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Handwritten Digit Recognition based on DWT and DCT

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Abstract

Automatic handwritten digits recognition is useful in a large variety of applications such as cheque verification and mail sorting. However, the selection of the technique for feature extraction remains the big challenge step for achieving high recognition accuracy. This paper presents a technique based on DWT and DCT to capture the discriminative features of handwritten digits. DCT coefficients are extracted from low-frequency sub-band (LL) of DWT image. These coefficients are fed into the ANN in the classification stage. This work has been tested with ADBase database containing 70,000 digits images, and a comparison made against some existing techniques, and promising results have been obtained.

Keywords: *Handwritten digit, DWT, DCT, ANN*

1. Introduction

Off-line handwritten digit recognition plays a significant role in several applications such as cheque processing or the automatic sorting of postal mail. Recognition of handwritten digits is a difficult task due to the wide variety of styles, sizes and orientations of digit samples for the same writer and between different writers. Arabic (Indian) numerals are composed of 10 digits (0-9). There are several challenges in handwritten digit recognition arise due to the nature of the handwriting style. Figure 1 shows some samples images of handwritten Arabic (Indian) digits.

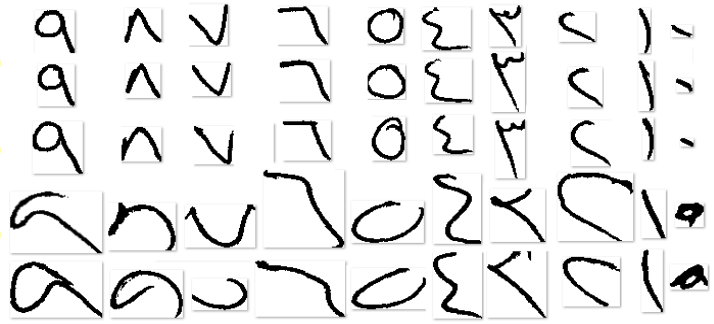

Figure 1. Different Samples Images of Handwritten Digits

However, there are many researches in handwritten digit recognition. Al-Omari *et al.* [1] presented a system using an Artificial Neural Network (ANN) for recognition of handwritten digits. Sabri [2] proposed a system based on Gabor filters and Support Vector Machines (SVMs) for recognition of Arabic (Indian) handwritten digits. Rashnodi *et al.* [3] introduced a technique using SVMs for recognition of handwritten Persian digits where Discrete Fourier Transform is used for extracting features of the digit. EL Qacimy *et al*. [4] introduced an approach based on Discrete Cosine Transform (DCT) to extract features of handwritten digits. These features are then fed into SVM for classification. Babu *et al.* [5] proposed a system for

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handwritten digit recognition based on structural and statistical features and K-nearest Neighbor Classifier. Ebrahimzadeh and Jampour [6] presented an approach using Histogram of Oriented Gradients and linear SVM for handwritten digit recognition. Romero *et al.* [7] introduced a technique based on Wavelet transform and ANN for handwritten numerals recognition. A comparison between DCT and Discrete Wavelet Transform (DWT) to capture features of Arabic handwritten characters without overlapping characters has been introduced by Lawgali *et al*. [8]. However, the selection of the method for feature extraction remains the big challenge step for achieving high recognition accuracy. Both DCT and DWT are widely used in the field of digital signal processing applications [9]. In this paper, handwritten digit recognition based on DWT and DCT is presented. Each digit image is decomposed into one level by DWT. DCT is applied on the low-frequency sub-band (LL) of DWT image to extract DCT coefficients. These coefficients are fed to the ANN in the classification stage. The organization of the paper is as follows. Section 2 describes data acquisition and pre-processing. Section 3 discusses the techniques used for feature extraction while Section 4 describes the classification stage. Section 5 discusses the results and their analysis. Section 6 concludes the paper.

