Analysis on Pathway Finding Algorithm for Unmanned Aerial System

Hla Myo Tun

***Abstract* – The paper mentions the path planning design for Unmanned Aerial System (UAS) that utilizing Comprehensive A* algorithm as the main contribution for the UAV to navigate the area of interest autonomously and transportation to a goal desired by autopilot system. The objective for the autopilot system for UAV is to find the best possible path along the probable path in any random prospect autonomously. Autonomous UAV navigation systems have need of the amalgamation of many research works such as trajectory tracking, sensing on position and orientation of UAS, control of UAS, and avoiding the obstacles for UAV. The main contribution of this research is to fashion and expand a suitable path for UAV able to circumvent many obstacles like building and mountains in its pathway and achieve a goal designated situation from its initial position. Therefore, many simulations were performed in different fixed atmosphere, and the results prove that the UAV accomplishes its goal with bump gratis blockages. In the present analysis, different experiments have been performed by including the pathway of simulation for UAV in MATLAB and using GUI for the algorithm implementation.**

***Index Terms* – Path Planning Algorithm, UAV, A Star, Autonomous System, UAS Navigation, Trajectory Tracking.**

I. INTRODUCTION

An Unmanned Aerial System (UAS) is one that is competent of autonomous take-off and landing based on autopilot navigation system. It is auto-controlling and auto-adjusting, consequently it is capable of manage in and respond to its atmosphere lacking exterior command and control. The procedure of navigation for UAV can be gone down into four steps: (1) recognizing and representing the atmosphere, (2) confining the UAV contained by the atmosphere, (3) arranging and fixing on the desired movement of UAV and (4) implementing the desired motion of UAV. Moreover, path planning with modeling for UAV movement is an imperative and tough issue that has many purposes in the field of artificial intelligence, effective authenticity, self-governing instrument simulation and unmanned aerial vehicles [1-6]. Therefore, researchers were proposed various methods to solve vehicle path planning problems. These various methods are such as prospective pasture technique, artificial neural networks approach, genetic algorithm, global C-space method and particle swarm optimization (PSO) have been developed to unravel this trouble. In general, those techniques are categorized into two classes according to the feature of the atmosphere, specifically the off-line comprehensive path planning based on the replica of identified atmospheres and the on-line local path planning based on sensors' perceiving of unidentified atmospheres [7-10]. The comprehensive technique using the comprehensive information can acquire globally best possible path with impact free blockages. Nevertheless they involve the accurate atmosphere replica, which is to state; the pre-information of atmospheres should be obtained with precedence. While, the atmosphere is moderately or even entirely unidentified for the UAV whose sensors has frontier recognition assortment [11-17]. Furthermore, the rate of re-arranging the changed atmosphere is excessively elevated to acclimatize the real-time condition in the dynamic atmosphere. However, local path planning technique does not involve the accurate atmosphere replica and can contend with undecided circumstances in the atmosphere. Unmanned Aerial Vehicle (UAV) system is one of the significant regions of concentration in off-line decision making processes for UAS. In this predicament, the goal for finding appropriate path for UAV is to locate from initial location to the desired location along the correct pathway without crashing blockages. A common practice in UAV simulation is to perform path planning and collision avoidance in an atmosphere replica [18-22]. The issue of planning a pathway given an initial and a final position is described the path planning predicament. To solve this predicament, a modified technique of comprehensive path planning based on A* algorithm has been presented in this research work. In this technique, the appropriate goal is based on the location of the desired point and blockages in the atmosphere. Consequently, the best possible pathway can be created with this technique when the UAV reaches its desired point [23-30].

II. SYSTEM OVERVIEW

The workflow diagram of the Unmanned Aerial Vehicle (UAV) path planning system is illustrated in Fig. 1. At first, source node and destination node have been specified in the predetermined area. And then, Comprehensive A* algorithm have been utilized to find the best pathway from a specified initial point to a desired point. By using the path tracking program, the UAV could be avoided collision obstacles. In addition, the optimal path could be planned out by approaching the following stages in this work.

