Engineering, Test & Technology
Boeing Research & Technology

Challenges identified in the SESAR ER: DART project

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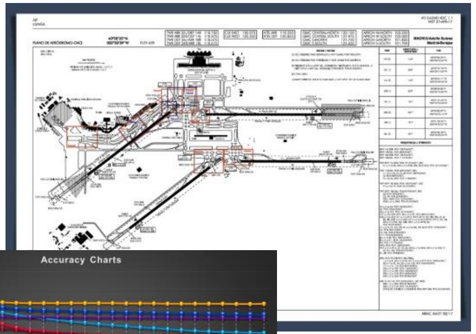
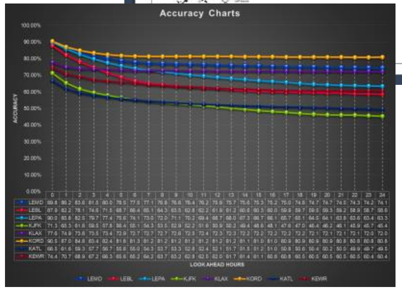
DART in a nutshell

DART (Data-driven AiRcraft Trajectory prediction research) addresses the topic “**ER-02-2015 - Data Science in ATM”** exploring the applicability of **data science** and **complexity science** techniques to the ATM domain. DART delivers an understanding on the suitability of applying big data and agent –based modelling techniques for predicting aircraft trajectories based on data-driven models and accounting for ATM network complexity effects, considering multiple correlated trajectories.





DART focused on answering following questions:

• What are the supporting data required for accurate trajectory predictions?

Flight plan, weather, surveillance, airspace (sectors, regulations, RADs) and intent (derived)

• What is the potential of machine learning algorithms to support high-fidelity aircraft trajectory prediction?

Hidden Markov or Markov decision process

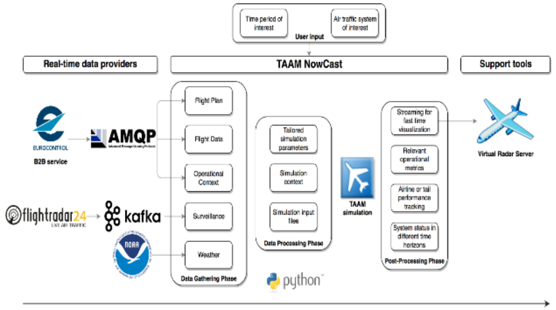
Clustering + Neural Networks/ random forest

Ensemble Meta-Estimators

Gradient Boost Machine

• How the complex nature of the ATM system impacts trajectory predictions?

• How can this insight be used to optimize the ATM system?



