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An Accurate Handwritten Digits Recognition system Based on DWT and FCT

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Abstract

In this paper an accurate Indian handwritten digits recognition system is proposed. The system used three proposed method for extracting the most effecting features to represent the characteristic of each digit. Discrete Wavelet Transform (DWT) at level one and Fast Cosine Transform (FCT) is used for features extraction from the thinned image. Besides that, the system used a standard database which is ADBase database for evaluation. The extracted features were classified with K-Nearest Neighbor (KNN) classifier based on cityblock distance function and the experimental results show that the proposed system achieved 98.2% recognition rate.

Keywords: Handwritten digit, DWT, FCT, KNN, FCM.

نظام دقيق لتميز الارقام المكتوبة بخط اليد مبنيه على اساس DWT و FCT

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الخلاصة

في هذا البحث تم اقتراح نظام دقيق للتعرف على الأرقام الهندية المكتوبة بخط اليد. يستخدم النظام ثلاثة طرق مقترحة لاستخراج السمات الأكثر تأثيرا لتمثيل كل رقم. تم استخدام DWT في المستوى الأول و DCT لاستخراج الميزات من الصورة المنحفة. وبالإضافة إلى ذلك، استخدم النظام قاعدة بيانات قياسية هي قاعدة بيانات ADBase لغرض التقييم. تم تصنيف الخصائص المستخرجة من قبل المصنف KNN بأستخدام دالة المسافة cityblock والنتائج التجريبية تبين أن النظام المقترح حقق معدل تعرف 98.2٪.

1. Introduction

Recently, there are great need for handwritten digits recognition system because of the wide spread of electronic devices that facilitate the acquisition and archiving of documents, produces growing numbers of paper documents that are converted into electronic form [1].The purpose of the recognition of writing is to transform a written text into a machine-readable representation easily reproducible by a word processor. This task is not trivial because the words have an infinity of representations because each person produces a writing, the differences in layouts and complexity of the handwritten. Depending on the type of writing that a system must recognize (manuscript, cursive or printed), the

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operations to be carried out and the results vary significantly. The proposed work of this paper focuses on the recognition the sequences of handwritten digits [2].

2. Literature Review

There are many proposed systems used to recognize the handwritten digits based on various techniques, which reviewed in the following:

❖ Omid et al. [3] proposed a system for recognize the handwritten Arabic digits using 80,000 handwritten digit images.Support Vector Machine (SVM) has been used for classification. Besides, Fourier transform is used for extraction the required features.

❖ Bouchra et al. [4] used a Discrete Cosine Transform (DCT) to extract features of the handwritten digits in order to develop a digit recognition system. Authors used MNIST database for evaluation and SVM for classification purpose.

❖ Ravi et al. [5] proposed a recognition system based on structural and statistical features for recognize the handwritten digit using K- Nearest Neighbor classifier.

❖ Diego et al. [6] introduced a new technique for handwritten numerals recognition using on Wavelet transform for features extraction and Artificial Neural Networks (ANN) for classification.

❖ Seyyed et al. [7] have introduced an Arabic/Farsi handwritten digit recognition based on Histogram of Oriented Gradient (HOG) and Chain Code Histogram (CCH). Besides, the SVM was used for classification and HODA handwritten digit dataset which consist of 60000 and 20000 training and test samples for evaluation the proposed system [8].

3. Genaral Concepts in Reognition System

A theoritecal bachground of the standard database,methods and techniques that used in the proposed system are explained here in details.

3.1 Database

In each recognition system a standard database is needed, therefore ADBase database [9] is used. The database contains 70,000 handwritten digits images, which can be written by 700 different writers. The ADBase has two sets for evaluation, used (60,000 digits for training the system and 10,000 digits used for testing). A samples of the ADBase database are illustrated in Figure-1.

Figure 1-Database Samples of ADBase.

