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Offline signatures matching using haar wavelet subbands

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ABSTRACT

The complexity of multimedia contents is significantly increasing in the current world. This leads to an exigent demand for developing highly effective systems to satisfy human needs. Until today, handwritten signature considered an important means that is used in banks and businesses to evidence identity, so there are many works tried to develop a method for recognition purpose. This paper introduced an efficient technique for offline signature recognition depending on extracting the local feature by utilizing the haar wavelet subbands and energy. Three different sets of features are utilized by partitioning the signature image into non overlapping blocks where different block sizes are used. CEDAR signature database is used as a dataset for testing purpose. The results achieved by this technique indicate a high performance in signature recognition.

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1. INTRODUCTION

Lately a major amount of research effort is being dedicated in developing the algorithms and techniques related to signatures field. Behavioral, physiological and psychological characteristics are used in biometric systems for identifying the individual. Handwritten signatures are a type of the behavioral characteristics, although with the development of other biometric characteristics but the signature remain quite important [1]. Therefore, signature is an important guide to validate a document handwritten signature of a person which recognized by signature verification [2]. Despite the great development in knowledge-based systems, handwriting signatures remain of particular importance and this may be due to the fact that those systems require user guides in the form of information, often a password and id, to verify the identity of the individual, in addition to the above, the signature cannot be stolen or missing [3]. Methodology of signature recognition comprises four general steps which are: data acquisition, pre-processing, feature extraction and matching. There are two categories in handwritten signatures according to the method of data acquisition: on-line (dynamic approach) and off-line (static approach).

Any person may use letters or symbols or a combination of both to represent the signature. Accordingly, the signature must be treated as an image [4]. In offline mode camera and scanner are used to obtain the images of the signatures from a paper, in such situation noisy signatures are acquired compared to these in on-line mode [5]. Many studies have been introduced as literature. Hazem *et al.* [6] presented a system for verification the off-line signature. The system comprises of four steps: preprocessing step, registration of signature, feature extraction and verification step. Discrete wavelet transform (DWT) was used in this system to extract the feature from signature and mathematical formulae with logical operations were utilized in verification step. The system obtained good measures for verification [6].

Doroz *et al.* [7] introduced a new method for verification the handwriting signatures. In this method the signature was described by creating a complex characteristic for each signature, the created characteristics were based on dependencies analysis between the dynamic characteristics which registered in the tables. Complex characteristics were utilized to create vectors for describing characteristics, by using the suggested measures, the elements of vectors were computed. Evaluated the similarity between the signatures had been accomplished by determining the similarity of corresponding vectors of the compared signatures. 96.67% was the results obtained by this method [7].

Malik and Arova [3] presented a method for signature recognition. Euler number was used to study the signatures of various people. Their adopted method consists of three phases. In the first phase, two sets of feature vectors were generated by extracting the features of training signatures dataset and features of testing signatures. In the second phase, using Manhattan distance classifier to compare between the training signature feature and the set of the feature of the testing signatures. The result of recognition was displayed to the user in the last phase. The train and test data which used in dataset had a little change but the suggested method can be extended to dataset which had a great change of the train and test data [3].

Hedjaz *et al.* [8] introduced an approach for recognition the offline signature. Binary statistical image features (BSIF) and local binary patterns (LBP) were used to extract the features. Two public datasets were used: MCYT-75 and GPD-100. By utilizing a K-nearest neighbor (KNN) classifier a performance of recognition reaches 97.3% for MCYT-75 and 96.1% for GPDS-100 [8]. The main contribution of this paper as follow: to introduced an efficient technique for offline signature recognition depending on extracting the local feature by utilizing the haar wavelet subbands and energy.

2. PROPOSED SYSTEM

This work aims to develop an efficient technique for offline signature recognition depending on extracting the local feature by utilizing the haar wavelet subbands and energy. The proposed approach is composed of the following steps: The layout of the suggested signature system is appeared in Figure 1. The flow of the proposed work is as follows: the system consists of three main phases: pre-processing phase, feature extraction, binarization and matching, the details of each one is introduced in the next sections.