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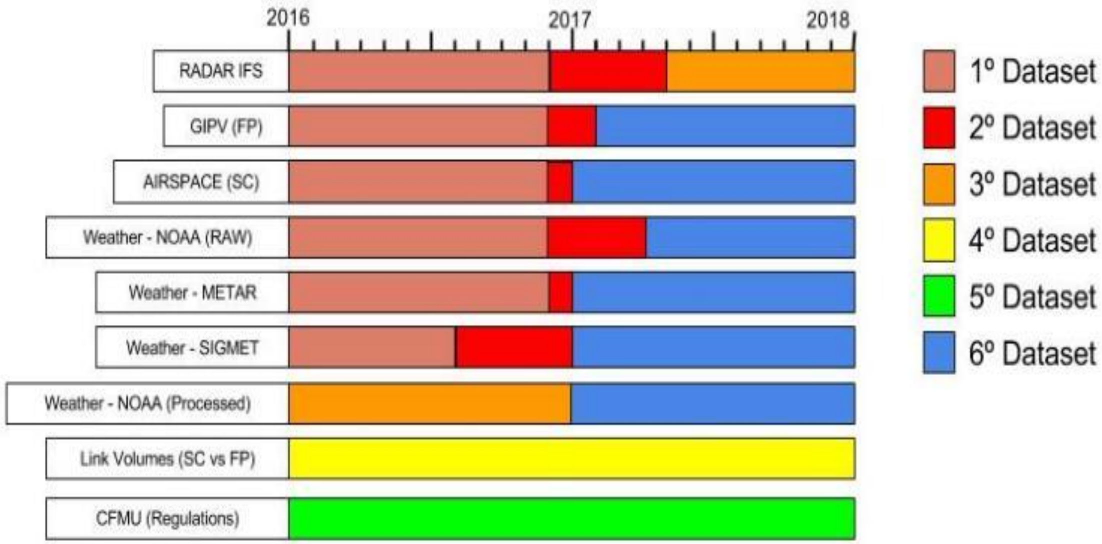
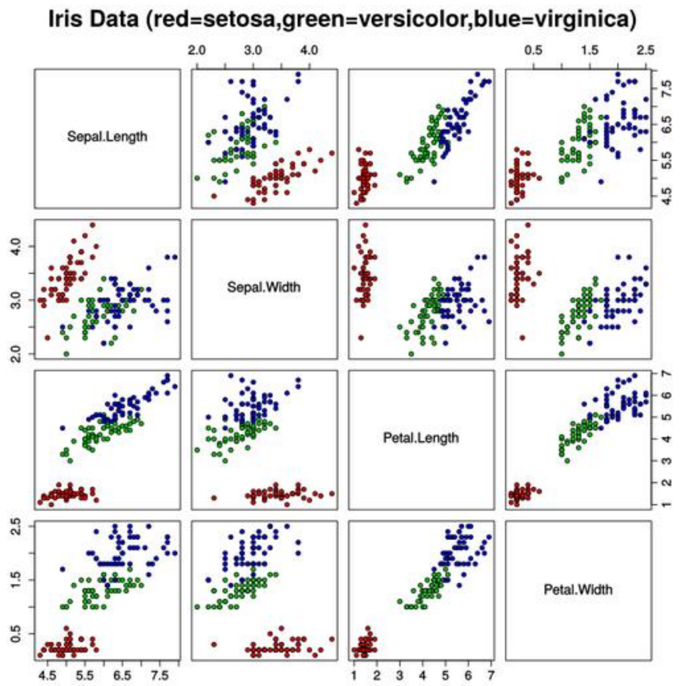
Challenge 1: Data sources for training

- **Data volumen: Ex. DART uses two years of data including surveillance, flight plan, airspace, weather**
- **Quality of the data: Noise (frequency, scattering, outliers) and gaps**
- **Access to those data sources: Ex. Partnership with an ANSP**
- **Conversion from data to the input of a ML algorithm (e.g., categorical variables,…)**
- **Opportunity: Common dataset for training and validation (Ex. [Iris flower data set] for aviation? Role of Eurocontrol?)**





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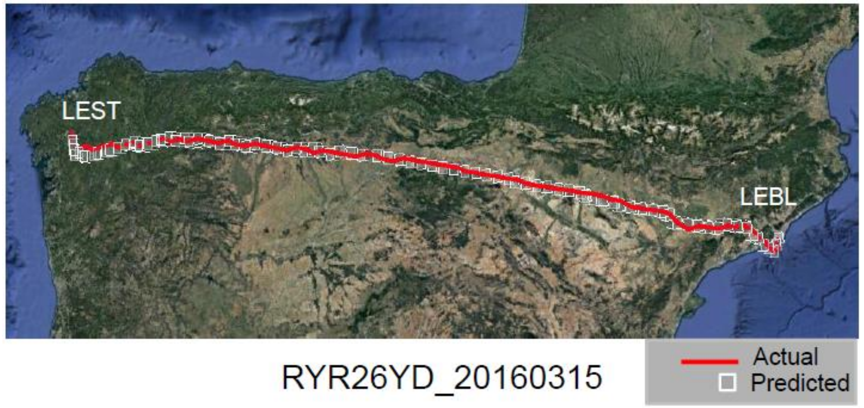
Challenge 2: Algorithms used

