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Mendable consistent orientation of point clouds☆

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HIGHLIGHTS

- An orientation-benefit normal estimation method is proposed.
- We use multi-sources normal propagation to achieve more consistent orientation.
- Propagation sources are extracted automatically to alleviate the manual work.
- A considerable amount of comparisons with state-of-the-art are provided.

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ABSTRACT

Consistent normal orientation is challenging in the presence of noise, non-uniformities and thin sharp features. None of any existing local or global methods is capable of orienting all point cloud models consistently, and none of them offers a mechanism to rectify the inconsistent normals. In this paper, we present a new normal orientation method based on the multi-source propagation technique with two insights: faithful normals respecting sharp features tend to cause incorrect orientation propagation, and propagation orientation just using one source is problematic. It includes a novel orientation-benefit normal estimation algorithm for reducing wrong normal propagation near sharp features, and a multi-source orientation propagation algorithm for orientation improvement. The results of any orientation methods can be corrected by adding more credible sources, interactively or automatically, then propagating. To alleviate the manual work of interactive orientation, we devise an automatic propagation source extraction method by visibility voting. It can be applied directly to find multiple credible sources, combining with our orientation-benefit normals and multi-source propagation technique, to generate a consistent orientation, or to rectify an inconsistent orientation. The experimental results show that our methods generate consistent orientation more or as faithful as those global methods with far less computational cost. Hence it is more pragmatic and suitable to handle large point cloud models.

1. Introduction

Surface reconstruction from raw points is a fundamental problem in computer vision and computer graphics [1–8]. Consistently oriented normals are critical for surface reconstruction. The state-of-the-art reconstruction algorithms [1,9,2,10] may produce poor quality results without consistent orientation [11,12]. Although some advanced 3D scanning devices are capable of generating some additional properties, such as color and normal, when acquiring point positions, more general digitizing devices and computer vision algorithms do not provide such properties. Hence consistent orientation of raw points has drawn increasing attention recently [13,14,11,12,15–17].

As pointed out in [4,7], robust orientation is as difficult as reconstructing the whole surface itself. Furthermore the acquired point sets are inevitably ridden with noise, outliers, non-uniformities and holes [7], which challenges the traditional local orientation methods. Hence, more attention is paid to global approaches [15–17], since they are robust to these defects. In addition, sharp features also bring changes to both local approaches (see (b) and (d) of Fig. 1) and global approaches (see (c) of Fig. 1). Many feature-preserving methods, such as [18], generate faithful normals which benefit consistent orientation. However, normals preserving features may lead to incorrect orientation as illustrated in Fig. 2. Thus we design an orientation-benefit normal estimation algorithm for

