Minimizing LIBS Damage in the Analysis of Historical Tiles using Adaptative Color-Clusters

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Motivation

Extracting elemental information from cultural heritage samples poses a unique challenge, as these materials are often fragile and must not be damaged due to their significant historical and artistic value. Therefore, it is essential to minimize the use of invasive analytical techniques while still obtaining detailed insight into their atomic composition. This work proposes a novel strategy that integrates spectral and RGB data clustering to identify visually and chemically identical regions. By comparing the regions obtained from both clustering approaches, the method will lead to a reduction in the number of measurements required, thus preserving the integrity of cultural heritage artefacts while still delivering reliable compositional insights.

Sample and Instrumentation

A spectral map covering an area of 8 × 9 cm² of a ceramic tile was acquired using a Laser-induced Breakdown Spectroscopy (LIBS) prototype with a 1064 nm Nd:YAG laser (51 mJ), a spot size of about 300 μm, and a step of 250 μm. The acquisition was performed with an 8-channel Avantes spectrometer (180–926 nm).

Figure 1. Studied ceramic tile with different shades of blue on a white background.

Validation Method

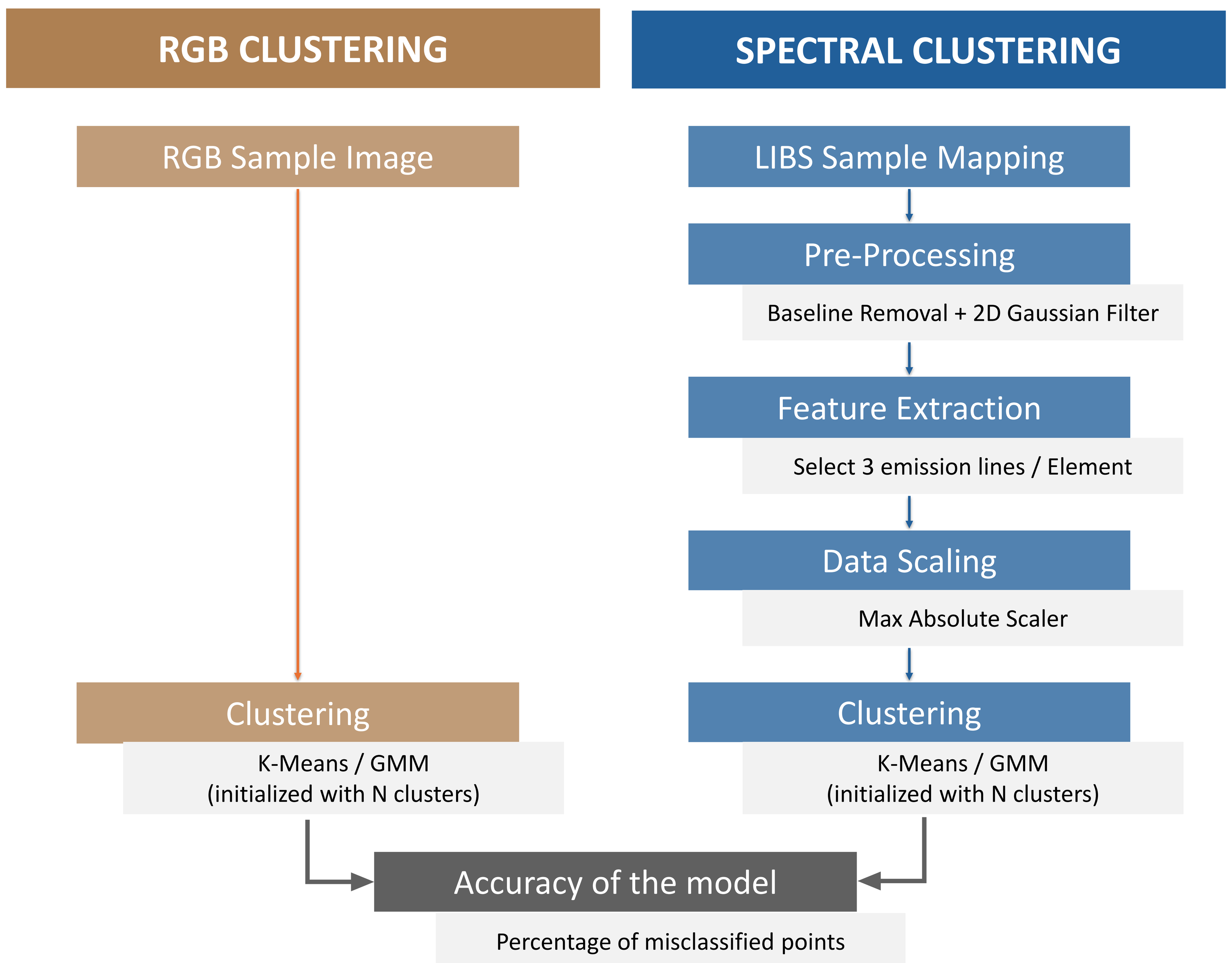

Figure 2. Clustering workflow for RGB images and LIBS spectral data.

Proposed Approach

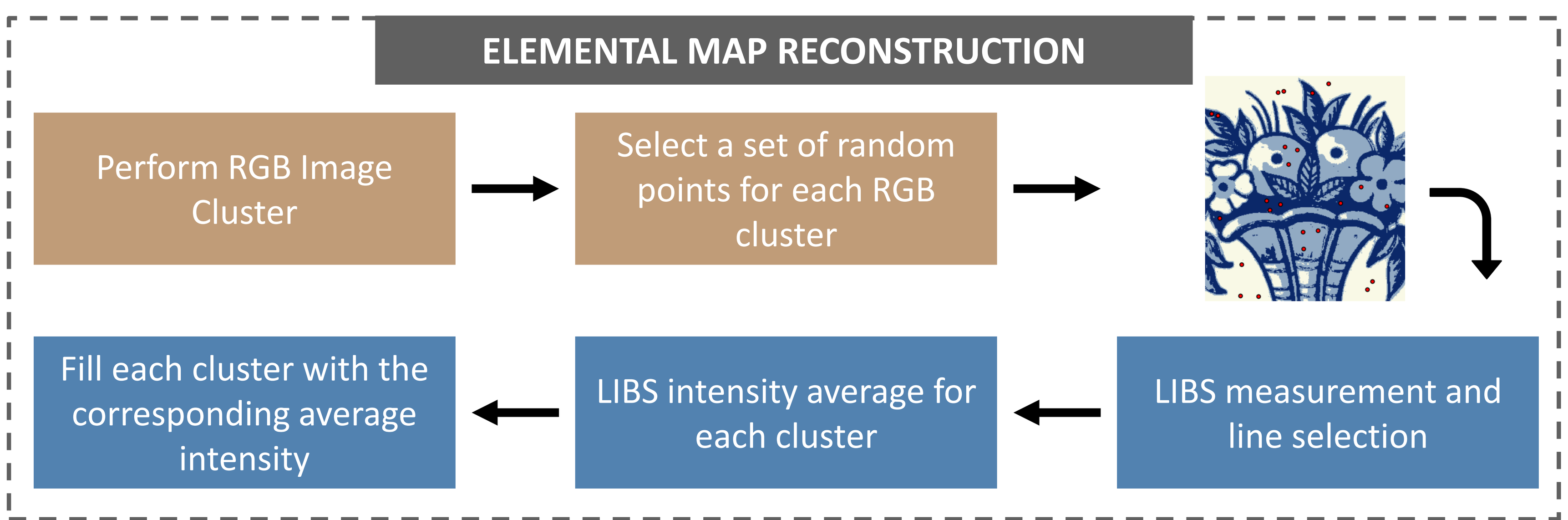

Figure 3. Elemental map reconstruction pipeline.

Results

For the proposed method, emission lines from the elements cobalt, lead, tin, calcium, lithium, and hydrogen were considered, totaling 16 emission lines.