This research covers the advance path planning techniques and autonomous UAV path planning design. The path planning techniques is the vital role of autopilot system for UAV system. There are a lot of path planning techniques to solve that present work. However, in this work, the Comprehensive A* algorithm is the main contribution to solve the path planning issue. The UAV navigation function which could be supported by MATLAB environments is the specific goal. The MATLAB supported functions could be created by following the ideas of path planning system.

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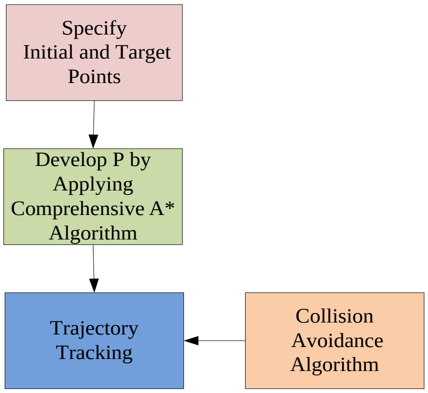

Fig. 1 Workflow Diagram for Trajectory Tracking of Unmanned Aerial System (UAS)

III. AUTONOMOUS NAVIGATION SYSTEM

The navigation systems have been extensively focused on the many research areas for autopilot systems in unmanned aerial vehicle. Consequently, the significant issue in the development of UAV is the navigation system, which is one of the majority crucial phases of UAS. The gap and how it is obtained is an imperative function in the field of affecting an intelligent system. It can elucidate that significance by the subsequent rationale:

1. It offers the essential data to perform path planning.
2. It furnishes data for observing the location of the autonomous unmanned aerial vehicle during the implementation of the desired pathway.
3. It is crucial that the UASs have the capacity to create and use replicas of its atmosphere that facilitate it to recognize the configuration of atmosphere. This is essential to realize commands, arrangement and implement pathways.

Autonomous navigation is an imperative feature for UAS and for sensing devices with the objective of serving the autopilot to find the way in convinced atmospheres. Navigation can be identified as the procedure or commotions of precisely finding out one’s location, arranging and tracking a direction. In UAS, navigation denotes the pathway an UAV attain an observation of the atmosphere where it is engrossed in, comes across its approach and is capable of move about itself in that atmosphere. Inherent in any navigation scheme is the desire to reach a goal without receiving misplaced or deafening into any substances [5-9].

A. *Matching Issue*

The matching issue survives when the UAS establishes lacking a map of the atmosphere where it is engrossed in and additionally assembles one as it finds the way. While in motion, the UAV senses the atmosphere and recognizes key characteristics which permit it to record data of its atmospheres. The major apprehension for the matching issue is how the UAV does distinguish the atmosphere. There are numerous sensors applied for matching, being the majority regular sonar, digital cameras and range lasers. The involvedness of the matching issue is the consequence of a diverse figure of aspects, being the majority significant: size of the atmosphere, noise in observation and actuation, and perceptual uncertainty.

Matching approaches based on images confined by a specific sensor, have been generally proficient through the withdrawal of ordinary characteristics from the atmosphere or all the way through the recognition of particular synthetic way-points. Synthetic way-points principally comprise hard-color or template-based characteristics. Hard-color way-points are in the majority issues effortlessly individual, but can sometimes be intermingle into the atmosphere and turn into fewer noticeable. On the contrary, templates are fewer unclear with the background situation and can also be simply recognized. A system based on ordinary way-points extant in the atmosphere is a supplementary calculatingly challenging issue, but reimbursements from the reality that there is no necessitate for a synthetic estimation of the atmosphere.

B. *Path Planning Process*

Path planning process is the development of appearing in advance at the consequence of potential events, and probing for the most excellent progression that will undeviating the UAV to a desired point. It occupies searching a pathway from the UAV’s present position to the desired position.

Pathway finding techniques for navigation of UAS can be alienated into local pathway finding and global pathway finding. They principally diverge on the capacity of data of the atmosphere they need to hold. Local pathway finding techniques merely require data of the atmosphere that is close to the UAS, while global pathway finding techniques employ complete data of the atmosphere. There are numerous diverse advances to path finding, as they aspire to resolve the issue using dissimilar practices.