3.2 Fuzzy C-Mean (FCM) Clustering

Fuzzy c-means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters. There are two main processes for Fuzzy c-means clustering which are: the calculation of cluster centers and the mentioning of points to these centers using Euclidian distance. In order to make the cluster centers are stable, the process is repeated. For each item of the data for the clusters FCM assigns a membership value within a range of 0 to 1. So it combines the fuzzy set's concepts of partial membership and forms overlapping clusters to support it. [10]

3.3 Zhang-Suen Algorithm

Zhang-Suen algorithm is fast parallel iterative thinning technique where every unwanted pixels are deleted after identify the whole wanted pixels. Zhang-Suen use 3 X 3 window as shown in Figure-2 cantered at pixel I(i,,j) of an image I and define connectivity number that represent the number of 0 to 1 transitions in a clockwise direction from pixel P9 back to itself [11].

P9 (i-1,j-1)	P2 (i-1,j)	P3 (i-1,j+1)
P8 (i,j-1)	P1 (i,j)	P4 (i,j+1)
P7 (i+1,j-1)	P6 (i+1,j)	P5 (i+1,j+1)

Figure 2-Zhang-Suen use 3 X 3 Window.

Zhang-Suen algorithm consist of two sub-iterations:
First sub-iteration:A pixel I(i,j) is deleted if the following conditions are satisfied:
1. Its connectivity number is one.
2. It has at least two black neighbours and not more than six.
3. At least one of I(i,j+1), I(i-1,j), and I(i,j-1) are white.
4. At least one of I(i-1,j), I(i+1,j), and I(i,j-1) are white.

Second sub-Iteration: A pixel I(i,j) is deleted if the following conditions are satisfied:
1. Its connectivity number is one.
2. It has at least two black neighbours and not more than six.
3. At least one of I(i-1,j), I(i,j+1), and I(i+1,j) are white.
4. At least one of I(i,j+1), I(i+1,j), and I(i,j-1) are white.

The algorithm is stopped, if at the end of either sub-iteration there are no pixels to be deleted [11].

3.4 Discrete Wavelet Transform (DWT)

DWT method is used to extract the image features. DWT have four level of decomposition. These levels are the Low Pass Ffilter (LPF), and High Pass Filter (HPF),may be found at each level and to each row applied. Or column of the image to decompose this into one low-frequency sub-band (LL) and three high frequency sub-bands (LH, HL, HH) to be used as features [12]. Figure-3 shows the one level DWT.

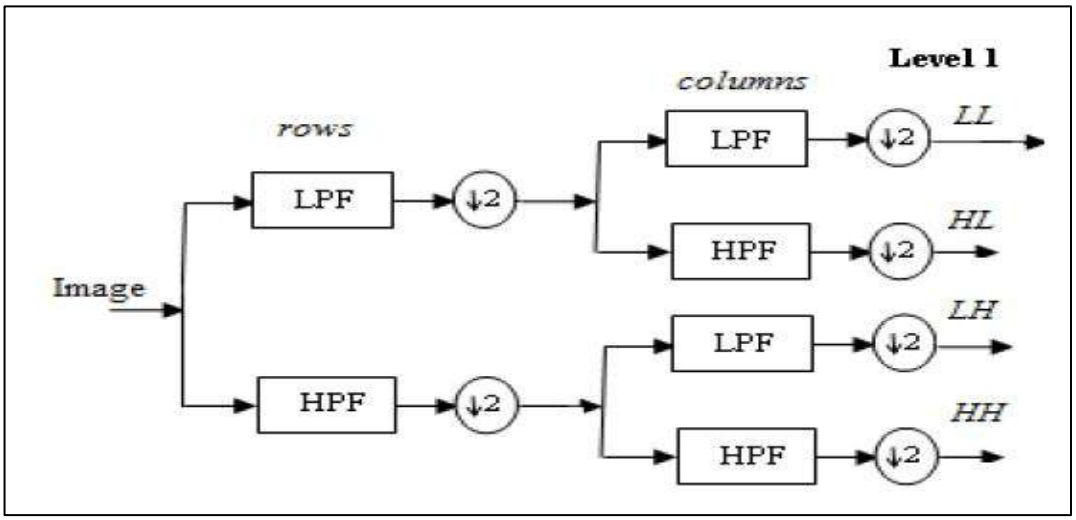

Figure 3-One Level DWT.

