System simulation of a fleet of drones to probe cumulus clouds

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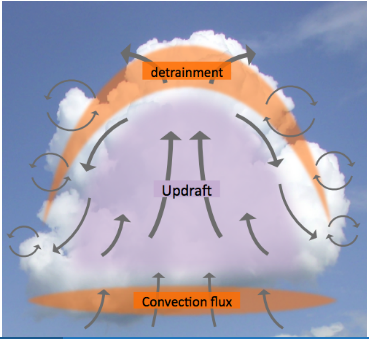
Context

- Characterize the boundary layer of clouds
- Follow 4D evolution of the cloud



Problem statement

Collect data with spatial resolution of 10m at 1Hz over the cloud lifespan: 1 hour over $1km^3$

Exploring clouds is a particularly complex task:

- Follow the 4D evolution of the cloud along 1D manifolds
- Highly constrained problem: Mission duration, UAV size and wind influence

The only way is to use muliple UAVs

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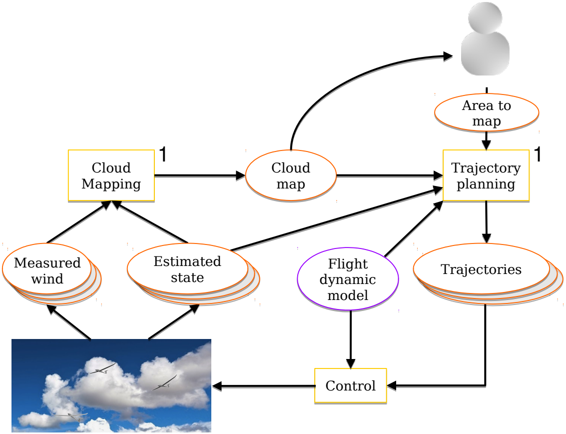
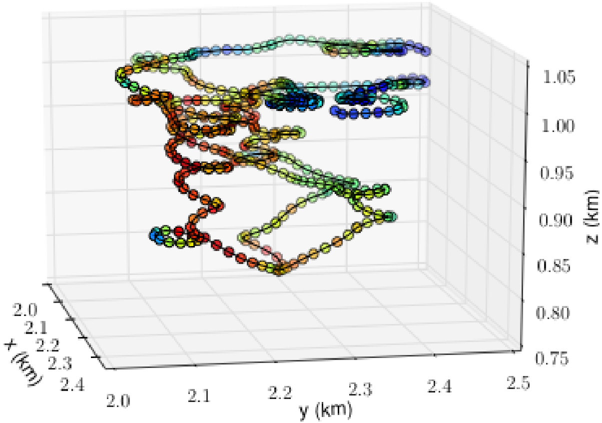
Overall structure



[1] C. Reymann, A. Renzaglia, F. Lamraoui, M. Bronz, and S. Lacroix, "Adaptive sampling of cumulus clouds with a fleet of UAVs," Autonomous robots, Jan. 2017.

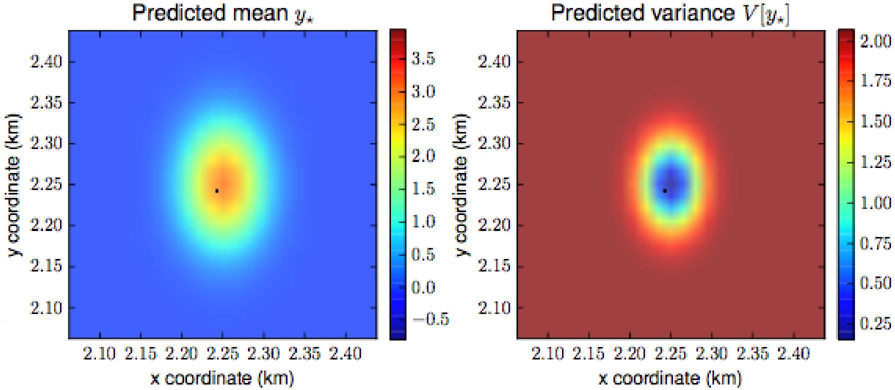
Main algorithms

Planning *Coarse level:* "map those volumes"
Fine level: on-line optimal path generation.



