Monitoring Atmospheric Phenomena within Low-Altitude Clouds with a Fleet of Fixed-Wing UAVs

**Context**

SkyScanner: 2 years long research project involving atmosphere scientists and drone / robotics scientists
- Refine aerological models of cumulus clouds
- Enduring agile drone conception and control
- Fleet control

**2-levels approach**

- High level mission planning (coarse macroscopic cloud model, drone allocation to given regions)
- Local planning (dense cloud model, drone trajectories optimization)

**Dense cloud mapping**

Mapping a 4D structure from data perceived over a (small) set of 1D manifolds
- Parameters to estimate: 3D winds, P, T, U, LWC...
- Sparse information: use of Gaussian regression processes

**Challenges:**

- Optimize hyper parameters learning (exploit sparsity, develop incremental schemes, …)
- Choice of the kernel
- Exploit mapped parameters correlations
- Relations with the coarse macroscopic model?

**Planning trajectories**

Maximizing the utility gathered along the path taking into account the air flows
- Finite-horizon optimization problem

\[
\begin{align*}
\arg\max_{\alpha^{(1)}, \ldots, \alpha^{(N_p)}} & \quad \sum_{t=0}^{T} U(x_t^{(1)}, \ldots, x_t^{(N_p)}, \alpha^{(N_p)}) \\
\text{s.t.} & \quad |\alpha_t^{(j)} - \alpha_{t-1}^{(j)}| \leq \Delta \alpha_{\max} \quad \forall i, j
\end{align*}
\]

- Planning in the control space composed of two phases:
  1. blind Random Search to initialize the trajectories
  2. constrained Simultaneous Perturbation Stochastic Approximation algorithm to converge to a local maximum

**Challenges:**

- Sound definition of the utility
- Exploiting a realistic energetic model
- Multi-criteria optimization scheme
- Learn planning hyperparameters \((\delta x, \delta t)\)

**Experiments @ENAC**

- Aircraft modeling: aerodynamic and propulsion models, polar curve
- On-line wind estimation

- Vane to measure the angle of attack
- Paparazzi autopilot

**MesoNH cloud simulation**

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