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WAVEFRONT ALGORITHM FOR MOTION PLANNING AND OBSTECALES AVOIDING IN STATIC ENVIRONMENT

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Abstract— This paper aims to find the optimum collision free path from any point to another one in two dimension (2D) static environment with fixed obstacles. For this aim a Modified Wave Front algorithm is proposed to tackle the problem effectively. The Wave Front algorithm is applied with 2, 4, and 8-geometry neighborhood. Then, the results of the above algorithm are compared with A-Star algorithm. From the comparative study, it is found that the proposed algorithm with 8-geometry neighborhood gives optimal and faster results.

Keywords— Wave Front algorithm, A-Star algorithm, Modified Wave Front algorithm, motion Planning.

I. INTRODUCTION

The most important factor in human-robot interaction is the safety [1]. So that, the motion planning and obstacle avoiding approach is being more attractive for robotics researchers, which it is can find an optimum path from a start point to the goal without colliding into obstacles respect to static or dynamic environment. This problem appears in mobile robots [2] and manipulators [1, 3], which are used in welding or drilling. In addition, it also appears in game applications like "snake game", and in Computer Numerical Control (CNC) machines [4] …, etc.

For robot path finding in static or dynamic environment, many algorithms could be existing. When the environment is static, that is called stationary, obstacles avoidance has achieved by identifying the relative position of the obstacles to the robot and generating the path of the avoidance. In addition, when the environment is dynamic; then the obstacle avoidance is harder because the robot has to detect not only the position but also the direction of the moving obstacles. There are several algorithms for motion planning such as sensor less techniques which are called blind techniques, where the robot didn't know the place of the obstacle, like breadth-first, uniform-cost, depth-first and bidirectional algorithms. In addition, the sensor-based techniques, which are based on grid such as A-star [6], D-star, and wave front [7, 8] algorithms.

In this work, a Modified Wave Front algorithm(MWFA) with 8-geometry neighborhood is considered to solve the problem of the motion planning and obstacles avoiding in 2D-static environment. The Modified Wave Front algorithm is used to prevent the full wave expansion, in contrast the Wave Front algorithm which must expansion the wave in the full grid. Then, the proposed algorithm is compared with the Wave Front with 2,4, and 8-geometry neighborhood and the A-Star algorithms.

This paper is organized as follows; in section II, the environment is presented. The section III is devoted for the motion planning algorithms and the proposed approach. To demonstrate the efficiency and the applicability of the proposed approach, section IV illustrates the simulation results, which compared with several algorithms which had demonstrated in section III.

II. THE ENVIRONMENT PRESENTATION

The environment considered here is an M×N zeros matrix and it is in a form of a grid. In this matrix, while the robot on the start point, which have any values, it presents in the map as a star shape. In addition, the target has a value of one as a square shape and the obstacles have a (-1) value, which have a triangle shape. Fig.1, shows the gray frame to represent the workspace environment.

