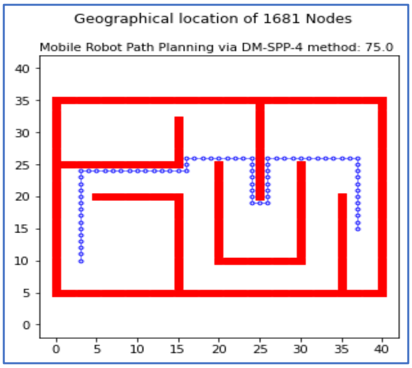

Figure 4. The planning path generated by DM-SPP-4 for a Medium Map (41*41 grid model).

Table 2 gathers all the results generated by several methods where DM-SPP-4 outperforms all of them in computational time and path distance.

Table 2. Performance comparison between the proposed DM-SPP-4 method and seven different methods on a Medium map (41x41 grid map)

	B-Dijkstra	M-Dijkstra	A*	M-A*	BFS	BRFS	DFS	DM-SPP-4
Length	76	76	76	76	96	76	220	75
Time (s)	4.29	4.32	3.19	3.21	2.75	2.97	2.61	0.05

3.3. Hard Map

In order to more verify the rapidity of the DM-SPP-4 method, a simulation comparison is conducted in a third 41x41 environment. The shortest path (109) is generated by DM-SPP-4 in (0.05 second) and is depicted in figure 5 (where the waypoints are represented by the blue line).

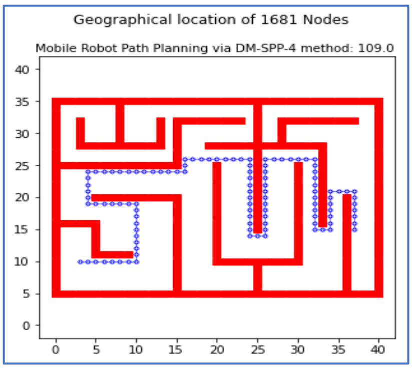

Figure 5. The planning path generated by DM-SPP-4 for a Hard Map (41*41 grid model).

From table 3, it is clear that DM-SPP-4 is the fastest method (only 0.05 second) and the most accurate one (109). Whereas, the other methods require more time (and some of them cannot rich the best solution) such as (3.95 seconds) for the B-Dijkstra.

Table 3. Performance comparison between the proposed DM-SPP-4 method and seven different methods on a Hard map (41x41 grid map)

	B-Dijkstra	M-Dijkstra	A*	M-A*	BFS	BRFS	DFS	DM-SPP-4
Distance	112	112	112	112	118	112	224	109
Time (s)	3.95	3.96	2.96	2.97	3.17	3.81	2.35	0.05

Table 4 gathers all data concerning the computation time in order to compare the rapidity of DM-SPP-4 to all the methods on three grid maps: For example, DM-SPP-4 is (87.60) rapider than B-Dijkstra, (62.20) rapider than M-A* etc.

Table 4. Comparing the rapidity of DM-SPP-4 to seven methods on three (41x41) grid maps (41x41 grid map)

Method	Easy map	Medium map	Hard map	Average	% Dev
B-Dijkstra	4.90	4.29	3.95	4.38	87.60
M-Dijkstra	5.30	4.32	3.96	4.53	90.53
B-A*	2.96	3.19	2.96	3.04	60.73
M-A*	3.15	3.21	2.97	3.11	62.20
BFS	1.54	2.75	3.17	2.49	49.73
BRFS	2.95	2.97	3.81	3.24	64.87
DFS	2.68	2.61	2.35	2.55	50.93
DM-SPP-4	0.05	0.05	0.05	0.05	1.00

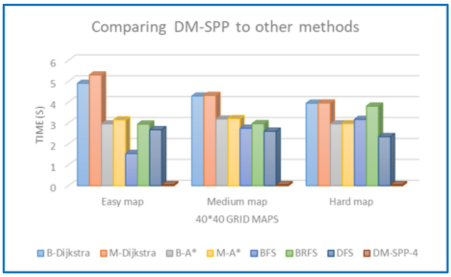

Figure 6. Comparing the proposed DM-SPP-4 to several methods.

Figure 6 summarizes the generated results on the three case studies (Easy, Medium and Hard maps with 41x41 representations). Obviously, DM-SPP-4 outperforms all the other methods (Basic Dijkstra, Modified Dijkstra, Basic A*, Modified A*, Best First Search Algorithm, Breadth First Search, Depth First Search algorithms).

Figure 7 illustrates the rapidity of DM-SPP-4 compared to all the other methods.

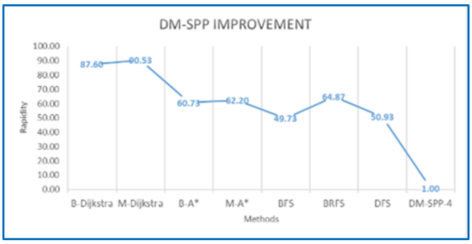

Figure 7. The rapidity of DM-SPP-4.

4. Conclusion

The purpose of the current study is to plan the shortest path for a mobile robot with obstacles collision-free in static environment using a novel variant of the novel Dhouib-Matrix-SPP (DM-SPP) method entitled DM-SPP-24. Actually, DM-SPP-24 is based on four movement directions and one of the most significant findings to emerge from this study is the rapidity with the accuracy of DM-SPP-4 against different other methods namely Basic Dijkstra, Modified Dijkstra, Basic A*, Modified A*, Best First Search Algorithm, Breadth First Search, Depth First Search algorithms. The application of DM-SPP-4 on the mobile robot path planning problem is a new attempt. Hence, the finding of this manuscript in terms of rapidity of DM-SPP-4 in incomplete graph complements those of earlier studies in DM-SPP.

This paper only focuses on the resolution of the mobile robot short planning problem with statical obstacles and grid map representation of the environments. Since, there are many challenging investigations which need to be addressed. In future works, DM-SPP-4 will be tested to solve this problem on other representation of the environments with a dynamic obstacles model.

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