Learning to Identify Multispectral Signatures from Weakly Annotated Data: Iron Age Ostraca as a Case Study

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Abstract

Multispectral (and hyperspectral) imaging across different spectral domains has emerged as a common non-invasive technique for identifying the material composition within various historical media. For instance, multispectral imaging can be employed to distinguish between carbon ink and clay, as they exhibit distinct reflectance properties, aiding in the identification of ink within ancient inscriptions. Unfortunately, the preservation of these documents, which were inscribed over two and a half millennia ago, is often poor due to post-depositional processes. Consequently, they frequently exhibit signs of effacement, blurring, and staining, with ink traces that are often barely visible. As a result, classifying the ink pixels within such inscriptions poses a significant challenge. In our study, we tackle the task of identifying multispectral signatures using weakly annotated data. The task is further complicated by sparse and partial labels, where only a fraction of image pixels is manually annotated by human experts. To address these challenges, we develop a transformer-based deep neural network (DNN) model, alongside methods for pre-processing and enriching the data representation via tailored visual augmentations, weakly-supervised and self-supervised multispectral learning. The transformer-based DNN exploits the complex shape and spectral cues available in the data, which allow for better discrimination of ink and background and possibly even the reconstruction of ink invisible to the naked eye. The outcome of the proposed methodology is an image that assigns a probability to each pixel, indicating its predicted likelihood of containing ink. We demonstrate the significance of the multispectral characteristics of the data and the effectiveness of our approach on Iron Age Hebrew inscriptions from the Judaean desert, dated c.a. 600 BCE, with implications to image binarization.

Keywords: Multispectral segmentation, image binarization, weakly supervised learning, transformers neural networks, Iron Age ostraca.