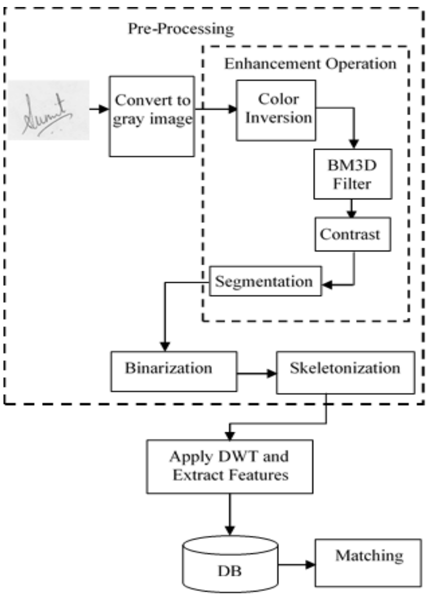

Figure 1. The layout of system model

2.1. Pre-processing phase

The preprocessing phase consists of some steps, due to the noise that occurs in offline signatures mode, pre-processing is an essential point to start a real treatment phase where the importance of pre-processing lies in getting rid of the visual and unwanted information in the signature form and establishes to prepare for successful feature extraction.

2.1.2. Load signature image stage

The pre-processing first involves loading and preparing the signature image by obtaining a gray-scale image (GI) from a BMP image (I), loads an image into a variable of type of image. Four types of images (.gif, .jpg, .tga, .png) images may be loaded. To load correctly, images must be located in the data directory of the current sketch. The gray-scale image should enhance to gain the best results as clarify below:

2.1.3. Enhancement stage on signature image

Four steps are applied in order to enhance the signature image and obtain a clearer form:

– Inversion the color

As mentioned earlier, the signature image which obtained by a camera or scanner is more noisy than others image in on-line situation approach and accordingly color inversion process is utilized to allocate the required region by specifying only the important data (signature's part) and cancelation the unwanted data surrounding to the signature. By moving $(n * n)$ window on the gray-scale signature image and at each instance position in the window the threshold is applied as described in (1):

$$\overline{GI}(i,j) = \begin{cases} mean - GI(i,j) & if\ GI(i,j) < mean \\ 0 & otherwise \end{cases} \quad (1)$$

where $\overline{GI}$ is the signature image after inversion it's color.

– Removing the noise

Noise reduction is an essential step in image processing due to its importance in obtaining better results, the block matching with three-dimensional filtering (BM3D) denoising is used in this step. Many studies shown that the BM3D filter is very important in term of noise reduction due to its results comparing with other filters [9, 10]. The implementation of this filter is explained in detail in [11]

– Contrast

The subjective criteria of images are important for human visualization, so an appropriate contrast in an image is desired to make the signature more distinct from the background and other objects. Visual properties of an image are enhanced by applying a method proposed in [12].

In this method a global mean G_{mean} is computed by applying average filter on the whole input image while local meansL_{mean} are computed by applying the same filter on each 3×3 block in an image. By applying the transformation in (2):

$$O(i,j) = N(i,j) + [L_{mean} - G_{mean}] \quad (2)$$

where $O(i,j)$ acts the pixels of the image after contrast process and $N(i,j)$ acts the pixels of the image after applying BM3D filter.

– Segmentation

Focusing on the signature area in the image and neglecting the remaining unimportant parts is the primary goal at this step. This is achieved by detecting each row and column, then removes these rows and columns which don't contain the signature's information. Recently, more attention paid on the unsupervised image co-segmentation approach, where the segments are forced to be consistent across a collection of similar images. Many natural image collections contain similar or related objects. For instance, photo collections of a particular theme.

2.1.4. Binarization

Image binarization is one of the basic pre-processing steps that leads to a considerable reduction in the amount of information that is undergo to further analysis, which leads to faster implementation and this is very useful in applications which required the recognition of the shape rather than the color analysis [13]. The most important aspect of this operation is to find the appropriate threshold value, assigning a single value to threshold and apply this value to whole image is called global binarization technique [14]. In this work the best threshold value is determined by test and the output of binarization operation is a signature image contain 1's and 0's for all pixels according the following in (3):

$$b(i,j) = \begin{cases} 1 & if\ f(i,j) \geq threshold \\ 0 & otherwise \end{cases} \quad (3)$$

2.1.5. Morphological operation

Thinning is a type of morphological operation; the goal of thinning process is to find the skeleton of on object. A skeleton that finds the fundamental topology and the information's shape of the required object in a simple form is very important to hold different problems. To achieve the morphological operation, Zhang Suen algorithm is applied because it's fastest and the implementation of this algorithm is simple; after the binary image is used as input, decreases the pixels and represent the skeleton of the signature in one-pixel width [15, 16].

