Distributed Detection for Tomographic Measurements of Component Concentrations in Fire Generated Plumes

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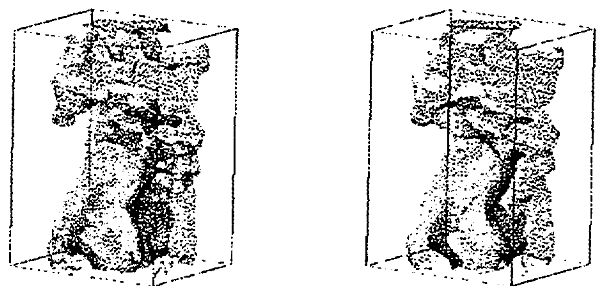
One of the major goals of fire research is to develop the capability to make realistic assessments of fire impact and risk by utilizing models. Currently the large scale fire/plume models may not be validated and hence calculations which may have a large economic/safety impact are may be considered suspect. As a consequence, these models are under utilized. In order to increase the level of confidence placed in these computational models to an acceptable level a rigorous experimental tomographic validation technique has been under development at BFRL/NIST. In this pursuit, we have analyzed data from both laboratory and computer generated plumes (Figure #1) in order to determine the number of line-of-sight measurements, the detector topology, and the temporal resolution needed to obtain accurate tomographic reconstructions of the component concentrations in asymmetric turbulent flow fields.

Current techniques only allow for line of sight and point measurements, which are inadequate for large scale model validation. At a minimum model validation will require the ability to measure the concentrations of smoke and gases in room scale enclosures (~ 27 m^3 in volume) as functions of both time and space with a spatial resolution ranging from about 1 to 20 centimeters and a temporal resolution of about 100 Hz. This measurement density is much too high to achieve using conventional point sampling techniques such as thermocouples and gas sampling probes. Computed tomography [1-10], which is based on line-of-sight rather than point measurements, provides a basis for making accurate time-resolved three-dimensional measurements of component concentrations in fire environments and is already a mature technology with many routine applications in medical imaging [10] and nondestructive evaluation [1]. Typical commercial tomographic systems utilize a source of monochromatic x-rays in configurations which produce images with high spatial resolution and low temporal resolution over a well-defined sample volume in a controlled environment. While these systems have been very successful in medical and industrial settings, they are not suitable for application to the problem of interest which requires the capability to image large, time dependent flow fields with quantitative accuracy. The further development of this measurement technique, to the point where it can provide accurate descriptions of the transport of smoke and gases in turbulent plumes, presents a significant challenge because of the dynamic nature of the measurements, the physical dimensions of the volume, the adverse conditions, and the complex geometry of the measurement space. Previous results obtained in this laboratory, indicate that the spatial variation component concentrations in the plumes above small smoldering wood fires at a time resolution of about 1 minute are well described by a 4 parameter Gaussian model. In principle, this means that as few as 4 line-of-sight measurements are sufficient for accurate reconstructions of the component concentrations in a cross-sectional volume of the plume at this temporal resolution. Further analyses of computer generated mixture fraction fields confirms the intuitive notion that the spatial density of measurements needed to obtain accurate reconstructions of turbulent plumes increases with the temporal resolution of the measurements. Nevertheless, the number of measurements needed to obtain an acceptable level of accuracy (on the order of 10% relative error), even in highly time resolved measurements ($\Delta t = 0.01$ s), is considerably less than what is conventionally used in typical applications of computed tomography.

Our approach is to develop a distributed detection system for the tomographic measurement of component concentrations. Distributed detection systems are ideally suited to tomographic plume diagnostics given the high degree of flexibility, the extremely high data aquistion rates now available, and the relatively low cost of implementation. In the detection system under development each detector utilizes a separate collection system which resides at the detector location and can be controlled by a single computer via a multiplexed RS-485 communications system. Each collection system runs autonomously with an independent microprocessor and requires no intervention during an experiment. This parallelization allows for incremental expansion, complex detector geometries of varying size, high multichannel aquistion rates, and upgradability to new technologies.

Figure# 1



Actual Model   A-10 L-26

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