Generating optimal aircraft trajectories with respect to weather conditions

Brunilde Girardet, Laurent Lapasset, Virginie Aubreton

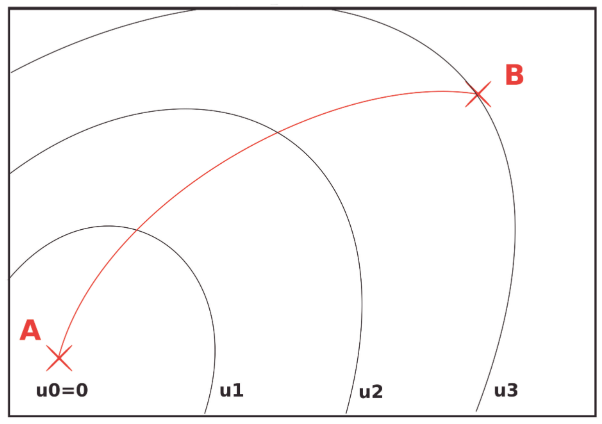
Generating optimal aircraft trajectories with respect to weather conditions

Goal: Compute optimal routes in Cruise Flight.
Why? Increase Air Traffic Capacity and reduce time travel and fuel consumption.
Assumption: Constant Air Speed and Constant Flight Level.

Our methodology : Front Propagation method

Relied on **Ordered Upwind Algorithm**: technique to track the propagation by solving a partial differential equation known as the **Hamilton-Jacobi equation**:

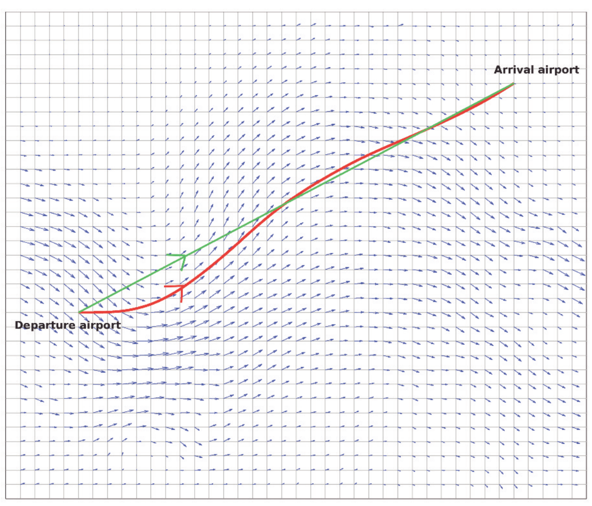
$$\begin{cases} \|\nabla u\| F\left(x, \dfrac{\nabla u}{\|\nabla u\|}\right) = 1, & \text{where u is the optimal cost and F is the speed of the front in the normal direction} \\ u = 0 & \text{on the initial point} \end{cases}$$



Principle:
1 - Start at the initial point with the cost u=0;
2 - Compute the propagation of the front from the initial point corresponding to the minimal cost u;
3 - Construct the optimal path by tracing backward.

One aircraft

Without Obstacle
Speed of the front: F = Aircraft Ground Speed

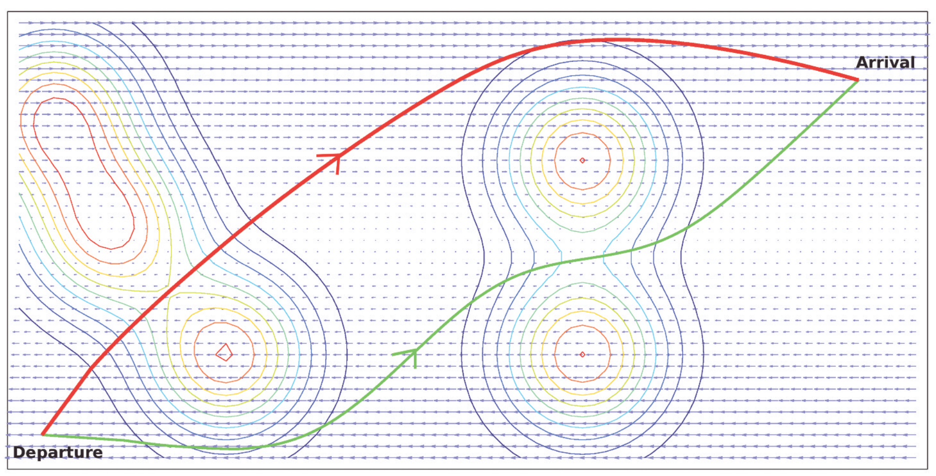


Optimal route
Direct route
Wind

	Time (seconds)
Optimal route	1470
Direct route	1498

Profit: ≈ 30 seconds for 30 min of flight time; 1.9% of time saved for the trajectory.

With Obstacles
F = function(Aircraft Ground Speed, Obstacles)



No obstacle
Impassable obstacle

Optimal path without wind
Optimal path with wind
Wind

A different optimal path with or without wind.

Several aircraft

Idea: Propagate the front in the configuration space of several aircraft.
Example: for two aircrafts, state space $\Re^4 - \Delta$ with $\Delta = \{(x_1, y_1) = (x_2, y_2)\}$ and $(x_1, y_1, x_2, y_2) \in \Re^4$ *the coordinates of both aircraft.*
Problem: Curse of dimensionality.

Proposed solution: Use **Approximate Dynamic Programming** methods to compute good approximations and not the exact optimal trajectories.

Contacts
Brunilde Girardet - PhD Student - brunilde.girardet@capgemini.com
Laurent Lapasset - Engineer R&D ATM - laurent.lapasset@capgemini.com
Virginie Aubreton - Manager ATM Unit - virginie.aubreton@capgemini.com

Capgemini
CONSULTING.TECHNOLOGY.OUTSOURCING