College of Engineering

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Department of Electrical and Computer Engineering

Reconstructing Broken Vessels Using Border Anchor Points

Zexi Liu, Fernand Cohen, and Ezgi Taslidere
Department of Electrical & Computer Engineering,
Drexel University, Philadelphia, PA, 19104

Introduction

The mending of unearthed archeological ceramic shards to reconstruct vessels that the fragments once formed is currently a tedious and time-consuming process. Nevertheless, it is a vital step in interpreting archeological records and an important component in understanding and preserving cultural heritage. This paper presents a method to assist in the tedious process of reconstructing ceramic vessels from excavated fragments.

Methods – Part I: Coarse Alignment

Our algorithm models the fragment borders as 3D curves and uses intrinsic differential anchor points on the curves [1] for mending. Corresponding anchors on different fragments are identified using absolute invariants and a longest string search technique [2]. A rigid transformation is computed from the corresponding anchors, allowing the fragments to be aligned and virtually mended.

Step 1: *3D scanning*

Step 2: *Extract boundary curve*

Step 3: *Extract anchor points & search for matching anchors*

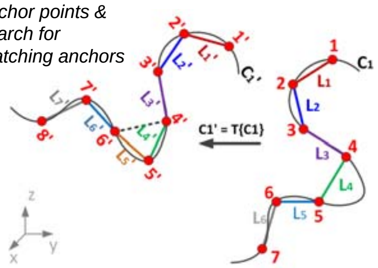
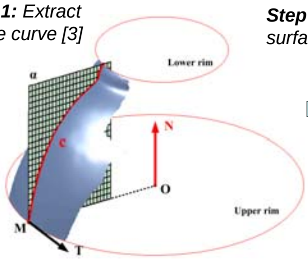


Figure 1: Absolute invariants with anchor points with some possibly missing. This algorithm will always find the longest matching string.

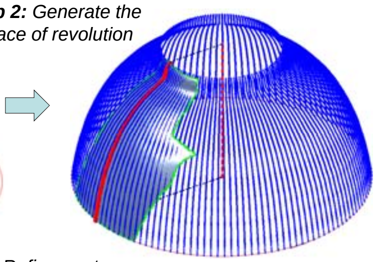
Methods – Part II: Refine Alignment

A global constraint induced by the surface of revolution (basis shape) to decide on how all pairs of mended fragments are coming together as one global mended vessel is used. The accuracy of the mending is measured using the distance error map metric between the surface of revolution and the mended pieces.

Step 1: *Extract profile curve [3]*



Step 2: *Generate the surface of revolution*



Step 3: *Refinement based on the surface of revolution*

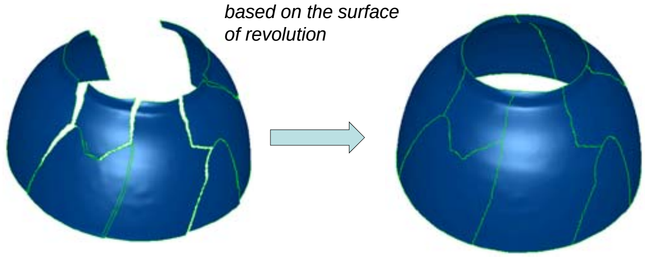


Figure 2: Global Optimization.

An example of combining Part I and Part II:

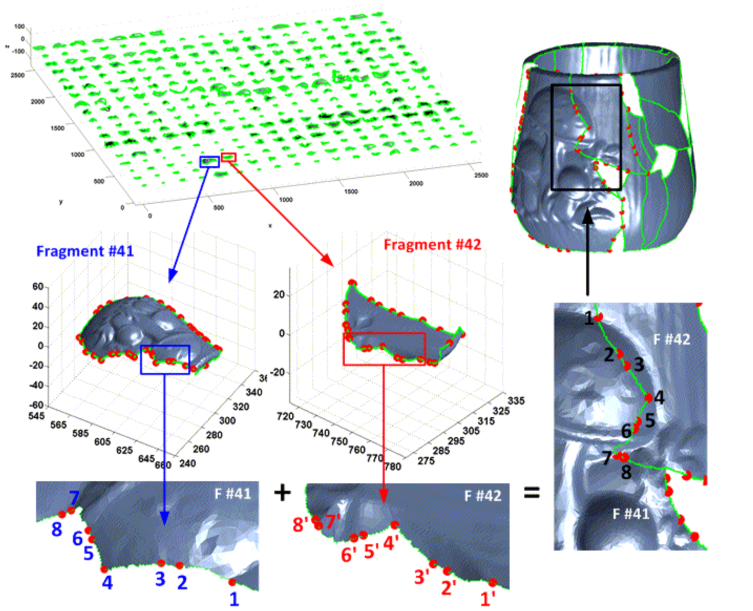


Figure 2: Fragment mending based on anchor points (red dots).

Results

The method is tested on a set of 3D scanned fragments (313 pieces) coming from 19 broken vessels. 80% of the pieces were properly mended and resulted into alignment error at or below the scanner-resolution-level. The method took 59 seconds for mending the pieces plus 60 minutes for 3D scans. This is to be compared to 12 hours for manual expert stitching.

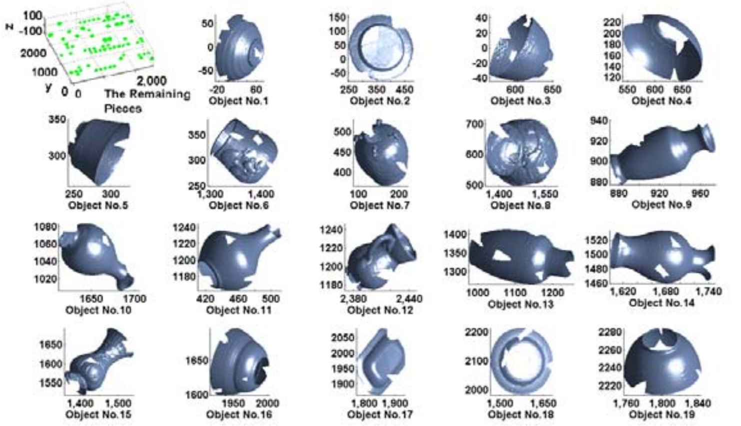


Figure 4: Mended objects.

Conclusions

We present a methodology to mend fragments into vessels based on anchor points on fragment borders. The work has focused on the use of one aspect (fragments borders) amongst many embedded in the fragments. This aspect, in conjunction with many others such as markings, texture, or surface information, could be collectively used as enabling technology to help in the mending process. This is particularly important if anchor points are absent due to complete erosion of the fragments borders on abutting fragments, which would limit the success of such a method. This work is considered as a great need by the U.S. Department of the Interior National Park Service.

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References

[1] Kühnel, W. 2006. *Differential geometry : curves - surfaces - manifolds*. Providence, R.I., American Mathematical Society.
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[3] Willis, A., X. Orriols, et al. 2003. Accurately Estimating Shard 3D Surface Geometry with Application to Pot Reconstruction. CVPR Workshop: ACVA. Madison, WI, USA, IEEE Computer Society.