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Handwritten Recognition based on Hybrid ANN and Wavelet Transformation

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Abstract— **This paper provides the application of Artificial Neural Network (ANN) and Wavelet Transformation (WT) into the problem of handwritten character recognition. The Design of a recognition system model that handle this problem based on applying Artificial Neural Network (ANN) of Kohenen ACON type. The feature extraction process made use of WT (the Haar Type). It's used to extract the parametric features of the handwritten characters. The system was implemented using a database of 130 persons, 70 sample from the database were used for training, and the all 130 samples were used for testing the system.The efficiency of the system was tested using the Recognition Rate, and the results were promising**.

Keywords— Handwritten Recognition, Character recognition, ACON Neural networks, simulation, WT.

I. INTRODUCTION

The Character recognition problem (CRP) is widely studied in the pattern recognition (PR) field , because of it's both theoretical value in PR and it's different applications like:
- Automatic processing of post addresses in mail letters,
- Automatic money amounts determination in bank checks,
- Processing and analyzing of handwritten documents [1].

One of the most common divisions between character recognition systems (CRS) lies whether the recognizer focused on handwritten text , or machine printed text [2]. The Handwritten text recognition technique can be further classified into two main classes, based on the way of acquire data by the recognition system (RS), that are :-
- On line RS, in which, data is given to the system as sequence of coordinates (x,y,t), where t is time, and
- Off line RS , where the data is given to the system as a bitmap image typically form a scanner [3].

On the other hand, CRS can be classified according to the recognition level. There are two general approaches:
-The first approach involves the text segmentation into individual characters, and the recognition of each character separately.
- The second approach involves , the text segmentation into words and recognition of each word as complete entity using some global features of the word and using the semantic roles of the language [4].

The advances in the field of handwriting identification and recognition result from a better understanding of the fundamental biophysical and psychophysical processes involved in handwriting generation, and the application of this knowledge to various types of specific systems. The design of a handwriting identification or recognition system is based on the fact that people do not write according to a standard penmanship, and the deviation from the norm is individual dependent [5][6].

This paper treats with handwritten character recognition (HCR) systems in specific way, although we will mentions some of its features as PR system features in general, since HCR systems is PR system in the origin.

This paper contains in addition to section I other four sections. Section II describes the literature survey, while section III provides a description of the handwritten Recognition system (HRS). The Section IV. Section IV provides the proposed the CRS and section V provides the conclusion.

II. LITERATURE SURVEY

The Handwritten character recognition (HCR) proves to be challenging problem due to the large variance the data may exhibit, not only there are changes and distortions from one writer to another, but even for samples produced by the same writer [7] [8].

Researches on HCR have made impressive progress and many systems have been developed. However there is still a significant performance gap between handwritten and machine printed character recognition systems [9]. In fact, several companies have produced low-cost software that can, when used with scanners, read documents of several fonts. However, in spite of many years of research's, optical readers that can recognize handwritten materials at a satisfactory rate are rare. Even if they exist, they typically can read only hand-printed digits that must be legible and consistently placed [10].

Character recognition (CR) comes into picture when various patterns of handwritten or optical characters are to be recognized digitally. Many researchers have proposed different approaches for CR in different languages. In [11] , they have reviewed several CR Techniques. The main important phases of CR include preprocessing, segmentation, feature extraction and classification. Various feature extraction techniques and classification techniques have been surveyed in [12] and an attempt is made to draw a conclusion regarding HCR techniques from the literature survey [13].

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The " Hybrid feature extraction" (HFE) method is proposed for the verification of handwritten numerals [14]. The hybrid features consist of one set of two dimensional complex wavelet transform (2D-CWT) coefficients and one set of geometrical features. As 2D-CWT does not only keep WT's properties of multi-resolution decomposition analysis and perfect reconstruction, but also adds its new merits: its magnitudes being insensitive to the small image shifts and multiple directional selectivity, which are useful for HFE [15]. A two kinds of wavelet features proposed:

- Kirsch edge enhancement based 2D wavelets and
- 2D complex wavelets.

