

Smell-Based Molecular Communication for Mobile Robots Using Gas Sensing

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Summary:

We present an experimental demonstration of smell-based molecular communication for mobile robots using gas sensing. Inspired by biological systems, information is encoded in chemical signals that propagate through the environment as volatile plumes and are detected by a gas-sensor-equipped receiver as transient responses. A robotic-compatible platform enables autonomous emission, detection, and interpretation of these signals. Representative sensor measurements exhibit distinct transient dynamics, enabling reliable detection of individual chemical pulses. The received signal shows clear attenuation with increasing transmitter–receiver distance and sensitivity to transmission pulse duration. The system demonstrates stable and reproducible communication behavior under varying spatial configurations. These results establish chemical sensing as a viable communication modality and provide a foundation for smell sensing-driven information exchange and coordination among autonomous robotic systems.

Keywords: molecular communication, gas sensors, robotic communication, chemical sensing, volatile organic compounds

Background, Motivation and Objective

Communication between autonomous robots is predominantly based on radio frequency or optical technologies, which can degrade in cluttered, confined, or electromagnetically noisy environments. In contrast, biological systems widely employ chemical signaling to enable robust and decentralized information exchange. Inspired by these natural mechanisms, molecular communication has emerged as an alternative paradigm [1]. However, its practical realization in mobile robotic systems remains largely unexplored despite recent advances in robotic olfaction and gas-sensing platforms [2, 3]. In particular, the integration of chemical sensing and actuation into autonomous platforms, and understanding signal propagation under realistic conditions, remain open challenges. In this work, we develop a gas sensor-based molecular communication framework for mobile robots and investigate its behavior under varying spatial and environmental conditions.

Description of the New Method or System

We present a molecular communication system designed for integration with robotic platforms

and evaluated under controlled experimental conditions. The transmitter emits controlled pulses of aerosolized vinegar vapor, while the receiver captures the resulting signals using a metal-oxide gas sensor. The system is designed to operate under realistic conditions, where signal propagation is influenced by spatial configuration and environmental factors.

Unlike most existing studies based on highly simplified setups, the proposed framework enables experimental investigation of chemical signal propagation under controlled yet spatially varying conditions. The design allows systematic evaluation of how distance, pulse duration, and environmental factors affect signal detectability. This approach establishes chemical sensing as a practical mechanism for communication in robotic systems.

Results

Experimental observations demonstrate distinct sensor responses to controlled chemical pulse transmissions. The experimental setup, shown in Fig. 1, consists of a transmitter that emits periodic bursts of volatile molecules and a receiver equipped with a gas sensor positioned at a

defined spatial offset. This configuration enables systematic investigation of signal propagation under controlled geometric conditions. The measured signals exhibit a characteristic transient response to chemical pulse transmission, consisting of a rapid rise upon arrival followed by a gradual decay. As shown in Fig. 2, the sensor response varies systematically with the transmitter–receiver distance. Increasing distance results in a clear reduction in peak amplitude. This behavior reflects the attenuation and temporal spreading of the chemical plume during propagation. Despite these effects, the signal remains clearly distinguishable across all configurations.

As shown in Fig. 3, increasing the pulse duration leads to a stronger received response and a more prolonged decay profile. Despite these variations in amplitude and temporal extent, all cases retain a similar overall transient shape. This result indicates that the measured signal is sensitive to transmission duration and reflects the temporal characteristics of the emitted chemical pulse.

Extended periodic transmissions demonstrate repeatable sensor behavior over long durations. As shown in Fig. 4, successive chemical pulses produce distinguishable transient responses with similar overall temporal profiles across cycles. The responses maintain similar amplitude and temporal profiles across cycles, indicating stable system performance over time. These results highlight the capability of the sensing mechanism to support continuous signal transmission with clear event separation, suggesting its suitability for low-rate information exchange.

These findings demonstrate that smell sensing can support reliable information exchange, providing a foundation for autonomous robotic systems operating in environments where conventional communication methods are limited. Additional results, including mobile robotic implementation aspects, will be presented at the conference.

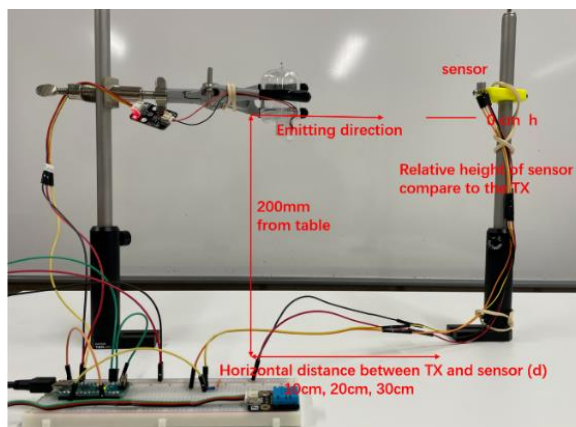


Figure 1: Experimental setup for smell-based molecular communication.

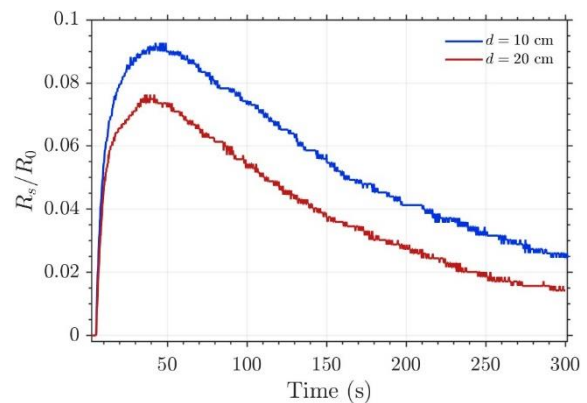


Figure 2: Representative gas sensor responses to a chemical pulse at two transmitter–receiver distances.

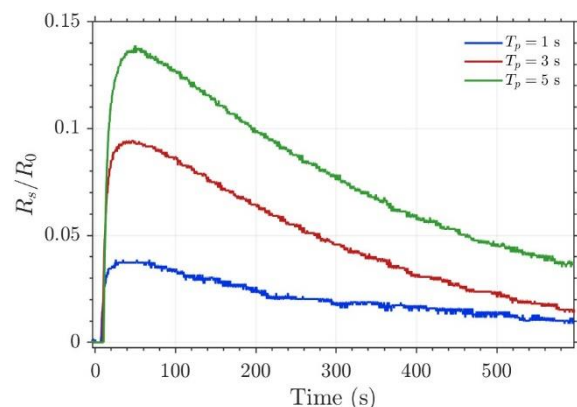


Figure 3: Representative gas sensor responses to chemical pulses of different pulse durations.

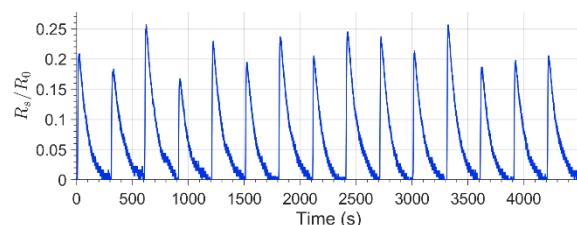


Figure 4: Representative sensor responses under periodic chemical pulse transmission.

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