IV. OBSTACLE AVOIDANCE APPROACHES

In the literature survey, there subsist a great number of published techniques for resolving the path finding issue for UAV in an atmosphere where the blockages are stationary and their configurations identified. In many situations, these methods are readily applicable to performing obstacle avoidance in previously unknown environments. The UAV’s atmosphere depiction can assortment from an unremitting geometric depiction to a geometric map based on decomposition technique or still a map topologically. The primary pace of several path finding schemes is to convert this probably unremitting environmental representation into a discrete map appropriate for the preferred path finding schemes.

A. *Prospective Field Technique*

The potential field technique is a scheme that disintegrates the free space into a well rectangular cell which is then explores for a free path. Each cell is assigned a ‘prospective’, where the goal point and adjacent cells are allocated an ‘attractive’ prospective and obstacles possess a ‘repulsive’ potential. This ensures that the path created moves towards the goal while steering clear of any obstacles.

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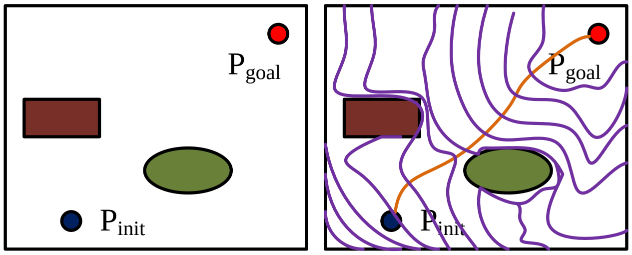

Fig. 2 Prospective Field: (a) Obstacle Allocation (b) Pathway through Equi-prospective Shape [5]

B. *A* Algorithm*

This is achieved using what is termed an evaluation function. It is used when searching adjacent points, and estimates the effective pathway from that node to the goal to approximate its likelihood of being on the effective pathway. The evaluation function t(p) is defined as follows:

$$t(p) = s(p) + a(p) \quad (1)$$

Where, s(p) is the actual cost of an optimal path from initial point to desired point and a(p) is an estimate cost of the best possible pathway from initial point to desired point estimate a(p) is obtained by simply computing the straight line distance between initial point and desired point. A* algorithm explores the entire region by sustaining an unlock record and a blocked record to get an optimized pathway. They are called the unlock record and blocked record. The record can be found as the flowchart below Fig.3.

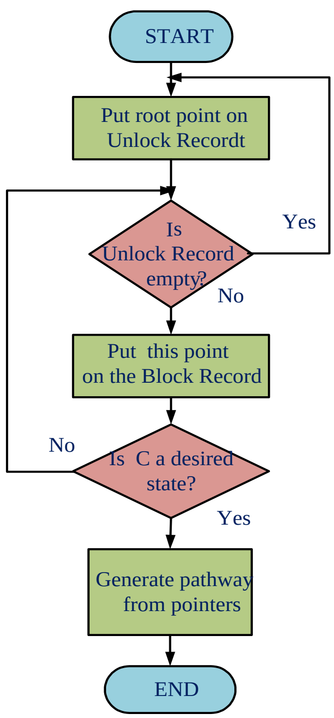

Fig. 3 Flowchart for A* algorithm

The unlock records maintain cells which are immobile in the estimating procedure by pathway finding scheme, and the blocked record maintains cells which have previously been estimated by the pathway finding result. A* is a diagram best-first optimal pathway finding scheme, that utilizes a self-controlled technique for evaluating the distance between two points. A* is the best only if the self-controlled technique is a inferior vault of the distance. In that issue, the self-controlled technique is said to be tolerable. To implement the A* pathway finding scheme into a numerical program where we can effectively amalgamate it with the functions we require, there won't be any revolutionizes to the general use of the scheme. The scheme is declared on the point of the diagram that corresponds to the primary location of the UAV on the map.