Wavelet transforms has two common types, can be applied, which are Haar and Biorthogonal. Each of them has its particular features. Based on experiments results, using Haar transform in handwritten

recognition gives the best results have been achieved. In the coefficients of the low frequency (LL), which be closed to the original image containing most image details, therefore these coefficients used in several works to the features detected [13].

3.5 Fast Cosine Transform (FCT)

Makhoul [14] proposed a fast computation of the Discrete Cosine Transform (DCT) based on the Fast Fourier Transform (FFT) .By taking the Discrete Fourier Transform (DFT) of a 2N-point even extension of the signal the DCT of an N-point real signal could be derived. Using only an N-point DFT of a reordered version of the original signal, with a resulting saving of ½ the same result may be obtained. If FFT is used to compute the DFT, the result is a fast cosine transform (FCT) that can be computed using on the order of N log2 N real multiplications. FCT had an effecint used in features recognition stage [15].

3.6 K-Nearest Neighbors (KNN)

The K Nearest Neighbor is a classification technique use vectors in a multidimensional feature space, each with a class label as training samples which are stored at the training phase. In a classification context of a new observation X, the basic idea is simply to vote nearest neighbors of this observation. X has a class is determined according to the class majority among the K nearest neighbors of the observation X. To find the nearest K of a given rank the Euclidean distance has been used. The following steps are illustrated the KNN process[16].

1) Define k (integer number)
2) Find the distances between the *x test* and xi using Equation1.

$$d(\mathbf{x}_i, \mathbf{x}_j) = \sqrt{\sum_{k=1}^{d} (x_{ik} - x_{jk})^2} \quad (1)$$

naller distances
4) Count these k obseravtions in each class, determining the correspondents classes.
5) Choosing the most represented class using Equation2.

$$class(X_{test}) = argmax\, X_k \sum_{xj \in KNN} d(x_{test}, x_j) \quad (2)$$

Furthermore, other common distance measures of KNN are hamming and cityblock which shown in Equations 3 and 4 respectivly.

$$D_H = \sum_{i=1}^{k} |x_i - y_i| \quad (3)$$

$$D_C = Max(\sum_{i=1}^{n} |x_i - y_i|) \quad (4)$$

The main advantage of this algorithm is its simplicity and the fact that it does not require learning. It is associated with a distance function and a choice function of the class in terms of the classes of the nearest neighbors, who is the model. The KNN then fall into the category of non-parametric models. The introduction of new data can improve the performance of the algorithm without require the reconstruction of a model. This is a major difference with algorithm such as neural networks (NN)[17].

4. The Proposed Work

The proposed digit recognition system used ADBase database and has several major steps which are: preprocessing, features extraction, classification and recognition. The input to the system is an image of handwritten Indian digits, which enter into preprocessing stage of the proposed system. After that, the system extract a features for each handwritten Indian digit and classify these handwritten Indian digits based on their desired class labels. The last step of the system is to recognize the desired editable Indian digit based on the input image. Figure-4 illustrated the main steps of the proposed Indian handwrittien recognition system.

