AI for Air Traffic Management and Large Scale Urban Mobility

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- ENAC
- Head of the optimization and machine learning team (OPTIM)
- Meta-heurristics and ML for large scale optimization problems with application to ATS.

Nicolas Couellan (Pr)

- ENAC (OPTIM, IMT, AOC))
- In charge of Machine Learning activities
- **Research focus :**
  - Optimization for machine learning
  - Robust optimization for machine learning, robustness in neural networks, SVM, ...
  - Applications of machine learning in Air Transport Systems (ATM, ATC, GNSS).

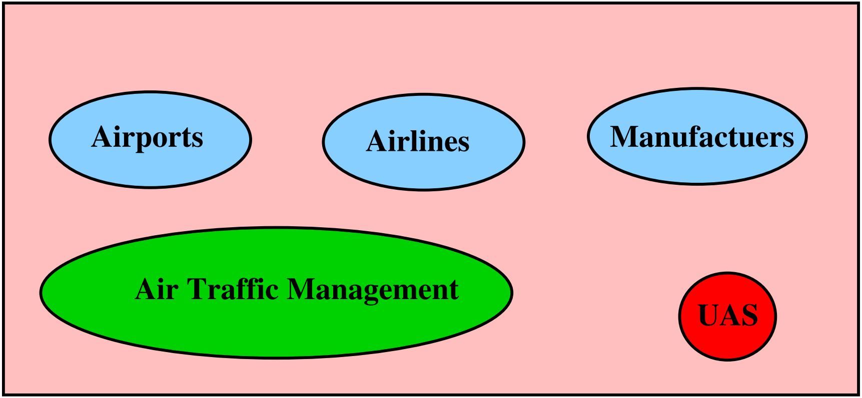
Emmanuel Rachelson

- ISAE, Head of the Supaero Reinforcement Learning Initiative
- Reinforcement Learning and Sequential Decision problems

Stéphane Puechmorel (Pr)

- ENAC
- Scientific Advisor of the dean of studies.
- Machine Learning, Information Geometry

Air Transportation System



Some Key Features of ATS Woldwide

- Flights per day $\simeq$ 100 000
- Airports $\simeq$ 50000 (Atlanta , Beijin...)
- Take Offs : $21\text{x}10^6$
- Flown kms : $34\text{x}10^9$
- Flown hours : $54\text{x}10^6$
- Aircraft : $\simeq$ 20000
- Airlines : 340
- Passengers per year : $3.4\text{x}10^9$
- Turnover : $720\text{x}10^9$\$ (profit : $23\text{x}10^9$ \$)
- Fuel consumption : 355.10^9 liters (320 000 liters for A380)

One day of Traffic in Europe

Traffic in Europe ...

AI for ATM

On Board Automation

Ground Control Approach (GCA) at Orly 1951 ...

Full Automation for Landing

Today, Aircraft can navigate and land automatically...

What about the ground evolution ?

The “plotting” 1949...

- The aircraft are symbolized by magnets (id, direction, the positions are **transmitted by the pilots**).

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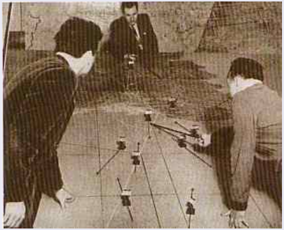
Plotting table at Aix-en-Provence ACC in 1949



Current Control Position in France

Approach at Paris Roissy ...

What is the objective of the chair in this area ?

We propose in this chair to develop new AI Decision Support Tools to increase the level of automation of the ground segment.

AI for UTM

What is UTM ?

New actors are coming....




Airbus Vision of UTM ...

For such UTM/UAV... traffic

- More autonomy is requested
- Large scale trajectory planning is needed

Large scale trajectory planning by AI (ENAC)...

