Complexity in Air Traffic Management

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Introduction

Air traffic Management Requirements

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- Separation delegated to aircraft.
- Trajectory based air traffic management.
- Introduction of decision support tools / automated conflict solvers.

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Workload

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- Increases with :
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  - interdependence of conflicts.
- Relevant in an highly automated ATM system.

Air traffic complexity uses

Airspace design

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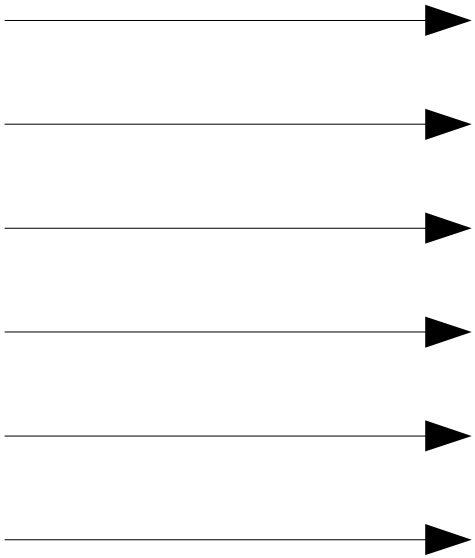
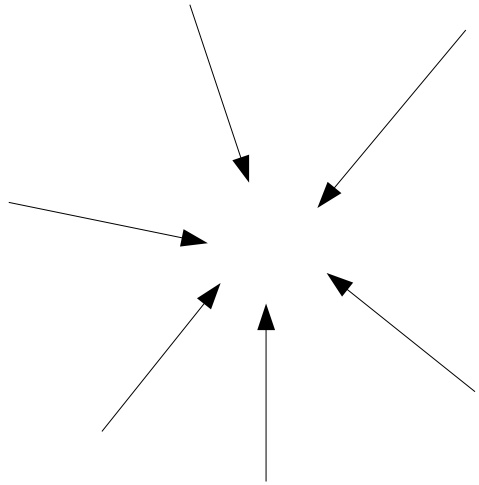
4D contract framework

- 4D Trajectory design.
- Forecasting of potentially hazardous traffic situations.
- Automated Conflict Solver enhancement (robustness of the solution).

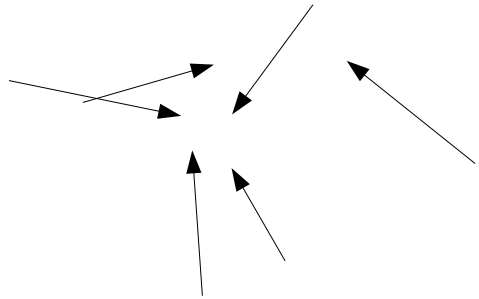
Intrinsic part of complexity



High predictibility
Conflict-free



High predictibility
Conflict
No induced conflicts



Low predictability
Conflict
Secundary conflicts induced

Defining complexity

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- A complexity map is produced.

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- Related to mixing.
- A complexity map is produced.
- A relation exists with the minimal amount of information needed to organize the traffic

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- Let $(t_i, x_i, v_i)_{i=1...N}$ be the measured positions and velocities at given times.

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Interpolation criterion

- Let $(t_i, x_i, v_i)_{i=1\ldots N}$ be the measured positions and velocities at given times.
- The interpolating field X must satisfy : $X(t_i, x_i) = v_i,\ i = 1 \ldots N$.

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Functional criterion

$$\int \int \|\Delta X(x,t)\|^2 + \mu \|\frac{\partial X}{\partial t}(x,t)\|^2 dxdt$$

where μ controls the relative importance of both smoothness requirements.

Interpolating spline

Original problem

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- Solution is a sum of singular radial basis kernels :

$$p(t,x) = \frac{1}{\|x\|}\mathbf{erf}\left(\mu^{1/4}\frac{\|x\|}{2\sqrt{|t|}}\right)$$

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Modified problem

- Interpolation condition is relaxed :

$$\frac{1}{(2\pi\sigma)^{3/2}}\int_{\mathbb{R}^3} e^{-\frac{\|x-x_i\|^2}{2\sigma^2}} X(t,x)dx = v_i$$

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$$X(t,x) = \sum_{i=1}^{N} \lambda_i p(t-t_i, x-x_i) + Ax + b$$

with $\lambda_i, b \in \mathbb{R}^3$ and A a 3×3 matrix.

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- Coefficients λ_i, A, b are obtained by solving a linear system.

Example

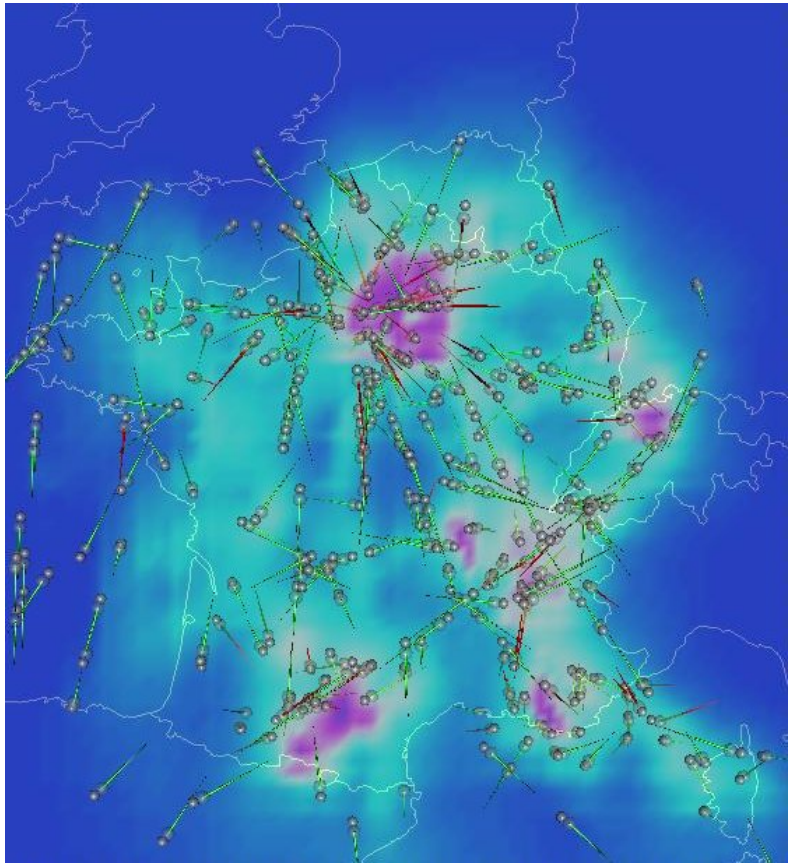

Figure: Complexity map produced over France

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Future work

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- Introduce tensor-product splines.