Recognition Techniques for Online Arabic Handwriting Recognition Systems

Mustafa Ali Abuzaraida[1], Akram M. Zeki[2]
Kulliyyah of Information and Communication Technology
International Islamic University Malaysia
Kuala Lumpur, Malaysia
[1]abuzaraida@yahoo.com, [2]akramzeki@iium.edu.my

Ahmed M. Zeki
Department of Information Systems
College of Information Technology
University of Bahrain
Manama, Kingdom of Bahrain
amzeki@uob.edu.bh

***Abstract*— Online recognition of Arabic handwritten text has been an on-going research problem for many years. Generally, online text recognition field has been gaining more interest lately due to the increasing popularity of hand-held computers, digital notebooks and advanced cellular phones. However, different techniques have been used to build several online handwritten recognition systems for Arabic text, such as Neural Networks, Hidden Markov Model, Template Matching and others. Most of the researches on online text recognition have divided the recognition system into these three main phases which are preprocessing phase, feature extraction phase and recognition phase which considers as the most important phase and the heart of the whole system. This paper presents and compares techniques that have been used to recognize the Arabic handwriting scripts in online recognition systems. Those techniques attempt to recognize Arabic handwritten words, characters, digits or strokes. The structure and strategy of those reviewed techniques are explained in this article. The strengths and weaknesses of using these techniques will also be discussed.**

Keywords- Text Recognition, Recognition Engine, Online Arabic recognition system.

I. INTRODUCTION

Text recognition system is a program designed to convert a scanned text (offline) or handwriting on writing device (online) into a text documents. The field of Text recognition is one of the major fields of the pattern recognition area which has been the subject of much research in the past three decades.

This field has been gaining more interest lately due to the increase of pen computing applications like tablet devices, digital notebooks, and advanced cellular phones. Nowadays, these devices are commonly used worldwide that encouraged companies to improve their products to deal with multi languages. However, these devices can deal with many different languages spoken by billions of people around the world such as Latin, Chinese, Japanese, Indian, Korean, Arabic, and many others from textual or speech manner.

From the literature in the text recognition field, it is noticeable that most of the research works were dedicated to Latin characters and other languages such Chinese. On the other hand, a few researches and studies have been published to develop new methods and algorithms in this area for Arabic language. In addition, online Arabic handwriting recognition researches are still too few in number compared to those done on offline Arabic recognition.

Most of the online text recognition systems follow the typical structure of pattern recognition systems which basically consists of four major stages [1, 2] which are preprocessing, feature extraction, recognition, and post-processing phase as illustrated in Figure 1. However, some studies provide extra phases or ignore some phases of the systems. In this paper, a brief overview of the recognition techniques used as recognition engine in the area of online Arabic handwriting recognition will be described and compared.

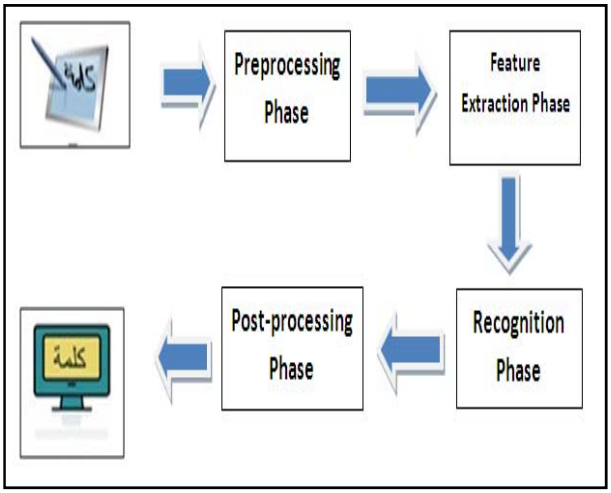

Figure 1. Typical phases of online Text Recognition System

II. ARABIC LANGUAGE SCRIPTS CHARACTERISTICS

More than 280 million people are speaking this language as a first language in all Arabic countries and by 250 million as a second language in many Islamic countries. In the year of 2011, Arabic language comes as the fifth rank of most commonly used languages in the world and as one of the six official languages of the United Nations [3]. In addition, there are some other languages related to Arabic language. These languages have some similarities with Arabic language whither from the letters shapes or from the pronunciation. These languages are Jawi, Persian, Urdu, Pashto, Bengali, and others. These languages are spoken by millions of people in many Islamic countries such as Iran, Afghanistan, Pakistan, parts of India, Bangladesh, Sri Lanka, Malaysia, Indonesia, and other countries [3].