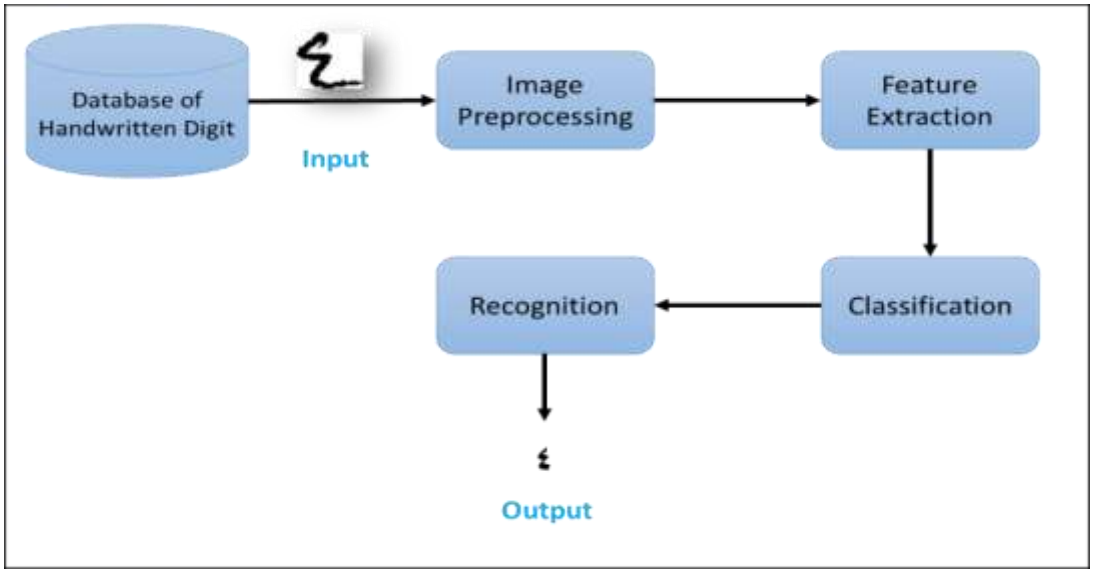

Figure 4-Main Steps of the Proposed System.

4.1 Preprocessing

Preprocessing is an essential stage of any recognition system which performed after the acquisition process. The preprocessing is designed to prepare the image of the route to the next stage of analysis. It is essentially to reduce the noise superimposed data and keep as much as possible significant information as presented. The preprocessing of the proposed system, has four steps which are: image binarization, image thinning, image cropping and image scaling as shown in Figure-5.

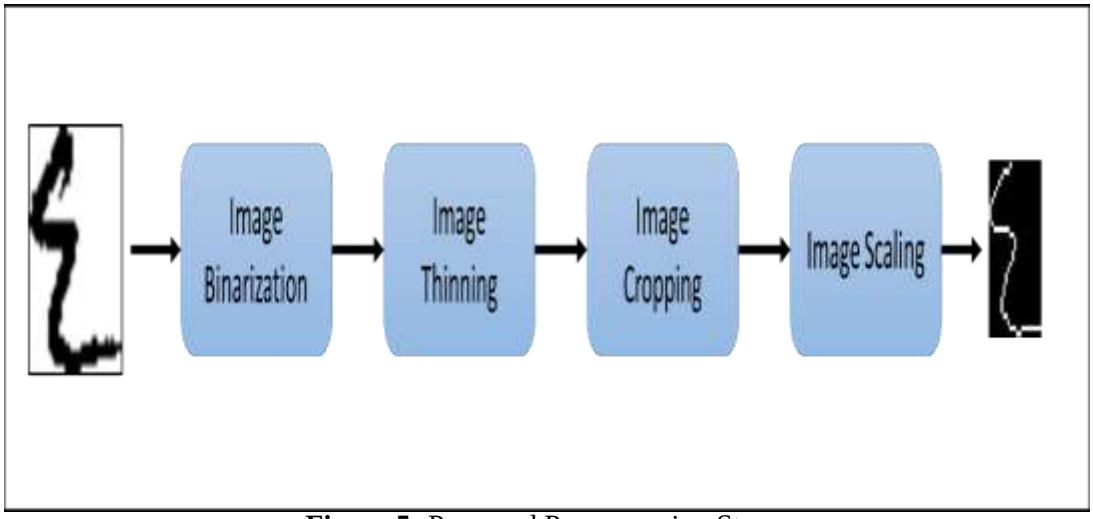

Figure 5- Proposed Preprocessing Stage.

4.1.1 Image Binarization

In order to convert the gray image into a binary image the binarization process is used. Binary image is composed of two values 0 and 1, which make the image simple and easy to process. In the proposed system FCM clustering method is used for binarization process. In addition, two clusters are selected for FCM one for the background (black) and the other for the foreground (white). The output binary image after applying the FCM method illustrated in Figure-6.

