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On Using Anisotropic Diffusion for Skeleton Extraction

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Abstract We present a novel and effective skeletonization algorithm for binary and gray-scale images, based on the anisotropic heat diffusion analogy. We diffuse the image in the direction normal to the feature boundaries and also allow tangential diffusion (curvature decreasing diffusion) to contribute slightly. The proposed anisotropic diffusion provides a high quality medial function in the image: it removes noise and preserves prominent curvatures of the shape along the level-sets (skeleton features). The skeleton strength map, which provides the likelihood of a point to be part of the skeleton, is defined by the mean curvature measure. Finally, thin and binary skeleton is obtained by non-maxima suppression and hysteresis thresholding of the skeleton strength map. Our method outperforms the most related and the popular methods in skeleton extraction especially in noisy conditions. Results show that the proposed approach is better at handling noise in images and preserving the skeleton features at the centerline of the shape.

Keywords Skeletonization · Feature extraction · Heat flow · Computer vision

1 Introduction

Skeleton or medial axis (Blum 1967) is a thin version of the shape, which is an important feature for shape description in image processing and computer vision. It offers simple and compact representation of shapes while preserving its topology. Skeletons can be used for instance to classify objects (Aslan et al. 2008; Ward and Hamarneh 2010) or to estimate their poses and orientations (Macrini et al. 2008). There are different algorithms for skeletonization of shapes in images. We review skeletonization techniques divided into two categories: the ones that are limited to the pre-segmented binary images (Sect. 1.1) and the ones that are capable of extracting skeletons from gray-scale images (Sect. 1.2).

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1.1 Skeletonization of Binary Images

Popular techniques used for skeleton extraction in binary images are based on thinning (Lam et al. 1992), Voronoi diagrams (Ogniewicz and Kubler 1995), distance transform (Arcelli and Baja 1992; Kimmel et al. 1995; Malandain and Vidal 1998), Poisson equation (Gorelick et al. 2006), Newton's law (Siddiqi et al. 1999) and Electrostatic field (Grogorishin et al. 1996). Thinning (Lam et al. 1992) is a process that deletes object boundary pixels iteratively with a set of conditions. Complex conditions are required to terminate this deleting process as well as to preserve the topology and the connectivity of the skeleton. In Ogniewicz and Kubler (1995), the skeleton is extracted from the Voronoi diagram computed on the boundary of the object. This approach is theoretically well defined in a continuous space, which means a high sampling rate of the boundary points is required to compute a Voronoi diagram of good quality. The Voronoi skeletons also need complex post-processing stages to prune the branches. Recently, Krinidis and Chatzis (2009) proposed a physics-based deformable model for skeletonization that does not produce spurious branches.

A medial function is a scalar function that locally assigns higher values to skeleton points than non-skeleton points.