Study and Development of Intelligent Capability for Small-Size UAVs
Report #9, 25.11.2016

Jaskirat Singh

[Info above hidden]

0.1 PID parameter configuration

In order to allow autonomous flight, the quadcopter first need to fly in hover mode decently. This is still not achieved by the current firmware and therefore some effort has been put into this task.
First of all, all the propellers have been balanced using this guide: https://www.bitcraze.io/balancing-propellers/.
After the physical aspect was as balance as possible, the PID tuning process have been performed by relying on the following 4 great web pages:

1. https://forum.bitcraze.io/viewtopic.php?t=192
2. http://myfirstdrone.com/tutorials/how-to-tune-a-quadcopter/
3. http://open-txu.org/home/special-interests/multirotor/cleanflight-pid-tuning/
4. http://aeroquad.com/showwiki.php?title=PID-Tuning

Simplifying, I proceeded as follows:

1) Crafted a system to hold still the drone while performing this tuning (see Figure 1).

Figure 1: Support to hold still the drone when performing PID tuning.

2) Put the integral and derivative coefficients to zero for all the 3 PIDs (pitch, roll, yaw).
3) Increased the proportional coefficient until high oscillation instability was reached. That final value was kept with a light negative offset (5-10).
4) Then the integral coefficient has been tuned, and since we need a stable flight, it resulted to be almost the double of the proportional one.
5) The derivative coefficient has been left to zero because right now it is not so important. It is just useful to eliminate any overshooting when flying using rapid manoeuvres.
6) I worked with the yaw PID tuning only when the drone was not tied to the support system.
7) This procedure was repeated for the rate and attitude PID coefficients.

Finally, the good PID parameters found for my drone are the following:

```
//these are the rate PID parameters
#define PID_ROLL_RATE_KP  100.0
#define PID_ROLL_RATE_KI  250.0
#define PID_ROLL_RATE_KD  2.0
#define PID_ROLL_RATE_INTEGRATION_LIMIT    100.0

#define PID_PITCH_RATE_KP  70.0
#define PID_PITCH_RATE_KI  170.0
```

```
#define PID_PITCH_RATE_KD  0.0
#define PID_PITCH_RATE_INTEGRATION_LIMIT   100.0

#define PID_YAW_RATE_KP  80.0
#define PID_YAW_RATE_KI  10.0
#define PID_YAW_RATE_KD  0.0
#define PID_YAW_RATE_INTEGRATION_LIMIT     50.0

//these are the attitude PID parameters
#define PID_ROLL_KP  3.4
#define PID_ROLL_KI  2.0
#define PID_ROLL_KD  0.0
#define PID_ROLL_INTEGRATION_LIMIT    20.0

#define PID_PITCH_KP  3.2
#define PID_PITCH_KI  2.0
#define PID_PITCH_KD  0.0
#define PID_PITCH_INTEGRATION_LIMIT   20.0

#define PID_YAW_KP  1.0
#define PID_YAW_KI  0.0
#define PID_YAW_KD  0.00
#define PID_YAW_INTEGRATION_LIMIT     10.0


#define DEFAULT_PID_INTEGRATION_LIMIT  5000.0
```
Listing 1: Jaskirat Crazyflie 2.0 PID settings.

0.2 Hovering in the Z axis

After the PID tuning, the drone was able to fly correctly in the X and Y axes but the hovering at the same altitude was and is still not achieved. In the firmware there is a command to ask to the drone to hold the altitude but it seemed to not working correctly. Therefore, we proceed to analyse the barometer data and try to implement a filter after a quick characterization (see next Section).

Only after few days, with Daniele's help, we realized that the actual hovering is not in the master branch anymore but in a different branch (from 2015). According to Daniele, that hovering was exploiting the barometer to hold the altitude within ± 0.5 metres.

0.2.1 Barometer

The current barometer has an accuracy of ±1 metre as stated in the datasheet. In practice, this is true but only for the stationary case, while when the motors rotate the noise, the vibrations, and the air flow have negative impacts on the barometer accuracy.