2. Data Acquisition and Pre-Processing

Digits were read from the ADBase database [10] written by 700 different writers which containing 70,000 digits images. Each writer wrote the digits from 0 to 9 twenty times. The database is divided into two sets (60,000 digits for training and 10,000 digits for testing). The pre-processing task is used to remove the details that have no discriminative power in the process of recognition. Noise removal and binarization were carried out in the development of the database [10]. Before extracting the features of the digits, the original digits are normalized by normalizing the thickness and sizes. This is achieved by extracting the skeletons of digits which are then increased at a steady rate for all digits to achieve normalization. The images of digits are resized as 45 x 45 for normalization purposes.

3. Feature Extraction

Feature extraction converts the digit image into a set of vectors to be passed onto the matcher to assist in the classification process. Therefore, these features should poss the essential characteristics of the digit which make it different from another. Feature extraction techniques differ from one application to another [11, 18]. DWT and DCT are widely used in the field of digital signal processing applications [9]. Therefore, in this paper, DWT and DCT are used to extract the features of the digits.

3.1. Discrete Wavelet Transform

DWT is a technique used to extract the features of the digits where, at each decomposition level, a low-pass filter (LPF) and a high-pass filter (HPF) are applied to each row/column of the image to decompose this into one low-frequency sub-band (LL) and three high frequency sub-bands (LH, HL, HH) [12]. Figure 2 shows the decomposition of DWT at one level.

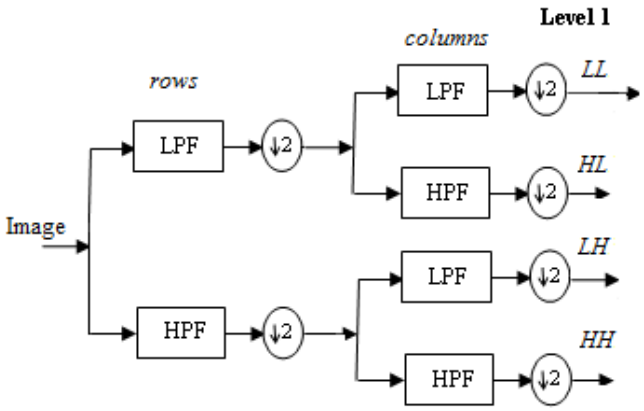

Figure 2. DWT Decomposition at One Level

There are various types of wavelet transforms which can be applied, such as Haar and Biorthogonal, and others. Each of them has its particular features. From practical experiences, best results have been achieved in Arabic handwriting recognition by using Haar transform [13]. The low-frequency coefficients (LL) are close to the original image containing most details of the image, and several works have used these coefficients to detect the features [12]. In this paper, each normalized digit image is decomposed into one level by the Haar wavelet and the low-frequency coefficients (LL) are used to extract the features of the digits. Figure 3 shows the decomposition of DWT at one level.

(a) Original Image (b) DWT Decomposition (c) Decomposed Image

Figure 3. One Level of Decomposition of Digit Image

3.2. Discrete Cosine Transform

DCT is a technique to convert the pixel values of an image into its elementary frequency components [9]. It clusters high value coefficients in the upper left corner and low-value coefficients in the bottom right of the array. By applying DCT on each image, DCT coefficients of that image are obtained. The DCT coefficients are extracted in a zigzag fashion and stored in a vector sequence. DCT coefficients *f(u,v)* of *f(m,n)* are computed by:

$$f(u,v) = \alpha(u)\alpha(v)\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f(m,n)\cos\left[\frac{(2m+1)\pi u}{2M}\right]\cos\left[\frac{(2n+1)\pi v}{2N}\right]$$

Where

$$\alpha(u) = \begin{cases} \frac{1}{\sqrt{M}}, u = 0 \\ \sqrt{\frac{2}{M}}, 1 \leq u \leq M-1 \end{cases}$$

and

$$\alpha(v) = \begin{cases} \frac{1}{\sqrt{N}}, v = 0 \\ \sqrt{\frac{2}{N}}, 1 \leq v \leq N-1 \end{cases}$$

One of the characteristics of DCT is its ability to convert the energy of the image into a few coefficients [14]. DCT is applied on the low-frequency sub-band (LL) of DWT image to extract DCT coefficients. The number of DCT coefficients chosen in the classification stage was set at 50 coefficients. Extensive experiments were carried out using different values of coefficients, and it was found that these coefficients were the most appropriate. Figure 4 illustrates the low-frequency sub-band (LL) of DWT image and that after DCT application.

