Scheduling of UAV Using Predefine UAV Regions and Using Battery Utilization in Previous UAV Mission

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Abstract

This paper proposes approach of scheduling UAV (Unmanned Arial Vehicle) by its region and by calculating maximum flying distance that is based on battery consumed in last mission. Regions are made to achieve parallel motion of UAV and maximum distance is used to check if mission distance is achievable or not. A robust model is introduced to find maximum distance UAV can cover and which UAV is better for mission. Another model is use to find in which UAV region designated point falls. Before accepting destination point UAV check the maximum fly distance and accordingly takes decision. Actual and simulated results show feasibility of the proposed approach.

Introduction

One of the biggest innovations of this century has to be drones. They became so popular, that nowadays, they are being used in almost every sphere of life. From security to entertainment, drones have become an integral part of our life. Just like any other thing, it also needs a food source to keep on going and herein comes the beating heart of this device: the drone batteries.

Batteries are responsible for feeding the drones the power to perform. Each drone according to the application has a different battery capacity. So, the power source selection depends on various factors like the flying time required, weight of the drone, overhead power required for the application specific devices like cameras, etc.

Battery Endurance

In our drone system each drone has a 3S (3 Li-ion cells in series) battery with 3000 mAh,12 V. The maximum charging is 12.6 V above which it gets permanently damaged. We can't use the battery pack to its full capacity till it gets empty. The lower voltage till which battery can be used is around 10.8 V. So, each cell can charge maximum up to 4.2 V and discharge till 3.6 V.

According to the calculation the battery voltage which is usable for drone operation is around 2 V. In Drone scheduling application which uses multiple drones to complete a certain task, each drone may have a different battery voltage at given instance **t**. Some batteries may have high discharging rates (∂V) compared to others and vice versa. As the charging and discharging cycles for the battery increases its storage capacity decreases. To overcome the issues of battery difference, a term called ***BATTERY CONSTANT*** is used to find the maximum distance which can be covered by the drone in the available battery. The term battery constant is denoted by $\boldsymbol{\alpha}$. Battery Constant for a drone is defined as the battery consumed by the drone to cover 1 m distance. i.e. Battery Gradient.

Assumptions done for calculation of $\boldsymbol{\alpha}$:

- Wind speed is not considered. If the region is windy the fly time of drones decreases by 2-3 mins. It needs to be considered when flying in windy area.
- Weight of Drone is kept constant. The change in weight increase the thrust required to pick up its weight which in turn affects the battery capacity.
- Drone speed is kept constant. According to the application the drones are used their speeds are kept constant.

Now when the drones are used first, they are scheduled based on the shortest distance between their home and destination coordinates. The flying height for a particular mission is kept constant (20 m). Here the region of each drone is fixed. If the destination falls under their area the drone is available for task completion. If the destination falls under two drone the both drones are available.

After completing the first mission the parameters like initial battery voltage ($\boldsymbol{v_1}$), final battery voltage at the time of LAND flight mode ($\boldsymbol{v_2}$), total distance covered by drone, the flying altitude are required to calculate battery constant $\boldsymbol{\alpha}$.

$$\boldsymbol{\alpha} = \left(\frac{\boldsymbol{v_2} - \boldsymbol{v_1}}{\boldsymbol{D_t}}\right)$$

Where $\boldsymbol{\alpha}$ is battery constant

$\boldsymbol{v_2}=$ Drone (UAV) Battery Voltage Level after landing

$\boldsymbol{v_1} =$ Drone (UAV) Battery Voltage during Takeoff

D_t = Total distance covered by the drone

$\boldsymbol{D_t} = (\boldsymbol{2h} + \boldsymbol{2d})$

Where **h** is the relative altitude of the drone

d = Distance between home and destination

This calculated battery constant value $\boldsymbol{\alpha}$ is stored in a database/file for future fleet management. Now for the next flight the battery constant ($\boldsymbol{\alpha}$) is used to calculate the maximum flying distance for the particular drone keeping the assumptions constant.

$$\boldsymbol{Max\ fly\ Distance} = \left(\frac{v_{takeoff} - v_{threshold}}{\alpha}\right)$$

Where,

V$_{\textbf{takeoff}}$ = Battery voltage before takeoff from ground station.
V$_{threshold}$ = Minimum voltage under which battery gets discharged and require a charging.
Ideally V$_{threshold}$ = 10.8
The $\boldsymbol{\alpha}$ value is read from the file in which it is saved from previous flight.

