Multi-Package UAV Delivery System

Daniel Lavell, Brandon Luu, Yegeta Zeleke

University of California, Santa Cruz

Hybrid Systems Laboratory

Abstract

For a few years now, delivery companies have been developing a variety of package-delivery systems using drones. Such technologies will most likely be integrated and implemented into fully functioning autonomous Unmanned Aerial Systems (UAS) in the near future. However, the lack of studies on the effect of such a delivery system on the current National Airspace (NAS) traffic is unstudied. Moreover, storage and performance requirements to implement a fully autonomous delivery system have not yet been quantified. In this project we implemented a test bench to that uses terrain, building, and population data to build an environment in which a package delivery scenario may be run using quadcopters. We showed that how number of vehicle per warehouse, how soon the warehouse guarantee the package to be delivered, and on board storage required to run the system.

Figure 1: Example of Package delivery system

Introduction

With growing interest to improve efficiency of package delivery, some companies, such as Amazon, Walmart, and Google, are strongly considering the use of Unmanned Aerial Systems (UAS) as carriers for the packages. In terms of the National Airspace (NAS), the traffic this would induce has been mostly unstudied. The Federal Aviation Administration (FAA) wants to regulate the air traffic in the NAS in the interest of the people. The companies trying to implement this delivery service want to maximize throughput while meeting time constraints. We propose a solution that meets the requirements of both the FAA and prospective companies using a multiple package per vehicle delivery scheme.

Approach

1. Data Collection - In order to simulate a more realistic simulation environment we collected terrain, population, Walmart, and K-12 schools from San Jose. The data was provided from the United States Geological Survey (USGS), United States Census Bureau, Walmart.com, and Schooldigger.com, respectively.
2. Initial Framework - The structure of the simulation focused around which warehouses were chosen to have a delivery fleet. Elevation and obstacles around these warehouses are compiled before the simulation runs.
3. Single Package Delivery - UAS vehicles responded to one package request at a time traversing to the destination and following the same path back to the warehouse.
4. Multiple Package Delivery - After being assigned the first package to deliver, the vehicle waits on the ground until a nearby second package is requested or until there is no more time to wait before missing the time constraint.
5. Analysis - To assess the feasibility of a multiple package per vehicle delivery system, we ran the simulation using both the single and multiple package per vehicle approach comparing the average flight distance, total number of packages delivered, and so as to compare how the vehicle would perform.

