Wind Awareness for Energy Consumption in Drone Simulations (Demo Paper)

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Abstract

Drone simulators are often used to reduce training costs and prepare operators for various ad-hoc scenarios, as well as to test the quality of algorithmic and communication aspects in collaborative scenarios. An important aspect of drone missions in simulated (as well as real life) environments is the operational lifetime of a given drone, in both solo and collaborative fleet settings. Its importance stems from the fact that the capacity of the on-board batteries in untethered (i.e., free-flying) drones determines the range and/or the length of the trajectory that a drone can travel in the course of its surveilance or delivery missions. Most of the existing simulators incorporate some kind of a consumption model based on different parameters of the drone and its flight trajectory. However, to our knowledge, the existing simulators are not capable of incorporating data obtained from actual physical measurements/observations into the consumption model. In this work, we take a first step towards enabling the (users of) drones simulator to incorporate the speed and direction of the wind into the model and monitor its impact on the battery consumption as the direction of the flight changes relative to the wind. We have also developed a proof-of-concept implementation with DJI Mavic 3 and Parrot ANAFI drones.

CCS Concepts: • **Computer systems organization** → **Embedded and cyber-physical systems**; • **Computing methodologies** → **Modeling and simulation**; • **Information systems** → **Information systems applications**; **Spatial-temporal systems**.

Keywords: surveillance, drones, simulation, battery lifetime

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1 Introduction and Motivation

In the recent years, Unmanned Aerial Vehicles (UAVs) – often sinonymously called drones – have experienced extreme popularity gains both in terms of research as well as use in various civilian and military applications [6], spanning through domains of geographic area monitoring and surveying, search and rescue mission, transport, target detection, etc. [8]. Abstracting away the specifics of a particular application, the targeted phenomena can be analyzed from three different perspectives (cf. [3]): (1) *Material* – focusing on the nature, location and purpose of a particular object; (2) *Functional* – utilizing material features for the purpose of interpreting processes, "footprint" changes, and other status-evolution; and (3) *Symbolic* – where the surveyed features are classified into elements of interest, and are used to generate a subsequent action in response to a detection. Often times, the analysis requires collaboration among multiple drones [5].

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A pressing problem in the research and development of drones (in addition to the context-awareness of the mission) is the lack of standardization of flight controller architectures and the use of proprietary closed-source flight controllers on many UAV platforms [4]. To avoid the overheads of development and testing, often times open-source flight controllers are used to validate and build upon existing research. However, as the domain of use of UAVs have become more diverse, their operating environments are covering a spectrum ranging from dangerous (e.g., disaster management, military missions) to heavily constrained (e.g., urban delivery, precision farming, power-line inspection) settings. Testing in such scenarios may reveal unforeseen problems in communication, aerodynamics features, power consumption, etc. – which could incur heavy cost/losses. This, in turn, necessitates that use of simulation to ensure conformation to the viability standards before finalizing a design and having the drones airborne [7].

An important component affecting the operational characteristics of UAVs in any application domain is their operational lifetime – i.e., how long can the on-board battery [1] support the flight of drone. This, in turn, is often dependent on environmental factors, in particular, the wind speed and direction, coupled with the operational characteristics of a particular drone as well as its mission-dictated trajectory. While certain simulators may include *model-based* selection of parameters for a particular simulation – the specific goal of this work was to investigate the question *can actual field-based measurements of drones battery consumption be incorporated in UAV flight simulators*. To this end, we have developed a proof-of-concept implementation with the following properties:

- We used actual drones (Parrot ANAFI and DJI Mavic 3) that were flown under different weather conditions for multiple hours and in varying directions, to have factual data regarding the battery consumption based on relative directions of the drones' trajectories and wind, as well as the respective speeds.
- We have developed a desktop application that allows users to input the desired drone configurations and flight paths for surveillance to be used in a simulation.
- We augmented the simulator with the option to select the wind direction and speed from a server, integrate it with the drones' flight plans and display the changes in the battery consumption along the flight.

In the rest of this paper, Section 2 describes the system architecture and the process of data gathering for developing battery consumption models, Section 3 describes the steps for demonstrating the functionalities of our system, and Section 4 presents concluding remarks and outlines directons for future work.

[1]For untethered drones – i.e., drones without any physical cable connecting them to a power source[3].

2 System Aspects

The base application for this project was Microsoft AirSim (https://microsoft.github.io/AirSim), using Unreal Engine 4 simulator for cars and drones. This simulator with multiple Python APIs that can control the movement of the drone motion (e.g., hover, move in a direction with a given speed, etc.) as well as other parameters such as wind velocities and weather conditions (e.g., rain).

