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Path Planning of a Quadcopter for Search and Rescue Operation

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Abstract: This paper proposes an attempt to develop a path planning algorithm for a Quadcopter which is an Unmanned Aerial Vehicle (UAV) to carryout search and rescue operations in the event of natural calamities like floods, hurricanes, tornadoes etc. In this work, a UAV system is designed to carry out search and rescue operations in a heavy flooded terrain. During the search operation, it detects and transfers the GPS information of the location of the victim to the ground station of the rescue team. For initiating such a search, a primary path of the UAV connecting the various region of flood affected zone is to be planned. The Wave front algorithm is proposed for the coverage path planning in each of this region. The satellite image of the flood affected zone provides the geometric details of the area for victim identification. For the victim identification, the UAV is equipped with a passive infrared sensor and a thermal imaging camera. The victim locations are identified through inbuilt GPS and GSM modules and are communicated to the ground stations.

Keywords: Unmanned Aerial Vehicle, Rescue Operation, Passive Infrared Sensor

I. INTRODUCTION

Natural calamities like floods, earthquake, tornadoes, most important thing is to find the survivors or victims from that environment at earliest. In a flooded condition the victims trapped in different locations, when the rescue team fail to find them at earliest leads to death. In heavily flooded conditions only way to search for the victims are using the boat and helicopters. Boat and helicopters are inaccessible to some areas and are time consuming. Due to these reasons, an alternate solution for the search and rescue is very important. In this work an alternate solution for the search and identification of the victim locations are attempted using a drone.

There are different solutions are proposed to solve such problems. Alive human detection system is a novel approach is done by (Asha Gupta et al) [1] using PIR sensor and GPS and GSM modules. Similarly, A human tracking autonomous robot is developed by Purnima G et al. [2] and they developed a car with GPS module controlled by remote controller. A four wheeled robot with hand is developed by Mittika Ukey et al, [3] for human detection. In both the cases PIR sensor is used for human detection. This drone system scan or cover an area find the location of survivors and send their location information to a rescue team. The location information given by the drone can efficiently help the rescue team for an early assistance to the victims. The camera image supplied by the drone system shows the situation of the area and makes more precaution during the rescue operations. PIR (Passive Infrared Sensor) is used for the detection of live victims. A coverage path planning scheme based on the Wave front algorithm is used for by the drone for its search operation in the selected area. Alive human detection system is a novel approach is done by (Asha Gupta et al) using PIR sensor and GPS and GSM modules. Similarly, A human tracking autonomous robot is developed by Purnima G et al. is a car with GPS module controlled by remote controller. An PIR sensor is used for the human detection purposes. A four wheeled robot with hand is developed by Mittika Ukey et al, the robot with a hand and human detection system. PIR sensor is used for that purposes. Coverage path planning is more complex than obstacle avoidance algorithms. There different type of CPP algorithms are available, L H Nam et al [4] propose a new path planning algorithm is wave front algorithm. This algorithm used in the area decomposed in to cells. This algorithm has a wave propagation or cost distribution from target node to starting node. Valente et al. [5] proposed a cellular decomposition coverage path planning algorithm for agriculture field machines. it also the area decomposed into cells. this work describing decomposition methods path generation.

This paper presents a full coverage path planning scheme for a drone based on an approximate cellular decomposition and wave front algorithm. In section 2 represents the human detection system and section 3 is algorithm for coverage path planning. Section 4 for path planning, experimental results given in the section 5and 6 and finally conclusion in section 7.