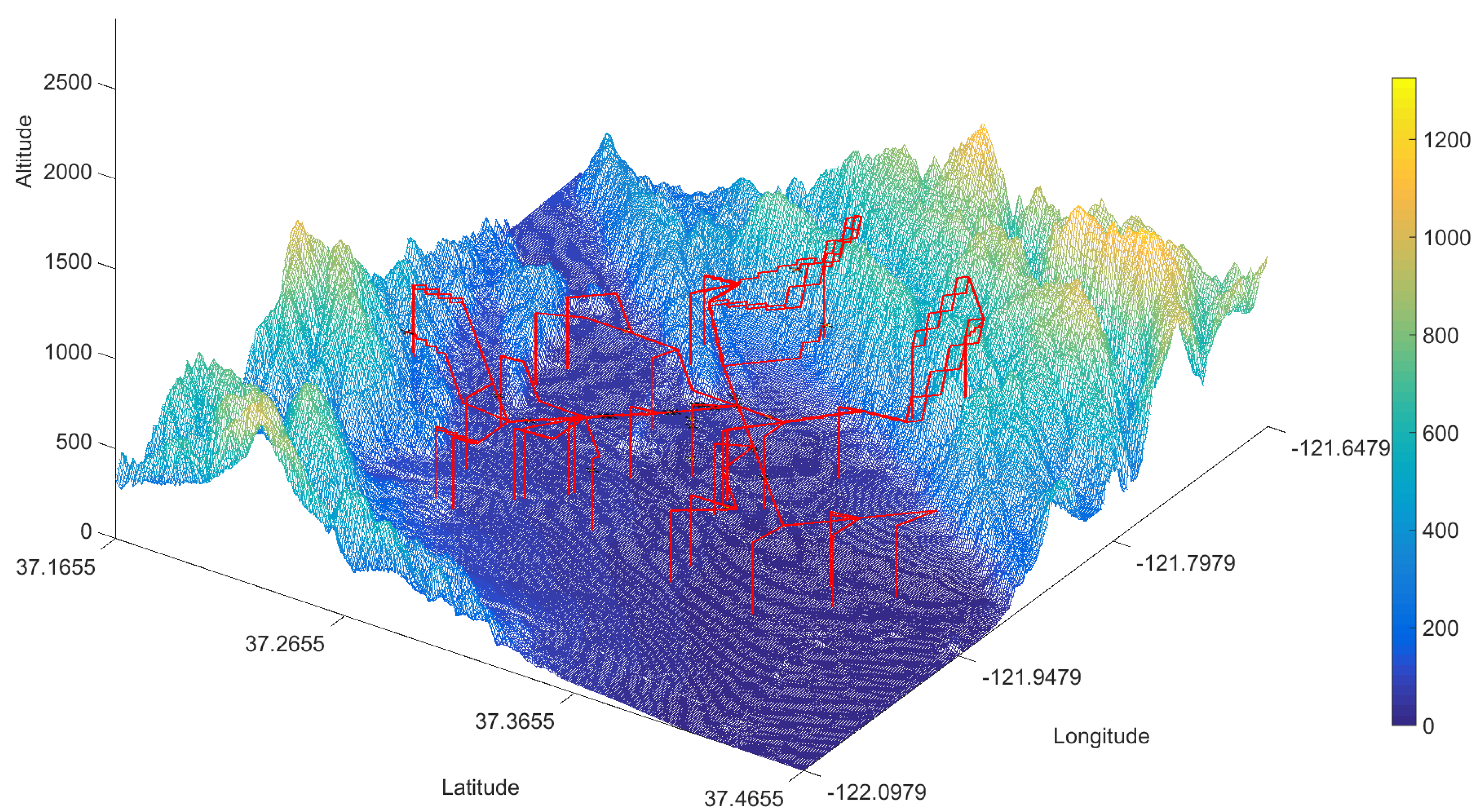

Figure 3: Simulation run with 25 vehicles delivering around a warehouse located in San Jose.

System Model

The vehicle is modeled using a point mass system driven by a controller providing reference points along the trajectory in latitude (λ) longitude (τ) coordinates pairs. The equations of motion can be described as

$$\dot{\lambda} = \frac{1}{(R+h)} V_g \cos X_g \tag{1}$$

$$\dot{\tau} = \frac{1}{(R+h)\cos\lambda} V_g \sin X_g \tag{2}$$

$$\dot{h} = V_h \tag{3}$$

where R is Earth's radius, V_g is the ground speed, V_h is the climb rate, X_g is the tracking angle, and h is the altitude.

