Temasek Defence Systems Institute

Comparative Analysis of Neural Networks & Ant Colony Optimisation for Predicting and Minimising Flight Delays

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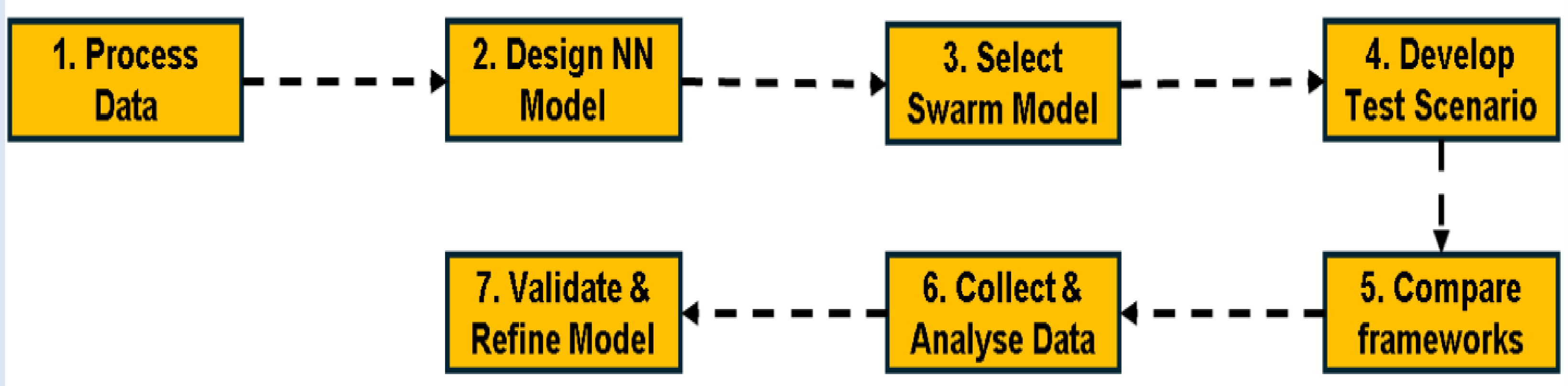
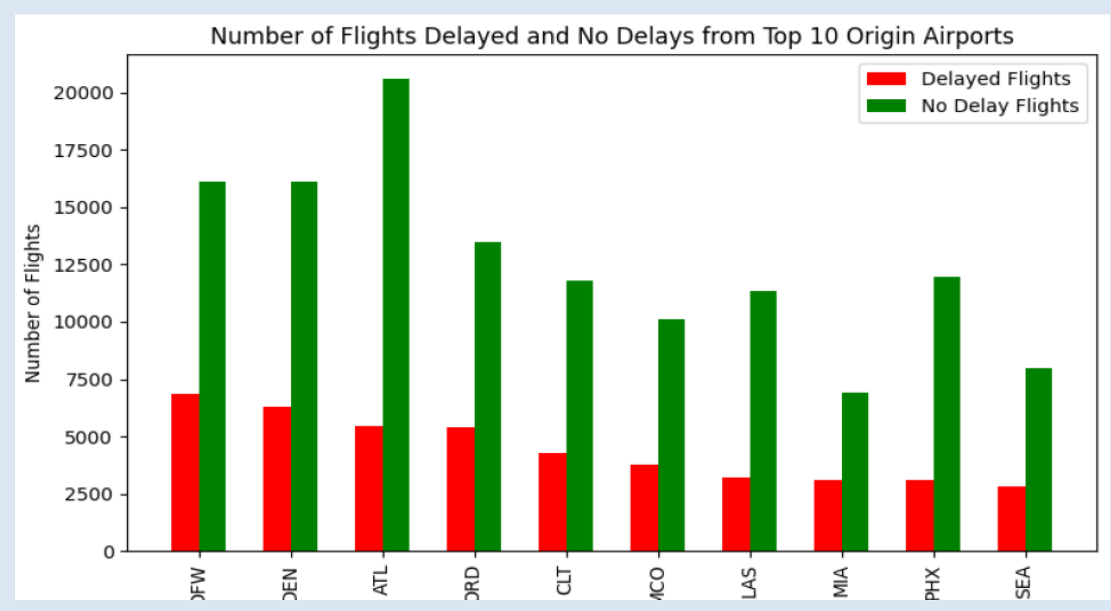
Introduction