II. HUMAN DETECTION SYSTEM

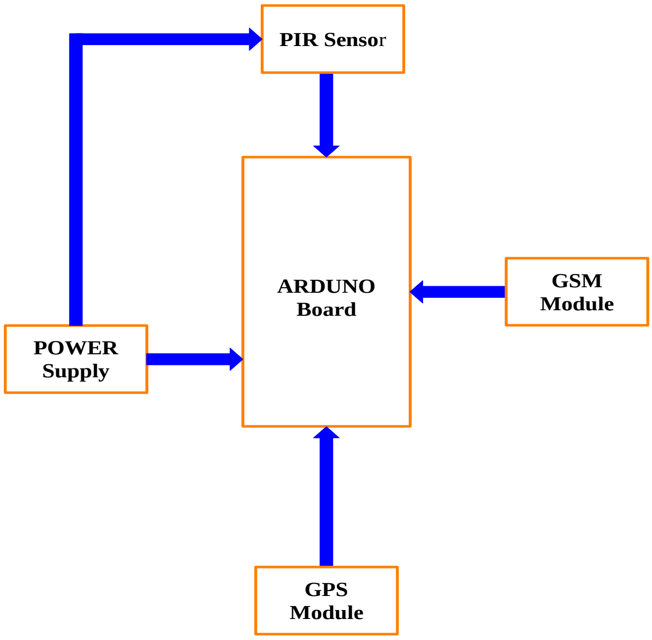

Fig 2.1 Block diagram of human detection system

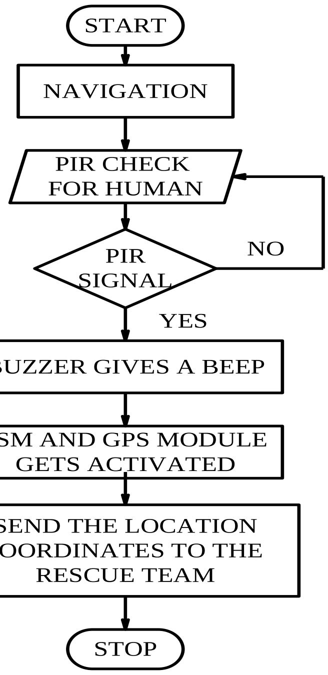

Fig 2.2 Flowchart of human detection system

Fig 2.1 represents the human detection system block diagram. PIR sensor GPS and GSM modules are integrated with Arduino Uno board. Power supply to the entire system is by a 5V battery. AtMega328 is a microcontroller used in this system. The presence of a alive human is detected by sensing the infrared radiations from human and a high voltage level is produced from PIR sensor and send to the microcontroller and consequently the microcontroller activate both GSM and GPS modules. Then the GSM module sends the location information to rescue team. The system is represented in flowchart shown in Fig. 2.2 and this system is programmed in python language

III. DEVELOPMENT OF PATH PLANNING ALGORITHM

Coverage path planning algorithm is more complex than usual path planning algorithm for obstacle avoidance. The area coverage is achieved by the drone motion along the planned path. The coverage of sample terrain is important, that plan of an area is generated by help of graphic software. It is tested in real life environment, areal image taken from the Google earth. Then the optimised area division and path planning algorithm is developed, executed and tested using Python programming language.

3.1 Defining the Area Plan

Most important is full coverage path plan in a terrain, so the image corresponding to the area is created by graphic software paint. It is similar to the aerial view of an Island in which land is coloured by green and the surrounded water body is coloured as blue. To have a relation between the created image and actual workspace it is assumed that 25$pixels$ (px) in the image corresponds to 20 m in real life environment. As the drone scanning region or area size is proposed to be 400m^2, 625px^2 will be the smallest unit in the image created. In this study a test area of 400m × 400 m is considered, so the image size to be created is 500 px × 500 px. Some test images are created by above considerations.

a. Image processing

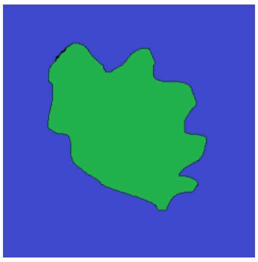

Fig. 3.1 Domain, Area for path generation

Fig. 3.2 binary image

The image obtained from camera is subjected to image manipulation techniques like conversion to grayscale, binary conversion. But here, the image is created in graphics software instead of camera image. The image is shown in Fig. 3.1, which represents an Island and in actual case it will be an aerial view of a region surrounded by water. The image is converted to grayscale. Then it is converted to binary image as shown in Fig. 3.2.

3.2 Grid Formation in Workspace Area

The image of the room or room map is then subjected to gridding. Gridding involves splitting the image into smallest square tiles, where each tile is having the size of the scanning region of drone. The grids will be $25px \times 25px$ in the image and $20m \times 20m$ in real life as shown in Fig. 3.3. After, the gridding process, each cell is analyzed for black pixels. Wherever there is a cell if a black pixel is encountered the cell is marked as obstacle (water) because it is not for scanning area for drone.