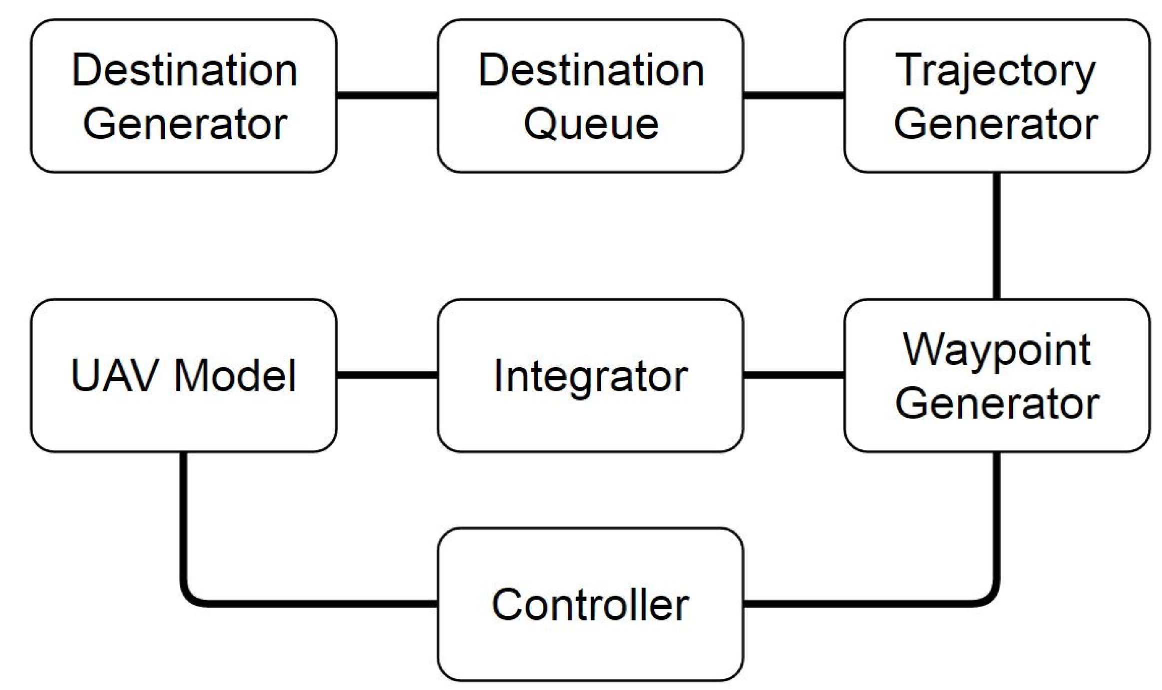

Figure 2: Simulation Flow Chart

Results

For both 8 and 4 hours of simulated delivery time, the multiple package delivery scheme out performed the single package delivery scheme in overall performance and cost for the delivery service.

Table 1: Simulation Results - Comparing single and multiple packages per vehicle with a 25 vehicle fleet

Packages Per Vehicle	Simulation Time	Average Distance Traveled	Packages Delivered
One-Package	8 Hours	120 Km	121
One-Package	4 Hours	67.07 Km	77
Two-Packages	8 Hours	101 Km	127
Two-Packages	4 Hours	64.4 Km	81

By showing that more packages can be delivered when multiple packages are transported by one vehicle we prove that it would be more cost efficient for a warehouse to invest in vehicles with larger payload capacity. Our simulations also shows that by using the right logic for which packages are assigned to which vehicle, we can ensure that deliveries are made within the time constraint set by the warehouse. We have proved our delivery concept as a success since we can deliver more packages in the same amount of time using the same number of vehicles while reducing the average distance each vehicle has to traverse.

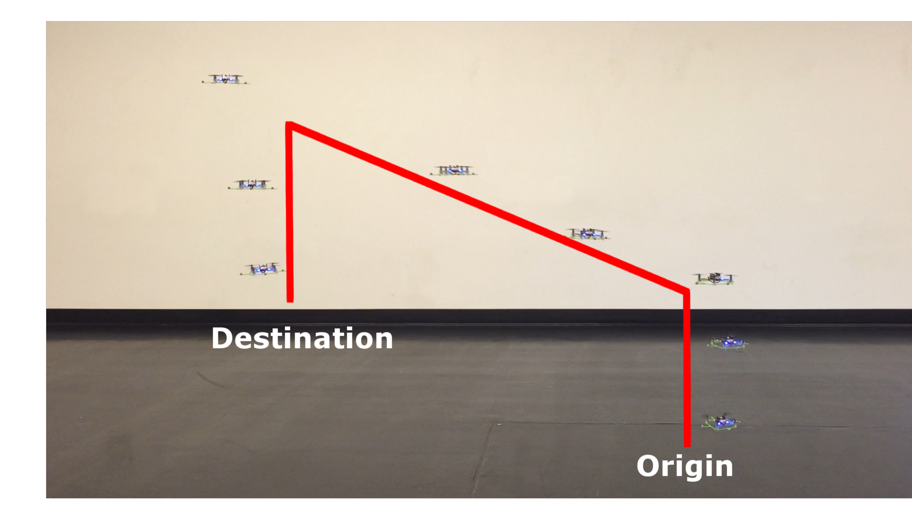

Figure 4: Crazyflie quadcopter hardware-in-the-loop example

Future Work

Due to the highly unstudied nature of this subject, there are many possible future directions that this project can take, some of which include:

1. Creating a hardware-in-the-loop testbed, as exemplified in figure 4.
2. Developing a navigation framework necessary to traverse dense urban environments.

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