Active turbulence rejection for tilt-wing MAV control

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Context [2]

Convertible UAVs have :

– interesting operational characteristics (flight and hovering).

– energy advantages, with increased autonomy compared to quadcopters

– an increased sensitivity to turbulence and aerological disturbances.

Figure 1: The flight steps of a tiltwing UAV [Dufour Aero]

Objectives of the PhD thesis

→ Propose and identify a model for a new tiltwing architecture developed at ENAC, based on a non-actuated rotating wing.

→ Propose different control solutions with or without a model to maintain mission requirements.

→ Improving disturbance rejection by measurement (five-hole probe) and extending the previous commands to take turbulence into account.

Materials and methods

Colibri UAV:

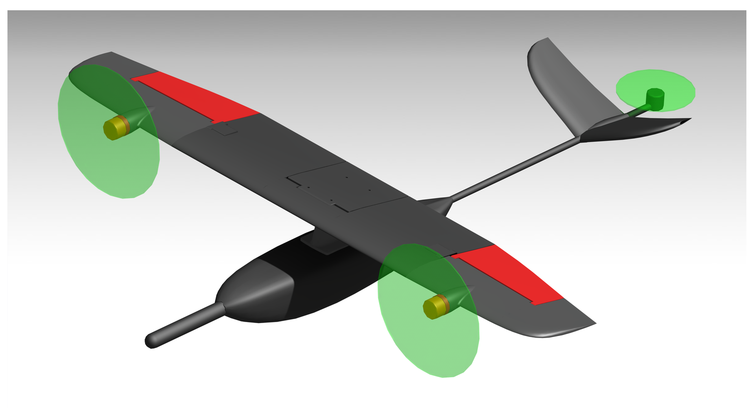

Fig. 2: Colibri CAD model

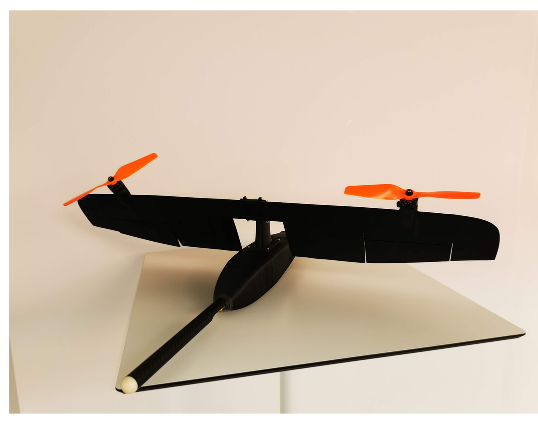

Fig. 3: Colibri UAV, 3D printed

Φ-theory [3] : Singularity-free aerodynamic model over the entire flight envelope

Dynamics based on multi-body modelling with the Udwadia-Phohomsiri equations [4]

$$\begin{cases} M(q,t)\ddot{q} = Q(\dot{q},q,t) \\ A_m(\dot{q},q,t)\ddot{q} = b_m(\dot{q},q,t) \end{cases} \implies \ddot{q} = \begin{bmatrix} (I - A^+A)M \\ A \end{bmatrix}^+ \begin{bmatrix} Q \\ b \end{bmatrix}$$

with $(*)^+$ the Moore-Penrose pseudoinverse.

Wind tunnel experimentation to validate the model [5]:

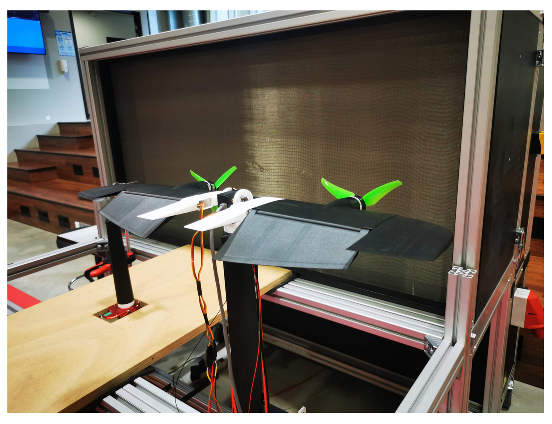

Fig. 4: Horizontal flight

Fig. 5: Transitional flight

Results

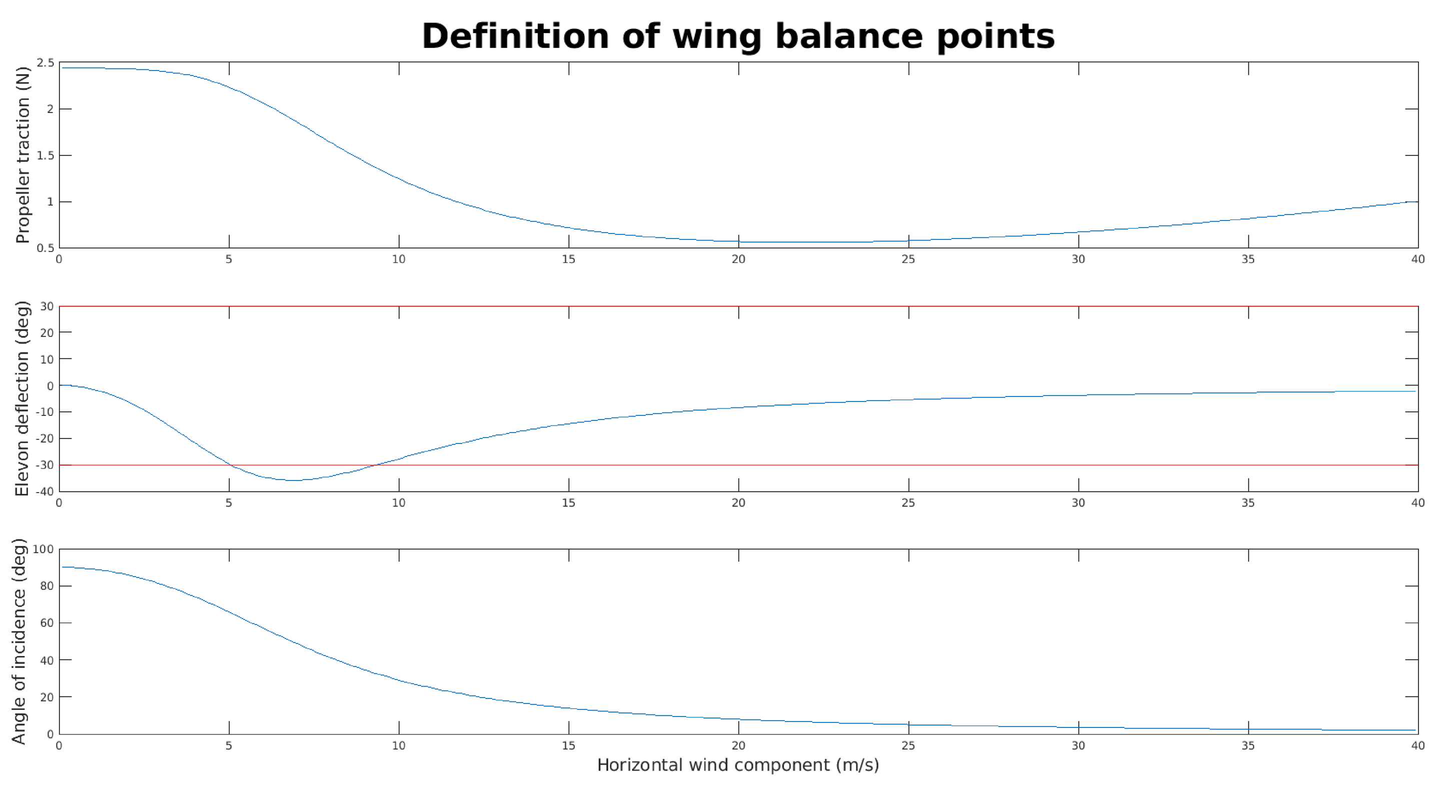

Fig. 6: Equilibrium points

Obtaining the set of equilibrium points from the phi-theory modelling for a wind in the vertical plane of the UAV.

LPV model (Linear Parameter-Varying)

$$\dot{x} = A(\theta(t))x + B(\theta(t))u$$

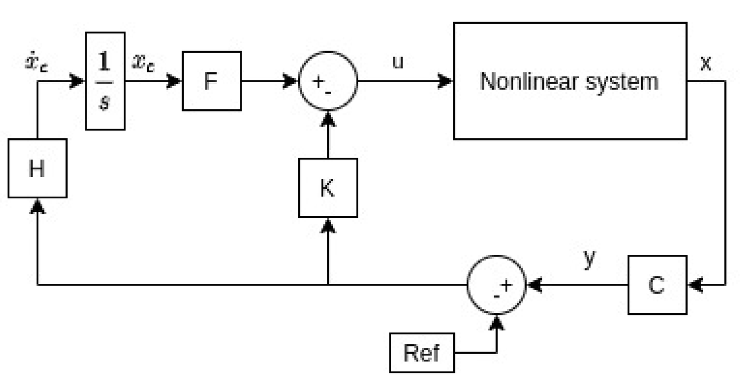

Fig. 7: Control architecture

Optimisation of a linear controller (fig. 7) with Systune [1] to obtain wind tunnel balance points. The use of integrators to compensate for non-modelled effects and thus to determine the difference between the model and the real system

References

[1] Pierre Apkarian, Minh Ngoc Dao, and Dominikus Noll. "Parametric Robust Structured Control Design". In: *IEEE Transactions on Automatic Control* 60.7 (July 2015). Conference Name: IEEE Transactions on Automatic Control, pp. 1857–1869. ISSN: 1558-2523. DOI: 10.1109/TAC.2015.2396644.

[2] Guillaume J. J. Ducard and Mike Allenspach. "Review of designs and flight control techniques of hybrid and convertible VTOL UAVs". en. In: *Aerospace Science and Technology* 118 (Nov. 2021), p. 107035. ISSN: 1270-9638. DOI: 10.1016/j.ast.2021.107035. URL: https://www.sciencedirect.com/science/article/pii/S1270963821005459 (visited on 10/14/2021).

[3] Leandro Ribeiro Lustosa, François Defaÿ, and Jean-Marc Moschetta. "Global Singularity-Free Aerodynamic Model for Algorithmic Flight Control of Tail Sitters". In: *Journal of Guidance, Control, and Dynamics* 42.2 (Feb. 2019), pp. 303–316. DOI: 10.2514/1.G003374.

[4] Aaron Schutte and Firdaus Udwadia. "New Approach to the Modeling of Complex Multibody Dynamical Systems". In: *Journal of Applied Mechanics* 78 (Mar. 2011). DOI: 10.1115/1.4002329.

[5] Ezra Tal. *Global Trajectory-tracking Control for a Tailsitter Flying Wing in Agile Uncoordinated Flight.* 2021. URL: https://scholar.google.com/citations?view_op=view_citation&hl=fr&user=zZuIRwYAAAAJ&sortby=pubdate&citation_for_view=zZuIRwYAAAAJ:0EnyYjriUFMC (visited on 12/10/2021).