The two selected drone types were:

- DJI Mavic 3: with 46 min. maximum flight time, 15km transmission range and 5000 mAh LiPo battery, and improved obstacle avoidance.
- Parrot ANAFI: programmable model with 25 min. maximum flight time, 4km transmission range, and 1700mAh LiPo battery.

During multiple (over 100) hours of actual flight-testing (cf. Figure 1 we followed the guidelines provided by the FAA [1, 2] for which proper registration and training was conducted.

Figure 1. Drone flight testing

During the flight, we were recording the wind speed and direction, and varied both the drone speed and its relative direction with respect to the wind in three different modes: hover, constant speed horizontal flight, constant speed with ascending and descending flights. The battery charge was measured both before the flight and after its completion. Using the stored measurements, we subsequently generated graphs and derived (approximation) equations, which are illustrated in Figure 2 (for DJI Mavic 3) and Figure 3 (for Parrot ANAFI).

The Unreal Engine 4 was where the actual simulation of the drone (and its environment) executed. It enabled displaying the relevant UI information including the drone model, wind velocities, weather conditions, and the remaining battery life of the drone. The features involving Unreal were

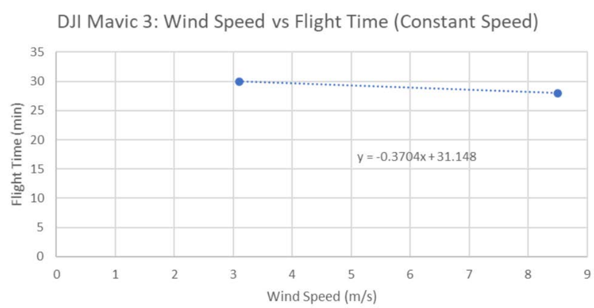

Figure 2. Battery Expenditure Modeling – DJI Mavic 3

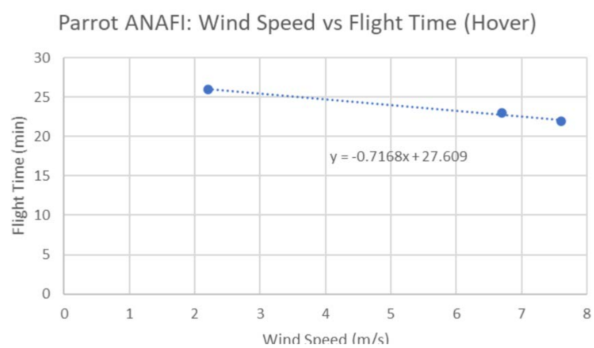

Figure 3. Battery Expenditure Modeling – Parrot ANAFI (hovering)

built using the default blocks environment that comes with downloading AirSim from the Git repository. We used three main components:

1. *Widget blueprint* with a Designer tab determining the main UI components and the Graph tab to enable the scripting functionality of UI elements (e.g., drone model, wind, weather, and battery UI). Battery progress bar changes colors depending on how full it is: green (battery > 50%), yellow (20% < battery ≤ 50%), red (battery *leq* 20%)
2. *Level Blueprint* to enable custom events that update UI in the widget blueprint and values in the pawn blueprint.
3. *Pawn Blueprint* which controls the aspects of the pawn/player character (i.e., the drone), such as the battery life value is associated with the pawn (potentially allowing multiple drones to fly with their own related battery information), along with the changes made to the battery value (e.g., increment, decrement).

The Python client was responsible for the main functionality of the project. It connected to Unreal and controlled the drone's movement. The client could also adjust wind velocities (in X,Y,Z directions) as well as the weather conditions including the amount of rain and snowfall. In addition, it calculated the remaining battery life of the selected drone model in real time – based on the data collected during the actual drone flights. The main tasks implemented within Python API were threefold:

1. *Battery drainage* The battery value depreciates depending on the selected drone model and the current wind velocities. This module was sending battery UI updates to Unreal whenever the battery level changed in the client.
2. *Drone Trajectory* This module was in charge of moving the drones throughout a given area (for visual effects in the demo, we used Blocks.sln to emulate building environments). The modul can be extended to cater to customized areas of operations.
3. *Wind Conditions* This module enabled changing both the speed (in m/s) as well as the direction of the wind.

The UI updates in Unreal were driven by console commands sent to Unreal by the Python client.