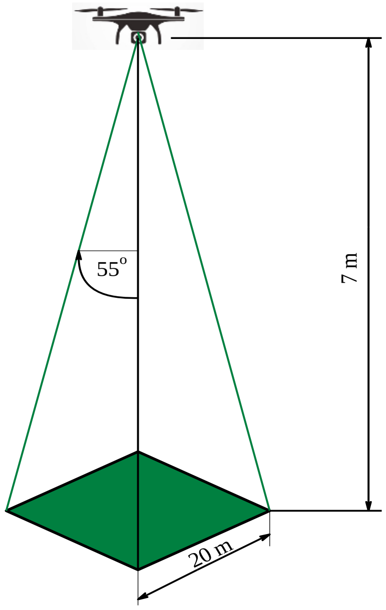

Fig 3.3 Scanning area of drone

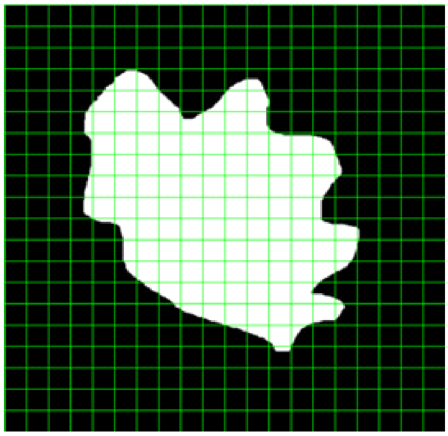

Fig 3.4 Grid image of domain

The image is converted to binary for the easiness of obstacle identification. In the binary image the accessible area is white and the obstacle is black in color. Then by reading each pixel, the program can identify the pixel which is free from obstacles. Store these pixel details to create the workspace and remaining pixel treat as obstacle. Then the image split into square grids by equal distance division along breadth and width direction, the gridding makes path planning easy. The numbering of each cell helps to identify their location during path planning. Fig. 3.4 represents image after gridding.

IV. PATH PLANNING

After completing the image processing the next step is path planning. The path planning process initiated by scanning points these are the points obtained after image processing. Path planning is the process of generating path for the motion of the drone. In this work is to get a path which cover the all the area and least number of multiple visits in a single cell. As the path generated for this work is to attain coverage of a certain area, the complete path for an entire area needs to be defined. For this, certain algorithms were studied and out of this one is selected.

1.1 Wave Front algorithm

Wave font path planning algorithm is a coverage path planning algorithm. In this algorithm assigned values in the cells are increased from the target value to starting cell. The nodes in a wave i.e. nodes at equal distance from the target node are assigned the same value provided node is not an obstacle. Consider navigation function Φ like as a potential function. Navigation cost of goal cell is $\Phi(C_G) = 1$, if the cost of adjacent cells has greater cost than the goal cell. So, the cell before the goal cell in the path having larger navigation cost. Consider a way point v^*, the near cell of a way point u is may reduce cost (gradient descending) or increase cost (gradient ascending). There are two type of wave front path planning algorithm, one is wave front ascending algorithm and wave front descending algorithm. Wave front descending algorithm is used for shortest path finding and wave front ascending algorithm is used for CPP.

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Navigation function can be established with wave front propagation algorithm

1. Initiative $X_0 = C_G$; i = 0
2. Initiative $X_{i+1} = \Phi$
3. For every c ϵ X_i, assign $\Phi(c) = i$ and insert all unexplored neighbors of c into X_{i+1}
4. If $X_{i+1} = \Phi$, then terminate; otherwise, let i = i+1 and go to step 2

Before implementing cost function, need to check the connectivity between the cells for drone movement. Drone move from one cell to four directions or in 8 directions.