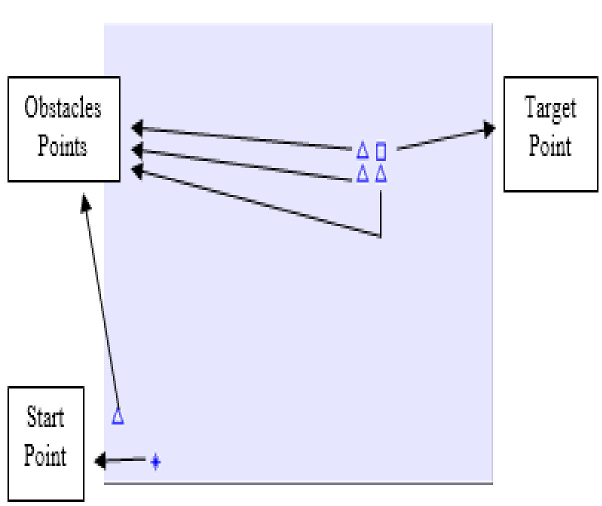


Fig.1. The simulated environment

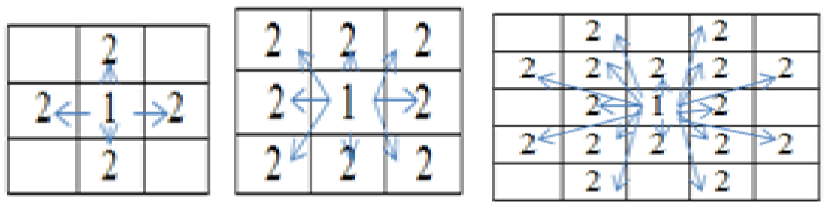
III. MOTION PLANNING ALGORITHMS AND MODIFIED WAVE FRONT ALGORITHM

Next, the motion planning algorithms and the Modified Wave Front algorithm are demonstrated as a main contribution.

A. Wave Front Algorithm

Wave Front algorithm(WFA) uses the breadth first searching method [7]. It works on grid map which has a number of columns and rows. At first, in order to expanding the wave in the environment, the value of the target point has been assumed as one. Then, the values of its adjacent cells are increasing by adding one from the target point until fill up the workspace regardless the obstacles points, which the start point gives a largest value in the workspace. Secondly, the path from the start point to the target is generated by going from the largest value to the nearest node of that value decreased by one until reaching to the smallest positive value, which is the target. Whenever, the number of geometry neighborhood increased the performance of the Algorithm becomes closer to optimal. So that, 2, 4 and 8 geometry neighborhood algorithms are applied as shown in Fig.2.

For this algorithm, each call presents a pixel in the considered workspace. Then, the N-geometry allows edges with the angles of $i\pi/N$, for all i, *N*= 2, 4, 8 and ∞ corresponding to rectilinear, 45°, $22 \cdot 5^{\circ}$, and Euclidean geometries, respectively. For 2-geometry neighborhood, the interested cells are the north, south, east, and west of a cell, all of the cells that are distance 1 unit from the center cell, as shown in *Fig.2(a).* Then, the 4-geometry neighborhood each cell of the workspace has eight neighbors that have distances of 1 unit in the direction of north, south, east, and west and $\sqrt{2}$ unit in the diagonal direction as shown in *Fig.2(b).* In addition, the 8-geomtry neighborhood, each cell has 24 related neighbors, which provide a new search direction with a $\sqrt{5}$ unit distance as in *Fig.2(c).*



(a) 2-geometry neighbor. (b) 4-geometry neighbor. (c) 8-geometry neighbor.

Fig.2, Cell connection types

From the analysis results, the wave front algorithm is still having a disadvantage of full wave expansion, which takes a long time in exploring the all node in the workspace. The Modified wave front algorithm has considered to give a good result.

B. Modified Wave Front Algorithm

While the Wave Front Algorithm is based on full wave expansion, this problem has been solved by the (MWFA), Where, the modified wave front algorithm prevent to expand the wave for all of the workspace, but it expanded the wave from the start point due to the target point. Firstly, the wave beignning to expand from the target point value and then add one for all of neighbor nodes respect to the N-geometry form until all of the nodes to the start point filled by values greater than zero. Secondly, the path will be generated from the start point, which have the biggest node value in the wave by decreasing by one value in the direction of the target point as shown in Fig.3.

