SS 2023-2024, SMT-Rob, DISAL-SP186 Project Summary

Integration of Local Wind Measurement for Robotic Gas Sensing Task

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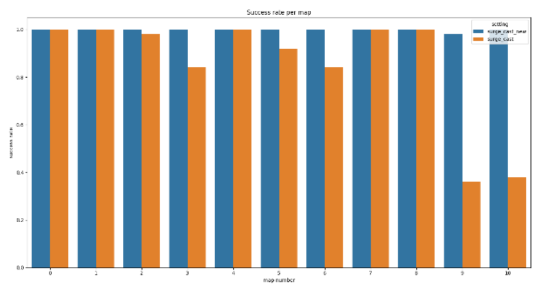
The detection and localization of gas leaks present a significant challenge, traditionally exposing humans and animals to risks. Mobile robots have been studied for gas source localization (GSL) tasks over decades, yielding various algorithms. Bio-inspired algorithms, one of four categories of GSL algorithms, are suggested to be less effective in complex environments due to their reactive nature, which only considers current observations, and sensors not being on par with the capabilities of animals. While wind measurements integration has been studied to enhance them by following an upwind direction when gas is carried by wind, research has primarily focused on obstacle-free environments. My project aims to adapt an algorithm conceived for a 3D obstacle-free environment to a 2D cluttered environment.

The experimental setup involved a simulated wind tunnel measuring 13 meters by 4 meters, with multiple maps featuring different obstacle configurations to test the algorithm under various conditions. The robot's initial position and the gas source locations were fixed to ensure consistency in testing. Key performance metrics evaluated included success rate, distance traveled over the minimum distance ratio, number of iterations, and navigation time. Since bio-inspired algorithms do not declare a source position, success is defined by reaching within 0.5 meters of the source position within a limited number of iterations.

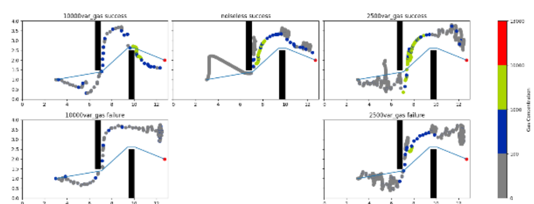
The study began by comparing two plume reacquisition methods: surge-cast and surge-spiral. Initial tests indicated that surge-cast had a higher success rate, leading to its selection for further development. This method was then updated to address specific issues observed during preliminary testing, such as high variability in gas concentration measurements and low wind intensity. These enhancements were crucial in improving the algorithm's overall robustness and effectiveness. Post-update, the algorithm showed significant performance improvements, especially in environments with higher obstacle complexity. The success rate increased notably, while the distance traveled and navigation time decreased,



1: Success rates, in orange before and blue after update

suggesting more efficient navigation. Robustness tests introduced Gaussian noise to wind measurements and gas concentration to evaluate the algorithm's tolerance to measurement errors. It demonstrated resilience to wind noise but was more affected by noise in gas concentration, highlighting the importance of precise gas sensors.

Further tests were conducted with random initial positions to assess the generalizability of the algorithm. The results confirmed that it maintained similar success rates regardless of the starting position, indicating robustness and adaptability to different conditions.



2 Trajectories from left to right high gas concentration noise, no noise, low gas concentration noise, on top successful runs, on bottom failures, colour bar for gas concentration

Despite these improvements, several limitations were identified. The algorithm relies heavily on precise gas concentration measurements, which may not always be feasible in real-world scenarios. Additionally, the method's performance decreases in low wind intensity conditions, necessitating further refinement. The navigation speed was also identified as a potential issue, as the method is relatively slow, which could be problematic in time-sensitive situations.