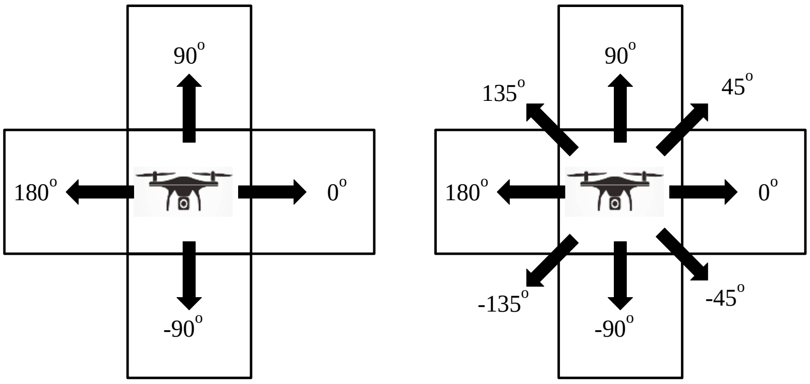

Fig 4.1 (a) Von Neuman neighborhood (b) Moore method

In Von Neuman neighbourhood method only four direction (90^0) is possible for movement between cells. But in Moore neighbourhood method there are 8 direction movement is possible (90^0, 45^0) shown in fig4.1. The goal of this method to obtain a path which needs to be completely covers an area. Using wave front algorithm can easily find out the work area and also generate path is completely cover an area. But this method is not suitable for all the irregular areas, so modified the algorithm which completely cover the area.

a. Numbering algorithm

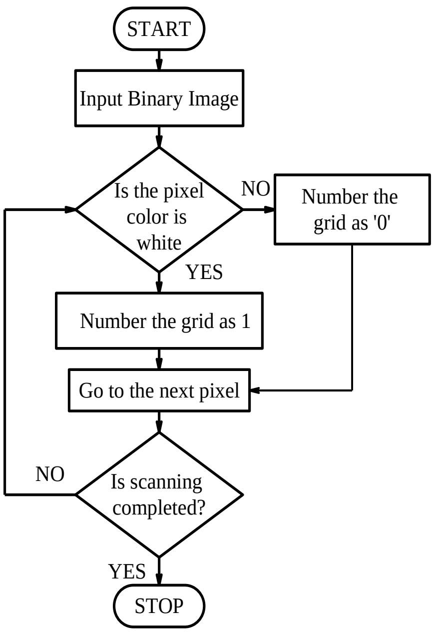

Fig. 4.2 Numbering algorithm flowchart

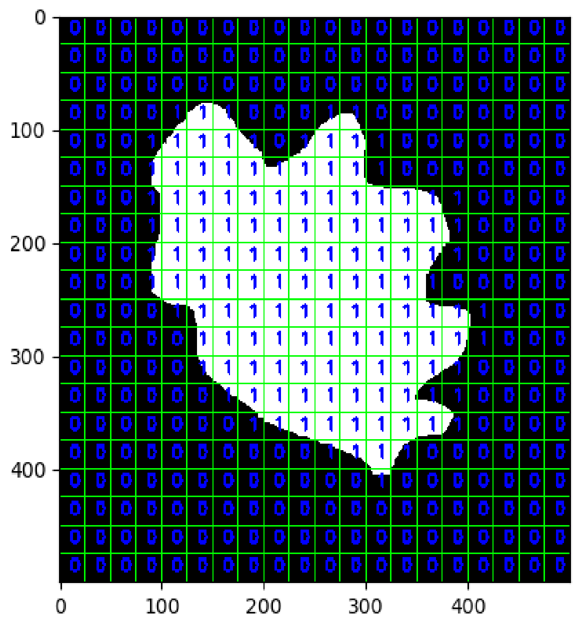

Fig 4.3 Work area extraction

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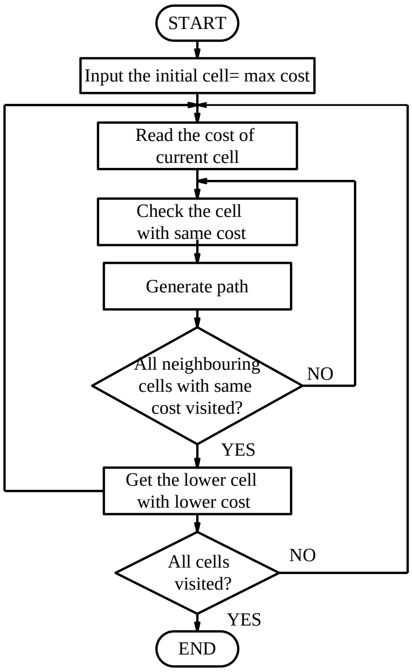
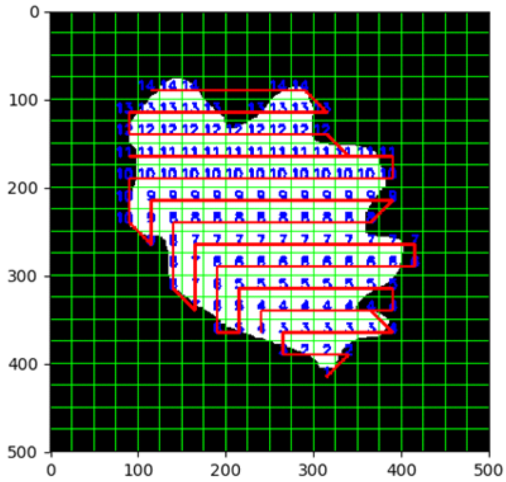


