PX4 VTOL Vector Control of a Tail-sitter

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Motivation

Why is fixed wing VTOL interesting?

- take-off and land like a helicopter
- fly efficient like fixed wing plane

Requirements

- low mechanical complexity
- suitable for prototyping, testing (small scale, easy repairable)
- high efficiency

Examples

Transition Robotics' Quadshot

BirdsEyeView Aerobotics' FireFly6

Canadair CL-84

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Airframe

Our Solution: Caipirinha Tail-sitter

- use conventional wing and upgrade it to VTOL
- weight: $900\,\mathrm{g}$, wingspan: $0.84\,\mathrm{m}$
  $\Rightarrow$ allows convenient, save testing
- low mechanical complexity (no rotation of body parts necessary)
- non-destructible EPP foam
- autopilot: Pixhawk with PX4 firmware

Challenges

- choice of engines and props is crucial: efficiency vs. airflow for control authority
- moment generation using flaps is highly airspeed dependant
- large area for wind to attack during hover

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Control

What are the main challenges?

- three flight phases: hover, transition, horizontal flight
- controller needs to work for all phases $\Rightarrow$ very difficult
- flap actuation non-linear dependant on airspeed
- relevant airspeed is combination of vehicle airspeed & prop induced airspeed
- aerodynamic forces (lift drag) and moments have large impact on vehicle dynamics
  $\Rightarrow$ need good model for control

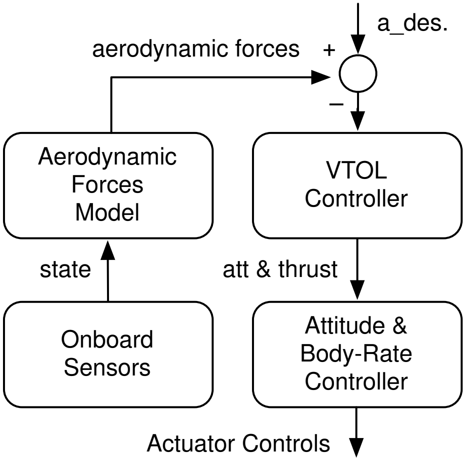
Possible solution: Controller switching

- run multicopter and fixed wing controller and do switching/blending
- gives good results but not elegant, brute force

$\Rightarrow$ **want a single controller which can handle all phases**

Better solution: VTOL controller

- use cascaded control strategy (position → velocity → acceleration)
- compute desired attitude and thrust from desired acceleration
- compensate desired acceleration for aerodynamic forces
- use onboard sensores & aerodynamic data to model forces
- can use approximations e.g. lift cancels gravity in horizontal flight

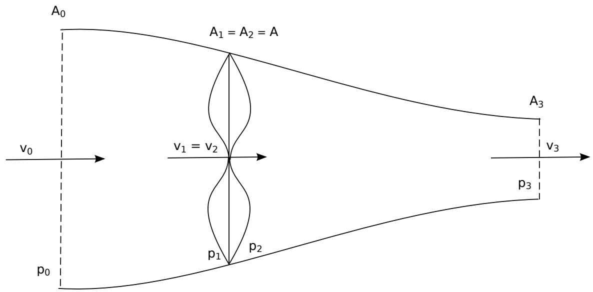


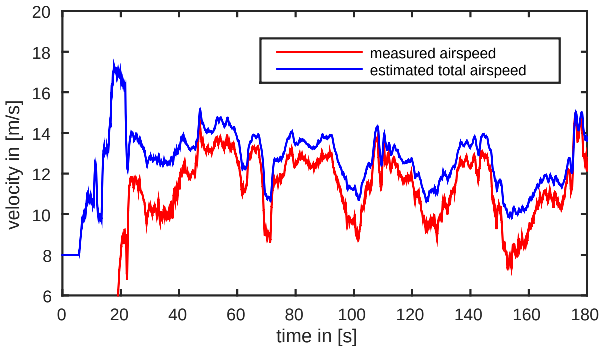
Advantages

- no controller switching necessary, no phase distinction necessary
- can use most structure from multicopter position/attitude controller

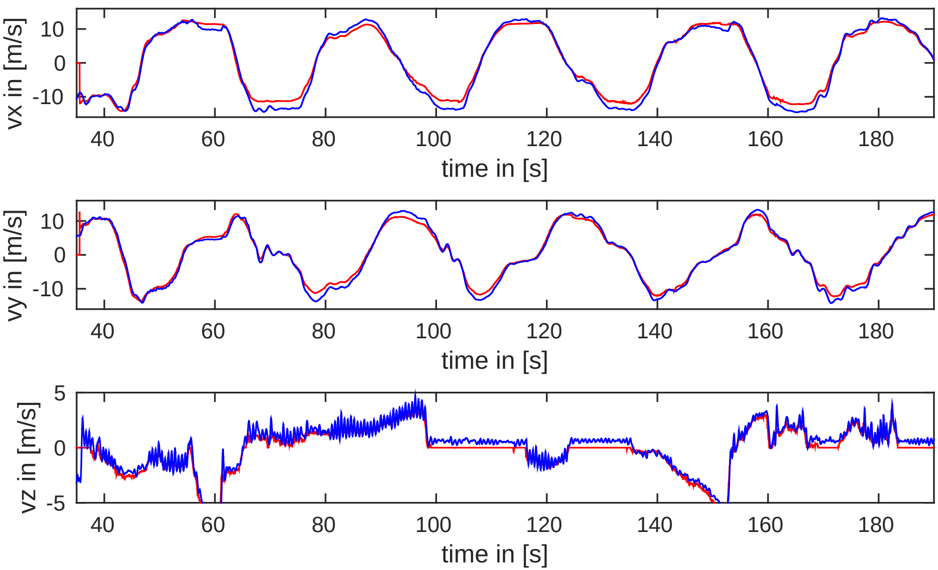
Modelling example: Estimation of total airspeed at flaps

- use simple model of airflow and current measurements to estimate total air velocity behind propeller
- can use estimate to scale attitude controller gains





Velocity tracking results in horizontal flight



reference: red, actual: blue

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Conclusion & Outlook

Conclusion

- VTOL controller allows elegant control throughout entire flight envelope
- no switching of controllers or flight mode distinction necessary
- but: need a good aerodynamic model $\Rightarrow$ wind tunnel data?
- further testing and development required

Outlook

- fly transitions based on desired velocity trajectory
- find suitable aerodynamic model
- make controller robust to model uncertainties

Thank you for your attention