

Experimental Wind Field Estimation

Gautier Hattenberger

Joint work with :

Jean-Philippe Condomines and Murat Bronz

ENAC UAV Lab, French Civil Aviation University, France
gautier.hattenberger@enac.fr

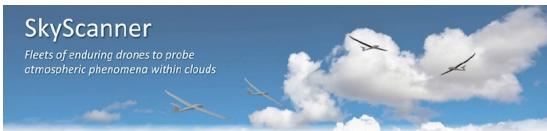
ISARRA2016 – Toulouse – mai 2016



- 1 Introduction
- 2 Wind Field Estimation
- 3 Improvements with Aircraft Model
- 4 Conclusion and Future Work

SkyScanner

Fleets of enduring drones to probe atmospheric phenomena within clouds



Founded by STAE Foundation, outcome from the Micro Air Vehicle Research Center of Toulouse

<https://www.laas.fr/projects/skyscanner>

<http://websites.isae.fr/mav-research-center>

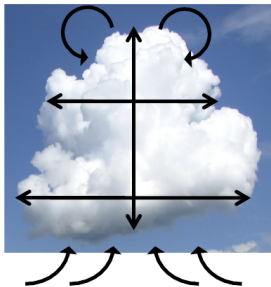
- Study and experimentation of a fleet of mini-drones that coordinate to adaptively sample cumulus-type clouds
 - refine aerological models of clouds
 - conceive enduring and agile micro-drones
 - fleet control and trajectory optimization

Objectives

Within the global scope of the project, some particular objectives:

Aircraft performances identification aerodynamic and propulsion performances are required for aircraft control and trajectory planning

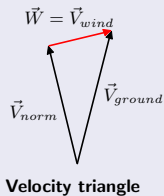
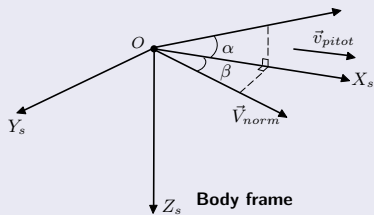
Wind field estimation real-time estimation of the local wind field for the atmospheric studies but for the trajectory planning as well



- 1 Introduction
- 2 Wind Field Estimation**
- 3 Improvements with Aircraft Model
- 4 Conclusion and Future Work

Principles

Based on the velocity triangle



$$\vec{V}_g = \vec{V}_n + \vec{W}$$

Problem

A direct measure of the wind is not possible

Problem

A direct measure of the wind is not possible

Full airspeed measurement

3D airspeed sensors compatible with mini-UAVs are available but can be fragile and expensive

Problem

A direct measure of the wind is not possible

Full airspeed measurement

3D airspeed sensors compatible with mini-UAVs are available but can be fragile and expensive

No flow sensor

Without airspeed measurement, wind-field can still be estimated from GPS/IMU data, but needs special trajectories:

- flying in circle for the horizontal components
- gliding for the vertical component

Problem

A direct measure of the wind is not possible

Full airspeed measurement

3D airspeed sensors compatible with mini-UAVs are available but can be fragile and expensive

No flow sensor

Without airspeed measurement, wind-field can still be estimated from GPS/IMU data, but needs special trajectories:

- flying in circle for the horizontal components
- gliding for the vertical component

This solution gives too much constraints on the trajectories, especially the glides

Low-cost sensors solution

Wind estimation is done with a non-linear Unscented Kalman Filter (UKF) by fusing at least:

- GPS velocities
- accelerometers, gyrometers and magnetometers
- airspeed norm from Pitot tube

Wind Estimation

Low-cost sensors solution

Wind estimation is done with a non-linear Unscented Kalman Filter (UKF) by fusing at least:

- GPS velocities
- accelerometers, gyrometers and magnetometers
- airspeed norm from Pitot tube

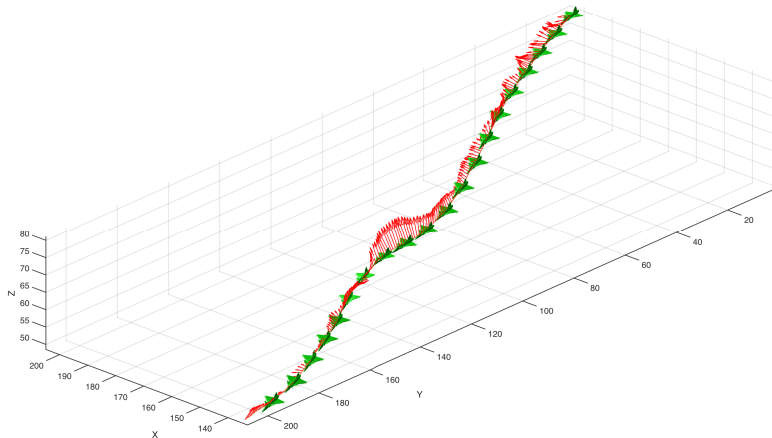
Improvements

Add an extra angle-of-attack probe in order to improve the estimation of the vertical component

$$(S) \begin{cases} \dot{v} = v \times \omega_m + q_m^{-1} * A * q_m + a_m & \text{(evolution)} \\ \dot{v}_b = 0 \end{cases} \quad \begin{pmatrix} y_v \\ y_V \\ y_B \\ y_\alpha \end{pmatrix} = \begin{pmatrix} | \langle v, e_1 \rangle | \\ q_m * v * q_m^{-1} + v_b \\ q_m^{-1} * B * q_m \\ \tan^{-1} \left(\frac{\langle v, e_3 \rangle}{\langle v, e_1 \rangle} \right) \end{pmatrix} \quad \text{(measurement)}$$

