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Sphere-based cut construction for planar parameterizations

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ABSTRACT

We present a novel algorithm to compute high-quality cuts for generating low isometric distortion planar parameterizations. Based on the observation that conformal spherical and planar parameterizations have similar distortion distributions at the extrusive areas that lead to high isometric distortions, our method utilizes a spherical parameterization of the input mesh to guide the cut construction. After parameterizing the input mesh onto a sphere as conformal as possible, a hierarchical clustering of the divisive type is conducted on the sphere to find high isometric distortion regions, where high isometric distortion may also be introduced in the planar parameterization and which are connected to define a cut. Compared with previous methods, this approach can generate better cuts, resulting in lower isometric distortions. We demonstrate the efficacy and practical robustness of our method on a data set of over 5000 meshes, which are parameterized with low isometric distortion by two existing parameterization approaches.

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1. Introduction

Computing inversion-free planar parameterizations with low isometric distortion is fundamental in many computer graphics and geometry processing applications, such as texture mapping [2,3], remeshing [4,5] and inter-surface mapping [6,7]. The low isometric distortion property requires that the parameterized mesh should preserve isometry to its original shape as much as possible.

Since good cuts are able to improve the quality of parameterizations, while inappropriate cuts tend to introduce unacceptable effects, cutting closed triangular meshes to disk topology is an important procedure for generating low distortion parameterizations. In the context of this paper, a cut is considered to be *good* when it satisfies the following requirements as much as possible: (1) the resulting parameterizations contain low isometric distortions; (2) the cuts are feature-aligned, which implies visual beauty in terms of high-quality texturing; (3) the cuts are short.

Many attempts have been proposed to construct cuts in a way that satisfies above requirements. Gaussian curvature [8,9] is often used to detect the potential regions that are connected via a minimal spanning tree (MST) to define the resulting cuts. Since these curvature-based methods do not consider the distortion directly, they may ignore some regions with low average Gaussian curvature but small neighborhoods where the curvature is locally high, which introduces high isometric distortion. Gu et al. [10] iteratively parameterize the surface to the plane and find the shortest cut from the vertex with maximal distortion to the boundary. This alternate algorithm stops if the parameterization distortion increases or the maximal distortion appears on the boundary. However, they may also ignore some interior high-distortion regions, since the highest distortion appears on the existing cut in the last iteration (see the comparison in Fig. 15). Recently, Poranne et al. [3] proposed a method to simultaneously optimize cut length and distortion. However, their cuts require additional user manipulations to be finalized and are often not feature-aligned (see the comparison in Fig. 16).

In this paper, we propose a sphere-based cut construction method to automatically compute high-quality cuts for the purpose of generating low isometric distortion planar parameterizations. Our idea comes from a simple fact that the high isometric distortion mainly appears at the extrusive regions when a mesh is parameterized onto a constant curvature domain (e.g. a sphere or plane) as conformal as possible. In other words, the high isometric distortion regions from an as-conformal-as-possible spherical parameterization are also the places that may cause high isometric distortion in the planar parameterization. Therefore, we first parameterize an input mesh onto a sphere as conformal as possible, then use a divisive hierarchical clustering algorithm to detect high isometric distortion regions, and finally connect these regions by constructing the MST on that sphere and map back to the input mesh to determine the cut. The MST construction on the sphere results in a good balance between the feature-aligned and short requirements of the good cuts. This is our default choice in our experiments. Besides, we also provide another choice for users to construct cuts. If users want shorter cuts and do not care about

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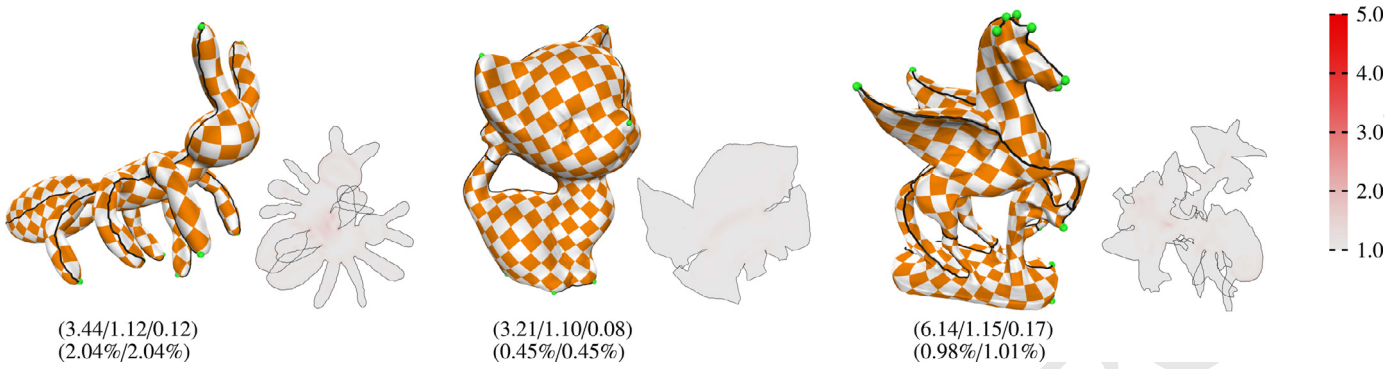