Table I. Comparison of Different Environments

Environment No:	Number of Obstacles in Maps	Number of Nodes of the shortest path	Total Distance of the Path (meter)
1	2	4	89
2	3	6	162
3	3	6	112
4	5	10	125
5	11	10	115

V. IMPLEMENTATION OF UAV PATH PLANNING SYSTEM

Firstly, source and destination points of blockages have been specified in the predetermined area. When the obstacle positions in point obtained, the cell-based method is applied to create map. This blockages' map can be exhibited by using the map function in MATLAB. A* pathway finding scheme can't be used if the location of the target is not known. Therefore the local minimum or target has to be determined by using the searching pathway function. According to the A* algorithm the initial point, the target point and the blockages are put in the map using MATLAB commands by changing the digits of matrix. Furthermore, the least-cost path could be evaluated by using this pathway function. The UAV navigation issue is solved by using the checking function. After analyzing that function, the get path value would be displayed on the MATLAB command window.

A. *Creation of Map Building*

The map building issues survive when the UAV does not comprise a map of its atmosphere and incrementally makes one as it finds the way.

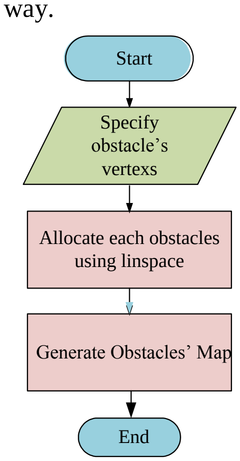

Fig. 4 Flowchart of Map Function

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Therefore, the start node (x_s, y_s) and end node (x_e, y_e) of obstacles' vertex is initialized in the predetermined area. By using linear spaced vector, these obstacles are set in the map.

The flowchart for detail function of map building is shown in Fig.4. In this flowchart, there are several steps to create obstacles' map. Firstly, source and destination nodes have been specified in the predetermined area. And then, each obstacle allocated in this area. In addition, obstacles' map could be generated by approaching specific stages in this research.

B. *Creation of Pathway Finding Algorithm*

To find a secure pathway in a hazardous atmosphere for the unmanned aerial vehicle is a crucial obligation for the achievement of several unmanned aerial systems.

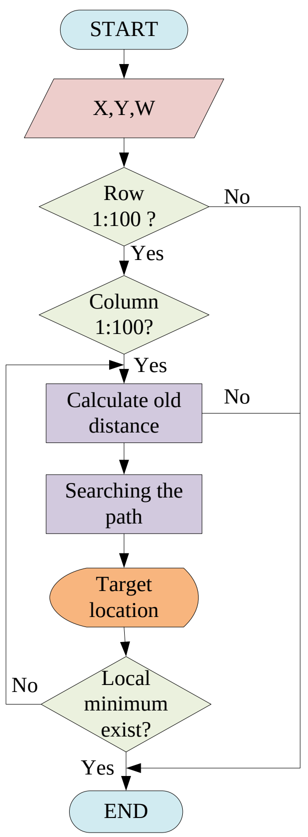

Fig. 5 Flowchart for Getpath Function

Therefore many researches on pathway finding schemes to formulate the UAS locate from the initial point to the desired point without collision with blockages is an essential obligation for the UAS security in atmospheres. In this research work, Comprehensive A* algorithm is selected to be implemented because A* gives faster calculation and uses lesser information storage than that of other algorithms. The flowchart for searching path system is shown in Fig. 5.

In this flowchart, there are many sub function to implementation of that searching pathway systems. The first task is to loaded the length of x, y and w from the obstacles' map. And then, the distance of goal y and goal x is calculated by using Pythagoras theory. From this calculation, minimum value of x and y can be obtained. This is the old distance of goal x and y. The next task is to locate the least-cost pathway. The pathway distance is the new distance of target point. The target distance is compared to the value of old distance x and y. Finally, local minimum or target point is obtained using get path function from the pathway finding algorithm.

The flowchart of checking function is shown in Fig.6. In this figure, there are several steps to check the location of obstacles. The important section of checking system is to solve the UAV navigation issue which will be displayed on the searching path results from the detection and tracking process.