Main algorithms

Mapping Gaussian Process Regression to model the cloud



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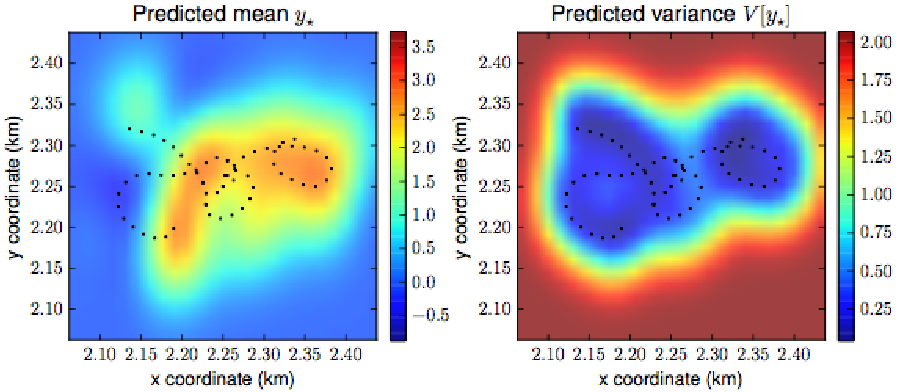

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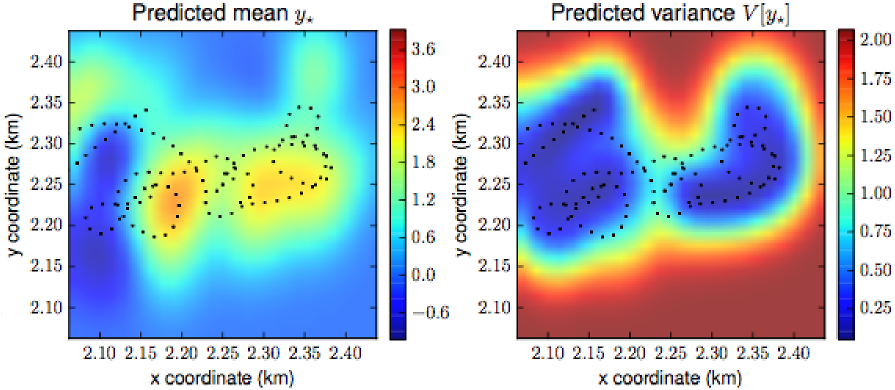

The need for a simulation architecture

Mapping and path planning were yet to be integrated with realistic flight simulators

No existing straightforward way to simulate this kind of system as a whole

Primary goals of this work:

- Build a software architecture integrating realistic simulators
- Integrate the mapping and exploration algorithms within this architecture
- Test and validate the whole system.

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Simulation backends

Environment:

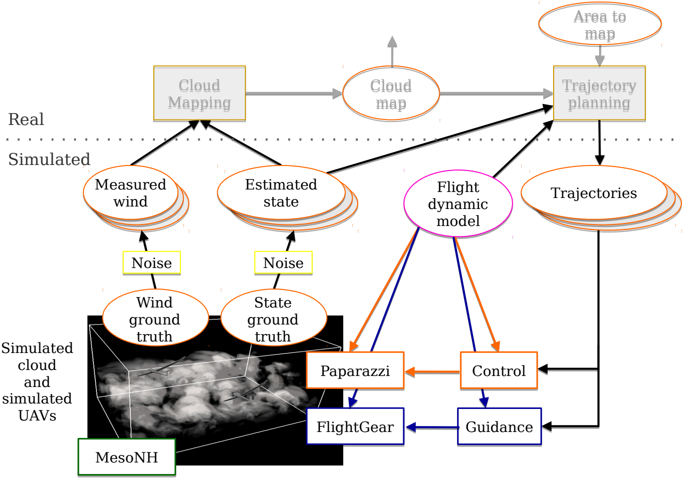
MesoNH MeteoFrance's realistic cloud simulator
Offline generation of a 64 km^3 fair weather scenario

Flight:

Paparazzi ENAC's open source autopilot and ground control software

FlightGear Open source flight simulator

Concept of the simulation architecture



Requirements of the new simulation architecture

Design a new software architecture being able to:

- Be prepared to handle a fleet of aircraft
- Integrate the project's previous work
- Seamless transfer the algorithms to the real implementation
- Add new functionality easily

We decided to use the Robot Operating System (ROS) framework

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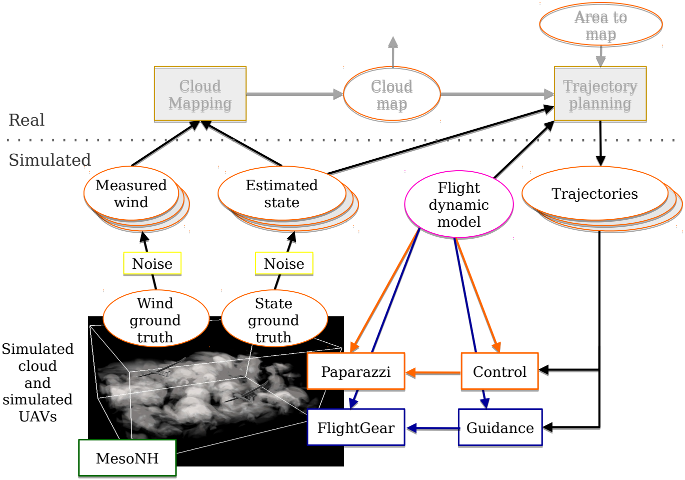
ROS implementation of the simulation architecture



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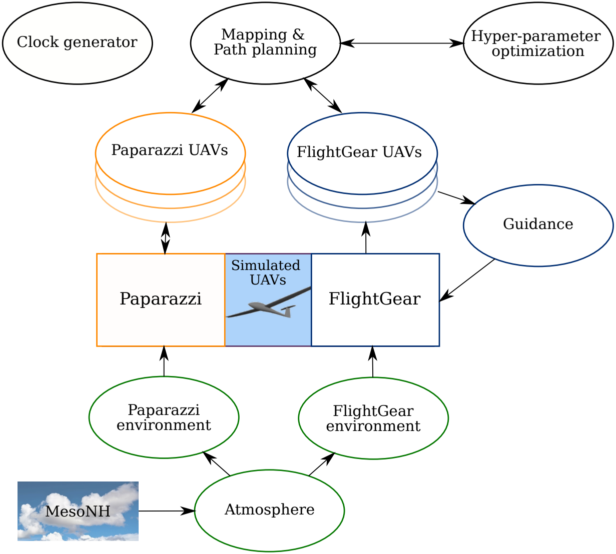
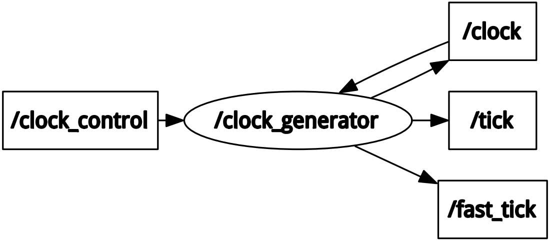
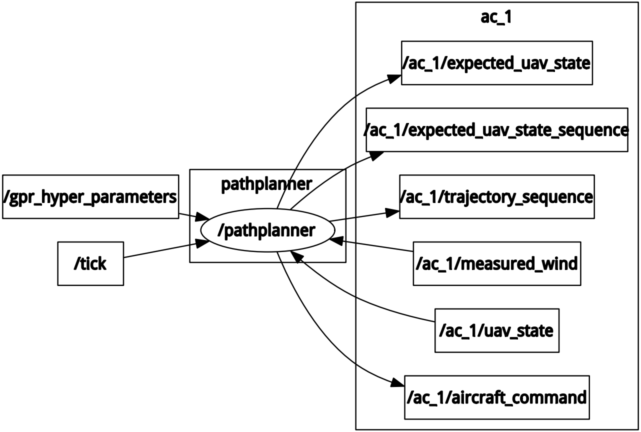


