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Energy Aware Path Planning For UAV- An Analysis

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Abstract: *The obstacles on the path are usually a threatening factor for the UAV flight. With the regular 2D path planning technique it is not possible to navigate in the complex 3D irregular area of interest. So for the path planning algorithm to be a successful one, it should be intelligent, adaptable and make quick changes online to avoid the hindrance. The goal of the paper is to analyze the pre-existing techniques in 3D path planning algorithms for UAV, taking into account grid based decomposition, which are best in obstacle avoidance to control the energy consumption while satisfying the other parameters like completion time and coverage.*

Keywords - *UAV, MLE, CPP, AOI*

I. Introduction

The Unmanned Aerial Vehicles (UAVs) is one of the fastest growing technologies and for the improvisation in it; the factors like safety, power consumption, smoothness and shortest path cannot be ignored in civilian and military areas. At present, the failures of UAVs are still much higher than those of the manned aircrafts. This is why it becomes imperative to improvise on the research on the trail planning algorithms. The UAV path planning has a crucial role to reinforce the power of autonomous flight by obtaining a worldwide favourable path with the normal two dimensional (2D) path planning for static or known environments or with three dimensional (3D) path planning by considering the very fact that the trail is typically dynamic and unknown. But the 2D path planning technique is simple and is not able to deal with the complex environments like the uncertainties and the constraints involved in the structures so 3D path planning algorithms are most chosen. Often in 3D path planning, the area of interest plays a prominent role thus to review the literature, this paper concentrates on Coverage path planning (CPP) algorithm.

The idea behind the flight planner in CPP is being able to cover the whole area without being able to collide with the obstacles. The CPP decomposes the area of interest into small clusters that can be covered easily. The work place will be decomposed considering the technique of exact cellular decomposition or approximate cellular decomposition and it is ensured that every cell or cluster is visited once. The exact cellular fragmentation uses the traditional back and forth movement to have an access to each cell where the form of cell is within the sort of trapezoid and this method is even called trapezoidal decomposition. The imprecise cellular decomposition considers grid based area of interest. The clusters here are usually of equal size and shape, the merging of the cells will approximate to the entire area of interest.

This paper shall consider the comparison of grid based 3D approaches for path planning with suitable obstacle avoidance technique. The hindrances on the path, most likely called as obstacles considered here will be static and the paper aims to consider the parameters like 1) Avoiding the obstacles with the shortest possible path 2) The consumption of energy 3) Completion time.

II. THE STUDY ON 3D PATH PLANNING MECHANISMS

[1] The approach chosen by the author is to avoid the obstacles using the Radar. A series of video frames here are image processed to detect and avoid the obstacles. As the UAV's have a limited computational and memory constraints, the algorithm is formed in a way to reduce the requirement of computancy and is contrasted with the brute force algorithm in pixel by pixel manner and also with the Maximum Likelihood Estimation (MLE) algorithm. Initially a study on various birds within the locality is made and a listing is formed that comprises the speed of travel and sizes of birds that form a database. The Radar now marks the birds once they are entering the locale of the UAV. One can trace the bird and may calculate the interspaced gap for clearance with the image recognition technique. This gap has to be the minimum possible distance.

The flow of an algorithm is as follows: 1) The Radar finds the hindrance nearing the UAV. 2) No less than 3 pictures are clicked of the approaching element or hindrance 3) The pictures are fed into the code. 4) The difference between the present and the previous images are taken to get rid of the unnecessary background 5) If its modified MLE approach, then the picture considered gets color operated. i.e. the change of color tone from RGB to gray or binary tone. This process gets continued with detection of borders or edges using canny edge. 6) Further the image is cut in order to contain just the sides of the thing/body followed by comparing the trimmed image against the pre-stored set of images obtained by brute force method with pixel by pixel approach. Thus taking into account the knowledge gained at the survey, the hindrance is bypassed. 7) This approach is that the one almost like brute force method. 8) The approach after edge detection is, the sting of the obstacle is set over the first image with color and then segmented again into desirable pieces. The image segmented is then compared against a pre-stored data of images to seek out the simplest comparison using MLE. Considering the knowledge extracted at the operation, the hindrance is avoided or ignored. 9) If it's the avoidance by image segmentation algorithm, then initiating with the middle pixel, an attempt is made to find the extreme point and expand to urge the entire fringes or borders. Once the fringe or border is detected, the dimensions of the considered obstacle are measured and length for clearance is decided and using the knowledge obtained at the operation, the obstacle may be avoided. [1] The Brute Force: 35 seconds + 2 seconds/DB image, Modified MLE: 20 seconds + 2 seconds/DB image, Image Segmentation process: 10 seconds were the results obtained after comparing time taken by the three algorithms thus reducing the computational requirement.[1]

