UAV attitude failure detection

Alex Mejlevang Ellegaard - aelle20@student.sdu.dk
Anders Lind-Thomsen - andli20@student.sdu.dk
Peter Skibdal Frydensberg - pefry20@student.sdu.dk
Thomas Therkelsen - ththe20@student.sdu.dk

November 13th 2024

3 Exercises

3.1 F3322-22 Standard

Q1: §1.1.1 - "Compliance with this specification is intended to support an applicant in obtaining permission from a civil aviation authority (CAA) to fly an sUA over people."

Q2: §1.3 Units — The values stated in inch-pound units and can be converted as such: $ft = 0.3048m$, $lbs = 0.4436$. The formulas however can be used with both SI-units and and inch-pound units, as long as they are not mixed.

Q3: §1.4 - "This standard does not purport to address all of the Safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate Safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use."

Q4: §3.1.4 - "Autonomous triggering system, ATS, n—device or components independent from any flight critical system of the UA that will detect and initiate parachute deployment upon detection of a critical failure of the sUA in flight."

Q5: The Critical Number Motor Failure (CNMF) is the number of motor failures required to remove a small drone from stable flight, i.e. the CNMF for a 4-rotor drone is 1, and for a 6-rotor drone the number is 2.

Q6: The flight envelope is the range of values from the odometry sensors from which the drone can be safely operated within.

Q7: The Flight Termination System (FTS) is the system which will disable propulsion of the drone.

Q8: A Manual Triggering Device (MTD) is a trigger to deploy the parachute which overwrites the Autonomous Triggering System (ATS).

Q9: Opening Shock Load (OSL) is the maximum load force applied to the parachute under any condition during the opening of the chute.

Q10: Maximum Dynamic Chock Load (MDSL) is the maximum opening shock load the parachute is rated for.

Q11: A pilot chute is a parachute connected to the main canopy, which is smaller than the main canopy. The main purpose of this type of chute is to help deploy the larger chute by deploying before it.

Q12: The snatch force is the peak force needed by the pilot chute to fully extract the main parachute from its canopy to be able to fully deploy it.

Q13: The formula for the main canopy rate of descent at a specific altitude is:

$$vc = \sqrt{\frac{2 \cdot W_T}{S_0 \cdot C\left(D_0\right) \cdot p_0}} \cdot \sqrt{\frac{\rho}{\rho_0}} \tag{1}$$

Where vc is the descent velocity using a canopy, W_T is the the total measured weight of the object including drone, pilot schute and canopy, ρ_0 is the sea level air density, ρ is the air density for the specific altitude the object is in, S_0 is the total canopy surface area without including holes and $C\left(D_0\right)$ is the canopy's drag coefficient related to its area

Q14: The PRS (Parachute Recovery System) is not allowed to use the power supply of the UAS. It needs to have its own independent energy source such as a battery or capacitor.

Q15: The FTS is required to be onboard the drone, since it should still be able to active in case case that radio communication fails.

Q16: The FTS shall activate at the time of or before parachute deployment is initiated

Q17: In what cases is a manual triggering device obligatory, and what are the exceptions? The parachute recovery system shall be equipped with a manual triggering device (MTD) if the PRS is intended to be used on an sUA that is manually operated by an RPIC

3.2 PX4 log file analysis using an online tool

Having a look at both the 3D visualization and the PID analysis graphs we can see that for the first 3½ minutes the operator is testing that the drone works and can hover fine, before initiating the parachute test. At around 3m 50s, the drone starts ascending to around 55m altitude before the operator hits the killswitch and deploys the parachute.

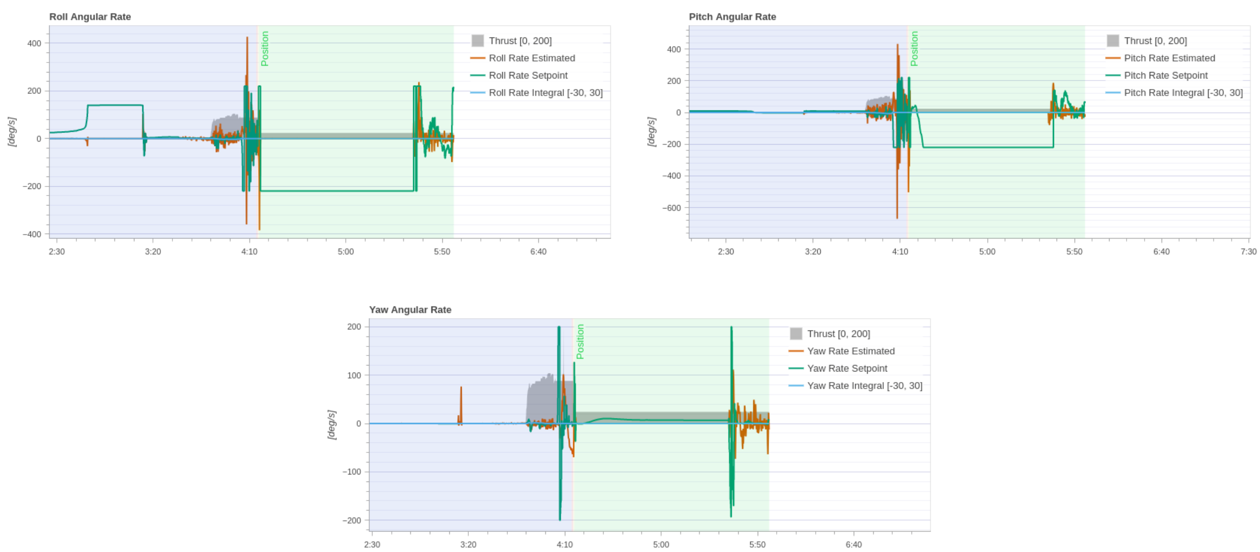

Figure 1: RPY PID Signal Analysis

Having a look at the RPY PID signal analysis plots in Figure 1, we can see that both the estimated angular velocities and the PID references start rapidly increasing in many orders of magnitude switching between both positive and negative, indicating that the killswitch has been hit and parachute has been deployed to simulate a triggered stall.

