Hybrid Arabic Handwritten Character Recognition Using PCA and ANFIS

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Abstract: *In this paper we will present a two phase method for isolated Arabic handwritten character recognition system. The proposed system is a hybrid system that uses the principal component analysis (PCA) feature technique and neuro-fuzzy classifier. The Adaptive Neural Network Fuzzy Inference System (ANFIS)were used at all levels of the character recognition stages with different learning algorithms and nonlinear outputs. The proposed system is applied to the Sudan University Sciences and Technology Arabic Recognition Group (SUST-ARG) data set. In this paper the work was divided into two stages. In the first stage, the system was applied to 34 Arabic characters and achieved 96.2% recognition rate for the tested data set. In the second stage, a private classifier for each group was created to recognize and classify the characters within a group which achieved 99.5% recognition rate for the tested data set.*

Keywords:*Isolated Handwritten Arabic Character Recognition, Principal Components Analysis (PCA), Feature Extraction, Adaptive Neural Network Fuzzy Inference System (ANFIS).*

1. Introduction

Handwritten Arabic Character Recognition system (HACR) is the system that attempts to recognize a text that has been written by a person (not a machine). Handwritten Arabic letters Recognize is aimed to convert handwritten Arabic text to be recognized by a computer and turn it into application software. To recognize handwriting text is not a difficult task for human, but for a computer, it is very difficult. The problem is how to program a computer to do that kind of task with conventional approach. It is very difficult to formulate a solution with a conventional approach. Intelligent approaches have been developed for this kind of problem. The new development in artificial intelligence (AI) such as fuzzy logic, artificial neural network, genetic algorithm, etc. have helped human to program computers to imitate organism behavior, although at a very basic level [1].

The goal of a character recognition system is to transform a character handwritten on paper into a digital format that can be manipulated by characters processor software.

Artificial neural network (ANN) and fuzzy set theory has been applied effectively either individually or in combined form to solve automatic character recognition problem. An ANNis an information processing system in which a large number of processing elements, called neurons, are arranged in layers and each neuron is connected to several other neurons by means of directed communication links. Each link is assigned a weight [2]. A neural network learns through training. Learning or training is done by adjusting weights between layers. Learning can be supervised (learning through teacher), unsupervised (learning without teacher) or reinforcement learning. In supervised learning, network is trained to achieve the target output vector by adjusting weights according to a learning algorithm [3]. Human beings are capable to deal with real world information that is fuzzy, partial and approximate because our experience provides us a way to put together and analyze these pieces of information into a structured way. Fuzzy logic is an effective tool to describe human knowledge involving vague or uncertainties. According to Zadeh [4], fuzzy logic is a method to solve and model the uncertainties associated with human thinking and reasoning processes. The concept of fuzzy set allows partial membership so a fuzzy set may have smooth boundaries. Membership of an element of fuzzy set is expressed by the degree of compatibility of the element with the definition of that set. Membership is expressed between number 0 (complete non-membership) and 1(complete membership). Value in-between 0 and 1 represents partial membership [5]. A fuzzy set A in the universe of discourse U (into the interval [0,1]) can be defined as a set of ordered pairs and is given by: $\tilde{A} = \{(x, \mu_{\tilde{A}}(xi)) \mid x \in U\}$ where $\mu_{\tilde{A}}(x)$ represents degree of membership of x in $\tilde{A}$ and called membership function of $\tilde{A}$. Fuzzy rules are by far the most used and successful method of fuzzy logic theory to represent inexact and ambiguous data.

Strength of neural network is its learning and storing capability, while fuzzy logic handles the complexity of fuzzy data very well by expressing it in the form of IF-THEN rules [6].

2. Adaptive Neuro-Fuzzy Inference System(ANFIS)

Adaptive Neuro fuzzy inference system (ANFIS) [7] is a kind of neural network that is based on Takagi–Sugeno fuzzy inference system. Since it integrates both neural networks and fuzzy logic principles, it has potential to capture the benefits of both in a single framework. Its inference system corresponds to a set of fuzzy IF–THEN rules that have learning capability to approximate nonlinear functions. Hence, ANFIS is considered to be universal approximator nonlinear functions.

