Increasing trajectory prediction accuracy under bad weather conditions

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Sub-challenge 1: approaches for uncertainty management in trajectory prediction
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- Characterization of uncertainty

- Large-Disruptive (weather phenomenon, other disruption, etc.)
- Normal Traffic uncertainty (inherent stochasticity of the system)
“Macro” uncertainty

- Optimization under uncertainty, e.g., stochastic programming, robust optimization, etc.
- RO’94, VBO’94, AEO’00, HM’07, BHM’10, ADL’11, AAEP’12, BS15, CLNV’16, BC’16

\[
\begin{align*}
\text{Min } & c_1(x_1) + E\left[ f_2(x_1, \omega_1) \right] \\
& x_1 \in X_1
\end{align*}
\]

Computational challenges:
- Multi-dimensional integration
- Integer Requirement
- Large volume of data

\[
\begin{align*}
\text{Min}\{ f(x) : g(x, u) \leq b & \quad \forall u \in U \} \\
& x \in X
\end{align*}
\]
“Micro” uncertainty

- Methods to measure and forecast congestion at airports
- K’76, M’95, PBO’95, WFM’04, H et al.’09, GNS’11, NH’12
Optimized Approach Sequencing (WP-E Robust-ATM, FAU-DLR, 2013-16)

Empirical Airport /A-SMGCSTraffic Data:
Arrival / Departure Delays with $\Gamma$-PDF Model

Monte-Carlo Simulation of pre-tactical Arrival Scheduling with Random Departure-Delays

Single 17h-Day: 209 Arrivals $a_i$, $\mu = 0$ min

Baseline: FCFS, Arrival Delays

Monte-Carlo Simulation of pre-tactical Arrival Scheduling with Random Departure-Delays

Single Flight 176 Departures: 7-12/2013, $\mu = 18$ min

FAU Optimizer (discrete, Gurobi-nominal)
Combining Optimized Sequencing with Dynamic Performance Prediction under Disruptive Weather. Example Low Pressure Event „Christian“

Wind speed & Gust data (METAR)
Fit with Dynamical Systems
Disturbance Model: Speed $v(t)$

Arrival Rate Data & Fit with Dynamical Systems Model for Performance-Disruption and Recovery

Dynamical Systems Model for Disturbance & Performance prediction

$$\dot{f}(t) = G(t)k(v(t))f(t)(1 - f(t))$$

$\rightarrow$ optimized Management Actions $G(t)$
Case of Heathrow airport*

Sub-challenge 2: identifying the need for prediction accuracy and defining the required level of certainty.

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• Is it enough?
Experience

- How to absorb time in a time constrained environment in the most efficient manner is a key issue, e.g., reducing speed in cruise (K. et al ’11, DP’12).
- Aircraft operators behaviour
  - Gap between system efficiency and individual efficiency
  - Rules / decision mechanisms / incentives to follow the “advised decisions”