Fig. 1. Planar parameterizations of three models. Our constructed cuts are shown by black lines, and the feature points of our clustered regions are shown by green points. The parameterizations are generated by AQP [1]. The isometric distortion metric (which is defined in Section 4) of each triangle is colored with white being optimal, and the models are textured by a checkerboard image. The first line of the text below each mesh indicates the maximum, average and standard deviation of the isometric distortion over all triangles, and the second line indicates the proportions of edge number and edge length of the cut. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

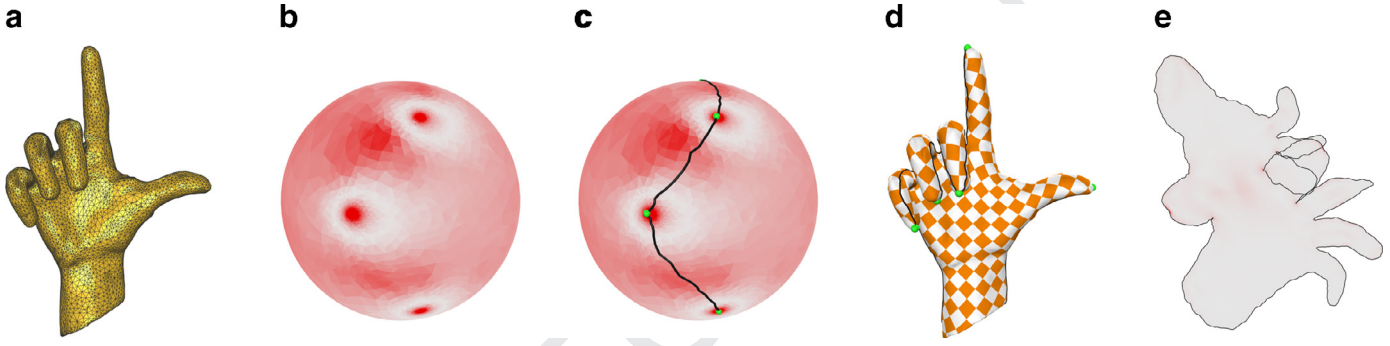

Fig. 2. The pipeline of our method. From an input triangular mesh (a), we first compute an as-conformal-as-possible spherical parameterization (b), then find feature points and a cut path on the sphere (c), finally cut the mesh (d) and parameterize to the plane using AQP [1] (e).

the feature-aligned property (i.e., emphasizing requirement (3) and discarding (2)), they could connect the feature regions on the original meshes, which results in a slightly higher distortion but much shorter cuts (see the differences in Figs. 6, 14–16).

We demonstrate the efficacy of our method on a data set containing more than 5000 complex models, which are parameterized using SA [11] and AQP [1]. Fig. 1 shows planar parameterizations of three models. Compared with state-of-the-art methods, our method constructs better cuts and achieves lower isometric distortion with stronger practical robustness.

2. Related work

Cut construction. There have been many algorithms trying to find an optimal cut in order to parameterize a closed mesh to the plane with low isometric distortion. By using curvature information, some previous methods define a cut by detecting and connecting regions with high curvature [8,9,12,13], since these regions are often considered as the reason why high isometric distortion of a planar parameterization appears. However, since the curvature information does not directly reveal the distortion distribution, some important places may be ignored, which still causes a high isometric distortion parameterization. Gu et al. [10] alternately parameterize a surface mesh onto the plane and find the shortest path from the vertex with maximum distortion to the existing boundary. This alternating method directly uses a measure of distortion to guide the cut construction. However, since in the iterative process, the maximum distortion region may appear on the boundary, the algorithm will stop and some interior high distortion regions will be ignored. The Autocuts method [3] simultaneously optimizes the cut length and the isometric distortion. Some

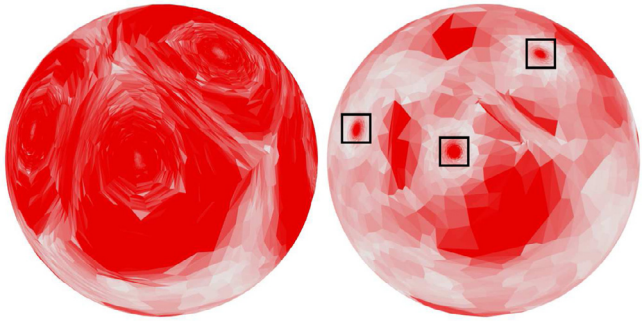

Fig. 3. Comparison between the spherical parameterizations of the Spider model (Fig. 12) using AIAP (a) and ACAP (b). Note that the clustering effect of the ACAP parameterization is more significant (black boxes in (b)) than the AIAP parameterization.

important parameters in their method should be adjusted by users to fine-tune the cut. Our method utilizes a sphere to automatically facilitate the cut construction, in which the isometric distortion is directly utilized to find a cut. We evaluate our constructed cuts via computing low isometric distortion parameterizations for more than 5000 meshes.

There have been many other methods that divide the an input mesh into multi-charts [2,14–18]. Although these methods can produce results with very low isometric distortion, the cut length is usually very long. Some applications, such as surface correspondence [6] and remeshing [4], prefer a short cut and a single chart.

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