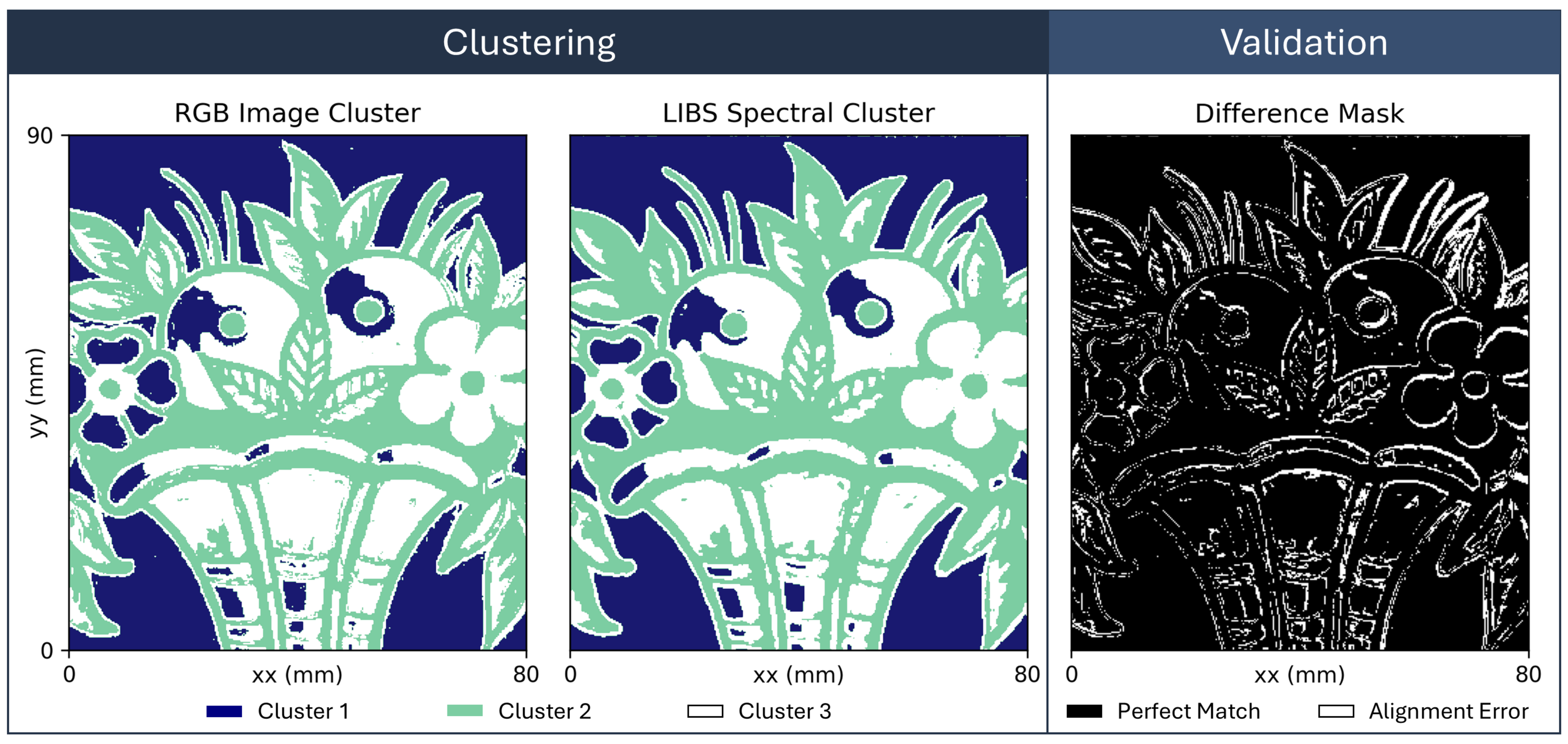

Figure 4. Clustering results (k=3 clusters) applied to both the RGB image and the spectral data. The outcome reveals a similarity of 88.4% between the two segmentation approaches.

