UAV LANDING WITHOUT GPS

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*A navigation system is determining the **U**nmanned **A**erial **V**ehicle (**UAV**) position, speed and orientation. This information is then used by the flight control system to guide the UAV along the planned trajectory. Inertial/GPS hybridization is the main method used for UAV navigation [1]. The type of UAV considered during this project is a fixed wing aircraft of the size of a general aviation aircraft. This type of UAV is equipped with an **I**nertial **M**easurement **U**nit (**IMU**) drifting at a rate of around 4km/h, that is why it is hybridized with a GPS. But the GPS signal availability cannot be guaranteed as it is very easy to jam and subject to solar flare perturbations. But without GPS the navigation system relies only on the IMU and is therefore drifting very fast, which is not compatible with the accuracy required for a landing. During this project a solution using only sensors already available on an industrial UAV developed by Safran Electronics & Defense has been studied. It is based on a Kalman filter using a directional antenna mounted on the ground station, a camera and a laser height sensor along with the IMU.*

Return Phase

The goal of the return phase is to bring the UAV from the point where it loses the GPS signal to a point where the UAV is aligned with the runway at a few kilometers, ready to start the landing phase. During the return phase an **E**xtended **K**alman **F**ilter (EKF) [2] is estimating the drift of the IMU using the azimuth from the ground station to the UAV measured by the directional antenna mounted on the ground station. This method is very efficient as shown in Figure 1 by the result of 500 closed loop Monte Carlo simulations; it is 40% more accurate than required in 99% of the cases.

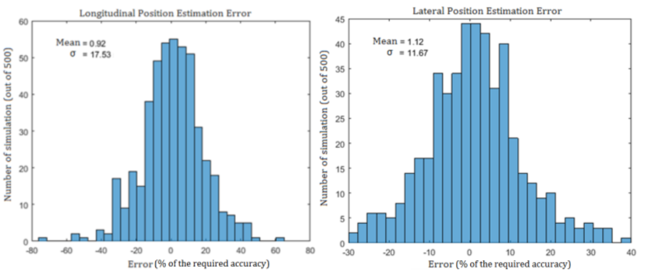

FIGURE 1- *POSITION ESTIMATION ERROR ALONG AND PERPENDICULAR TO THE RUNWAY AXIS, AT THE END OF THE RETURN PHASE*

Landing Phase

Once the UAV is aligned with the runway, the camera is started as shown in Figure 2. Computer vision algorithm was not in the scope of this project so only a tracking algorithm was used. A ground operator is pointing the touch down point on his screen and then the image processing algorithm is keeping track of this point in the pictures. This information is used in an EKF to estimate the drift of the IMU. And once the UAV is low enough, the laser height sensor is activated which gives one more measurement to the filter in order to estimate the drift of the IMU.

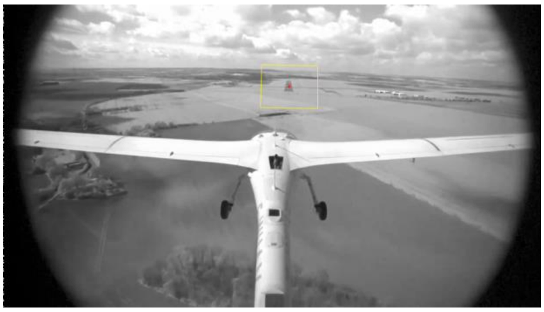

FIGURE 2 - *TRACKING ALGORITHM VIEW*

The filter in this phase has been extensively tested in closed and open loop, using data from real flights. A good idea of the performance of the filter, 100m to the touch down point, is given by Table 1. The position and speed estimation errors given in this table are the result of 1000 open loop Monte Carlo simulations using only data from a real landing except for the drift of the IMU which is simulated. The percentage of cases fulfilling the accuracy requirement is also given.

Axe	Mean Estimation Error	Standard Deviation	% Valid Case
Lateral Position	0.63	0.17	98
Longitudinal Position	0.22	0.19	100
Lateral Speed	0.77	1.2	84
Longitudinal Speed	0.29	0.4	96

TABLE 1 - *FILTER ERROR AT THE END OF THE LANDING PHASE, RESULTS ARE GIVEN AS A RATIO WITH THE REQUIRED ACCURACY*

Conclusion

In 98% of the cases, the required accuracy for the landing is reached in position but improvements can be made on the lateral speed estimation. Good lateral speed estimation is necessary because in the studied case the last second of the landing are done using only the IMU corrected by the last error estimation. The solution studied during this project has been validated and can now move to the next step which is the integration and testing on the real UAV.

Popular Science Article Summary of MSc[3]

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[2] R. Johansson, Predictive and Adaptive Control, Lund University, KFS, Lund, Sweden 2015, p.129

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