# Development and programming trajectory planning algorithms for large scale airspace

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## Introduction

**Due to air traffic growth, the airspace will be saturated. The solution is either adapting demand to airspace's capacity or adapting airspace's capacity to demand. ATM capacity increase -> reduce the mental workload on the controller.**

**Delays at the time of departure -> snowball effect -> more workload on the controller**

**Spatio-temporal separability of the air traffic to solve smaller problems.**

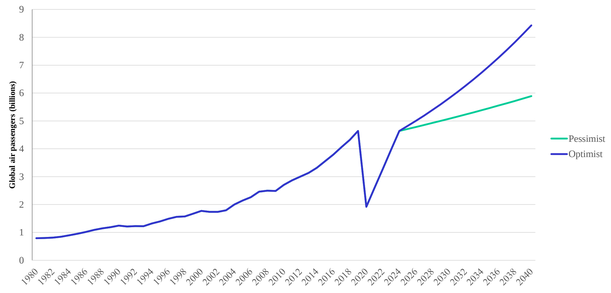


**Figure 1. Global Air Passengers Growth (pessimist and optimist scenarios) [1,2].**

## Methods

**Choose metric to evaluate the controller's workload. [3]**

**→ Linear Dynamical System (Slow, robust)**

**→ Speed covariance + distance (Fast, less robust)**

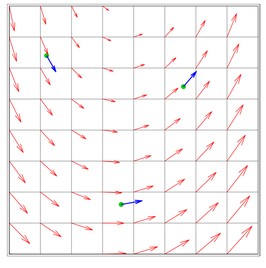

**Figure 2. Vector field produced by the Linear Dynamic System**

**Identify spatio-temporal clusters**

**→ Define spatio-temporal distance (4D volume intersection)**

**→ Numerical Analysis (Reduce bandwidth of interaction matrix) [4]**

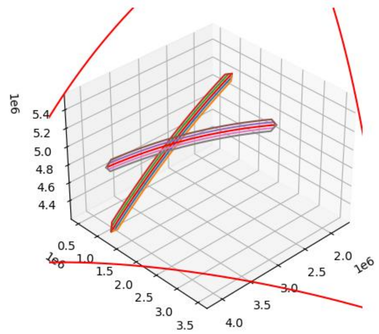


**Figure 3. Two flights with original and alternate orthodromic trajectories.**

## First algorithm

**Selective Simulated Annealing [5] process is chosen. The algorithm is based on the classic Simulated Annealing with the difference of selecting and changing the choices of the worse flights first.**

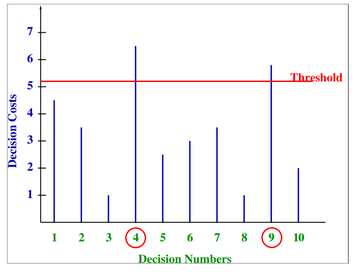


**Figure 4. Only decision 4 & 9 are selected and changed by the neighboring operator**

## First results

**Selective Simulated Annealing results on the French air traffic for a full day is shown in Figure 5.**

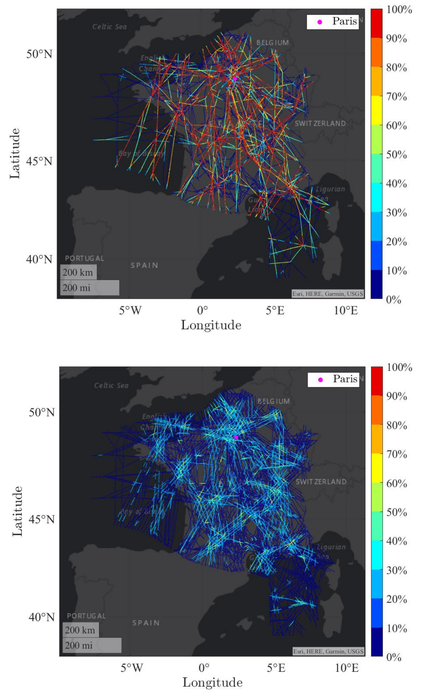


**Figure 5. Complexity of French air traffic before and after optimization with FL, routes, and time of departure choices.**

## Perspectives

**→ Solve smaller problems defined by the spatio-temporal clusters**

**→ Linear Dynamic System implementation on GPU**

## References

**[1] IATA, Passenger forecast infographic**

**[2] Data World Bank, Air transport, passengers carried**

**[3] D. Delahaye and S. Puechmorel, Modeling and Optimization of Air Traffic. Wiley, 2013, p. 352. doi: 10.1002/9781118743805.**

**[4] E. Cuthill and J. McKee, "Reducing the bandwidth of sparse symmetric matrices," in Proceedings of the 1969 24th national conference, New York, NY, USA, Aug. 1969, pp. 157–172. doi: 10.1145/800195.805928.**

**[5] J. Lavandier, A. Islami, D. Delahaye, S. Chaimatanan, and A. Abecassis, "Selective Simulated Annealing for Large Scale Airspace Congestion Mitigation," Aerospace, vol. 8, no. 10, p. 288, 2021.**