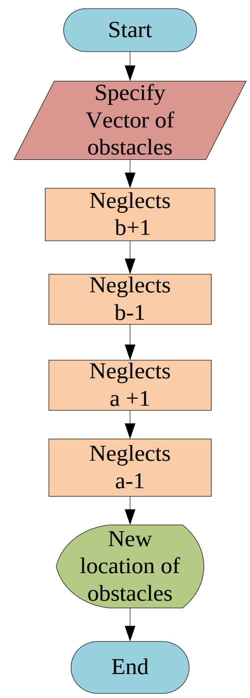

Fig. 6 Flowchart of Checking Function

VI. IMPLEMENTATION OF UAS PATHWAY FINDING SYSTEM

The purpose of the research work is to facilitate the UAS to find the way for indoor environment. The UAS has to circumvent blockages in partially known atmosphere that comprise both recognized and unidentified blockages. Moreover, the UAS gives with a map of the atmosphere in some issues, but the map is imprecise because unexpected blockages added in this map. Furthermore, predefined map (Map1) can be used to define the obstacles in the map. The predefined maps are shown in Fig.7

And then, the user can draw a barrier for start by using the left mouse button and right mouse button ending the barrier. In this way, the random obstacles can be inserted in the predetermined area. Fig.8 shows the position of obstacles. By using the variable point weight, the shape and size of the obstacles can be changed in the area. And then, the target has been chosen according to the user by using the left mouse button. Fig.9 shows the target point in a new map as red circle.

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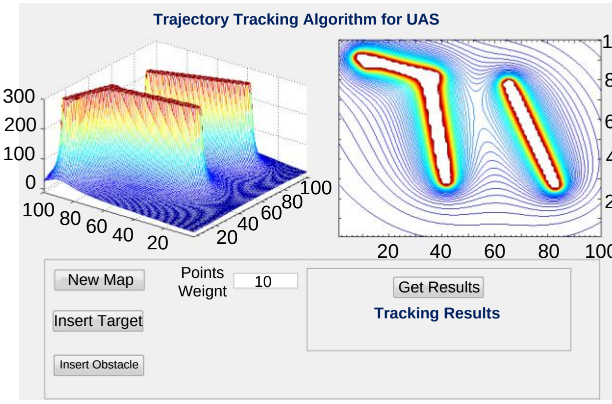

Fig. 7 Predefine Map1

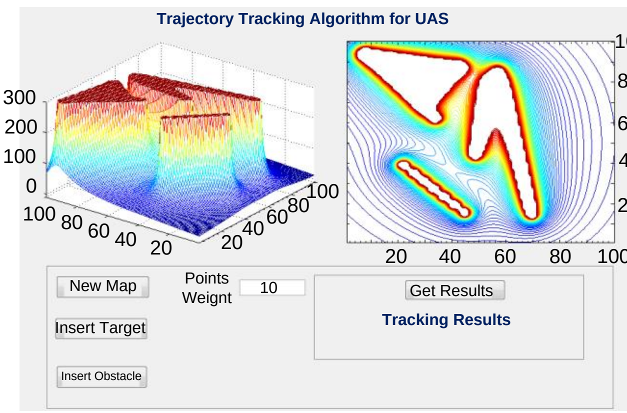

Fig. 8 Position of Obstacles in New Map

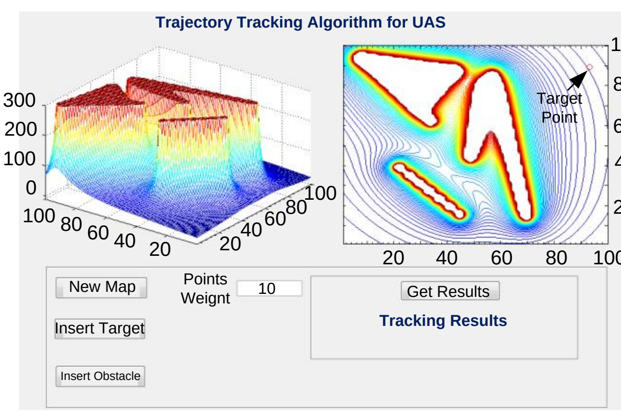

Fig. 9 Target Point Location in New Map

Finally, the "Get Results" button is pressed the user can get if the pathway finding algorithm is achievement or failed to locate a pathway. The "Result" can be "Path has been found" or "No solution has been found". It is noted that pathway finding algorithm handles the local minimum issue and if the handled process failed to locate a result then No solution result emerged.