The two sets of hybrid features are congregated by combining them with the geometrical features for the recognition of handwritten numerals. In paper [16] " an approach is presented for Arabic handwritten recognition (HR) of Arabic characters including the beginning characters, ending characters and some of middle characters. The approach utilized the hybrid transform, which consists of two transforms; the WT and the discrete cosine transform (DCT) . The used approach included many steps such as preprocessing, feature extraction and clustering.

The Statistical techniques for off-line character recognition are not flexible and adaptive enough for new handwriting constraints. Offline HCR of English alphabets using a three layered feed forward neural network is presented in [17]**.** The proposed RS describes the evaluation of feed forward neural network (FFNN) by combining four different feature extraction approaches (box approach, diagonal distance approach, mean and gradient operations). The proposed RS performed well on the benchmark dataset CEDAR (Centre of Excellence for Document Analysis And Recognition) [18].

Another issue arises in the context of handwritten text is that of both word and character segmentation, determination of the word boundaries, and which strokes are grouped together to form character [19]. Therefore researchers give three major categories into which " non-cursive text " may be grouped from a segmentation point of view:

- Box mode , characters are written in a predefined boxes.
- Ruled mode, characters and words are written in a predefined lines.
- Unrolled mode, characters and words may be written anywhere on the input surface and may also slope arbitrary.

III. HANDWRITTEN RECOGNITION SYSTEM

Many attempts have been made to make pattern recognition systems (PRS) reaches a level of performance that is close to emulating human capabilities in performing general image analysis functions. research in biological and computational systems continually is uncovering new and promising theories to explain the human visual cognition. However, the state of art in computerized image analysis for the most part is based on heuristic formulations tailored to solve specific problems, for example some machines are capable of reading printed, properly formatted documents at a speeds that are orders of magnitude faster than the speed that the most skilled human reader could achieve. That is, current theoretic and implementation limitations in the field of image analysis imply solutions that are highly problem dependent [20]. The techniques used in pattern recognition systems could be divided into three basic phases:

- low level processing,
- intermediate processing, and
- high level processing.

Although these subdivisions have no definitive boundaries, they do provide a framework for categorizing various processing that are inherent components of an autonomous PRS.

The Wavelet Transform (WT) in image transformation provides information regarding the spatial frequency content of the image. In general, a transformation maps image data into a different mathematical space via a transformation equation. The image in its native bit map representation gives only features that describes the shape of the objects in that image, in other words, only spatial domain details. In some pattern recognition problems, frequency details of the image would serve as features on which recognition will be made on, by using spatial to frequency transformation like Fourier transformation (FT) [21].

The WT can be described as a transform that has basis function that are shifted and expanded versions of themselves because of this, the WT contains not just frequency information but spatial information as well WT function is basically two types of filters, high pass and low pass filters, these filters processes the image in both horizontal and vertical direction and break down it to four sub-bands or sub-sections [22].

A) Classification Based on Neural Network

Generally the classification is the process of assigning each object, from set of objects, to one of a set of classes. In PR , the object is a pattern extracted from the image, and the classes are various categories occurring in the image. The pattern in this step of processing not usually a set of points, but, it is a set of numerical features formed by feature extraction process [23].

There are different models of classification system; the main three models are statistical, syntactical, and artificial neural network. Since most of neural networks approaches are based on statistical method. In this type of classifiers, the problem of PR is formulated as a statistical decision problem (SDP). Statistical pattern recognition (SPR) is a relatively mature discipline and a number of commercial RS have been designed based on this approach. The problem is estimating density functions in a high-dimensional space and dividing this hyperspace into regions of categories or classes. Decision making in this case is performed using appropriate discriminate function, thus, mathematical statistics form the foundation of this approach [24].

statistical classification methods (SCMs) grouped into two categories, supervised classification and unsupervised classification.

