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K-NN based automated reasoning using bilateral filter based texture descriptor for computing texture classification

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ABSTRACT

Regions in the visual field can be characterized by differences in texture, brightness, colour, or other attributes. Bilateral filter is an efficient way to smooth any digital image while preserving the fine information. In bilateral filter, it has been observed that by selecting carefully, the bilateral filter range parameter and bilateral filter domain parameter the ability to smooth any arbitrary digital image while preserving the edges can be improved. This trait of bilateral filter helps to adapt it to application specific requirements. In this study, a new feature extraction method is recommended by integrating the conventional Laws' mask method with bilateral filter, which results in the improvement of classification accuracy. The texture features are extracted by using different values of range parameter and domain parameter and are fed as input to k-Nearest Neighbor (k-NN) classifier for classification. The new fusion model is tested with Brodatz, VisTex, STex and ALOT databases. The results of the proposed method are also compared with the conventional Laws' mask descriptor for all the aforementioned four datasets. The experimental results show that bilateral filter based Laws' mask feature extraction technique provides better classification accuracy for all the four databases for various combinations of bilateral filter range and domain parameters.

1. Introduction

Texture is a property of image region. Texture analysis is one of the significant functions in pattern recognition and computer vision. In spite of its significance, texture analysis still is a great challenge. In 1970s the first work on texture analysis by Haralick is best known for co-occurrence matrix [1]. Random Markov Fields, a contemporary approach is used mainly for segmentation purposes [2]. Laws has recommended computing the energy of the image by using filters at the end of same decade [3]. Fractal geometry appeared as a powerful theory to obtain texture feature during the 1980s [4,5]. Later contribution to texture feature extraction is made by LBP (Local Binary Patterns) [6]. All the methods proposed are without considering the complementary information that cannot be expressed by the intensities of pixels, but only through particular operations over those pixels. Some authors have made an effort to achieve this gap, and proposed the extraction of features from other domains, like wavelets [7], discrete cosine transform [8], Hough transform [9], and others.

Recently some hybrid models have also been developed by integrating the traditional texture descriptors to obtain better classification accuracy. Yadav et al. have proposed hybrid models of DWT (Discrete Wavelet Transform) with different LBP variants and named as Multi-resolution local binary pattern variants. They have obtained best classification accuracy of 97.87% for DWTCLBP ^{u2} (325 features) at the third level of DWT decomposition for hardwood species [10]. Yadav et al. have also proposed hybrid models of Gaussian pyramid (GP) with LBP, LCP (Local Configuration Pattern) and LPQ (Local Phase Quantization) for hardwood species database and texture surface database. For texture database (UIUC) they have achieved classification accuracy of 98% for GPLCP^{riu2} hybrid model with SVM as classifier [11]. Qi et al. have proposed globally rotation invariant multi-scale co-occurrence local binary

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pattern and investigated the proposed technique on Outex database for texture classification [12]. Zhe et al. have proposed a local binary pattern based texture descriptors for classification of tea leaves [13].

Filtering methods also outstretched interests in texture analysis due to their simulation of human vision. Various filtering methods like Gabor filter, spatial filter, etc. are used for texture analysis [14–16]. Bilateral filter is a nonlinear filter developed in 1998 by Tomasi and Manduchi. The idea underlying bilateral filtering is to do in the range of an image what traditional filters do in its domain. Two pixels can be close to one another, that is, occupy nearby spatial location, or they can be similar to one another, that is, have nearby values, possibly in a perceptually meaningful fashion [17]. It has been observed that by selecting carefully, the bilateral filter range parameter and bilateral filter domain parameter the ability to smooth any arbitrary digital image while preserving the edges can be improved. Out of several applications, one application of the bilateral filter is texture and illumination separation. Based on a large-scale/small-scale decomposition of images, these applications edit texture and manipulate the tonal distribution of an image to match the capacities of a given display. Wang et al. have used a bilateral filter decomposition in which high-dynamic-range image is generated from a single low-dynamic-range image [18]. They seek to reconstruct data in over and under exposed areas of the image. They have used bilateral filter to create decomposition into texture and illumination motivated by Oh et al.'s work [19]. This allows them to apply user-guided texture synthesis to the detail (texture) layer, after bilateral filtering removed the large-scale illumination variations. Lin et al. have proposed switching bilateral filter as texture/noise detector for universal noise removal [20]. Zhang and Allebach have proposed adaptive bilateral filter for sharpness enhancement and noise removal. They have mentioned that, because bilateral filter is a combination of both range filter and domain filter, it ensures that averaging is done mostly along the edge and is greatly reduced in the gradient direction. Due to this reason, the bilateral filter can smooth the noise while preserving edge structures [21]. Cho et al. have proposed a novel structure of preserving image decomposition operator called bilateral texture filter where they have successfully removed texture while preserving main image structures [22]. Hinnawi and Daear have investigated the performance of the bilateral filter based on histogram moments and co-occurrence matrix for four low dose images of CT plastic phantom [23].

