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Towards improved characterization of high-risk releases using heterogeneous indoor sensor systems

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ABSTRACT

The sudden release of toxic contaminants that reach indoor spaces can be hazardous to building occupants. For an acutely toxic contaminant, the speed of the emergency response strongly influences the consequences to occupants. The design of a real-time sensor system is made challenging both by the urgency and complex nature of the event, and by the imperfect sensors and models available to describe it. In this research, we use Bayesian modeling to combine information from multiple types of sensors to improve the characterization of a release. We discuss conceptual and algorithmic considerations for selecting and fusing information from disparate sensors. To explore system performance, we use both real tracer gas data from experiments in a three-story building, along with synthetic data, including information from door-position sensors. The added information from door-position sensors is found to be useful for many scenarios, but not always. We discuss the physical conditions and design factors that affect these results, such as the influence of the door positions on contaminant transport. We highlight potential benefits of multisensor data fusion, challenges in realizing those benefits, and opportunities for further improvement.

1. Introduction

The ultimate goal of the research described in this paper is to develop approaches for the design and implementation of sensor systems that can detect and diagnose — in real-time — chemical or biological contaminant releases that pose acute hazards for building occupants. Such sensor systems should perform robustly — for example, identifying the location and mass of the release and suggesting safe evacuation routes — under diverse release circumstances, for different building operating conditions, and with limited and imperfect sensor information.

As building scale increases, the physical processes that govern indoor contaminant transport and fate become more complex and simple engineering rules of thumb may be insufficient for designing effective sensor networks. Instead, an integrated-design approach that considers contaminant transport processes, sensor characteristics, and sensor interpretation algorithms can help to develop a system that performs well in diverse conditions. The present paper builds on our previous efforts to develop system design methods and model-based algorithms capable of reconstructing and estimating the unobserved parameters of a release event [1–3].

Our previous research explored data interpretation based solely on contaminant measurements. The present paper considers fusing information from multiple sensor types. First, contaminant sensors are relatively expensive, so that adding different types of sensors may decrease the system cost without compromising performance. Second, some inexpensive-to-detect aspects associated with the state of the building, such as the operating mode of the air handling system or window and door positions, can play a significant role influencing contaminant transport. In general, the designer would wish to consider incorporating any information that would improve the predictive power or robustness of the detection and diagnostic system.

In this paper, we present elements of a conceptual framework and an algorithmic approach to integrate information from heterogeneous sensors into a diagnostic sensor system. Under ideal conditions — perfect information and a perfect interpretive model — many types of information would help to improve the event reconstruction, albeit to varying degrees. Under nonideal

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