VII. EXPERIMENTAL RESULTS

The different obstacles maps are applied in this section. Thus the output results are dissimilar because of the different inputs. At first, the start node (1, 1) has been defined in the predetermined area. The area of the map is 100x100 m^2 and one grid represents 10x10m^2 in this figure. But the target point can place any location in this area. Moreover the size and shape of obstacles can be changed by using variable point weight. Therefore the position of obstacles can be changed and the obstacles' map will be changed. The blue line represents the feasible (collision-free) shortest path for the unmanned aerial vehicle.

A. *Result of Environment1*

In Fig.10, two obstacles are placed in the area by using point weight 10 and point weight 20. Therefore the two obstacles' vertex values are varied. Also, the size and shape of obstacles are changed. But the optimal path can be generated in this situation. Local minimum or target distance is 89 meter. This data is shown in MATLAB command window after the process.

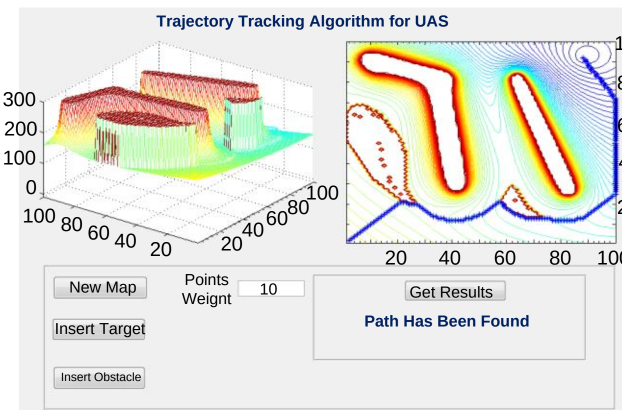

Fig.10 Result of Environment1

B. *Result of Environment 2*

In Fig.11, there are three obstacles, 6 selected nodes for the result shortest path. The first obstacle is placed in the map by using point weight 20. The two obstacles are initialized by using point 10. In this situation, the target and the minimum distance for this map are 162 meter for the UAV. The optimal path is found in this map for the UAV.

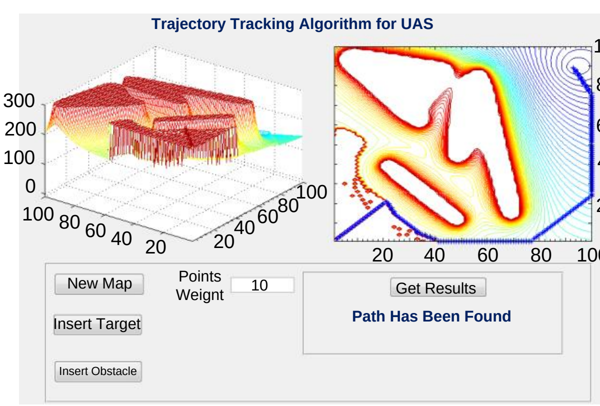

Fig.11 Result of Environment 2

C. *Result of Environment 3*

In Fig.12, three obstacles are included and 8 nodes of open list are used for the collision-free shortest path. By

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using point weigh 30, three obstacles placed in this map. Local minimum path for the process is 112 meter for unmanned aerial vehicle. In this situation, the vehicle truly detected the obstacles without collision until reached to the target.

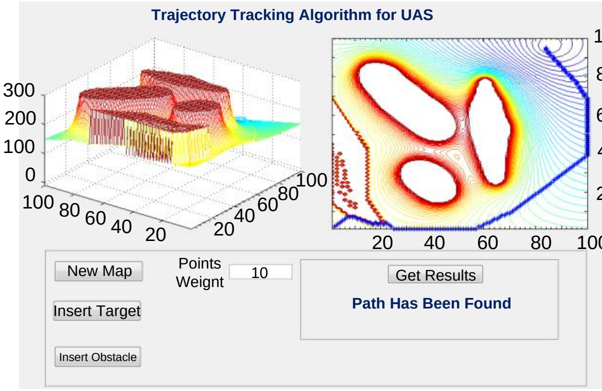

Fig. 12 Result of Environment 3

D. Result of Environment 4

In Fig. 13, five obstacles are included and 10 nodes of open list are used for the feasible path. The total distance between the start location and target point is 125 meter. The number of obstacles included in Map1, the used node for the result and the length of the shortest path are different to the environment 4. Moreover the time taken for the results and shape of the path are also different because of the position of the obstacles in each environment.