Time management



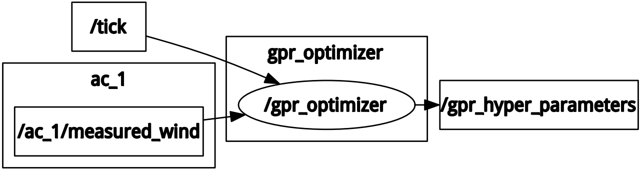
Input (Topic) Process (Node) Outputs (Topics)

Mapping & path planning node



Gaussian process hyper-parameters optimization

- Improve prediction with increasing wind samples



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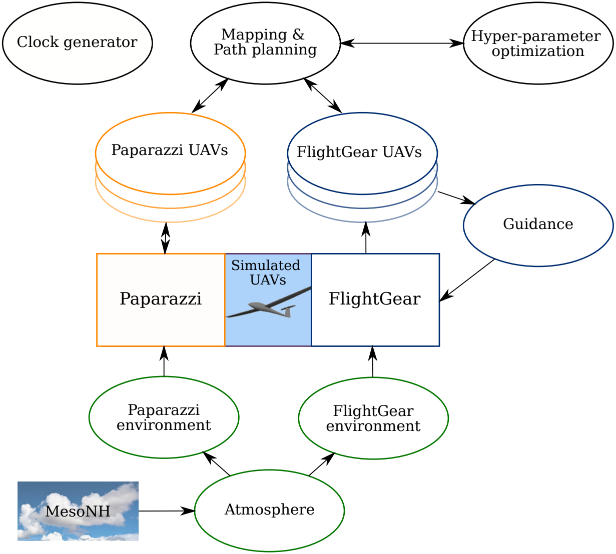
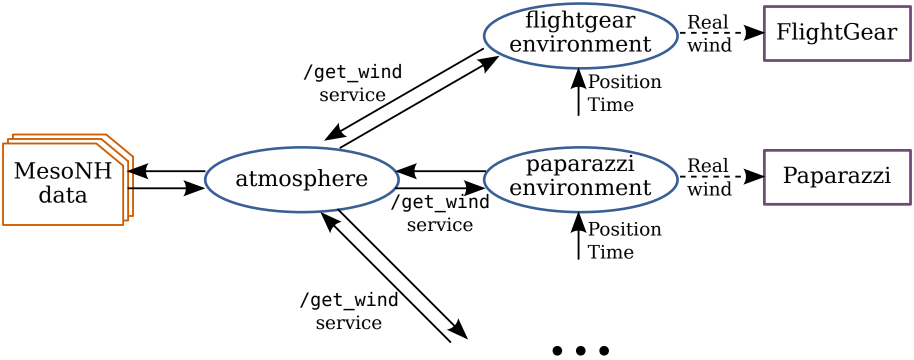
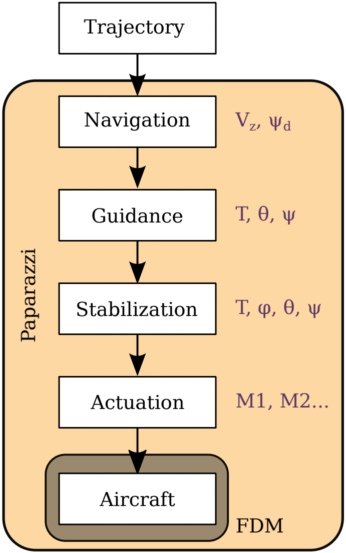
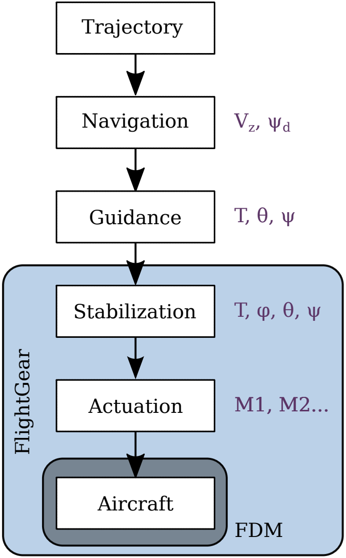


