Flight Control Laboratory 2019

Kick-off meeting

Tommaso Sartor

Systems Control and Optimization laboratory

26th of April 2019

Overview

1. Course presentation
   - Motivation
   - Organizational
2. Projects presentation
   - Airborne Wind Energy Backgroung
   - Airborne Wind Energy Projects
   - FPV Nano-Copters Racing Background
   - FPV drone racing projects
   - Project of previous years
3. Project discussion

What is the FCL?

Objectives

- Hands-on experience in control and/or estimation
- Working with a real and/or simulated aerial system
- YOU shall learn something / gain further insights
- A documented and *working* (*running*) project (demo)

You working crazy hours and getting frustrated is certainly NOT our goal!

Time-line

Deadlines and mandatory meetings:

- **Kick-off meeting** April 29, 2019
- **Project Proposal Presentation** (two weeks after Kick-off)
- **Mid-term Presentation** (first week of June)
- **Final Presentation** (last week of July) *graded!*
- **Final Report** *submission deadline* August 7th, 2019, 23:59

- **Weekly Report** *every* Wednesday, 23:59

Project Proposal Presentation

Project Proposal Presentation:

- 5-10 min each
- Present your Project:
  - Define goals
  - Identify approach(es)
  - Come up with detailed time line (plan for mistakes and detours!)
- make slides

Afterwards:
(individual) discussion of project, approaches and time line

Mid-term Presentation

Mid-term Presentation (1st week of June):

- work accomplished so far (including problems and taken approaches)
- current state
- planned work
- (updated) time line for remaining time
- NOT graded!

See this as a grand rehearsal for the final presentation.

Final Presentation

Final Presentation (last week of July):

- final state of your project
- Demo
- problems encountered, approaches taken
- Prof. Diehl will be there!
- 20% of your grade

Final Report

General:

- Article in the SYSCOP wiki!
- *about* 1000 - 2000 words (quality over quantity)
- 60% of the grade

Contents:

- Explanatory graphics
- Problems, tried Approaches, lessons learned, ...
- Point to code and Examples / Tutorial

Keep in mind while writing:
Other people will read (parts of) it when they want to use or build up on your work

Weekly Report & Meetings

What goes into the weekly report (deadline Monday 23:59)?

- Work accomplished in previous week, including problems and state of lab
- Plans for the next week
- point to commits you have made if any
- Mail or markdown document in your repository
- Structured text like bullet points or tables are a plus

Questions, Problems, want to try your presentation, . . . ?

→ Send an email and ask for a meeting!

Grading

Grading based on three components:

- 20% your final presentation
- 20% code and documentation
- 60% lab report (Wiki article)

Legal notice

Please note:

- Plagiarism or copyright violations will be rewarded with a 5.0 (you fail)
- Cite correctly! Wrong citations or missing citations are plagiarism.
- Indicate your source for any piece of intellectual property that is not yours (code, image, text), otherwise this is also plagiarism.
- Before you the intellectual property of somebody else make sure you have the right to do so, and that you are not violating any copyrights.

Suggested methodologies

Team work:

- We suggest to work in group of two people

Software:

- The usage of `git` is highly encouraged
- You will create a repository on gitlab.syscop.de server
- Linux is preferred over Windows
- Python/Jupyter is preferred over Matlab

Formalism:

- Quaternions are preferred over Euler angles

Organizational Questions?

2019 Projects theme

- Airborne Wind Energy
- FPV microdrone racing

Airborne Wind Energy - Conventional turbines

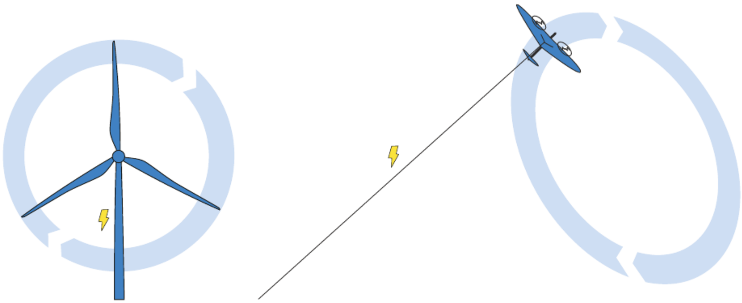

Figure: Comparison with conventional wind turbines, Illustration by R. Paelinck.

Airborne Wind Energy - Dual kite concept

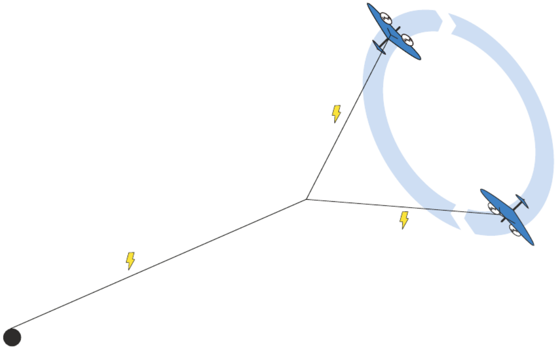

Figure: Dual-kite system, Illustration by R. Paelinck.

