Computational Fluid Dynamics to Assess the Impact of the Wake of a Quadcopter on a Plume of Gas

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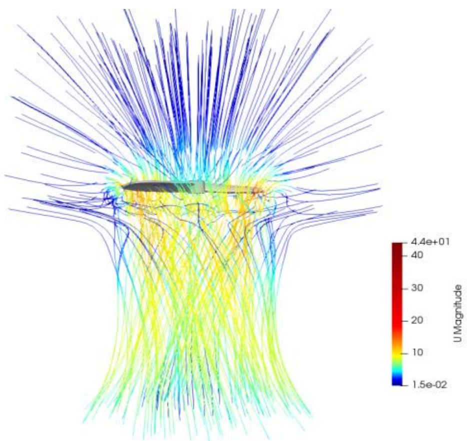
Odor distribution mapping is a technique that has the potential to be very useful for real world applications such as environmental monitoring. The research that has been carried out in this field focuses mainly on 2D localization and mapping, however, since gas distribution is a three-dimensional phenomenon, developing platforms able to operate in 3D has the potential to make a big impact. To accomplish this task, the use of a drone becomes the most natural choice to transport the gas sensor. Its use is however not without limitations; a major problem being the impact induced by the propellers on the nearby gas. Computational fluid dynamics (CFD) was used to assess the impact of the wake of the drone on the sensor measurement. CFD is a versatile tool that can offer answers for complex problems such as this one, without having to conduct wind tunnel experiments.



Flow around the rotating propeller

CFD Simulations of a single rotating propeller were designed and meaningful information such as the thrust generated and the magnitude of the velocity of the flow were extracted from the data. The thrust of the propeller was then compared with experimental data from the literature and showed a relative error of less than 4%.

Mesh	Thrust [N]	Relative Error (%)
Coarse	0.0835 ± 0.0006	5.7
Moderate	0.0867 ± 0.0005	3.2
Fine	0.0865 ± 0.0005	3.4

Thrust calculated from CFD

To test the impact of the wind field generated by the propeller on gas particles, an approximation of the local wind speed was implemented in Webots, a high-fidelity robotics software. Unfortunately, meaningful results could not be obtained from Webots for multiple reasons. The most important problem was that the gas particles generated by the physics plugin moved only according to the external wind, had no inertia and their position was updated with a simple Newtonian model. Although this approach works when the velocity is low and the field is defined in a large environment, it is not well adapted to localized, high velocity and turbulent flows such as the wake of a propeller.

From the CFD simulation, it was found that the velocity of the air on top of the quadcopter would be of the order of a meter per second, whereas the velocity at the bottom of the propeller is about ten times higher. However, imprecisions from the sensor measurement likely do not come from the wind itself, but rather from the fact that gas particles are deviated away from the sensor. As such, the quality of the measurement varies heavily with the direction of the plume of gas. For instance, gas coming from below is pushed away and the density of gas on top of the quadcopter would significantly be reduced. It was determined that the optimal placement of the sensor would likely be directly at the bottom of one of the propeller. In this position, gas coming from multiple directions could be measured, although multiple sensors would be needed. Two-phase flow CFD simulations could be used to determine the optimal height at which the sensor should be placed.