DIGITAL ASSIGNMENT TASK

BACKGROUND

In this assignment, you will address a real-world problem of routing optimisation for aeronautical networks. There are thousands of airplanes flying over the North-Atlantic every day, as seen in Fig. 1, where each black dot represents an airplane. In order to provide Internet access to passengers onboard, each airplane needs to find an optimal data packet routing path to a ground station (GS) in terms of one or two and more objectives to be optimized.

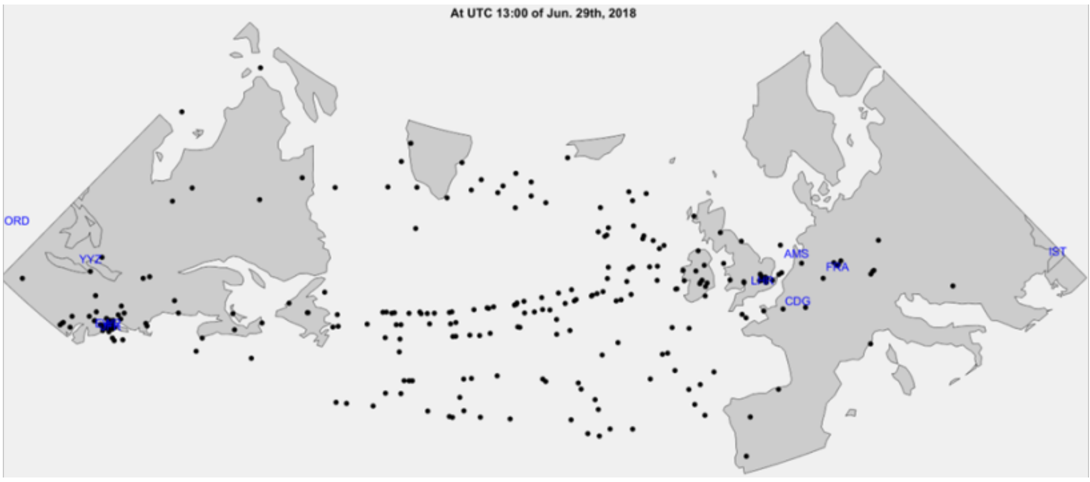

Figure 1: The topology of airplanes at UTC time 13:00 of Jun 29th, 2018

In order to find an optimal data packet routing path, there are two metrics to be considered, end-to-end data transmission rate and end-to-end latency.

The end-to-end latency is the sum of all delay imposed by each link. For example, a routing path is:
Airplane-5 --> Airplane-3 --> GS-1

The delay imposed by each link is 50 milliseconds (ms). So, the end-to-end latency of the routing path
Airplane-5 --> Airplane-3 --> GS-1 = 100 ms

The end-to-end data transmission rate is the minimum transmission rate of each link in the routing path. For example, a routing path is
Airplane-5 --> Airplane-3 --> GS-1

The data transmission rate between Airplane-5 and Airplane-3 is 52.857 Mbps, and the data transmission rate
between Airplane-3 and GS-1 is 43.505 Mbps, then the end-to-end data transmission rate of the routing path
Airplane-5 --> Airplane-3 --> GS-1 = 43.505 Mbps.

Explicitly, a link's transmission rate is determined by the distance of a pair of communicating airplanes, which is given in Table 1. For example, if the distance between Airplane-5 and Airplane-3 is 350 km, so 300 km < 350 km 400 km the data transmission rate of the link between Airplane-5 and Airplane-3 will be 52.875 Mbps.

Mode k	Mode color	Switching threshold (km)	Transmission rate (Mbps)
1	Red	500	31.895
2	Orange	400	43.505
3	Yellow	300	52.857
4	Green	190	63.970
5	Blue	90	77.071
6	Pink	35	93.854
7	Purple	5.56	119.130

OPTIMISATION PROBLEMS

There are two problems you should address:

1. ***Single-objective optimisation:*** Find a routing path having the maximum end-to-end data transmission rate for
each airplane that can access any of a GS, either at Heathrow airport (LHR) (Longitude, Latitude, Altitude) =
(51.4700° N, 0.4543° W, 81.73 feet) or Newark Liberty International Airport (EWR) (Longitude, Latitude, Altitude) =(40.6895° N, 74.1745° W, 8.72 feet).

