Drone delivery project

Optimization and Simulation Course (MATH-600)

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Introduction

You are in charge of the drone delivery system for an e-commerce business in a city. You have to decide the drone fleet, the location of the dispatching hubs and the drone deployment policy. Given the demand for online orders, you should define the best possible service to the customers.

The decisions that you have to make are:

- The drone fleet and the location of the dispatching hubs, i.e., the type and number of drones and from where the drones are dispatched.
- The deployment policy, i.e., the rules you apply when deploying drones in response to orders.

The aim of the "Simulation Project" is to develop a discrete event simulation that represents the system and to evaluate the performance of two solutions of drone fleet, hub location and deployment policy.

During the "Optimization Project", the discrete event simulation is expanded, and a good solution in terms of drone fleet, hub location and deployment policy is identified by an optimization algorithm.

Develop the discrete event simulation with a modular structure. It should be possible to modify the various components, such as the order rate, drone fleet and deployment policy, during the "Optimization Project".

Project description

The city is shaped like a 10 km square (i.e., each side is 10 km long) and is divided into two zones, the center and the periphery. The city center is shaped like a 3 km square, located in the center of the city.

Three different types of orders can be placed depending on the weight of the item to be delivered: light, medium and heavy. Once an order has been placed, a drone is deployed from a hub. Three types of drones are available: basic, standard and complete. A basic drone can only deliver light items, and it costs 100,000 €. A standard drone can deliver both light and medium items, and it costs 150,000 €. A complete drone can deliver all types of items, and it costs 300,000 €.

The drones always depart and return to the same hub after each delivery, irrespective of the type of item. Possible hub locations are reported in Table 1. We assume that the south-west corner of the city has coordinates (0;0). The drones travel at 50 km/h, and the distance between the hub and any delivery location is the Euclidean distance.

Hub	X-coordinate [meter]	Y-coordinate [meter]
1	3658	5254
2	7635	5303
3	4484	938
4	4046	6963
5	6279	8611
6	7720	4849
7	9329	3935
8	9727	6714
9	1920	7413
10	1389	5201

Table 1: Potential hub location coordinates

The total budget available is 16 million €. This budget is used to purchase drones or open hubs in available locations. At least one hub must be open. The cost of opening a hub is 1 million €.

There are two types of operating costs for the drones:

- Distance dependent. 0.20 €/km for all types of drones.
- Time dependent. 100 €/hour for a basic drone, 120 €/hour for a standard drone, and 200 €/hour for a complete drone. The time-

dependent operating cost is charged only when a drone is in service, i.e., not waiting at the hub.

Online orders requiring drone delivery occur at a rate a that varies over the course of the day and for each type of item (see Table 2). The probability of an order being located in the city center is twice as high as the probility of it being located on the periphery. The location of orders is evenly distributed between the two zones. The location is defined by x and y coordinates, both expressed in meters.

	Day (8:00-16:00)	Evening (16:00-24:00)	Night (24:00-8:00)
Light items	75	125	25
Medium items	60	100	20
Heavy items	15	25	5

Table 2: Arrival rate (a) of the orders

The drone service time on site, denoted t, includes drone landing, item removal, and drone take-off. It is a function of the type of item to be delivered. The exact time varies according to weather conditions, wind, and customers' familiarity with the system. The delivery procedure for light items requires 10 minutes plus an additional time uniformly distributed between 0 and 20 minutes. Medium items require 5 minutes plus a random additional time exponentially distributed with a mean of 5 minutes. Heavy items require 10 minutes plus a random additional time exponentially distributed with a mean of 10 minutes.

Simulation

For the simulation project, you are requested to:

- Develop a discrete event simulation to represent the described project.
- Define the indexes used to quantify the quality of the service
  - Remember that extreme cases are important; evaluate other indexes in addition to the mean. Moreover, the waiting time is an important factor for how your service is perceived.
  - Report the mean squared error of your estimation using bootstrapping when necessary.
  - Use variance reduction techniques to reduce the computational time.

- Decide the drone deployment policy, i.e., the rules you apply to deploy drones in response to orders. For example, you might consider different queues for different types of drones, or allocate orders to hubs according to their proximity.
- Evaluate the quality of the drone delivery service for 24 hours (from 8:00am) with two different configurations:
  - One hub open (hub number 1), and 30 basic drones, 50 standard drones and 15 complete drones
  - Three hubs open (hub number 1, 2 and 3), and 55 basic drones, 34 standard drones and 8 complete drones, all types equally distributed among the hubs.
  - (or other scenarios that show your simulation performance well)
- Make any necessary assumptions.

Optimization

For the optimization project, you are requested to:

- Identify the decision variables of the problem.
- Define the objective function.
- Design an optimization algorithm and apply it to solve the problem. The value of the objective function is evaluated using simulation.
- Like in the simulation project, the objective function can reflect various policies of the decision maker: whether they want to optimize over the average, best, worst, or certain percentile of the objective function distribution. Decide what your position is and justify it, or present results for several alternatives.
- Use your creativity and design a new dispatching strategy that leads to better performance.