



Domain Knowledge Assisted Robotic Exploration and Source Localization

av

Thomas Wiedemann

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Opponent: Assoc. Prof. Alcherio Martinoli
École polytechnique fédérale de Lausanne (EPFL)
Lausanne, Switzerland

Örebro universitet
Institutionen för Naturvetenskap och Teknik
701 82 ÖREBRO

Abstract

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Deploying mobile robots to explore hazardous environments provides an advantageous way to avoid threats for human operators. For example, in situations, where airborne toxic or explosive material is leaking, robots can be dispatched to localize the leaks. This thesis investigates a novel exploration strategy to automatically localize such emission sources with multiple mobile robots that are equipped with sensors to measure the concentration of the emitted gas.

The problem of localizing gas sources consists of two sub-problems that are addressed here. First, the thesis develops a method to estimate the source locations from sequences of localized concentration measurements. This approach can be also applied in case the measurements are collected by static sensor networks or human operators. Second, the thesis proposes an exploration strategy that guides mobile robots to informative measurement locations. With this strategy, a high level of autonomy is achieved and it is ensured that the collected measurements help to estimate the sources. As the main contribution, the proposed approach incorporates prior available domain knowledge about the gas dispersion process and the environment. Accordingly, the approach was coined Domain-knowledge Assisted Robotic Exploration and Source-localization (DARES). Domain knowledge is incorporated in two ways. First, the advection-diffusion Partial Differential Equation (PDE) provides a mathematical model of the gas dispersion process. A Bayesian interpretation of the PDE allows us to estimate the source distribution and to design the exploration strategy. Second, the additional assumption is exploited that the sources are sparsely distributed in the environment, even though we do not know their exact number. The Bayesian inference approach incorporates this assumption by means of a sparsity inducing prior.

Simulations and experiments show that the sparsity inducing prior helps to localize the sources based on fewer measurements compared to not exploiting the sparsity assumption. Further, the DARES approach results in efficient measurement patterns of the robots, which tend to start in downwind regions and move in upwind direction towards the sources where they cluster their measurements. It is remarkable that this behavior arises naturally without explicit instructions as a result of including domain knowledge and the proposed exploration strategy.

Keywords: Mobile Robot Olfaction, Robotic Exploration, Gas Dispersion Modelling, Bayesian Inference, Sparse Bayesian Learning

Thomas Wiedemann, School of Science and Technology Örebro University, SE-70182 Örebro, Sweden, thomas.wiedemann@dlr.de