(a) Low-Frequency Sub-Band (LL) (b) DCT Image of DWT

Figure 4. Applying DCT

4. Classification

A classifier is used to identify the digit by using the features obtained by applying DWT and DCT, these are compared and saved as models for the trained classes. Features of an unknown digit will be extracted and compared with the features of the training models to identify the unknown digit. ANN is widely used in the field of pattern recognition. Therefore, ANN is used to identify the unknown digit by using its features obtained by applying DWT and DCT.

4.1. Artificial Neural Network

An ANN has been used to deal with the features that have been extracted from the digit. An ANN consists of processing elements with weights which are learned from the training data. Three layers were used in this paper for the architecture of the network: the input layer, the hidden layer, and the output layer. Figure 5 depicts an example of the architecture of the 3-layer ANN. The input layer is fed by the features of the digit. The number of nodes in this layer depends on the number of features extracted by DWT and DCT for each digit. The last layer is called the output layer, and the number of its nodes is based on the desired outputs. The hidden layer lies between the input and output layers. Feed-forward network multi-layer perception (MLP) back propagation (BP) with supervised training algorithm is used in this work. It is the best-known paradigm of training the ANN to classify patterns [15]. A classifier is used to identify the digits by using their features obtained by applying DWT and DCT. 50 features are fed to the network as input

signals. The number of nodes in the output layer depends on the number of digits (10 classes). The number of nodes in the hidden layer was chosen experimentally to be 100 nodes to achieve the best performance.

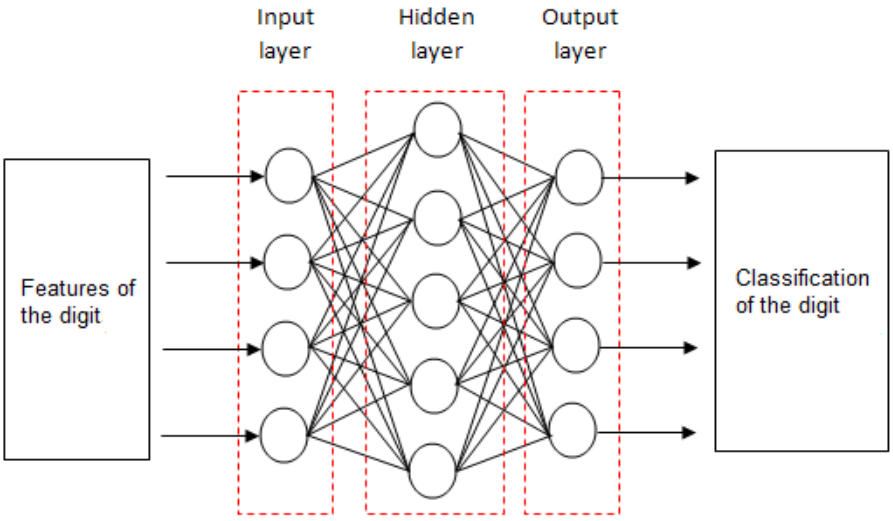

Figure 5. The Architecture of the ANN Used

5. Experimental Results

Experiments were carried out using an ADBase database containing 70,000 digits images written by 700 different writers and divided into two sets (60,000 digits for training and 10,000 digits for testing). Each normalized digit image is decomposed into one level by the Haar wavelet. DCT is applied on the low-frequency sub-band (LL) of DWT image to extract DCT coefficients. 50 coefficients were used to recognize the digit. These coefficients were fed to the ANN in the classification stage. The experiments were carried out in two steps. In the first step, DCT coefficients were extracted from normalized digit image. In the second experiment, DCT coefficients were extracted from low-frequency sub-band (LL) of DWT image. To allow for a fair comparison, the size of images was set to 45x45 for both experiments. Both methods were used and compared the effectiveness of capturing discriminative features of handwritten digits with the same ANN structure in the classification stage. An increase in performance was noted in the second experiment when compared with the first one. The results achieved in both experiments are summarized in Table 1.