There are much different between Arabic and other languages from the shape and the writing style due to several reasons and here are some of these reasons:

- First, Arabic characters written in four different shapes depending on their location in the word. These

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locations are beginning, middle, end, and isolate shape. Although, some characters have the same isolated and beginning shapes and also have the same middle and end shapes as shown in Table 1.

- Second, in Arabic scripts, there are some extra strokes written above or below the character which may be a single dot, multi dots, or *Hamza*. These strokes used to distinguish between the similar characters like the characters *Baa, Taa*, and *Thaa* or between the characters *Lam* and *Kaf* as shown in Table I.

TABLE I. ARABIC CHARACTERS SHAPES

Letter	Isolate	Beginning	Middle	End
Alif	أ	أ	ـا	ـا
Baa	ب	بـ	ـبـ	ـب
Taa	ت	تـ	ـتـ	ـت
Thaa	ث	ثـ	ـثـ	ـث
Jeem	ج	جـ	ـجـ	ـج
Haa	ح	حـ	ـحـ	ـح
Khaa	خ	خـ	ـخـ	ـخ
Dal	د	د	ـد	ـد
Dhal	ذ	ذ	ـذ	ـذ
Raa	ر	ر	ـر	ـر
Zai	ز	ز	ـز	ـز
Seen	س	سـ	ـسـ	ـس
Sheen	ش	شـ	ـشـ	ـش
Sad	ص	صـ	ـصـ	ـص
Dad	ض	ضـ	ـضـ	ـض
Taa	ط	طـ	ـطـ	ـط
Dhad	ظ	ظـ	ـظـ	ـظ
Ain	ع	عـ	ـعـ	ـع
Ghain	غ	غـ	ـغـ	ـغ
Faa	ف	فـ	ـفـ	ـف
Qaf	ق	قـ	ـقـ	ـق
Kaf	ك	كـ	ـكـ	ـك
Lam	ل	لـ	ـلـ	ـل
Meem	م	مـ	ـمـ	ـم
Noon	ن	نـ	ـنـ	ـن
Haa	ه	هـ	ـهـ	ـه
Waw	و	و	ـو	ـو
Yaa	ي	يـ	ـيـ	ـي

- Third, any Arabic word must be written cursively and the characters should be connected unless one of the characters (ا, د, ذ, و, ر, ز) exist in the middle of the word to make sub-words as shown in Figure 2.

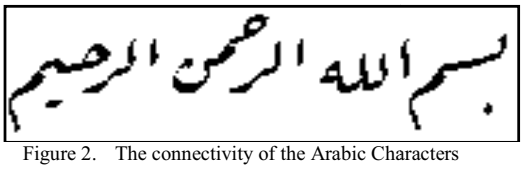

Figure 2. The connectivity of the Arabic Characters

- Fourth, in such a writing way some Arabic words may have overlap case especially in Arabic handwritten. Here, some characters come in vertical position above their next character. Overlapping may cause an ambiguity to the system to recognize the proper word as illustrated in Figure 3.

Figure 3. Arabic words overlapping

- Fifth, there are many different fonts for writing any Arabic word that make the characters and words having different outlook which make ambiguity to any recognition system. The most common fonts used for handwriting are *Nuskah* and *Ruqqah*. Figure 4 shows the difference between these types of writing the words (السلام عليكم).

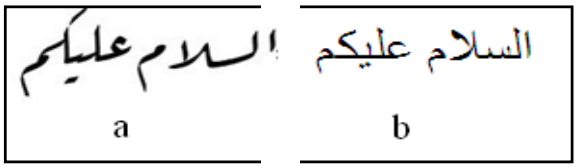

Figure 4. Peace upon to you(السلام عليكم) written by Ruqqah(a) and Nuskah(b)

III. TEXT RECOGNITION METHODS

There are different numbers of techniques used as recognition engine for online recognition system which can be grouped into four general types which are Statistical, syntactical and structural, neural network and elastic matching. [4, 5]. A brief overview of these techniques is described in the following sections.

A. Statistical methods

Statistical methods used to recognize each pattern by representing it in terms of features to be viewed as a point in dimensional space. This involves selection of features that all pattern vectors belonging to different categories or classes to occupy disjoint region in a dimensional space [5]. The statistical methods are based on prior probabilities of classes and assume variations in natural handwriting as stochastic in nature.

