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Processing Matters: 3D Mesh Morphology

Substantive advancements have been made toward automating the application of landmarks and semilandmarks. These approaches can aid in expediting the landmarking process, while simultaneously reducing landmarking errors and investigator bias. This study enlists a template-based approach to quantify deviations in mesh processing outputs using a Pontchartrain dart point from the collections of the National Forests and Grasslands in Texas, which was scanned and processed at multiple resolutions using microCT and laser scanners. Following data collection and output, meshes were processed using an automated and replicable workflow. A batch processing protocol was developed in Geomagic Design X and Control X to facilitate exploratory comparisons of the processed meshes, which indicated that the greatest changes to the meshes occurred along the lateral margins of the dart point. Results of the geometric morphometric study evince implications for processed meshes curated in digital repositories, making it clear that should investigators endeavor to incorporate curated meshes that they should begin with the unprocessed data, enlist uniform processing protocols across the sample, and comprehend the many vagaries of 3D data collection and processing across different modalities.

This endeavour is focused upon the variation introduced for a single artefact over six scan resolutions and nine Regen settings. Six 3D scans were collected at six resolutions with a NextEngine scanner; three using the HD settings in ScanStudio HD PRO (H1-3), and three using the HD settings in ScanStudio HD (SH1-3). To achieve the most consistent results possible, scan data were collected by scanning the same specimen using the identical placement for each scan, ensuring uniform data. The 360-degree scans were generated in three positions: one with the Pontchartrain point upright (vertical--point up, base down), one oriented on its lateral edges, and one of the edge profile. Following placement of point on the NextEngine stage, it was scanned six times, at six different resolutions prior to moving it to the second position, and again before to moving it to the third position.

Following data collection, each scan was saved twice. Once as a reference and backup that was uploaded to the Open Science Framework as an unprocessed mesh. The other was trimmed, aligned, fused, and polished to produce the nine meshes needed for the analysis, then uploaded to the Open Science Framework as an stl file. In total, 54 meshes were generated from six scans, each processed at nine resolutions for the same Pontchartrain dart point with the NextEngineHD. Three microCT scans were collected with a Bruker SkyScan that will be added to this analysis in a subsequent iteration.

While the preliminary results reported here include only the laser-scanned data, these findings demonstrate that the area of greatest impact is the contour around the periphery of the projectile point. This is noteworthy, as the bulk of all geometric morphometric and morphometric measures are collected from these high-curvature areas of the mesh topology. An additional issue entails the absence of data from selected areas of the ReGen9 datasets. It was not expected that holes would be present in these data, which needed to be filled in advance of batch processing the scans in the *Rvcg* package. Holes encountered following ReGen were addressed through a subsequent mesh regeneration, using the option to fill holes.

The geometric morphometric analysis will enlist the *auto3dgm* package to align and populate each of the microCT and laser scans using principal alignments and 1500 pseudolandmarks. Given that this project enlists scans of the same projectile, the topology of all scans are homologous. Thus, the pseudolandmarks provide sufficient information to gauge the point at which differences in mesh resolution may yield results that differ at the level of statistical significance. Whether or not that level of difference exists, the amount of variation across the scanning outputs warrants additional research.

The exploratory results of mesh comparisons in Geomagic Control X demonstrate that substantive differences in topology manifest when 3D meshes are processed at different resolutions. This finding alone requires that we urge caution in 3D studies where meshes are aggregated from different laboratories or data producers; particularly if data are being repurposed from different scanning modalities in the same study (i.e., laser, structured light, CT, and microCT), where the intricacies associated with data collection and processing differ most.

Thinking critically about where and how scan data originate is important in metrological and morphological studies. It is recommended that in those studies where 3D data is aggregated from digital repositories, that investigators download the unprocessed (raw) data, and process it themselves, enlisting a processing protocol that remains consistent across the entirety of the sample. It is also posited that higher-resolution scan data will have greater utility and reuse potential over time, since all scans can be downsampled, but no methods exist to increase the resolution of previously-scanned data.

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Data Availability Statement: The files and code associated with this project are available on GitHub (https://github.com/seldenlab/proc3dmesh), and are digitally-curated on the Open Science Framework (DOI: 10.17605/OSF.IO/H6YKX). Components of the curated project include the unprocessed 3D scan data (DOI: 10.17605/OSF.IO/QSKUZ), exported meshes (DOI: 10.17605/OSF.IO/HX2MT), and the code used for processing and analysis (DOI: 10.17605/OSF.IO/48BYA). This project is in active development, and it should be expected that code snippets and chunks will change until the manuscript is published.