Poster: An Application for Analyzing Stone Tool Artifacts

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ABSTRACT

This poster describes an application under development that supports quantitative analysis of 3D models of stone tools. The models are created from original artifacts by using a laser scanner. The application currently supports interactive labeling of flake scars on flint cores. We discuss our ideas for automatic labeling and future enhancements to the application.

1 INTRODUCTION

Analysis of stone tools and flint knapping techniques has been largely qualitative in nature. Recent advances in graphics and scanning technologies are enabling a more quantitative approach to studying these artifacts. A stone artifact can be placed on a turntable and scanned with a laser to create a 3D digital model. This model can be measured using software tools such as Rapidform [5]. Such tools, however, are not designed with anthropologist in mind, and many tasks may be difficult, tedious, or impossible. Our goal is to create a tool that enables the anthropologist to efficiently perform quantitative analysis of stone tools. The quantitative, objective measurements obtained from our tool will provide the basis of a broader study of prehistoric flintknapping behavior.

Our application will support analysis of two kinds of stone artifacts: *Flakes* are flat pieces of flint with a sharp edge that are used for cutting and scraping. They are created by chipping off of a larger stone called a *core*. Removing a flake leaves an indentation called a *flake scar*. Flake scars show a rippling pattern emanating from the point where the core was struck. The base of a flake has a bulge that fits into the deepest part of the ripple; this is called the *bulb of percussion*. Figure 1 shows a flake with the bulb of percussion visible. The pattern of flake scars gives some clue to how these tools were created in prehistoric times.

We identified several tasks and questions that should be supported by our application:

1. Label, possibly automatically, flake scars with the point and direction of impact.
2. Identify the plane of the surface where impact occurred.
3. Perform quantitative analysis of flake scar angles.
4. Measure the volume of the bulb of percussion.
5. Measure the area of the surface that is *cortex* (the unworked surface of the stone).
6. Create drawings for publication.

Figure 1. A 3D model of a flake. The bulb of percussion is visible on the upper surface on the left end of the model.

As of this writing, the application supports interactive labeling of flake scars and performing quantitative analysis of the scar pattern as described in Clarkson et al. [2]. We have had limited success at identifying and labeling flake scars automatically.

2 RELATED WORK

We are not aware of previous efforts to create software for analyzing stone tools. The anthropologist author of this poster currently uses Rapidform [5] to take measurements of stone tool laser scans, but this software does not support very well the tasks listed in the previous section. Clarkson et al. [2] suggest a way to quantitatively describe the pattern of scars on a core. Our software implements their technique

3 IMPLEMENTATION

3.1 Interactive Labeling

Rapidform is used to align the laser scans and export a model that our application can load and render. The user can then rotate and translate the model using the mouse. The user can create arrow labels of flake scars by pressing a key to enter editing mode. The user then left clicks at the point of impact for the flake scar, drags the mouse in the direction the flake was struck, and then releases at the opposite edge of the scar. The label is transformed from 2D screen space to 3D model space by casting a ray from the camera through the endpoints of the arrow in the image plane and finding where the ray intersects with the model. An arrow glyph is painted onto the model by projecting the vertices of the model onto the plane of the arrow and coloring those vertices that fall within the bounds of the glyph. A similar approach could be used to assign

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coordinates for texture mapping a glyph. Figure 2 shows a core with labels applied.

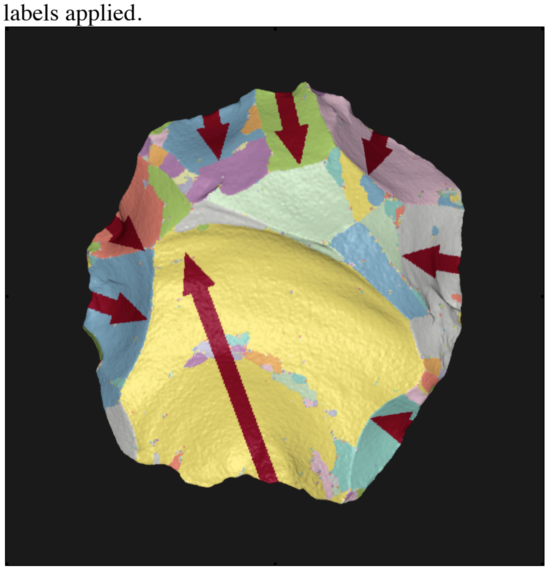

Figure 2. A core with labels that were interactively applied. Automatic segmentation is also illustrated, but this is not required for interactive labeling.