Statistical methods can be classified into two types which are parametric and non-parametric methods. In parametric methods, handwriting samples are statistical variables from distribution that is characterized by a set of parameters and each class includes its own distribution parameters. The selection of parameters is based on training data. The common example of parametric methods is Hidden Markov Model (HMM) which was used commonly in the field of text recognition.

For the second type, Non-parametric methods are directly estimated from training data. The most common non-

parametric methods are nearest neighbors. Here, parametric methods are preferred as compared to non-parametric methods as parametric methods are computationally easier than non-parametric methods. However, from the literature review of this field, HMM is the most widely used parametric statistical method applied to online handwriting recognition systems.

B. Structural and syntactical methods

Structural and syntactical methods are related to handwritten texts where structures and grammar are considered. Structural recognition provides a description of how the given pattern is constructed from the primitives. This paradigm has been used in situations where the patterns have a definite structure which can be captured in terms of a set of rules, such as waveforms, textured images, and shape analysis of contours.

In syntactic pattern recognition, a formal analogy is drawn between the structure of patterns and the syntax of a language. The patterns are viewed as sentences belonging to a language, primitives are viewed as the alphabet of the language, and the sentences are generated according to a grammar. Thus, a large collection of complex patterns can be described by a small number of primitives and grammatical rules. The grammar for each pattern class must be inferred from the available training samples [5]. An example of this recognition type is the chain codes which basically mean that a stroke is temporarily divided into few segments and these segments are then coded. These segments are small straight lines of equal lengths and consider information as directions, angles, geometric information in segments.

C. Neural network methods

Neural networks can be viewed as parallel computing systems consisting of an extremely large number of simple processors with many interconnections. Neural network models attempt to use some organizational principles such as learning, generalization, adaptability, fault tolerance, distributed representation and computation in a network of weighted directed graphs in which the nodes are artificial neurons and directed edges are connections between neuron outputs and neuron inputs.

The main characteristics of neural networks are that they have the ability to learn complex nonlinear input-output relationships, use sequential training procedures and adapt themselves to the data [5]. The most commonly used neural networks for pattern classification tasks are feed-forward network, which include multilayer perceptron and radial basis function networks. These networks are organized into layers and have unidirectional connections between the layers. Another popular network is the self-organizing map or kohonen network.

D. Elastic matching methods

Elastic matching is a generic operation in pattern recognition which is used to determine the similarity between two entities. The pattern to be recognized is matched against the stored template while taking into account all allowable changes. The similarity measure can be optimized based on available training set. Elastic matching is computationally demanding but with availability of faster processors, this approach is feasible [5].

Elastic matching is often called deformable template, flexible matching, or nonlinear template matching [6]. Elastic matching works very well for writer dependent data and does not require a relatively large amount of training data [7]. In literature, elastic matching method has been implemented by many researchers.

IV. PAST WORKS ON ONLINE ARABIC HANDWRITING

In the field of online Arabic handwritten recognition, several researches and studies have been published form late of 1980S. Many techniques have been used to implement systems to recognize Arabic texts which may be for isolated characters, digits, or even words. The results were encouraging and slightly high comparing to the difficulties of recognizing such a complicated text such as Arabic text. However, these results can not be compared as most of these systems are tested and trained with different characters databases, writers' databases and recognition methods. Here are reviews for some recognition techniques used in studies which have been done in the field of online Arabic handwritten recognition text.

Starting with Statistical methods which can be considered as the commonly use by researches in this area study. Early research [8] has been used this methods to present an on-line system for recognizing handwritten Farsi (Persian) and Arabic digits based on statistical techniques. Then, a discussion was done to develop a full-scaled Farsi recognizer and the difficulties associated with this task are assessed. The training was done by using 600 samples of each digit and was generated by 20 deferent writers. The system was tested by 14 writers who wrote each digit five times. This produced an average accuracy of 93.14% for these writers.

Later on, [9] a system based on Hidden Markov Models (HMMs) was developed to resolve most of the difficulties in recognizing Arabic script. These difficulties are mentioned here as letter connectivity, position-dependent letter shaping, and delayed strokes. The system was evaluated, and it showed the features and models selected were sufficient for the task of writer-independent handwriting recognition at a high rate of word recognition. Four trainers were asked to write 800 selected words. The words were selected to cover all Arabic letter shapes with almost uniform distribution. For testing, ten testers (the four trainers with six new volunteers) were asked to write 280 words that were not in the training data. The test set included 2,358 words in total. The system was tested using 5 different dictionary sizes. The results were an average of 92% of both independent and dependent test.