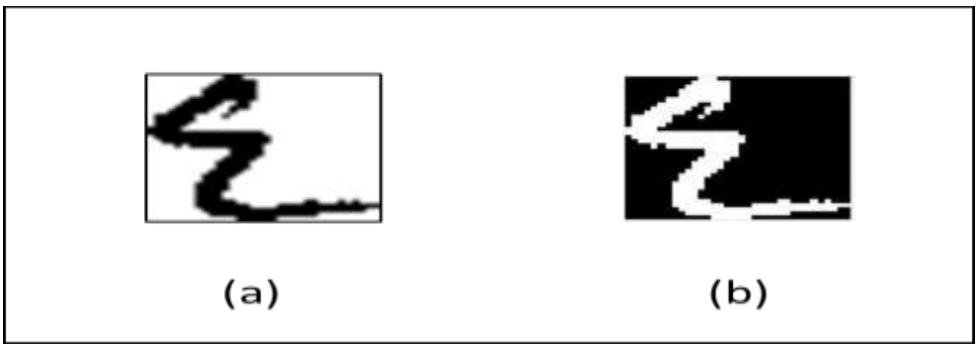

Figure 6- Image Binarization. (a) Original Image, (b) Binary Image.

4.1.2 Image Thinning

Thinning algorithm used to detect the object skeleton in the binary image. The object skelton is represet the image object in the less possible number of pixels. The most common thinning algorithm that works better for handwritten recognition is Zhang-Suen which is used in the proposed system and the result of applying this algorithm shown in Figure-7.

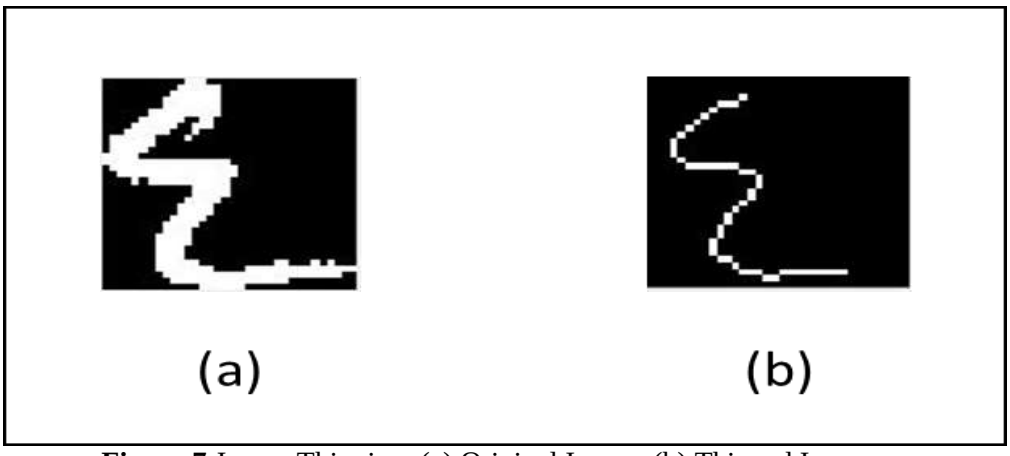

Figure 7-Image Thinning :(a) Original Image, (b) Thinned Image.

4.1.3 Image Cropping

Most of the image in ADBase database has unwanted spaces around the handwritten digits. These spaces represented by value (0) and do not give any information about the digits. Besides, it makes the features extraction methods take long time to process and extract undesired features from these locations. Therefore, image cropping process in the proposed system is used to crop only the required object from the image and eliminate the unwanted spaces without effecting the digit in the original image as shown in Figure-8.

Figure 8- Image Cropping: (a) Original Image, (b) Cropped Image.

4.1.4 Image Scaling

The images of handwritten digits in the ADBase database have various sizes and resolutions.The recognition systems are sensitive to small variations in the size and position as is the case in matching templates and correlation methods. Scaling of images size seeks to reduce variations between images due to the size of handwritten digit to improve the performance of the recognition. Therefore, in the proposed system and after many experiments all the images are scaled into size several sizes and by experments the best tested size was 32x32. An example of the scaling process is shown in Figure-9.

