Deep Learning for optical characterization of individual laser-trapped particles

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The inverse problem in light scattering theory (i.e., the characterization of particles from optical signals) constitutes one of its most important applications. High accuracy measurements and models are needed to accurately infer physical and/or chemical particle properties from optical signals (e.g., phase function, polarization, Raman scattering). Inferring physical characteristics (e.g., size, refractive index, type) of light-scattering particles can be extremely difficult (or sometimes impossible) if the inversion solution is not unique or if an appropriate model is not available. Here we investigate the inverse problem for Raman and elastic scattering and fluorescence data without the use of light scattering models.

The U.S. Army Research Laboratory has developed a laser trap for absorbing as well as non-absorbing particles. Trapped particles can be optically interrogated and an amalgamation of optical data can be measured (e.g., extinction, degree of polarization, Raman scattering). Such optical data can be treated as points in a multi-dimensional mathematical space of all measured quantities.

Here, we address the following fundamental questions:

1) Can Deep Learning techniques infer physical and/or chemical particle properties without using light scattering models?
2) If particles are subject to aging due to ultraviolet radiation, is the method robust enough to identify these particles by properties unaltered by aging?
3) Can we identity the optical signal of a few particles in a background of many different other particles?

The answers to these questions have potential uses in aerosol detection, particularly relevant to early warning for chemical or biological agents.

Preferred mode of presentation: Poster