# Toward an On-Line Handwriting Recognition System Based on Visual Coding and Genetic Algorithm

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## Abstract

One of the most promising methods of interacting with small portable computing devices, such as personal digital assistants, is the use of handwriting. In order to make this communication method more natural, we proposed to visually observe the writing process on ordinary paper and to automatically recover the pen trajectory from numerical tablet sequences. On the basis of this work we developed handwriting recognition system based on visual coding and genetic algorithm. The system was applied on Arabic script. In this paper we will present the different steps of the handwriting recognition system. We focus our contribution on genetic algorithm method.

## 1 Introduction

In the last few years a number of pen-based computers and personal digital assistants (PDA's) have been released. Most of the PDA's have difficulty to recognize handwritten text. Since handwriting is one of the most familiar communication media, pen-based interfaces combined with automatic handwriting recognition offer a very easy and natural input method. We notice the great increase of interest in the development of on-line handwriting recognition systems [1,2,3,4]. The user writes on the surface of a digitizing tablet with an electronic pen. The digitizing tablet captures the dynamic information about handwriting, such as number of stokes, stroke order, writing speed, etc, all in real time.

In recent years, some researches have made a lot of efforts in the field of the cognitive psychology and the linguistics to conceive the model of perception and reading by men [1,5,6]. The encoding of Arabic handwritten word consists of representing a word from its original sequence of 2D coordinating it to sequence of visual codes. In fact, our approach is based on the psychology of the visual perception to extract primitive description of the word, which is useful in the stage of on-line handwritten recognition. For this reason, some algorithms are used to extract automatically the visual codes from the cursive script. The extraction rate of this experiment is 72 % [1]. We correct the weakness of this heuristic strategy chosen for encoding the Arabic handwritten word by developing a basic concept of the genetic approach in order to select the best combination of characters that represent the correct Arabic word.

In this paper, we developed a system that recognizes on-line Arabic cursive handwriting. Previous research in the field of calligraphic characteristics and visual coding of the Arabic handwriting is reviewed in section 2. Section 3 is devoted to present our proposed recognition system which consists of the genetic algorithm concept. Experimental results and discussions were given in section 4.

## 2 Calligraphic characteristics and primitive extraction of the Arabic Handwriting

The Arabic is a consonantal and cursive writing. This property is met in two forms printed or handwritten. The Arabic alphabet is composed of 28 different letters. The difference between these letters is their positions in the word, the number and the position of the diacritic dots, the presence of the "hamza" and Vowels. In fact, the majority of letters change slightly in the shape of their character according to their position in the word (initial, medium or final) if they are joined to another letter either if they are isolated. Therefore we have 58 Arabic letters without diacritics as shown in the following figure.

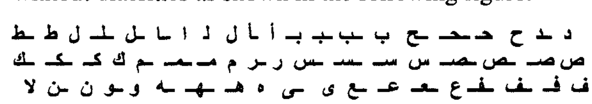


Fig.1. The 58 Arabic letters in their different positions

### 2.1 Diacritical symbols influence

Some Arabic letters have the same shape; however, they are distinguished from each other by the addition of dots in different positions relative to the main stroke. Some Arabic characters use special marks to modify the character accent. When diacritical symbols (dots, specials marks) are used, they appear above or below the characters and they are drawn as isolated entities as shown in fig. 2. Diacritical symbols are positioned at a certain distance from the character. In fact, this makes some difficulties in separating the border of a text line.

Indeed, diacritical symbols can generate some redundant separate lines [1]. We count 15 among the 28 letters of the alphabet, which contain dots. Some letters present a zigzag shape said 'Hamza'. It is considered as accent "vowel" in the Arabic alphabet. All diacritics are not considered in our work.

### 2.2 Primitive extraction

The word has generally two main zones: the median zone and the striking zone. Every zone is composed of its own visual indications as it is presented in the tables (1,2) [1].

**Table.1** Visual codes information of the prominent zone

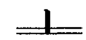
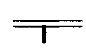
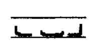
| Notation | Visual code | Shape |
|---|---|---|
| *Alif* | Al |  |
| Shaft | Ha |  |
| Left oblique shaft | Hog |  |
| Left oblique shaft | Hod |  |
| Leg | Ja |  |
| Pocket | Po |  |

**Table.2** Visual codes information of the median zone

| Notation | Visual code | Shape |
|---|---|---|
| Valley | Va |  |
| Occlusion | Oc |  |
| Curve open right | Cod |  |
| Left open curve | Cog |  |
| Ain | Ain |  |
| Sad | Sad |  |
| Space inter tracing | # |  |

We attribute for every visual code a label as shown in table 3.

