Path Planning for Odor Distribution Mapping

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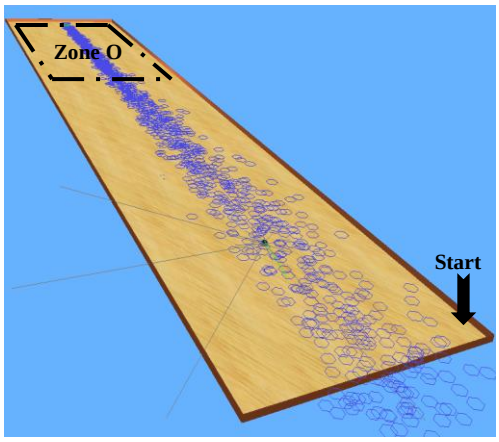
Odor distribution mapping (ODM) is aimed at mapping the odor field that contains chemical substances, which has been widely studies in last few decades. Compared with trained animals, robotic system for ODM could have many advantages. And a lot of path planning algorithms has been proposed for odor mapping efficiently. However, little attention has been paid to combine the information theory with path planning for odor distribution mapping. The goal of this thesis is to design path planning algorithms for odor mapping based on information theory. Besides, we do not focus on any particular application, but compare different algorithms about their performances. Time consumption and distance overhead are important criterion for the algorithm performance. The comparison is achieved by running experiments in abstract (Matlab) and realistic simulation (Webots).



Experimental arena in Webots

The spatial model of the odor field is assumed to be Gaussian. And Gaussian Process Regression is applied to fuse observations from sensors into an estimate of the underlying field. As for the path planning algorithms, we put forward four information-theoretic algorithms:

(1) “Fixed-Grid” algorithm: as a reference algorithm, evenly distribute the samples as a grid over the field;

(2) “Entropy” algorithm, an indicator of uncertainty, choose next sampling position with max entropy value;

(3) “Mutual Information” algorithm: an indicator of mutual dependence of variables, choose next sampling position with max mutual information between sampled and unsampled positions (predication quality);

(4) “Balanced Mutual Information” algorithm: consider combined effect of estimation magnitude and uncertainty level.

For a full exploration of the algorithms, more than 400 experiments are carried out in Matlab and Webots. Based on the experiments results, each algorithm presents its advantages and drawbacks. Generally, three information-theoretic algorithms are more preferable than “Fix-Grid” algorithm. The Mutual Information algorithm works efficiently to map the whole field in an early phase, but it’s more CPU and computation intensive. However, even though Entropy algorithm works far less efficient to reduce the estimation error in the beginning few steps, it consumes less computation time. As for Balanced Mutual Information algorithm, it obtains great performance regarding the large RMSE reduction and little computation time, but it is not preferred from the Covariance criterion. Nevertheless, when the influence of inefficient robot navigation is considered, the performance will all be deteriorated for these information-theoretic path planning algorithms.

	Fix-Grid	Entropy	MI	BMI
Prompt Response	-	+	++	+
Overall RMSE	-	+	+	++
Covariance	-	++	++	+
Simulation T	-	+	++	+
Computation T	++	++	-	++

Performance comparison of path planning algorithm