Contourlet Based Multiresolution Texture Segmentation Using Contextual Hidden Markov Models

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Abstract. In this paper, block based texture segmentation is proposed based on contourlets and the hidden Markov model (HMM). Hidden Markov model is combined with hidden Markov tree (HMT) to form HMM-HMT model that models global dependency between the blocks in addition to the local statistics within a block. The HMM-HMT model is modified to use the contourlet transform, a new extension to the wavelet transform that forms a true basis for image representations. The maximum likelihood multiresolution segmentation algorithm is used to handle several block sizes at once. Since the algorithm works on the contourlet transformed image data, it can directly segment images without the need for transforming into the space domain. The experimental results demonstrate the competitive performance of the algorithm on contourlets with that of the other methods and excellent visual performance at small block sizes. The performance is comparable with that of wavelets and is superior at small block sizes.

1 Introduction

In statistical image segmentation, it is necessary to capture both global and local statistical structure of textures. Texture segmentation is achieved using block-based modeling considering statistical dependencies between blocks. Contourlet transform is better suited for representing singularities such as edges and ridges in an image that characterize textures. The multiresolution property of contourlets makes HMM based texture segmentation [2] possible.

The de-correlation property of the contourlet transform greatly reduces the number of hidden states, hence the complexity is reduced. Here image and its contourlet coefficients are treated as random realizations from a family or distribution of signals. Coefficients are modeled either as jointly Gaussian or as non-Gaussian but independent. The HMM-HMT model [6] takes global and local dependencies between blocks and gives improved segmentation results. The HMM-HMT approach is modified for application to contourlet transform to acquire the segmentation results for several resolutions.

2 Contourlet Transform

The contourlet transform is a new extension to the wavelet transform in two dimensions using non-separable and directional filter banks. It is composed of basis images oriented at varying directions in multiple scales. With this rich set of basis images, the

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contourlet transform can effectively capture the smooth contours in the natural texture images. Non separable multiscale representations capture the intrinsic geometrical structures in the textural images which wavelets fail to capture. Based on the two dimensional non-separable filter banks, contourlets possess multiresolution, time-frequency localization features in addition to high degree of directionality that allows one to jointly model scale, space and directional parameters of an image.

Contourlets [3] are implemented by the pyramidal directional filter bank (PDFB), which decomposes an image into directional subbands at multiple scales. PDFB is a cascade of a Laplacian pyramid and a directional filter bank. The directional filter bank decomposes images into any power of two's number of directions. Here the multiscale and directional decomposition are independent of each other. The Fig. 1 shows contourlet transform of an image, which is having four directional and three scale decompositions.

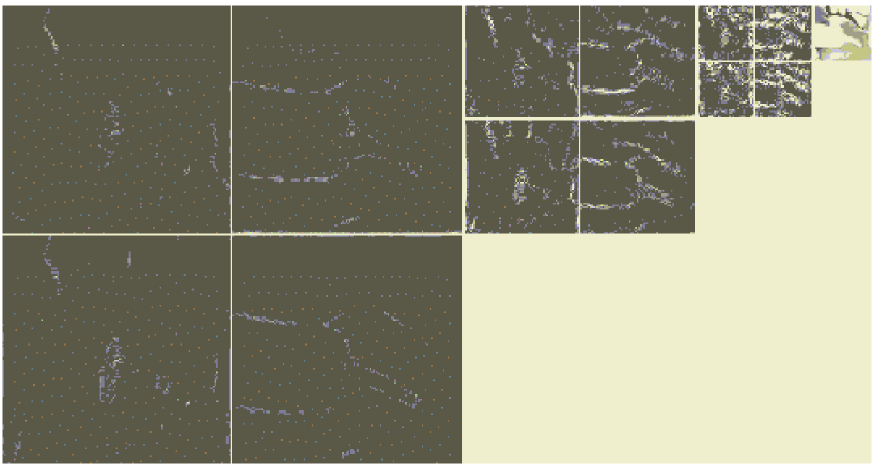

Fig. 1. Contourlet decomposition of Peppers image

The singularities such as edges in the support region affect the magnitude of contourlet coefficients. The contourlet coefficients of 2-D images are naturally arranged in the form of quad-trees. In a quad tree each node will have four children nodes. Thus image is represented as a tree after transforming it. A coefficient in a low subband (parent) can be thought of as having four descendants (children) in the next higher subband. The four descendants each also have four descendants in the next higher subband and a quad tree will emerge.

The contourlet transform picks out edge contours and represents those using coefficients. Due to the small compact support of the contourlets, edges contribute energy to a small number of coefficients. The contourlet coefficients of natural images exhibit residual dependency structure both across scale and within scale. Images have been modeled based on these dependencies. The coefficients of a 2D image are represented using quad trees and the inter-scale dependencies are captured using a hidden Markov model [5].

Fig. 2 shows the histogram of the finest subband of contourlet coefficients of an image. The distribution is characterized by a sharp peak at zero amplitude and ex-