MUHAMMAD ASIF ARAIN received his Bachelor of Engineering degree in Electronic Engineering from Mehran University of Engineering & Technology, Pakistan, in 2005. In 2012, he obtained a dual master's degree under the European Union's mobility program of Erasmus Mundus, European Master on Advanced Robotics (EMARO) from Warsaw University of Technology, Poland, and University of Genova, Italy. Since then, he has been a doctoral student at the Center for Applied Autonomous Sensor Systems at Örebro University, Sweden.

Human-caused greenhouse gas emissions are one of the major sources of global warming, which is threatening to reach a tipping point. Inspection systems that can provide direct information about critical factors causing global warming, such as systems for gas detection and location of gas sources, are urgently needed to analyze the fugitive emissions and take necessary actions.

This thesis presents an autonomous robotic system capable of performing efficient exploration by selecting informative sampling positions for gas detection and gas distribution mapping – the Autonomous Remote Methane Explorer (ARMEx). In the design choice of ARMEx, a ground robot carries a spectroscopy-based remote gas sensor, such as a Remote Methane Leak Detector (RMLD), that collects integral gas measurements along up to 30 m long optical-beams. The sensor is actuated to sample a large area inside an adjustable field of view, and with the mobility of the robot, adaptive sampling for high spatial resolution in the areas of interest is made possible to inspect large environments.

In a typical gas sampling mission, the robot needs to localize itself and plan a traveling path to visit different locations in the area, which is a largely solved problem. However, the state-of-the-art prior to this thesis fell short of providing the capability to select informative sampling positions autonomously. This thesis introduces efficient measurement strategies to bring autonomy to mobile remote gas sensing. The strategies are based on sensor planning algorithms that minimize the number of measurements and distance traveled while optimizing the inspection criteria: full sensing coverage of the area for gas detection, and suitably overlapping sensing coverage of different viewpoints around areas of interest for gas distribution mapping.

A prototype implementation of ARMEx was deployed in a large, real-world environment where inspection missions performed by the autonomous system were compared with runs teleoperated by human experts. In six experimental trials, the autonomous system created better gas maps, located more gas sources correctly, and provided better sensing coverage with fewer sensing positions than human experts.

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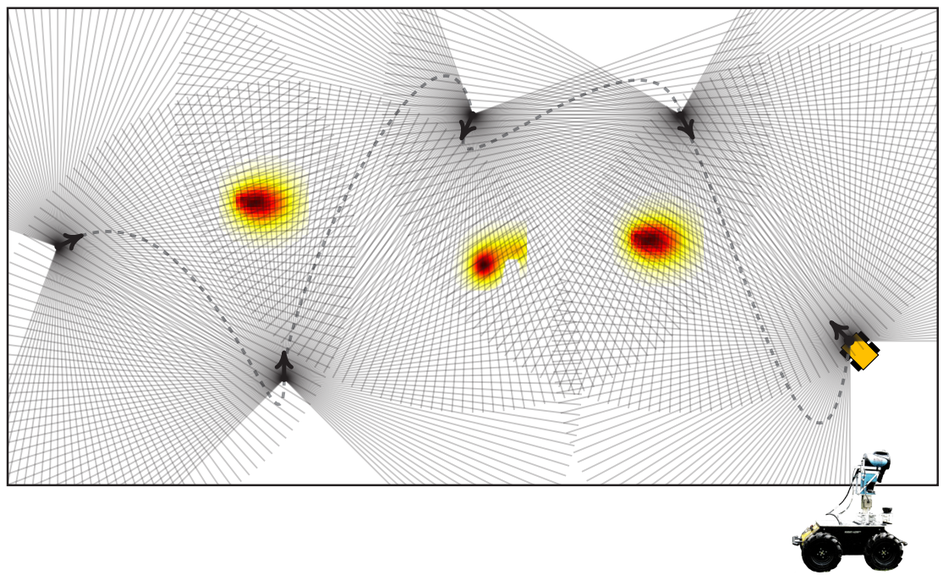

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