At the very beginning, under suggestion of Michele, I tried to quickly evaluate one of the best barometer available in the lab: the MEAS MS5611-01BA. Without performing any optimization, the new barometer subject to the same condition of 100% of trust yield similar or worse performance related to the integrated LPS25H sensor (see Figure 2 and Figure 3).

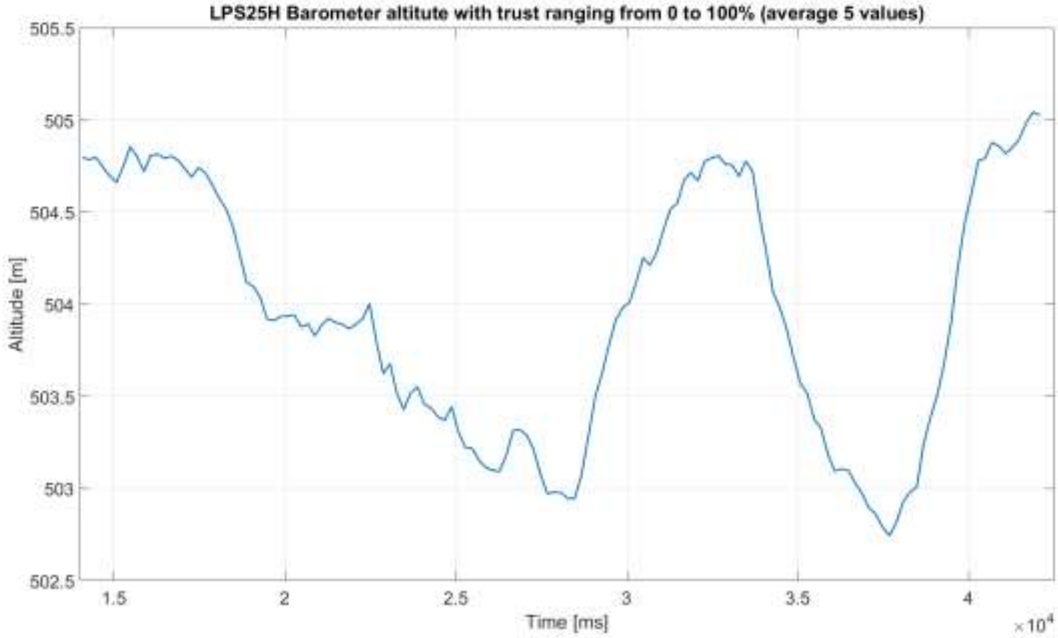


Figure 2: Integrated LPS25H barometer accuracy with trust changing from 0 to 100%.

