Course notes, module 5, week 39

UAV attitude failure detection

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1 Agenda

- Practical information.
- Short Introduction to the module theory and exercises.
- Exercises.

2 Theory presented in class

The topic of this module is the basic principles of UAV attitude failure detection. The F3322-18 standard specification is paramount in relation to this, as it is the first industrial standard to deal with the requirements of a Parachute Recovery System (PRS). The data logged by the Pixhawk 2.1 Cube Flight Controller (FC) and the analysis of this data is also a prerequisite of this module.

The following are the learning goals of this module.

1. Get familiar with the concepts of UAV attitude failure detection principles.
2. Get familiar with the F3322-18 standard specification published by American Society for Testing and Materials (ASTM).
3. Gain knowledge about logging on the Pixhawk 2.1 FC.

3 Exercises

The exercise materials are structured in the following way:

```
/exercise_materials
├─ /csv_files
│  ├─ /TEST5_30-01-19/
│  ├─ /TEST8_30-01-19/
│  └─ /TEST9_09-02-19/
├─ /ulog_files
│  ├─ /TEST5_30-01-19.ulg
│  ├─ /TEST8_30-01-19.ulg
│  └─ /TEST9_09-02-19.ulg
├─ /data_reader
│  └─ /data_reader.py
├─ /2015_Mass_threshold_for_harmless_drones.pdf
└─ /readme
```

The data has been collected with a hexarotor with the Pixhawk 2.1 FC[1]. The hexarotor can be seen in figure 1. The tests have been conducted in the following manner;

1. Arm the UAV.
2. Fly up to an altitude of 50-70 m.
3. Disarm the UAV in air.
4. Deploy parachute.

The tests used for this lecture can be seen at:

Test 5: https://youtu.be/raK2fnk5ULk
Test 8: https://youtu.be/gJK06kHUvz8
Test 9: https://youtu.be/opDSC2ox-c4

Basic physical parameters of the UAV (and parachute) can be seen in table 1.

Parameters	Symbol	Value
Gravity	g	$9.8m/s^2$
Multirotor mass	m	$1.95kg$
Air density	ρ	$1.225kg/m^3$
Effective cross-sectional area of parachute	$A_{parachute}$	$1m^2$
Coefficient of drag for parachute	$C_{parachute}$	1.6

Table 1: Multirotor and parachute parameters.

[1] https://docs.px4.io/en/flight_controller/pixhawk-2.html

Figure 1: S550 Hexarotor with Pixhawk 2.1 Cube FC used in parachute system tests.

3.1 Parachute Recovery Systems

3.1.1 What does a PRS consist of, and what should it be able to do? Please include a high level sketch/diagram of a PRS.

3.1.2 Describe in brief the testing procedures required for multirotors according to the F3322-18 standard. What is the minimum number of tests that needs to be performed?

3.1.3 In your opinion does the F3322-18 standard define a comprehensive validation of the PRS? Are there other requirements to the PRS and/or testing that could be relevant to include?

3.1.4 List in details the PRS documentation recommended for CAA approval of a UAS with a PRS installed according to the F3322-18 standard.

3.1.5 List a set of rules/pseudocode/flowchart that formally define how a failure scenario algorithm should be able to detect the possible failure scenarios.

3.2 Failure Scenario Analysis

3.2.1 Inspect the ulog files in the online tool and inspect the videos of the flights. What kind of failure scenario is this? Briefly describe and note time stamps for the major events of the failure scenario.

https://logs.px4.io

3.2.2 Get familiar with the Python simple CSV loader class. Plot IMU and velocity data. Comment on the results

3.2.3 Implement as a Python class an algorithm that is able to detect the failure scenario. If you can think of two different methods, implement both and then compare them in the following exercises. Describe your algorithm(s) here.

3.2.4 Test your algorithm(s) on the data sets from tests 5, 8, and 9. Comment on the results.

3.2.5 Show graphically your failure detection algorithm(s) together with relevant IMU data. Comment on the results.

3.2.6 Investigate the available CSV files, what other relevant data could be used when detecting failures?

3.2.7 Determine the kinetic energy at ground impact of the three flights. Is this within the kinetic energy threshold defined in the publication "Mass threshold for harmless drones"?

3.3 Available parachute systems (optional)

3.3.1 Perform a quick state-of-the-art survey of parachute systems for drones. List the different major manufacturers and briefly describe their product in a single paragraph.