This value of Max fly distance is unique for each drone according to its battery constant and the battery before takeoff. The Max fly distance is published by the ground control station (GCS) for each drone.

Defining area of drones

To cover maximum area with minimum drones we assign an area to each drone. this area is predefined. area define maximum approach of each drone. area can draw using great circle formula and We can manually take location coordinate of area. Or we can get the circular area with defined radius. The destination occurs in multiple drone region. Because area of the drones is overlap on some region. The area where region is overlapping their multiple drones can go then we decide priority of capable drones. Multiple or single drone can go to that point according to user or work of drone.

Formula to define area

$$\boldsymbol{Lat2 = asin(sin(lat1) * cos(d/R) + cos(lat1) * sin(d/R)cos(bearing))}$$

$$\boldsymbol{Lon2 = lon1 + atan2(\sin(bearing) * \sin\left(\frac{d}{R}\right) * \cos(lat1), \cos\left(\frac{d}{R}\right) - \sin(lat1) * \sin\ (lat2))}$$

Where **lat1** is latitude of home coordinate
lon1 is longitude of home.
Bearing is clockwise from north
d is distance of curve and
R is radius of earth.

This will give the destination point and final bearing travelling along a great circle.

When destination point is received, we check under which drone area does it fall. After getting destination point, we compare destination point with points of circumference of region. And decide whether the point is under one UAV or multiple UAV. Then we get the most Efficient UAV which can complete the task. If multiple UAV are need to be scheduled one needs to tackle the collision issue and further, they are scheduled.

Scheduling

The GCS of each drone continuously publishes the heart bit, its own ID, home coordinates and battery voltage. The messages are published on a publishing node.

These published messages are continuously listened by the schedular node. This node keeps record of all the parameters required for scheduling. The schedular need to know the number of drones available for task allocation. It makes a list of Drone Id available.

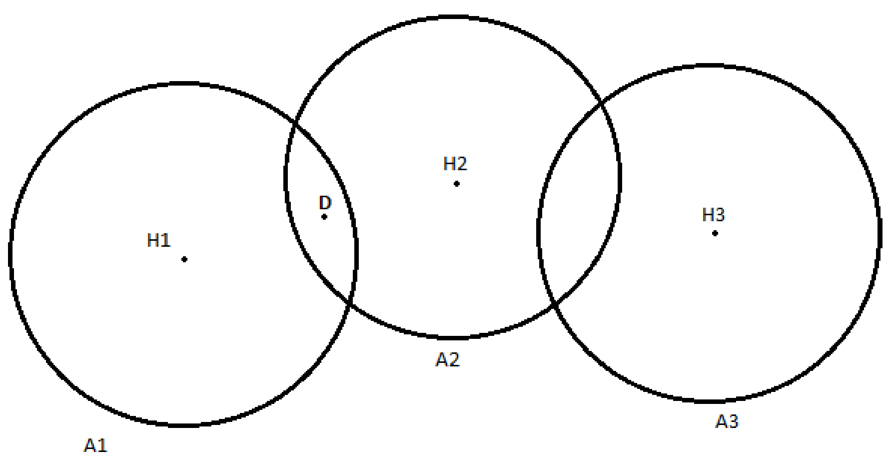
Now the schedular takes the destination coordinates and calculate the distance between home and destination for each drone separately. Further the schedular calculate the parameter called backup distance which is defined as the maximum distance which can be covered by drone before battery falls below threshold voltage.

$$\boldsymbol{backup\ distance} = \mathbf{max}\,\boldsymbol{fly\ distance} - \mathbf{2}(\boldsymbol{d} + \boldsymbol{h})$$

d = Distance between home and destination coordinate

h = The flying height

The schedular gets the Drone Id's under which the destination falls.



Here H1, H2, H3 are the home position for the UAV's and A1, A2, A3 are the area covered by them respectively. D is the destination point which falls under Drone Id 1 and Drone Id 2. The schedular further asks the number of drones to send to the required position. Based on the scheduling algorithm the best and most efficient drone is sent first, followed by others if required.

Here in above example the destination point D falls exact in between two drones. So, by comparing the backup distance for each drone available the decision is taken. Drone with max backup distance are prioritized over others.

Further the schedular publishes the Drone Id and the fly height. The GCS subscribes the schedular node and reads the Drone Id, height. The script Drone Id runs on the GCS for each drone separately and compare its Drone Id with the received Drone Id. If the instruction is for the Drone further commands are sent using telemetry.

Conclusion: