The Optimization of Flight Routes: Enhancing Connectivity and Reducing Cost

Leveraging Optimization Models for Profitability!

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Context

Rapid Industry Growth

Complex Networks

Technological Advancement

Benefits of Modern Simulation

Research Question

What variables can airlines manipulate to optimize flight routes across the continental United States to enhance efficiency and maximize profitability?

Flight Route Optimization vs. Standard Optimization

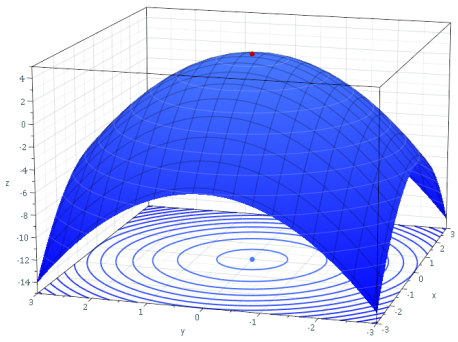
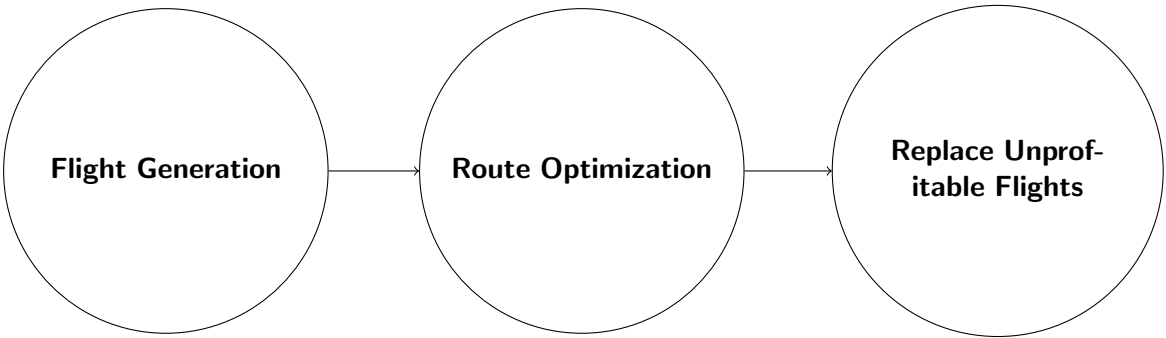


Figure: Example of a Standard Optimized Plot

- **Discrete Decision Making:**
  - All-or-Nothing Routes
  - Incremental Adjustments
- **Strict Operational Constraints:**
  - Fixed vs Dynamic Variables
  - Levels of Flexibility on Constraints
- **Data Integration:**
  - Simulation vs Functions
  - Balanced vs Feasible Solutions

Strategy of the Three Algorithms



Flight Generation

```
flight_number: 1
origin: LAX
destination: PHX
passengers: 49
flight_path: LAX, None, None, PHX
n_stops: 0
__FLIGHT_RECORD_SEPARATOR__
flight_number: 2
origin: LAX
destination: DEN
passengers: 64
flight_path: LAX, SEA, None, DEN
n_stops: 1
__FLIGHT_RECORD_SEPARATOR__
flight_number: 3
origin: LAX
destination: DFW
passengers: 57
flight_path: LAX, MIA, MCI, DFW
n_stops: 2
__FLIGHT_RECORD_SEPARATOR__
```

Overview:

- Generate all possible flights from predefined airports
- Base File Pior for Modification

Details:

- Produces flights from one airport (origin) to all other listed airports
- Random number of stops and amount of passengers
- IATA codes with an associated latitude and longitude coordinate.

Figure: Output within `generated_flights_new.txt`

Haversine Formula

Description:

$$a = \sin^2\left(\frac{\Delta\phi}{2}\right) + \cos(\phi_1)\cdot\cos(\phi_2)\cdot\sin^2\left(\frac{\Delta\lambda}{2}\right)$$

$$c = 2\cdot \operatorname{atan2}\left(\sqrt{a}, \sqrt{1-a}\right)$$

$$d = R\cdot c$$

where ϕ_1 and ϕ_2 are the latitudes, $\Delta\phi$ and $\Delta\lambda$ are the differences in latitudes and longitudes, and R is the Earth's radius.

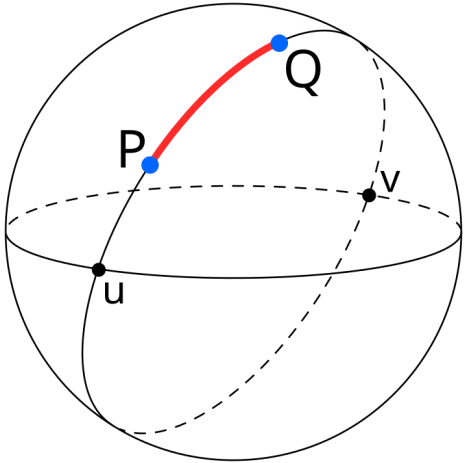


Figure: Haversine Formula Visualization

Route Optimization

```
REORDER: 1 310.07875842955656 ['LAX', 'PHX'] 310.07875842955656
ORIG: ['LAX', 'SEA', 'DEN']
OPTIMAL: ['LAX', 'DEN', 'SEA']
REORDER: 2 1720.3251381031996 ['LAX', 'DEN', 'SEA'] 1607.0480523143033
ORIG: ['LAX', 'MIA', 'MCI', 'DFW']
OPTIMAL: ['LAX', 'MCI', 'DFW', 'MIA']
REORDER: 3 3522.954323132324 ['LAX', 'MCI', 'DFW', 'MIA'] 2551.50200846393
REORDER: 4 2135.772293104575 ['LAX', 'JFK'] 2135.772293104575
REORDER: 5 2029.5732616512466 ['LAX', 'MIA'] 2029.5732616512466
```

Figure: Trial Error of the sorting algorithm of three flight routes

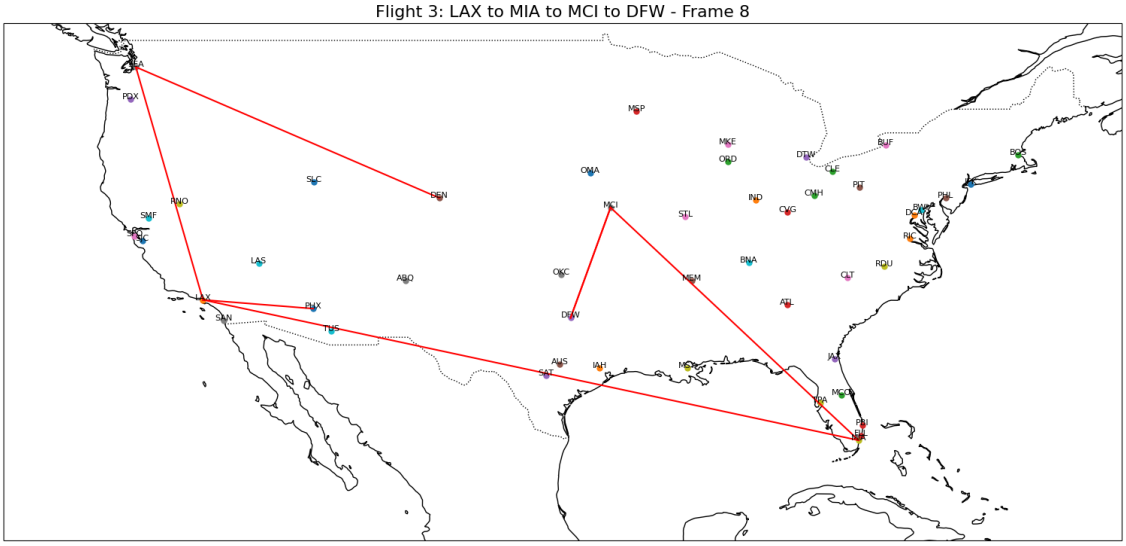
Overview:

- Utilizes Airport IATA Codes as coordinate pair.
- Sorts the distance using the Haversine formula

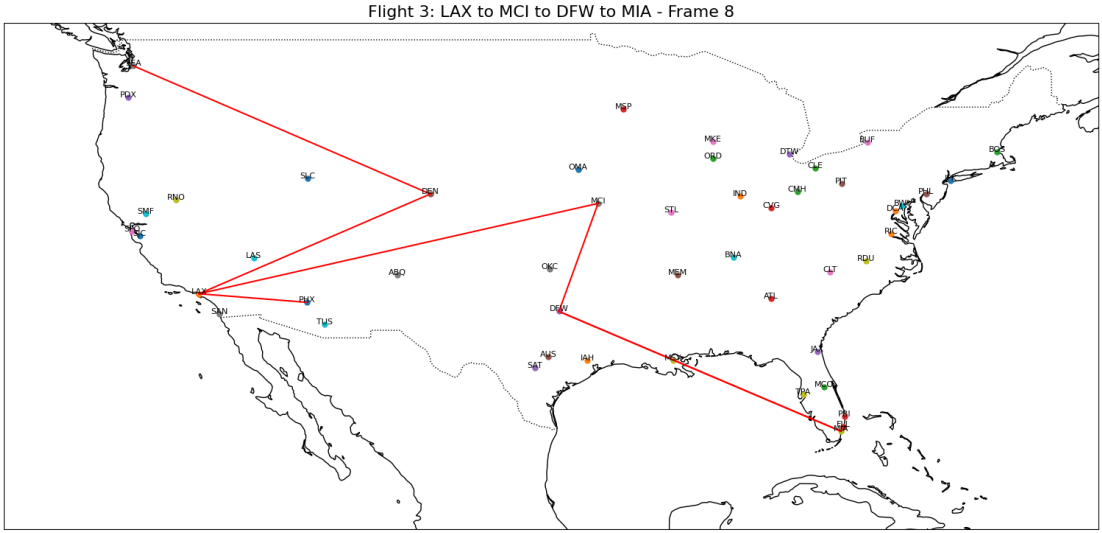
Details:

- Explains the importance and impact of sorting distances
- Enhances route efficiency by minimizing travel distance

Visualization of the Sorting Algorithm: Unsorted Flights



Visualization of Sorting Algorithm: Sorted Flights



Replace Unprofitable Flights

```
REPLACEMENT: Flight 27: DEN, MCI, DFW, MIA -> Flight 76: ABQ, PHX, DFW, MIA
            $ -12471.263962290022   ->   $ 47914.60656796576
REPLACEMENT: Flight 28: DFW, MIA, LAX, SEA -> Flight 46: MIA, DFW, LAX, SEA
            $ -25666.983748255916   ->   $ 26609.28941328331
```

Figure: Bad Profitable Flight to Profitable Flight (Net Profits Below Flight Routes).

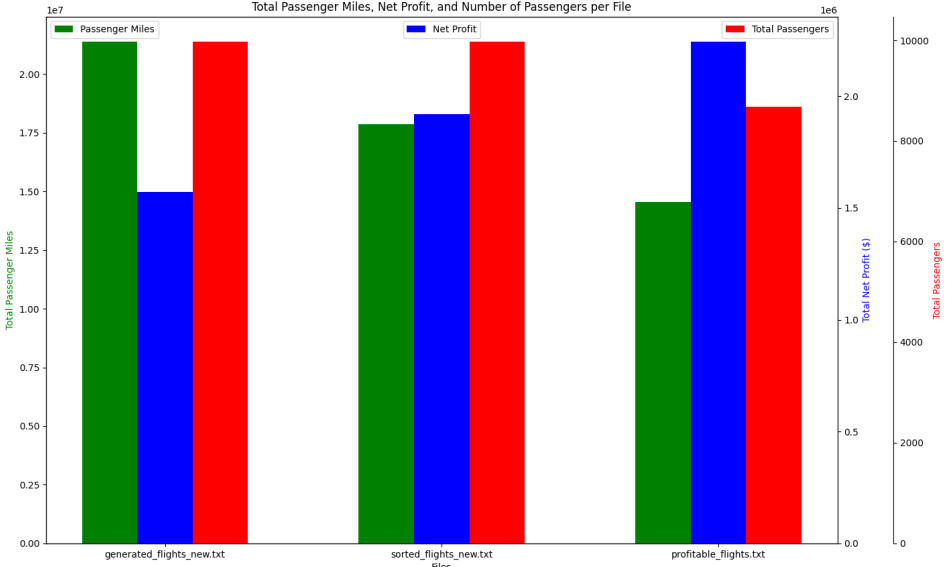
Overview:

- Remove Unprofitable Routes
- Replace with Nearby Profitable Flights

Details:

- Matched Closest Profitable Paths
- Adhered to Passenger Capacity Limits

Results


Total Passenger Miles, Net Profit, and Number of Passengers per File
1e7
1e6
Passenger Miles
Net Profit
Total Passengers
Total Passenger Miles
Total Net Profit ($)
Total Passengers
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
0.0
0.5
1.0
1.5
2.0
0
2000
4000
6000
8000
10000
generated_flights_new.txt
sorted_flights_new.txt
profitable_flights.txt
Files

Future Work

- Consider passenger boarding and deboarding at intermediate stops.
- Incorporate dynamic ticket pricing based on flight distance.
- Adapt to real-life flight routes with only an origin and a destination, with no intermediate stops.
- Modify Total Passenger Miles also to reflect its contribution to income.
- Integrate weather conditions and no-fly zones into the data analysis.