Pre-flight Battery Consumption Model for UAV Missions

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Abstract

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***K*eywords** Unmanned Aerial Vehicle · UAV · Drone · Battery · Battery Consumption · Battery Usage · Predict

1 Introduction

In recent years, unmanned aerial vehicles (UAVs) have become increasingly popular in non-military contexts. As their technology improves, these devices become more and more integrated into society as they allow for tasks to be easily completed by a user in a remote location along a route. For example, Amazon and other distribution companies are developing methods that use these devices to deliver packages to their users in a fast and simple manner. As drones become more effective at delivering packages, they can replace trucks on short, relatively light deliveries, which will reduce the total amount of carbon dioxide emissions and have a positive impact on the environment [**?**]. This technology is not limited to the aforementioned companies, instead, it is also used by archeological sites and other sports companies to conduct surveillance missions for certain dig sites where a camera might not be the best choice, or at a football game. Police forces also have begun to use these UAVs in situations where it is not entirely safe to send in an officer. By allowing that officer to remotely control a drone, it allows them and many others to be safe.

One of the many things holding UAVs back from doing such things is the simple fact that the battery usage is not easily predictable. By having the ability to know how much battery a given drone will consume can put the user at a much greater advantage as they can now determine whether or not a certain flight mission is feasible. Going back to the previous example with Amazon, their delivery drones may not always be charged to maximum capacity, therefore, if they can see how much battery a delivery will take up, then they can determine whether or not a different drone or a battery replacement will be required. Up until now, most UAV software can only communicate to the user how much battery is remaining in real time, and while that may be enough for most users, in some situations—like the one mentioned previously—it is important to know how much will be consumed before the UAV leaves the ground.

While there have been a few attempts at creating such a model, there has not been a successful method that results in an accurate or efficient prediction. This is partially due to drones being relatively new, having only been introduced in the past few years, and as a result, not much research has been conducted. It is from this lack of literature that many have had difficulty creating a functional model. Specifically, one of the assumptions made about these drones is that the total battery energy consumption is constant from flight-to-flight [1], however, through various data samples, this is not the case; it is variable. This and many other assumptions make up some of the shortcomings in existing literature, that if not proven correctly, can result in a considerable setback in the UAV field.

2 Related Work

With very few pieces of literature in the spectrum of UAV battery consumption, there were a select few that stood out. Previous attempts at creating a similar model have attempted to separate the maneuvers a UAV performs during its flight into separate categories such as vertical, hover, and horizontal movements [1]. Others took a more detailed approach and had back, down, forward, roll left, roll right, up, yaw left, and yaw right [3]. Although these two studies were not entirely successful, they were still able to provide motivation to isolate the maneuvers into ascending, descending, hovering, and any horizontal movement.

As previously stated, these studies come with slight caveats. For the case of the detailed maneuver model, the data they collected on their quad-copter showed surprising results as shown in Figure 1. Here, they were able to map the current in Amps being drawn by each maneuver and deduced that down and roll left consumed little to no battery; up consumed the most; back, forward, roll right, yaw left, and yaw right consumed an amount in between the others. There are some aspects of this finding that raised concern, for example, roll left consumed a minuscule amount of current whereas roll right consumed much more. This puts roll left on the same level as moving down which seemed questionable.

2.1 Improvements

After collecting data from several flights, there was no similar pattern to that of their original findings, therefore, leading to the conclusion that roll left did not consume less power than roll right. Additionally, another finding in the data set showed that the differences in power consumption between all maneuvers in the horizontal plane were minute, thus allowing the classification of maneuvers to only include ascend, descend, hover, and horizontal movement. However, it is important to note that the UAV they used had four total rotors (quad-copter) while the one used primarily in this project had six rotors (hexa-copter) which could lead to a difference in results.

3 Methods and Procedure

intro stuff just talking, blah blah blah

Maybe put the methodology stuff in here

3.1 Data Collection

jfkladjflas

3.2 Machine Learning

This is all the machine learning and stuff

3.3 Power Statistics

This is all the power statistics and stuff

4 Results and Discussion

4.1 Machine Learning

4.2 Power Statistics

$$\xi_{ij}(t) = P(x_t = i, x_{t+1} = j | y, v, w; \theta) = \frac{\alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})}{\sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})} \tag{1}$$

5 Conclusion

References

[1] A. S. Prasetia, R. Wai, Y. Wen, and Y. Wang, "Mission-based energy consumption prediction of multirotor uav," *IEEE Access*, vol. 7, pp. 33055–33063, 2019.

[2] Y. Chen, D. Baek, A. Bocca, A. Macii, E. Macii, and M. Poncino, "A case for a battery-aware model of drone energy consumption," pp. 1–8, 10 2018.

[3] L. Corral, I. Fronza, N. El Ioini, and A. Ibershimi, *A Measurement Tool to Track Drones Battery Consumption During Flights*. 01 2016.

6 LaTex Examples

6.1 Previous Research

Previous research

Equation Example:

$$\xi_{ij}(t) = P(x_t = i, x_{t+1} = j | y, v, w; \theta) = \frac{\alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})}{\sum_{i=1}^{N} \sum_{j=1}^{N} \alpha_i(t) a_{ij}^{w_t} \beta_j(t+1) b_j^{v_{t+1}}(y_{t+1})} \tag{2}$$

Paragraph The Mentioned paragraph continues onto muliple lines it is a paragraph after all. What else do I write? I don't know

When you have a paragraph you can also cite it. [1] and see [2] and see [3].

And for a URL, the documentation for `natbib` may be found at

`http://mirrors.ctan.org/macros/latex/contrib/natbib/natnotes.pdf`

Of note is the command `\citet`, which produces citations appropriate for use in inline text. For example,

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\citet{hasselmo} investigated\dots
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produces

> Hasselmo, et al. (1995) investigated…

`https://www.ctan.org/pkg/booktabs`

6.2 Figures

See Figure 1. Here is how you add footnotes. [1] See Section 6.

6.3 Tables

See awesome Table 1.

References

[1] A. S. Prasetia, R. Wai, Y. Wen, and Y. Wang, "Mission-based energy consumption prediction of multirotor uav," *IEEE Access*, vol. 7, pp. 33055–33063, 2019.

[2] Y. Chen, D. Baek, A. Bocca, A. Macii, E. Macii, and M. Poncino, "A case for a battery-aware model of drone energy consumption," pp. 1–8, 10 2018.

[1] Sample of the first footnote.

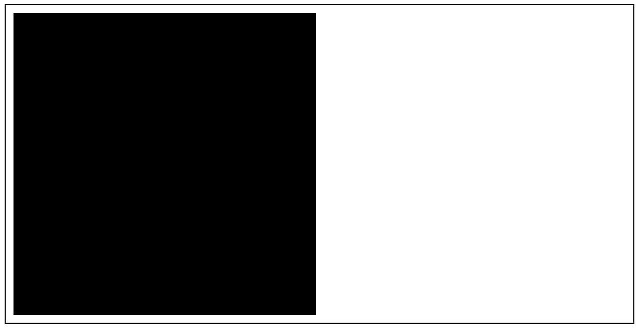

Figure 1: Sample figure caption.

Table 1: Sample table title

Part		
Name	Description	Size (μm)
Dendrite	Input terminal	$\sim$100
Axon	Output terminal	$\sim$10
Soma	Cell body	up to 10^6

[3] L. Corral, I. Fronza, N. El Ioini, and A. Ibershimi, *A Measurement Tool to Track Drones Battery Consumption During Flights*. 01 2016.