Real-Time Measurement of Aerosol Size Distributions with the Fast Integrated Mobility Spectrometer (FIMS)

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Abstract

While the Fast Integrated Mobility Spectrometer (FIMS) has greatly improved aerosol size distribution measurements with its ability to capture data within a size range of 10 to 600 nm at a time resolution of 1 second, its offline analysis mode has imposed certain limitations. Abrupt temporal changes in the observed aerosol size distribution are identifiable only hours later, during post-measurement data analysis. This delay between data collection and analysis impedes real-time detection of swiftly changing aerosol environments and of instrument anomalies during data collection.

To overcome these limitations, we developed a real-time data analysis pipeline for FIMS, enabling continuous computation of size distributions during sampling. Our pipeline comprises two computational stages: image processing, which detects particles passing through the FIMS detector and calculates their residence time within it; and data inversion, which employs Twomey inversion to translate observed particle counts within some time window to a particle size distribution. Real-time analysis requires processing images at a rate of 10 Hz and combining particles counted from multiple successive images to produce an updated distribution each second.

Our work gives FIMS the ability to characterize a broad aerosol size range with low delay and high temporal resolution. Efficiency tests on a Raspberry Pi 4 processor show that our pipeline can process an image in 38ms and invert a vector of counts in 69ms, well below the requirements of 100ms and 1000ms, respectively, to produce an updated distribution every second. Imposing a delay of 2.4 seconds between image processing and inversion is sufficient to produce results in 100% agreement with offline methods. Our efficient C++ code allows compatibility with embedded platforms, expanding FIMS' reach. Our work allows real-time aerosol environment monitoring, eliminating lengthy delays between data collection and analysis and boosting FIMS' potential for aerosol research.