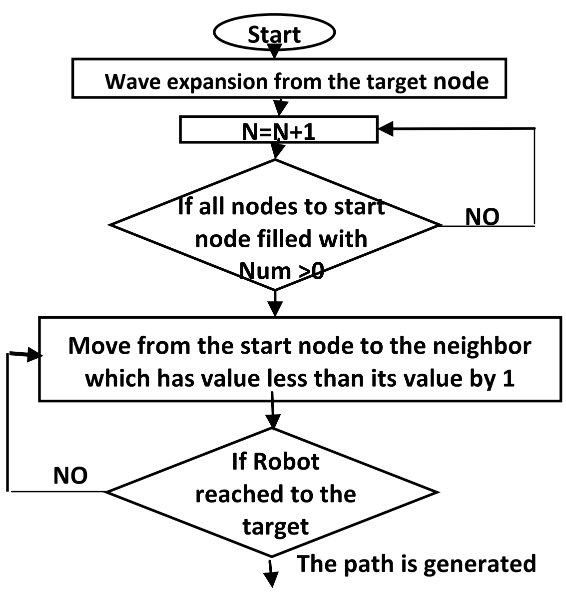
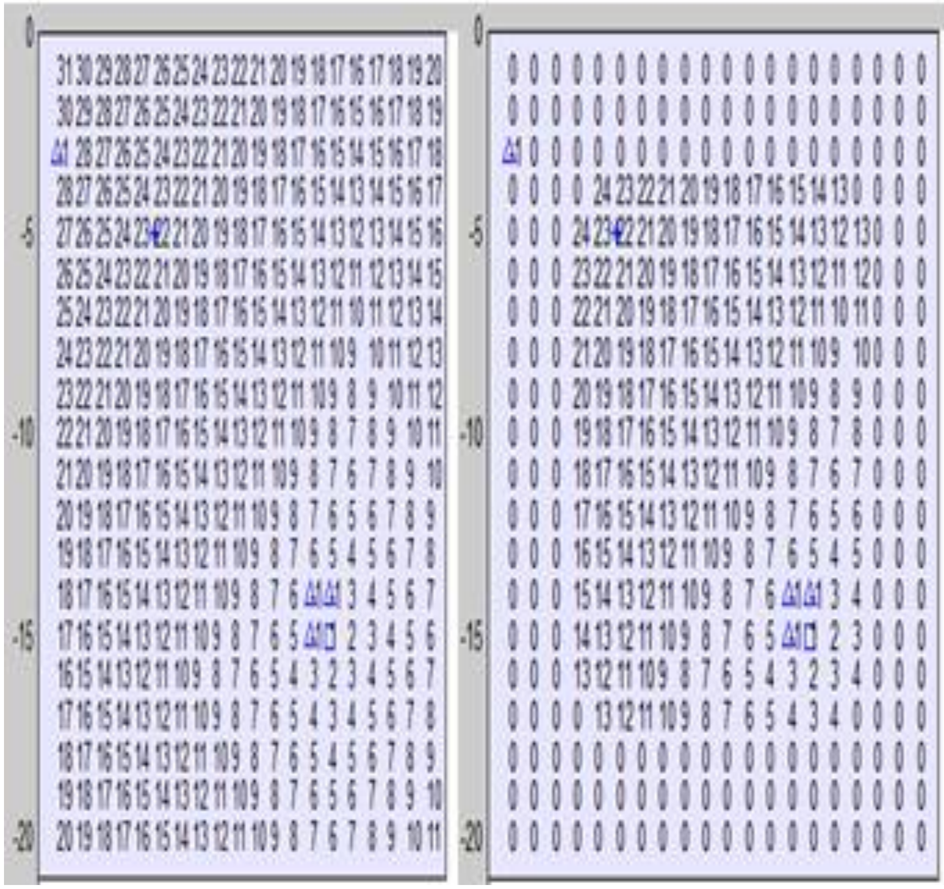


Fig. 3, Flow chart of Modified wave front algorithm



(a) Wave front algorithm expanded. (b) Modified wave front algorithm expanded

Fig.4. Simulated wave expanded.

C. A-Star Algorithm

The A-Star algorithm is considered here as another algorithm, which compared with the WF and the MWF algorithms. The A-Star algorithm has been dependent on the distance as a function from the present node to an any neighbor node and the distance from the present node to a goal node. The total cost function of the algorithm is calculated as in (1) for each node, the smallest total cost function has been selected [6].

$$f(n) = g(n) + h(n). \qquad (1)$$

where,n is the present node, $f(n)$ is the total cost function, $g(n)$ is the distance between the present node and its neighbor, and $h(n)$ the distance from the present node to the considered goal node. This is done by creating two lists CLOSED and OPEN. Closed list and open list are the basic characteristics for building the A* algorithm, “closed list” used to write and save evaluated nodes that have been tested, “open list” used to record adjacent nodes to those already calculated, and calculate the distances moved from the
“initial node” with distances to the “target node” and also saves the parent node of each node, these parents are used at the last step of the algorithm to plan the path from
the target to the start point, therefore finding the optimal path [9].