- **Variables to be predicted: 4D? 4D+mass?,nD? (Depends on the application, data availability,…)**
- **Temporal sequence of aircraft states**
- **Time between re-trainings (training time and re-training frequency)**
- **Opportunities: Clustering & Time series based algorithms**

State variable	Symbol	Units
Latitude	φ	$\circ$
Longitude	λ	$\circ$
Pressure altitude	H_p	ft
Elapsed flight time	t	s
Aircraft mass	m	kg



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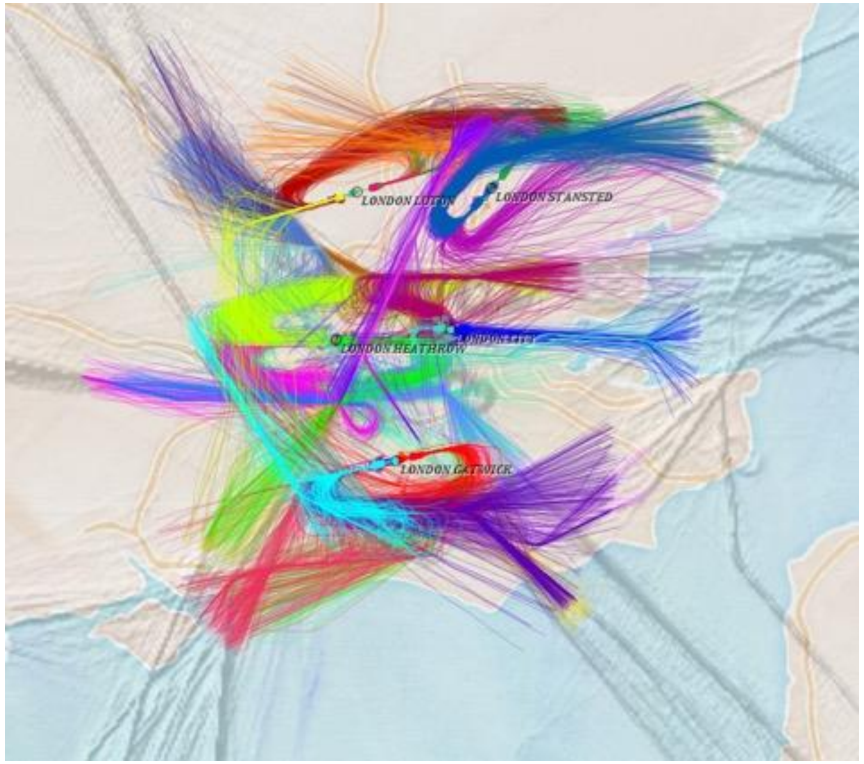
Neural Networks (NN) used to predict the vertical profile of a trajectory [1],
Regression methods used to relate the influences of traffic flow and wind conditions [2]
Dynamically updated clustering methods to infer an estimation of the aircraft intent that represents a flown trajectory [3].
Density-based Spatial Clustering of Application with Noise (DBSCAN) clustering algorithms combined with Interacting Multiple Model (IMM) Kalman filters [4]
K-nearest neighbors in combination of regression methods using wavelet decomposition in Sobolev space [5].
Data-driven Aircraft Trajectory Predictions using Ensemble Meta-Estimators [6]

