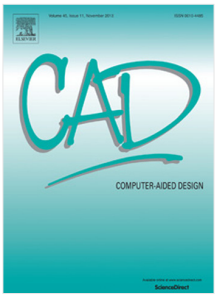
Accepted Manuscript



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PII: S0010-4485(18)30054-X
DOI: https://doi.org/10.1016/j.cad.2018.02.001
Reference: JCAD 2578

To appear in: *Computer-Aided Design*

Received date : 3 July 2017
Accepted date : 1 February 2018

Please cite this article as: Zhou J., Liu X., Cao J., Wang W., Yin B. Deep mesh labeling via learned semantic boundary guidance. *Computer-Aided Design* (2018), https://doi.org/10.1016/j.cad.2018.02.001

Deep Mesh Labeling via Learned Semantic Boundary Guidance

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Abstract

We propose a novel method for 3D mesh labeling based on a deep learning approach. We train two deep networks to produce initial labels and semantic boundary maps for test meshes. By using dropout technique, discriminative features can be extracted from our deep networks to improve mesh labeling and boundary detection. Given the detected boundary map, a smoother distance field with closed boundary depiction is calculated for succeeding optimization. Then, based on the initial labels, we obtain the final smooth results through a graph-cut optimization guided by the semantic boundary distance field. With the semantic boundary guidance, labeling is improved distinctly, especially, when large mislabeling regions appear or the boundary of initial labels is not reliable. Furthermore, our algorithm is robust to mesh noise, and can handle mixed dataset with meshes from different categories effectively. Experimental results show that our method outperforms the state-of-the-art methods on public benchmarks.

Keywords: Semantic, Boundary Guidance, Mesh Labeling, CNNs

1. Introduction

The goal of mesh labeling and segmentation is to divide 3D meshes into semantic parts and also to estimate part correspondences across these 3D meshes. In recent years, with the explosive growth of 3D data, mesh understanding plays an increasingly significant role in geometric modeling [1, 2], manufacturing [3], deformation [4] and texture transfer [5]. As a key ingredient for high level understanding of 3D models, mesh labeling is attracting more attentions.

In the past few decades, with the development of data-driven technology, many approaches have been proposed for mesh labeling and segmentation [6, 7, 8, 9]. The key idea is to learn an effective and robust mesh representation from multiple low-level geometry features of 3D shape data, which has been proved to be effective in classical recognition tasks [10, 11]. All those methods employ some graph-cut methods [12, 13, 14] to smooth segmentation boundaries and improve the learned labels. However, the improvements are limited since the regularization term (smoothness penalization) only depends on the dihedral angle between adjacent triangles, which is sensitive to noise and unaware of semantic boundary regions with low curvatures, shown in bottom right conner of Figure 1. Therefore, we learn a semantic boundary to improve 3D mesh labeling. Due to the discontinuity occurring in the learned semantic boundary, we introduce the calculation of the boundary distance field to obtain a smoother boundary representation, which can be used to guide the graph-cut method to optimize the labeling results. Benefiting from the semantic boundary guidance, our methods can achieve more credible labeling results and overcome the effect of mesh noise. The pipeline of our approach is shown in Figure 1.

In this paper, we also apply deep learning approach to learn a discriminative, effective and robust mesh representation from a large pool of geometric features. For this purpose, we use small convolution filters in convolutional layers and dropout [15] in fully-connected (FC) layers. Those techniques can be used to overcome over-fitting so as to obtain robust representations for 3D mesh labeling and semantic boundary detection. Due to the ability to extract discriminative mesh representations, our networks can also handle mixed dataset for mesh labeling and boundary detection.

The main contributions of this paper include: (1) a novel networks architecture is employed to extract a discriminative and robust mesh representation, which can be used to 3D mesh labeling and semantic boundary detection tasks; (2) a semantic boundary distance field is used for guiding labeling optimization, and experimental results show that our approach outperforms state-of-the-arts in many categories and our method is robust against noise.

The rest of this paper is organized as follows: Section 2 reviews related work and Section 3 introduces how to train the deep networks for mesh labeling and boundary detection. Then we demonstrate impressive performance in the experiments in Section 4. Finally, the paper is concluded in Section 5.

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