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Original

Multi-resolution Laws' Masks based texture classification

Sonali Dash *, Uma Ranjan Jena

Department of Electronics and Telecommunication Engineering, Veer Surendra Sai University of Technology (VSSUT), Burla 768018, Odisha, India

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Abstract

Wavelet transforms are widely used for texture feature extraction. For dyadic transform, frequency splitting is coarse and the orientation selection is even poorer. Laws' mask is a traditional technique for extraction of texture feature whose main approach is towards filtering of images with five types of masks, namely level, edge, spot, ripple, and wave. With each combination of these masks, it gives discriminative information. A new approach for texture classification based on the combination of dyadic wavelet transform with different wavelet basis functions and Laws' masks named as Multi-resolution Laws' Masks (MRLM) is proposed in this paper to further improve the performance of Laws' mask descriptor. A *k*-Nearest Neighbor (*k*-NN) classifier is employed to classify each texture into appropriate class. Two challenging databases Brodatz and VisTex are used for the evaluation of the proposed method. Extensive experiments show that the Multi-resolution Laws' Masks can achieve better classification accuracy than existing dyadic wavelet transform and Laws' masks methods.

Keywords: Multi-resolution Laws' Masks; Dyadic wavelet transform; Feature extraction; Texture classification

1. Introduction

Texture is a repetition of intensity patterns present in an image. It is one of the significant visual characteristic and a rich source of information for any image analysis. Hence, it is a vital element in many areas of applications, such as object recognition, content-based image retrieval, remote sensing, image segmentation, medical image analysis, automated inspection, document processing and so on. An important step in the classification of texture is the extraction of feature. The different types of feature extraction techniques for texture identification are structural (Haralick & Shapiro, 1992), statistical (Haralick, 1979), geometrical (Pikaz & Averbuch, 1997), model-based (Mao & Jain, 1992) and signal processing (Laine & Fan, 1993). Gaussian Markov random fields (GMRF) and Gibbs random fields are also proposed to characterize textures (Cross & Jain, 1983; Kashyap & Khotanzed, 1986). In addition, local linear transformations are utilized to compute texture (Laws, 1980a; Unser, 1986). The traditional statistical approaches for texture analysis have limitations to spatial interactions over small neighbourhoods on a single scale only.

In the field of multi-resolution analysis, wavelet analysis has become a powerful tool during the past decades. The wavelet transformation provides a precise and unifying framework for the analysis and characterization of signals at different scales. The discrete wavelet transform of an image simultaneously reserves the time and frequency domain information of the signal and efficiently extracts the key features of the image. Several multi-resolution and multi-channel transform algorithms have been used for texture classification such as dyadic wavelet transform (Arivazhagan & Ganesan, 2003; Mallat, 1989a, 1989b), wavelet frame transform (Unser, 1995), Gabor filters (Jain & Farrokhnia, 1991; Manjunath & Ma, 1996), steerable pyramids (Simoncelli & Freeman, 1995) and fusion of multi-resolution methods (Li & Shawe-Taylor, 2005). The signal processing techniques rely mainly on texture filtering to analyze the frequency content either in spatial domain (Laws, 1980b; Unser, 1986) or in frequency domain (Bajcsy & Lieberman, 1976). Among the multi-resolution techniques, discrete wavelet transform is not translation-invariant (Xiong, Zhang, & Moon, 2000).

* Corresponding author.
E-mail address: sonali.isan@gmail.com (S. Dash).

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Although the aforementioned methods proved to deliver good classification accuracy, recently some authors have introduced hybrid models jointly by combining the traditional techniques with multi-resolution techniques for an additional improvement of texture classification. Few examples of hybrid models proposed are Multi-scale grey level co-occurrence matrices for texture description, Multi-resolution LBP (Ojala, Pietikainen, & Maenpaa, 2002), Gaussian image pyramid-based texture features and Multi-scale Co-occurrence Local Binary Pattern. (Siqueira, Schwartz, & Pedrini, 2013; Yadav, Anand, Dewal, & Gupta, 2015a, 2015b; Qi, Shen, Zhao, Li, & Pietikainen, 2015).

