Objective delineation of river bed surface patches from high-resolution spatial grain size data

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Gravel-bed rivers commonly display distinct sorting patterns on their beds. Visually, this heterogeneity often appears to form an organization of distinct textural patches or facies. The local bed surface grain size, and therefore bed surface patchiness, exerts considerable influence on local bed mobility, bedload transport rates, hydrodynamic roughness, and benthic microhabitats. Despite the ecological and morphodynamic importance of bed surface patchiness, we lack accurate and objective methods to delineate bed patches. However, recent advances in photographic measurement of bed surface grain size distributions are capable of providing data at a spatial resolution high enough to allow us an opportunity to answer the question: what is a patch?

Here, we explore a variety of techniques that can be applied to high-resolution spatial grain size data to automatically generate maps of grain size patches. We applied a state-of-the-art image processing and machine learning procedure to a photographic survey of the bed surface of a near-field scale flume to extract grain size data and to generate a spatial grid of bed surface grain size distributions. The flume bed was composed of gravel 2-45 mm in diameter and it featured clearly identifiable sorting features.

Using this dataset, we investigate several possible methods of patch delineation. The grid of grain size distributions can be represented by a graph of nodes (grain size distributions) connected by edges whose weight is a function of the similarity between two nodes. Spectral graph theory is then used to optimally cut the edges in order to produce a spatial structure of patches that minimizes the association between patches and maximizes the association of nodes within a patch. In a different approach, agglomerative clustering of spatially adjacent grain size distributions is used to produce a hierarchical dendrogram that can be thresholded to partition the bed into patches. We also explore using the $k$-means algorithm and Gaussian mixture models to classify the raw grain size distributions into distinct clusters, which then can be mapped and analyzed spatially. Our analyses suggest that high-resolution spatial grain size measurements can produce a meaningful and objective characterization of bed surface patchiness.