Volumetric Imaging and Multi-Angle Illumination for Dense Sprays Characterization

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In this work the authors propose an imaging strategy appropriate for dense sprays utilizing arrays of consumer-grade electronics for both illumination and sensing. Given the preliminary nature of the work the target in question was static but the method is agnostic to motion. The results are not a two-dimensional image of the target but rather a three-dimensional map of all light scattering sources in a volume. Using a novel illumination scheme that actually benefits from multiply-scattered light the authors demonstrate how an array of inexpensive imaging sensors can be utilized to provide microscopic resolution at every location in a macroscopic volume. In fact, under ideal conditions, the resolution of the output can far exceed that of any single sensor. With the current optical configuration this would result in an imaging resolution better than 39 mm in all three dimensions over the entire cylindrical target volume: 135 mm high by 135 mm across – or more than 32x10^8 possible volume elements.

The authors evaluate the performance of this technique under varying levels of obscuration until an extinction fraction estimated at 99.8%. Though the spatial resolving power of the technique decreases with increasing extinction, the three-dimensional structure of the target was resolvable for all cases.

Figure 1. The target was an arrangement of twelve 200 mm monofilament strands to which 187 mm glass beads were affixed. Such a structure has similar light-scattering characteristics to water or fuel in air in that it both refracts and reflects light. Shown here is a photograph of the top 9% of the target at higher resolution than during data acquisition.

Figure 2. Subset of a single image on a single sensor showing a bead affixed to a monofilament line. The pixel resolution is 39 µm while the resolving power of the optics is closer to 100 µm.

Figure 3. Rendered image of the 50% isocountour of the volumetric map without obscuration. Plotted here is the top 25 mm of the 135 mm tall cylindrical measurement volume. The resolution of the output is greater than that of any single image such as in Figure 2. Therefore, the proof-of-concept data set can be evaluated at a resolution greater than 39 µm per pixel in all three dimensions throughout the entire volume.

Figure 4. Even at 98% obscuration the details of the imaging target are still easily resolved. The authors demonstrate the technique to a total obscuration of 99.8% and though the small-scale details are lost it is still possible to identify to location of all twelve monofilament lines through the measurement volume.