Automatically Assembling Frescos from Noisy Pairwise Fragment Measurements

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(Extended Abstract)

Combining fragments of shattered artefacts together manually is an extremely difficult task for archaeologists. There could be many fragments that go to one artefact, and some could be missing. The artefact fragments are themselves fragile or difficult to handle. Then, some fragments could have deteriorated , and it is not clear whether two fragments should go together in the final puzzle. Finally, with a large number of fragments, there are simply too many combinations to test, especially without an automated system. Based on the above, it is reasonable to use computational methods correctly piece fragments together.

Most previous methods that can reconstruct the entire fresco rely on hierarchical clustering (e.g. [Castaneda 11]). In this technique, a best-first approach iteratively merges pairs of clusters. Global relaxation needs to be applied to resulting clusters in order to find the best transformations to align fragments within clusters. Global relaxation uses least squares (LS) method to find the best rotations and translations for fragments in a cluster. However, if a portion of the matches from a cluster are incorrect, least squares should not be used because the objective function becomes dominated by squared residuals [Singer 11]. A more robust method of finding optimal rotations and translations within the cluster should thus be used.

Our goal is to produce a set of globally consistent transformations given noisy pairwise fragment matches. We present a method based on [Singer 2011], which separates the problem into a first stage that uses an Eigenvalue method to solve for rotations followed by a second stage that uses multilinear robust regression to solve for translations. The advantage of this approach is that a globally optimal set of rotations can be found by solving a convex optimization. It also can be applied iteratively by culling outlier matches according to how consistent they are with computed fragment rotations.

We test the rotation search algorithm on a set of 114 fragments which were obtained from a fresco created and shattered to test reconstruction techniques. A ground truth of 239 correct matches is available for this fresco. To test our algorithm, we add subsets of high scoring wrong matches obtained from [Funkhouser 11], and compare the resulting angles to manually created ground truth. When 30% of the matches are incorrect, least squares can recover at most 35% of angles within margin of error pi/16, while our method recovers more than 70%.

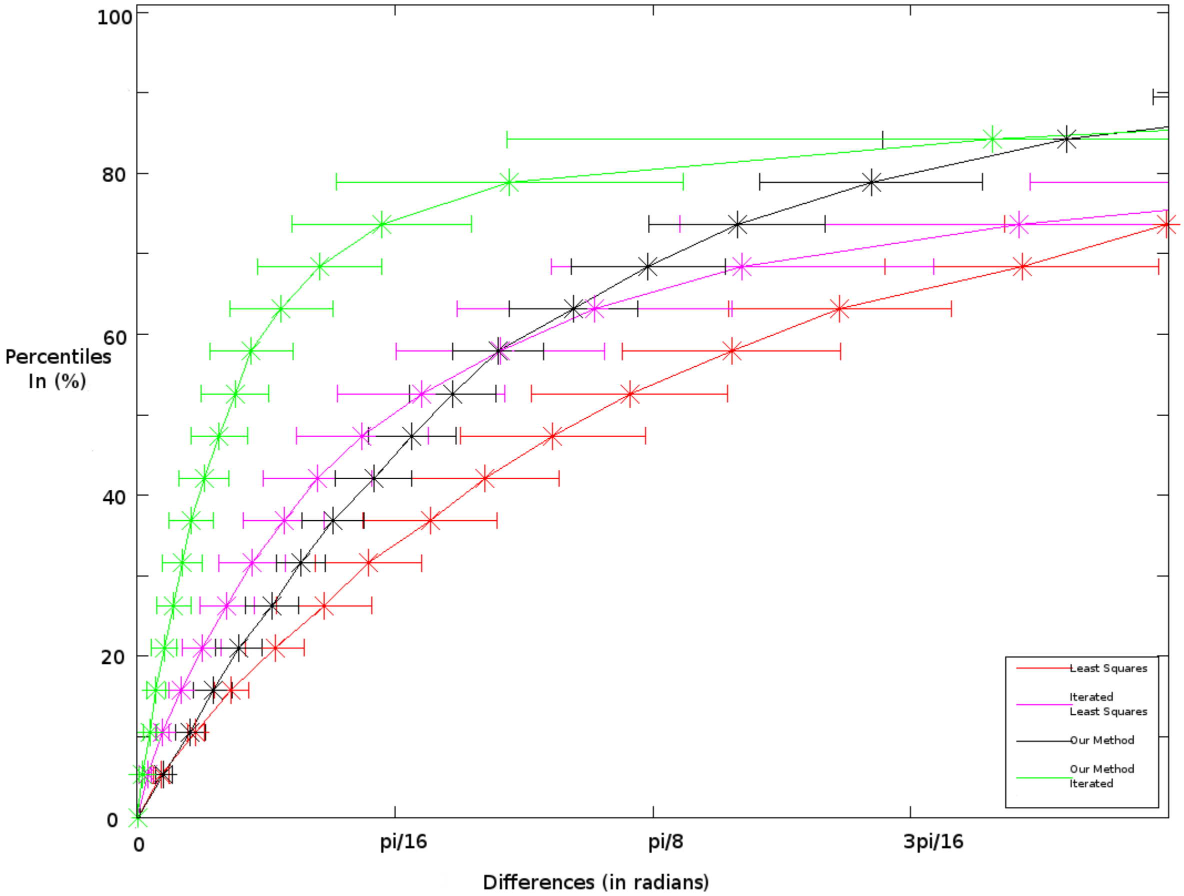

Figure 1: Percentiles of angular error achieved during a run of the methods with 114 fragments, 339 matches of which 239 are correct. The results are aggregated over 10 runs on different 100 wrong matches added. The stars are the mean percentiles of the given error, and the horizontal lines represent standard deviation. Least squares (LS), performs poorly compared to other proposed methods. The method we propose, known as normalized eigenvector method (nEVM in the plot), finds more than 65% of the fragment angles within margin of error of pi/8. Even better results are obtained when the methods (LS and nEVM) are iterated.

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