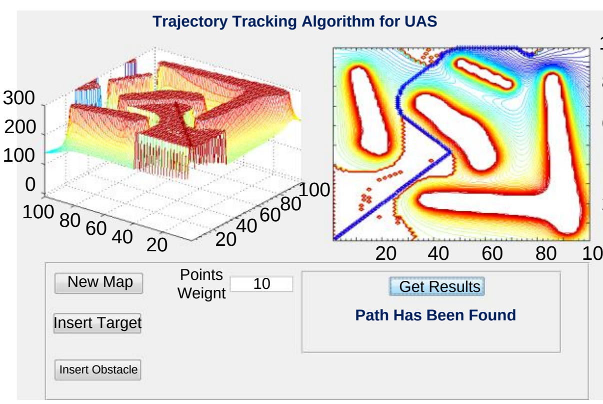

Fig. 13 Result of Environment 4

E. Result of Environment 5

Fig.14 shows the process and result of the Environment 5. In this environment, eleven obstacles are included and ten nodes of open lists are used for the collision-free shortest path. The shorter distance for this environment is 115 meter for the UAV. The number of obstacles included in Environment 4 and Environment 5 are the same.

But the volume and outline of blockages are different and the target location is changed in this environment. Therefore, the distance of Environment 4 is larger than Environment 5. As the UAV travels frontward direction, it regularly perceives any blockages in front of it. The movement essentially follows the constraint of gap of the prearranged region. In this way, the UAV continued moving until it reaches the target.

VIII. STATISTIC TABLE

Five environments and different number of blockages are used for the testing process of pathway finding research work. Therefore different nodes for the trajectory pathway and different pathway distance are included in the Table. I. These two factors of the research work depend on the locations of the blockages. The different maps contain different number of blockages, different positions of blockages and the number of nodes used in the feasible path. The UAV tracking distance is also depends on these above factors. If the size and shape of blockages are larger than the UAV, the shortest path could not be found. Therefore the positions of blockages are very important for searching the best collision-free pathway (feasible) appropriate path for UAV to perform their tasks. If the obstacles are very complex in the map, the computation times taken and total distances are large for the UAS.

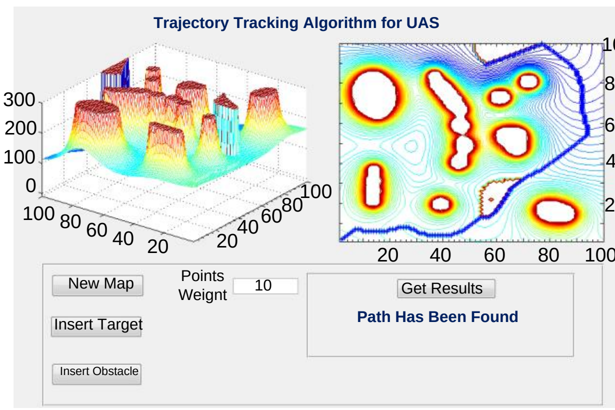

Fig. 14 Result of Environment 5

IX. CONCLUSION

Pathway finding is a main core in all UAV navigation system. The UAV used the pathway finding algorithm to find a path to reach to the target while avoiding blockages. In this research work, the pathway finding algorithm implemented to create fulfills the pathway plan by utilizing the A* algorithm as a main frame in helping the UAS to find the way a self-controlling of the region of effort and enlistment to a target desired by the autopilot. According to the experimental results, the UAV has certainly fulfilled the desired location. Formerly getting the update data, the UAV can arrange the appropriate path in merely few seconds with enhanced A* algorithm verified by the experimental results. As conclusion of research, it can be expressed that reviewing all UAV systems, testing the feasible optimal path results for different environments. Moreover the computation time of the process is depending on the number of obstacles, location of obstacles and size of obstacles. Optimizing of this UAS with MATLAB program is performed effectively.

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