Coordinated flight routes optimization

Project owner: Kien Huynh

Project Background

Commercial airlines operate numerous long-haul flights every day, connecting cities across continents. These flights are carefully planned to balance travel time, fuel consumption, weather conditions, and safety considerations. However, flight paths are not always perfectly optimized, and there is often room for improvement in terms of cost, efficiency, and environmental impact. Flight route optimization can either be done in (or close to) real time or offline – long before the actual takeoff. This project will focus on the latter category.

Many offline optimization methods for flight routes exist; however, a large portion of them are rarely designed for multiple flights, i.e., they don't necessarily take potential collisions between flights in airspace into account. Coordinated and cost-efficient flight routes are needed for practical reasons, but pre-computing optimal routes is very expensive if the number of flights is large. There exist optimization methods that tackle multi-aircraft flight routes planning, but each of them has its own limitations as well as tradeoffs. This project provides an opportunity for students to study such methods and propose their own improvements.

Aim and purpose

In this project, students will conduct a literature review on recent optimization methods for flight routes with some level of coordination. The objective of the optimization is to save time and/or environmental cost (fuel burned, emissions, etc.). The students will summarize these works, listing their contributions and drawbacks, and whether they can be applied in practice.

The students should choose one work with available codes, or whichever is implementable within the project's timeline, to run experiments. Then, the students should propose a method that is an extension of previous study(s) and compare it with the prior experimental results. At the end, the students need to evaluate the practicality of the methods (Can they deal with the hourly flight volume in some Swedish airspace sectors? Or at least flights coming to/taking off from Arlanda? Are the modeling assumptions too unrealistic?).

Project tasks and requirements

- Conducting a literature review of coordinated flight routes optimization: this involves reading and understanding relevant work. A summary of each work and a comparison of all of them should be provided.
    - Coordination can be in many different forms (for example, conflict-free flight routes planning or imposed capacity of airspace sectors). As long as the work involves multi-aircraft flight route optimization, it should be a valid candidate.
- Experiment & programming: the students will choose one method for experiments on flight data. For this task, students should be familiar with different programming languages, as they may have to reuse a publicly available codebase of previous research. If the students decide to reimplement their own code, any language should work as long as the implementation is correct.
    - Data: real flight data will be provided to the students. This includes historical flight routes and their costs (time, emissions, etc.). The students should compare their optimized routes with past routes.
    - Experiment scope: the students should prioritize optimization of the cruise phase of flight trajectories.
- Method proposal: an optimization method, extended from previous work(s) (not necessarily from the chosen method in the previous task). Extension should not be trivial and needs to be well thought-out. Implementation is required, and this method will be compared with the previously chosen method. Similar experiments on flight data will be carried out. Any language/tool/software is allowed for this task.
- A measurement of how practical the methods/frameworks are.

Project group

The project should be conducted by a group of at least three and at most five students.

Contact

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Usage

The results will be a contribution to the research project “Reducing Aviation GHG Emissions: Optimized Routes, Drop-in Fuels, and Incentives (RAGE)”, funded by Trafikverket.

Grading

Except for the common requirements related to course grading specified in the course information, project-specific grading is given according to the scale Fail, 3,4, or 5 (or the corresponding ECTS grade).

For grade 3, at least the following steps have to be carried out:

- A detailed project specification and time plan, carefully written in English.
- Give a literature review of related works. A summary of these works as well as a comparison between them, showing their strengths, limitations, and scopes.

- Become familiar with past flight data and how to measure flight cost (time, fuel burnt, etc.). Compute the cost of past flights to serve as a benchmark.

- Choose one optimization framework in the literature and run experiments using this framework on the provided data. Compare optimized routes/trajectories with past flights.

For grade 4, the grade 3 steps have to be carried out with very good results, and the following steps have to be carried out:

- Present a new framework that is an extension of some previous work(s).
- Justify the design of this framework over the ones in the literature review (broader scopes, faster runtime, better coordination, etc.).
- Implement this framework and compare it with previous experimental results.

For grade 5, the grade 3 and 4 steps have to be carried out with extremely good results, and the following steps have to be carried out:

- Evaluate potential trade-offs between optimization goals (time vs. emissions).
- Analyze how scalable the chosen/implemented frameworks are.
    - Quantitatively, the software can be measured in terms of the runtime required (on similar hardware) as the data grows larger.
    - Discuss whether the framework could realistically be scaled up to larger problem instances, focusing on computational limits and data requirements.
- Compare the chosen/implemented framework with at least one method or software that is used in practice (even if it is not designed for coordination). Highlight differences in scope, assumptions, and limitations.