The ANFIS uses two learning algorithms, a hybrid to tune the parameters of a Sugeno-type fuzzy inference system (FIS). The two learning algorithms used are a combination of the least-squares and back-propagation gradient descent methods to model a training data set. The back-propagation is used to find the optimal values of the nonlinear learning parameters.

Several classification techniques using neuro-fuzzy and others classifiers have been proposed as a solution for this problem.

In [8], authors presented a new method based on structural characteristics and a fuzzy classifier for off-line recognition of handwritten Arabic characters in all their forms (beginning, end, middle and isolated). They applied three preprocessing operations on character images: thinning, contour tracing and connected components detection. Invariant pseudo-Zernike moments was used as a feature extracting technique. Five Fuzzy ARTMAP neural networks were employed; each one is designed to recognize one subset of characters. They achieved recognition process is in two steps: in the first one, a clustering method affects characters to one of the five character subsets. In the second one, the pseudo-Zernike features are used by the appropriate Fuzzy ARTMAP classifier to identify the character. Training process and tests were performed on a set of character images manually extracted from the IFN/ENIT database. There system achieved 93.8 recognition rate.

In[9], authors have proposed a neuro-fuzzy inference engine to recognize the Farsi numeral characters. They used Mamdani inference engine on fuzzy rules with a multilayer perceptron neural network's learning on features of the different fonts' characters which leads to more comprehensive recognition of Farsi numeral characters in the proposed system. The recognition rates of testing dataset of numeral characters were greater than 97%.

In[10],the authorshave presented an off-line Multiple Classifier System (MCS) for Arabic handwriting recognition. The MCS combined two individual recognition systems based on Fuzzy ART network used for the first time in Arabic OCR, and Radial Basis Functions. They used various feature sets based on Hu and Zernike Invariant moments. For deriving the final decision, different combining schemes were applied. The best combination ensemble has a recognition rate of 90.1 %.

In this paper, ahybrid neural-fuzzy system with two learning algorithms model will be presented. The proposed system works by interpreting the fuzzy rules in terms of the neural network. Fuzzy sets are taken as weights, while fuzzy rules, input and output variables are taken as neurons.

The paper is organized as follows: Section 2 describes our dataset, section 3 describes the approach architecture, experiments and results, section 4 will introduce a new isolated Arabic handwritten character recognition system and the conclusion is presented in section 5.

3. Dataset

SUST-ARG dataset which stands for Sudan University for Sciences and Technology Arabic Recognition Group (SUST-ARG) is used in this research paper. The dataset includes one hundred and forty one forms filled by different subjects. The form, as shown in Figure 1, has been designed to collect the required handwritten letters. These forms are scanned by a scanner device with an accuracy of 300 dpi, saved as color images. Figure 2 shows the letter extraction process. This process extracts each specific letter from all forms and puts it in a separate folder as gray scale image. Each handwritten letter will be collected from 1410 hand written images.

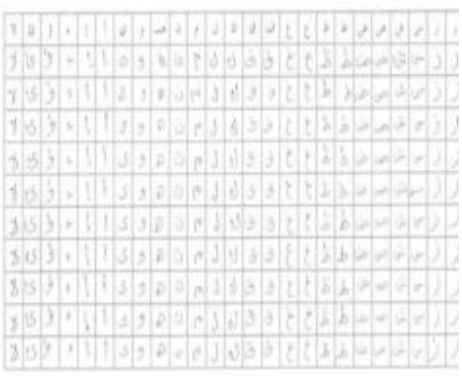

Figure 1. The form used to collect the alphabet Arabic letters document

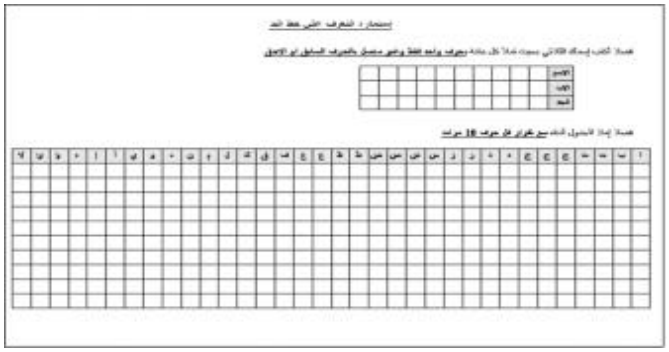

Figure 2. The letters extraction process

4. The Recognition Process

The proposed system for recognition of handwritten isolated Arabic characters is made of three main processes which are the preprocessing, feature extraction and classification processes as shown in figure 3. The preprocessing is utilized to remove noise and afterwards features are extracted from each character. These features are then used for classification to identify the character, using the new proposed neuro- fuzzy algorithm.