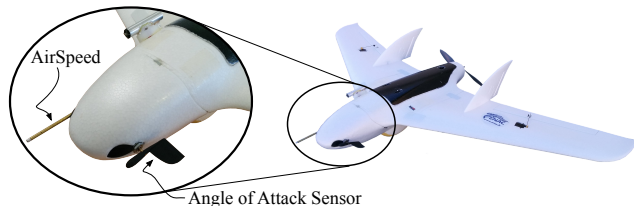
Wind Estimation Results

Estimation of an updraft during a gliding phase



Aircraft Instrumentation

- Aircraft integration
 - commercially available airframe (Mako)
 - GPS, IMU and barometer for position and attitude estimation
 - integration of a Pitot tube and an angle of attack probe
 - on-board data logging on SD card
 - controlled using *Paparazzi UAV* system
<http://paparazziuav.org>



Angle of Attack Sensor

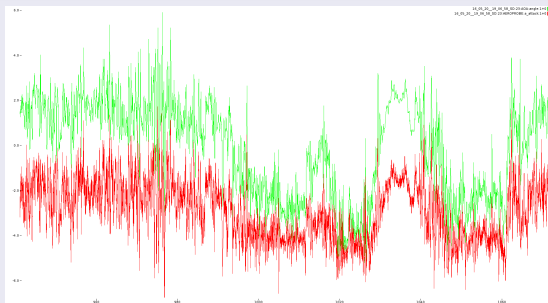
- Homemade with an absolute angular sensor (US Digital, 12 bits resolution, hall effect) and 3D-printed flag
- Calibration in wind tunnel is required to compensate interaction with the fuselage



Angle of Attack Sensor

- Homemade with an absolute angular sensor (US Digital, 12 bits resolution, hall effect) and 3D-printed flag
- Calibration in wind tunnel is required to compensate interaction with the fuselage

In-flight comparison with a 5-holes probe (Aeroprobe) (in red)



variations are coherent
but there are an offset
and a scaling error

- 1 Introduction
- 2 Wind Field Estimation
- 3 Improvements with Aircraft Model**
- 4 Conclusion and Future Work

Improving the Wind Estimation

Estimation can be improved by knowing:

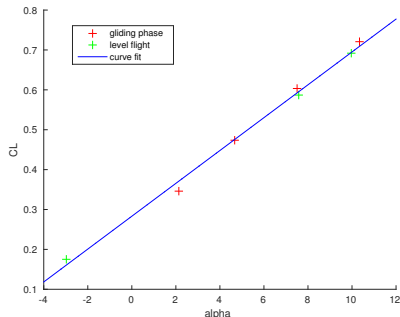
- the aircraft aerodynamic model
- the propulsion set model

Improving the Wind Estimation

Estimation can be improved by knowing:

- the aircraft aerodynamic model
- the propulsion set model

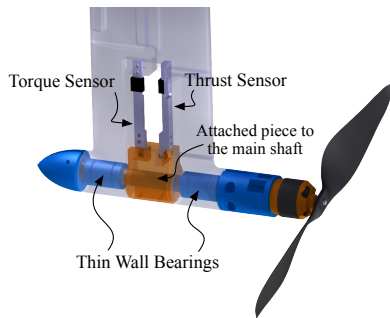
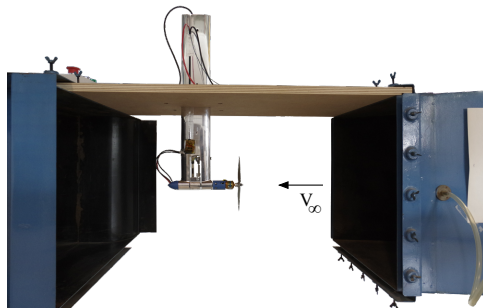
Lift coefficient results



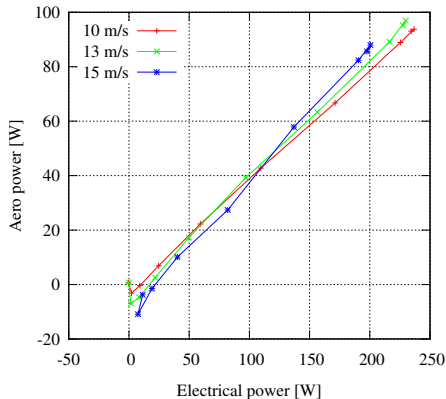
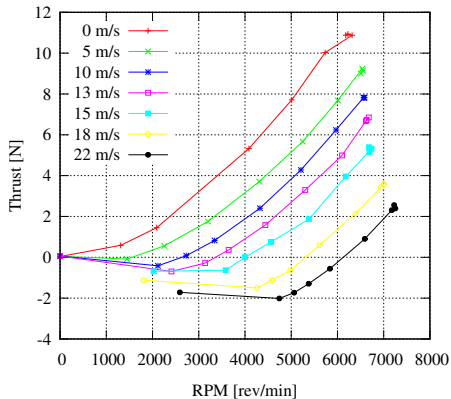
- Angle-of-attack sensor is also used for aircraft identification
- Extracted points comes from gliding phases (in red) and from level cruise flights (in green)

Motor Test Bench

- Build an accurate model of the propulsion system
- Automated measurement procedure in wind tunnel



Motor Analyses



In the useful range of airspeed, linear relation between the electrical power input and the resulting propulsive power

- 1 Introduction
- 2 Wind Field Estimation
- 3 Improvements with Aircraft Model
- 4 Conclusion and Future Work

Conclusion

- Development of a wind field estimation algorithm
- Evaluation on real flight data
- Integration of extra low-cost sensors
- Aircraft and motor identification

Future Work

- Use the aircraft and propulsion data in the wind estimation filter
- Integrate the filter on an on-board computer for real-time processing