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Structure-Sensitive Superpixels via Geodesic Distance

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Abstract Segmenting images into superpixels as supporting regions for feature vectors and primitives to reduce computational complexity has been commonly used as a fundamental step in various image analysis and computer vision tasks. In this paper, we describe the structure-sensitive superpixel technique by exploiting Lloyd's algorithm with the geodesic distance. Our method generates smaller superpixels to achieve relatively low under-segmentation in structure-dense regions with high intensity or color variation, and produces larger segments to increase computational efficiency in structure-sparse regions with homogeneous appearance. We adopt geometric flows to compute geodesic distances amongst pixels. In the segmentation procedure, the density of over-segments is automatically adjusted through iteratively optimizing an energy functional that embeds color homogeneity, structure density. Comparative experiments with the Berkeley database show that the proposed algorithm outperforms the prior arts while offering a comparable computational efficiency as TurboPixels. Further applications in image compression, object closure extraction and video segmentation demonstrate the effective extensions of our approach.

Keywords Superpixel segmentation · Geodesic distance · Iterative optimization · Structure-sensitivity

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1 Introduction

Image over-segmentation has been widely applied in various computer vision pipelines, such as segmentation (Arbelaez et al. 2009; Xiao and Quan 2009; Wang et al. 2008; Hoiem et al. 2005), recognition (Kaufhold et al. 2006), object tracking (Wang et al. 2011; Rasmussen 2007), localization (Fulkerson et al. 2009) and modeling (He et al. 2006; Nwogu and Corso 2008; Micusík and Kosecká 2010).

In these applications, over-segments (aka superpixels) represent small regions with homogeneous appearance and conform to local image structures, and thus provide a better support for region-based features than local windows. With superpixels, the computational cost significantly decreases especially for probabilistic, combinatorial or discriminative approaches, since the underlying graph is greatly simplified in terms of graph nodes and edges. Most superpixel methods have to face the following challenges: on one hand they are required to reduce image complexity by locally grouping pixels regarding intensity boundaries, and on the other hand they should avoid under-segmentation and maintain a certain level of detailed structures. These two aspects conflict with each other, and there have been various optimization techniques proposed to make trade-offs in order to solve this dilemma, for example, the mean shift algorithm (Comaniciu and Meer 2002), the normalized cuts (Shi and Malik 2000), the local viaration (Felzenszwalb and Huttenlocher 2004), the geometric flows (Levinshtein et al. 2009b) and