41st Southeastern Symposium on System Theory
University of Tennessee Space Institute
Tullahoma, TN, USA, March 15-17, 2009

Combining Wavelet Transforms and Neural Networks for Image Classification

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Abstract

A new approach for image classification based on the color information, shape and texture is presented. In this work, we use the three RGB bands of a color image in RGB model to extract the describing features. All the images in image database are divided into 6 parts. We use the Daubechies 4 wavelet transform and first order color moments to obtain the necessary information from each part of the image. The proposed image classification system is based on Back propagation neural network with one hidden layer. Color moments and wavelet decomposition coefficients from each part of the image are used as an input vector of neural network. 150 color images of aircrafts were used for training and 250 for testing. The best efficiency of 98% was obtained for training set, and 90% for the testing set.

Key words: Wavelet Transform, Neural Network, Image Classification, Color Moment

1. Introduction

Image classification from a database is particularly difficult for traditional machine learning algorithms because of the high number of images and many details that describe an image. For these reasons, traditional machine are unstable to classify images from a database. Furthermore, these machines take long time for classification. Existing image storing systems such as QBIC [1] and VisualSEEK [2] limit classification mechanism to describe an image based on color information [3], texture, or shape features.

One of the existing methods for recognition, classification and retrieval of images is based on Neural Networks (NN). Images that we use in this paper have 700 pixels thus, image includes 35,000 RGB pixels. If such image is used as an input of NN, the number of input unit of NN are going to increasing and cause to The size of the NN also are increasing. Thus, because of existing many images that are classified and high number of input unit of NN, Learning of the NN is very difficult. To handle this high dimensionality, image classification systems usually rely on a pre-processing step to reduce the information of images. This reduced set is then used as new input variables of NN.

One of the pre-processing steps is based on wavelet transform. Wavelet transforms nowadays in the most popular method to Analysis images and gives information from an image such as a shape and texture. In this paper, we use the Daubechies wavelet transform coefficients and color moments information as an input of NN. Color moments have been successfully used in many color based image classification systems, especially when the image contains just the object. Back Propagation NN (BPNN) with one hidden layer is used in this paper for classification. Optimized methods with Momentum are used to learning the NN. In this paper, we are interested in determining if a photo of a given aircraft belongs to one of the six categories shown in Figure 1.

The reminder of paper is organized as follows. Section 2 discusses about previous work. Section 3 describes the image content representation including color moments and wavelet decomposition coefficients and presents divisional methods in order to obtain better performance in classification. Section 4 and 5 present the proposed method for classification. The evaluation of the proposed approach is presented in section 6. Concluding remarks are offered in section 7.

Figure1. Definition of six classes for classification.
(Class1) Commercial plane in land, (Class2) commercial plane in air, (Class3) war plane in land,(Class4) war plane in air, (Class5)Helicopter in land, and (Class6) helicopter in air

2. Related works

In this section, we describe about previous works for image classification using neural networks and wavelet transforms. In [4] Harr and a bank of perceptrons applied to image classification from a database of 600 images (300 for training and 300 for testing). They obtain 81.7% correct classification for training set and 76.7% for testing test. In [5], combination of wavelet transforms and neural networks applied to image classification. They report performances is near to 80%. In [6] Daubechies wavelet transforms are used to classification. 120 color images of airplanes were used for training and 240 for testing. The best efficiency of 88% was obtained. Our proposed method is this paper also is based on the wavelet transform and neural networks. We decompose a color image to the three RGB bands, use the Daubechies 4 wavelet transform and first order color moments to obtain the input of NN.

3. Image content representation

Content and features of an image has many applications in image classification. In this section, color moments and wavelet decomposition coefficients are introduced to represent the image content. The all images have 700*500 pixels. From the original image, we first get an image of 256*256 pixels by down sampling. In this work, we use the three RGB bands of a color image in RGB model to extract the describing features. Each color band of original image is divided into 6 parts in size of 128*128 (Figure 2).