Also, in [10] a structured model for recognizing online Arabic handwriting written in continuous form was presented based on Hidden Markov Models (HMMs) to recognized Arabic strokes. The basic units of recognition used are strokes which are sub-letter parts. The system was evaluated and gave an accuracy of an average of 75% for both strokes and letters. Same technique was used by [11] to develop an on-line Arabic handwritten recognition system based on the new stroke segmentation algorithm. The recognition technique which has been used was Hidden Markov Models (HMMs). The proposed system gave a

recognition rate of up to 97% for words and 92% for letter recognition.

Recently, [12] an on-line recognition system for the Arabic handwritten personal names was implemented using HMM. The system was based on new delayed strokes detection and lexicon reduction methods. The system is validated using ADAB dataset of 300 samples, and a highly encouraging recognition rate with an average of 94%.

Structural and syntactical methods were used in the early research on online Arabic handwriting recognition which was done [13]. A structural recognition method for cursive Arabic handwritten words was proposed. In this method, words were first segmented into strokes. These strokes were then classified using their geometrical and topological properties. Then, the relative positions of the classified strokes were examined, and the strokes were combined in several steps into a string of characters that represents the recognized word. Experimental results on handwritten texts by two people showed high recognition accuracy with a rate of 81.25%.

A few years later, an online Arabic handwriting recognition system based on decision-tree techniques was proposed [14] to recognize Arabic handwritten words. The system has only been tested only on 13 Arabic characters' shapes that build the four words (زقاق, دار, محله, حي) which are used as postcodes in some Arab countries. The results reach an average of 86%.

Later, in [15] an efficient structural approach for recognizing on-line Arabic handwritten digits was proposed. The recognizer technique is based on the changing signs of the slope values. The primitives are identified and extracted. The proposed system has been tested on an on-line dataset representing the digits 0-9 collected from 100 users. The average of the recognition accuracy was about 95%. For [16] they proposed a system to recognize online Arabic cursive handwriting based on Rule-based method to perform simultaneous segmentation and recognition of word portions in an unconstrained cursive handwritten document using dynamic programming. The training database was written by four writers which include of 317 words (1814 characters). The testing database was written by other four writers which include 94 words (435 characters). The experimental results were 92% for recognizing the characters, with the same accuracy for the strokes and 77% for the words.

Another study used this method was done [17] by presenting a multi-level recognizer for online Arabic handwriting. The multi-level recognition is performed through a series of filters that aim to reduce the search space. At each phase, the number of candidates is reduced. The core of the system is based on modified dynamic time warping, which is followed by a shape context classifier applied on the resulting top k candidates. The system has been tested and several tests have being performed on the various datasets in which encouraging results were received.

Neural networks methods were used as a recognition technique in the online Arabic recognition area and some studies have used this technique such as [18] by implementing a new deductive method based on finding the maximum and minimum local points of Persian/Arabic script. The proposed online handwritten character recognition was initiated to recognize all Persian/Arabic Script without any primary vowel points. A back Propagation and Multilayer Perceptron neural network has been performed as a supervised classifier and recognizer for the Persian/Arabic script. Then, a comparison among different character shapes showed that it got higher recognition rate, that was 96.84% for isolated shape and the lowest rate was 92.60% for final shape.

In [19] a hierarchical recognition system for online Farsi handwritten words was proposed based on decision tree combined with neural networks. A combination of three features which are Start-to-End Vector, Directional Vectors, and Sharp Edge Points, and Local Maxima were used for features extraction phase. The system which was tested by using 50and 150 normalization size gave a recognition rate of 81% and 76% respectively.

The fourth technique was used by [20] who developed an Arabic handwritten recognition system based on matching template algorithm and genetic algorithm method. In the learning of the system, a data set of 500 Arabic words was created. Then, two experiments have been done to test the system. The first experiment consisted of inviting a scripter to handwrite a set of words that included the learning data base. The system recognized correctly 92% of the proposed words. The second experiment composed of pre-selected words that contained pseudo-words which were included in the learning word-set, a list of them is presented to the writer who compose his own test-set. Performance of the second test is about 70%.