[2] If an asymmetrical Area of Interest (AOI) is considered, then the straightforward geometric gliding marks like back and forth movement to unravel coverage path planning problem might not be sufficient. Hence in such scenario grid based methods inherit existence. The grid based approach demand the high computational time and typically applies the simplistic cost functions thus resulting in expensive or long paths which are inefficient in practical cases. Therefore the grid based approach should follow the accurate energy model that targets to bring down the power or energy utilized while operation happens in irregular area of interest.

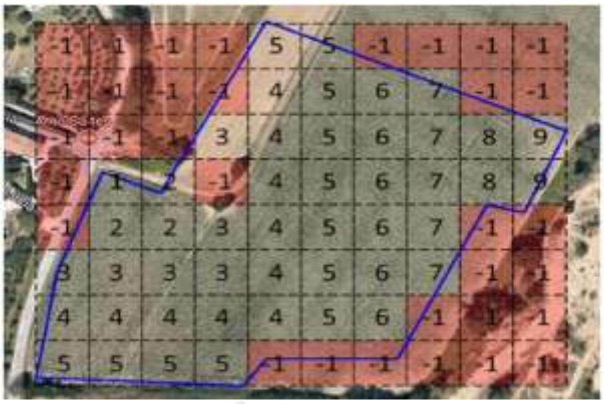


Fig. 1. The regular grid is constructed from irregular shaped area by discreatizing. The start point is symbolised with 1, the surrounding clusters with 2 and is continued. The cell with no fly zone or the one with obstacles is denoted as -1.

The algorithm utilized in this paper involves two trimming methods that drastically decrement the computational interval when a true world scenario is taken into account. 1) Within the first technique the closest adjacent cell having the very best value is picked to move on the entire path. This case basically chooses the highest value. If two or more cells have an equivalent value then no cell amongst these should be ignored. The entire path coverage should undergo every node in the adjacency graph just one occasion. A deep search with limited values will create a tree with every possible coverage trails. 2) Within the second technique, requirement to compute the value of path from first cluster to the present can be avoided, but only the value can be created by choosing subsequent neighbor. The algorithm executes the design phase without being online and therefore the generated coverage trail or path is fed into an unmanned vehicle within the sort of waypoints. The energy aware cost function is defined to form a complete coverage with minimum cost path.

$$\Gamma = \sum_{i=1}^{m} \gamma_k^{\{i\}}, k \in \{135^\circ, 90^\circ, 45^\circ, 0^\circ\}$$

Symbol m denotes the way points considered. They'll be 1 to m. γ denoted the angle of i-th waypoint which is flattened by the k set. The trail is typically calculated by the amount of turns and therefore the turns are correlated to the consumption of power. However the value functions are unaware of rise and fall during the turns. [2] This algorithm has energy retention of 17% during the important movements of UAV's and with the assistance of energy model accuracy was estimated as 97%. With energy aware grid based approach the computational interval are often reduced by 99%. As an example, it's possible to find a reduced-cost path to move onto a neighborhood divided in 36 cells in 35 seconds, rather than quite 3 hours. Since the computational time has been considerably decremented, the algorithm is often run over various start points to seek out the minimum cost path. This is possible with less number of operators time that saves energy in better level for irregular area of interest or workspace.

[3] The algorithm considers the key constraints like size, weight and power. The changes in size of the traced way points from the succeeding frames are found making an analysis. The technique is applied over an obstacle to detect the feature points and then finds the obstacles which have close probability of nearing the UAV in next instant. Next is to match the area ratio of the spot of the UAV by comparing and therefore the

obstacle is detected. The essential idea of this method is to seek out the obstacles which are likely to hit the UAV. Then the UAV performs the avoidance by combining the waypoints with the 2D image of the obstacle. To accomplish tasks like obstacle sensing and detection onboard camera is mounted. The algorithm considers the monocular camera to detect the respective size enlargement of obstacles that are approaching the UAV from a distance between 90 to 120 cms and has 97.4% accuracy. [3]

