3D Scanning for Profile Acquisition and Reconstruction of Mayan Ceramics

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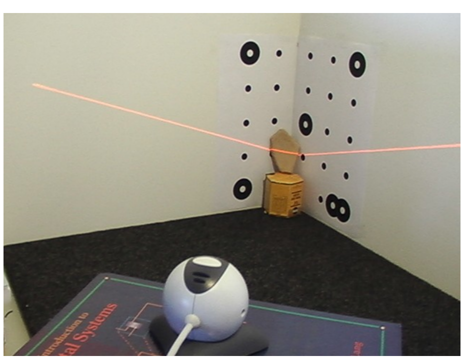
Ceramics are a staple for archaeological investigation, providing insight into a culture's religious practices, relationships with other communities, and daily life, to name just a few. Intact pots are a rare find in excavations, but ceramic fragments, known as “sherds”, are common and anything from their position and orientation in the ground to their physical composition can offer information about the societies from which they come.

There is a particular project being conducted in a region that runs from Tikal, Guatemala to the Belize River Valley in which ceramic sherds are used to study the shift of economic and trade structures in the Late to Terminal Classic period in Mayan history. Archaeologists are finding commonalities in the shape of Late Classic ceramics across this broad region, suggesting that the pottery was produced in one place and then widely distributed. Once these trade networks began to break down, individual communities had to produce their own pots introducing more variability in the Terminal Classic period.

Example of hand-drawn profile

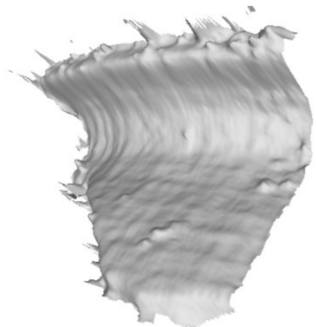
The form of a ceramic sherd is described by its radius of curvature at the rim and its vertical profile. Traditionally, only fragments that contain an original rim or base edge, referred to as “diagnostics”, are considered useful to the archaeologist. The methods used to determine these features are somewhat coarse: a circular gauge of known dimension is used to estimate roughly the diameter of the sherd. Then the rim or base is held against a flat surface in order to determine its orientation and the profile is visually inspected and drawn by hand. A perfectly vertical broken edge will resemble the desired profile – but this is rarely the case. A jagged break distorts the profile, making the previous experience and skill of the archaeologist a prominent factor in the accuracy of the recorded data.



Low budget 3D scanner using webcam and line laser running free software on a windows-based PC

Not surprisingly, computer based systems have a lot to offer in this field. A simple model created from a 3D scan of a ceramic sherd could at the very least provide a way for any computer-literate user to extract an accurate profile. The scanning process takes between ten and twenty minutes per sherd to get data sufficient for profile extraction, and this is comparable with the estimated time the traditional process takes to provide similar information with less accuracy (Melero, Leon, Contreras, & Torres 2003).

3D scanner software is available that allows the user to scan objects with any consumer level webcam and a line laser. This method gives decent results that, while noisy, could provide useful information about the general form of the sherd, but texture and composition information is obscured by artifacts from the scanning process. The cost of commercial 3D scanners have dropped by a factor of ten (to $2500) in recent years and are small enough to be practical in a mobile field lab. Furthermore, these scanners are packaged with software that automates most of the scanning process making it necessary only to set up each scan and initiate the procedure.