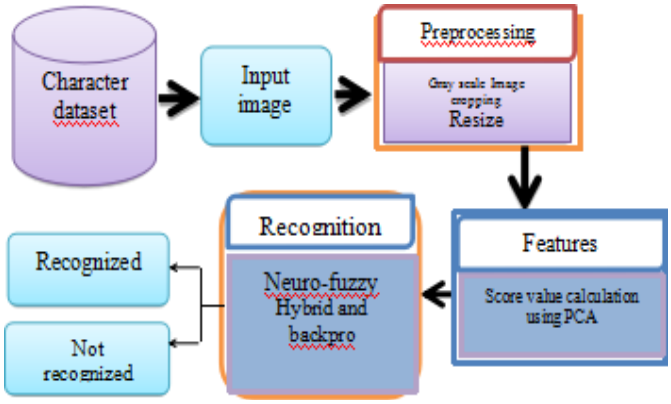

Figure 3. Block diagram for the recognition system

4.1 Preprocessing

A handwriting character was sampled on A4 size paper. They were scanned using a scanner with a resolution of 300dpi. These characters will be separated according to their own character group and stored as greyscale images after the images are cropped and resized to 50 by 70. Figure 4 shows a sample of the characters ba and kha.

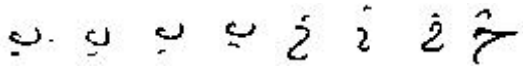

Figure 4.A sample of characters (ba) and (kha) scanned and collected together

The preprocessing step goes through the following operations:

A. Normalization

The process of changing the intensity value of the pixel in an image to the range of [0, 1] is called normalization. The conversion of various dimension images into fixed dimensions is also called as normalization. Normalization is used in digital signal processing.

B. Cropping the Image

Cropping refers to the removal of the outer parts of an image to improve framing, accentuate subjectmatter or change aspect ratio. The unwanted background parts of the image are omitted leaving the focus to only the character. This makes the feature more accurate and accordant. The image is scanned row by row until the last set of rows from the top and from the bottom have a value of '255' for all their pixels is obtained. This is followed by a step to crop the left and right side of the image. Here, the image is scanned column by column. The last column from the left with all pixels having a value of "255" is obtained. The same is done to the right side of the image. The final step of cropping is adding a safety margin of one row of white pixels at all sides of the image. This leaves us with just the image of the character.

This technique is shown in figure 5 where a character "ط" is being cropped and resized.

Figure 5a.Ta letter before cropped

Figure 5b. Cropped and resized

C. Resizing Image

Image interpolation occurs when you resize or distort your image from one pixel grid to another. Image resizing is necessary when you need to increase or decrease the total number of pixels. We resize each image after cropped to 50 by 70. In[14], authorshave resized images to a constant dimension as input for their proposed system using a resizing algorithm [15]. The input image is resized to a dimension of 35:1 vector.

4.2 Features Extraction

The purpose of feature extraction is to reduce the original data set by measuring certain properties, or features, that distinguish one input pattern from another. Thirty fife character features based on the copped gray level image have been used in this research paper. The PCA was used for this step. PCA is a very popular technique for dimension reduction. In [11], the de-noised images were given to the next process in order to calculate the score values using the PCA technique. The score values that were obtained from the PCA techniques were then used by the ANFIS classifier for the training process. Based on the predefined threshold value, the image under test was specified as recognized or not recognized. In [12],the researchers proposed five Arabic handwritten character recognition classifiers system. They used 95 feature vectors which included secondary component features, main body features, skeleton features, and boundary features. They then applied the Principal Component Analysis.