- Self-Adaptive Arrival Manager
- Automatic conflict resolution (no proven algorithms (aerodynamic))

Learning from Trajectories

Challenges in Air Transport Systems

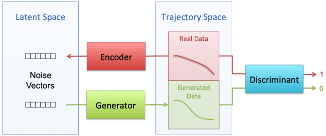
Context

- Usually Large scale complex systems
- Need for reliability (ex : certification, safety)
- Data are heterogeneous (ex : voice, sensors, physical models, radar, meteo...)
- In ATM/ATC, trajectories are subject to external control (limitation of physical models)

Scientific Challenges

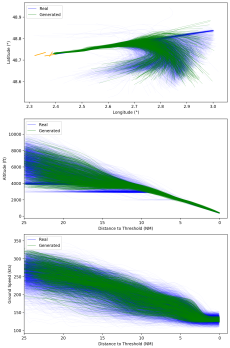
- Large Scale Combinatorial Optimization problems in ATM
- Learning of infinite dimensional data (trajectories)
- Robust machine learning techniques

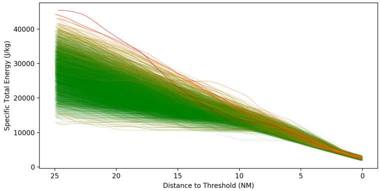
GAN for Aircraft Trajectory Generation and Atypical Approach Detection

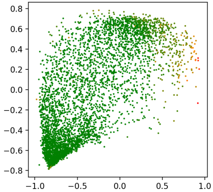


- Learn approach trajectory distributions using GAN
- Simulate new flight paths (takes into account ATC orders unlike physical models)
- Use GAN discriminator to detect abnormal behavior
- Allows for infinite dimensional trajectories to be represented in the latent input space (in low dimension)

Learning of infinite dimensional data (trajectories)







Gabriel Jarry, Nicolas Couellan, Daniel Delahaye. On the Use of Generative Adversarial Networks for Aircraft Trajectory Generation and Atypical Approach Detection. to be presented at EIWAC 2019 :, 6th ENRI International Workshop on ATM/CNS, Oct 2019, Tokyo, Japan

Learning infinite dimensional objects

In this chair, one objective is to design specific machine learning algorithms for infinite dimensional data

Geometric Machine Learning

Fault detection in UAVs

- Problem statement : early detection of failure from embedded sensors.
- Data : rotation rates and acceleration, measured by on-board IMU.
- Sources of failure : actuators, motors and propellers.
- Attitudes and positions of the UAV are represented as elements of $SE(3)$.
- UAV state observation through time yields a trajectory in $SE(3)$.
- Lie group machine learning are applied to cluster trajectories in $SE(3)$ for failure detection and characterization.

Learning traffic patterns based on complexity I

- A traffic sample is given by a set $(x_i, v_i)_{i=1\dots n}$, where v_i is the aircraft speed at sampled position x_i.
- In the neighborhood of each point (x, v), we assume that the spatial distribution of the speeds is gaussian.
- We estimate its mean and covariance matrix using a kernel K, $K_h(x) = \frac{1}{h}K(\frac{x}{h})$,

$$m(x) = \frac{\sum_{j=1}^{N} v_j K_h(x - x_j)}{\sum_{j=1}^{N} K_h(x - x_j)}, \quad \Sigma(x) = \frac{\sum_{j=1}^{N}(v_j - m_i)(v_j - m_i)^T K_h(x - x_j)}{\sum_{j=1}^{N} K_h(x - x_j)}$$

Learning traffic patterns based on complexity II

- Evaluating $m(x), \Sigma(x)$ on a evenly spaced grid of points yields an image whose pixels are vectors and SPD matrices.
- Keeping only the Σ part gives an image with values in the manifold of SPD matrices.
- Using the affine invariant metric and the convolution operator on the manifold allows an extension of the deep learning manifold that can be used to take into account the traffic complexity into decision support tools.

In this chair, one objective is to use and understand geometry of the trajectory data to improve learning algorithms

Questions ?