2.2. DWT and feature extraction phase

The wavelet is an efficient multi-resolution technique for sub-band decomposition, and this is performed by implementing a digital filtering [17-19]. The low and high pass filters are used to obtain the approximation information and detail information respectively [17]. DWT utilizing filtering and sub-sampling to decompose the signature image in multi scales which leads to reveals the redundancies in many scales.

2.2.1. Haar wavelet transform

Haar wavelet transform is used to extract the local features in the signature image. One of the important aspect of haar wavelet transform is to find corners and contours [18-21]. The reason for choosing the haar wavelet in this work is due to its being required low computational cost, fast and each sub bands (detail) contains a special edges type [22-26].

2.2.2. Applying DWT and find the features

Four sub-bands are generated after performing 2-D wavelet transform. the low-low sub-band denoted (LL) containing the approximation of the enhanced input image, where the details of the same image in different directions are contained on three sub-bands (high-pass) where (HL), (LH) and (HH) for horizantal, vertical and diagonal direction respectively. Different block sizes are used in this work and three methods are adopted in order to find the vector for the required features by using the (4-8) as shown in Figure 2.

$$Energy = \sum_{x=xs}^{xe-1} \sum_{y=ys}^{ye-1} wavelet(x,y)^2 \tag{4}$$

$$p_E = Energy(LH) + Energy(HL) + Energy(HH) \tag{5}$$

$$Norm = \sum_{x=xs}^{xe-1} \sum_{y=ys}^{ye-1} |wavelet(x,y)|^{0.5} \tag{6}$$

$$P_N = Norm(LH) + Norm(HL) + Norm(HH) \tag{7}$$

$$Norm = \sum_{x=xs}^{xe-1} \sum_{y=ys}^{ye-1} |wavelet(x,y)|^{0.75} \tag{8}$$

2.3. Matching phase

In this phase, generation of the template from training samples and feature matching are used to obtain the similarity degree between the training samples and entered signatures. Numerical value is the output of matching phase, so high result indicate that the signature sample belongs to the same signature. Normalized mean square differences (NMSD) and normalized mean absolute difference (NMAD) are used to determine the similarity degree.

2.3.1. Generation the template

In order to generate the template a number of signature are utilized for each individual as samples for training. The template of an individual contains all features which extracted from all the training samples. For each person a mean feature vector and concerning standard deviation are kept in data base. The following in (9, 10) are used to calculate the mean and standard deviation.

$$\bar{F}(p_{no}, f_{no}) = \frac{1}{s} \sum_{s_{no}=1}^{s} F(p_{no}, s_{no}, f_{no}) \tag{9}$$

$$\sigma(p_{no}, f_{no}) = \sqrt{\frac{1}{s} \sum_{s_{no}=1}^{s} (F(p_{no}, s_{no}, f_{no}) - \bar{F}(p_{no}, f_{no}))^2} \tag{10}$$

where p_{no} is a person number, s_{no} is a sample number and f_{no} is a feature number, F acts the features vector and s represent the total number of samples.