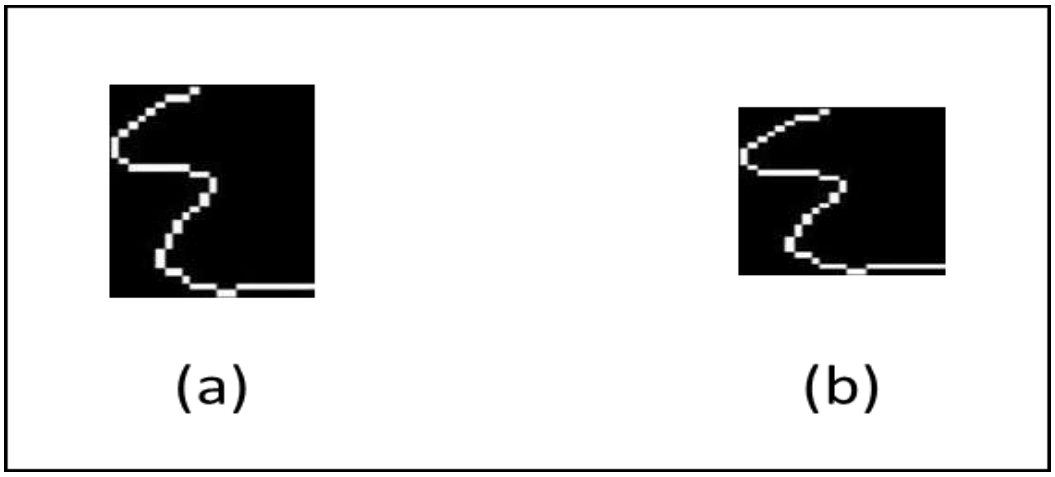

Figure 9- Image Scaling: (a) Original Image, (b) Scaled Image.

4.2 Extraction of Features

In the extracted feature the digit image can be converted into a set of vectors to be passed onto the classifier in order to classify it. extracted features should be essential to show features of each digit and make it different from another. Various features extraction techniques are used in various applications. In this paper, three types of features based on DWT and FCT are extracted for the handwritten digits.

Each scaled digit image in this paper is decomposed by the Haar wavelet into one level, and to extract the features of the digits the low frequency coefficients (LL) is used, as shown in Figure-10.

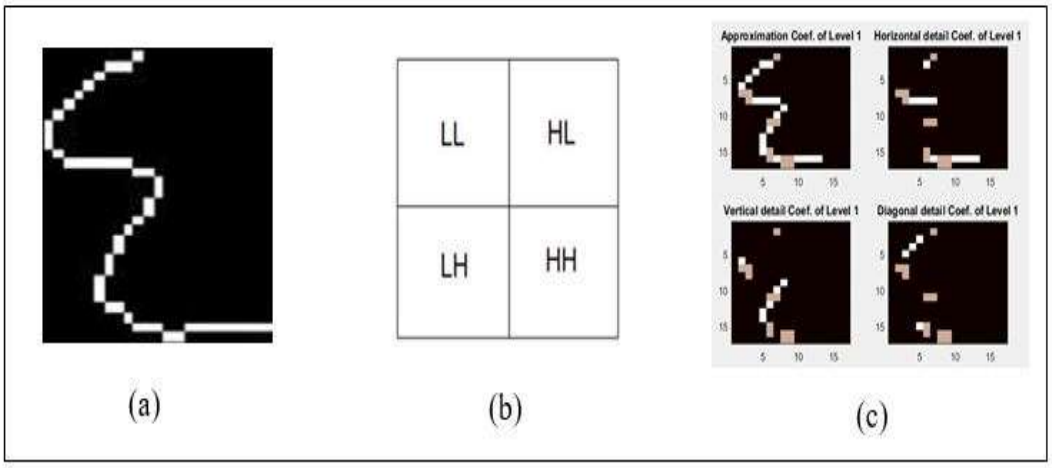

Figure 10- DWT process: (a) Input image, (b) Decomposition, (c) Decomposed Image.

The LL coffecinets are the most clos part inot the original image which cotaines the most details about the handwrittien digit in the image. In the proposed system LL coffecinets are used to extract the required features by taking the first 50 coffecints in zizag order. After that, the obtained coffecints are saved in one dimention array that used as a features vecter to represent the handwrittien digit image. The main steps of extracting DWT features are illustrated in Algorithm 1.

Algorithm 1: DWT Features **Input:** Thinned Image **Output:** Features Vector
Step1: Read the input image (I) \\ Thinned image **Step2**: Apply the DWT Haar decomposition at one level **Step3**: Get only the low frequency coefficients (LL) from DWT result **Step4**: Obtain the first 50 cofficints of LL in zizag order **Step5**: Save the obtained results into one dimension array \\ Feature Vector **Step6**: Return (Feature Vector)

In the proposed system the thinned image that obtained from the preprocessing stage divided first into four equivalent blocks as in Figure-11.

