Drone Delivery Optimization

Project Proposal

ME 308 - Industrial Engineering and Operations Research

Department of Mechanical Engineering, IIT Bombay

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1 Introduction

Drone delivery for commercial products is a fast-growing and widely researched field. It all started when Amazon, Inc made the revolutionary announcement in 2013, of delivering packages via drones. Since then, there have been multiple organizations that have implemented this system. Drones have several advantages over traditional delivery methods. They are less expensive to maintain and are usually faster than road transportation. They can also be used during emergency situations to supply food, water, and medical equipment to areas not reachable by road transportation. Though drone delivery is a boon in today's traffic-prone and time-sensitive world, there are multifarious challenges that arise, for example, the life of the drone battery, changes in the weather and terrain, and availability of suitable charging locations. To tackle these issues, extensive research and optimization are required.

In this project, we aim to optimize the delivery locations and the trajectory followed by the drones, given some fixed locations of charging stations. Initially, we consider only one drone and one package to be delivered. If possible, we would like to build up on this topic by introducing multiple drones and multiple packages, with the possibility of optimizing the charging locations too.

1.1 Motivation

Drone delivery systems can significantly reduce delivery times, result in cost savings by reducing the need for ground-based delivery vehicles and personnel, and reduce the environmental impacts associated with delivery by emitting fewer emissions. The major limitations of drone systems stem from the current state of the battery technology that does not support economically viable long-distance travel. Hence, the need to optimize the systems is of paramount importance.

As a group, our interests intersected in trajectory optimization, and after having looked at various problem statements on it, we collectively agreed on trajectory optimization for drone-delivery systems. What also excites us is the virtually infinite add-ons that the project has, for example, we can further optimize the battery-swapping locations in a given service area, extend our formulation for multiple drones and multiple packages, and maybe even relax a few of the initial assumptions made to simplify the problem.

2 Challenges Perceived

2.1 Data Collection

- The first challenge we perceived is the sparse research done on this topic. Having to find papers even for the initial research turned out to be a greater task than expected.
- Another challenge would be to gather sufficient data on the population density and thus the delivery demand in an area, drone capabilities like the build and the battery life, flight paths, and other relevant variables. This data is crucial for building an optimization model, and without accurate data, the results of the optimization problem may be unreliable. We plan to collect relevant data from online sources and proceed with our problem.

2.2 Choosing a Geographical Area

- For modelling the drone delivery system, we would require a sample geographical area that encompasses all the variations possible in the environment. Choosing such a map is difficult and requires research. We would be going ahead with a reasonably large area, which cannot be traversed within a single battery charge. We would also take into account the topography of the area and its effect on the shortest possible routes.

2.3 Choosing an Objective Function

- There are two major objective functions that can be defined - one to minimize cost and one to minimize delivery time. We need to strike a balance between these two to get the best results for our project.

2.4 Robustness

- Drone delivery operations are subject to many sources of variability, such as weather conditions, pay-load weight and its influence on battery. Incorporating this variability into the optimization problem can be difficult and may require developing probabilistic models or using robust optimization techniques.
- We plan to implement a feedback mechanism that takes in real-time battery status and location to calculate the trajectory. Modelling the battery behaviour for different loads in our simulation is a challenge.

2.5 Collision Avoidance for Multiple Drones

- In case of a multiple-drone problem, we need to model the collision avoidance algorithms to avoid collisions and safer delivery paths. There is sufficient material available on the internet, through which we plan to model this.

3 Tentative Deliverables

- A program that generates optimal delivery locations within the feasible set, and an optimized trajectory that takes into account the environment surrounding it (buildings etc.) and gets updated in a loop according to weather conditions, battery status, and nearest battery swapping station.
- Conduct simulations to validate our results and visualize the optimized flight path of the drone, in order to demonstrate the effectiveness of the algorithms used for optimizing the delivery system.
- If time permits we will include multiple drones and multiple packages in our delivery system.

4 Project Timeline

Week 1	Finish literature review and start modelling our problem carefully.
Week 2	Wrapping up the modelling of our problem and starting the formulation making reasonable assumptions along the way.
Week 3	Refining the formulation and finalizing it before the week. Choosing a sample geographical area on which we could test our implementation, which would encompass all the perceivable variations in the environment.
Week 4	Installing all the resources required for the pipeline. For example, ways to import the chosen geographical area into our program, choosing a suitable optimization solver, and starting to code our problem.
Week 5 & 6	Completing the coding aspect of the problem, and testing and validating the solution using simulations.
Week 7 & 8	Refining our code and trying to make it more robust. Start working on the final report and try to expand our problem statement to multiple drones and multiple packages if time permits.

5 References

- Optimization of battery swapping infrastructure for e-commerce drone delivery, Taner Cokyasar, 2020
- Vehicle Routing Problems for Drone Delivery, Kevin Dorling, IEEE, 2016