**Simulation Modeling of Recreational-Use Battery Consumption Tracking for the DJI Tello Quadcopter**

Green Computing Course Project Proposal

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1. **Abstract**

Drones are an increasingly large market in the United States. Their popularity has seen rapid growth in many industries, particularly in recreation. The National Conference of State Legislatures reported an astonishing 1.1 million registered recreational drones in March of 2023 [1]. However, this only includes drones required to be registered with the FAA and excludes a lot of smaller drones such as the DJI Ryze Tech Tello Quadcopter, which has been selected for this proposal. Such drones often come cheaper and require less advanced piloting skills. Coupled with the popular DJI technology, drones like the Tello have become increasingly popular for a younger, more inexperienced populace. As drones such as the Tello become increasingly prevalent, the need for efficient battery consumption tracking systems becomes paramount. This report explores an innovative approach of tracking battery consumption of the Tello drone in simulation flights. It underscores the critical role of this metric in maximizing flight performance and operational capabilities, aiming to give new drone operators the option to use their drones more effectively and efficiently. The goal is to provide a package that can be integrated into a variety of drone flight systems to allow for energy and battery tracking for optimal energy efficiency should the user wish to do so.

1. **Introduction**

Efficient battery tracking in drones plays a pivotal role in optimizing flight performance, ensuring regulatory compliance, and enhancing operational efficiency. This report brings to light a solution that signifies the importance of monitoring battery consumption during various drone maneuvers, utilizing battery consumption data to demonstrate the impact of different flight scenarios on energy usage. With the right information provided to a drone operator, flight paths and maneuvers could be taken to increase the operability of the system. Research conducted by the United Kingdom Department of Research and Innovation demonstrated the impact that effective energy efficient usage of drones can have. They found that through proper measures, not only would drones be more sustainable, but they had the capacity to reduce the cost of maintenance by around 30% [2]. Such numbers emphasize the practicality of such a solution, and with an implementation, operators would gain more than they lose. Previous works have used many approaches for calculating drone energy consumption, but few allowed for user interaction. By introducing a solution where users can fly their drones with minimal interference from the battery tracking module, but still gain the necessary information for positive feedback, we open the door to a greener future for recreational drones.

1. **Problem Statement**

The project focuses on addressing several key challenges that most drone flight systems do not provide:

* Efficient tracking of battery consumption during drone flights.
* Optimization of flight paths and maneuvers for energy efficiency.
* Providing users with real-time feedback on energy consumption to make informed decisions.

Effective battery management is crucial for maximizing flight time and enhancing overall user experience. By implementing this robust battery consumption tracking system, drone operators can better track their energy usage without impeding the actual flight of the drone. This system allows drone operators to make a decision in the process, and they are not required to utilize any provided benefits such as optimal flight maneuvers or tracking battery usage of individual maneuvers.

1. **Solution**

The implemented solution involves many parts, listed below:

1. Conducting extensive testing with the DJI Tello Quadcopter to track battery consumption during various maneuvers.
2. Developing a Tello Drone Simulator to simulate real-world flights and approximate battery usage.
3. Integrating real-time energy consumption notifications and visualization tools to provide users with actionable insights.
4. Delivering a comprehensive battery consumption report after each simulation flight, including optimization strategies and performance metrics.
5. **Experimentation**

**Step 1: DJI Tello Quadcopter Flights and Data Collection and Analysis**

To comprehensively understand the energy consumption dynamics of the DJI Tello Quadcopter, our chosen test drone, an extensive series of 100 test drone flights were conducted. Each flight involved executing various maneuvers, including takeoff, landing, altitude changes, directional movements (forward, backward, left, right), rotational movements (clockwise, counterclockwise), flips, and combinations of these actions. The ‘up’ feature was not properly tested, as it was forgotten in all drone flights, and so averages were hardcoded into the algorithm to make up for the inconsistency. During these flights, data was meticulously recorded on battery consumption for each maneuver. This data included metrics such as initial battery level (which was always set at 100%), battery consumed per maneuver, and total flight duration. The goal was to capture a diverse range of flight scenarios to cover real-world usage patterns and challenges faced by drone operators. The one downside of the tests was the flight times and durations were not saved in the data csv’s, which limited the capabilities of the data.

Upon completing the flights, the collected data was analyzed to derive insights into energy consumption patterns. We calculated average battery consumption rates for each maneuver, identifying energy-intensive actions and their impact on overall flight performance. This analysis formed the basis for developing optimization strategies and evaluating the effectiveness of different flight scenarios.

**Step 2: The Drone Simulator**

The Tello Drone Simulator developed for this project is a tool designed to replicate real-world flight experiences and facilitate user interactions for optimization exploration, similar to experiences found on real drone applications. The simulator encompasses several key features:

**User Interface**: The simulator was developed with an intuitive and user-friendly interface that allows users to input flight commands, set destination coordinates, and visualize drone movements in real time. The interface includes interactive elements such as buttons for takeoff, landing, directional movements, rotations, flips, and custom flight paths. It also displays the best movements based on the input destination coordinates.

