WS 2023-2024, SMT-ROB, DISAL-MP53 Project Summary

Towards Robust Gas Source Localization in Built Environments: Algorithm Design and Validation

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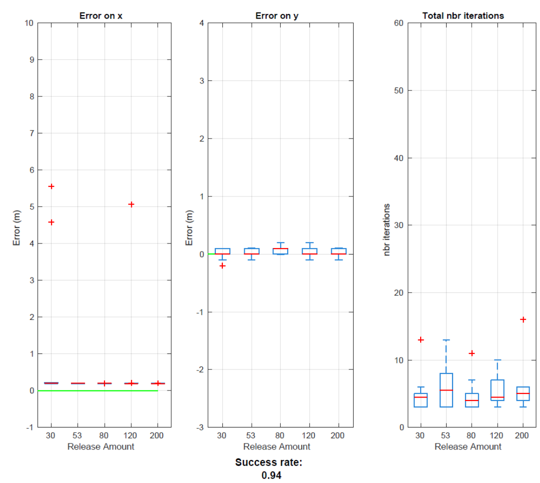
Gas Source Localization (GSL) consists in identifying the origin of a gaseous emission in an environment, and is crucial for environmental monitoring and industrial safety. In particular, the area of Mobile Robotic Olfaction (MRO) is growing. It consists in performing gas concentration measurements with mobile robots, and it offers better spatial coverage compared with fixed-sensor networks, particularly in chal- lenging environments.

Numerous GSL strategies exist, among which the Source Term Estimation (STE) framework that combines a gas plume model with gas concentration measurements to estimate the location of the source. Jin et al. have proposed a data-driven plume model (DDPM) to successfully perform GSL in cluttered environments. In their latest work, Jin et al. have also proposed to collect measurements in motion instead of the traditionally used “stop-sense-go” strategy justified by the slow responses of commonly used Metal Oxide (MOX) sensors. They have proved that this new “continuous STE” strategy performed as well as the “stop-sense-go” strategy while reducing the total time to locate the source.

Building upon Jin et al.'s previous work, this project quantitatively investigates the impact of environmental features and sensor properties on GSL performance and assesses the robust- ness of continuous STE. Parameters such as robot velocity, sensor dynamics, measurement sampling density, and gas release rate are studied. Additionally, we have proposed new likelihood formulations using binary gas detection events with fixed and dynamic gas concentration thresholds, as well as relative gas concentration measurements, to improve robustness to variations in unknown env- ironmental parameters such as the gas source release rate.

In particular, we have shown that continuous STE could be successfully applied to arbitrarily slow sensors as long as the robot velocity was adapted accordingly. We have also demonstrated that by introducing a new relative concentration measurement through the use of cumulative distribution functions, leveraging the statistical properties of the collected data and assuming they follow a gaussian distribution, continuous STE can successfully locate a gas source with an unknown release rate, which was not the case for the original implementation. These improvements provide promise for real-world applications where the release rate of a leak is often unknown.



Relative concentration algorithm performance for different gas source release rates in a cluttered environment

While continuous STE demonstrates robustness, challenges remain in the de- pendency of this entropy-based algorithm to the navigation strategy. These issues highlight the need for real-world testing and further im- provements to the exploration/exploitation trade-off in the navigation strategy.