In this paper the following steps were conducted to extract the most important features of each character: First, the image is converted to grayscale image and then to binary image using the threshing technique. In the second step, the binary image is then cropped into a sub image. The size of the sub-imageis not fixed so to solve this problem, the sub-image is resized to 50×70 matrices. In the last step, the 35 input features are derived by calculating the average value in each 10×10 block. The 50x70 imagewill be converted to an image of 5×7 matrices with entry values between 0 and 1 (fuzzy values).

The PCA is used as features extraction technique to reduce the dimension of the images. The process of PCA starts by computing the mean of the data matrix then computing the covariance. After that the Eigenvalues and Eigenvectors are then computed. Figure 6 shows the flow chart for the PCA process.

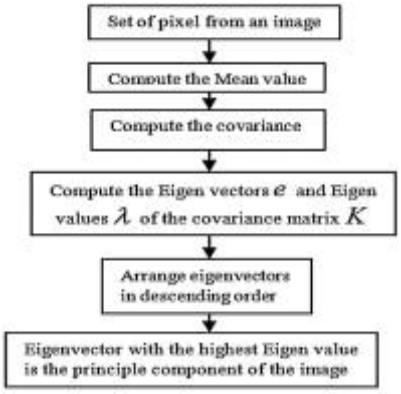

Figure 6. The flow chart of the principle component analysis

4.3 Classification

The classification process is carried out at the final stage to recognize characters. It assigns an input character to one of the many pre-specified classes which are based on the extracted features. The ANFIS was used for the classification process in this paper. The proposed Neuro-Fuzzy topology is shown in figure 7. Many experiments have been conducted to find the best recognition rateoutput (z).

4.4 ANFIS Architecture

The structure of the ANFIS consists of four inputs and a single output. The four inputs represent the different character features calculated from each image. Each of the training sets forms a fuzzy inference system with eighty one fuzzy rules. Each input was given three generalized bell curve membership functions and the output was represented by three nonlinear membership functions. The outputs of the eighty one rules are condensed into one single output that represents the system output for that input image.

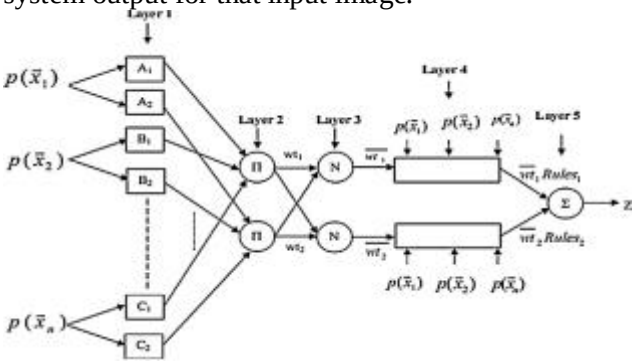

Figure 7. TheANFIS architecture for the Sugeno type reasoning

5. Experimentsand Results

The data set (the set of Arabic handwritten characters) was divided into three levels as shown in figure 8. The first level contains all characters as one class. The second level hasre-grouped the one class in the first level into fifteen different classes in the second level. The last level places each character in a separate class called letter class. For the experiments, different size were selected for the training and testing data sets for all levels as shown in table 1.

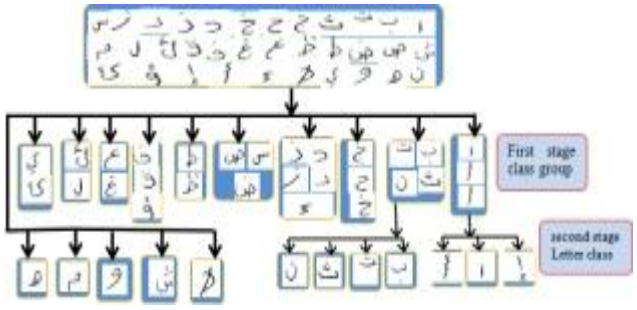

Figure 8. The proposed two-stage Arabic Handwritten character recognition system

Table 1: Dataset types and sizes for training and testing.

Dataset Type	Dataset size	Training dataset	Testing dataset
All dataset with 34 characters in one class (first level)	6800	5100	1700
Grouping dataset into 15 different classes (second level)	3000	2250	750
Similar characters (1 to 5) class for each character (three level)	each character with 200 image	150*class number	50*class number

Two stages classifier were used for the experiment. The first stage is based on features extracted from groups of similar characters. The second stage has sub-classifiers. A sub-classifier is a multiple adaptive neuro-fuzzy classifier to recognize characters of only one group.