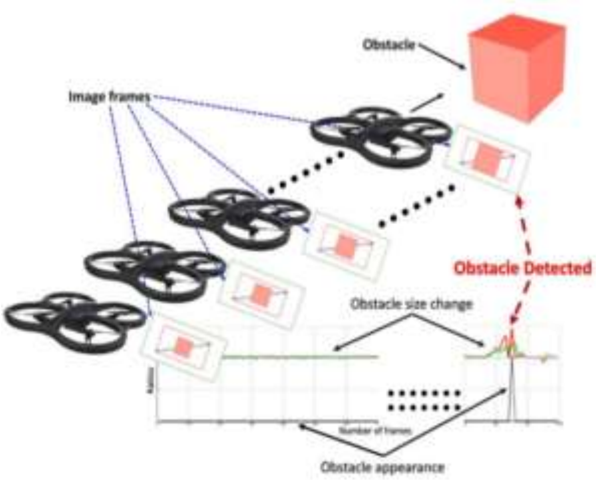


Fig. 2. The concept of obstacle detection.

The approach drops the whole cluster or cell that contains the obstacles. So if the obstacle is detected even in a negligible part of a cluster, the total cluster will not be traversed, because of which the area coverage rate considerably decreases in this case. Along with this, avoiding the whole cluster will increase the length of the travel and turning angle. The approach increases both the consumption of power and the task completion time though the accuracy is better compared to other existing techniques.

[4] The author proposes an energy aware path planner algorithm. The goal lies in reducing the power utilization while satisfying a set of parameters like coverage and resolution considering the energy model derived from the measurements involved when operated practically. The path planning algorithm breaks the total travel into 3 major entities. 1) Way points are created from the original point till the longest bounding line through the edges. 2) Way points are created using the scans parallel to the longest bounding line in back and forth pattern. 3) Way points from the final point to the initial location via edges if they are not coincident. To minimize the total power consumption, acceleration is set at the optimal figure for every straight distance .[4]

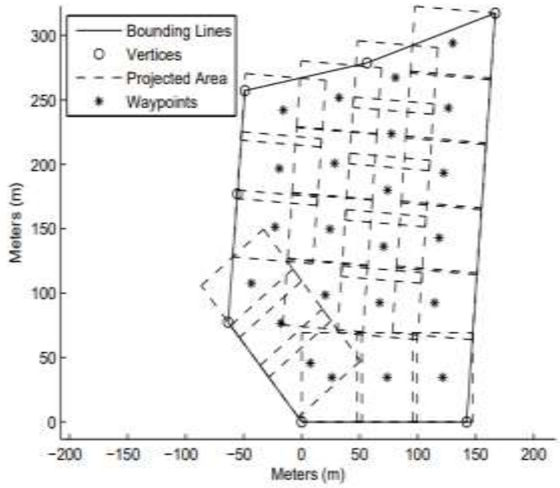


Fig 3. Coverage path planning computed with the algorithm

Total power consumed by the path is,

$$E_{tot} = E_{climb}(0, h_{max}) + E_{desc}(h_{max}, 0) + n_t E_{turn} + \sum_i (E_{acc}(0, v_i^*) + E_v(d_i, v_i^*) + E_{dec}(d_i, v_i^*))$$

A UAV is considered with criteria for measurement (Weight, type of power supply, the propellers used) to derive an energy model that can be generalized. The aim of the model will be to foretell the energy utilization in various operating states or parameters. The energy consumed during the movement from lower value to higher is called energy for climbing. The energy consumed during the movement from higher value to lower is called energy for decending and to cover a high point displacement Δh is E_{climb} and E_{desc} respectively. The energy consumed during standing still in the air to hover in given interval is $E_{hover.}$. The energy required for steep turns is E_{turn}. The energy consumed in a straight flight is E_v. Energy in acceleration interval and Energy in deceleration interval is E_{acc} and E_{dec}. h_{max} is the maximum highpoint in which the UAV can fly. v_i is the vertex. d_i is the distance. E_{tot} is the total energy consumed.

[5] The research here has two phases, 1) Using the top view of the area, a trajectory trail is generated offline. 2) This phase is dependent on the previously obtained paths. At first the captures from the onboard camera are related to the front angle of the scene which includes the object or hindrance. Now idea is to somehow bypass the obstacle to determine the new location where UAV has to travel. Every obstacle considered is static. The steps involved are 1) Capture the facing area image. 2) Calculate the dimensions of the area. 3) Form a grid. 4) Project the UAV cell. 5) Now check the projected cell if the value is greater than zero or equal to zero. 6) If it is greater than zero then find the set of boundaries and solutions. Extract the grid boxes containing the sets and the position of UAV. Apply subdivisions to calculate the path lengths. Select the shortest path amongst the calculated path lengths. Now plot the next drone position vertex and move the drone to it. 7) If the projected cell has value equal to zero then select the current cell vertex to the next UAV position and move the UAV to it.

