Terracotta Reassembly from Fragments Based on Surface Ornamentation Adjacency Constraints

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Introduction

In the area of computer graphics and computer-aided design, fragments assembling provides a popular manner for reassembly of fractured objects [HFG*06]. It analyzes the geometry of the fracture surfaces or break-curves to find a globally consistent reconstruction of the original object. A heretofore unsolved problem of great archaeological importance is the automatic reassembly of Terracotta made by humans from the fragments found at an excavation site. The traditional techniques for reassembly of 3D objects will always fail due to the incompleteness of the fracture surfaces and break-curves.

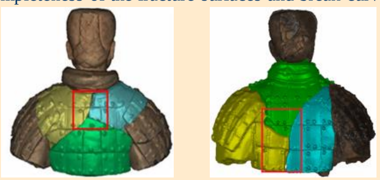
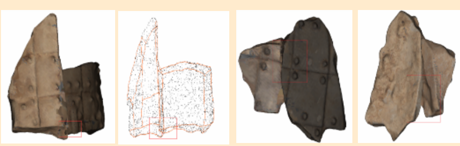


Figure 1. Example of reassembly of the Terracotta. Fragments both have diverse levels of incompleteness in fracture surfaces.

The difference of our work is that fragments can be registered according to the surface ornamentation information – the structured feature lines, which are often complete and can provide enough surface adjacency constraints, and are also the clues used by archaeological expertise.

Previous work

Methods based on the break-curve matching [UT99] or based on the fractured surface matching [HFG*06] both fail to handle the fragments with diverse levels of incompleteness in fracture surfaces or break-curves. Although sometimes the geometry-driven reassembly method described in [MRS10] may handle this case, it is semi-automatic.



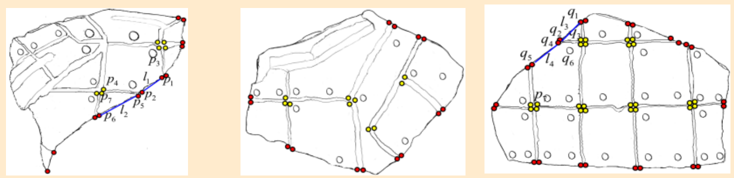
(a) (b) (c) (d)

Figure 2. Limitations of previous work. (a) Fragments with incompleteness. (b) Results based on contours. (c) Results based on fracture surfaces. (d) Results based on inner surfaces.

Our Method

The surface ornamentation information is a set of structured feature lines that have similar properties with structured texture: locality, periodicity and the repeatability. Furthermore, the minimum structure is similar to a rectangle. We thereby use the structure information of the feature lines and the completeness of the rectangles to search matching pairs of fragments.

- Given a set of point clouds of fragments of Terracotta, the method first extracts the feature lines on the original surfaces, and thereby the structured information is represented by some typical vertices, red points and yellow points as shown in Figure 3. Red points are utilized for matching, namely matching points, whereas yellow points are utilized for representing the local features of the matching points.



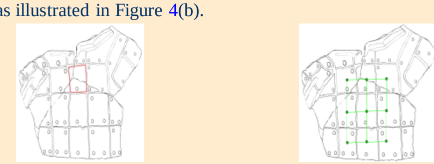
(a) (b) (c)

Figure 3. Feature lines and typical vertices.

- The neighbors of a matching point consist of a red point that is nearest to the matching point and a yellow point that connected with the matching point. Then a chord is form by two successive points along the contours, however, the two points should not be neighboring of each other, as shown in Figure 3. For example, the neighbors of p_5 are p_2 and p_7 ; chord l_1 is formed by p_1 and p_2 . Chord l_1 is a short chord since the yellow neighboring points of p_2 and p_1 are different (p_3 and p_4 respectively), whereas chord l_2 is a long chord since the yellow neighboring points of p_5 and p_6 are the same (p_7).
- For a given fragment, each chord is matched with chords on other fragments. The error criterion is an energy function (Equ. 1), which qualifies the structure of the feature lines. p, q are the matching points, N represents the adjacency constraint. f is the matching function formed by the features of the chord, including long or short, length of the chord and the direction of the chord. D is the errors of the completeness of the new rectangle, as shown in Figure 4(a).

$$E(f)=\sum_{\{p,q\}\in N} V_{p,q}(f_p,f_q)+\sum_{\{p,q\}\in N} D_{p,q}(f_p) \quad (1)$$

- It does occur in practice that an incorrect match may have a smaller match-error than will a correct match. Incorrect matches may be quickly identified via two methods: 1) by validating the completeness of reassembled rectangle, as illustrated in Figure 4(a); or 2) by validating the continuity of the structure, as illustrated in Figure 4(b).



(a) (b)

Figure 4. Incorrect matching detection.

- When matching fragments are detected, ICP method is utilized to complete the local registration. After constrained local registration we used merge the fragments of each sub-fragment into a single 'virtual' fragment for further global matching.

Results and Future work

We have used several examples to test our reassembly algorithm. The input point clouds of Terracotta were scanned by Creaform VIU handy scanner. Our goal is to find pairs of fragments with incompleteness in break – curves or fractured surfaces. Therefore we performed 6 sets of reassembly results as follows.

We will engage in matching the fragments on shoulders that have total different structured feature lines in our next work.

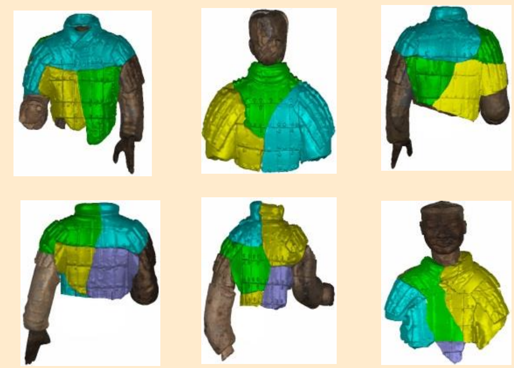


Figure 5. Results of reassembly of Terracotta.

Contributions

- Enables the reassembly of fragments with incompleteness in fracture surfaces and break-curves.
- Presence of a reassembly method of fragmented objects based on structured feature lines, instead of geometry driven.
- Using the features of neighbors of matching points decreases the computational costs.

Acknowledgments

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References

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