From Mobile Robot Olfaction to Heterogeneous Sensing Systems for Real-World Monitoring

Hazardous gas leaks and air pollution are major environmental risks, yet their sources often remain hidden, inaccessible, or outside the spatial coverage of existing monitoring networks. Mobile Robot Olfaction (MRO) – and its airborne extension, Aerial Robot Olfaction (ARO) – addresses this gap by combining robots, gas sensors, and environmental sensing for autonomous, real-time measurement. In the field, however, turbulent and intermittent gas transport together with slow, drifting sensors mean that methods developed under controlled conditions often need substantial adaptation before they can be used operationally. No single platform optimizes data quality, spatial coverage, and temporal coverage at once: fixed networks cover time but are spatially sparse and costly; ground robots provide high-quality local measurements but cannot cover large areas; aerial platforms offer rapid, flexible access but are limited in endurance and localization accuracy; and dense, low-cost sensing trades data quality for spatial reach. Heterogeneous sensing systems respond by combining complementary platforms, compensating for their individual limitations, and fusing the measurements into coherent maps of gas and dust distributions.

As an overview talk, this keynote introduces the concepts of MRO and ARO, heterogeneous sensing, gas tomography, and passive smart-dust chemosensing, and explains how they contribute to real-world detection, mapping, and localization tasks. It shows how they fit together through recent work ranging from completed deployments to ongoing validation. A stationary low-cost network in an operating steel hot-rolling mill, combined with mobile reference instruments, was used to assess how representative conventional measurement campaigns are. Building on this, multimodal, AI-supported monitoring of several gases is now being tested at industrial sites, where ground robots and drones validate and recalibrate fixed sensor networks. Ground-based gas tomography for spatially resolved imaging has been validated under controlled conditions, with outdoor methane-release trials and an aerial extension as next steps. Finally, passive, power-free chemosensors read out by standard camera drones have been field-tested for low-cost detection of hazardous regions, while gas-phase detection remains future work.

Together, these examples show that added value comes from combining platforms and validating the resulting systems under realistic conditions, rather than from any single robot or sensor. Two challenges currently limit routine use: reliable gas measurement from moving platforms, especially aerial ones, and gas source localization in turbulent flow. These are joined by practical constraints such as positioning in GNSS-denied environments, platform endurance, and long-term field validation. The keynote argues that reproducible operation in real deployments is required before integrated robotic olfaction systems can be used routinely in environmental protection and industrial safety.