LIBS-RS-XRFS Multisensor Data Fusion for Soil Analysis

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With the commercial introduction of handheld chemical analyzers for field use, there is now an opportunity for the development of integrated multisensory systems for the rapid, in-situ analysis of natural materials in the field under ambient environmental conditions. We are undertaking development of a multi-sensor system based on current handheld analysers for laser-induced breakdown spectroscopy (LIBS), Raman spectroscopy (RS) and X-ray fluorescence spectroscopy (XRFS).

Soil samples from 6 sites in central New Mexico (USA), each of a single soil type, were analysed using COTS handheld instruments for LIBS, RS, and XRFS to assess the performance benefit of 3-sensor data fusion. Leave-one-sample-out cross-validation was used, with the number of samples per class ranging from 4 to 14. Individual spectra for each sample were classified by the sensor-specific classifiers and then averaged to produce a single classifier confidence per sample. These average confidences were used to generate the accuracies per sensor and as the inputs for the fusion classifier to generate the fusion accuracies.

All soil classes were well separated by multivariate statistical analysis of the single-sensor data, except two temporally similar soil units. The classification accuracy was 91%, 80%, and 89% respectively for LIBS, RS, and XRFS spectral data. Data fusion was conducted hierarchically in two stages. First, sensor-specific classifiers were developed to process the sample data from each sensor. Then, individual analyser outputs were used as features for a second stage classifier that determined the class assignment of each sample. With this approach, pairing the RS data with either the LIBS or XRFS data increased classification accuracy to 96% correct. Pairing the XRFS and LIBS sensors did not improve accuracy. Three-sensor fusion did not increase accuracy beyond the improvement already observed by pairing the LIBS or XRFS data with the RS data.