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ScrollStats: a Python tool for quantifying scroll bar morphology on meandering rivers

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Summary

Scroll bars are elongated arcuate topographic features deposited along the inner bank of meandering rivers. As the river continues to meander across the floodplain, the series of scroll bars deposited in its wake is known as ridge and swale topography. The ridge and swale topography, readily observed in LiDAR-derived digital elevation models (DEMs), contains a visually intuitive record of the river's migration history, and the specific morphology of each ridge may serve as a proxy for the hydrological, geomorphological, and sedimentological conditions under which each individual scroll bar is formed. The ridge crests, with their higher elevation relative to the swales, also encourage the growth of colonizing vegetation, which in turn stabilizes the ridges and mitigate future erosion (Zen et al., 2017). While there has long been an interest in the formation and preservation of scroll bars, research into the specific drivers of ridge morphology and what information it may contain is new (Nagy & Kiss, 2020; Strick et al., 2018).

Statement of need

`ScrollStats` is an open-source Python tool to quantify the morphology of scroll bars preserved in the ridge and swale topography commonly found in the floodplains of meandering rivers adjacent to the river channel. This quantification will allow researchers to investigate the relationships between ridge morphology and the environmental factors affecting its formation, such as the hydrology at the time of deposition, spatial variations in the river width, the channel curvature, the position along the meander bend, and the floodplain vegetation coverage and composition.

`ScrollStats` generates a series of migration pathways (an adaptation of the "erosion pathlines" from Hickin (1974)) that trace the paths of migration across the bend from the channel centerline to the most ancestral ridge (Figure 1). These migration pathways are then used to sample the underlying DEM and binary ridge area raster to create a series of one-dimensional (1-D) signals of ridge elevation and ridge presence (Figure 2). Then, from each 1-D signal, the ridge's amplitude, width, and spacing (distance from the previous ridge) can be calculated at every intersection of the migration pathway and a ridge (Figure 3).

The intersections of migration pathways and ridge lines form a migrationally relevant grid, which allows for the measurements at each intersection to be aggregated to larger spatial scales (ridge-scale, transect-scale, bend-scale) (Figure 4). This hierarchical spatial relationship enables researchers to study ridge morphology as it changes over time (from ridge to ridge) and along the channel (from migration pathway to migration pathway) and examine the associations between these changes in ridge morphology and the environmental factors affecting their formation. This allows for researchers to leverage the morphological information stored in the floodplains of meandering rivers to deduce past events such as changes in flow regimes, river planform and bend dynamics, sediment flux, and carbon storage and release. Such information has potential to also inform the predictions of future meander migration patterns and habitat suitability for riverine fauna and flora including riparian forests.

Figures

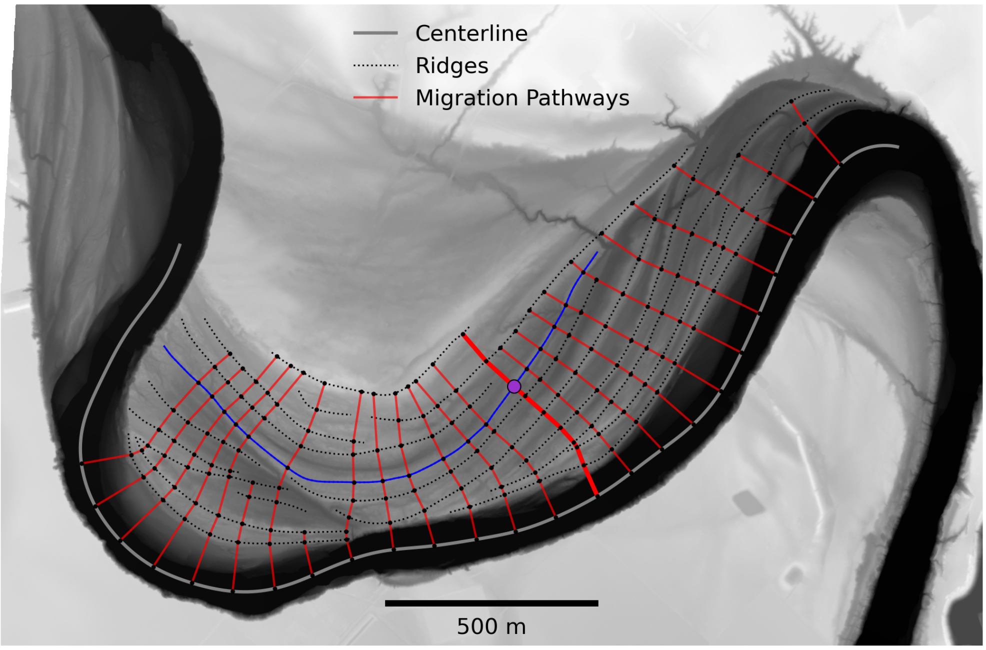

Figure 1: Ridgelines (dotted black) and channel centerline (solid grey) are manually digitized from interpretation of the DEM (Brazos River, Texas) and the binary ridge area raster (not pictured). `ScrollStats` then generates migration pathways (solid red) from equally spaced starting points along the centerline by "walking" up the floodplain from ridge to ridge (see Fig 3 from Hickin 1974 for transect generation procedure via calculation of vertical resultants). Ridge amplitude, width, and spacing are then calculated at each intersection (black dots) through analysis of the 1D signals generated by sampling both the DEM and binary ridge area raster along each transect. These calculations are shown for an example intersection (purple dot) of a ridge (solid blue) and migration pathway (thick solid red) in the following figures.

