Feature Extraction and Classification of Wide Angle Optical Scattering Patterns from Single Aerosol Particles

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Abstract—The aim of this investigation is to discriminate between elastic light scattering patterns produced by reference materials, namely clusters of polystyrene (PSL) spheres, and by spores of Bacillus globigii (Bg), a known simulant of anthrax. TAOS (two-angle optical scattering) is an experimental technique which records the intensity patterns of laser light scattered by single aerosol particles over an extended range of the scattering angles $\theta$ and $\phi$ \cite{1}. Particles are produced at a controlled rate and illuminated by a Q-switched Nd:YAG laser at $\lambda = 532$ nm. The TAOS patterns are recorded by an intensified CCD camera and stored for off-line processing. Typical patterns from PSL aggregates and Bg spores are shown in Figures 1 and 2, respectively. Since in this context deterministic obstacle inversion is impossible, pattern recognition is a must. The pattern classifier under development consists of four stages. 1) Pre-processing. 2) Feature extraction by spectrum-enhancement \cite{2}. 3) Training, in which principal component (PC) analysis is applied to features extracted from a training-set ($T$) of images and classification is rated

Figure 1: Scattering pattern of a polystyrene (PS) sphere aggregate.

Figure 2: Scattering pattern of Bacillus globigii (Bg) spores.

Figure 3: Classifier output: Representation of TAOS patterns on the plane of the first two PCs, $z_1$ and $z_2$. 

$\text{FoM}_8 = 0.624$

$\text{FoM}_9 = 0.600$ (class 2).
by the following figure of merit (FoM):

\[
FoM_8 = \frac{1}{2} + \frac{1}{2M_T} \sum_{m=1}^{M_T} \sum_{j=1}^{2} \frac{d_{m,j} - d_{m,i}}{d_{j,i \mid m}}.
\] (1)

Here \(M_T\) is the number of patterns in the T set, \(i[m]\) is the class, 1 or 2, to which pattern \(m\) is known to belong and \(d_{m,j}\) is the distance from pattern \(m\) to the class \((i\) or \(j)\) centroid. Validation, rated by \(FoM_9\), a figure of merit where \(M_V\), the number of patterns in the validation (V) set, replaces \(M_T\) of \(FoM_8\). A typical classification result, which corresponds to \(FoM_8 = 0.624\) and \(FoM_9 = 0.600\) is shown in Figure 3. Feature extraction depends on a few parameters. The latter are optimized via the \(FoMs\). Sensitivity of results to \(T\) and \(V\) set composition is assessed by swapping patterns between \(T\) and \(V\) sets and then repeating classification. The above described classifier can be applied to TAOS patterns in real-time.

REFERENCES