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Fast Texture Segmentation Based on Semi-Local Region Descriptor and Active Contour

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Abstract. In this paper, we present an efficient approach for unsupervised segmentation of natural and textural images based on the extraction of image features and a fast active contour segmentation model. We address the problem of textures where neither the gray-level information nor the boundary information is adequate for object extraction. This is often the case of natural images composed of both homogeneous and textured regions. Because these images cannot be in general directly processed by the gray-level information, we propose a new texture descriptor which intrinsically defines the geometry of textures using semi-local image information and tools from differential geometry. Then, we use the popular Kullback-Leibler distance to design an active contour model which distinguishes the background and textures of interest. The existence of a minimizing solution to the proposed segmentation model is proven. Finally, a texture segmentation algorithm based on the Split-Bregman method is introduced to extract meaningful objects in a fast way. Promising synthetic and real-world results for gray-scale and color images are presented.

AMS subject classifications: 65M10, 78A48

Key words: Semi-local image information, Beltrami framework, metric tensor, active contour, Kullback-Leibler distance, split-Bregman method.

1. Introduction

Texture segmentation is among the most challenging problems in image segmentation. The problem already begins with the definition of textures. The human eye can easily recognize different textures, but it is quite difficult to define them in mathematical terms. Then, there is a deliberate vagueness in the definition of textures, which explains the difficulty to conceptualize a model able to describe it. Besides, textures raise the problem of non-existence of significant edges and the non-homogeneity of intensity distributions

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lying in images. However, it is consensually admitted (e.g. [3]) that textures are fine scale-details, usually with some periodicity and oscillatory nature.

Different approaches deal with the extraction of homogeneous features from textures. Among these texture descriptors, some are statistical-based or transformed-based as the structure tensor [8,54] or the Gabor filters [38]. Some recent methods propose to use the Beltrami framework [47], [27]. In this paper we propose a new method for the extraction of homogeneous regions or textures based on the Beltrami framework and on semi-local image information. We will see that our texture feature is more robust with respect to noise than the one we have previously presented in [27].

Once the feature extraction step is completed, a fast and robust algorithm to perform texture segmentation/extraction is needed. To reach this objective, we develop an algorithm based on the active contour model. In this image segmentation method, an initial contour is subjected to a speed term which drives the contour toward the boundary of the object to be segmented. The speed term is determined by the minimization of an energy functional composed of a contour smoothing term (internal energy) and an attraction term that pulls the contour towards the object boundaries (external energy). Active contour models have a long history. This method was originally introduced by Kass et al. in [31]. Then, Caselles et al. in [10] and Kichenassamy et al. in [32] proposed an intrinsic geometrical model, called geodesic/geometric active contours, where the curve evolution is handled by the level set method introduced by Osher and Sethian in [40]. Thus, the first generation of active contour segmentation methods [10,31,32] was based on edge detection. However, boundary-based segmentation is often too limited in many applications such as in medical image segmentation where fuzzy contours can be encountered or in natural images with textures. To deal with these problems, segmentation models based on region descriptors such as mean [14] or variance [29,55] have been developed. Among the region descriptors, the probability density function (pdf) (or histogram) is proven to be an efficient and general region descriptor.

Zhu and Yuille in [56] and Paragios, Rousson and Deriche in [41,45] approximated the pdf of the image regions by mixture of Gaussians, each one representing a homogeneous intensity region to be segmented. Jehan-Besson, Aubert, Barlaud, Faugeras and Herbulot in [1,26,29] used the pdf of evolving regions of interest as a general region descriptor. The regions of interest are given by the minimization of region-based energies using the shape derivative tool defined by Delfour and Zolesio in [16]. Aubert, Barlaud, Faugeras and Jehan-Besson proved in [1] that minimizing a region-based functional with the shape derivative tool is equivalent to minimizing boundary-based functional with the calculus of variations. These authors applied in [1,29] the shape derivation tool to the image segmentation problem. Along the same lines, Herbulot et al. in [26] used the shape derivative tool and information theoretical concepts (entropy and mutual information) to also perform image segmentation.

All these methods enable us to find local minimizers of the segmentation problem. Local minimizers mean that the quality of the segmentation results depends on the choice of the initial condition. In other words, the initial contour is critical to get satisfactory segmentation results, and to avoid bad local minimizers. The authors of [5,12] proposed to refor-