3.1. Color moments

Color moments have been successfully used in many color based image retrieval systems [8], especially when the image contains just the object. The first order (mean) , the second order (variance) color moments and the third order color moments (skewness) have been proved to be efficient and effective in representing color distributions of images [9]. We use the first order of color moment as an input of the NN. Mathematically, the first two moments can be defined as:

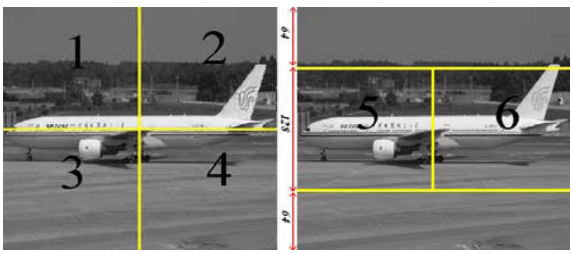

Figure 2. The Image divided into six parts

$$\mu_k = \frac{1}{MN}\sum_{i=1}^{N}\sum_{j=1}^{M} p_{i,j}^{k} \qquad (1)$$

$$\sigma_k = \left(\frac{1}{MN}\sum_{i=1}^{N}\sum_{j=1}^{M} (p_{i,j}^{k} - \mu_k)^2\right)^{1/2} \qquad (2)$$

$$s_k = \left(\frac{1}{MN}\sum_{i=1}^{N}\sum_{j=1}^{M} (p_{i,j}^{k} - \mu_k)^3\right)^{1/3} \qquad (3)$$

Where $p_{i,j}^{k}$ is the value of the k-th color component of the image ij-th pixel, and M is the height of the image, and N is the width of the image.

3.2. Wavelet transform

The computation of the wavelet transforms of a 2D signal involves recursive filtering and sub-sampling [13]. At each level, the signal is decomposed into four frequency sub-bands, (LL_n, LH_n, HL_n, HH_n), where L denotes the low frequency and H denotes the high frequency and n is the decomposition level of wavelet transform. LL_n is the residual low resolution image (cA_n), HL_n is the vertical detail of image (cV_n), LH_n present the horizontal details (cH_n) and HH_n presents the diagonal information of image (cD_n). Since wavelets capture shape, texture, and location information of an image in a single unified framework, wavelet transform features are often used in content-based image retrieval systems. In this paper, we use the symlets that are nearly symmetrical wavelets proposed by Daubechies [9] as modifications to the db family. After the six-level wavelet decomposition.

4. Proposed method

Our goal is classification of large number of images based on the color and shape information. So that we use wavelet, first order color moment and neural networks. Between different methods of neural network, we use the back propagation neural network. This method is very practical in image classification [7], [10]. At first step, we define the number of neural network inputs .considerable point is the size of neural networks, because the large size increases the time of learning and it is not optimum. So that we try to decrease the number of input units for network (The size of network depend on the number of input layers, hidden layers and output layers).

The size of all images that we have used is 500*700 pixels. We decomposed the image to its three-based color (Red, Green and Blue) and got three images in three basic bands. after that we down sampled these images to 256*256 pixels .now we divided each colorful bands to

six equal parts with 128*128 pixels as mentioned at part 3 and getting inputs of network in two stage :

a. calculate the first order color moment (mean) of each six parts , for three basic bands and got 18 inputs for network that contains color's information.

b. We apply the db4 wavelet transform with sixth level of decomposition to six parts of three basic bands of original image to get the horizontal, vertical and diagonal detail with size 2*2 (cH6, cV6,cD6). we used this information as inputs of neural network (the image with low information that had got from wavelet (cA_6) hasn't used) .To avoid large number of inputs for network we use the horizontal information of six parts of red band (cH6-R) , the vertical information of six parts of green band (cV6-G) and the diagonal information of six parts of blue band (cD6-B) . totally 72 inputs of network were obtained from wavelet transform that contain the shape and texture information.

c. The next three input of NN are obtained from wavelet decomposition energy Eh, Ev and Ed, which contain the percentages of energy corresponding to the horizontal, vertical, and diagonal details, respectively. We apply the first level of db4 wavelet transform to three RGB band of original image and find the Eh, Ev and Ed of each band. Therefore, other nine input of NN are obtained. finally after these three steps, the network has 99 input units (Figure 3).

