Photogrammetric Potsherd Profiling

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Abstract

An archaeologist lamented the fact that students having any interest in programming typically go off to study computer science. At the same time, students who are fully committed to archaeology have neither the interest nor the capacity to develop the types of computational tools that would speed up the tedious, repetetive aspects of archaeological practice. Perhaps specialists, in collaboration with generalists, can accomplish more together than either could accomplish alone. For example, imagine how useful it would be to leverage recent advances in photogrammetry and machine learning for the purpose of more quickly and accurately measuring a batch of objects and arranging them into a provisional hierarchy. This article describes a simple method for photographing pottery vessels and for turning those photographs into 3-D models, from which we derive characteristic measurements that will be useful in the evaluation of object similarity, and, ultimately, classification. The example includes fully-annotated **R** code for manipulating the modeled object in space, obtaining cross-sections, and calculating characteristic quantities. Subsequent articles will describe how to quantify similarity between objects, present a principled method for determining feature importance, and suggest an iterative process for generating provisional archetypes and resolving any resulting mis-classifications.

1. Related Work

Photogrammetry Using Photoscan[1]

Björn K. Nilssen[2] combines photography with minimal manual modeling to create 3D models from of very large objects, such as sculptures and buildings. The Poor Man's Guide To Photogrammetry[3] illustrates in great detail the modeling of small objects.

[1] Photoscan is available at (http://www.agisoft.com)

[2] SketchUp with PhotoScan plugin (http://bknilssen.no/X/Photogrammetry/)

[3] Poor Man's Guide (http://bertrand-benoit.com/blog/the-poor-mans-guide-to-photogrammetry/)

Open Source Photogrammetry

For more control over the modeling process, the artist, Gleb Alexandrov, presents a photo scanning workflow based on open source projects VisualSFM[4], Meshlab[5], and Blender.[6]

[4] Visual Structure From Motion, by Changchang Wu(http://ccwu.me/vsfm/)

[5] Meshlab, the open source system for processing and editing 3D triangular meshes (http://www.meshlab.net)

[6] Blender, an open source 3D creation suite (https://www.blender.org)

Photogrammetry for Archeology

The nonprofic corporation, chi[7], demonstrates photogrammetry in the field of cultural heritage. The Archaeology Data Service at University of York has published a number of Guides to Good Practice, including Close-Range Photogrammetry: A Guide to Good Practice.[8] Potsherd: Atlas of Roman Pottery[9] recommends CCD flatbed scanning for small, flat objects.

[7] Cultural Heritage Imaging

[8] Guides to Good Practice (http://guides.archaeologydataservice.ac.uk/g2gp/Phot 1)

[9] `http://potsherd.net/atlas`, P A Tyers, Sherd Scanning Advice (http://potsherd.net/atlas/topics/scanning)

Machine Learning for Archeology

A group of German researchers[10] describe how, using measurements obtained from a 3D-scanner, they have classified nearly 600 clay vessels from a Bronze-Age site in Saxony. Beginning with a pair-wise analysis of morphological features, they explain how to assess similarity between pairs of artifacts, and then find clusters of similar items. In the second phase, they develop a rational approach to calculating feature importance. Then they alternate between describing archetypes and classifying the artifacts using those preliminary definitions, adjusting the typology until the complete hierarchy emerges.

[10] Hörr, Lindinger, and Brunnett, in **Machine Learning Based Typology Development in Archaeology**

2. Photography

You will need:

- One or more potsherds to measure
- Location with plenty of natural light. See photography guidelines
- Work table
- Camera
- Tripod
- Turntable
- Dark background

Prepare the photography area as follows:

- Put dark paper or cloth under and behind the turntable to serve as a backdrop
- Adjust the height of the camera on the tripod so the center of the lense is at the same height as the center of the artifact to be photographed