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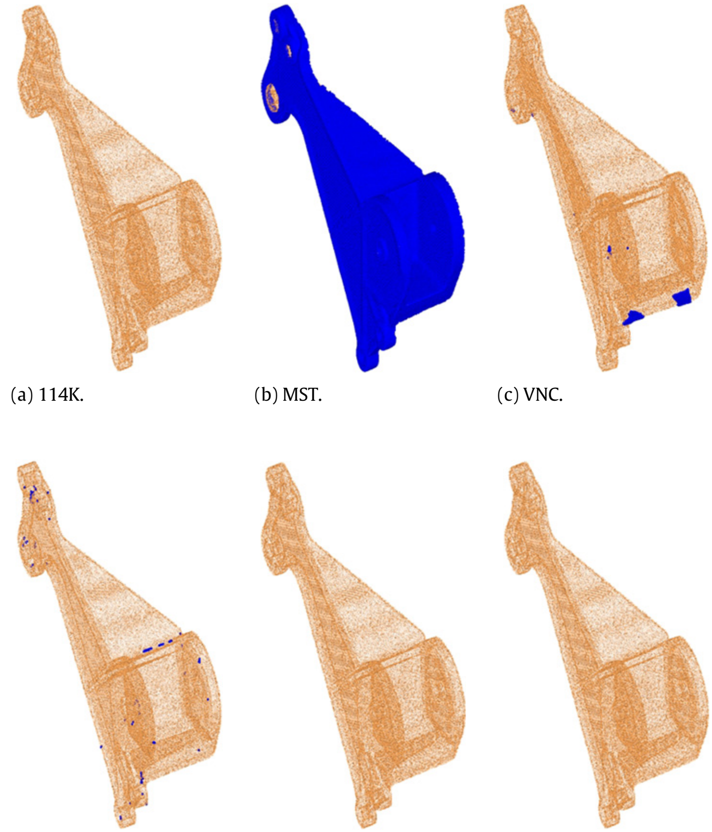
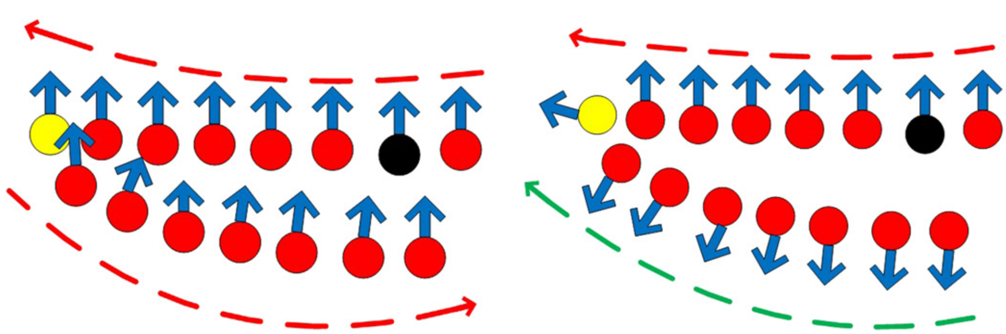


(a) 114K. (b) MST. (c) VNC.

(d) ORT. (e) CSV. (f) Ours.

Fig. 1. Orientation of the Daratech model (114K) (a) with thin sharp features and nearby surface sheets. The columns from left to right are the results of (b) MST [19], (c) VNC: variational normal computation [17], (d) ORT: the adaptive spherical cover approach [12], (e) CSV: constrained Laplacian smoothing and visibility voting [15] and our approach (f) respectively. VNC and ORT generate small incorrect orientation near some sharp feature regions and CSV and our method generate comparable consistent orientation for this model. Ratios of incorrect normal orientation to the total number of normals are $\frac{65080}{114983}$, $\frac{526}{114983}$, $\frac{118}{114983}$, $\frac{0}{114983}$ and $\frac{0}{114983}$ respectively. Blue spheres mark incorrect orientation. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)



(a) WPCA. (b) OBNE.

Fig. 2. MST with normals estimated by WPCA is prone to propagate across thin sharp features while ours not. The black points are source points and the yellow ones are feature points. (a) Incorrect orientation by MST with normals estimated by WPCA. (b) Orientation by MST with normals estimated by our OBNE. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

reducing wrong normal propagation across sharp features. Finally, as far as we know, none of any local, even global methods is capable of achieving consistent orientation for all point clouds and none of them offers a mechanism or strategy to identify and make right the inconsistent normals. The inconsistent orientation is hard to detect just from the surface itself, because they tend to be surrounded by sharp features and satisfy the geometry constraints of the algorithm generating them.

To address the above issues, we present a mendable local orientation propagation method, since it generates comparable results as the global approaches and has the potentiality of rectifying inconsistent orientation faster for huge point cloud data. We have to mention that not all the local or global methods can exploit the inconsistent orientation identified to correct their results. Detailed descriptions can be found in Section 2. Our method consists of a novel orientation-benefit normal estimation algorithm (OBNE) for reducing wrong normal propagation across sharp features, a multi-source orientation propagation algorithm (MMST) for orientation improvement, and visibility voting process to identify multiple credible sources. It involves four main steps. Taking a raw point set as input, its initial normals are estimated by weighted principal component analysis (WPCA). Based on the