Classification systems are expected to automatically classify or cluster patterns based on the measured properties or features. In such systems, each input vector should be decided whether it belongs or not belong to a particular class or category. with this view point, a neural network (which can be defined as the system that recognize patterns) can be used for designing a classification system [25] . As with SCMs , there are two basic categories of neural classifiers. Supervised Neural Network Classifiers: and Unsupervised Neural Network Classifiers [26][27]**.**

IV. Proposed Character Recognition Systems

The Proposed CR System based on the PRS architecture will be described as shown in fig.1

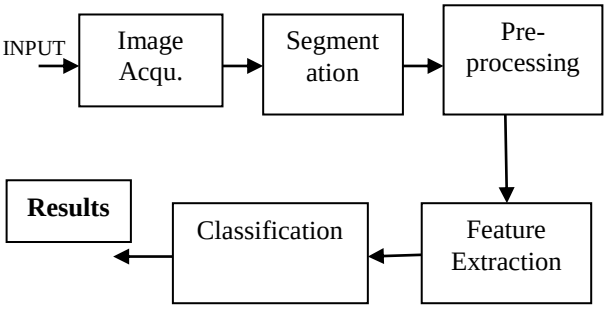

Fig.1 The CR System block diagram used in

Each block of this proposed system will be explained in details:

A) Image Acquisition

Image that contains the text to be recognized is acquired by using scanner and a bitmap image with true colors will be saved for further processing. Database is made to support the training and testing processes of the system . Samples are taken from 130 different persons , each person is asked to write all 26 English characters on a white paper in it's capital and small cases. Images are scanned with 150 dpi resolution, and saved as 24 bit per pixel bitmap.

B) Segmentation

It is generally the first step in any attempt to analyze or interpret an image automatically. It is defined to be the process of partitioning the image into distinct region that are meant to correlate strongly with objects or features of interests in the image. it also be regarded as a process of grouping together pixels that have similar attributes .

Image Threshold is a segmentation technique, and since it classifies pixels into two categories, and there are two possible output values, therefore, threshold segmentation creates binary image, and the nature of the image depends on the property being threshold. Because the Threshold produces image with only two colored value, it's seems better to make the segmentation process earlier than the preprocessing step because of data reduction that is made by segmentation process.

The algorithm used for Threshold the image into two values 0 and 1 is stated bellow:-

{ let Image **1** be the input image in which each pixel has 3 colored values ImgGreen, ImgRed, and ImgBlue.

Let **T** be the threshold that will split the image pixels into two categories of pixels 0 and 1.

For each pixel in the image Img(x, y), do :-

1. Find gray scale

Grayscale=(ImgGreen(x,y) + ImgRed(x, y) + ImgBlue(x, y))/3

2. IF Grayscale >=T then

Set Img(x ,y)= 1

Else

Set Img(x, y)=0 **}**

C) Preprocessing

The main aim of preprocessing is to improve the input image in a way that increase the chances for success of the following process, and using different image processing techniques for normalizing input patterns.

For CRS, the preprocessing will include **edge Thinning** or **Skeletonizing** and **Noise Removing**.

Edge thinning is an attempt to represent the structural shape of a plane region and reduce it to a graph. This reduction may be accomplished by obtaining the skeleton of the region via a thinning algorithm.

This step will reduce some of the variance that is usually found in characters like the width of their edges, therefore, it is considered as a uniforming process to make all the characters with (1) pixel width.

The **Edge Thinning** algorithm will assume that edge points have "1" value, and the background points have "0" value. The process consists of successive passes of two basic steps applied to the contour points of the given region, where a contour point is any pixel with value "1" and have at least one 8-neighbors valued "0" .

The algorithm is given below:-

{ Let p_1 be a point in the image have value 1 and have 8-neighbor that is $p_2, p_3, p_4, p_5, p_6, p_7, p_8$ and p_9.