In the experiments, ANFIS classifier with two learn algorithms was used; hybrid and back-propagation. Four features was used as inputs to the system. Obviously when the number of features increases so does the memory consumption and time. Three triangular membership function was used for each input and output. A set of different experiments were applied on the training data set and the testing data set as shown in table 2.

Table 3 shows the recognition rate for grouped class in the first stage and table 4 shows the percentage recognition for character classes in the second stage.

Table 2. The accuracy rate for the training and testing data set

Dataset type	Training accuracy %		Testing accuracy%	
	Hybrid	Backprop	Hybrid	Backprop
All data set	91.59	90.40	**91.39**	90.38
Grouping data set	96.4	95.6	**96.2**	95.1
Similar data set	99.62	99.2	**99.38**	99.12

Table 4. A sample of accuracy rate for group two that containssimilar character in separate class

Accuracy	Group	N	Accuracy	Group	N
97.66	ع غ	8	96.13	ا إ أ	1
97.9	ف ق ؤ	9	95.36	ب ت ث ن	2
97.28	ل ك	10	96.06	ج ح خ	3
97.45	م	11	95.92	د ذ ر ز ء	4
97.99	هـ	12	96.33	س ص ض	5
96.68	و	13	98.54	ش	6
93.90	ئ ي	14	99.21	ط ظ	7
93.96	لا	15			

Comparative Study

A comparative study for the proposed system has been presented is compared with the method presented by balola, shaout and elhafiz[13]. In this comparative study, we compared neuro-fuzzy proposed system with neural network system designed for Arabic handwritten characters. Table 5shows the result of both systems on the same size of SUST-ARG data sets. The comparison shows the effectiveness of our new proposed system. In [16] authors proposed an offline character recognition system for isolated Arabic alphabet written by a single writer. They obtained 97%recognition accuracy with five stages. When we compared this result with our proposed system for grouped dataset of SUST-ARG dataset, which was written by 141person, the recognition accuracy shows an improvement in our proposed system as shown in table 5.

Table 5. Comparison results of proposed method with other method

authors	Technique	Testing accuracy%		
		All dataset	Grouping dataset	Similar dataset
Proposed method	Neuro-fuzzy	91.39	96.2	99.38
balola, shaout and elhafiz et al.[13]	Neural network	54.3	78.77	92.77
Randa E, M. A. RashwanabdSamia A. M.[16]	decision fusion	74.48%.	96%	98.6%

Table 3. The accuracy for the 34 class of characters

Accuracy	characters	N	Accuracy	characters	N
94.36	ع	18	91.94	ا	1
94.65	غ	19	87.16	ب	2
95.39	ف	20	89.40	ت	3
96.97	ق	21	90.14	ث	4
96	ك	22	90.41	ج	5
95.13	ل	23	92.16	ح	6
94.12	م	24	92.11	خ	7
88.83	ن	25	88.46	د	8
95.89	هـ	26	93.6	ذ	9
94.90	و	27	91.13	ر	10
88.08	ي	28	96.66	ز	11
91.78	لا	29	95.87	س	12
92.76	ء	30	96.61	ش	13
91.61	أ	31	95.98	ص	14

94.73	إ	32	97.09	ض	15
85.21	ؤ	33	100	ط	16
82.40	ئ	34	98.23	ظ	17

7. Conclusion and Future Work

In this paper, we have presented a system for recognizing handwritten isolated Arabic characters using a two-stage neuro-fuzzy system with different learning algorithms based scheme using the PCA to extract and reduce features. From the experimental results, the overall recognition rate for the proposed system is 96.4%. Many experiments have been conducted in this research. The experiments used 34, 15 and (1 to 5) character classes. The highest result accuracy for testing data set with 15 classes was 96.2% as shown in table 3 and for one group we had a rate of recognition of 99.2% as shown in table 4. The recognition rate results shows that there was improvement in performance of the proposed system.

In our further research work, we would like to improve the recognition accuracy of neuro-fuzzy for handwritten Arabic character recognition by using more training samples and using good feature extraction techniques and different membership functions.

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