Project Proposal: Flight Arrival Gate Scheduling at BWI Airport

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Summary

This project proposes a SciML-based framework that integrates Neural Ordinary Differential Equations (NODEs) for passenger deplaning flow prediction and Learning-to-Optimize (L2O) methods for gate and staffing allocation at Baltimore/Washington International (BWI) Airport, with the goal of minimizing both passenger processing times and airport operating costs.

Introduction

Airports face increasing challenges in balancing passenger experience with operational efficiency. When multiple flights arrive within a short period, delays in gate allocation and insufficient staffing can lead to prolonged passenger waiting times, congestion inside terminals, and reduced service quality [1]. At the same time, operating too many gates or overstaffing ground operations leads to unnecessary costs and resource waste [2]. Traditional scheduling strategies often rely on fixed heuristics or large-scale optimization models, which may struggle with real-time adaptivity and scalability [3].

Baltimore/Washington International Thurgood Marshall Airport (BWI), as a medium-hub airport in the U.S., provides a representative case with its five concourses (A–E) and over 70 gates. This project leverages real flight arrival data, tail-number-to-aircraft mapping, and concourse-level gate information to develop a predictive-optimization pipeline. The proposed framework aims to forecast passenger arrival streams after landing and optimize the assignment of gates and ground staff resources in near real-time.

Objectives

- Develop a NODE-based predictive model for estimating passenger deplaning flows based on flight arrival time, aircraft type, and estimated passenger load.
- Formulate an optimization framework for gate allocation and staffing that balances service efficiency and operational costs.
- Apply L2O methods to accelerate decision-making under dynamic arrival scenarios.
- Evaluate performance using BWI gate layout and simulated passenger demand data.

Technical Approach

The technical workflow is composed of two integrated modules:

Passenger Flow Prediction with NODE

Historical flight arrival data (from BTS On-Time Database) will be used that combine aircraft information derived from tail numbers. Passenger loads will be estimated using seat capacity and average load factors. NODE models will be trained to get the continuous-time dynamics of passenger deplaning, taking into account variability in aircraft size, concourse assignment, and taxi-in delays. The output is a predicted passenger flow trajectory arriving at terminal gates.

Optimization with L2O

The predicted deplaning flows serve as inputs to an optimization model for gate and staffing allocation. The decision variables include (i) the assignment of flights to available gates within concourses A–E, and (ii) the number of service windows and ground staff to open during each time slot. The optimization objective is formulated as:

$$\min \ \alpha \cdot \text{AvgPassengerProcessingTime} + \beta \cdot \text{GroundOperationCost}$$

where α and β represent trade-off weights, average passenger processing time includes the time for deplaning and walking to terminal. Constraints include gate capacity per concourse, staffing limits, and turnaround buffer times between consecutive flights.

Integration with BWI Gate Layout

I incorporate the concourse and gate distribution of BWI Airport (Concourse A–E). Each concourse is modeled with its available gates, and concourse walking times are included in the passenger experience metric. This ensures that results reflect realistic operational constraints.

Expected Outcomes

- A NODE-based passenger flow prediction model validated on historical BWI arrival data.
- An L2O-based optimization engine capable of producing near-optimal gate and staffing schedules with reduced computational overhead.
- Quantitative metrics demonstrating reduced average passenger deplaning times and lower operational costs compared to baseline strategies.
- A proof-of-concept framework that can be generalized to other airports, contributing to the development of intelligent and adaptive airport operations.

References

[1] Hyunsoo Lee, Jiyoon Kim, and Minho Park. Dynamic rescheduling strategy for passenger congestion in airports. *Mathematics*, 13(13):2208, 2025.

[2] Wei Li, Chen Zhao, and Jian Wu. A historical data approach to optimal gate assignment considering taxi delay and passenger walking time. *Journal of Operational Research Society*, 2024.

[3] P. Aditya, K. Ramesh, and A. Sharma. A review on air traffic flow management optimization. *Discover Artificial Intelligence*, 4(1):77, 2024.