- Flight delays are a pervasive and costly problem in the aviation industry, impacting not only airlines but also passengers and the broader economy. (FAA) and Nextor had estimated the annual costs of delays in 2019 to be US$33 billion, considering direct cost to airlines and passengers, lost demand, and indirect costs.
- Traditional models often fall short in capturing the intricate, nonlinear interactions between various factors that contribute to delays, such as weather conditions, air traffic congestion, and aircraft maintenance issues.
- The motivation for this research is rooted in the urgent need for innovative solutions to the persistent problem of flight delays. As global air traffic continues to rise, airlines are under increasing pressure to enhance operational efficiency and maintain high levels of service quality. The aim is to conduct a comparative analysis of Neural Networks (NN) and Ant Colony Optimization (ACO) as predictive and optimisation tools for minimizing flight delays.
- NN: Ability to model complex, nonlinear relationships in data, are expected to provide high accuracy in delay predictions by learning from historical flight data and real-time inputs
- ACO: Inspired by the foraging behavior of ants, offers a promising approach to optimizing flight schedules by exploring and exploiting the best possible routes to minimise delays.

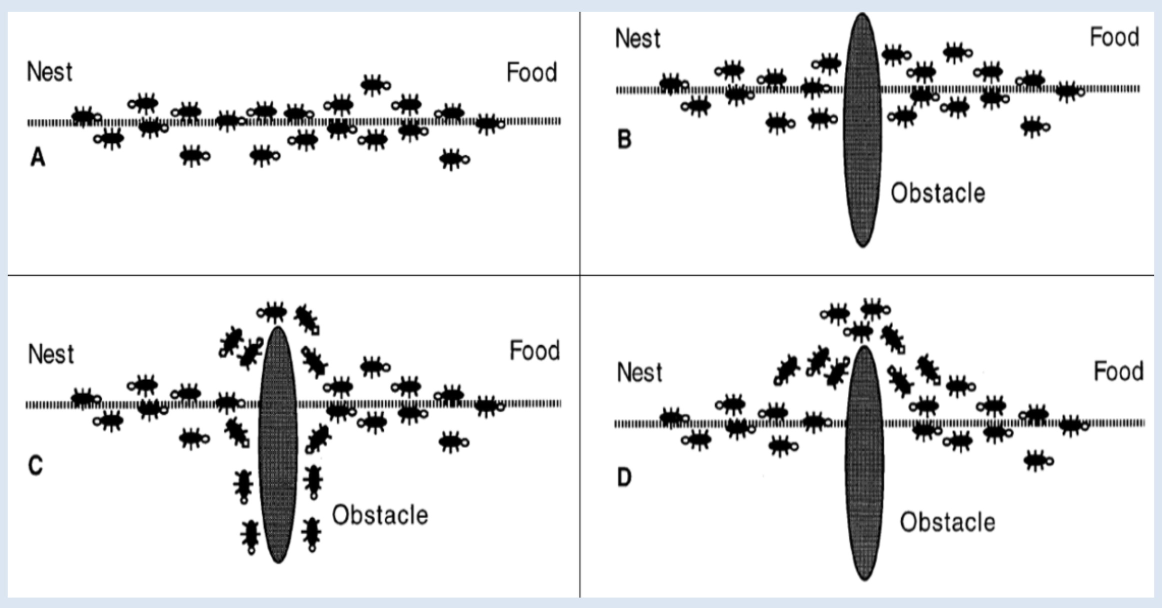
Methodology



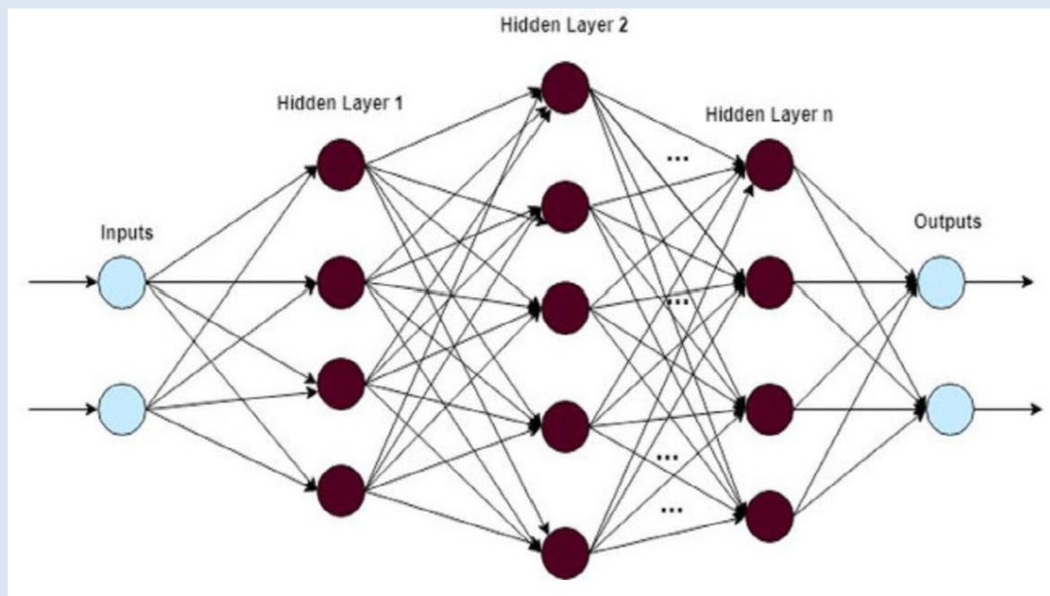
1. Understand the data and prepare the data to be used.
2. The design of NN model involves the selection of the right NN model structure, defining the essential features and designing the layers of the network. The parameters are also determined to ensure the performance and accuracy are acceptable.
3. The design of basic ACO model and ensuring the parameters are correctly configured during implementation.
4. The test scenario is required to create and find suitable dataset that accurately represent real-world conditions.
5. Performance data from the comparisons between NN and ACO tests will be collected to understand how the system is performing under different conditions.
6. Based on the analysis, NN and ACO model is refined. This involved iterative testing and adjustment to enhance the system's performance.



- Database taken from US BTS.
- DFW international airport is identified as one of the airports with the highest number of flight delay.
- Prediction will be focus on DFW airport.



- Input Data: Use training data and historical delay data.
- Solution Construction: Each ant is a solution, explore different paths (schedules), guided by pheromone levels.
- Prediction: Best schedule for flight departures by iteratively refining the solutions based on pheromone trails, aiming to minimise delays.



- Input Data: Use 11 features from Correlation Heatmap, use training data and historical delay data
- Model Design: A deep network and optimise parameters
- Prediction: Best Schedule for Departure, minimising delays

