Digitization and Reconstruction of Archaeological Artifacts

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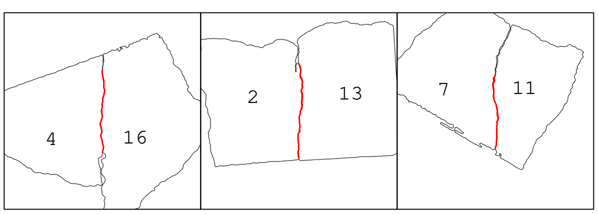
Abstract. We describe an ongoing research project on efficient methods for reconstruction of objects from large collections of irregular fragments, such as ancient pottery, collapsed murals, etc.. Our solution for flat objects uses multiscale matching and constrained dynamic programming, and we are now extending it to curved pottery fragments. We seek collaborative projects with museums and other potential users.

1. The fragment reassembly problem. Our project aims at developing efficient algorithms that can find adjoining pieces in a large collection of irregular fragments, by comparing their shapes. Besides archaeology, we expect these algorithms will be useful in art restoration, failure analysis, and other areas.

For flat objects, the data typically consists of $\approx 10^4$–10^5 irregular fragment outlines, each defined by $\approx 10^3$ sample points. The goal is to find any pairs of curves that have long sections with similar shapes — as similar as expected from adjacent fragments of the same object:



2. Information contents. One basic question is whether there is enough data to solve the problem. By statistical analysis of the fragment shapes, we can determine how much information a given length of one outline gives about the shape of the matching section of the other outline. In one test with fractured ceramic, we measured 18 bits of useful information per centimeter [1] — so even large instances of the problem seem solvable in principle.

3. Multi-scale curve matching. Our outline-matching algorithm is based on multi-scale comparison of the curvature graphs [2]. After filtering and resampling the fragment outlines at many different scales of detail, we look for promising candidates (pairs of similar outline fragments) at the coarsest possible scale, where each outline has been reduced to a few tens of samples. We then repeatedly select the most promising pairs, and recompute their optimum fit at the next finer scale of detail. The optimum fit between two outline segments is found with an optimized dynamic programming algorithm, which only looks for solution similar to the best fit found at the previous scale. In the end, we are left with a small set of fragment pairs that are most likely to be adjacent in the original objects.

4. Experimental validation. Our methods were tested on a collection of 112 ceramic tile fragments. In a typical run, out of 6000+ potential pairs of fragments, our programs selected 60 pairs, of which 46 were indeed adjacent in the original tiles.

5. Ongoing research. We are extending our tools to handle curved pottery fragments. For that, we need to compute the tangent plane at each point along the fracture line, by stereo vision techniques, in order to obtain the true (view-independent) curvature of the outline at that point.

6. Call for collaboration. We seek collaboration with potential users, especially archaeological museums who own extensive collections of pottery fragments. A possible joint project would be the preparation of a digital database of their ceramic holdings, imaged with fairly high resolution (several pixels per millimeter) — both to use as a test database for our tools, and as a valuable resource for archaeologists, historians, and museum curators.

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References

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[2] H. C. G. Leitão and J. Stolfi. A multi-scale method for the re-assembly of fragmented objects. In *Proc. British Machine Vision Conference - BMVC 2000*, volume 2, pages 705–714, Sept. 2000.