Path Planning for Gas Distribution Mapping

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Nowadays, mobile robots are commonly used for environmental monitoring purposes, thanks to their efficiency, versatility, and accessibility to hazardous environment. One specific application is called Gas Distribution Mapping (GDM), which aims to gather gas information about a given environment in order to create a map of its distribution. Another application is called Gas Source Localization (GSL) and aims to find the location of the gas dispersion.

Robotic GDM and GSL have been under extensive research, with a focus on developing algorithms to process the data acquired by the mobile platforms. However, most of the work employs ground vehicles rather than aerial, which would be more suitable given the 3D nature of the phenomenon. Researchers at DISAL have shown that a Nano Aerial Vehicle (NAV) equipped with a gas sensor can be successfully used for these tasks. However, because of its limited time budget, it is essential to optimize the path of the NAV to maximize the amount and quality of the information gathered.

In this project an Informative Path Planning (IPP) algorithm has been implemented in the DISAL gas mapping framework. The algorithm is based on the Rapidly-exploring Random Tree (RRT) algorithm and one of its variants, the Rapidly-exploring Information Gathering (RIG).

First, a random tree is grown, where a reward is attributed to each node based on the entropy of the measurements. Then, the best branch is computed based on the immediate reward and the discounted future reward. Finally, the first node is transmitted to the drone controller as the next goal, and a new cycle can start.

Two experiments have been carried out in simulation. The first one is with GDM and the analysis of the hyperparameters of the RIG algorithm (Fig.1). It has been demonstrated that the tree should be grown with step sizes comparable or greater than 10 times the size of the drone. Moreover, the size of the tree (number of nodes) can remain fairly small which has a significant impact for lowering the computational cost. The results for GDM have proven that RIG algorithm can be competitive against state of the art techniques, while reducing computation.

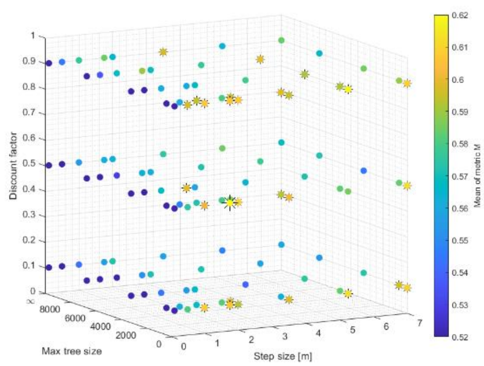

Figure 1: RIG hyperparameter analysis for GDM. Better results with step sizes higher than 1m and a maximum tree size of 70 nodes. Best: s=1.75m, d=0.5, n=70.

The second experiment is with GSL, where the growth of the tree is steered towards the estimation of the source location with a defined probability. It has been shown that higher steering probabilities lead to better and more consistent results. In addition, it has highlighted the trade-off between GDM and GSL, comparable to the trade-off between exploration and exploitation.