IV. SIMULATION RESULTS

The MATLAB software is used as a simulation tool to implement each algorithm. To demonstrate the efficient of the MWF algorithm, three maps are considered and it is compared with the WF and the A-Star algorithms in such maps. The considered maps as follow:

Map 1: The workspace is a 20×20 matrix, the start and target point are at (1.1) and (15.15), respectively. In addition, the obstacles are placed at point (15,14), (14,15), (14,14), and (3.1), which shown in Fig. 5.

Map 2: It is the same as the first map beyond the start point is placed at (5,5) shown in Fig. 6.

Map 3: The workspace is a 30×30 matrix, the start and the target point are at (1.7) and (25.25), respectively. In addition, the obstacles are placed at point (1,3), (24,24), (25,24), (24,25) and (5,15), see Fig. 7.

The compression between the different algorithms depends on some of parameters. These parameters are the number of the explored node, the number of steps, the path length, the number of turns, the total angle turns, and the time that the algorithm takes from the start and target points.

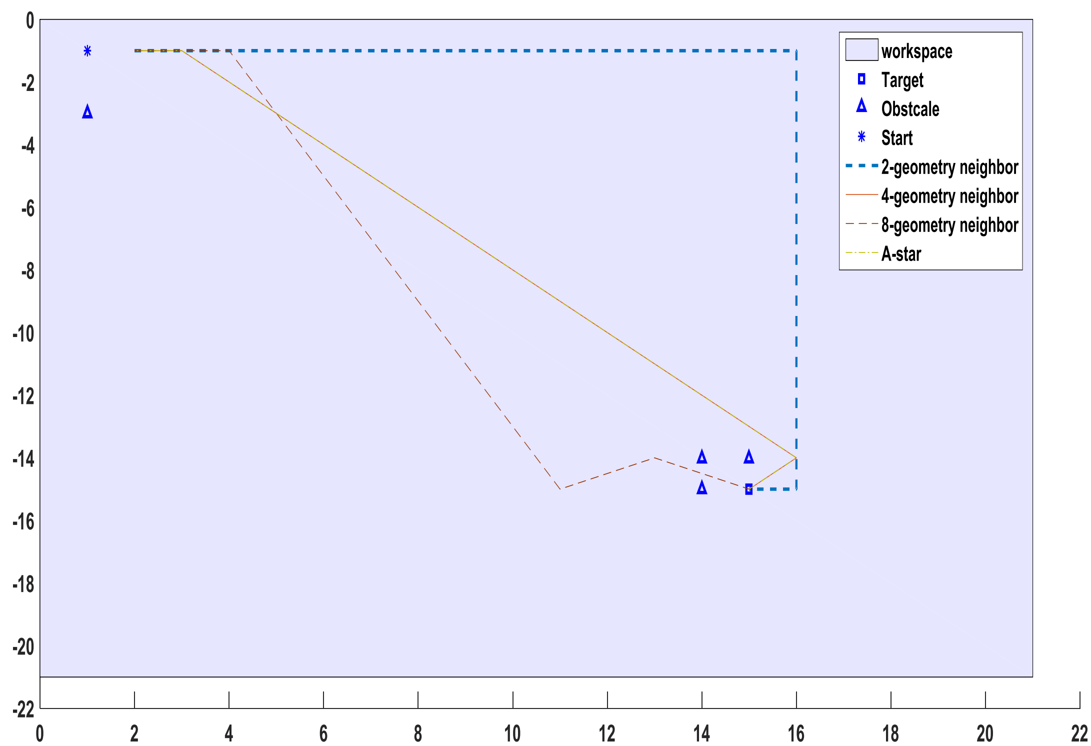


Fig.5. The workspace, map (1)

