Fall 2021
EE 134
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EE 134: Graph Theory in Engineering

Project - Part 2
Due: Dec 2 at 11:59pm

1 Project Description

Congratulations! your project is selected by the company **X** to support sensor deployment in a jungle with the purpose of monitoring wildlife. However, apart from providing your suggested optimal sensor placement, the company asks some additional help from you. In particular, **X** plans to use drones to drop the sensors to the locations your scheme designated on the map, and wants your help on planning the routes of the drones. You are asked to work out two scenarios:

Scenario 1. The company will use a large drone that can carry all the sensors; however, this drone consumes fuel fast, and thus it is important to minimize the total travel distance of the drone. The drone will start from a drone station at the center of the map (where the receiver/sink will be), and needs to return to the same point. Moreover, because it is a large drone, as it flies above a square x, it can simultaneously drop sensors not only on the square x but also on all neighboring squares inside a 5×5 square with center x.

Scenario 2. The company will use multiple drones, that are smaller and need to obey the following restrictions:

- Each drone can carry up to 300 sensors at a time.
- Drones depart again from the central node (sink) and can fly to any location on the map even across blocked areas, however, due to fuel constraints, each of these drones can travel a distance of at most 1100 units (counting the return distance) and then it needs to return to the central node to refuel.
- **X** has only M drones that can be used for deployment.

Goals.

For **Scenario 1**: Find the shortest route for the drone in terms of distance.

For **Scenario 2**: Design the routes of the M drones that minimize the total deployment time assuming that all drones fly at speed 1 unit/second.

In both cases, to reduce the computational complexity, instead of finding the optimal routes, you can design approximation algorithms.

Input. We will be given the designated locations where the sensors need to be placed. For simplicity, we assume that the area is divided into a grid of squares with side 1 unit. If you wish, you are allowed to slightly pertube the location of the sensor nodes, provided that the worst case min-cut does not reduce by more than 5% and that the sensing coverage also does not reduce by more than 5%.

You are also allowed to use the locations that you have from project 1 (or any new placement) provided that the coverage does not drop below 85% and the worst case minimum cut does not drop below 3.

2 Map

We will use the same $300x300$ map as in Project 1. The map is a black and white image which we represent as 2-D array. The elements of the arrays take the value 0 or 1, with 1 representing a pixel of an unobstructed area and 0 representing a pixel of an obstructed area.

In addition to the map array, we provide a placement array which has the same size as the map and each entry takes the value 0 or 1, with 1 representing a designated sensor location and 0 representing no sensor. Recall that, if you wish, you can change this array as described in the previous section. The distance between two adjacent elements in the same row or same column of the array is assumed to be unity.

3 What to submit

Please fill in the attached notebook the following functions/cells:

- *single_route*: A function that finds the route of the big drone in scenario 1.
- *routes*: A function that designs the paths for the M sensors to minimize the total deployment time.
- *simplify_graph*: Optional function to simplify the graph by ignoring some links to reduce the complexity of solving the problem without highly affecting the deployment time.
- Plots: A figure plotting the number of drones vs the total deployment time for number of drones M in $\{1, 3, 5, 8, 10\}$.

You should submit a zip file containing the following items:

1. A PDF report (maximum 2 pages) describing the algorithm/s. (10 points)
2. For scenario 1, report the achieved total distance and plot the trajectory of the drone.
3. For scenario 2, report the optimal deployment ratio (min [deployment time/number of drones]).

4. A figure plotting the number of drones vs the total deployment time for number of drones in $\{1, 3, 5, 8, 10\}$, for scenario 2. Please include this in the PDF report. Please plot also the trajectories of the drones. (5 points)

5. The python code. (10 points)

The name of the file should be: FirstName1 LastName1_FirstName2 LastName2_FirstName3 LastName3. Please include your names and UIDs at the beginning of the PDF report.