Figure 11- Blocks Division.

Furthermore, the FCT is applied for each block in order to get the DCT coefficients. After that, the Standard Division (SD) and Entropy (En) are computed for the low frequency coffecinets and the results will be used as a features. The obtained features are two for each block, which will be collected for the all blockes and saved in on dimention array that represent the features vector for the input handwrittien image. The implementation of the proposed features extraction method based on FCT is illustrate in Algorithm 2.

Algorithm 2: FCT Features **Input**: Thinned Image **Output**: Feature Vector
Step1: Read the input image (I) \\ Thinned image **Step2**: Divide the input image into four blocks **Step3**: Apply FCT for each block **Step4**: Find the SD and En for low frequency coffecinets in each FCT result **Step5**: Combine the obtained SD and En results into one dimension array \\ Feature Vector **Step6**: Return (Feature Vector)

In order to obtain a better recognition results, a proposed features extraction approach is used. The proposed approach uses both DWT and FCT to extract the desired features from the input handwritten images. First of applied for the whole thinned image. Thus, the DWT is applied on the FCT results to extract the required features. The implementation of the third proposed features extraction method are shown in Algorithm 3.

Algorithm 3: Proposed Features **Input**: Thinned Image **Output**: Feature Vector
Step1: Read the input image (I) \\ Thinned image **Step2:** Apply FCT on thinned image (I) **Step3:** Apply DWT on the FCT coffecints **Step3**: Get only the low frequency coefficients (LL) from DWT result **Step4**: Obtain the first 50 cofficints of LL in zizag order **Step4:** Accumulate the results into one dimension array \\ Feature Vector **Step5:** Return (Feature Vector)

4.3 Classification

In the complete process of a pattern recognition system, the classification plays an important role in pronouncing on the belonging of a form to a class. The idea of classification is to attribute an example (a form) not known to a predefined class from the description into parameters of the form. In the proposed system, K-Nearest Neighbors (KNN) is employed for classification by assign each digit into its desired class label. Figure-12 ilustrated the classification process of the proposed system.

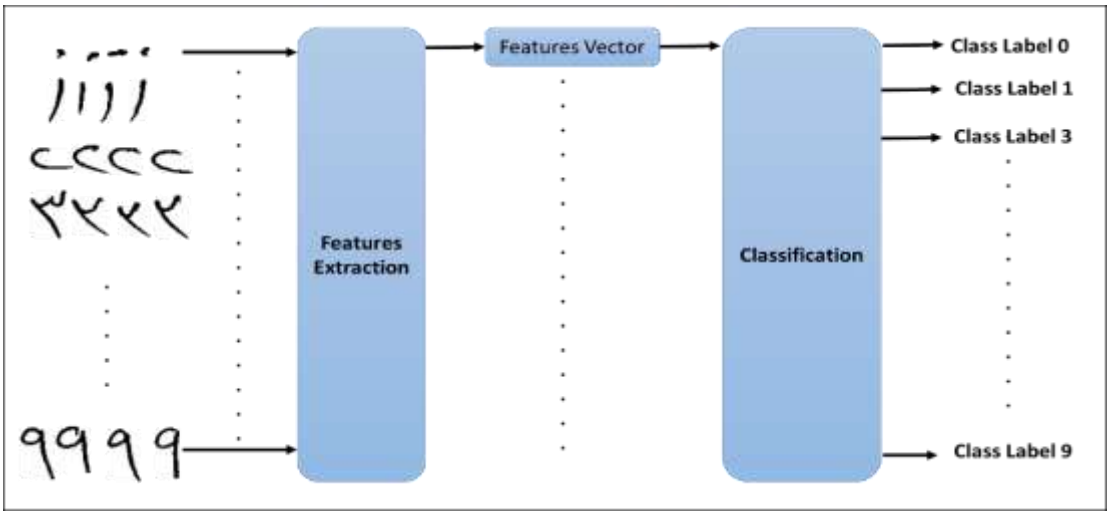

Figure 12- Digits Classification.

