Multi-Robot Gas Distribution Mapping in Simulation

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Gas Distribution Mapping (GDM) aims at constructing a map of the gas distribution that can be useful during rescue operations in adverse situations. Recent works used Nano Aerial Vehicles (NAVs) with gas sensing capabilities to generate 3D gas distribution maps. The goal of this project is to explore the benefits of using a swarm of NAVs and develop a navigation strategy for GDM. The system consists of Crazyflie V2.1 as the NAVs and the performance will be evaluated in Webots simulator.

In any multi-robot system, there are different levels of coordination. We implemented and tested three coordination strategies: Individualist (no sharing of the information), Cooperative (only sharing their measurements), and Collaborative (sharing their measurements and coordinating movements). For the collaborative strategy, we have implemented a multi-robot task allocation method to effectively assign the goal positions to the drones to optimize the total time taken. The navigation technique used here is an Informative Path Planning (IPP) algorithm based on the Kullback-Liebler Divergence (KLD) quantity. The experiment volume of 7x2x0.5 m^3 is discretized into grid cells, and we select the cell that has the highest KLD quantity. A simple collision avoidance strategy was also developed that prevented any 2 drones to be closer than a safe distance (threshold). The baseline navigation strategy is the lawnmower movement where the robots follow a fixed predetermined path.

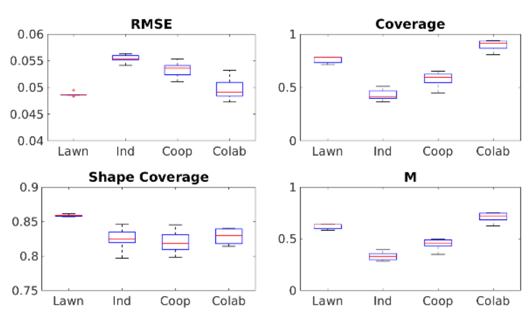

Figure 1: Simulation results of 10 runs for the baseline movement and different levels of coordination for two drones

As we can see in Figure 1, the individual has the worst performance and the collaborative has the best across all metrics except the RMSE. Therefore, we notice that the overall performing increases as we share more information and move higher in the levels of coordination.

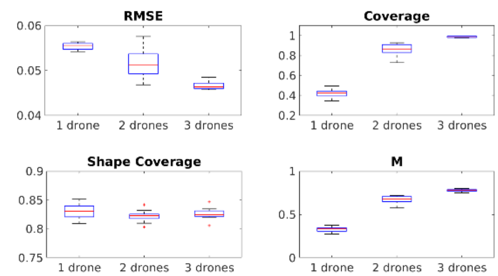

Figure 2: Simulation results of 10 runs for a varying number of drones using KLD method with collaborative strategy

Figure 2 shows that by increasing the group size, we improve performance in all the metrics. With coverage values reaching 97%, the only metric with room for improvement is the RMSE since the shape coverage will also improve with it.

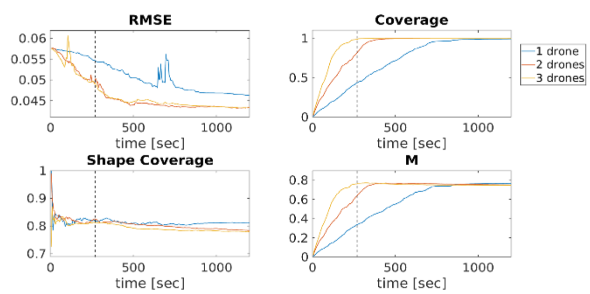

Figure 3: Evolution of metrics for a varying number of drones

It is evident from Figure 3 that by employing a higher number of drones, we drastically increase the rate at which we arrive at the final results. It also suggests that, with enough number of drones, we can overcome the drawback of limited flight time of NAV since the performance at the end of the time budget, in case of 3 drones, is very close to the saturation values. Therefore, proving that by using a multi-robot system, we overcome the limitations of a single robot and achieve higher performance by exploiting the coordination strategies.