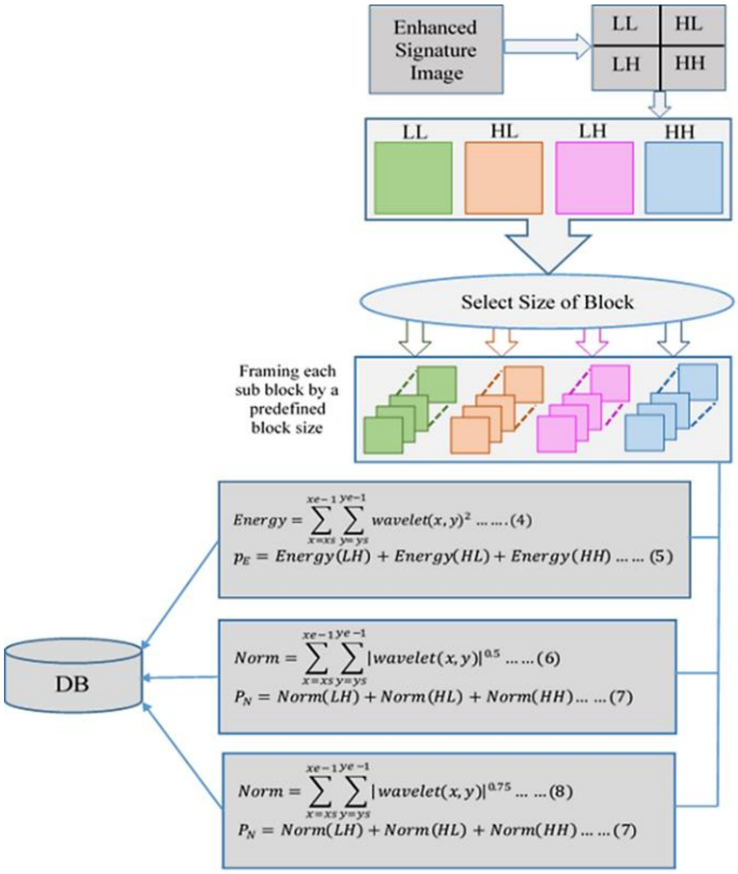

Figure 2. Methods of feature extraction

2.3.2. Features matching

For the purpose of features matching, statistical analysis is used. NMSD and NMAD are adopted to discover the nearest stored match with the given entered signature. Consequently, the output of this stage is to determine whether the signatures samples belong to the same signature or not, in (11, 12).

$$NMSD = (p_{no}, f_{no}) = \sum \left(\frac{F(p_{no}, s_{no}, f_{no}) - \bar{F}(p_{no}, f_{no})}{\sigma(p_{no}, f_{no})} \right)^2 \quad (11)$$

$$NMAD = (p_{no}, f_{no}) = \sum \left| \frac{F(p_{no}, s_{no}, f_{no}) - \bar{F}(p_{no}, f_{no})}{\sigma(p_{no}, f_{no})} \right| \quad (12)$$

3. RESULTS

The performance of the techniques used in this paper was evaluated and compared to other existing techniques. Furthermore, the performance of the efficient technique for offline signature recognition was evaluated in terms of its recognition and compared to other feature selection techniques. Three different sets of features are utilized by partitioning the signature image into non overlapping blocks where different block sizes are used. CEDAR signature database is used as a dataset for testing purpose. All the experiments and the results achieved are presented in this section.

3.1. Performance analysis

The performance of the haar wavelet subbands and energy techniques and the feature extraction techniques was analyzed. From CEDAR database [19] the dataset is utilized in the testing process. The dataset is consisted of 55 persons and twelve signature samples for each person, each signature image is a .bmp file type with 24 bit/pixel. Five features (LL, HL, LH, HH and power) are utilized by applying 1-level decomposition of haar wavelet transform. 21*23 is selected as the size of block with the methods of matching and for one set of features, results are described in Tables 1, 2 and 3.

Table 1. The rate of recognition using the energy with one set of features

Matching Methods	LL	LH	HL	HH	Pow (P_E)
NMAD	88.182	63.636	76.364	55.303	68.182
NMSD	97.727	90.606	93.788	81.970	90.000

Table 2. The rate of recognition using $P_N = 0.5$ with one set of features

Matching Methods	LL	LH	HL	HH	Pow (P_N)
NMAD	67.424	43.788	50.000	39.697	45.000
NMSD	87.121	65.303	70.303	54.242	60.152

Table 3. The rate of recognition using $P_N = 0.75$ with one set of features

Matching Methods	LL	LH	HL	HH	Pow (P_N)
NMAD	69.697	46.061	53.939	41.364	46.667
NMSD	89.394	68.788	74.242	56.364	64.697

Ten features (LL-LH, LL-HL, LL-HH, LL-pow, LH-HL, LH-HH, LH-pow, HL-HH, HL-pow and HH-pow) are the results of combining the two features of haar wavelet transform (two sets of features). The recognition rates are presented in Tables 4 showed the rate of recognition using the energy with two sets of features, Table 5 showd the rate of recognition using $P_N = 0.5$ with two sets of features 5 and 6 by using the matching methods with block size equals to 21*23. Table 6 show the rate of recognition using PN = 0.75 with two sets of features

Table 4. The rate of recognition using the energy with two sets of features

Matching Methods	LL-LH	LL-HL	LL-HH	LL-Pow (P_E)	LH-HL	LH-HH	LH-Pow (P_E)	HL-HH	HL-Pow (P_E)	HH-Pow (P_E)
NMAD	82.4242	88.1818	79.2424	81.6667	83.1818	66.0606	70.7576	69.6970	75.4545	61.9697
NMSD	98.1818	97.5758	97.1212	96.3636	98.1818	93.0303	94.3939	94.0909	93.7879	88.0303

