DRONE-BASED PACKAGE DELIVERY: OPTIMAL PATH PLANNING AND COST ESTIMATION

Group 14

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1 Objective

Primary Objective

⇒ A Drone has to deliver a package from a depot or warehouse to the predetermined destinations or consumers. The main objective of this project is to provide path planning that aims to minimize the delivery cost and reduce the total energy consumption

⇒ Given the drone capacity and maximum number of available drones as constraints, model should be able to **allocate path & stack of packages** to each drone

⇒ Read the GPS data from Google Map and build a visualizer to animate the package delivery solution

Secondary Objective

⇒ Considering scenarios for drones and other vehicle delivery to do the **Cost Benefit Analysis** among drones and traditional delivery methods

⇒ Model will also predict the total minimum cost & delivery time of each item by taking into account the actual physical model of each drone

2 Current Status

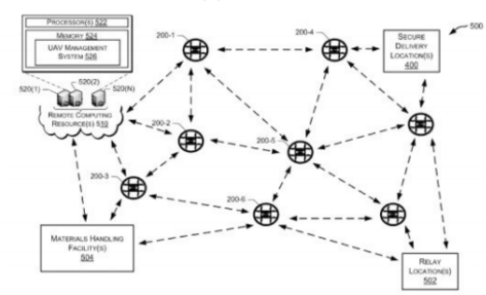
Problem Formulation

The theoretical model for power calculation and hence, The running cost of drone estimation.The power consumption of drone when the payload decrease and moving with constant velocity.

$$\text{Power consumption (in kW)} = \frac{(m_p + m_v)V}{370\eta r} + \text{p}$$

$$\text{Battery capacity} = \frac{(\text{Npack} + m_v)Vt}{370\eta r}$$

- The warehouse has been chosen as centre point
- The weight and size of parcel is given each delivery GPS point
- First we are clustering the region into different segments, Predicting the required number of drones and then we will Optimise path of each and every drone based on it's Performance curve



Ref:-dronecenter.bard.edu/files/2017/09/CSD-Amazons-Drone-Patents-1.pdf

Algorithm implementation

Dynamic programming based algorithm for TSP, **Genetic algorithm** for paths allocation to various drones and **clustering algorithm** for solving problem with large data set has been implemented

3 Input Parameters

- Number of maximum available drones
- Maximum capacity of each drone(payload vs time of flight for specific motors and speed)
- An Excel file which contain node name in first column, (x,y) coordinates in second and third column and weight of package required at each point in third column
- The optimal path allocation model also takes maximum and minimum value of clusters to be drawn to find optimal solution
- Genetic algorithm takes the population size and generations as input which will dictate accuracy of the solution

4 Algorithm and Working Code

Optimal path for Each drone using Dynamic Programming

Initially we started with TSP problem with inequality constraints where revisiting of each node was restricted and used the dynamic approach to solved it using the following approach -

Let the given set of vertices be {1, 2, 3, 4,....n}. Let us consider 1 as starting and ending point of output. For every other vertex i (other than 1), we find the minimum cost path with 1 as the starting point, i as the ending point and all vertices appearing exactly once. Let the cost of this path be cost(i), the cost of corresponding Cycle would be cost(i) + dist(i, 1) where dist(i, 1) is the distance from i to 1. Finally, we return the minimum of all [cost(i) + dist(i, 1)] values. This looks simple so far. Now the question is how to get cost(i)?

To calculate cost(i) using Dynamic Programming, we need to have some recursive relation in terms of sub-problems. Let us define a term *C(S, i) be the cost of the minimum cost path visiting each vertex in set S exactly once, starting at 1 and ending at i.*

We start with all subsets of size 2 and calculate C(S, i) for all subsets where S is the subset, then we calculate C(S, i) for all subsets S of size 3 and so on. Note that 1 must be present in every subset.

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If size of S is 2, then S must be {1, i},
 C(S, i) = dist(1, i)
Else if size of S is greater than 2.
 C(S, i) = min { C(S-{i}, j) + dis(j, i)} where j belongs to S, j != i and j != 1.
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For a set of size n, we consider n-2 subsets each of size n-1 such that all subsets don't have nth in them.

Using the above recurrence relation, we can write dynamic programming based solution. There are at most $O(n*2^n)$ subproblems, and each one takes linear time to solve. The total running time is therefore $O(n^2*2^n)$. The time complexity is much less than O(n!), but still exponential. Space required is also exponential. So this approach is also infeasible even for slightly higher number of vertices.

Source: www.geeksforgeeks.org/travelling-salesman-problem-set-1/

Path Allocation for Each Drone using Genetic Algorithm

- Based on the given population input, we generate random candidate initial population
- Then we run the genetic algorithm to initialize the parents
- To derive the next generation parents, we first generate two two descendants individuals taking 2 random parents from four randomly chosen parents using the fitness function
- We then select two randomly cutting points and generate two children after doing
- After a mutation(swapping operation), we get the next generation of the parents
- After the fixed iterations, we get the improved optimal solution which minimize the total cost

5 Usefulness and Validation of the project

- Validating by taking some region in Mumbai from Google Map, motor parameters, battery ratings, number of rotors, payloads. The data from other delivery vehicles to estimate cost
- Companies or other start-ups who are planning to use drone based delivery system for low weight, low cost and energy efficient package delivery. Also motivate other mode delivering companies to use drones to reduce emission
- Given the consumer locations, the algorithm should be able to find out optimum path which has the minimize the cost
- Given the characteristics of the drone, we should be able identify the operating point for maximum efficiency which reduces the time of flight and hence less power consumption
- Delivery by drone is more economical in high demand areas and in the region of heavy traffic jams

6 Distribution of work so far and future work

Shivam Yadav :
-> GPS data collection
-> Drone Modeling and correlations with collected data
-> Flying Cost estimation for a chosen drone

Hemant Kumar Mehta:
-> Problem Formulation
-> Algorithm Implementation for Optimum path & Minimum Cost
-> Visualisation of obtained path

Rai Varunkumar Rajesh:
-> Market survey of other package delivery methods
-> Time and cost calculations for existing methods
-> Comparison with drones based delivery systems

C S Ruben:
-> Market research on various drones
-> Data collection for various drones & impact of drone delivery
-> Cost benefit analysis