A statistical perspective on oil & gas reinjection water colorimetry

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ABSTRACT

Controlling reinjection water quality is a critical aspect of petroleum production, as even relatively small deviations of planned specifications can directly affect equipment performance and reservoir integrity, compromising operability and potentially leading to negative environmental impacts. Oil content and particulate matter must be carefully monitored to ensure compliance with operational specifications and to minimize formation damage (Hu et al., 2025; Tang et al., 2025). In this research, we investigated the viability of applying computer vision tools to colorimetric images of filtration membranes used in reinjection water analysis. In order to explore different color spaces, to reduce channel redundancy, and to evaluate if the available images contain sufficient predictive information, this study proposes a statistically driven methodology instead of directly following conventional machine learning trial-and-error approaches, which can be time consuming and resource intensive (Bischl et al., 2021). The framework consists of analyzing the statistical description of pixel intensity in the region of interest of the images for all investigated channels. The Pearson correlation and the mutual information metrics were used to quantify both linear and non-linear relationships between image-derived features and measured concentrations of oil and iron oxide in the samples. Preliminary analysis indicates that several color channels present significant redundancy, with the CIELAB space showing greater statistical independence. However, most evaluated combinations showed weak correlations and high data dispersion, with limited evidence of monotonic patterns across concentration ranges. Visual inspection of the samples also corroborates that simultaneous variation of iron oxide concentration and oil content affects tonal variation in a way that can produce similar color patterns under distinct compositions. The present results should be interpreted as an initial assessment rather than a definitive conclusion. Nevertheless, the proposed statistical framework provides an objective basis for determining whether image based modeling is justified before advancing to more complex machine learning architectures, indicating the need to reassess the scope of the research or to perform alternative image preprocessing for improved feature discrimination. Future work will focus on simplifying the analysis by isolating the variation of a single component, investigating the effects of image preprocessing on the extracted statistical descriptors, and confirming potential improvements through comparative performance analyses using the same model architecture across different preprocessing strategies and color spaces.

Keywords: computer vision, colorimetric analysis, statistical modeling, process monitoring, oilfield process

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