Table 5. The rate of recognition using $P_N = 0.5$ with two sets of features

Matching Methods	LL-LH	LL-HL	LL-HH	LL-Pow (P_N)	LH-HL	LH-HH	LH-Pow (P_N)	HL-HH	HL-Pow (P_N)	HH-Pow (P_N)
NMAD	57.7273	60.6061	53.4848	57.1212	50.7576	43.3333	45.7576	45.4545	47.2727	42.5758
NMSD	81.8182	83.3333	78.9394	79.6970	74.0909	63.3333	66.2121	64.8485	68.3333	57.4242

Table 6. The rate of recognition using PN = 0.75 with two sets of features

Matching Methods	LL-LH	LL-HL	LL-HH	LL-Pow (P_N)	LH-HL	LH-HH	LH-Pow (P_N)	HL-HH	HL-Pow (P_N)	HH-Pow (P_N)
NMAD	61.0606	65.6061	56.9697	60.0000	55.4545	44.5455	47.4242	47.2727	50.4545	44.0909
NMSD	86.8182	86.9697	83.1818	84.6970	79.3939	68.0303	69.5455	70.3030	73.1818	61.2121

Also, ten features (LL-LH-HL, LL-LH-HH, LL_HL-HH, LL-LH-pow, LL-HL-pow, LL-HH-pow, LH-HL-HH, LH-HL-pow, LH-HH-pow and HL-HH-pow) are the results of combining three features of haar wavelet transform (three sets of features) and as previous step, by applying the matching methods with block size equals to 21*23 the recognition rates are showed in Tables 7, 8 and 9. All the results above indicates that the best results when using energy, so the Tables 10-12 are allocated to test different sizes for blocks with energy. All the previous results recorded in the three tables showed that 21*23 is the best size to block.

Table 7. The rate of recognition using the energy with three sets of features

Matching Methods	LL-LH-HL	LL-LH-HH	LL-HL-HH	LL-LH-Pow (P_E)	LL-HL-Pow (P_E)	LL-HH-Pow (P_E)	LH-HL-HH	LH-HL-Pow (P_E)	LH-HH-Pow (P_E)	HL-HH-Pow (P_E)
NMAD	86.364	77.576	82.576	80.000	83.939	76.364	75.000	78.030	67.273	69.545
NMSD	98.485	98.030	96.970	97.424	96.667	95.909	96.667	96.818	93.333	93.333

Table 8. The rate of recognition using P_N = 0.5 with three sets of features

Matching Methods	LL-LH-HL	LL-LH-HH	LL-HL-HH	LL-LH-Pow (P_N)	LL-HL-Pow (P_N)	LL-HH-Pow (P_N)	LH-HL-HH	LH-HL-Pow (P_N)	LH-HH-Pow (P_N)	HL-HH-Pow (P_N)
NMAD	57.576	51.667	53.485	54.545	54.848	50.455	46.818	49.242	44.394	45.758
NMSD	81.212	76.970	78.333	77.879	79.091	75.152	69.545	71.515	63.939	64.091

Table 9. The rate of recognition using P_N = 0.75 with three sets of features

Matching Methods	LL-LH-HL	LL-LH-HH	LL-HL-HH	LL-LH-Pow (P_N)	LL-HL-Pow (P_N)	LL-HH-Pow (P_N)	LH-HL-HH	LH-HL-Pow (P_N)	LH-HH-Pow (P_N)	HL-HH-Pow (P_N)
NMAD	61.061	56.364	56.515	57.273	58.788	53.788	50.152	51.970	45.303	47.576
NMSD	85.758	80.606	83.030	81.818	83.636	78.939	75.152	75.606	68.182	69.091

