Multi-Package UAV Delivery System

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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 Vehicles (UAV) 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 using terrain, building, and population data to construct an environment for a package delivery scenario. We showed that extending the payload capabilities of the UAV improved the number of packages delivered.

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 UAV as carriers for the packages. In terms of the 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 environment we collected data for 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 were compiled before the simulation ran.
3. Single Package Delivery - UAV responded to package requests one at a time and then traversed the same path to and from the warehouse.
4. Multiple Package Delivery - After being assigned the first package to deliver, vehicles waited on the ground until a nearby second package was requested or until the time to wait on the ground expired.
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 to evaluate their performance.

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.

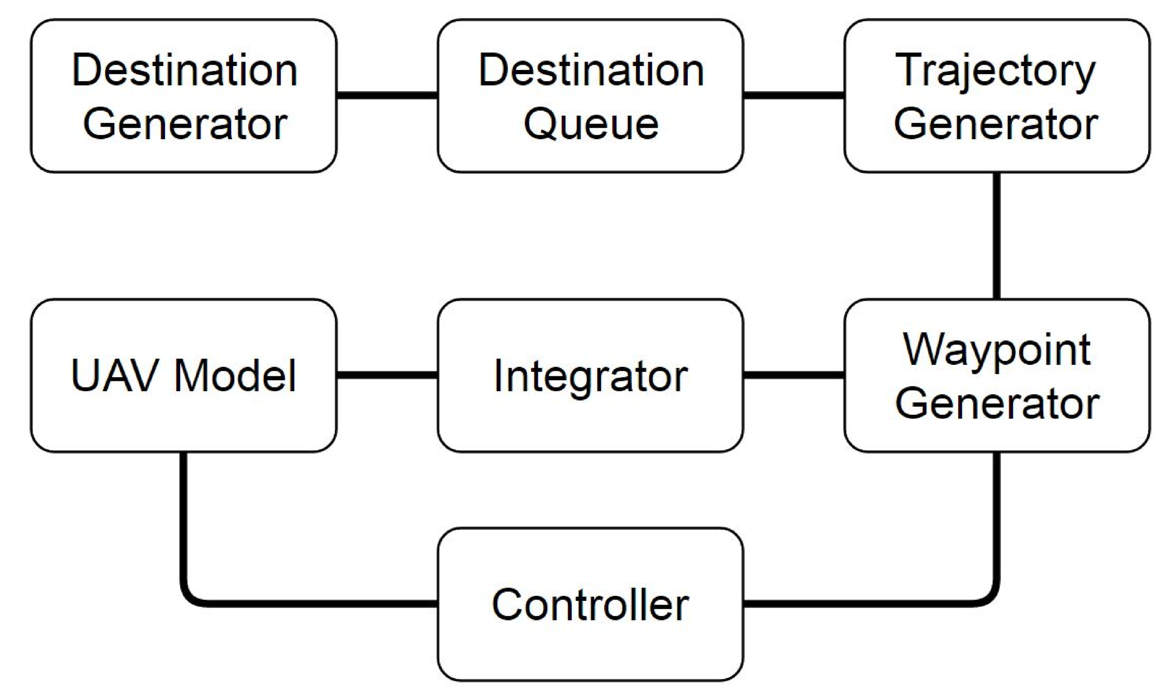

Figure 2: Simulation Flow Chart

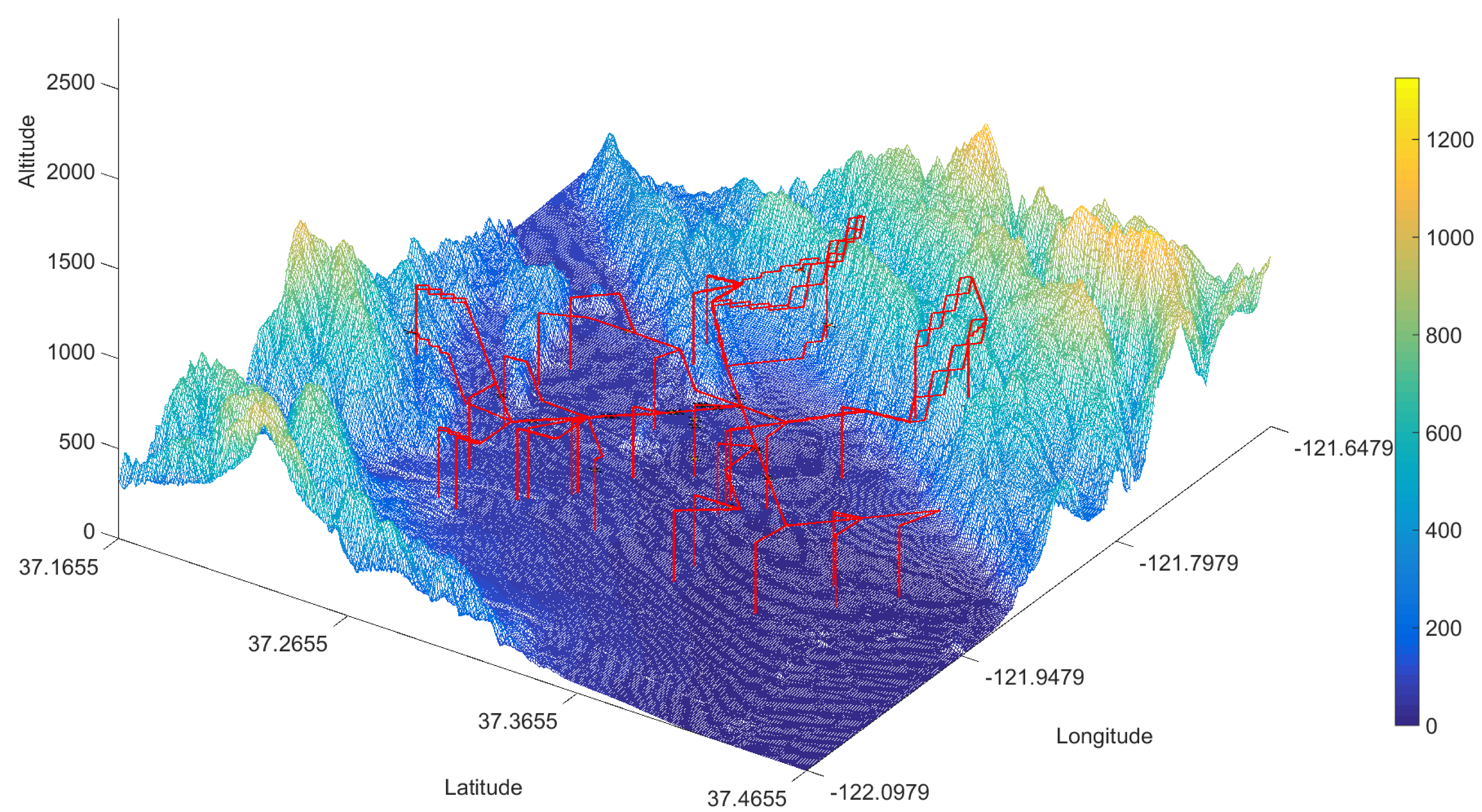

Figure 3: Simulation run with 25 vehicles delivering around a warehouse located in San Jose.

Results

For both 8 and 4 hours of simulated delivery time, the multiple package delivery system out performed the single package delivery system 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 showed 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 the multiple package delivery system was successful since we delivered more packages using the same resources while reducing the average distance each vehicle had to traverse.

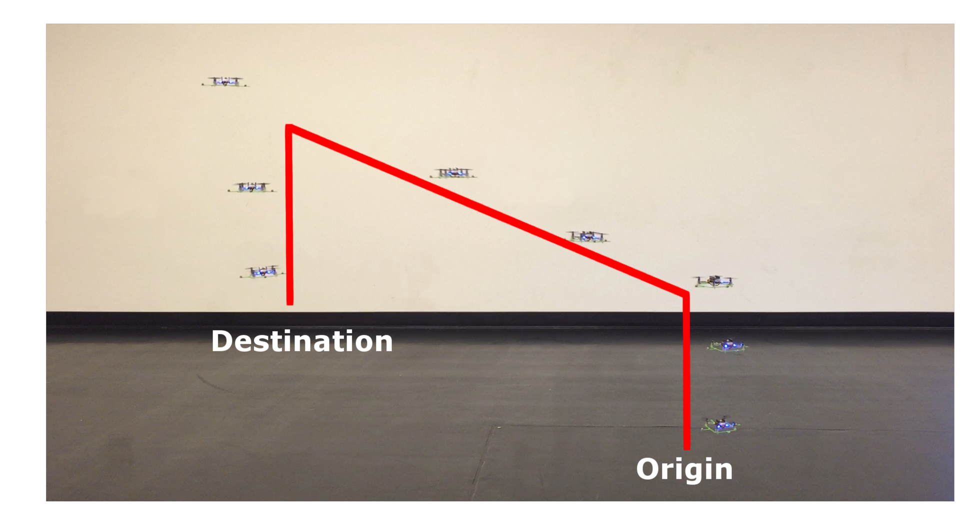

Figure 4: Quadcopter hardware-in-the-loop example

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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