3.3 UAV attitude failure detection algorithm

3.3.1 Implement algorithm

We chose to develop an algorithm using just the barometer, with the argument being that the pressure data is independent of orientation. This also means that our algorithm doesn't deploy if the drone starts rapidly spinning. But we think that the parachute should only be deployed if the drone is actually descending rapidly - which rapid spinning will most often lead to anyways.

The algorithm starts by filtering the pressure data and computing its time derivative. If the derivative then exceeds a threshold of 50 hPa/s we deploy the parachute.

3.3.2 Test algorithm & 3.3.3 Visualization

Figure 2, 3 and 4 shows our parachute activated system deployed on the datasets of test 5,8 and 9 respectively. Each figure contains two plots, where the left plot shows the unfiltered pressure data in black, the filtered pressure data in blue, the parachute activation in red and kill switch activation in green. The right hand side shows the unfiltered pressure time derivative in black, the parachute activation in red and kill switch activation in green.

For all plots we see that the parachute deployment works as intended `Test 5:` with a slight delay from the kill switch signal. The delay for each test are:

```
Test 5 activation delay:  0.42 s
Test 8 activation delay:  1.19 s
Test 9 activation delay:  1.10 s
```

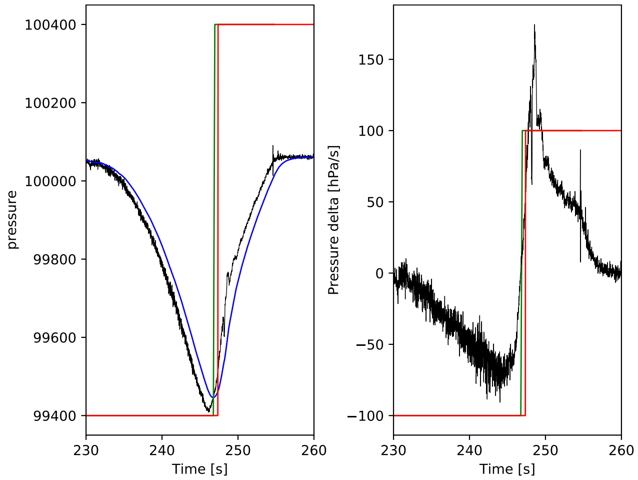

Figure 2: Test 5

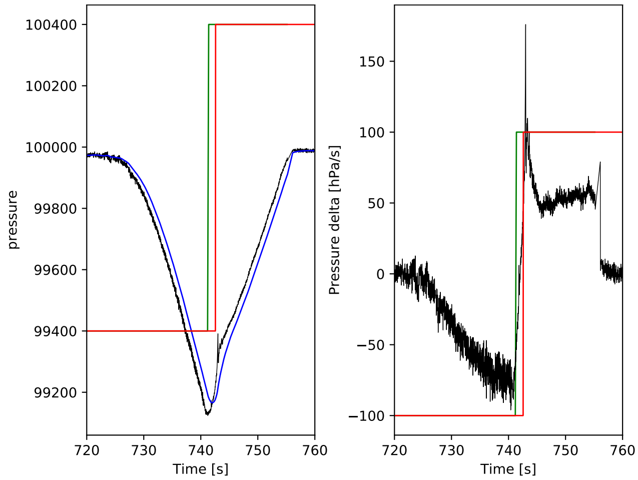

Figure 3: Test 8

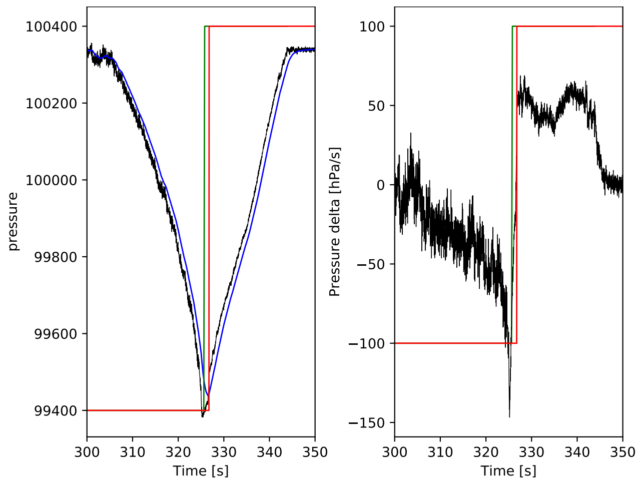

Figure 4: Test 9

3.3.4 Parachutes

ParaZero Makes drone safety systems and parachutes both for small and large drones for commercial use.

Drone Rescue Systems Makes parachute systems for large drone for commercial use.

Fruity Chutes Specialized in smaller drones both for hobbyist and commercial use.

Flyfire Tech Makes parachute systems co-designed with DJI for their drones.