Step (A): For each point p_1 in the image do the followings:

1- Find $N(p_1)$ which is the number of nonzero neighbor points that is: $N(p_1) = p_2 + p_3 + p_4 + p_5 + p_6 + p_7 + p_8 + p_9$.

2- Find $S(p_1)$ which is the number of 0-1 transitions in the ordered sequence of $p_2, p_3, p_4, p_5, p_6, p_7, p_8, p_9$.

3- Test for the following conditions to be satisfied all :

a. $2 \le N(p_1) \le 6.$

b. $S(p_1)=1.$

c. $p_2 . p_4 . p_6 = 0$.

d. $p_4 . p_6 . p_8 = 0$.

If all conditions are satisfied, then the point p_1 is flagged .

Step (B): Delete the flagged points

Step (C): For each point p_1 in the image test for the following conditions to be satisfied all:

a. $N(p_1) <= 6$.

b. $S(p_1)=1.$

c. $p_2 . p_4 . p_8 = 0$.

d. $p_2 . p_6 . p_8 = 0$.

If all conditions satisfied, then the point p1 is flagged .
Step (D) Delete the flagged points . **}**

D) Feature Extraction

Feature extraction process will generate feature sets that represent characters occurrences in the image. In the proposed system , features are extracted by using two different techniques, ***WT*** or ***character moments***.

Each character image will be transformed by using WT. Coefficients produced in this transformation will act as features sets. There are different types of WTs depending on the bases functions used in the transformation. In the proposed system, Haar transformation (HT) is used to implement WT. The Haar bases vectors are :-

Low pass : $\frac{1}{\sqrt{2}}[1,1]$

High pass: $\frac{1}{\sqrt{2}}[1,-1]$

The transformation will be implemented by convolving these vectors with rows and then with columns. WT will be applied to all characters been extracted in the previous step.

The algorithm of the used HT is demonstrated as follows:

For each character image in the character:

1- Convolve the low-pass filter (LPF) with rows and save the results .

2- Convolve the LPF with the columns (of the result from step-1) and sub-sample this result by taking every other value.

3- Convolve the result form step-1, the LPF rows, with the HPF on the columns. Sub-sample by taking every other value to produce the low pass / high pass image .

4- Convolve the original image with the HPF on the rows and save the results .

5- Convolve the result form step-4 with the LPF on the columns, sub-sample to yield the high pass low pass version of the image .

6- Convolve the columns from step 4 with HPF to obtain high pass version of the image .

The WT is applied with character image of size (64*64) and with two level of resolution. In the first level 4 sub-bands are resulted , each of these sub-bands (D_1 , D_2 , D_3 and D_4) is (32*32) size ,each of these sub-bands can act as feature set, because of the unique distribution and reduction of characteristics that describe the image. For the first band D_1, it corresponds to the lowest frequencies and contains the global characteristics of the image, D_2 will gives the vertical high frequencies and contains the horizontal details, D_3 will give the horizontal high frequencies and contains the vertical details, and D_4 will gives the high frequencies in both diagonal directions and contains the diagonal details. Now each sub-band has a certain way of describing the character image , so it is promising to use these bands as feature sets.

For the next level of resolution, the algorithm will be applied only on D_1 , since it contains the global characteristics and describe the general shape of the character. This will yields also four sub-bands, with the same manner, only one difference that the size of each band is reduced to (16*16).

For two level of resolution, this method will produced (8) feature sets that describes the character.

E) Classification

The process of classification will operate on the feature sets produced by feature extraction process, each character here is recognized and classified according to its features. Neural Network classifier is used to classify characters instances, and self-organization Neural Network model is used in this work.

1- Kohenen Neural Network (KNN)

The (KNN) is one of the unsupervised competitive learning neural network. It is widely used as unsupervised by using data clustering process.