[1] Le Fablec, Y., & Alliot, J. M. (1999). Using Neural Networks to Predict Aircraft Trajectories. In IC-AI (pp. 524-529).
[2] Kun, W., & Wei, P. (2008, July). A 4-D trajectory prediction model based on radar data. In *Control Conference, 2008. CCC 2008. 27th Chinese* (pp. 591-594). IEEE.
[3] Yang, Y., Zhang, J., & Cai, K. Q. (2015). Terminal-area aircraft intent inference approach based on online trajectory clustering. The Scientific World Journal, 2015.
[4] Song, Y., Cheng, P., & Mu, C. (2012, June). An improved trajectory prediction algorithm based on trajectory data mining for air traffic management. In Information and Automation (ICIA), 2012 International Conference on (pp. 981-986). IEEE.
[5]Tastambekov, K., Puechmorel, S., Delahaye, D., & Rabut, C. (2014). Aircraft trajectory forecasting using local functional regression in Sobolev space. Transportation research part C: emerging technologies, 39, 1-22.
[6] Data-driven Aircraft Trajectory Predictions using Ensemble Meta-Estimators, DASC 2018

Challenge 3: Data curation



- **Clustering based on O-D or other clusters or no cluster**
- **Cluster for prediction or cluster combined with another technique**
- **Normalization of the data**
- **Opportunity: Could we with limited data (based on a series of O-D clusters) identify a model so it can be applied to any O-D?**

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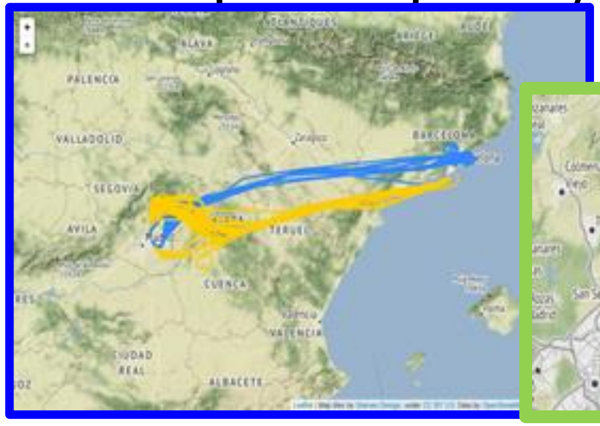
Challenge 4: “Single” trajectory prediction and “multiple” trajectory prediction

- **Single predition typically based on O-D clusters**

- **Poor results capturing SIDs/STARs**



- **Results difficult to assimilate or correlate with model-based**

Latitude

Feature	Type
Estimated route distance	Numerical
Runway arrival	Categorical
TOC temperature	Numerical
Arrival temperature	Numerical

Longitude

Feature	Type
TOC temperature	Numerical
Arrival temperature	Numerical
Estimated route distance	Numerical
Estimated departure time	Numerical

- **Interaction between clusters for multiple trajectory predictions (traffic)**

- **Learning from data allows you to learn from de-conflicted data. Advantage or disadvantage?**

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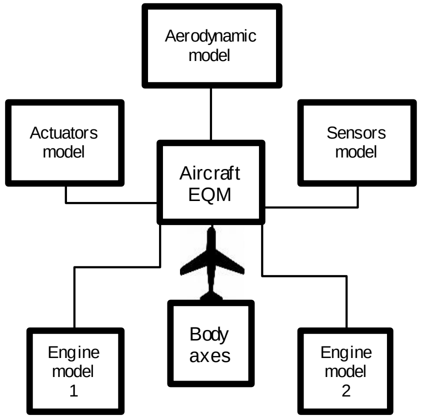
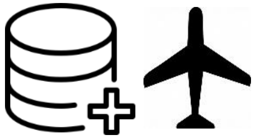
Challenge 5: Hybrid approach

- **Models obtained from data and used to feed a traditional model-based TP (that only captures a/c dynamic)**
  Ex. TP of a Flight plan improved knowing runway and/or SID/STAR assigned

- **a/c dynamic based on data (new data sources, like QAR)**



Model-based methods	Data-driven methods
Rely on simplifications of actual aircraft behavior	Data-driven methods do not consider **any aircraft behavior**!
Require initial input data which is normally not known	Require only **recorded flight information** from previous operations
Miss the effect of actions that can not be modelled	Capture **tactical variations** affecting flights thanks to acquired knowledge



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