To cut or to fill: a global optimization approach to topological simplification

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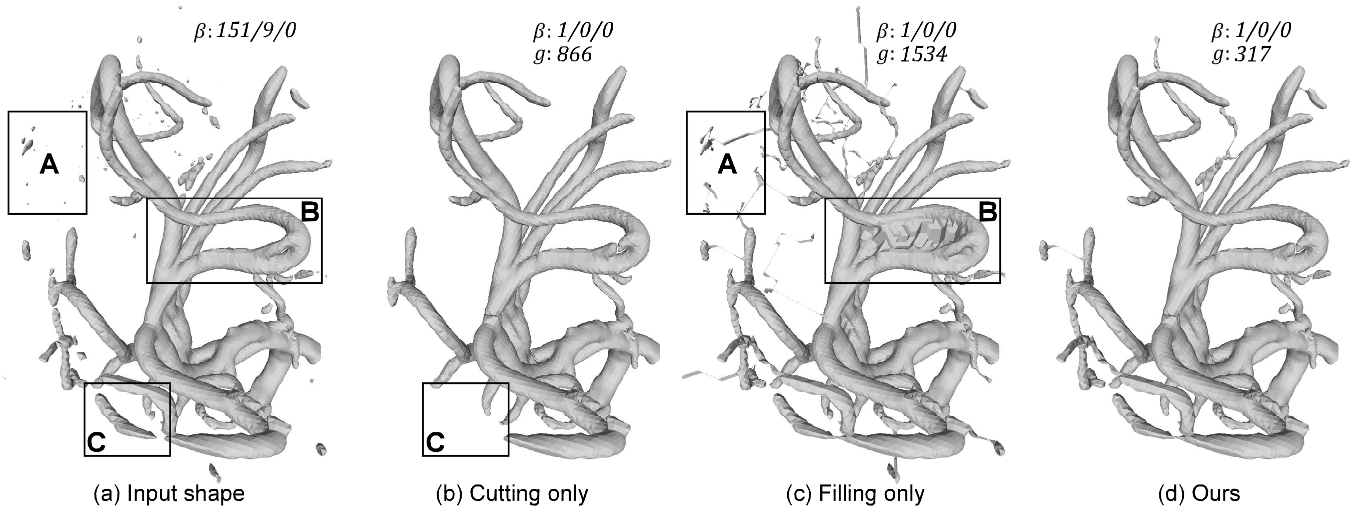

Fig. 1. To simplify the topology of a 3D shape (a), performing *cutting* alone (b) or *filling* alone (c) results in excessive changes, such as removing large components (box C in (b)), creating long bridges to distant islands (box A in (c)) and large patches to fill in a handle (box B in (c)). Given a set of pre-computed cuts and fills, our method optimally selects a subset of them to maximally simplify topology while minimizing the impact on the geometry (d). (β: number of connected components, handles, and cavities; g: geometric cost)

We present a novel algorithm for simplifying the topology of a 3D shape, which is characterized by the number of connected components, handles, and cavities. Existing methods either limit their modifications to be only cutting or only filling, or take a heuristic approach to decide where to cut or fill. We consider the problem of finding a globally optimal set of cuts and fills that achieve the simplest topology while minimizing geometric changes. We show that the problem can be formulated as graph labelling, and we solve it by a transformation to the Node-Weighted Steiner Tree problem. When tested on examples with varying levels of topological complexity, the algorithm shows notable improvement over existing simplification methods in both topological simplicity and geometric distortions.

CCS Concepts: • **Computing methodologies → Shape analysis**; **Volumetric models**.

Additional Key Words and Phrases: Topology simplification, graph labelling, Steiner tree, cell complexes, global optimization

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1 INTRODUCTION

Shapes reconstructed from raw data often include many topological features, such as connected components, topological handles, and cavities (i.e., voids inside the shape). While some of these features are intended, many could be artifacts of the reconstruction (e.g., Figure 1 (a)). Excessive amount of topological features can be detrimental to many geometry processing tasks, including parameterization, shape analysis, and physical simulations.

A topological feature can be removed either by *cutting* contents from the shape or *filling* the shape with new contents (see Figure 2). For example, a handle can be removed by cutting open the handle body or filling in the handle hole. A connected component can be