**Table.3** Visual codes labels

| Visual code | Va | Oc | Po | Al | Ja | Ha | CoD |
|---|---|---|---|---|---|---|---|
| Label | *1* | *2* | *3* | *4* | *5* | *6* | *7* |

| CoG | HoG | HoD | Ain | Sad | # |
|---|---|---|---|---|---|
| ***8*** | ***9*** | ***10*** | ***11*** | ***12*** | ***13*** |

### 2.3 Features extraction of the Arabic script

We represent an arabic word by 2 strings: the first string represents the visual indices and the second one represents the different letters which are called "chromosomes". The number of strokes is determined by calculating the number of the velocity maxima of the handwriting trajectory [2].
The following table shows the visual indices and the visual codes of some Arabic letters. These features are used in the preliminary operations of genetic algorithm.

**Table.4** Example of some letters with their visual features and stroke number

| Arabic Letters | Indices | Stroke Number | Visual Codes |
|---|---|---|---|
| ا | 1 | 1-2 | Al |
| ـا | 2 | 2-3 | Al / Va |
| ب | 3 | 3-4 | Va |
| س | 4 | 3-4-5 | Va / Va / Va |

## 3 Genetic algorithms

Genetic algorithms are a class of optimization and search methods that use randomness to avoid local extrema. They are capable of adaptive and robust search over a wide range of space topologies [3]. Genetic algorithms are distinguished from other techniques by a principal characteristic: they search in intrinsically parallel fashion from a population of solutions and not from a single solution. A genetic algorithm is too an iterative algorithm that depends on the generation-by-generation development of possible solutions, with selection schemes permitting the elimination of bad solutions and the replication of good solutions that can be modified. The robustness of a genetic algorithm is also due to the fact that it manipulates according to parameters rather than the parameters themselves. There are three stages in a genetic search process: selection, crossover and mutation.

### 3.1 Gene structure

A handwritten word is represented by a continuation of visual codes of letters. In this case the order of these letters is considered. We attribute N-the number of basic letters extracted from a cursive word. Therefore, every gene of the population has N chromosomes and every chromosome has one of the 58 possible values (1 to 57 for the basic Arabian characters and the value 0 for characters with more than one visual indication) numbered from the right to the left.

For example, if the letter □ has 6 strokes, we code it as follow. Visual codes: va/ain/0/0/0/va

Label codes: 1/11/0/0/0/1

An other example for the complete word: علم

The visual codes are: Cod/Va/Va/Al/Va/Va/Occ/Ja

The chromosomes are : 27 / 40 / 42.

The following figure shows us the different codes:

| Letters | 0 | 0 | 0 | 0 | ـم | 0 | 0 | ـلـ | 0 | 0 | عـ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Visual indices | 5 | 0 | 0 | 2 | 1 | 1 | 4 | 1 | 1 | 0 | 7 |
| Chromosomes | 0 | 0 | 0 | 0 | 42 | 0 | 0 | 40 | 0 | 0 | 27 |
| Stroke order | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

Fig.2. Example of an Arabic word representation

### 3.2. Fitness function

The value returned from the fitness function for one chromosome represents the degree of match between the word represented by that chromosome and the real handwritten word. The calculation of the fitness value is based on sum of the resemblance measurement between two visual indices strings. The following table (Table 5) presents the different values of fitness function. The genetic algorithm will find the best combination of characters to reconstruct the analyzed word. In the selection-reproduction stage, the solutions with high fitness values are given more chance to reproduce, which gives them more effect on the population change. In this stage, the best chromosomes will dominate while the worse ones are discarded.

**Table.5** Fitness values matrix

| **VI** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 0 | 1 | 1 | 1 | 1 | 0.5 | 0.5 | 1 | 1 | 0.5 | 0.5 | 1 |
| 3 | 1 | 1 | 0 | 1 | 0.5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 4 | 1 | 1 | 1 | 0 | 1 | 0.5 | 1 | 1 | 0.5 | 0.5 | 1 | 1 | 1 |
| 5 | 1 | 1 | 0.5 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 6 | 1 | 1 | 1 | 0.5 | 1 | 0 | 1 | 1 | 0.5 | 0.5 | 1 | 1 | 1 |
| 7 | 1 | 0.5 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0.5 | 0.5 | 1 |
| 8 | 1 | 0.5 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0.5 | 0.5 | 1 |
| 9 | 1 | 1 | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 0 | 0.5 | 1 | 1 | 1 |
| 10 | 1 | 1 | 1 | 0.5 | 1 | 0.5 | 1 | 1 | 0.5 | 0 | 1 | 1 | 1 |
| 11 | 1 | 0.5 | 1 | 1 | 1 | 1 | 0.5 | 0.5 | 1 | 1 | 0 | 0.5 | 1 |
| 12 | 1 | 0.5 | 1 | 1 | 1 | 1 | 0.5 | 0.5 | 1 | 1 | 0.5 | 0 | 1 |
| 13 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