3.2 Automatic Labeling

Flint cores may have many flake scars, so to alleviate the tedium of labeling them, we have attempted to create an automatic labeling system. The first step in this process is to compute the curvatures and curvature directions of the surface. The next step is to identify the ridges. We use a modified version of the algorithm of Ohtake et al. [4]. Our modification extends ridges to form junctions more readily with other ridges. Figure 3 shows the maximum curvature and the ridges. Possible flake scars are identified by segmenting regions of low curvature. The algorithm connects contiguous sets of triangles that do not contain ridges. Color-coded flake scars can be seen in Figure 2.

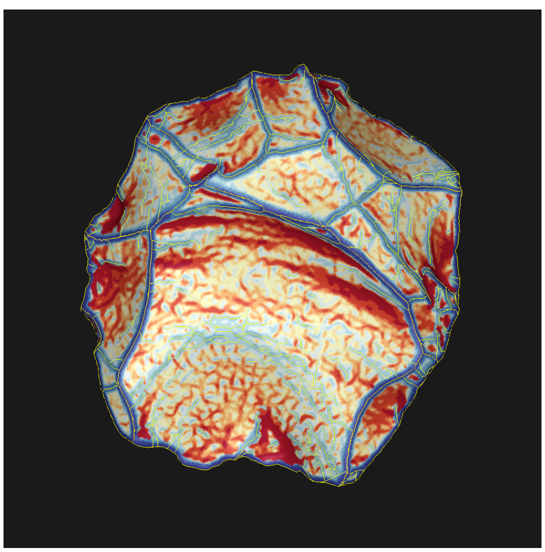

Figure 3. The maximum curvature of the surface rendered in a red-to-blue color scale. The ridges are highlighted in yellow.

Once the flake scars are identified, the next task is to identify the directions at which the flakes were struck off of the core. Since the previous steps generate hundreds of tiny regions in addition to a few large ones, the following steps are only run on the 20 largest regions. Our algorithm chooses 5000 points at random from a region and then fits a surface to it using non-linear optimization. The best surface we have found so far is created as follows:

1. Find the bounding sphere of the 5000 sample points.
2. Choose a diameter of the sphere.
3. Sweep a parabola along the diameter.

The sum of squared errors between the surface and the sample points is minimized by optimizing 5 parameters: two to determine which diameter of the sphere is used and three to describe the parabola. The diameter is used to label the direction at which the flake was struck. We determine which endpoint of the diameter is the strike point by computing, at each endpoint, a distance-weighted average of the sample points' curvatures. Based on our observations of flint cores, we assume that the flake was struck off at the more sharply curved edge. The algorithm frequently mislabels scars, but these labels may be interactively edited or deleted just as user-applied labels can.

4 Summary and Future Work

Our contributions include a prototype tool for labeling and analyzing flake scars on flint cores, and lessons learned in automatically identifying flake scars with software. Future work will include increasing the software's usability through expanding the feature set and exploring new interactions. Many of the tasks mentioned in the introduction remain unimplemented. We also need to improve the surface feature detection and give the user more flexibility in placing and editing annotations. Flake scar identification may be improved by using a function that more closely matches the shape of typical scars and may be based on a physical understanding of how flint fractures. For example, we know that a pattern of concentric ripples forms around the point of impact. An interesting future direction is to explore techniques that combine user interaction with automated analysis, since perfect identification of surface features is unlikely. For example, a "magic wand" tool could allow the user to guide the ridge-detecting algorithm to the regions of interest.

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