4.4 Path planning algorithm flowchart



4.5 Path generated by basic Wave front algorithm domain

The area for work in an image is find out by numbering algorithm, which shown the obstacle cells as zero and workspace cell denoted as 1 shown in Fig 4.3. Applying wave front algorithm, it put scores or navigation cost in the cells from the goal cell into all the cells. Generate the path which connects the entire cells once from the starting cell to goal cell shown in Fig.4.4. This will be used as the path for the option of the drone. Now this path information has to be changed into a format that is easily understood by the robot for its actual motion. So, this path is then converted to numerical matrix data form.ie, into the path length and the directions to turn. The numerical matrix data form is then transferred to drone controller.

V. RESULTS

The prototype of drone is shown in Fig.5.1. All component except human detection circuit is assembled. The base frame lower face for fixing the human detection circuit.

Fig 5.1 Assembled Drone

5.1 Path Planning in an Aerial Image

The full coverage path planning algorithm is tested on an aerial image. The generated path and its completions time calculated. The aerial image for the generation of the path planning is taken from the Google earth satellite view. The longitudinal and latitudinal values of the area are shown below. Satellite camera height is about 399 m and the area choose is a school ground.

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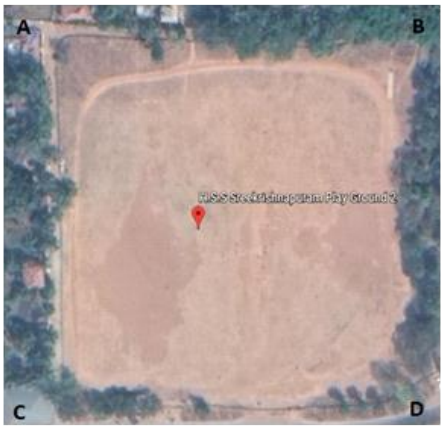


A-100 53' 57" N 760 23' 59" E
B-100 53' 55" N 760 24' 05" E
C-100 53' 52" N 760 23' 58" E
D-100 53' 51" N 760 24' 04" E

Table 6.1Actual Dimensions of the Workplace

Workplace Size	Width	Length
	160 m	160 m

Fig. 5.2 The Aerial View of the Work Area

Wave front ascending algorithm is implemented on the area and generates the coverage path is showing in Fig. The satellite image area is $\mathbf{160\ m \times 160\ m}$ converted into $\mathbf{500 \times 500}$ pixel area. Path completion time can be calculated by theoretical approach [8]

$$T = \frac{S}{V} + \sum_{i=1}^{k} \frac{\psi i}{\omega}$$

Where, T is completion time, S is the route length, V is the UAV movement speed, k is the number of turns, $\boldsymbol{\psi}$i is the angle of ith turn and $\boldsymbol{\omega}$ is the UAV rotation rate.

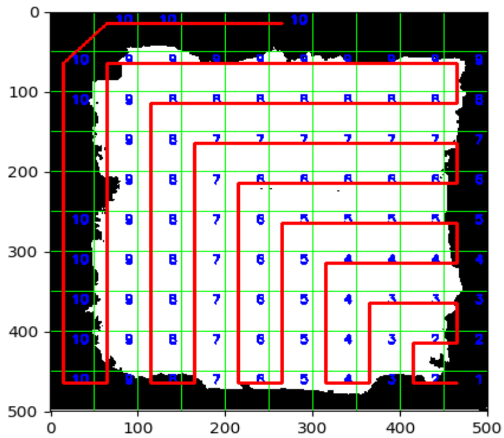
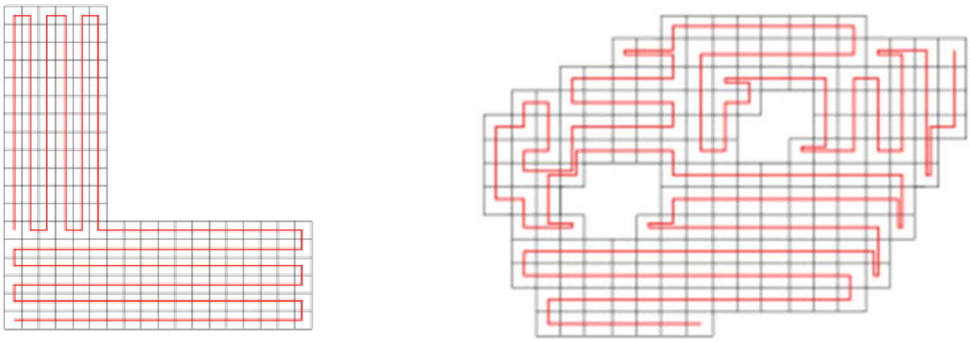


