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Texture and color segmentation based on the combined use of the structure tensor and the image components

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Abstract

In this paper, we propose a novel segmentation scheme for textured gray-level and color images based on the combined use of the local structure tensor and the original image components. The structure tensor is a well-established tool for image segmentation and has been successfully employed for unsupervised segmentation of textured gray-level and color images. The original image components can also provide very useful information. Therefore, a combined segmentation approach has been designed that combines both elements within a common energy minimization framework. Besides, an original method is proposed to dynamically adapt the relative weight of these two pieces of information. Quantitative experimental results on a large number of gray-level and color images show the improved performance of the proposed approach, in comparison to several related approaches in recent studies. Experiments have also been carried out on real world images in order to validate the proposed method.

Keywords: Image segmentation; Texture segmentation; Local structure tensor; Nonlinear diffusion; Kullback–Leibler distance; Level set theory

1. Introduction

Image segmentation is a key step for image interpretation applications and it may be of high interest for some image processing applications, such as image coding. Generally speaking, the segmentation process relies on the extraction of appropriate features from the image that bear high discriminative power, the more discriminative the more likely the eventual segmentation will be successful.

The present work introduces a novel segmentation method for textured images, a well-known problem for which a *golden* solution has not been reported. Many different approaches have been employed in the literature for texture segmentation and texture classification, which is a closely related problem. These include those based on Markov Random Fields [1–4], Gabor filters [5–9], multiple resolution techniques [10,11] or neural network

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classification methods [12,13], just to mention a few. Most of these approaches provide segmentation results with a spotty appearance, as they are pixelwise classification methods. As opposed to them, contour-oriented segmentation has gained much relevance in the last years.

In this paper, we propose a contour-oriented segmentation approach for textured images. As for implementation, level-set methods [14–18] are employed for curve evolution. They have gained much relevance lately due to their good properties: as opposed to parametric active contours [19–21], the curve is represented implicitly, so topological changes can be handled naturally; it can be directly extended to higher dimensions and efficient schemes for numerical solutions have been developed [22]. Moreover, different types of information can be used in a common level set framework, including boundary information [15,23,24], region information [25–30] and even shape prior information [31–34].

In our approach, the texture features will be employed as region information in a geodesic active regions (GAR) framework. This model was proposed by Paragios and Deriche [28] and constitutes a common framework for contour-oriented image segmentation problems, where different sources of information can be incorporated within a general Bayesian formulation.

With regard to texture feature extraction, we propose an adaptive mixed approach based on the combined use of the local structure tensor (LST) and the image components. The LST was proposed for orientation estimation [35–38] and it is widely accepted as a powerful feature extractor for textured images. Based on the LST, Rousson et al. proposed in [39] a segmentation method for textured images that applies the GAR model to a vector-valued image where the channels are the components of the LST. This method showed interesting results. However, the advantages of extracting the texture features with the LST are partially lost because of the vector processing of that information. Based on this work, in [40] tensor processing was applied to the LST for texture segmentation. In that work, intrinsic tensor dissimilarity measures based on geometric properties of their respective images were employed in a level-set framework. Prior effort in this direction had been done in the field of diffusion tensor imaging (DTI) for the segmentation of anatomical structures in tensor-valued images [41–48]. The use of these intrinsic dissimilarity measures on the structure tensor drew a performance improvement over the vector processing of these features. Even though the use of the LST information for texture segmentation has shown considerably good results, it suffers from a major drawback, namely, the LST does not include any intensity information (or color information) from the image, which may constitute a significant information misuse or loss. This problem was partially solved in [40] with the introduction of several modified structure tensor architectures (i.e. extended and compact structure tensor) but again, two main issues remain unsolved. First one is adaptivity. A detailed analysis of each image characteristic shows that the relative importance of the texture and components information may vary from case to case. Second, although texture information may be appropriately encoded in a tensor architecture, the components information naturally fits a vector scheme (in fact, the convenience of a separate analysis of the texture and the color information was shown in [49]). Therefore, different dissimilarity measures should be employed for each case.

Different approaches for the combination of texture and intensity information for image segmentation have been proposed recently in the literature. In [50], a supervised classification method is designed for images containing both textured and non-textured parts, based on a texture-structure decomposition of the image. The global segmentation is performed by combining the segmentation results for the geometrical and textured components using a logical framework. However, it is necessary to know what the logical combination of the geometrical and textural patterns into the different classes should be, thus making this approach strongly supervised. In [51], a technique is devised to measure the local scale based on a property of the total variational flow. This novel feature is added to the intensity and the components of the structure tensor to perform the segmentation in a feature space of dimension 5. This method incorporates the local scale as a valuable new feature to describe textures, but does not balance the importance of the different kinds of information for each particular image. Other attempts more closely related to our approach will be later discussed, once our method is described.

The method presented in this work is intended for the segmentation of both gray-level and color textured images. With regard to the segmentation