Master Thesis

Computer Vision Applied to Airborne Wind Energy for Bird Collision Avoidance and Position Tracking

Contact/Applications to:

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Motivation

Because of their 10x lower specific material requirement compared to conventional wind turbines, power generating kites have the potential to generate clean energy at a very low cost without subsidies (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. Electrical power is transmitted to the ground at a medium voltage level via electric cables in the tether.

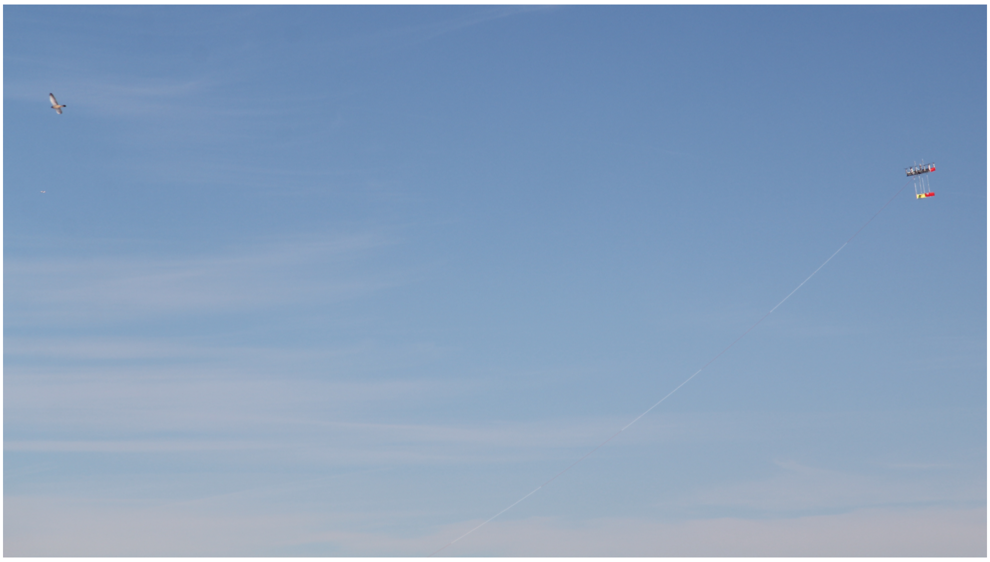

Figure 1: Flying Kitekraft demonstrator. (Video available online: https://youtu.be/gZ06BumGPAU, accessed: Feb 18, 2022).

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Tasks, Suggested Solution Approach, Expected Results

At TUM, project Kitekraft is developing drag power kites. Two camera have already been mounted to the kite and one to the ground station. The video streams have greatly enabled performance analysis.

This master thesis solves the following topic: The kite should never collide with a bird, for both public acceptance and to avoid any damages to the kite. To solve this issue, another camera specifically for this task shall be added to the ground station, which is pointed towards the kite (automatically through the ground station's azimuth alignment with the wind). Simple computer vision algorithms (not necessarily based on neural networks/AI, though it is a possibility) shall be investigated and implemented to detect birds in real time and warn the kite control software. In the simplest case, the kite would then switch from the power generating figure-8 flight to hovering and wait until the birds have passed. In a future scenario, the kite could also first shift the figure-8 pattern or perform an evasion maneuver in order to not stop the power generation. (The action the kite should take is not part of this master thesis.)

In a first step, the computer vision algorithm only needs to be capable to detect a bird in the view field of the camera, i.e. the result would be very conservative: when ever a bird (or rather foreign object) is detected, the kite would go to hover and wait. The computer vision algorithm must be able to distinguish a bird (foreign object) from the kite, tether, clouds, aircraft in the background/sky or possibly landscape features in the background. At least as a first simple solution to solve the latter issue, the camera might be mounted such that the view field is always slightly above the horizon. As the current position of the kite is always known e.g. via GPS, the control software could feed the computer vision algorithm with the kite's position such that also a misinterpretation of the kite (and tether) as a bird (foreign object) should be mitigated relatively easily. Clouds and aircraft in the background could be mitigated by triggering a bird (foreign object) detection only if the detected object has enough pixels with enough contrast compared to the background.

In a second step, the distance (and possibly size) of the bird to the kite and tether could be detected with the computer vision algorithm. Possibly, for a proper position/distance detection of the bird, instead of using a single camera, two cameras (stereo camera) could be used.

In a third step, instead of using the GPS and other sensors of the kite feeding to the computer vision algorithm, the computer vision algorithm is extended to explicitly detect the kite and feeds that result back to the kite control software, i.e. the computer vision algorithm serves as kite position sensor.

This work has to start with a selection of proper/suitable camera hardware: e.g. standard USB/IP camera vs. night vision camera vs. solid state Lidar (vs. maybe further possibilities). The hardware selection must take into consideration, that the bird detection must work also at night, rain, fog, snow (e.g., camera shall not freeze), and for years of operation (everything must work even if there is some dirt on the camera). The camera might also look into the sun directly (see also Youtube videos from our test flights: https://www.youtube.com/channel/UCQ2Brn4ll-jzyyjNojmsnHg). At the same time, the hardware costs must be low-cost and the overall hardware equipment should be not complex. It is, however, thinkable to, e.g., add infrared lights to the kite. Even better, if one makes use of what is there anyways, e.g. making use of the kite's lighting: The kite has flash lights on its wingtips which blink in a certain frequency and pattern (1 blink every 1...3 seconds). This timing can be made available to the computer vision algorithm and synchronized with it, i.e. execution of the bird detection algorithm synchronized with the lights every 1-3 seconds, such that the kite may be relatively easily be detected at day and night. A relative high performance industrial linux computer is available to execute the computer vision algorithm.

Further extensions of the computer vision algorithms may include: (1) Adding the so-called small earth grid lines to the ground station's video stream to allow simple post-flight analysis and comparison of the kite's (visual) position with the one detected by onboard sensors like GPS. (2) Detecting the tether's shape (3D position values) to allow for accurate simulation-measurement comparisons. (3) Detecting the kite's orientation. (4) For safety reasons, detecting people, who may enter the danger zone (wherever the kite flies is currently a danger zone established, until all redundancies are implemented and safe operation is proven).

The developed soft- and hardware shall be tested on real prototypes. Besides the documented software, the master thesis as theory documentation and 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 electrical engineering, informatics, or related fields,
- has good skills/background knowledge in computer vision, C/C++, electronics, USB and IP cameras, micro controllers, Linux, MATLAB, 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: Feb 18, 2022.