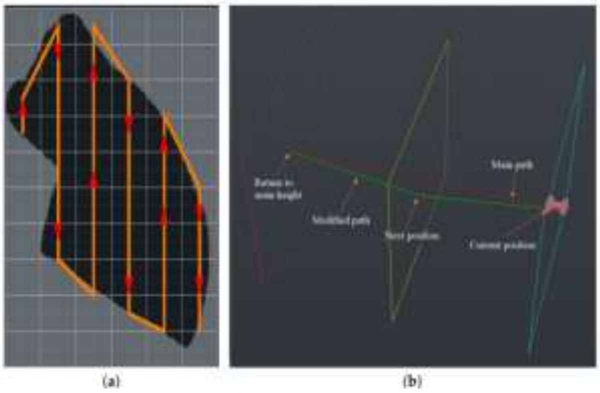
1. 

Fig.4. a) Area of interest from top view. b) A front section with the obstacle is denoted by red line to indicates the original path followed by green color to represent the fresh path.[5]

The evaluation metrics in the algorithm are 1) Turning angle because it is the one that affects the energy consumption. The Euclidean distance between the vertices results in the turning angle. 2) The total time includes the time required to fly from initial point to final plus the hovering time. The energy optimization is directly proportional to the optimized length of the trajectory and the total time. 3) The power consumption is the energy required to traverse the total path.

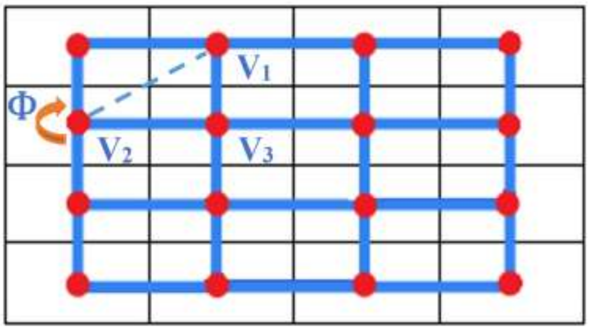


Fig.5. The graphical representation where red line represent the vertices and blue indicatest the edges.[5]

The total energy utilization is given by,

$$E_{total} = E(T_{total}) + E(\Phi) = \sum_{i\in V}\sum_{j\in V}\lambda e_{ij} + \sum_{i\in V}\sum_{j\in V}\sum_{k\in V}\gamma\frac{180}{\pi}\Phi_{ijk}$$

γ is the utilized energy per angle degree. λ is the utilized energy per unit distance. λ = 0.1164 KJ/m and γ = 0.0173 KJ/degree is assumed in this algorithm. The energy required to move in turns is denoted as E(Φ). eij = d(vi , vj) is Euclidean distance between the vertices denoted as vi, vj respectively. The Vertices in a graph-like construction G(V, E) has the list of vertex and edges represented as V and E respectively. Energy consumption E_{total} in KJ is 142.12.

	The Basic Approach	Energy aware obstacle avoidance
Route length T in meters	507.003	486.514
UAV speed v in m/s	8	8
Turns in degree	1476	1107
Rotation rate ω in degree/s	30	30
Completion-time τ in sec	112.575	97.714
Energy consumption E_{total} in KJ	84.551	75.782

So compared to the rest of the approaches, the obstacle avoidance in 3D with energy aware grid based technique has better approach in solving energy consumption problems and the results of the algorithm stands efficient to bring out lesser energy consumption.

III. CONCLUSION

The paper analyzes the taxonomy of 3D path planning algorithms which take energy into consideration. From the survey it is understood that the energy aware techniques on grid based cellular decomposition approach with the three dimensional coverage is effective. The approach exploits the energy model to fix a favorable rate for every section of the travel. The model also looks into minimizing the power utilization while satisfying the other parameters like coverage, turning angle and completion time. In future, researchers can boost the efficiency of these energy aware algorithms by putting in better optimization techniques by the dynamic and faster programming methodologies. The better algorithm powered UAV can have its applications in disaster management, community mobilization to improve health levels or to address humanitarian challenges during the natural calamities and epidemics/pandemics with improved efficiency.

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