Control of a Fleet of UAVs to Explore a Fire Plume

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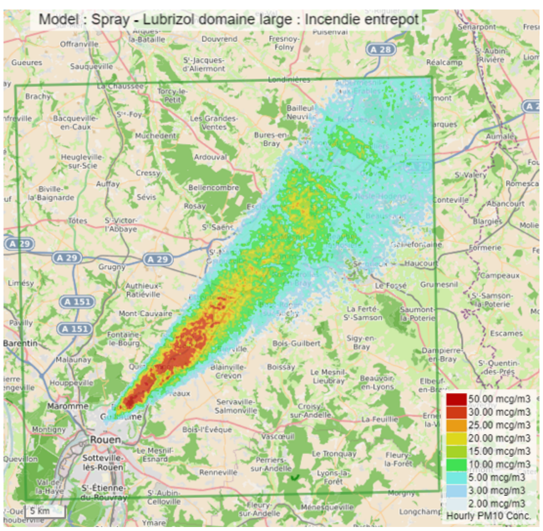
In case of an industrial fire, it is of the utmost importance to provide an immediate response. Stopping the fire is the first priority, but the combustion products may be as hazardous as the fire itself: being able to rapidly characterize the content, shape and future evolution of the fire plume is equally important for protecting the neighboring population.

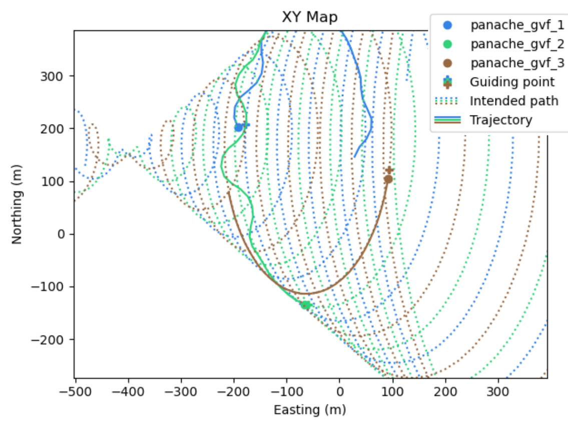
To do so, the best way is to directly sample the plume by sending in a fleet of UAVs. But, because of the inherent scale of the problem (several kilometers in width, tens of kilometers in length) we study the question of using a fleet of fixed-wing UAVs for plume exploration, a question which has received little attention.



Lubrizol factory fire, plume modelization (Rouen, 2019)

We limit ourselves to path design and path following for the fleet, disregarding data collection and interpolation, as it turned out that this problem alone is more difficult than anticipated. The plume is represented by a Gaussian Model, a statistical approximation averaging time and spatial behavior. This approximation is enough for our needs, as it defines a conic area to explore.

Two main paths are designed to explore the cone with a fleet of UAVs: one based on growing sinusoids, the second on a growing, drifting ellipse.



Growing, drifting ellipse followed by three coordinated fixed-wing aircraft in the PaparazziUAV simulator using our path following method

These curves are 3D and self-intersecting. Such properties require a specialized path following algorithm. We use the *Parametric Guiding Vector Field* approach (Yao et al.,“Singularity-Free Guiding Vector Field for Robot Navigation”,2021), specifically designed to solve this issue and compatible with a coordination mechanism. But this approach requires intense gain tuning and is not adapted to handle properly unbounded paths, such as our growing drifting ellipse.

Our main contribution is adapting the method to handle unbounded curves. This is done by dynamically adapting the step taken by the algorithm to match given physical length, instead of being based on the arbitrary definition of the parametric curve defining the path to follow. With this improvement, we are able to efficiently follow the growing drifting ellipse path while simplifying gain tuning and maintaining comparable following accuracy.

The method we developed, called *Guiding Vector Field Normalized*, is compatible with the coordination method of the former algorithm. It even ensures better coordination accuracy, but degrades the path following accuracy. They are both due to oscillations around the path to follow.

The main limitations are oscillations during coordinated path following, and the remaining sensitive gains existing in the method. We estimate both of these can be lifted by developing an appropriate automatic tuning strategy based on the aircraft characteristics.