4.4 Recognition

Recognizing the desired Indian digits is consider the last step of the proposed system. The output of KNN are a class labels that represent the Indian digits. These class labels then passed into an Indian index that contains the editable Indian digits for matching and to be displayed for the user in the system GUI. Thus, according to the class labels of the classification process the editable inndian number that match the desired class label as in Figure-13 will be displayed for the user.

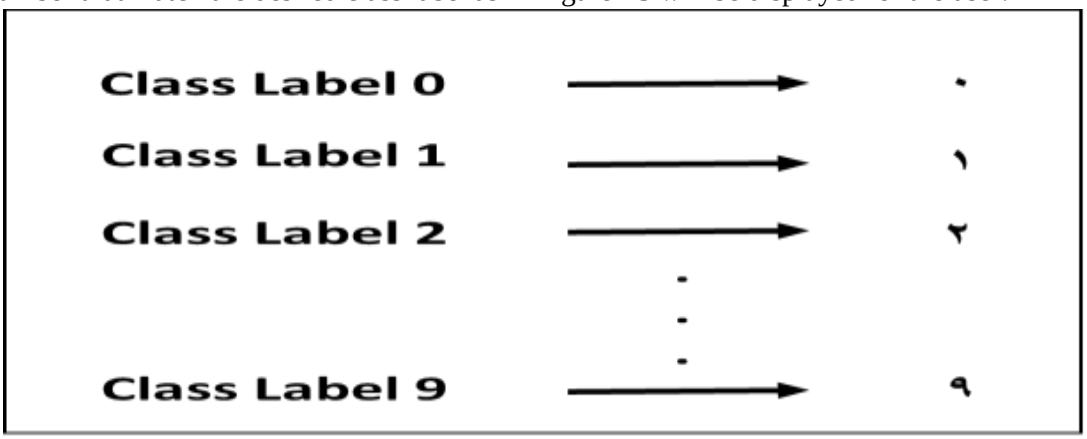

Figure 13-Digits Recognition.

5. Experimental and Discussions

Matlab 2016a is used for implementing the proposed system. The experiments are accomplished on an Intel Core i7, 64 bit Window Operating System, 2.50 GHz processor and 6GB RAM. However, in the proposed system different distance functions of KNN are used. KNN is commonly used with euclidean, hamming and cityblock functions. A multiclass KNN classification has been used in the proposed system and it achieved a very high recognition accuracy using the cityblock function. Table-1 shows the accuracy rate of applying the three kernels of KNN classifier. The results show that, the cityblock function gives the best accuracy rate.

Table 1-Comparison Recognition Results of Different KNN Distance Functions.

KNN distance functions	Euclidean	Hamming	Cityblock
Accuracy	97.8%	97%	**98.2%**

Moreover, the proposed system used 70% of ADBase database for training and 30% of the database for testing the system. The proposed system achieved a satisfied recognition results within the three proposed features extraction algorithm and the best obtained results was using algorithm 3 as shown in Table-2.

Table 2- Recognition Results of Different Features Extraction Methods.

Features	**Accuracy**
DWT	94.8%
FCT	96%
DWT & FCT	**98.2%**

In another hand, the recognition results of the proposed system achieved are better than obtained results of the existing system which applied for the ADBase database. The comparison results of the proposed system and the existing digit recognition systems are illustrated in Table-3.

Table 3- Recognition Results of The Existing System and The Proposed One.

Author	**Features Extraction Method**	**Classifier**	**Accuracy**
J. Al Khateeb [22]	DCT	DBN	85.26%
S.A.Mahmoud [23]	Directions and length feature	FATF	97.18%
A. Lawgali [24]	DCT	ANN	97.25%
Proposed system	DWT & FCT	KNN	**98.2%**

6. Conclusion

In this paper an accurate handwritten digit recognition system based on DWT and FCT for extract the most appropriate features of the digits handwritten has been proposed. The proposed system used ADBase database for evaluation. Several preprocessing steps are applied for the handdwrittien digit images that leads to an efficient results. The system achieved a satisfied recognition rates using cityblock distance of KNN classifier. The experiments were carried out showed that the proposed system achievements are better than the existing systems.

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