Airborne Wind Energy - Rotorkite concept

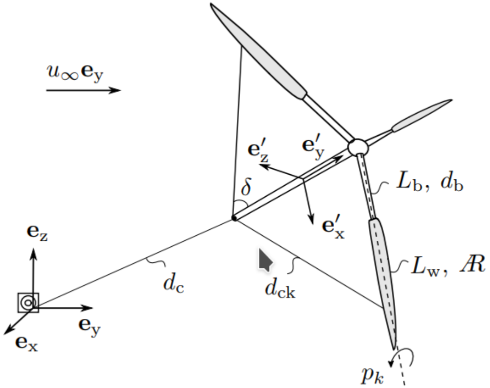

Figure: Conceptual schema of Rotorkite Airborne Wind Energy System (RAWES), Illustration by J. De Shutter.

Airborne Wind Energy - Rotorkite prototype

Figure: Real world rotorkite prototype, Copyright © 2019 Bladestips Energy

Airborne Wind Energy - Literature review

- Syscop wiki rotorkite pages
- Syscop cloud rotorkite folder
- Ask the course supervisor for credentials

Rotorkite experimental Setup 1 - Helicopter

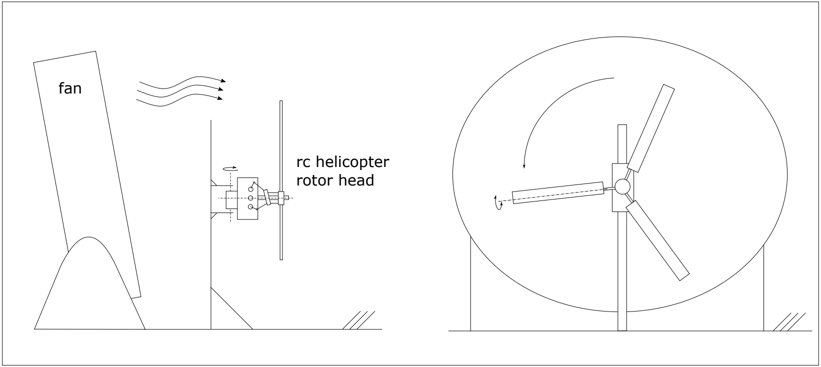

Figure: RAWES experimental setup, Illustration by T. Sartor

Rotorkite experimental Setup 2 - Autogyro

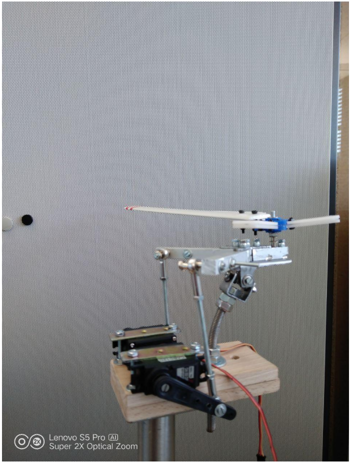

Figure: Autogyro-like rotor experimental setup

Project 1: Swash-plate setup, Close-loop control yaw angle

- Formulate a model of the system
- Identify main parameters
- Design a controller to achieve Close-loop Yaw angle tracking
- Run simulations and experiments
- Compare and explain the results
- Bonus:Add IMU, change MCU

Project 2: Identification and trust vector control

- Formulate a model of the system
- Design a controller to maximize the total aerodynamic force along some direction[1]
- Run simulations and experiments
- Compare and explain the results
- Bonus: Add transnational degree of freedom along power generations direction

[1] I.e the estimated direction of the tether

Project 3: Design next experimental setup (Nr.3)

- Unify setup 1 and 2, allow the blades to flap, control blades pitch, control incidence angle of the rotor.
- Be able to use current infrastructure to measure weight.
- It should have the ability to flight with minor changes.

Project 4: Rotorkite NMPC control in simulation

- Formulate a mathematical model for the system
- Generate optimal trajectories to maximize power estimation
- Formulate the on-line optimal control problem
- Choose the numerical solver to be used
- Run simulations