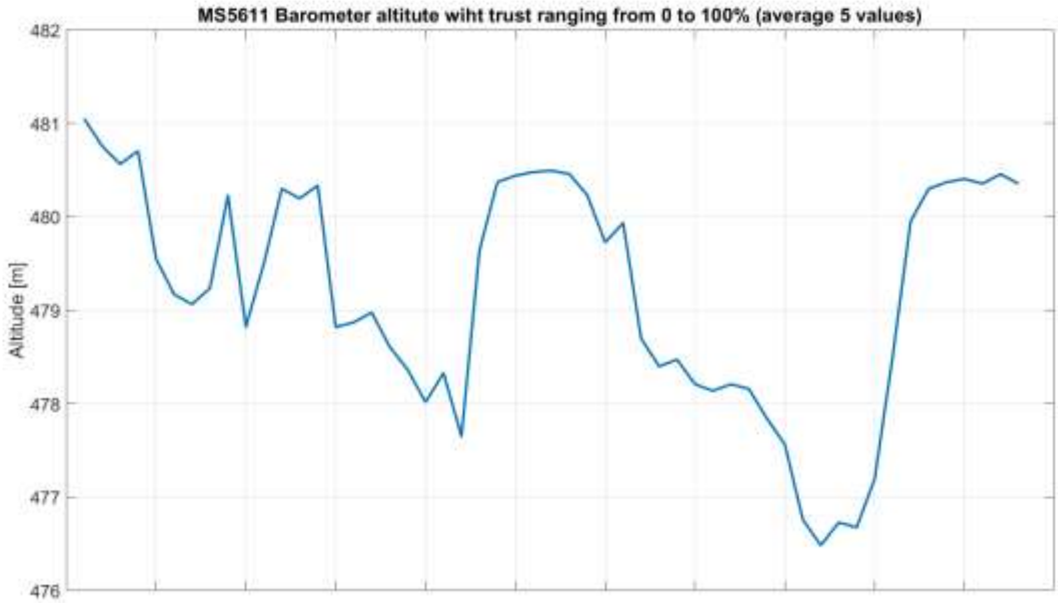


Figure 3: MS5611 barometer accuracy with trust changing from 0 to 100%.

On the other hand, when hold still the MS5611 should behave better than the other barometer: see comparison in Figure 4.

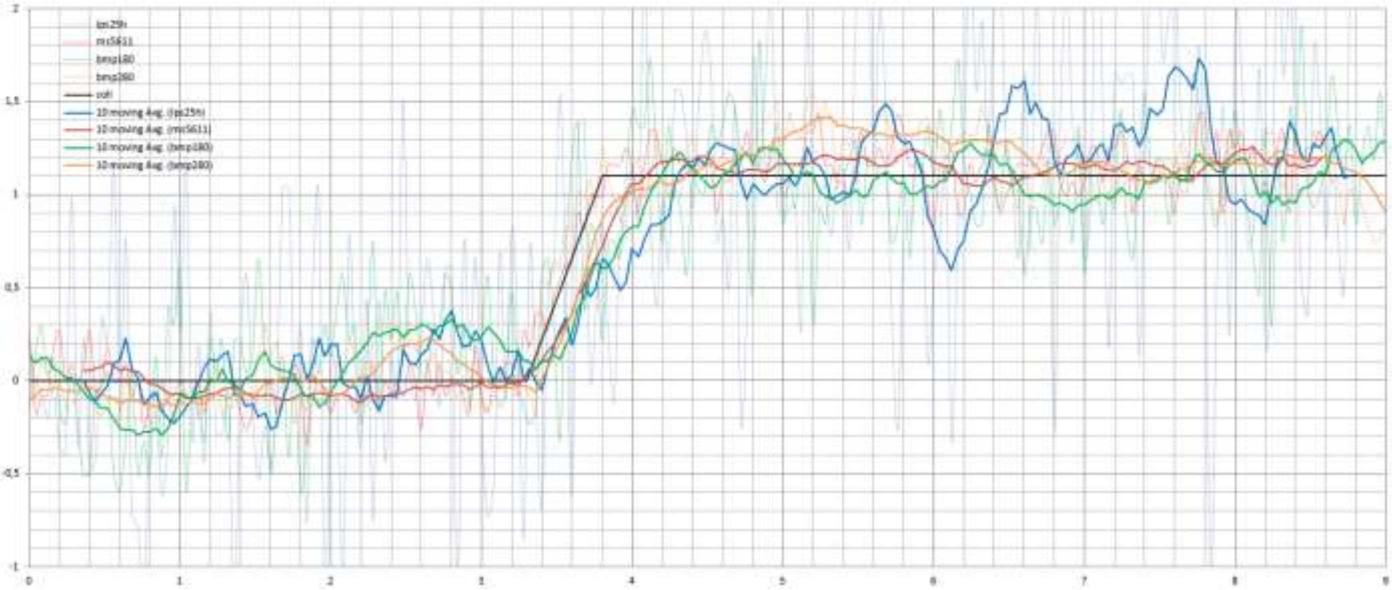


Figure 4: LPS25H, MS5611, BMP180 and BMP280 barometer comparison. Source: Tobias Kaisermayer http://electronics-from-t.blogspot.ch/2016/02/lps25h-vs-ms5611-vs-bmp180.html

