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A fast texture segmentation scheme based on active contours and discrete cosine transform☆

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ABSTRACT

This paper presents a novel and efficient parametric active contour model based on the texture describing properties derived from coefficients of the two-dimensional Discrete Cosine Transform (2-D DCT) for segmenting texture objects against complex backgrounds. Block based 2-D DCT is applied in the local neighbourhood of all the contour control points and some randomly chosen object points. DCT coefficients in the horizontal, vertical and diagonal directions which represent the dominant textures are used to construct the histograms those exhibit different structures for different texture regions. Heterogeneity of these histograms corresponding to contour and object points is measured by Wasserstein distance metric. Finally, DC coefficient which represents the energy of the corresponding block modulated by the calculated Wasserstein distance is employed as the external energy of the proposed active contour model. Experiments on synthetic and natural texture images show the efficiency of our model in terms of accuracy and speed.

1. Introduction

The task of segmenting an object of interest from its background is essential as it forms the preliminary part in many higher level image processing and computer vision problems. As most of the real world objects have some kind of texture on them, so it's important to consider the texture features in segmentation. Although distinction among different texture regions in an image is almost an effortless job for a human observer, it is far from being trivial for a computer. This difficulty is due to the fact that there does not exist any universal mathematical model for describing all kind of textures [1]. Nevertheless, many algorithms have been proposed for segmenting texture objects. These algorithms mostly have the following components, (i) modelling the texture features by representing the image in some transformed space such as Fourier space, Gabor space [2], Wavelet space [3] etc. (ii) Extraction of texture features from these representation spaces (iii) Use of different metrics to quantify the distinction of the features in different regions in the image like Euclidean, manifold, Kullback–Leibler [4], Wasserstein distances [5] etc. and finally (iv) formulation of some objective function based on the above metrics which is then optimized or some algorithm like clustering [6] is used to get the final segmentation result [7]. Texture segmentation using deformable models like Active Contours (AC) also follow the same steps as mentioned above and is an emerging research area as they are flexible, capable of achieving sub-pixel accuracy and provide smooth and close contour as segmentation results.

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Active Contour Models (ACMs) also known as snakes were first introduced by Kass et al. in 1988 [8]. These are widely used for segmenting an object of interest. In recent researches, they are also modified to segment texture images. The main concept of ACM is that, an initial arbitrary contour is moved towards the object boundary by minimizing an energy functional. Based on how this energy function is defined, there exist two variations of ACM, (i) Parametric ACM [8] (ii) Geometric ACM [9]. Both these models are equally adopted for texture segmentation. Geometric ACM are mostly based on level set formulation [9] and some geometric ACM used explicitly for texture segmentation may be found in [4,7]. However, studies show that although these models can handle topological changes and work for complex images, they have higher computational complexity and hence are slower than parametric ACM. Therefore, in this work, we will concentrate on the latter. The energy function of parametric ACM is known to contain two energy terms related to two different types of energies. These are the internal energy, which controls the contour's movement and the external energy, which drives the contour towards the desired object boundary. The external energy in traditional ACM is based on the image gradient, so it cannot be used in texture segmentation as it will suffer from local maxima problem. So, many modifications have been proposed to the external energy of active contour to achieve texture segmentation [10–13]. However, it is found that although these methods work well for synthetic texture images, when it comes to natural textures, these fail to achieve the desired level of accuracy.

In an attempt to devise an active contour model for texture segmentation which works better for natural textures, in the present work, we propose a new external energy term for ACM which is based on the texture describing properties of the DCT coefficients. Although DCT was originally used for image compression, recently it is being extensively used for many other image processing and computer vision problems such as, image retrieval, where features extracted from DCT coefficients are used for the retrieval process [14–17], in image de-noising, where a noise pixel is decided based on the value of the DCT coefficients [18], and in steganographic methods for real-time data hiding by modifying the DCT coefficients for hiding the data without affecting the visual appearance of the image [19] etc. Motivated by the above DCT based approaches, in our proposed method, texture features are extracted by finding the local block based 2-D DCT at the contour control points and object points. The external energy for active contour is derived from these features which would be able to drive AC towards the desired object boundary. The advantages of the proposed method achieved over other state-of-the-art methods are summarized below which are later validated through experimental results.

- The time required for execution is greatly reduced as our proposed method uses DCT to extract features which is a faster transform as compared to the transforms used by the state-of-the-art methods like Gabor [13], DWHT [12] or statistical moment calculation [11].
- It also reduces the overhead of finding the required number of transformed or moment images and again transforming them back to the spatial domain as it extracts texture features by finding the local block based DCT only at the contour and object points.
- Due to good texture discrimination property of the DCT coefficients our method achieves better segmentation accuracy especially for natural texture images.

Rest of this article is organized as follows. Section 2 reviews the works done related to our approach, Section 3 gives introduction to the underlying mathematical model of ACM, 2-D DCT and Wasserstein distance, Section 4 presents our proposed approach, experimental results and comparisons are given in Section 5 and finally concluding remarks are drawn in Section 6.

2. Related studies

As our proposed approach integrates the ideas from two different fields i.e. parametric ACM and texture feature extraction from DCT, so we break this section accordingly into two parts.

2.1. Parametric ACM for texture segmentation

Traditional parametric ACMs are not suitable for segmenting texture images, as gray level features are not adequate for texture segmentation. Below we have discussed some of the parametric ACMs with new external energies those deal with texture images.

A two-phase rectification-conducted adaptive snake for texture segmentation was proposed by Chan et al. [10]. In the first phase of this method, an edge-conducted evolution is performed to adopt to the salient image edges and in the second phase, rectification of the unmatched snake fragments is done. However, it is a more complex method than finding a suitable external energy incorporating the texture features.

In the same perspective, Vard et al. have proposed two different types of pressure energies as external force of ACM for texture segmentation. In their first work, they found the pressure energy from the statistical moments of the image [11]. Texture features of the contour and object points from the moment images are compared and a decision on whether the contour needs to shrink or expand is made to drive the contour towards the desired object boundary. Unfortunately, due to high computational complexity, it is not suitable for real-time applications. In an attempt to overcome this, in another similar work, they found the texture pressure energy from the faster Directional Walsh Hadamard Transform (DWHT) [12].