The network architecture of KNN consists of two layers of nodes first layer consist of (N) nodes, where N is number of the features presented to the network. the output layer consist of (26) nodes representing the possible classes the input patterns (or characters instances) may fall into.

a - Classifier Architecture

The inputs domain in this work considered to be the English characters in its capital and small cases, so, the classifier will have total (52) outputs representing the character classes. For each character case (capital and small) a classifier is made to deal with each case.

The ***Minimum Designating*** layer is used to make the final decision by selecting the minimum output value from the two classifiers (minimum distance is the most probable answer about the class of the input).

Each of these classifiers build as ***unsupervised KNN*** and ***Supervised LVQ Neural Network***, and in KNN, two types of architecture can be used in the designing of the Neural Net that is ***OCON*** and ***ACON***. We decide to choose the ACON type in the proposed system.

b – ACON type

Small case character classifier and Capital case classifier are designed each with ACON architectures. In ACON, all character classes are within one neural net , the training will include all characters at once.

c - Learning Phase

The network will be trained by using 130 sample taken from 130 different persons, each person have been asked to write the 26 characters from (a) to (z) and from (A) to (Z) in capital and small form without any writing constrains. 65 of these samples have been used for training , and all 130 samples is used for testing .

The algorithm used for training the network is as follow :

{ Step (1):

Let $x = \{x_1, x_2, ..., x_n\}$ be the training pattern vector .

$$w_{i,j}^{t+1} = w_{i,j}^{t} + \alpha(x_i^t - w_{i,j}^t)$$

Let n be the input vector length (number of features).

Let m be the number of output nodes (number of clusters or classes).

Step (2): Initialize the weight vectors w_j for j=1,...,m .

Initialize α learning rate ($0<\alpha<=1$) .

Step (3): While stopping condition is false , repeat steps 4-10.

Step (4): For each input vector x , do steps 5-7

Step (5): For each j compute

$D_j = \sum_i (w_{ij} - x_i)^2$ for j=1,....,m

Step (6): Find index j such that $D_j = \min_{j=1,...,m} (D_j)$

Step (7): Update the winner weight vector(cluster

Step (8): Update the learning rate , α .

Step(9): Find $E^t = \| W^{t+1} - W^t \|$.

Step(10): If $E^t \le \varepsilon$ stop ,else go to Step(3) .

}

d- Weights and Learning Rate Initialization

Weights and learning rate are initialized by using different kinds of procedures.

In this work , initialization is as follows :-

- learning rate α is initialized to a small positive number $< \alpha'$,where $0< \alpha' <0.1$,and $0< \alpha < \alpha'$.
- As the learning process progresses , α is increased slowly toward α' ($\alpha = \alpha + 0.2 * \alpha$) .

This slow increasing in α forces the weight vectors to be close to the input vectors through gradual separation of the weight vectors according to the input clusters used for training .

- When α become $>= \alpha'$ and the learning proceeds , α is decreased ($\alpha = \alpha * 0.999$)slowly until the stopping condition is reached .
- Weights vectors are initialized by choosing randomly 26 input vectors to represents the 26 classes ,these input vectors will represents the weight vectors that learning process will starts from.

e - Stopping Condition

The network training is stopped when the weight vectors changes are very small for two successive iterations.

V. CONCLUSIONS

- The recognition rate indicates that KNN- ACON architecture scores the highest recognition rate with all feature sets presented to this model.
- Some weakness of the ACON neural network in term of recognition rate, is due to the overlapping of the clusters centers among the characters in the feature space, this makes the neural network miss recognize some of the characters.
- Results showed that WT coefficients give acceptable recognition rates in comparison with other features extraction techniques, and the second level of resolution in WT gives the good description to characters image and thus gives the high recognition rates among some of well-known feature extraction techniques.
- WT enhance the recognition rates with small amount when combined with geometrical features like moments and complex moment. This because the description level of moments and complex moments overcome the description provided by WT .
- Some of the characters were written by different persons contains high difference in their general shape. This considered a drawback for the recognition rate, and it will be minimized if the number of training sample increases.

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