2. ***Multiple-objective optimisation:*** Find a routing path having the maximum end-to-end data transmission rate and minimum end-to-end latency for each airplane that can access any of a GS, either at Heathrow airport (Longitude, Latitude, Altitude) = (51.4700° N, 0.4543° W, 81.73 feet) or Newark Liberty International Airport (Longitude, Latitude, Altitude) = (40.6895° N, 74.1745° W, 8.72 feet).

REQUIREMENTS

Your implementation should be in Python. You are allowed to use existing Python optimisation libraries or implementations if you need to, but you should aim to implement as much as possible from scratch by yourself. If there is novelty/contribution of the optimisation algorithm, it will help you to get a higher mark. You must apply your implementations to the two routing path optimisation problems and critically evaluate the results, plotting the results in figures, and comparing the performance, strengths, and weaknesses of the approaches you have used in terms of quality of the solution, running time, etc.

DATASET

The dataset for this assignment consists of one file: NA_11_Jun_29_2018_UTC11.CSV

The NA_11_Jun_29_2018_UTC11.csv file contains the following columns:
1st column: Flight No. – such as AA101, AA109.
2nd column: Timestamp, which is UTC time 13:00 of Jun 29th, 2018.
3rd column: Altitude in a unit of feet.
4th column: Latitude in a unit of degree.
5th column: Longitude in a unit of degree
Note that to calculate a 3D straight distance from latitude, longitude and altitude, you will first need to convert your points to 3D cartesian coordinates.

SOLUTION FORMAT

The solutions file contains a list of routing paths and the value of the cost function in terms of the optimized objective.

An example journey is given below (Here is just an example, not a real optimized routing path):

{'AA101', 'routing path': (AA113, 43.505), (AA51, 93.854), (LH421, 43.505), (LHR,93.854), End-to-end data rate: '43.505'}

where interpretation is as follows:

AA101: is the source airplane

(AA103, 43.505): The next relay node is AA103, the data transmission rate between AA101 and AA103 is 43.505 Mbps.

(AA51, 93.854): The next relay node is AA51, the data transmission rate between AA103 and AA51 is 93.854 Mbps.

End-to-end data rate: '43.505': the final end-to-end data rate is 43.505 Mbps.

SUBMISSION FORMAT

Your submission must consist of:

1. Report in the shape of a Jupyter notebook, that contains the following sections: Front matter, Problem definition, Methodology (all steps), Experiments & discussion, Conclusion, Future work and References. The report must be a combination of text and working code, relevant figures (e.g. evolution of the objective function values over time), tables and anything else you deem useful in communicating your work (e.g. interactive visualisations or animations). You must make sure that your notebook executes from top to bottom without any intervention.

2. PDF version of your Jupyter notebook. This can be produced by simply printing your notebook to a .pdf file. The feedback will be provided via Turnitin on this document.

3. Solution files representing your best solutions to the two optimisation problems. The files should
follow the format given in the section "Solution format".

MARKING CRITERIA

The following criteria will be used to assess the assignment:

Criteria	Comments
Problem definition, Postulated deployment of Search and Optimisation (S&O) methods	• Problem definition • S&O requirements specification • Justification of S&O adopted methods • Clarity of objectives
S&O implementations	• In-depth knowledge and understanding of S&O approach deployments • Implemented solver Completeness • Articulated evidence of covered constraints and Improvement of the S&O benchmark approaches • Visualized experimental/analytical results
Coding	• Novelty of coding and good usage of software libraries • Embedded challenges and complexities for S&O implementation • Efficiency for S&O solver convergence
Evaluation, validation and lessons learned	• Appraisal of achievement of project objectives. • Appraisal of achievement of a good understanding of S&O benchmarking in real-world problems • Conduct of statistical tests and analyse • Quality of evaluation, validation, and lessons learned. • Quality of future recommendations
Project report	• Document structure and coherence. • Literature support and references • Scholarship and clarity of narratives

Marks :

- Review-1 = 10 Marks
- Review-2 = 15 Marks
- Report = 5 Marks

Dates:

- 1st Review : June5 to June 9, 2023
- 2nd Review: July 10 to July 14, 2023
- Final Report and Solution Submission: During 2nd Review