Multi-Robot Gas Distribution Mapping and Source Localization in Simulation

Yasmine El Goumi

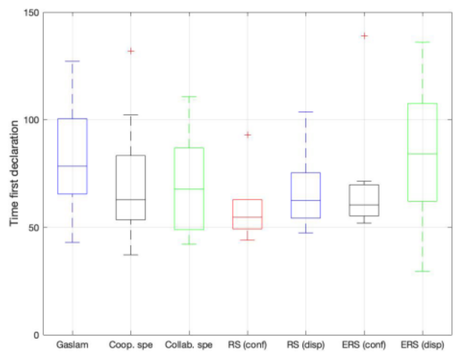
Professor : Alcherio Martinoli
Assistant(s) : Chiara Ercolani

Studying gas distribution mapping (GDM) and gas source localization (GSL) in robotics is essential to prevent dangerous situations and assist humans when gas leaks occur. While GSL and GDM have mostly been treated separately in literature, a new promising approach, called GaSLAM, aims at achieving both simultaneously. GaSLAM combines a state of the art Source Term Estimation (STE) algorithm performing GSL to the widely used 3D Kernel DM+V/W algorithm for GDM. The performance of GaSLAM was tested using a Nano Aerial Vehicle (NAV), yielding promising results.

In this project, we apply GaSLAM to a multi-robot system of two NAVs, and we study the effect of specialization in such a system. More precisely, one robot focuses on GSL (search robot) and the other on improving GDM (exploration robot). Two approaches are evaluated: cooperative and collaborative specialization. In both cases, the robots share their retrieved sample and they both update STE and Kernel algorithms. The cooperative approach consists of an independent and static specialization: both robots are attributed a fixed task from the start. In the collaborative case, instead, the specialization can change during the experiment. If a robot is closer to the other robot's goal, they can swap their goals and with it, their specialization. In this summary, the methods that achieve cooperative or collaborative specialization are explained.

The cooperative specialization consists in defining two separate goals. The exploration robot goes to the area of highest information content thanks to informative path planning, while the search robot goes to the current STE estimation of the source position. Finally, when the confidence in the source position is high enough, the search robot explores areas of difference between the map constructed by the Kernel algorithm and the map outputted by the underlying plume model used by STE. In the collaborative specialization, a Hungarian algorithm is used to determine whether it is more beneficial to swap goal (and specialization). When comparing the results of both methods, similar performances were obtained, and the optimization of navigation is thus, not necessary to improve a method.

Methods featuring spatial constraints techniques were tried to improve the outcome of the system. Radius search (RS) is a method that consists in defining a sphere around the STE estimations and use the exploration robot to search in a radius around it. The search robot does the same as in the cooperative specialization, and the exploration robot moves to the point of highest KLD within his exploration area. This showed promising results, achieving the best success rate and speed at finding the source. An adaption of RS to collaborative specialization was implemented called Exhaustive RS (ERS). In this case two areas are defined, and the search and exploration robots move to the point of highest KLD within their respective areas. If a robot finished exploring before its teammate, it helps by taking on another specialization for a few iterations. The obtained results were less satisfactory than RS; it shows the importance of a trade-off between exploration and exploitation since in ERS, we exploit less.



Time of the first source declaration for the different approaches explored in this work. All methods except one improved with respect to the GaSLAM baseline without specialization

Overall, we concluded that specialization is useful: it improved GDM, robustness and for some methods, time, while staying competitive with GaSLAM.