We note that we have conducted multiple testing scenarios, as well as the multiple testing of the software implementation (unit, integration, interface, regression, . . .), and more detailed description can be found in the publicly available document http://sdmay22-33.sd.ece.iastate.edu/docs/33FinalDesignDoc.pdf.

3 Demonstration Scenario

We now provide a detailed description of the demonstration scenarios that the attendees will be able to experience.

The demo will consist of the following four main steps:

1. The users will be able to select a model of the drone (DJI Mavic 3 or Parrot ANAFI).
2. Upon selection of a drone model, the users will be able to choose from multiple time-duration of a particular speed as well as direction (in X, Y, Z coordinate system) of the wind.
3. Subsequently, the users will be able to select a trajectory (i.e., a flight plan) of the drone, including hovering as well as motion along a given direction and with a given speed.
4. Then, the users will be able to see a visualization of the simulation of the drone's flight and the changes in the battery reserves throughout the flight.

An example of the UI that the users will experience is shown in Figure 4, for the DJI Mavic 3 drone model [2].

In addition, we will provide the attendees with the complete view of the recordings of the battery expenditure during actual flights, and the corresponding models used.

[2]We note that a brief video of the UI, including parts of actual drone flights, is publicly available at https://www.youtube.com/watch?v=qwr6wM6oT_M

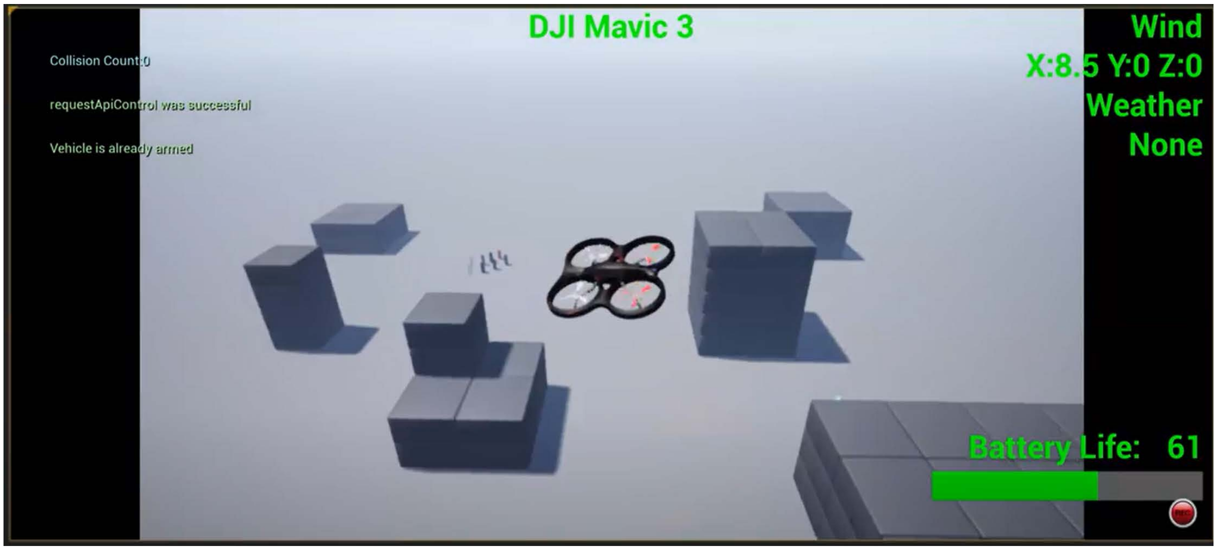

Figure 4. Demo interface

4 Concluding Remarks

This work presented our prototype implementation of a system for UAV flight simulation which extends the traditional simulators by enabling:

- A selection of a particular drone model.
- Use of actual data obtained through real measurements of how the wind speed and direction, and (relative to it) the speed and direction of the drone, to determine the battery consumption.

We note that there exist several works that have tackled the broad problem of drones/UAV simulations [3, 4, 7] and have highlighted the benefits of different approaches, as well as challenges. In this context, our work introduces the aspect of obtaining real measurements, developing corresponding models, and incorporating them into the simulator.

While this is a preliminary proof-of-concept work, we believe that it provides a foundation for incorporating real-life measurements data in drones simulation. One of our immediate extensions is to enable actual measurements for collaborative fleet of drones operation which, in turn, could yield improved testing for energy expenditures in such settings. Our next extension is to incorporate the feature of realistic data measurement of energy consumption due to communication, both among the drones in a fleet, as well as with ground base station, for the purpose of more realistic simulation for such settings.

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