Project 5: Identify Pitch dynamics of half-wing setup

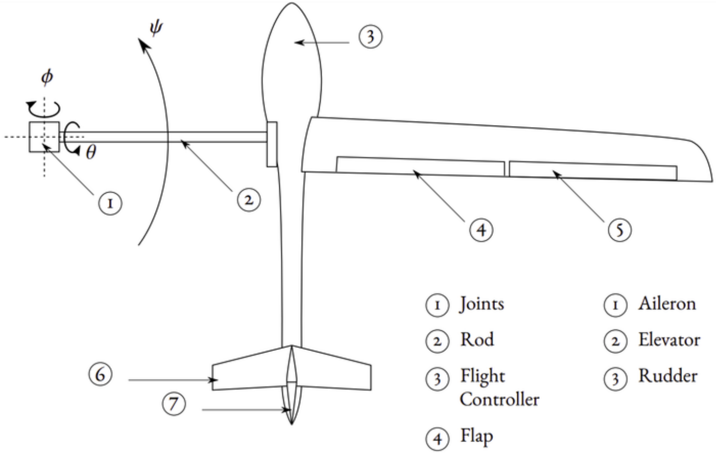

Figure: Half Wing Setup, Illustration by Jonas Schlagenhauf

FPV Nano-Copters - Vehicles

Figure: 70mm FPV nano copter - Trashscan

FPV Nano-Copters - Circuit

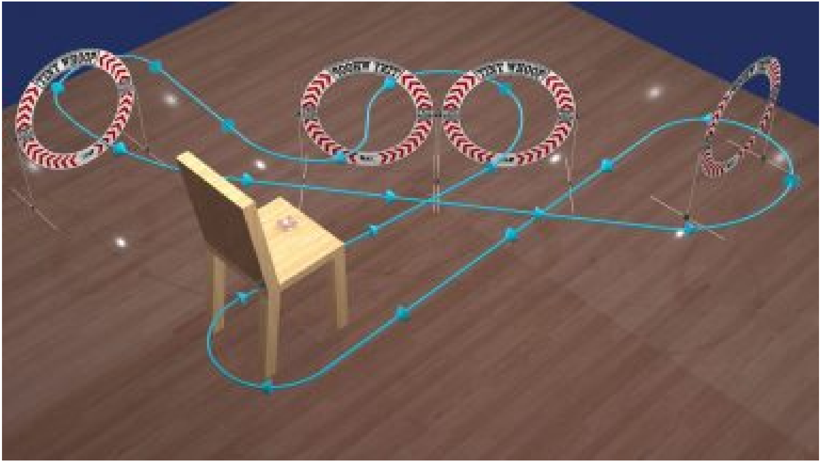

Figure: MultiGP UTT7 circuit

FPV Nano-Copters - Race video

FPV Nano-Copters - Available tools

- VIO[2] algorithms
- Datasets with data from: FPV cameras, Imu and MoCap[3] Ground Truth
- Drone simulators

[2] Visual Inertial Odometry
[3] Motion Capture, like VICON

FPV Nano-Copters - Literature review

- Syscop wiki pages about Nano-Copters Racing
- Syscop cloud `nanocopters` folder
- Ask the course supervisor for credentials

FPV Nano-Copters - Hardware

- Video receiver and analog video acquisition card
- Nano-Quadcopter with camera and video transmitter
- Multi-protocol Radio

FPV Nano-Copters Racing - Main motivation

- Replace expansive motion capture system with on-board vision sensor
- Lift the constraint of doing all computation on-board communication delay compensation
- Replace expensive high-performance embedded platform for on board processing with wired processing power.
- Minimize flying fixed cost payload unlocking the nano-size range.
- As a consequence safety protections and relative cost are also
- Achieve very cost effective autonomous indoor navigation.

FPV Nano-Copters Racing - Overview

- Run a fast control loop on-board based on MPC or LQR for trajectory tracking, able to run also only with IMU.
- Estimate pose of the device from the video stream using off-the-self monocular VIO algorithms, generate new trajectory and update on-board information.
- Collect and aggregate past VIO and control input to continuously refine the current knowledge of the dynamics, noise and possibly of the environment.

(Every point can be a project on its own)

Examples from previous Year 2018

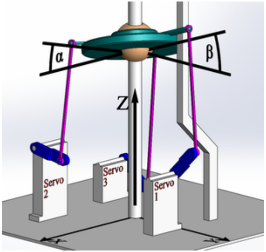

Figure: Lower swashplate assembly

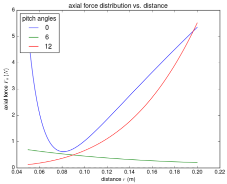

Figure: Rotorkite modelling and control

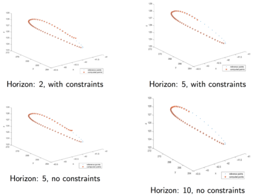

Figure: Control of Rotary Kite System in Simulation

Examples from previous Year 2017

Figure: Learned odometry model

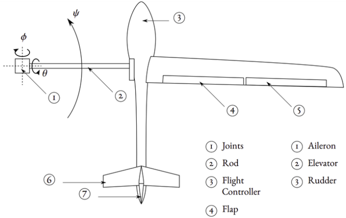

Figure: Learned State Estimator

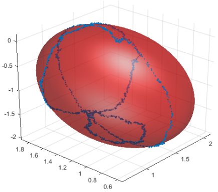

Figure: Magnetometer Calibration

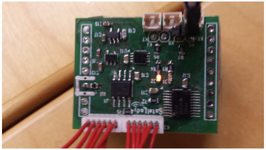

Figure: PCB development for a gps module

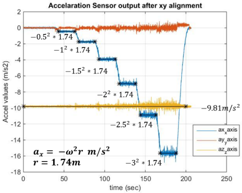

Figure: Accelerometer Calibration

Project Discussion