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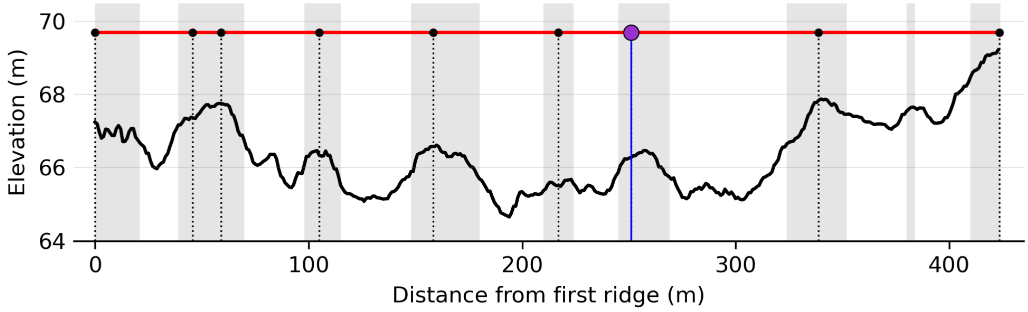

Figure 2: The 1D signals sampled from the DEM (solid black line) and binary ridge area raster (ridge areas shown in light grey patches) along the example migration pathway (solid red line) from Figure 1. The location of each ridge intersection along the migration pathway is shown with a black dot and dashed line. The zero point along the y axis starts at the intersection with the first ridge on the floodplain and increases with distance from the channel. Subjectively digitized ridge lines often, but do not always, fall within the bounds of the objective ridge area classification (see second to last grey patch near 400m). Ridge metrics are only calculated along the migration pathway for intersection points with the ridge lines. Ridge metric calculations are shown graphically for the example intersection (purple dot and blue line) on Figure 3.

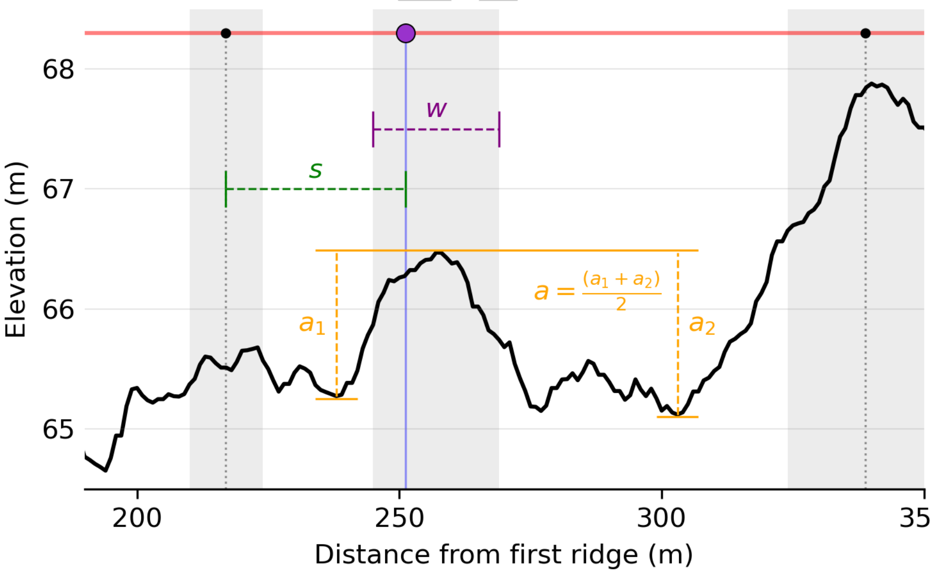

Figure 3: Graphic representation of ridge metric calculations for the example intersection (purple dot). Amplitude (a; shown in yellow) is calculated by averaging the differences between the maximum elevation found within the corresponding ridge area (grey patch) and the minimum elevation values found in the preceding (a1) and following (a2) swale areas. Width (w; shown in purple) is the distance between the edges of the corresponding ridge area. Spacing (s; shown in green) is the distance between the intersection point and the adjacent intersection point closer to the channel.

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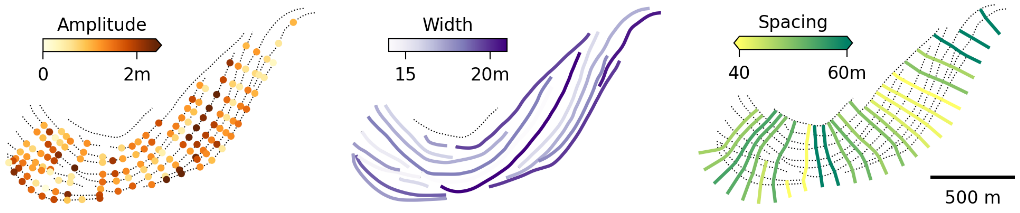

Figure 4: Measures of ridge amplitude (orange), width (purple), and spacing (green) are shown at the intersection, ridge, and migration pathway scales. Aggregate values represent the medain value of each measurement taken at a ridge or migration pathway.

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