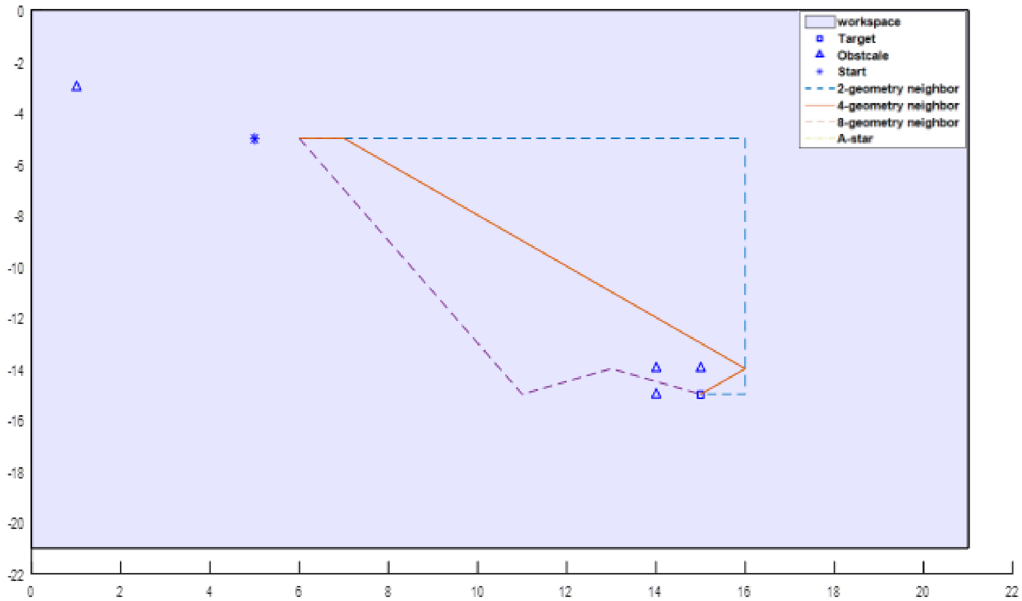


Fig.6. The workspace, map (2)

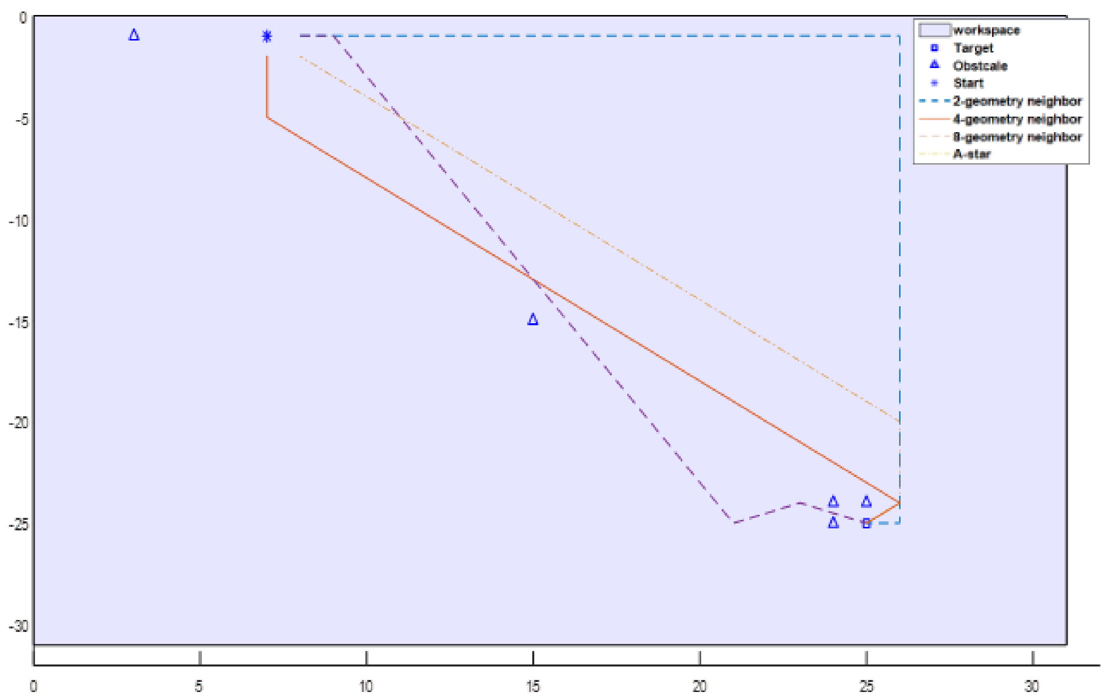


Fig.7. The workspace, map (3)

Table. (1) The analysis results of A-Star, WF and MWF algorithms with 2,4, and 8-geometry using map 1.