MesoNH interface with flight backends



Paparazzi vs. FlightGear control loops





Interface with Paparazzi

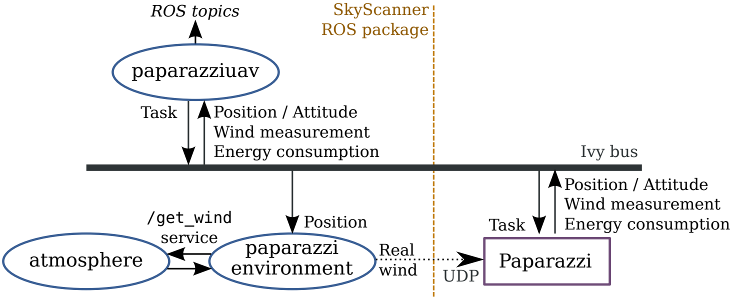


Figure: Interface between Paparazzi and SkyScanner ROS package

Interface with FlightGear

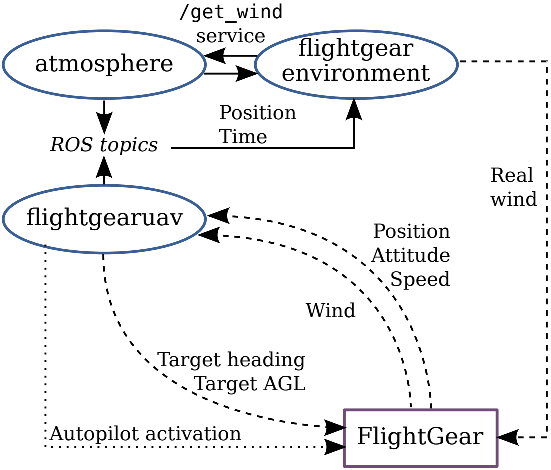


Figure: Interface scheme between FlightGear and SkyScanner ROS package

The SkyScanner ROS package

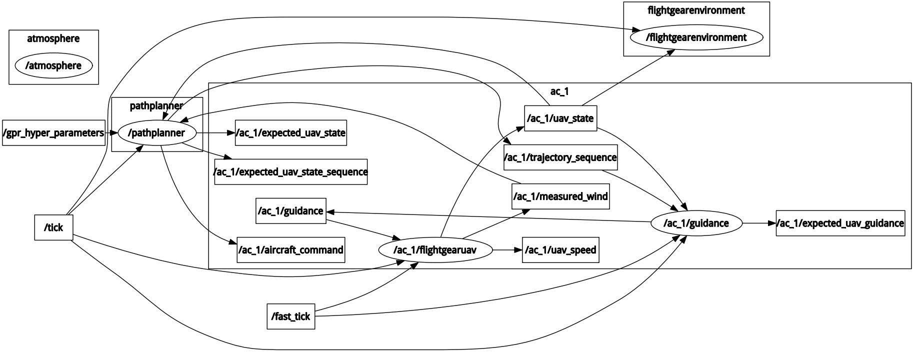
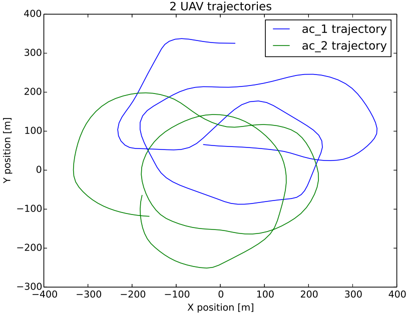
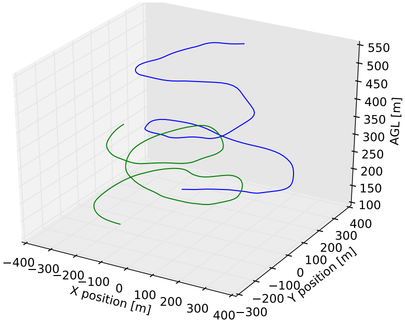


Figure: Whole simulation and control loop

Resulting trajectories





Summary

- Deployment of a simulation architecture
  - Path planning and mapping algorithms integration
  - Interfaces with realistic simulators
  - **Extensible & Reusable**
- Available in: `http://github.com/rafael1193/skyscannner_integration`