"**VI**": Visual indices

### 3.3 Crossover operation

The crossover operation consists on the selection of two parent solutions, with a higher probability for chromosomes possessing high fitness values. During crossover, portions of each parent pair are selected and resulting chromosomes are created by concatenation of the exchanged substrings. The main goal of the crossover stage is to generate new solutions, which will contain the useful parts of both parent solutions and which will have better fitness values. The number of crossover positions should not be before a zero, i.e. it should not break a character between two blocs. (See figure 3)

| Word | 0 | 0 | ن | ـيـ | ' ' | 0 | ـز | 0 | 0 | 0 | ـهـ | ـب |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IV | 0 | 3 | 1 | 1 | 13 | 5 | 1 | 1 | 0 | 2 | 1 | 1 |
| CH | 0 | 0 | 46 | 4 | 10 | 0 | 13 | 0 | 0 | 0 | 44 | 4 |
| Order stroke | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

| Word | 0 | ـر | ' ' | 0 | 0 | 0 | ـو | 0 | 0 | 0 | حـ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IV | 0 | 5 | 13 | 5 | 0 | 2 | 1 | 1 | 0 | 0 | 8 |
| CH | 0 | 14 | 10 | 0 | 0 | 0 | 51 | 0 | 0 | 0 | 9 |
| Order strokes | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

Fig.3. Example of crossover operation between 2 words

The crossover will be done on the fourth stroke. Two generations have been reproduced. (See figure 4)

Word1 « حزين »

Word2« تمور »

| Word | 0 | 0 | ن | 0 | ـيـ | ' ' | 0 | ـز | 0 | 0 | 0 | حـ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VI | 0 | 3 | 1 | 0 | 1 | 13 | 5 | 1 | 1 | 0 | 0 | 8 |
| CH | 0 | 0 | 46 | 0 | 4 | 10 | 0 | 13 | 0 | 0 | 0 | 9 |
| Order stroke | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

| Word | 0 | ـر | ' ' | 0 | 0 | 0 | ـو | 0 | 0 | 0 | ـهـ | 0 | ـب |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| VI | 0 | 5 | 13 | 5 | 0 | 2 | 1 | 1 | 0 | 2 | 1 | 0 | 1 |
| CH | 0 | 14 | 10 | 0 | 0 | 0 | 51 | 0 | 0 | 0 | 44 | 0 | 4 |
| Order stroke | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

Fig.4. Crossover results

"CH": Chromosome

### 3.4 Mutation operation

Just as in nature, some individuals will have random mutations occur in their genes. The mutation rate specifies the odds that a given gene in an individual will be mutated. If a gene is selected for mutation then its value will be changed. In the case of bit representation, the gene will simply be flipped. (See figure5)

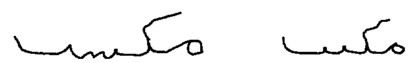
| Word | 0 | 0 | ـم | ‘ ’ | 0 | 0 | 0 | ـو | 0 | 0 | ـلـ | 0 | 0 | عـ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IV | 5 | 0 | 2 | 13 | 5 | 0 | 2 | 1 | 1 | 4 | 1 | 1 | 0 | 7 |
| CH | 0 | 0 | 41 | 10 | 0 | 0 | 0 | 51 | 0 | 0 | 40 | 0 | 0 | 27 |
| Order stroke | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

| Word | 0 | 0 | ى | ‘ ’ | 0 | 0 | 0 | ـو | 0 | 0 | ـلـ | 0 | 0 | عـ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| IV | 3 | 0 | 7 | 13 | 5 | 0 | 2 | 1 | 1 | 4 | 1 | 1 | 0 | 7 |
| CH | 0 | 0 | 53 | 10 | 0 | 0 | 0 | 51 | 0 | 0 | 40 | 0 | 0 | 27 |
| Order stroke | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |

Fig.5. Mutation result of the word « علوم »

## 4 Experimental results and discussions

In order to evaluate the performance of our system, 24 participants were invited to contribute to the handwriting data construction for our recognition experiment. The data set of words of each participant was stored in one data file. When producing the data file, each participant was asked to write some Arabic words. We collected 500 words written by different writers. 200 words we used as data prototypes for the selection of the initial population of the genetic algorithm, the others used for testing our system. In the first stage where the heuristic strategy chosen for encoding the Arabic handwritten word, The extraction rate obtained is about 72 %, but in the second stage which consist to correct the weakness of the previous method, we developed a genetic algorithm in order to select the best combination of visual codes extracted by a heuristic method from a word. The evolutionary approach here permits the recognition of cursive handwriting without limitation of a lexical dictionary. The number of generations (500) and the fitness value (0.5) were fixed as a convergence condition criterion. The recognition rate obtained is about 89%. These results obtained were encouraging. Compared to the on line recognition system of the cursive handwriting in [3] which have a manually segmentation system of the handwritten words, our system contains an automatically segmentation process of the handwritten words. This segmentation approach is based on a combination of the visual extractor and the evolutionary genetic algorithm system. Some errors were due to the style of the writer handwriting and were difficult to be avoided even by a human reader. For example there is confusion between the two Arabic words shown in the following figure.



Maksabon Maktabon

Fig.6. The confusion between two Arabic words

As a future work, we can remove this confusion and improve the recognition rate obtained by adding to our system a matching template algorithm and a large lexical Arabic dictionary.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