Fig. 5.3 Coverage path for the area

VI. COMPARISON OF THE PATH PLANNING ALGORITHM

Comparing the path planning approach with another path planning algorithm developed by Eduard Santamaria and Florian Segor et all, "Path planning for Rapid Aerial Mapping with Unmanned aircraft systems" [7]. This path planning algorithm they developed is for reducing the number of turns in path. The path is generated for the different shapes such as L shape with 180 cells and other arbitrary shape with 178 cells are shown in Fig. 6.1

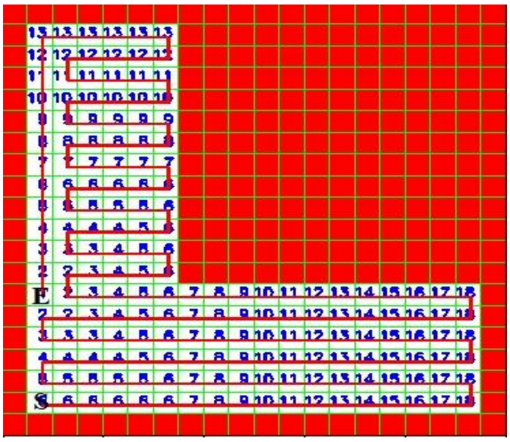


(a) (b)

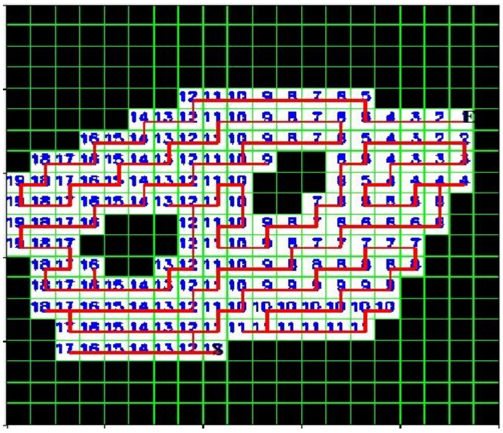
Fig. 6.1 Path generated using Eduard Santamaria algorithm [7]

Fig 6.2 path generated foe these L shaped (a)and an arbitrary shape (b) with Wave Front algorithm is shown. Compare the number of turns in the generated path. Number of turns increase the path completion time during flight. Less number of turns will be good for a path, generated in an area.

Table 6.2 represents the comparison between path planned with strides-based algorithm and wave front algorithm at different domains. The path length formed in wave front algorithm is less than or same with path formed with strides-based algorithm in all domains. The number of turns in all the domains, very less in strides-based algorithm, but 45 degree turns not formed in wave front algorithm and there is a turn other than 90 and 45 degree formed in strides-based algorithm. Path length in third domain by wave front algorithm is less than the path formed by strides-based algorithm.



(a)



(b)

Fig. 6.2 Path Generated using Wave Front algorithm

Table 6.2 Comparison between wave front and strides-based algorithm

Shape	Approach	Path length (pixel)	Number of turns
L shape	Strides based algorithm	3540	20
	Wave front algorithm	3540	90^0 – 35
Contour 2	Strides based algorithm	3740	90^0-56
	Wave front algorithm	3560	90^0-91

VII. CONCLUSIONS

A prototype of the Drone is developed and it is working satisfactorily. An image processing algorithm for the extraction of the search domain is developed. The developed a path planning algorithm is generated path on sample terrains efficiently. Path completion time is also calculated. Human detection capability of the proposed system could not be tested. This testing and assessment can be done as a future work.

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