Results

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Day 1 - Generation 1: Best delay = 31.0158815779184
Day 1 - Generation 2: Best delay = 30.50217991218565
Day 1 - Generation 3: Best delay = 29.719998233634726
Day 1 - Generation 4: Best delay = 29.719998233634726
Day 1 - Generation 5: Best delay = 29.719998233634726
Day 1 - Generation 6: Best delay = 29.719998233634726
Day 1 - Generation 7: Best delay = 29.55624199702342
Day 1 - Generation 8: Best delay = 29.55624199702342
Day 1 - Generation 9: Best delay = 29.55624199702342
Day 1 - Generation 10: Best delay = 29.55624199702342
Day 1 - Generation 11: Best delay = 29.55624199702342
Day 1 - Generation 12: Best delay = 28.8483175858896
Day 1 - Generation 13: Best delay = 28.56479303796581
Day 1 - Generation 14: Best delay = 28.56479303796581
Day 1 - Generation 15: Best delay = 28.208784523832318
Day 1 - Generation 16: Best delay = 28.208784523832318
Day 1 - Generation 17: Best delay = 27.973418642414043
Day 1 - Generation 18: Best delay = 26.800497657769633
Day 1 - Generation 19: Best delay = 26.800497657769633
Day 1 - Generation 20: Best delay = 26.800497657769633
Day 1 - Generation 21: Best delay = 26.800497657769633
Day 1 - Generation 22: Best delay = 26.800497657769633
Day 1 - Generation 23: Best delay = 26.800497657769633
...
Day 7 - Generation 49: Best delay = 12.153414144278859
Day 7 - Generation 50: Best delay = 12.153414144278859
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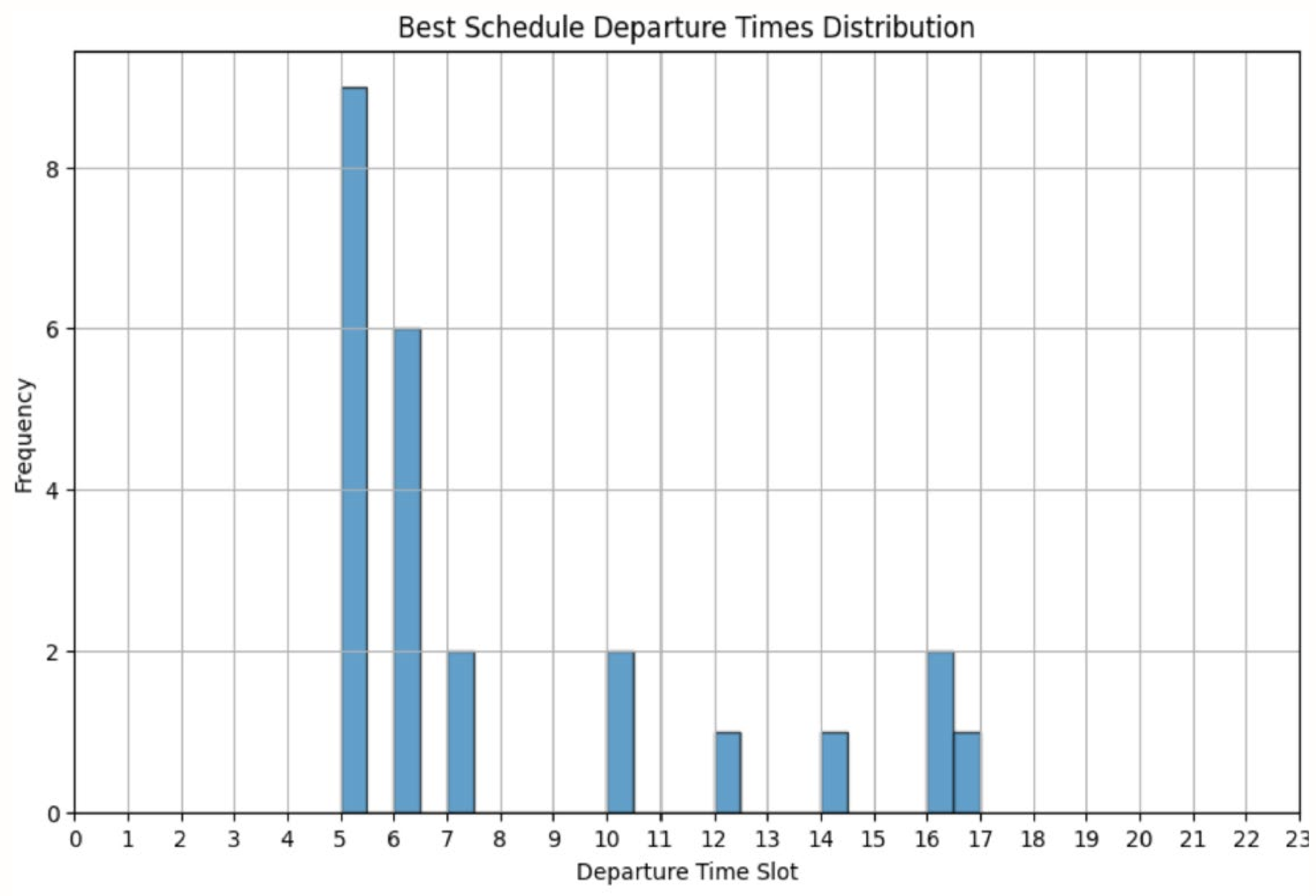

- Most optimal departure times to minimize delays are predominantly clustered around the early morning hours, particularly between 5 AM and 7 AM.

Conclusion

- Effectiveness of both Neural Networks (NN) and Ant Colony Optimization (ACO) in predicting and minimising flight delays.
- While NNs generally offer better accuracy and computational efficiency, ACO provides a flexible and adaptive approach that can be fine-tuned for complex optimisation tasks.
- Both methods show potential in enhancing operational efficiency in the aviation sector, with NNs excelling in handling large datasets and ACO offering robust solutions in dynamic environments.

Future Works

- Integration of NN into ACO
- Further Hyperparameters tuning
- Applications on other domains

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NUS National University of Singapore