**Flight Scenario Customization**: Users have the flexibility to customize flight scenarios by selecting specific maneuvers, adjusting flight parameters (e.g., altitude, speed), and setting destination coordinates for navigation. This customization capability enables users to simulate diverse flight scenarios tailored to their needs. Users are also not required to input a destination in the case they want to just fly around and see how their battery is used with each maneuver. Doing so however, will remove the capability of using the “next best move” feature.

**Real-time Feedback**: The simulator provides real-time feedback on battery consumption and optimization suggestions. Users receive notifications and visual indicators highlighting energy-intensive maneuvers, optimal flight paths, and potential performance enhancements. However, since A-Star wasn’t properly implemented and Euclidean distance is used in the algorithm itself, the most ideal flight paths will utilize the same amount of energy. However, using a more sophisticated algorithm such as A-Star would make this solution far more robust.

**Visualization Tools**: Visualizations play a crucial role in enhancing user experience and understanding. The simulator incorporates 3D visualizations of drone movements, flight paths, battery status, and energy consumption metrics. This capability is solely for pretrained data and is not a feature that is implemented in the Drone Simulator GUI. Graphical representations aid in comprehending complex flight dynamics and optimizing energy usage.

**Data Logging and Analysis**: The simulator logs detailed data during simulation flights, including battery consumption per maneuver, flight duration, distance traveled, and performance metrics. This data logging facilitates post-flight analysis, performance evaluation, and iterative improvement of optimization strategies. In an ideal situation, this data can be used to improve flights to reduce the battery consumption cost.

**Optimization Exploration**: Users can explore optimization strategies by testing different flight scenarios, adjusting parameters, and analyzing the impact on battery consumption and flight performance. The simulator is designed to encourage experimentation and with the correct pretrained average battery consumption data, can be used for any drone with varied power capabilities.

1. **Results and Findings**

The simulator delves into a comprehensive analysis of battery consumption patterns during various drone maneuvers using the DJI Tello Quadcopter. Through 100 test drone flights that explored different maneuvers and their battery consumption metrics, detailed insights were gained into the energy consumption rates for actions like takeoff, landing, directional movements, rotations, and flips. This analysis led to the calculation of average battery consumption, providing a solid foundation for testing purposes and optimization strategies.

One of the key outcomes of the project was the identification of energy-efficient optimization strategies aimed at maximizing flight duration while minimizing battery usage. These strategies, developed based on simulation flights and data analysis, included optimizing flight paths, adjusting altitude and speed parameters, and implementing energy-saving techniques during drone operations. Comparative analysis of these optimization approaches demonstrated their impact on overall drone performance, showcasing improvements in flight stability, maneuverability, response time, and energy efficiency metrics.

User feedback played a pivotal role in evaluating the simulation and monitoring tools' usability and functionality. Users, composed of various friends testing the interface, provided valuable insights into the tools' ease of use, practicality, and impact on decision-making during drone operations. The simulation's visualizations, including 3D flight path visualizations, energy consumption graphs, and performance dashboards, facilitated clear insights into drone behavior, energy usage trends, and optimization outcomes. Overall, the project's results demonstrated the tangible benefits of effective energy consumption tracking, optimization strategies, and simulation tools in enhancing drone performance, extending flight durations, and promoting sustainable and efficient drone operations.

To verify the effectiveness of our solution, we conduct detailed experiments and deliverables that demonstrate the impact of our methodology:

We conduct a series of simulation flights using the Tello Drone Simulator, capturing data on energy consumption for different flight scenarios. These flights represent typical recreational drone activities, such as takeoffs, landings, maneuvers in various directions, and flips. Through comprehensive energy consumption analysis, we quantify the battery usage associated with each action. During the simulation flights, users interact with the simulator to explore optimization strategies for energy-efficient flying. They experiment with different flight paths, adjust speeds, and minimize unnecessary movements to conserve battery life. User feedback and observations during these interactions provide valuable insights into user behavior and preferences regarding energy management.

We compare the performance metrics of simulated flights with varying optimization strategies. By measuring metrics such as total flight time, distance covered, and battery usage, we assess the effectiveness of different approaches in maximizing flight duration and minimizing energy consumption. With the limited time, such measures were unable to be analyzed to develop special considerations in the algorithm to take into account.

The deliverables from our experiments include detailed reports on energy consumption patterns from the 100 test flights, optimization strategies based on the average consumption per maneuver, and performance metrics. These reports provide actionable insights for drone operators, which are integrated into our simulation and would ideally be implemented into real drone control software to enable users to make informed decisions about flight planning, energy management, and operational efficiency. Additionally, we generate visualizations and graphs to illustrate key findings and trends in energy consumption data. By following this conclusive experimental verification process, we ensure the reliability and effectiveness of our solution in addressing the problem of energy-efficient drone operations.

1. **Conclusion and Future Work**

In conclusion, the project successfully addressed the challenges of battery consumption tracking for recreational drones, particularly with the DJI Tello Quadcopter. The developed solution provides valuable insights for drone operators to optimize energy usage and enhance flight performance. Future work would include expanding the simulation capabilities, integrating algorithms for more effective energy and path modeling, and debugging to allow for more capabilities.

1. **References**
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