ERO Report

Snow Problem

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1 Introduction

1.1 What problems are we dealing with?

The given scenario relates to a graph problem constrained by minimal cost and efficiency. We had to figure out a way to traverse given graphs in the most cost effective way possible with regards to the theoretical part of the problem.

On the practical side, we also had to take into account real life constraints such as the number of workers, number of machine and the efficiency of each machine, among other resources.

Below is a detailed explanation of how we approached each problem and a solution that we think is more optimal than the generic methods.

2 Questions

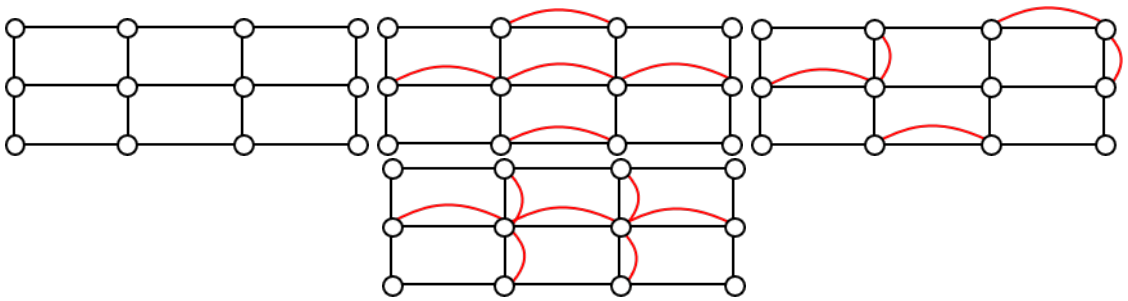
2.1 Question 1

The very first problem that we had to tackle is the following : *Determine the minimum path of the drone when flying over the road network, it must perform a complete complete examination of the road network to be able to bring a sufficiently fine analysis.*

Basically, we have to find a shortest closed circuit that visits every road of the Montreal city. Here the cost is the time it requires to complete the full sweep of the city.

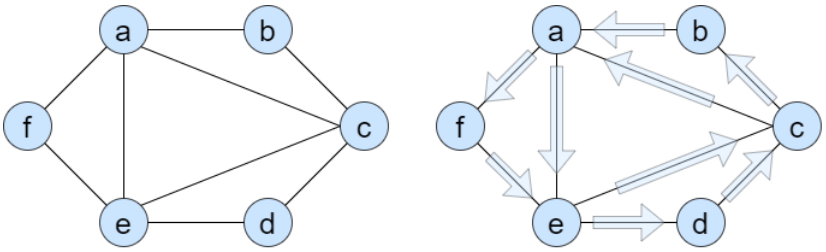
On the theoretical side , it turns out that solving this problem corresponds to solving the **Chinese Postman Problem**; which is the following : **The Chinese postman problem or route inspection problem is to find a shortest closed path or circuit that visits every edge of an undirected graph at least once**.

But why are we choosing a solution that works only on undirected graphs? Well, because the drone is not constrained by the flow of traffic, therefore it can cross the edge of the graph in any direction.



On the practical side, we solved the Chinese postman problem by using a graph theory problem of finding the optimal eulerization. The constrains of eulerization are, the graph must be connected. In this

case, because we are dealing with a road network within a city, we can safely assume that the network will always be connected. Furthermore, to not bother pedestrians we won't go faster than the speed limit when crossing these streets. So this will need be taken into account when calculating the shortest path (Dijkstra) in eurilizaiton. In fact , Chinese Postman Problem is a variation of Eulerian circuit problem for undirected graphs.

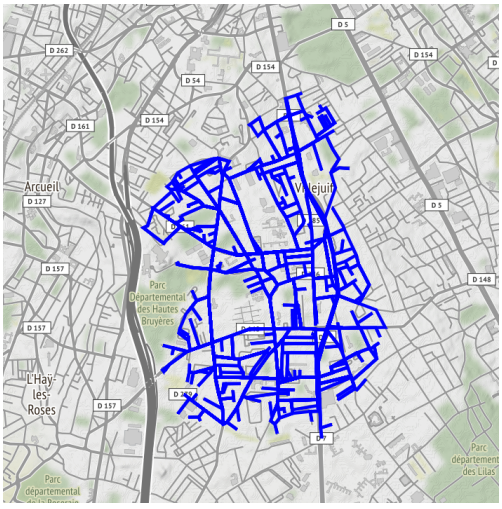


Euler Circuit: a-e-c-a-f-e-d-c-b-a

2.2 Question 2

The second question is the following : *Determine the minimal path for a snow plow to clear the zone for the city, this one only needing to go through two streets once.*

This problem can be formalized in different ways. It can be a mixed Chinese postman problem where we have some directed arcs and some undirected edges. Which would represent one-way and two-way streets. We can also pose this as a directed graph as a whole creating two arcs for each edge that is a two-way street, and pose it as a Minimum-cost flow problem. Or lastly, we can just consider the problem the same as Question 1, only the cost is not based on the speed since the snow Plower would be limited a max speed of 30mph, and we would also want to reduce the distance to minimize the fuel cost. Therefore the criteria is base not on time but on distance/fuel cost. We also assume, that there are no one-way streets or that we can go through one-way streets in any direction.



Knowing this, we decided to go for the 3rd formalization. Thus, we applied the same solution as the first except with the weights being the distance for the reasons listed above.

2.3 Question 3

The final question is to do with the practical application of the previous two questions.

Propose a cost model for citywide clearing operations based on the number of vehicles.

Given that we have 2200 machines to work with and 3000 employees we can estimate the cost for clearing up snow in the city of Montreal.

- Average Snow Removal Snow Plow Operator hourly pay in Canada is approximately $21.54
- The mileage of an industrial snow plower is 2.3383 km/L.
- Fuel consumption for the plower is 0.42766 L/km
- Price of fuel in Canada = $1.772/L
- Total distance to be covered according to our estimate is 4339.233141 km
- Snowfall season in Montreal usually last from November to April which is 6 months.

Utilising every resource we have, we get that each machine would have to operate over 4339/2200 km = 1.97 km $\sim$ 2 km.

In an ideal case, no two machine will over lap and since we know the fuel consumption of each machine, we know that we need 0.427 * 2 L = 0.834 L of fuel for each machine which translate to a total of 0.834 * 2200 L = 1834.8 L of fuel and plus a few litres per machine to make sure there is enough fuel to transport the trucks we get 6000 L Knowing cost of diesel today in Canada, money spent on fuel = $6000 * 1.772 = $10632 Hours worked per employee per day is approximately = 0.305 Hrs for 2 km per machine per day. This means that for 6 months, each employee gets paid $21.54 * 0.305 * 180 = $1182.5 Assuming it requires one employee to operate one machines and a few extra hundred to count for shift changes, for a year the total wages would be $1182.5 * 2500 = $2956250

The cost for clearing up snow from the roads of Montreal in a year, in ideal conditions, would therefore come to a total of $2956250 + $10632 = $2966882 $\sim$ 3 Million USD