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

Alessandro Renzaglia, Christophe Reymann, Simon Lacroix

LAAS-CNRS

Context

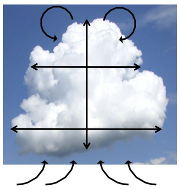
SkyScanner: 2 years long research project involving atmosphere scientists and drone / robotics scientists

- Refine aerological models of cumulus clouds
- Enduring agile drone conception and control
- Fleet control

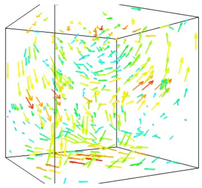
www.laas.fr/projects/skyscanner

2-levels approach

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



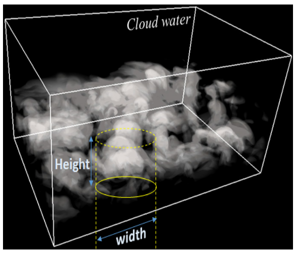
- Local planning (dense cloud model, drone trajectories optimization)



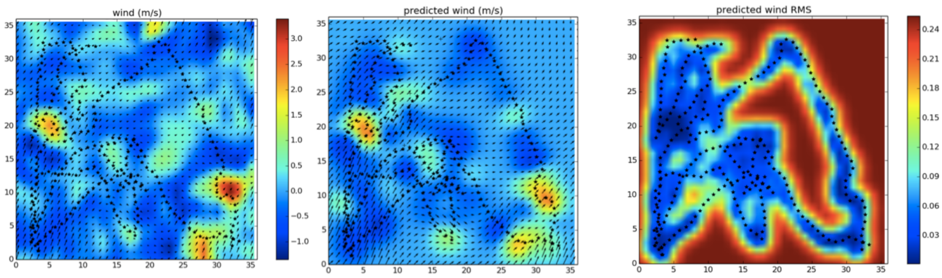
Dense cloud mapping

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



MesoNH cloud simulation
Produced by Faycal Lamraoui
CNRM/GAME Laboratory,
Toulouse



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

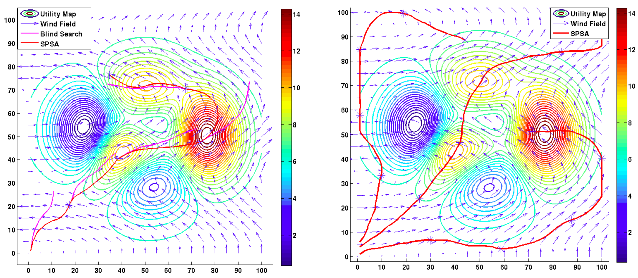
$$\underset{\boldsymbol{\alpha}^{(1)},\ldots,\boldsymbol{\alpha}^{(N_r)}}{\operatorname{argmax}} \sum_{t=t_0}^{t_0+\Delta T} U(\mathbf{x}_t^1(\boldsymbol{\alpha}^{(1)}),\ldots,\mathbf{x}_t^{N_r}(\boldsymbol{\alpha}^{(N_r)}))$$

$$s.t. \quad |\alpha_i^{(j)} - \alpha_{i-1}^{(j)}| \leq \Delta\alpha_{max} \quad \forall i,j$$

- 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 (δx, δt)



Experiments @ENAC

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

Vane to measure the angle of attack

Paparazzi autopilot