Parameters	**A-Star**	**2-geometry neighbor**		**4-geometry neighbor**		**8-geometry neighbor**	
		WF	*MWF*	*WF*	*MWF*	*WF*	*MWF*
Nodes explored	169	400	288	400	289	400	323
NO. steps	16	30	30	16	16	12	12
Time (ms)	868	3185	3093	1062	1050	683	666
Path length	21.798	30	30	21.798	21.798	13.338	13.338
NO. Turns	3	2	2	2	2	3	3
Total Angel Turned (^{O})	405	180	180	360	360	390	390

For all results, the number of steps has been calculated as the one step is equal a one pixel (1 unit) in the considered workspace. In addition, the angle of turns can be calculated respect to the algorithms are used, which in the 2-geometry neighborhood provide 90° only. Hence the 4-geometry neighborhood the path can turn at clockwise and anti-clockwise directions with 45°, 90°, 135°, and 180°. Where the 8-geometry can provide the all angles above in 2, 4-geometry as well a new angle of turns 30°, $60^{\circ}$and its supplementation.

Table. (2) The analysis results of A-Star, WF and MWF algorithms with 2,4, and 8-geometry using map 2.

Parameters	**A-Star**	**2-geometry neighbor**		**4-geometry neighbor**		**8-geometry neighbor**	
		WF	*MWF*	*WF*	*MWF*	*WF*	*MWF*
Nodes explored	135	400	192	400	196	400	252
NO. steps	12	22	22	12	12	8	8
Time (ms)	531	1844	1744	699	651	427	360
Path length	16.142	23	23	16.142	16.142	9.04	9.04
NO. Turns	2	2	2	2	2	3	3
Total Angel Turned (^{O})	360	180	180	360	360	420	420

Table. (3) The analysis results of A-Star, WF and MWF algorithms with 2,4, and 8-geometry using map 3.

Parameters	**A-Star**	**2-geometry neighbor**		**4-geometry neighbor**		**8-geometry neighbor**	
		WF	*MWF*	*WF*	*MWF*	*WF*	*MWF*
Nodes explored	215	900	524	900	528	900	620
NO. steps	20	40	40	20	20	15	15
Time (ms)	2867	15929	15770	3449	3330	2234	2081
Path length	28.284	40	40	27.87	27.87	17.081	17.081
NO. Turns	2	2	2	2	2	3	3
Total Angel Turned (^{O})	360	180	180	360	360	510	510

For the above tables, the Modified wave front algorithm with 8-geometry neighborhood is less in the number of steps to arrive the target and it is also takes a smallest time to go the target point with a shortest path length. In addition, the Wave front with 8-geometry algorithm is guarantee the number of steps, time, path length, and the total angle of turns compared with the A-Star algorithm and its 2, 4-geometry techniques. Finally, the 8-geometry neighborhood Modified wave front algorithm can provide a good result in the time and number of steps for the motion planning.

V. CONCLUSION

This paper has been considered a sensor-based technique for motion planning have implemented at deferent static environment. The A-Star and Wave front with 2, 4, and 8-geometry neighborhood algorithms implemented in 2-dimenssion static workspace, which compared with a Modified wave front algorithm with 2, 4, and 8-geometry neighborhood. The 8-geometry neighborhood modified wave front algorithm has provided a best result in this manner, which has a shortest path in smallest time.

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الملخص:

تهدف هذه الورقة البحثية الى ايجاد المسار الامثل من نقطة الى نقطة اخرى دون الاصدام بالعوائق في بيئة ثابة ثنائية الابعاد مع وجودعوائق ثابتة. ولهذا الهدف، تم اقتراح خوارزمية Modified Wave Front لمعالجة المشكلة بفاعلية. و تم تطبيق هذه الخوارزمية باستخدام المجاورات الثنائية و الرباعية و الثمانية. بعد ذالك، تمت مقارنة نتائج الخوارزمية المقترحة بخوارزمية A-Star . و من دراسة المقارنة، وجد ان الخوارزمية المقترحة باستخدام المجاورات الهندسية الثمانية يعطى نتائج مثالية و سريعة.