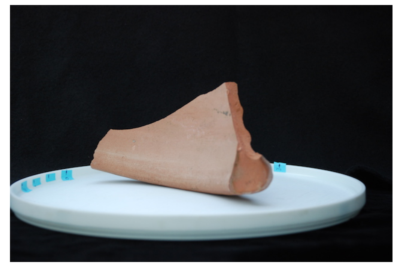


Figure 1: Using a Turntable

Photograph each artifact

- Place the pot (or potsherd) on the turntable.
- Even though the accompanying photo does not illustrate this, prop the artifact so that the rim of the pot is parallel to the turntable (Rim up or rim down is not so important)

- To minimize distortion, place the artifact so that the center of the rim (or base) is approximately on the center of the turntable
- Take a series of photographs at roughly 10-degree intervals, resulting in 36 images per artifact


Figure 2: Every Ten Degrees

3. Model Creation

image files –> textured mesh –> stereolithography

THE BASIC WORKFLOW is: (1) Take photographs from various perspectives, (2) Convert the photographs into a 3-Dimensional model, and, (3) since the model arrives as a textured mesh, convert it to stereolithography

Image Files –> Textured Mesh

- Upload images to ARC3D[11] web service

- Pour yourself a cup of coffee
- In a few minutes to a few hours, if all goes well, ARC3D will send you a textured mesh object

[11] If you are not already an ARC3D user, apply for a free account at `https://homes.esat.kuleuven.be/~visit3d/webservice/v2/request_login.php`

Textured Mesh –> Stereolithography

Enter the following command into a terminal window:

```
./meshconv textured_mesh.obj -c stl -o stereolithograph
```

This tells the conversion utility[12] three things: #. the object to use as input: *textured_mesh.obj*, #. the action(s) to perform: convert to stereolithography format [**-c stl**], #. where to put the results: in a file called **-o stereolithograph[.stl]**

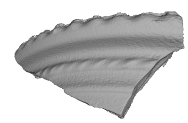


Figure 3: Textured Mesh Model

[12] The *meshconv* utility is available at (http://www.patrickmin.com/meshconv/)

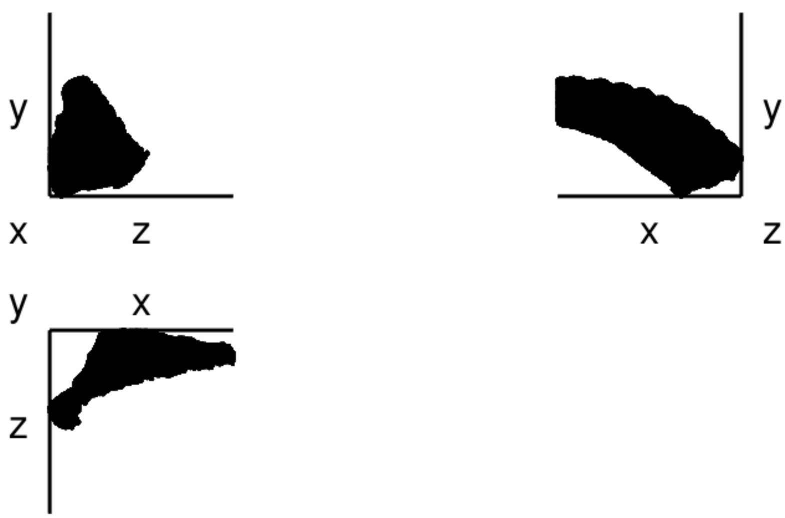
4. Cross-Sectioning

THE BASIC IDEA is to (1) find out which way is up, (2) orient the model squarely in the reference frame, (3) slice the model at various points between the base and rim, and, (4) slice the model from the perimeter toward the vertical axis of the vessel.