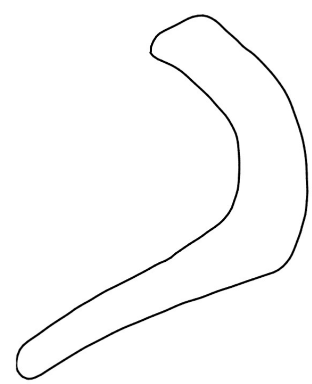


Scan from low budget system

Scan from commercial scanner with texture map

Thus far, this proposed process is only a modern version of the traditional method – it is still up to the archaeologist to determine the orientation of an intersecting plane relative to the sherd in 3D space when taking the profile line, and the 3D model alone doesn't offer a more effective way to measure rim diameter. Assuming the pot is rotationally symmetrical around a central axis, a set of points from the rim can be chosen to define a circle, which then defines the axis of rotation of the pot (a line perpendicular to the plane defined by the points on the rim, that passes through the center of curvature of the rim). The assumption that the pot is rotationally symmetrical is not necessarily safe to make – the pots from this particular region and time period in Belize were hand made without the use of a potter's wheel. Translating the horizontal plane defined by the rim downwards through the rest of the sherd model would provide other sets of points, (two sets for each plane, in fact: one for the inner surface and one for the outer), each of which approximate a circle, suggesting other axes parallel to that which was defined by the rim. These axes can be averaged together to obtain a more accurate approximation of the actual central axis of rotation.

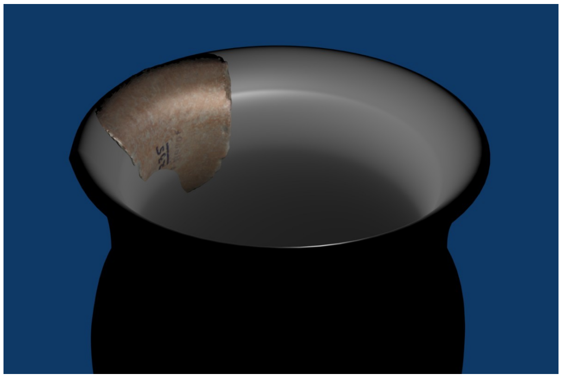
This method orients the axis to the plane defined by the rim of the pot and is thus assuming that this plane is parallel with the XZ plane. The traditional method makes the same assumption by placing the rim against a flat horizontal surface to determine the vertical orientation, so the profile data that results is sufficient for traditional analysis. A more accurate axis orientation, however, would improve a 3D reconstruction of an entire pot and this orientation can be refined by adjusting the orientation of the intersecting plane used to select the circular sets of points.



Vertical profile from intersection of a plane and sherd model

To describe this process, lets arbitrarily position the sherd model in 3D cartesian space so that the sherd is upright, the axis of rotational symmetry lies along the y-axis, and lastly where the projection of the model onto the XY plane has the least area (placing the XY plane approximately in the middle of the sherd and perpendicular to the curve of the surface). As explained before, a horizontal plane intersecting the model will define two sets of points (one inner, one outer) to which we will fit a circle. This plane must be properly oriented in two dimensions; first the rotation is adjusted about a line in the plane that is parallel with the x-axis to maximize the symmetry of the data across this line. Next the plane is rotated about a line in the plane that is parallel with the z-axis until the data best fits a circle. The best fit line through the centers of several circles found with this method will more accurately approximate the central axis of the original pot than the original axis found using the radius of curvature defined only by points along the rim. A profile is formed by the intersection of the sherd with any plane containing this central axis, and multiple profiles can be compared from the same sherd to give information regarding the variability of shape and wall thickness.

3D modeling software such as the open source program Blender can easily be used to recreate a portion of the original pot by rotating the profile around a the same axis previously used to define the intersecting plane thus creating a toroidal surface with the same height as the original sherd model. Furthermore, a database of complete pot profiles and mathematical models of these profile curves would allow for computer-aided classification of unidentified sherds. It is also conceivable that non-diagnostic, "body" sherds from the midsections of pots could be identified using a similar method as described above, grouping of both diagnostic and body sherds from pots of similar shape and size together thus aiding in the physical reconstruction of vessels.



3D reconstruction using manually obtained profile from sherd model

As it stands, this project has explored the potential of different scanning systems and obtained more objective results using new computer based methods than traditional methods can offer. We've proposed steps to be taken towards further reducing subjectivity involved using these new methods. Finally, we've suggested ways in which the identification and analysis process normally left up to the archaeologist could be aided by a computer providing objective, quantified data.

References:

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