The Laws' masks awareness also known as energy filters as conveyed by K.I. Laws, where he has suggested towards the filtering of images with specific masks created from the combination of one-dimensional kernel vector in order to assess the texture properties (Laws, 1979, 1980a). In the medical image analysis, Laws' masks have received wide acceptance (Elnemr, 2013; Rachidi et al., 2008) but for texture classification, Laws' masks have resulted very poor classification accuracy. Pietikainen has found that the performance of texture energy measures depends on the general forms of the masks rather than on their specific values (Pietikainen, Rosenfled, & Davis, 1983). To find the local rank order correlations of images with appropriate image and mask sizes, Laws' masks could achieve better result than achieved by the basic convolutions as reported by Harwood (Harwood, Subbarao, & Davis, 1985). Ade has considered different methodologies associated with Laws' measures while characterizing textures by using Eigenfilters (Ade, 1983). Comparative studies carried out by Buf and Ng have reported that Laws, Haralick and Unser methods provide better results for texture features (Buf, Kardan, & Spann 1990; Ng, Tan, & Kittler, 1992). In 1995, Harwood et al. have suggested a new method of texture analysis based on a local centre-symmetric covariance analysis, using Kullback (log-likelihood) discrimination of sample and prototype distribution (Harwood, Ojala, Pietikainen, Kelman, & Davis, 1995). This method can be viewed as a generalization of Laws' approach and the results are compared with that of Laws' measures. The experiments are carried out with 24 different Laws' (5×5) masks, and the classification error rates of 25.9% (image size of 64×64) and 39.2% (image size of 32×32) are achieved on Brodatz database. Sharma and Singh have shown maximum classification accuracy of 83.30% by using Laws' mask method for MeasTex database with k-NN as classifier (Sharma & Singh, 2001). The same authors Singh and Sharma have done another experiment with MeasTex and VisTex benchmarks with different texture descriptors. They have stated that by utilizing Laws' mask descriptor, the classification accuracies for MeasTex database are 82.80% with linear classifier, 75.10% with k-NN as classifier on original data and 69.30% with k-NN as classifier on PCA data. The classification accuracies for VisTex database are 68.80% with linear classifier, 56.10% with k-NN as classifier on original data and 53.20% with k-NN as classifier on PCA data (Singh & Sharma, 2001). Ertugrul has described adaptive texture energy measure. By employing adaptive texture energy measure best classification accuracy of 68.43% is obtained on Brodatz database (Ertugrul, 2014).

As we have examined our proposed method with Brodatz and VisTex database, a brief review on recently developed methods that classify these two databases are discussed. Qiao et al. have proposed a new method for extraction of texture features with a combination of the phase difference and the magnitude variation information of the complex wavelet coefficients, and then modelled the measure with the real generalized Gaussian distribution (GGD). They have verified the proposed method with two different datasets created from Brodatz database with different sizes of images and the third dataset is created from VisTex database with k-NN as classifier. The best classification accuracies achieved are 92.1% on the first dataset of Brodatz and 83.1% on the second dataset of Brodatz. Classification accuracy of 84.6% is obtained on VisTex database (Qiao, Zhao, & Song, 2009). Dong and Ma have suggested a new method for feature extraction through contourlet subband clustering for texture classification. They have evaluated the proposed method with two different datasets created from Brodatz database and two different datasets created from VisTex database, and obtained different classification results from each created databases using k-NN as classifier. They have achieved classification accuracy of 99.92% on the first dataset and $96.81 \pm 0.44\%$ on the second dataset of Brodatz database. The best classification accuracy of $99.25 \pm 0.38\%$ is obtained on the first dataset and $85.95 \pm 1.50\%$ on the second dataset of VisTex database (Dong & Ma, 2013). Susan and Hanmandlu have proposed a new method of probabilistic non-extensive entropy feature for texture characterization and achieved highest classification accuracy of 97.78% on Brodatz database using SVM as classifier (Susan & Hanmandlu, 2013). Yuan has recommended a rotation and scale invariant local binary pattern by collectively considering high order directional derivatives, circular shift sub-uniform, and scale space. The proposed method delivered highest classification accuracy of 75.2% on Brodatz database (Yuan, 2014). Murala and Wu have proposed a combination of Gabor transform with robust local binary (RLBP) operator and the maximum classification accuracy is found to be 84.92% on Brodatz database and 93.25% on VisTex database (Murala & Wu, 2014). Zhang et al. have recommended a technique by combining spiking neural network and Fast wavelet transform (SNN-FWT), and obtained best classification rate of 98.93% on Brodatz database with k-NN as classifier (Zhang, Wu, Zhuo, Wang, & Huang, 2015). Florindo et al. have recommended combinations of traditional texture descriptors with non-additive entropy. They have achieved best classification accuracy of 92.51% on Brodatz database and 93.52% on VisTex database with a combination of grey level co-occurrence matrix (GLCM) with non-additive entropy using Linear Discriminant Analysis (LDA) as classifier (Florindo, Assirati, & Bruno 2015). Tang et al. have suggested a new texture extraction method combining non-overlap window local binary pattern and grey level co-occurrence for green tea leaves classification, where they have also verified the proposed method on Brodatz database. They have achieved maximum classification accuracy of 94.8% on Brodatz database with back propagation neural network as classifier (Tang et al., 2015).

A thorough literature review in texture classification concludes that Law's mask descriptor provides poor classifi-