For simplicity and practicality, we decided to optimise the already mounted LPS25H barometer by first performing a characterization and then apply the needed filter.
Hence I collected the barometer data for 3 different altitudes and in 2 different states: hold still and 25% of trust.
The sample rate was about 100Hz and each measurements session lasted 5 minutes in an indoor enviroment.
The weather on the measurements day was the following:

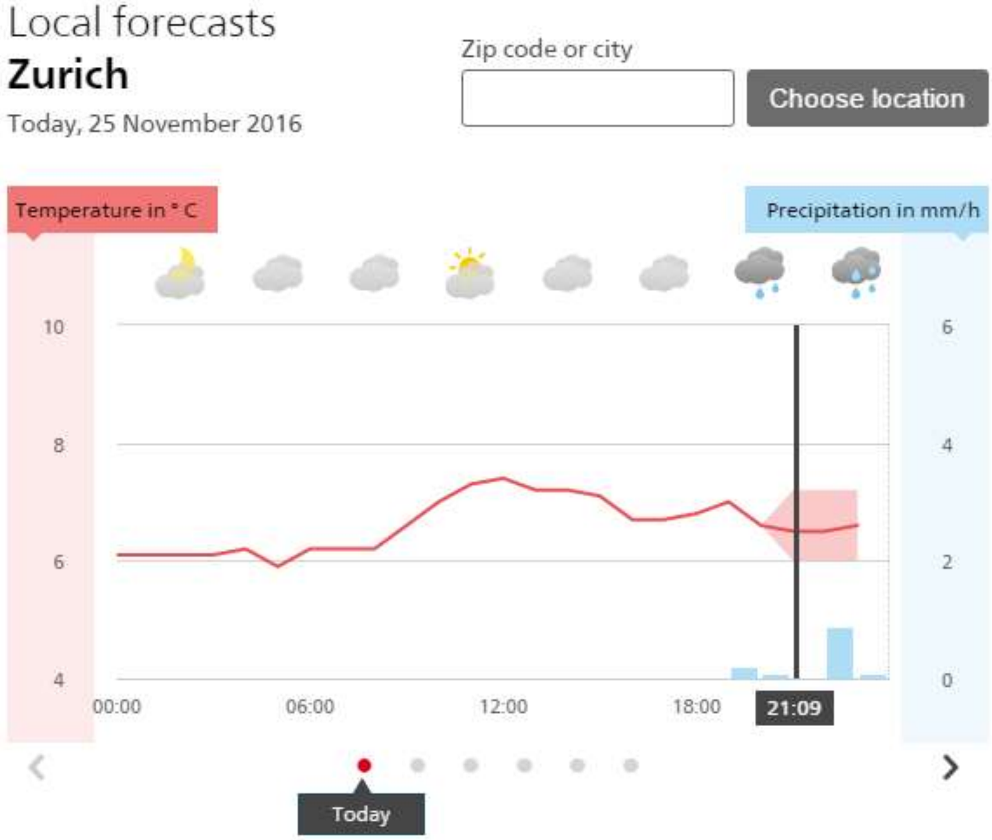


Figure 5: Weather on the day of the measurements. Source: http://www.meteoswiss.admin.ch/home.html?tab=overview

As we can see it is a pretty cloudy day which does not really help the air pressure measurements.

Now follows a preliminary analysis of the barometric data.

Table 1: Histogram plots.

