Master Thesis

Airspeed Identification Using the Rotors of a Drag Power Kite

Contact/Applications to:

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Motivation

Power generating kites have the potential to generate clean energy with 10x less material demand and at a very low cost (see e.g. [1, 2, 3] and references therein). "Drag power" kites generate power with onboard wind turbines and generators by flying fast crosswind motions, see Fig. 1 with video link in the description. Electrical power is transmitted to the ground at a medium voltage level via electric cables in the tether.

Figure 1: Flying Kitekraft demonstrator. (Video available online: https://youtu.be/42jvQpgfm94, accessed: Jan 11, 2022).

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Tasks, Suggested Solution Approach, Expected Results

The TUM spinoff and project Kitekraft is developing and researching drag power kites. The kite's airspeeds needs to be sensed/identified with the available sensors at all times. Instead of using a pitot tube or anemometer (which is cost costly, adds complexity, would need to be redundant, and can clog or otherwise fail) and instead of using GPS (which does not account for the speed of the wind field), the eight onboard rotors can be utilized as anemometers. In general, the rotor can be modeled aerodynamically with the "rotor map", i.e.

torque = function of airspeed and rotor-RPM.

This function may be given as Look-Up-Table and can measured in wind tunnel or computed via fluid simulations. The idea of using the 8 rotors as anemometers is to simply invert this function (without changing anything of the machine control), because the torque can be computed via the measured currents in the electrical machine and the rotor-RPM is also known by the power electronics, leaving the airspeed as the only unknown. However, the solution of the inversion of the function may not always exist and, more importantly, may not always be unique (i.e. several airspeeds fit to a trqoue-RPM pair). Additionally, torque and RPM are measured with certain noise, offset and other measurement errors, which might deteriorate the estimated airspeed significantly. A first master thesis on this topic is completed, and this new master thesis with low error at all times during the flight. Unlike a conventional aircraft, disturbances not only originate from gusts, but also from flight-state-dependent aerodynamic force and moment variations as well as moments induced by the tether. The chosen forward-stagger boxplane, which is optimal for power generation as well as hover-stability, poses an additional challenge and reduces open-loop stability margins of the angle of attack. On the other hand, not only the elevator but also the flaperons of the top wing (canard-like effect) as well as differential rotor thrust can be utilized in a control allocation for the angle of attack controller intelligently and efficiently. This master thesis includes the following works: Several basic controllers based on PID and state feedback are implemented, but need extension. The aerodynamics model needs better calibration. Extended control schemes based on Model Predictive Control (using a software library like CasADi or ACADO) shall be tested. All control implementations shall be tested in our C++ framework simulation as well as in flights on our demonstrator kites. Besides the documented software, the master thesis as theory documentation and tests report are important outcomes. This multidisciplinary task is supported by the members of the Kitekraft team.

Starting Point

This announcement, the literature list below, and additionally provided internal documents upon start.

Report and Presentation Guidelines

One report (or thesis) and at least one presentation of the results are required. Guidelines and templates can be downloaded from https://github.com/floba/StudentGuidelines.

Your Profile

This student work will be jointly supervised by the Institute for Electrical Drive Systems and Power Electronics and the TUM startup project Kitekraft. The ideal candidate

- is a student in flight dynamics engineering, control, math, robotics, mechatronics, electrical engineering, mechanical engineering, informatics, or related fields,
- has good skills/background knowledge in control theory, math, MATLAB, C/C++, Office, LaTeX,
- is motivated in the respective field of science and engineering,
- has good English and German language skills.

References

[1] M. Loyd, "Crosswind kite power," Journal of Energy, vol. 4, no. 3, pp. 106–111, 1980.

[2] U. Ahrens, M. Diehl, and R. Schmehl, Eds., Airborne Wind Energy, ser. Green Energy and Technology. Springer Berlin Heidelberg, 2013.

[3] Kitekraft: Website, https://www.kitekraft.de, accessed: Jan 11, 2021.