Table 1. Recognition Rates by Using different Techniques

Methods	Recognition rate
DCT	97.25 %
DWT and DCT	98.32 %

Figure 6 shows the comparison of the performance of two methods to recognize each class. The results showed that the feature extraction by DWT and DCT yields a higher recognition rate.

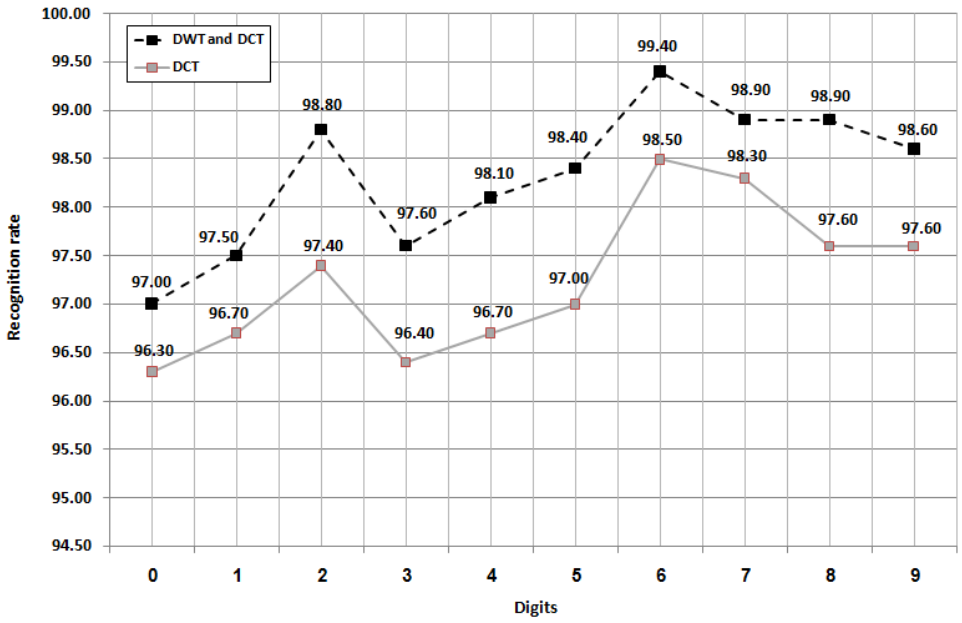

Figure 6. A Comparison of Two Methods to Recognize Each Class

This present work was compared with two approaches. These approaches were assessed on the same dataset, and the results of the comparison are shown in Table 2. Approach 1 [16] used polygonal approximations and fuzzy directional edges for recognition of handwritten digits while the DCT and Dynamic Bayesian Network classifier is used in approach 2. [17].

Table 2. Comparison of our Results with Previous Work

Approaches		Recognition rate
Approach 1		97.18 %
Approach 2		85.26 %
Our approach	DCT	97.25 %
	DWT and DCT	98.32 %

6. Conclusion

This paper has presented a technique based on DWT and DCT to capture the discriminative features of handwritten digits. The experiments were carried out in two steps. The first step DCT coefficients were extracted from normalized digit image. In the second experiment, each normalized digit image is decomposed into one level by the Haar wavelet. DCT coefficients were extracted from low-frequency sub-band (LL) of DWT image. Coefficients of both techniques were used with ANN for the classification of the digits. The results have demonstrated that features extraction by DWT and DCT has a higher recognition rate for handwritten digit.