Table 10. The rate of recognition of the one set of features with the energy

Block size	LL	LH	HL	HH	Pow (P_E)
Blk=5×7	73.9394	68.0303	74.5455	58.1818	67.4242
Blk=7×9	79.0909	72.4242	77.4242	61.6667	72.4242
Blk=9×11	85.3030	78.4848	80.3030	65.6061	76.9697
Blk=11×13	89.0909	82.1212	83.9394	68.4848	79.0909
Blk=13×15	92.1212	85.7576	87.2727	70.6061	81.6667
Blk=15×17	95.3030	88.7879	89.5455	74.5455	86.3636
Blk=17×19	95.3030	90.1515	90.7576	74.0909	83.6364
Blk=19×21	96.5152	93.6364	92.8788	82.4242	89.6970
Blk=21×23	97.7273	90.6061	93.7879	81.9697	90.0000

Table 11. The rate of recognition using two sets of features with the energy

Block size	LL-LH	LL-HL	LL-HH	LL-Pow (P_E)	LH-HL	LH-HH	LH-Pow (P_E)	HL-HH	HL-Pow (P_E)	HH-Pow (P_E)
Blk=5×7	77.1212	79.3939	71.8182	72.7273	82.2727	69.6970	73.4848	73.3333	74.8485	65.3030
Blk=7×9	82.5758	83.7879	76.0606	78.3333	86.9697	73.9394	78.3333	77.7273	79.8485	69.8485
Blk=9×11	87.8788	87.4242	82.8788	83.3333	89.3939	78.9394	83.0303	79.3939	81.9697	73.3333
Blk=11×13	91.6667	90.1515	85.9091	86.8182	91.2121	82.4242	85.0000	82.7273	85.6061	75.3030
Blk=13×15	94.3939	92.5758	90.0000	91.2121	94.6970	85.0000	88.9394	87.5758	89.2424	79.2424
Blk=15×17	95.9091	95.1515	93.6364	93.7879	95.9091	87.4242	91.0606	88.7879	91.5152	83.3333
Blk=17×19	96.3636	95.9091	93.3333	94.2424	95.9091	87.7273	90.3030	90.0000	91.0606	80.1515
Blk=19×21	97.7273	96.9697	95.9091	96.2121	97.4242	92.2727	93.7879	92.4242	93.4848	89.0909
Blk=21×23	98.1818	97.5758	97.1212	96.3636	98.1818	93.0303	94.3939	94.0909	93.7879	88.0303

Table 12. The rate of recognition using three sets of features with the energy

Block size	LL-LH-HL	LL-LH-HH	LL-HL-HH	LL-LH-Pow (P_E)	LL-HL-Pow (P_E)	LL-HH-Pow (P_E)	LH-HL-HH	LH-HL-Pow (P_E)	LH-HH-Pow (P_E)	HL-HH-Pow (P_E)
Blk=5×7	82.4242	75.4545	78.3333	75.6061	77.7273	71.9697	79.6970	80.4545	71.9697	73.0303
Blk=7×9	86.3636	80.1515	82.1212	81.0606	82.4242	76.6667	82.8788	84.6970	76.5152	77.8788
Blk=9×11	89.8485	85.7576	84.8485	86.0606	86.0606	82.4242	86.8182	88.0303	81.0606	80.3030
Blk=11×13	91.5152	88.6364	88.3333	88.9394	88.7879	86.0606	89.2424	89.5455	83.3333	82.7273
Blk=13×15	94.3939	92.4242	91.5152	93.0303	91.5152	89.5455	92.2727	92.4242	86.3636	86.8182
Blk=15×17	96.2121	95.0000	94.2424	95.0000	94.2424	92.7273	93.9394	94.3939	88.7879	88.6364
Blk=17×19	96.9697	94.6970	94.6970	95.1515	94.5455	91.3636	94.0909	94.3939	88.4848	89.6970
Blk=19×21	98.0303	96.9697	96.8182	97.1212	96.5152	94.6970	96.2121	96.3636	91.9697	92.1212
Blk=21×23	98.4848	98.0303	96.9697	97.4242	96.6667	95.9091	96.6667	96.8182	93.3333	93.3333

4. CONCLUSION

Offline signature verification is a task that benefits from matching both the global shape and local details an efficient technique for offline signature recognition depending on extracting the local feature by utilizing the haar wavelet subbands and energy was introduced, it consists of three stages. In preprocessing stage, the signature image was enhanced by applying many operation where the features were extracted by utilizing the haar wavelet subbands with energy in feature extraction stage. NMSD and NMAD were used in matching phase, the results indicated a high recognition rate (98.4848) when three sets of feature was used with block size equal to 21*23. The plans for feature include: using another partitioning method like Quadtree. Using different types and shapes for signature.

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