5. Neural network architecture

Back-propagation neural network with one hidden layer is used for classification. It has 90 input units ($x_1 ... x_{90}$), 64 hidden units (we use the several numbers of units in this layer and select the number that best performance is obtained) and 6 output units ($y_1 ... y_6$) .The NN structure is shown in Figure 4.

The feature vectors that obtained from the image are normalized using the following equation:

$$x_{i,new} = \frac{x_i - \min(x)}{\max(x) - \min(x)} \qquad (4)$$

Table 1 presents the Target vector ($t_1 ... t_6$) for the defined six classes of aircrafts.

The response of output unit (y_i) considered +1 if its activation is equal or greater than zero, otherwise the output unit value is -1. Learning rate of NN if 0.05. The Nguyen-Widrow algorithm is used to initialize the weights and bipolar sigmoid function is used as activation function [11].

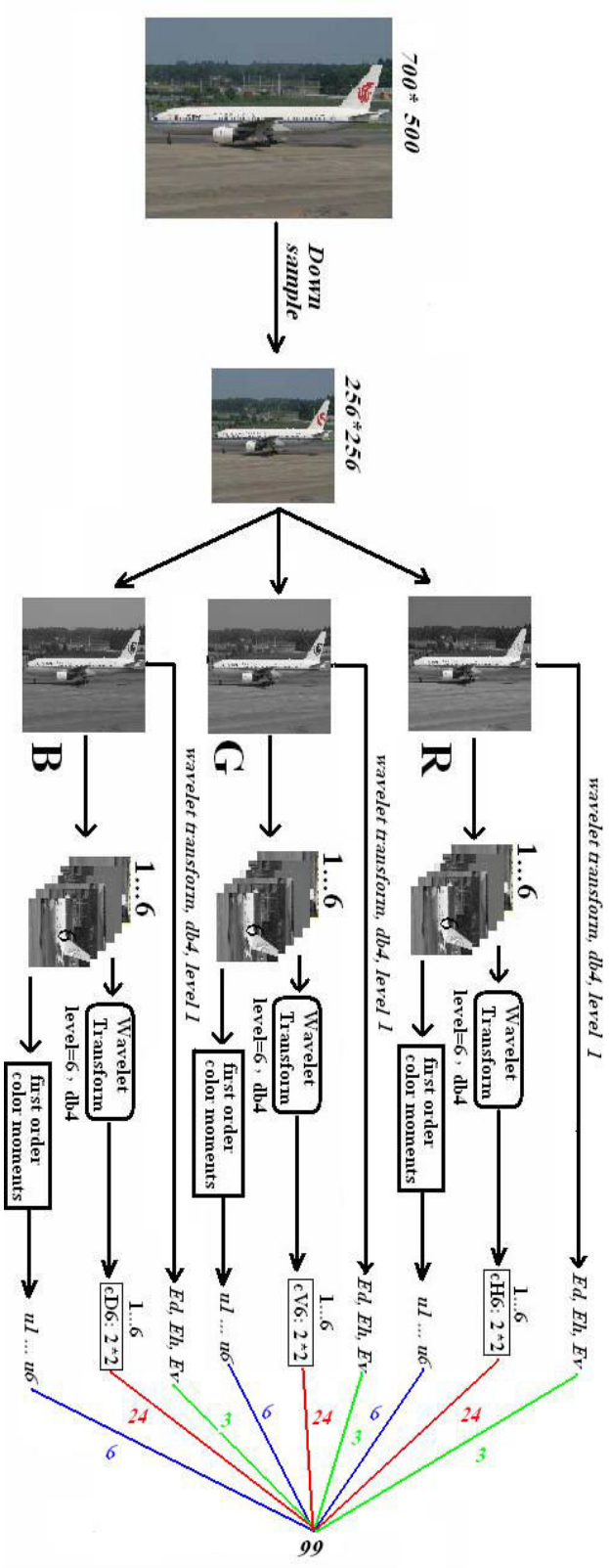

Figure 3. Proposed method to get input of NN

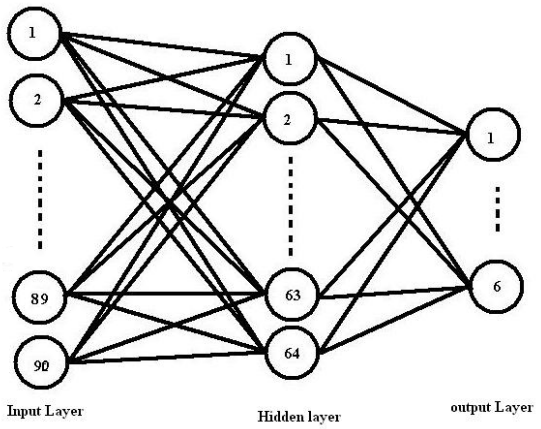

Figure 4. Structure of BPNN used

Table 1. Target vector definition for six classes

Target vector	t1	t2	t3	t4	t5	t6
Class 1	**1**	-1	-1	-1	-1	-1
Class 2	-1	**1**	-1	-1	-1	-1
Class 3	-1	-1	**1**	-1	-1	-1
Class 4	-1	-1	-1	**1**	-1	-1
Class 5	-1	-1	-1	-1	**1**	-1
Class 6	-1	-1	-1	-1	-1	**1**

We train the BPNN with momentum. The momentum value is 0.95. There are several methods to improve the training the neural networks. These methods are based on the composition of at least two data sets to evaluate the efficiency of the net. Several variants of this method have been proposed [12], [13]. We use the method similar to the [13] to train the BPNN. We distributed these 150 images into 5 sets C1,…,C5. Each set of 30 images contains five images of each one of the six airplane classes shown in Fig. 1. We perform NN training as follows:

1. In the first step, we use the C1, C2, C3,C4 and train the BNNN 100 epoch. We get the first set of weights for the NN.