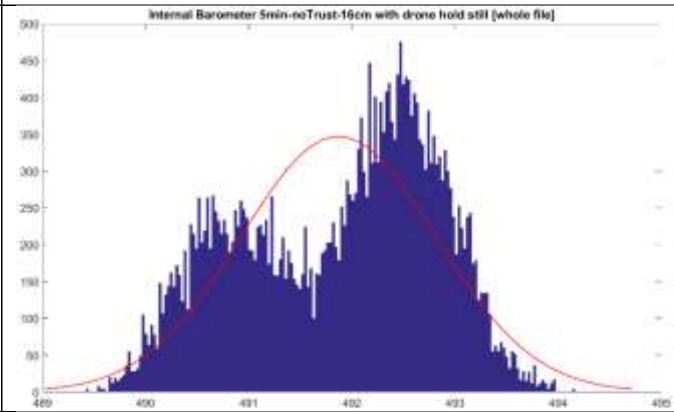
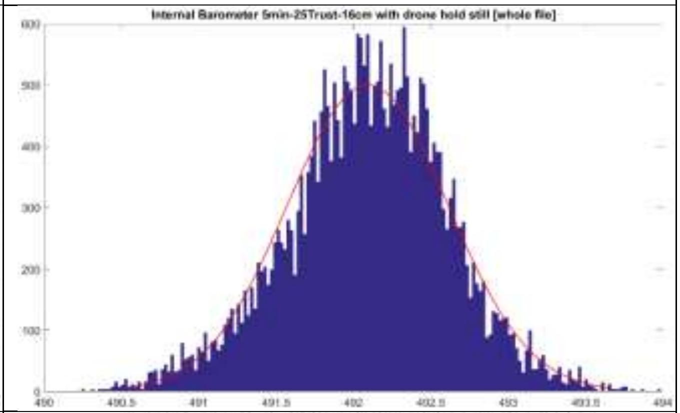
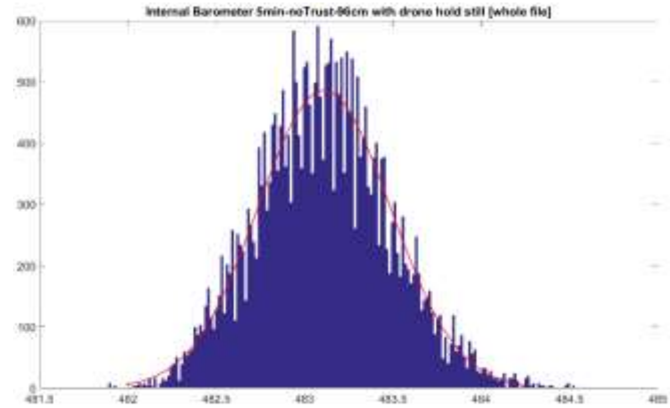
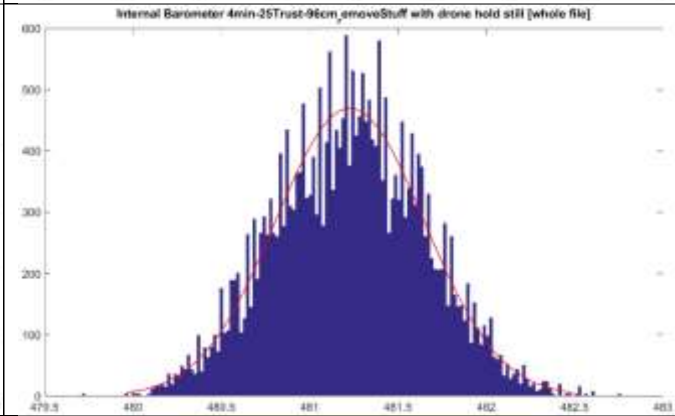
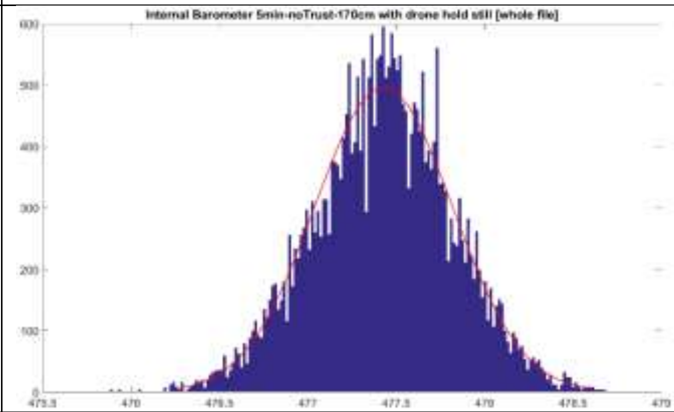
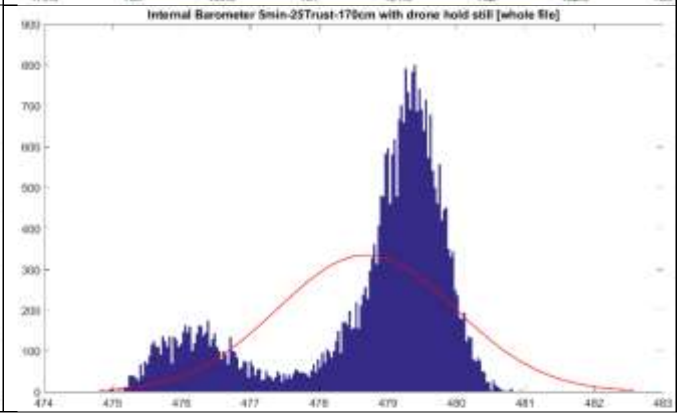
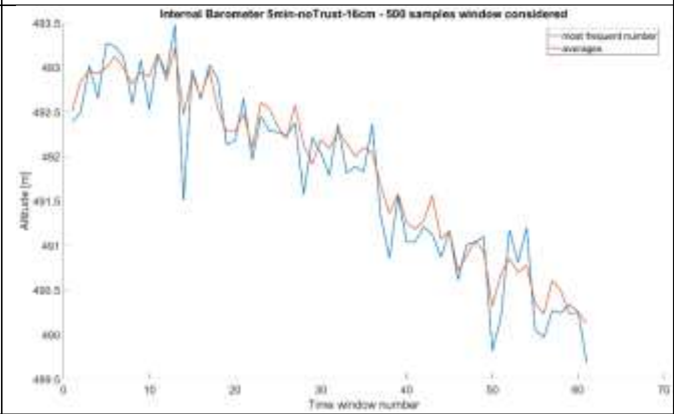
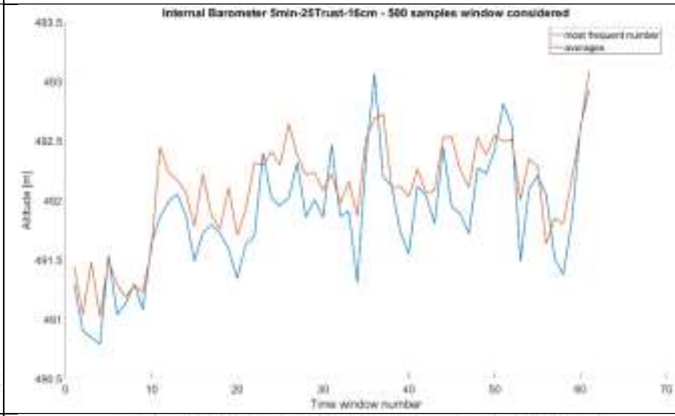
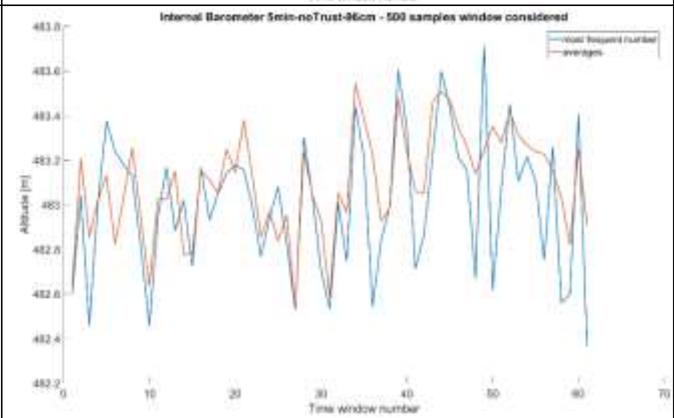
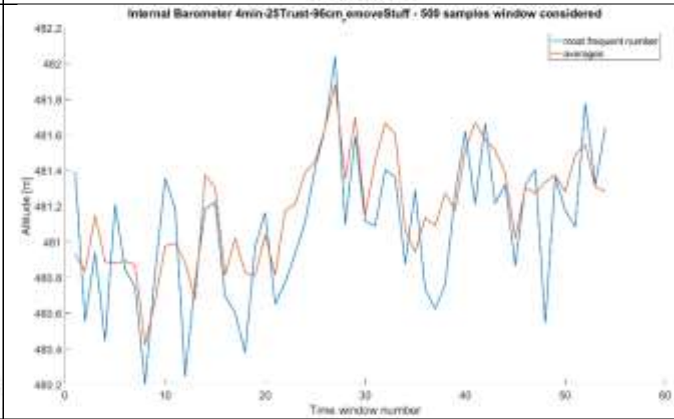
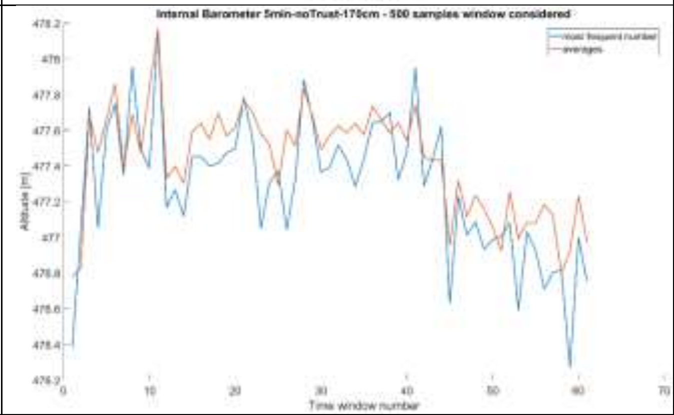
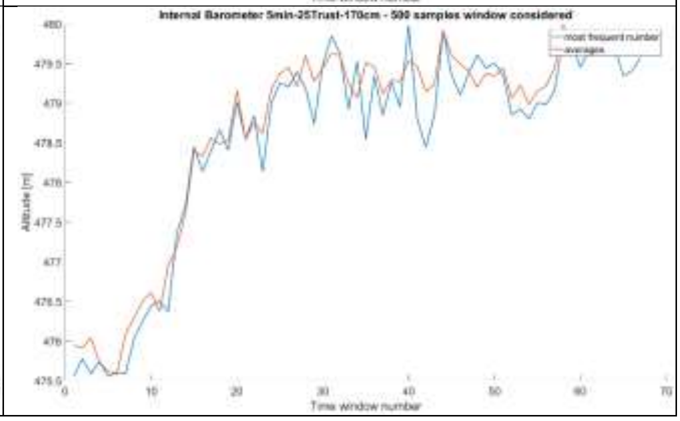
<table>
<tr><th></th><th>No trust</th><th>25% trust</th></tr>
<tr><td>16 cm</td><td>
</td><td>
</td></tr>
<tr><td>96 cm</td><td>
</td><td>
</td></tr>
<tr><td>170 cm</td><td>
</td><td>
</td></tr>
</table>

Table 2: Average and mode plots over 5 seconds time window. Average is red and mode is blue.

	No trust	25% trust
16 cm		
96 cm		
170 cm		

At a first glance we can observe a Gaussian distribution in almost all the case expect 2 plots. The latter discrepancy might be connected to the bad weather and because of the dynamic indoor environment (windows opening). Further analysis and additional plots (such as variance, confidence interval, and plot for different time window) will be done as next step.

Note that the barometric sensor was covered by some tape as suggested here:
"*I read somewhere that it is good to cover the pressure sensor with some breathing foam or similar to avoid the effect from the airflow from the propellers. Something worth a try to get better reading*." Source (https://forum.bitcraze.io/viewtopic.php?f=6&t=479&sid=006cb5ab03bfb55862741a3a2ffe748a&start=10).

[Info below hidden]