In [21] a trainable system for recognizing Arabic online handwriting was developed. The system was called AraPen to recognize Arabic characters. Two-level classifiers preceded by pruning step have been used. In the first level, a mathematical matching algorithm called Dynamic Time Warping (DTW) was used. The best three candidates are then further classified using a simple neural approach. The system results showed high recognition rate even by using a small collected corpus. The recognition rate in the non-cursive mode was about 91% and it increased to 98% after training the system with the user's handwriting. For cursive mode, the system gives a low accuracy with less than 50%. In [22] a template matching strategy used and applied to recognize an on-line Arabic script based on the additive scheme in combination with the graph strategies for connected character recognition. The results showed that the system gave the rate of 94.8% for isolated character recognition and word recognition rates of about 92%.

Also, in [2] a combination of decision tree and matching algorithm was presented to implement a recognition engine for recognizing online Arabic character handwritten text. Decision tree make the classifier faster to be recognize by the character and reduce the execution time. Every stroke is represented by one Freeman direction. The character recognition system is based on matching and similarity directional stroke string. The average accuracy rate of this system was 97.6%.

Tables II summarizes the recognition techniques for Arabic texts in the past online Arabic handwriting systems and the accuracy rates of these systems.

TABLE II. RECOGNITION TECHNIQUES USED IN PAST WORKS ON ONLINE ARABIC HANDWRITING

Recognition type	Authors and year	Recognition technique	Text type	Accuracy rates
Structural and syntactical	Almuallim & Yamaguchi , (1987) [13]	Text geometrical and topological properties	Words	81.25%
Structural and syntactical	Al-Emami& Usher. (1990) [14]	Decision tree	Words	86%
Statistical	Beigi et al. (1994) [8]	Hidden Markov Models (HMMs)	Digits	93%
Elastic matching	Rokbani et al. (2005) [20]	Matching template algorithm	Words	92% for dependent and 70% for independent test
Structural and syntactical	Al-Taani (2005) [15]	Primitives stings	Digits	95%
Statistical	Biadsy et al. (2006) [9]	Hidden Markov Models (HMMs)	Words and characters	Average of 92% for
Elastic matching	Alsallakh & Safadi (2006) [21]	Mathematical matching algorithm	Characters	98% dependent and 91% for independent test
Statistical	Al-habian & Assaleh (2007) [10]	Hidden Markov Models (HMMs)	Strokes and characters	75%
Structural and syntactical	Elanwar et al. (2007) [16]	Rule based	Characters and words	92% for characters 77% for words
Neural networks	Faradji et al (2007) [19]	Decision tree combined with neural networks	Words	81%
Statistical	Daifallah et al. (2009) [11]	Hidden Markov Models (HMMs)	Words and characters	97% for words and 92% for letter
Structural and syntactical	Saabni &El-Sana (2009) [17]	Modified dynamic time warping algorithm	Words	Average of 89%
Elastic matching	Sternby et al. (2009) [22]	Template matching	Isolated characters and words	94.8% for characters 92% for words
Elastic matching	Omer & Long, (2010) [2]	Decision tree and matching algorithm	Characters	97.6%
Neural networks	Harouni et al (2010) [18]	Back Propagation and Multilayer Perceptron neural network	Characters	96.84% for isolated shape 92.60% for final shape
Statistical	Abdelazeem & Eraqi (2011) [12]	Hidden Markov Models (HMMs)	words	Average of 94%

As seen from Table II, several studies have been done in this area using different recognition techniques which were briefly overviewed in section III. However, some studies have used a combination of different recognition techniques such as [2]. The results were quite high especially for systems dealing and conducting with characters.

V. CONCLUSION

Recognition phase considers as the heart of the text recognition system and for many pattern recognition approaches such as face, voice, signatures, and image processing recognition systems. Recognition phase is a phase of making the system decision. Based on the extracted features, the Recognition algorithm of the system attempts to identify the pattern that represents the input features. On the other hand, the success rate of any recognition system depends not only on the recognition techniques but it depends on several reasons such as the features extraction technique, the preprocessing stage, or the segmentation step. However, until now there is no such thing as the "best recognition method". It depends on many factors, such as available training set, number of free parameters, the text nature and the whole system methodology. To sum up, more researches are needed to find the best recognition techniques for online Arabic handwritten recognition systems.

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