2. In the second step, we now take sets C5, C1, C2, C3 and with them train the NN. Again 100 epochs where performed and we get the second set of weights for the NN. (In this step the first set of weights are used as initial weights).

We repeat this process for training sets: C4 C5 C1 C2, C3 C4 C5 C1 and C3 C4 C5 C1 to get final value of weighting sets for the BPNN.

6. Experimental results

In this section, we test the describing method. 150 color images of aircrafts are used for training and 250 for testing. Images were taken from http://www.airplane-pictures.net and http://www.militaryaircraft.de . For this we chose the 150 images used for training and 250 images for testing the neural network. The best efficiency of 98% was obtained for training set, and 90% for the testing set (The average of classification is 93% for combining the training pattern and test pattern). Table 2 compares proposed method with other methods.

Table 2. Comparison of classification methods

Method	[4]	[5]	[6]	[7]	Proposed method
Number of training images	300	--	120	--	150
Number of testing images	300	--	120	--	250
Classification percentage (%)	79	80	88	86	93

7. Conclusion

In this paper, we introduced a new approach for image classification using neural network and wavelet transform. Wavelet transform describe texture and shape features of images and color moments extract the color information. We use the three RGB bands of a color image in RGB model to extract the describing features. All the images in image database are divided into 6 parts. Then apply the first order color moment and Daubechies 4 wavelet transform to extract the input vector of neural network. We use the back propagation neural network for image classification and use optimum method to train it. The best efficiency of 98% was obtained for training set, and 90% for the testing set.

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