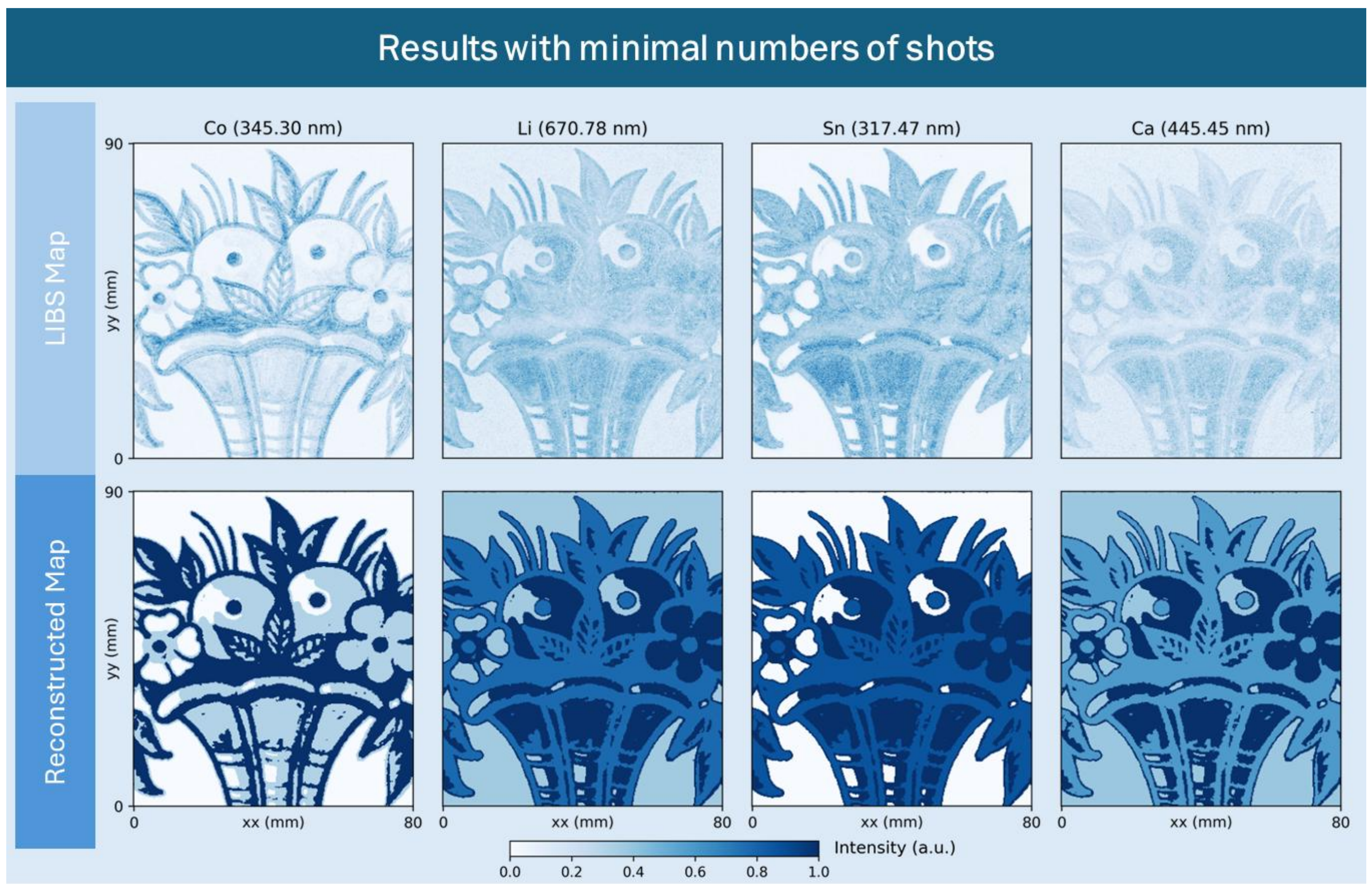

Figure 5. Comparison between the original spectral map and the reconstructed elemental map for Co, Li, Sn and Ca. The reconstructed map was generated by assigning to each cluster the mean elemental intensity calculated from its selected points. This methodology can be applied to any other spectral line present in the spectra of the chosen spots, providing an approximation of the spatial distribution of an element across the sample.

Conclusions

This study presents a clustering-based methodology designed to obtain detailed spectral information while minimizing damage to cultural heritage samples. The results demonstrate a strong similarity between the spectral images and the reconstructed maps generated using a minimal number of LIBS shots: reduced from 360 × 320 individual shots to only 8 shots per cluster. This finding confirms that, in future analyses, performing RGB clustering alone can effectively guide the selection of a few representative spots per cluster, enabling reliable extrapolation of the elemental composition across the entire region. This novel approach represents a paradigmatic shift in heritage science, offering a practical and less invasive solution for efficient compositional analysis of valuable materials.

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