The energy filters are designed to enhance some textural properties of the images by Laws [3]. This method is based on the application of convolutions of the original image, Y, using different filters f1, f2... fN, therefore obtaining N new images $F_n = Y * fn$ (n = 1,2,...N). However, in the medical image analysis Laws' mask descriptor for texture feature extraction has received wide acceptance. Rachidi et al. have used Laws' masks for bone texture analysis and found the TEM_{E5R5} and TEM_{E5W5} give very good result in terms of reproducibility [24]. Heba has used Laws' masks statistical texture features for cancer and water lung detection [25]. Setiawan et al. have used Laws' texture energy measure for mammogram classification. For Laws' descriptor, they have found accuracy of 93.90% for normal-abnormal and 83.30% for benign-malignant classification [26]. Legesse et al. have utilized laws' mask descriptor for automated detection of skin cancer and found classification results as 85% for sensitivity and 88% for specificity with all texture parameters [27]. In a comparative study for classification of Remote sensing data, Ruiz et al. have derived different classification accuracies for variety texture descriptors with different forest datasets. For combined descriptor GLCM (Gray Level Co-occurrence Matrix) + WV (WaveLet) + Gabor + Energy they have achieved highest classification accuracy of 88.41% on Urban dataset. By combining only GLCM and Energy (GLCM + Enegy) the maximum classification accuracy of 85.82% is obtained on Urban dataset. For only Energy filters the highest classification accuracy of 70.70% is achieved on FOREST 3 dataset [28]. Ertugrul has proposed adaptive texture energy measure. The classification accuracies of 0.08, 0.3292 and 0.3343 are obtained by TEM (Texture Energy Measure) on butterfly, flower seed and Brodatz datasets respectively. The adaptive TEM has delivered the correct classification rates of 0.0053, 0.2417 and 0.3153 respectively on the same three databases [29]. Sharma and Singh have shown maximum classification accuracy of 83.30% by using Laws' mask method for Meastex database with k-NN as classifier [30]. The same authors Singh and Sharma have done another experiment with Meastex and VisTex benchmarks with different texture descriptors. They have shown that by utilizing Laws' mask descriptor the classification accuracies for Meastex database are of 82.80% with linear classifier, 75.10% with k-NN classifier on original data and 69.30% with k-NN classifier on PCA (Principal Component Analysis) data. The classification accuracies for VisTex database are 68.80% with linear classifier, 56.10% with k-NN classifier on original data and 53.20% with k-NN classifier on PCA data [31]. Ojala et al. have compared a range of texture features extraction techniques by using nearest neighbour classifiers on Brodatz database. They have achieved best performance for the gray level difference method and poorest performance for Laws' mask method [32]. Ojala et al. have done two different types of experiments with grain mixture images. Firstly, the performances of Laws' texture energy measures are determined using k-NN classifier based on feature vectors. Secondly, distribution based classification experiments are performed. For Laws' energy measure, classification accuracies are found as 51.70% with sample size 128×128, and 39.93% with sample size 256×256. For histogram equalization (EQ) classification accuracies of 61.93% and 52.84% are obtained with sample size 128×128 and 256×256 respectively [33]. Harwood et al. have done texture classification by center-symmetric auto-correlation by using Kullback discrimination by distributions on Brodatz textures. They have also included experiments with 24 different Laws' 5×5 masks in order to see the influence of size of the masks. They have achieved error rates of 25.9% and 39.20% for 64×64 and 32×32 samples, respectively, for the best performing mask S_5S_5 [34].

Detailed assessment shows that for texture classification by using only conventional Laws' mask descriptor has not achieved attractive classification accuracy. Hence, with an objective to improve the performance of conventional Laws' mask descriptor a new method is proposed by integrating bilateral filter with Laws' mask descriptor. In bilateral filter selection of range parameter (σ_r) and domain parameter (σ_d) is very important. If their values are set too high, the filter will act as a smoothing filter. If their values are set too low noise cannot be removed. So very carefully, we have selected various combinations of bilateral filter range parameter (σ_r) and bilateral domain parameter (σ_d) and applied to the texture images. The generated filtered images for different values of σ_r and σ_d are convolved with Laws' mask descriptor. Once more, the convolved images are passed through three types of energy measurement filters for extracting the texture features. Further, k-NN classifier is employed to examine the effectiveness of the proposed technique.

The arrangement of the paper is as follows: The comprehensive review of bilateral filter and Law's mask descriptor is presented in Section 2. Section 3 discusses in detail the texture features extraction, classification, and validation. Section 4 conveys critical discussion of results of the proposed technique and comparison with conventional method. Section 5 concludes the work.

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