BOOSTING A LOW-COST SENSOR NETWORK WITH MOBILE HIGH-QUALITY SENSORS

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1. Introduction

Occupational health is an important topic, especially in industry, where workers are exposed to airborne by-products (e.g., dust particles and gases). Therefore, continuous monitoring of the air quality in industrial environments is crucial to meet safety standards. For practical and economic reasons, high-quality, costly measurements are currently only carried out sparsely [1], both in time and space, i.e., measurement data are collected in single day campaigns at selected locations only [2].

Recent developments in sensor technology enable cost-efficient gas monitoring in real-time for long-term intervals. This knowledge of contaminant distribution inside the industrial environment would provide means for better and more economic control of air impurities, e.g., the possibility to regulate the workspace's ventilation exhaust locations, can reduce the concentration of airborne contaminants by 50% [3].

This paper describes a concept proposed in the project "Robot-assisted Environmental Monitoring for Air Quality Assessment in Industrial Scenarios" (RASEM). RASEM aims to bring together the benefits of both – low- and high-cost – measuring technologies: A stationary network of low-cost sensors shall be augmented by mobile units carrying high-quality sensors. Additionally, RASEM will develop procedures and algorithms to map the distribution of gases and particles in industrial environments.

2. System Overview

2.1 Stationary Sensor Nodes

A stationary sensor network will be composed out of multiple self-built stationary nodes. Each node will be equipped with various low-cost sensors to assess gas concentration, dust particles, temperature and humidity (as an example see [2]).

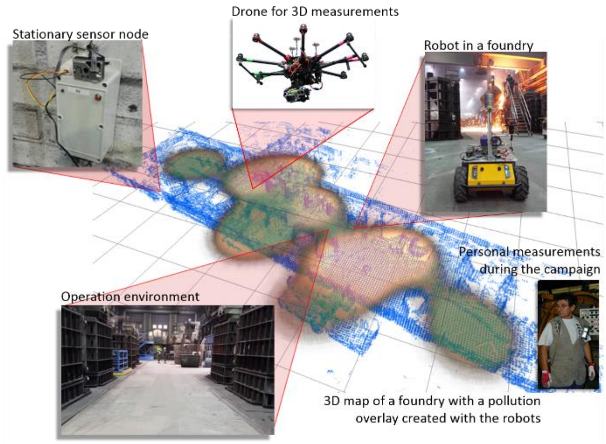

Fig. 1. The key idea of the RASEM project: Dust and gas measurements from stationary sensor nodes in combination with mobile robots and drones to create 3D dust exposure maps in industrial work environments like foundries (adapted from [1]).

The deployed sensor nodes will form a network, whose main tasks are to continuously monitor the dust and gas distribution and identify areas of interest. These areas may be areas with high gradient or noticeable variance.

2.2 Mobile Units

Mobile units (ground and aerial robots) will support the stationary low-cost sensor nodes with high-quality sensors. An aerial unit has the advantage that 3D measurements are possible. Also, it can move fast and independently through an industrial environment. For example, it can monitor a foundry with minimum disturbance for present workers.

While ground-based and aerial robots are fully controllable, the usage of semi-controllable and passive mobile units will be tested: Workers themselves (passive mobility) or forklifts (semi-controllable) can be equipped with portable sensors. The forklift could suggest the driver to drive in a certain direction, because sensor readings for a specific area are desired.

The mobile units will be equipped with a high-quality, high-cost professional measurement equipment for dust monitoring (e.g., DustTrak II Aerosol Monitor 8532), which can measure three different sizes of dust, namely PM1, PM2.5 and PM10. With this, distribution maps for different particle sizes can be created.

Together with the stationary network, the mobile sensors will complement the distribution maps as stationary sensor nodes cannot cover the whole area. Fully controllable mobile units shall be implemented with a pathfinding algorithm, to also investigate interesting spots, that are identified by stationary nodes. Also, the mobile units – equipped with the high-quality sensors – could be used for cross-calibrating the low-cost sensors.

3. Dust Distribution Maps

One of the main tasks of RASEM will be the development of algorithms to create 3D distribution maps. Distribution maps can display air quality in an intuitive way. The output will be visualized for non-experts (e.g. workers, managers, maintenance) and provide information of dust, gas and airflow.

The algorithms should include time- and event-dependency, e.g., a dependency on periodic events or a smelting process that causes a burst of dust and gas emissions. These dependencies allow extracting temporal patterns from the maps that can be correlated with changes in, e.g., the foundry operation and other seasonal changes (daily shifts, weekends), that enable the detection of abnormal situations with respect to mobility and sensing principle (e.g., excessively high dust level, increased temperature) that may be used to trigger alarms.

Combined with conventional models and exposure assessment methods, risk mitigation measures and human exposure will be estimated to carry out guidelines for the mitigation of health risks in industrial environments.

4. Sensor Planning

RASEM will study and explore approaches on how to effectively combine a dense network of stationary sensor nodes with sparse mobile sensor units. It will build on previous approaches [2] to find optimal positions for sensor nodes to monitor the industrial context.

It is planned to integrate different mobile units in the sensor network. In contrast to fully controllable aerial or ground-based robots, passive (e.g. workers equipped with sensors) and semi-controllable units (e.g. forklift suggesting a route) will be investigated.

5. Conclusion

The proposed concept promises a further examination and usage of recent developments in sensor technology. While low-cost sensors enable the setup of dense sensor networks, they can not deliver the same high-quality data as costly sensor technology can.

The system that is going to be developed in the scope of the RASEM project will be tested under real conditions in multiple industrial sites in Finland. With the cooperation of diverse research institutes and industry partners, it is planned to maximize the insights of how the combination of low-cost and costly sensor technology can enable effective gas/dust distribution mapping.

Acknowledgements

The authors thank the colleagues from Örebro University and Finnish Institute of Occupational Health. Also, the authors express their gratitude to SAF€RA for funding the project in the scope of the 2018 joint call.

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