Constructing a power model for mission based modular designed quadcopters

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Introduction

Predictability in power consumption is crucial in mission success. Power consumption models have applications in both the military and private industry. For example, they can be used to calculate the battery life of mission critical equipment. The purpose of this study was to create a power model that could predict the power consumption in mission–based modular designed UAVs and quadcopters. Multiple previous studies have been done related to aerodynamics, air pressure, stability, and durability of UAVs, however, very few studies have tested battery life and how it is affected by the components found on a UAV. At the International Conference on Autonomous Robot Systems and Competitions, Franco and Buttazzo "proposed an algorithm to divide an area of land into sections, taking into account UAVs relative capabilities and initial locations to measure a quadcopter's power consumption with the qualities of the photos divided in these areas" (2015). The method used in Franco and Buttazzo's study measured power consumed by a UAV used to take photos, much like the method proposed in this research, however, the measured variables are different. The primary variables that were focused on in this study were the mass, climb rate, air speed, acceleration, absolute values of pitch and roll.

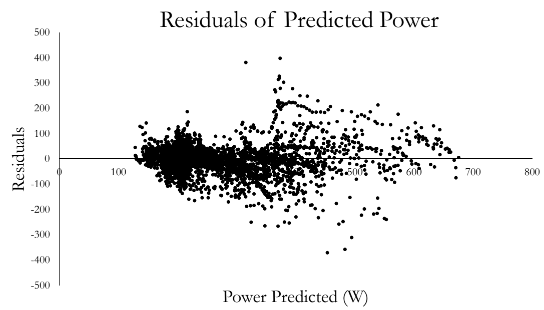
Materials and Methods

The materials used for this study were a pre-made Pixhawk 3D printed quadcopter designed by John Gerdes, a ground station, and a Raspberry Pi. The quadcopter collected data while the ground station collected and analyzed the results. Data was collected through flights using Mission Planner, a GPS system used for autonomous flight, and manual flights that followed the same path (Figure 1). Pixhawk, a GPS tracking system, was used to record the flight data, in the form of Log data, to include the six variables analyzed in this research. "All data was set into raw Log form, ready for analysis" (Bemporad, Pascucci & Rocchi, 2009). Data was collected through Mission Planner, processed through MATLAB, and analyzed through JMP. Data was merged into a master file so a power model could be made using the combined results from all tests. A total of 20 test flights were completed, ten manual and ten autonomous.

Materials and Methods (cont.)

Figure 1 (above): Displays the flight path designed in Mission Planner. Each autonomous test followed the same path. In each test, different variables were measured to see how they affected the battery. As for the manual tests, they followed the same path shown above.

Results



Graph 1: A plot of residuals based on the predicted power model.

$$-143.658 + 0.22123\,\mathit{Climb\ Rate} + 1.78560(\mathit{Speed} - 6.92052)(\mathit{Speed} - 6.92051) + 1.13502(|\mathit{Pitch}| - 10.7811)(|\mathit{Pitch}| - 10.7811) + 0.157895\,\mathit{Mass} + 0.00016(\mathit{Climb\ Rate} - 7.69507)(\mathit{Climb\ Rate} - 7.69507) - 0.927852\,\mathit{Speed} + 0.00004(\mathit{Mass} - 2165.15)(\mathit{Mass} - 2165.15) + 0.57245|\mathit{Roll}| + 1.54137|\mathit{Pitch}| + 0.08056(|\mathit{Roll}| - 3.94424)(|\mathit{Roll}| - 3.94424)$$

Figure 2: The power prediction model.

Results (cont.)

The six variables were used to generate 69 parameters to create a power predicting model. However, only ten were selected for the power model. Graph 1 shows the residuals between the predicted and actual power based on the ten selected parameters. A perfect model would have each data point clustered on the *x*-axis. With a root-mean-square error of 38.713 W, there was an R^2 value of 0.747. To determine which parameters were most significant in the model, a stepwise function was used to analyze the Bayesian Information Criterion (BIC). The BIC was used find the optimal combination of parameters. The lowest BIC value was calculated at ten parameters (Figured 2). The use of the BIC allowed for an analysis with fewer parameters.

Conclusion

The project was successful as the objective of creating a power model using flight test data was achieved. Data collection was not perfect as environmental conditions did affect the overall results. Issues discovered after data collection indicated a revolutions per minute (RPM) sensor should be added for future testing to each of the quadcopter's four motors. However, due to time constraints it was not possible to install the sensors and rerun trials in the scope of this research. The power model presented in this research was created without the use of RPM sensors, whereas a more accurate power model could be researched in a future study with the use of the RPM sensors. The same methodology in terms of data collection and parameter analysis would be used, considering the eight additional parameters monitored with the four RPM sensors.

References

Bemporad, A., Pascucci, C., & Rocchi, C. (2009). Hierarchical and hybrid model predictive control of quadcopter air vehicles. *IFAC Proceedings Volumes, 42*(17), 14–19. doi:10.3182/20090916–3–es–3003.00004

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