A. Model Orientation

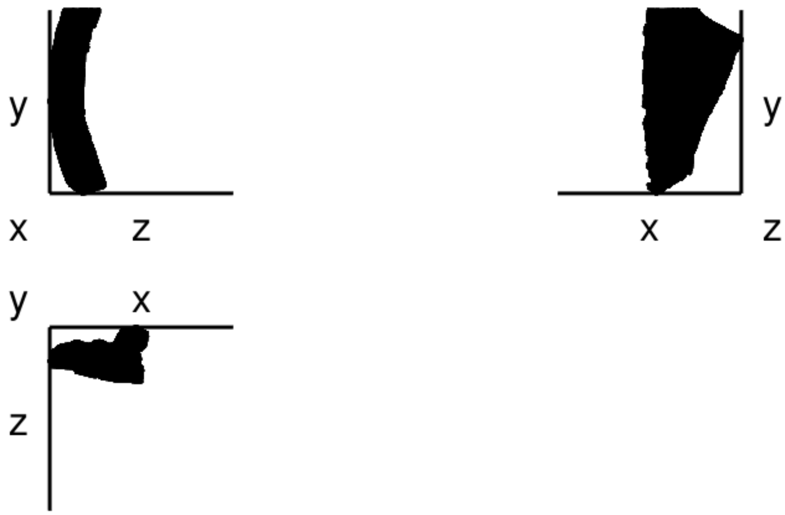
To find the best orientation for the model of the sherd, begin by measuring the extent of the model along each axis, and calculating the product of these dimensions. Then tilt the model slightly, recalculate the volume, and repeat until finding the minimum.

Initially, the object requires a box volume of at least 0.3653 units.



After repositioning the object, the box size is 0.1845 units.

```
multi_view( filenames_after )
```


y
x
z
y
x
z
y
x
z

B. Locate the Center of the Vessel

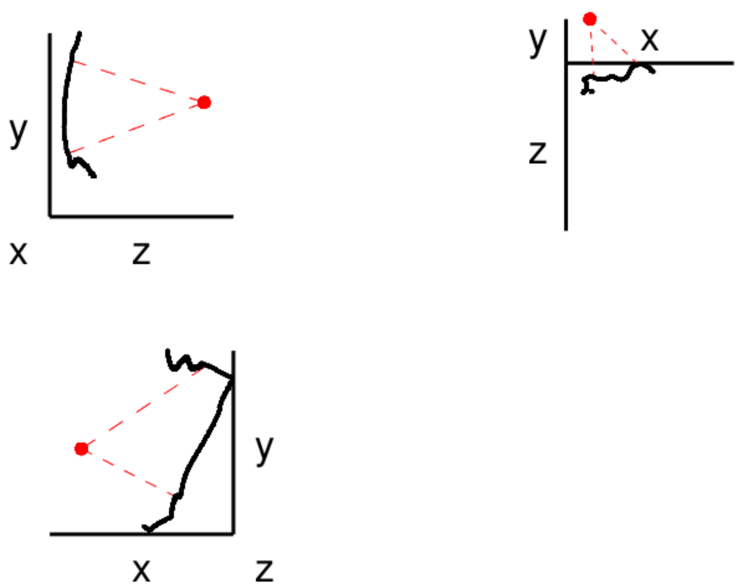
1. Extract a thin slice from the model, parallel with each axis
2. One of the resulting cross-sections should be roughly circular.
3. We will use this to estimate the center of the vessel and orientation of the axis of rotation

```
# Duplicate the model, once for each axis
models <- list()
models <- map( 1:3, ~make_model( model$get() ))

# Slice through the middle three ways
# (once in each model)
mids <- model$calculate( f = get_midpoint )
walk( 1:3, ~models[[ . ]]$get_band( ax=., ctr = mids[ . ], thickness = 4*STRIPE_WIDTH ))
```

- With estimated centers

```
multi_view(                          # Show the three slices with estimated centers
  list( 'slice_x', 'slice_y', 'slice_z' )
)
```



C. Profile

1. a numbered item
2. another numbered item

- a bullet-item
  - a sub-item
  - a sub-item

5. *Measurement*