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An Airborne Measurement System to Detect, Locate and Quantify Methane Emissions

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Summary:
An Airborne measurement system with onboard computer for data processing and recording with no need for constant radio communication for inspection and maintenance is presented that detects, locates and quantifies methane leaks.

Keywords: Leak Detection & Repair, Methane Mapping, Sensor Data Fusion, Remote Sensing, UAS

Introduction

The reduction of methane (CH4) emissions is important for environmental protection [1] and for operational safety in the energy sector, as gas mixtures with methane are potentially explosive. Methane is a major component of natural gas and biogas.

While earth observation satellites attempt to locate emissions on a facility scale [2], unmanned aerial systems (UAS) can find leaks at component level and provide maintenance staff with a more comprehensive view on leaks than regular ground-based inspections [3]. Based on experiences with a ground-based, portable system for detecting and quantifying [4] and a mobile robot system for localizing methane leaks [5], an UAS capable of remotely detect, locate and quantify methane leaks was developed.

Measurement System

The aerial inspection system consists of a measurement module, an onboard computer, a support box and a quadcopter drone, see Figure 1. The measuring module features a tunable diode laser absorption spectroscopy (TDLAS) sensor, two visual cameras and a laser rangefinder jointly mounted on a gimbal. The support box is used to safely accommodate additional PC components and the power distribution.

The onboard computer processes and stores both camera streams and all sensor signals from the measuring module and the drone. All data is simultaneously available on a ground station in real time. Due to the data processing and recording capabilities of the UAS, constant radio communication is not required during a mission. The drone allows to take measurements from different perspectives. In combination with a scanning gimbal full inspection of complex structures is possible. The position information is determined by the drone's real time kinematic (RTK) system. Knowledge of the drone's position, gimbal orientation and the measured range allow the system to locate each measurement point in a 3D coordinate system referenced in the global positioning system (GPS). The system utilizes the Robot Operating System (ROS), an established software framework for robot applications organized in microservices. All available sensor and actuator inputs are recorded, by default. All measurements are visualized live in a 3D viewport, see Figure 2, and can be exported as a point cloud file with extended information (wind speed, point of measurement, methane concentration, …) for post-processing tasks. The UAS does not have a sensor to measure the wind speed. Therefore, the wind speed is estimated from the drone's orientation as proposed in [6]. This circumvents the complicated mounting of

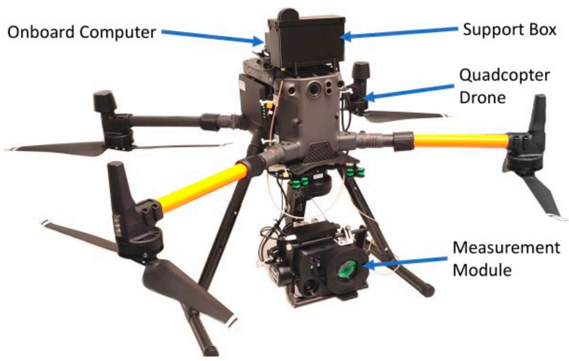

Fig. 1. UAS with cameras, laser rangefinder and TDLAS sensor to detect, locate and quantify methane leaks

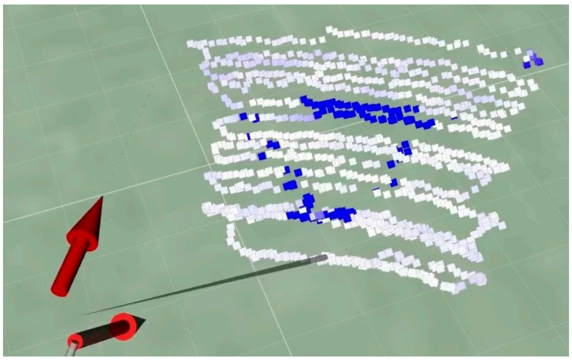

Fig. 2. Visualization of measurements from 0 ppm·m (white) to more than 300 ppm·m (blue) shown in the 3D viewport of the ground station. Arrows show drone's and gimbal's pose.

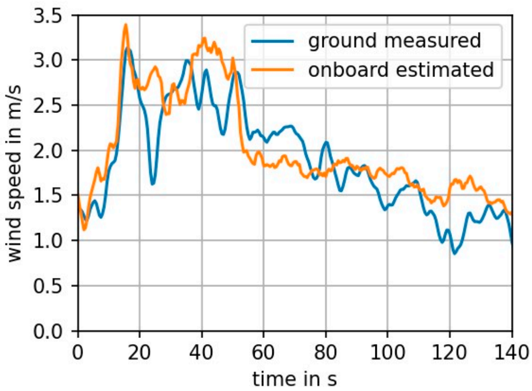

Fig. 3. Onboard estimated and ground measured windspeed for test data of 140 s.

an anemometer, such that it is not affected by the drone's own turbulences. Using methane concentration and wind speed allows estimating the amount of methane emitted [4].

Experimental evaluation

The UAS was evaluated in several field tests with methane-filled sample containers and mass flow controlled methane release under different weather conditions. The most important weather conditions are the level of cloud cover, as direct sunlight affects the TDLAS sensor and the wind speed, as this affects the methane dispersion and drone positioning. The results show that the drone can reliably hold its position and carry out measurements at windspeeds of at least 4 m/s. A sample container with a diameter of 0.2 m can be detected at a distance of 20 m. At a scan distance of approx. 10 m an area of 9.6 m²/min can be inspected. Figure 2 shows the result obtained for such scan speeds in the 3D viewport on the ground station. Regulated methane emissions of 43 g/h (approx. 60 l/h) can be located at ranges of over 10 m and wind speeds of at least 3 m/s. The wind speeds were measured with a 3D anemometer positioned close to the artificial leak and not at the drone's altitude. The wind speed measured on the ground is comparable with the wind speed estimated onboard the drone, see Figure 3. Under these conditions the estimated wind speed is sufficient to quantify methane leaks.

Summary and Outlook

Under normal wind conditions, the presented UAS is able to detect, from a technical point of view, small (approx. 60 l/h) methane leaks. It can inspect components and parts that are difficult to reach for ground-based inspections.

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