References

[1] S. Al-Omari, P. Sumari, S. Al-Taweel and A. Husain, "Digital Recognition using Neural Network", Journal of Computer Science, vol. 5, no. 6, **(2009)**, pp. 427-434.
[2] S. Mahmoud, "Arabic (Indian) Handwritten Digits Recognition Using Gabor-based Features", International Conference on Innovations in Information Technology, Al Ain, **(2008)**, pp. 683-687.
[3] O. Rashnodi, H. Sajedi and M. Saniee, "Persian Handwritten Digit Recognition using Support Vector Machines", International Journal of Computer Applications, vol. 29, no. 12, **(2011)**, pp. 1-6.

[4] B. E. Qacimy, M. Kerroum and A. Hammouch, "Feature Extraction based on DCT for Handwritten Digit Recognition", International Journal of Computer Science Issues, vol. 11, no. 2, **(2014)**, pp. 27-33.
[5] U. Babu, A. Chintha and Y. Venkateswarlu, "Handwritten Digit Recognition Using Structural, Statistical Features and K-nearest Neighbor Classifier", International Journal Information Engineering and Electronic Business, vol. 6, no. 1, **(2014)**, pp. 62-68.
[6] R. Ebrahimzadeh and M. Jampour, "Efficient Handwritten Digit Recognition based on Histogram of Oriented Gradients and SVM", International Journal of Computer Applications, vol. 104, no. 9, **(2014)**, pp. 10-13.
[7] D. Romero, A. Ruedin and L. Seijas, "Wavelet-Based Feature Extraction for Handwritten Numerals, Image Analysis and Processing", Lecture Notes in Computer Science, vol. 5716, **(2009)**, pp. 374-383.
[8] A. Lawgali, A. Bouridane, M. Angelova and Z. Ghassemlooy, "Handwritten Arabic Character Recognition: Which Feature Extraction Method", International Journal of Advanced Science and Technology, vol. 34, **(2011)**, pp. 1-8.
[9] A. Al-Haj, "Combined dwt-dct digital image watermarking", Journal of Computer Science, , vol. 3, no. 9, **(2007)**, pp. 740-746.
[10] E. El-Sherif and S. Abdleazeem, "A Two-Stage System for Arabic Handwritten Digit Recognition Tested on a New Large Database", International Conference on Artificial Intelligence and Pattern Recognition, Orlando, Florida, USA, **(2007)**, pp. 237-242.
[11] A. Lawgali, "An Evaluation of Methods for Arabic Character Recognition", International Journal of Signal Processing, Image Processing and Pattern Recognition, vol. 7, no. 6, **(2014)**, pp. 211-220.
[12] M. Jiansheng, L. Sukang and T. Xiaomei, "A digital watermarking algorithm based on dct and dwt", In Proceedings of the 2nd International Symposium on Web Information Systems and Applications, Nanchang, China, **(2009)**, pp. 104-107.
[13] Z. Razak, N. Ghani, E. Tamil, M. Idris, N. Noor, R. Salleh, M. Yaacob and Z. Yuso, "Off-line jawi handwriting recognition using hamming classification", Information Technology Journal, vol. 8, **(2009)**, pp. 971-981.
[14] J. AlKhateeb, R. Jinchang, J. Jianmin, S. Ipson and H. El-Abed, "Word-based handwritten Arabic scripts recognition using dct features and neural network classifier", in 5th International Multi-Conference on Systems, Signals and Devices, **(2008)**, pp. 1–5.
[15] A. Jain, M. Jianchang and K. Mohiuddin, "Artificial neural networks: a tutorial", Computer, vol. 29, no. 3, **(1996)**, pp. 31–44.
[16] M. Parvez and S. Mahmoud, "Arabic Handwritten Alphanumeric Character Recognition using Fuzzy Attributed Turning Functions", First International Workshop on Frontiers in Arabic Handwriting Recognition, **(2010)**, pp. 9-14.
[17] J. AlKhateeb and M. Alseid, "DBN – Based learning for Arabic Handwritten Digit Recognition Using DCT Features", 6th International Conference on CSIT, **(2014)**, pp. 222-226.
[18] A. Lawgali, "A Survey on Arabic Character Recognition", International Journal of Signal Processing, Image Processing and Pattern Recognition, vol. 8, no. 2, **(2015)**, pp. 401-426.

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