SS 2020-2021, SIN-EXC, DISAL-SP152 Project Summary

3D Gas Distribution Mapping in Simulation

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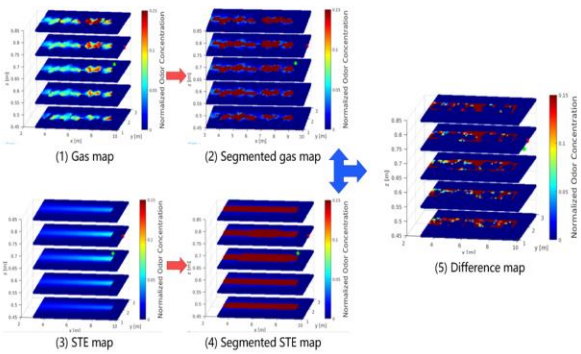
Gas Distribution Mapping (GDM) and Gas Source Localization (GSL) are helpful techniques to employ in real scenarios, such as environmental monitoring and support for rescue operations when leakages of harmful gas happen. Quadcopters are seen as the ideal platform to accomplish these two tasks, because of their ability to explore a 3D space and capture the tridimensionality of the phenomenon. Due to the inner connections between GDM and GSL, and the limitation of flight time caused by battery life constraint, this project aims to improve the performance and stability of current mapping framework and explore potential methods to achieve simultaneous 3D GDM and 3D GSL.



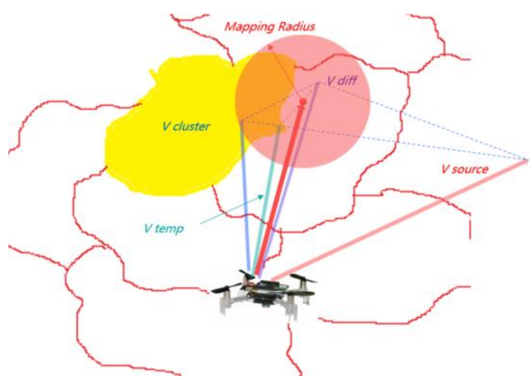
Main gas maps generated during this project

First, to achieve more steady performance in cluster-based 3D GDM, we focused on improving the way we navigate from one cluster to the next. We proposed several cluster switching algorithms using dynamic programming to provide an optimal cluster visiting order that makes the total switching path as short as possible. Experiments show that this can help to improve the stability of the mapping task.

Second, we extended Source Term Estimation (STE) from 2D to 3D and implemented it on the aerial robot. Compared with previous works for ground robots, differences lie in sampling methods and navigation strategies. In fact, the drone is allowed to sample the data all the time with a predefined frequency while it is moving. Moreover, the robot's set of possible navigation targets, which is limited to move on only one axis in each iteration, was extended from four-fold in 2D plane to six-fold in 3D space.

As for the GDM and STE coupling strategies, we first explored two solutions where the data fed to the STE comes from the mapping value obtained by the mapping algorithm. Experiments show that using either the total gas map or the segmented gas map, which gets rid of data of bad quality, as input for STE provides good source estimation, with the first strategy providing better performance in a simulation environment.

Then we tried to use the STE result to guide the 3D GDM. The difference map has been introduced to highlight areas where the gas map is not well captured, according to the map produced by STE. The higher the difference value is, the more urgently the MAV needs to visit the corresponding areas to gather more information.



Fusion strategies: the sum of variably weighted vectors

Last but not the least, we explore fusion methods based on sum of variably weighted vectors to decide the final goal position. Because the kernel mapping algorithm can extrapolate the sampled concentration within a certain distance, it is possible that several separated goal positions indicated by different path planning strategies can be covered simultaneously when the drone reaches its final position, at each step or in near future, thus improving the mapping efficiency and stability.