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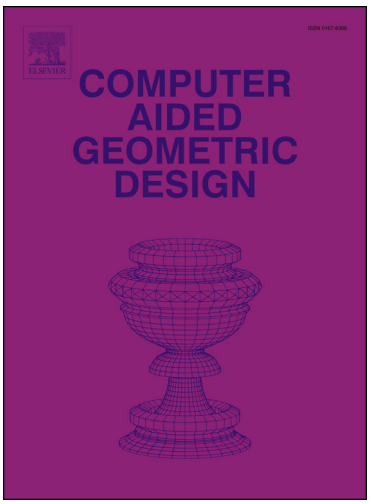

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Implicit Surface Reconstruction with Total Variation Regularization

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Abstract

Implicit representations have been widely used for surface reconstruction on account of their capability to describe shapes that exhibit complicated geometry and topology. However, extra zero-level sets or spurious sheets usually emerge in implicit algorithms and damage the reconstruction results. In this paper, we propose a reconstruction approach that involves the total variation (TV) of the implicit representation to minimize the occurrence of spurious sheets. Proof is given to show that the recovered shape has the simplest topology with respect to the input data. By using algebraic spline functions as the implicit representation, an efficient discretization is presented together with effective algorithms to solve it. Hierarchical structures with uniform subdivisions can be applied in the framework for fitting fine details. Numerical experiments demonstrate that our algorithm achieves high quality reconstruction results while reducing the existence of extra sheets.

Keywords: surface reconstruction, implicit representation, total variation, spurious sheets, level set

1. Introduction

Creating 3D digital representations of real world objects has been an attractive task with a wide range of applications in computer graphics and geometry processing. Many scanning techniques have been developed for data acquisition, such as laser-based range scanners, structured light scanners, multiview stereo camera systems, and depth cameras. When data are obtained from different scanning systems, the quality of the input point cloud for surface reconstruction varies a lot. The presence of missing data, noise, outliers, or non-uniform sampling becomes quite common. Combined with potentially complicated topology, regional geometric details, and large-scale data, surface reconstruction becomes an even more challenging task. A comprehensive survey on the recent progress is provided by Berger et al. [1].

Existing surface reconstruction methods can be roughly classified into two categories: polygonal mesh approaches and implicit surface representations [2]. Polygonal mesh approaches are mainly based on the Voronoi diagram and its dual, the Delaunay triangulation [3, 4]. They produce mesh representations by interpolating a subset of the input data as vertices [5, 6]. However, polygonal methods are usually sensitive to noise, and they are not very robust on incomplete or non-uniform data. These issues are addressed in [7, 8, 9].

Implicit approaches describe the underlying surface by the zero level-set of an implicit function or an indicator function. Compared with polygonal mesh approaches, implicit methods are more suitable for representing surfaces with complicated topology and geometry [10, 11], and they are less sensitive to noise and sampling strategy of the data. Consequently, many implicit approaches has been proposed for surface reconstruction, for example the Blobby model, signed distance fields, algebraic surfaces, moving least squares (MLS) surfaces, radial basis functions (RBFs), multilevel partition of unity (MPU), and so on.

However, extra zero-level sets can emerge in the reconstruction results of implicit approaches [12, 13, 14] and produce redundant mesh components in iso-surface extraction processes. A clean mesh is important in

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