Handwritten Tifinagh Text Recognition Using Fuzzy K-NN and Bi-gram Language Model

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Abstract—In this paper we present a new approach in Tifinagh character recognition using a combination of, k-nearest neighbor algorithm and the bigram language model. After the preprocessing of the text image, and the word segmentation, for each image character, the k-NN algorithm proposes candidates weighted of their membership degree. Then we use the bigram language model to choose the most appropriate sequence of characters. Results show that our method increases the recognition rate.

Keywords—Tifinagh character recognition; fuzzy k-nearest neighbor; features extraction; bigram language model.

I. INTRODUCTION

The task of handwritten text recognition is challenging and has been a focus of research for several decades [1][3][7]. A human always use his language knowledge when reading a text. Thus the input image is not enough to estimate the most likely characters (or words) sequence, but also the target language [2]. Thus, modern recognizers use a statistical approach in which the returned characters (words) sequence is the one that maximizes the probability with respect to the input image according to a model trained on handwritten text as well as the language according to a model trained on a language corpus.

This paper is organized as follows: Section 2 presents two techniques used for features extraction, the gravity center distance method and the pixel density method. The fuzzy k-Nearest neighbor and bi-gram language model are presented in section 3. Our complete handwriting recognition process is outlined in section 4. Experimental results and discussions are in section 5, then the conclusion in section 6.

II. FEATURES EXTRACTION

Pre-processing techniques like word segmentation, thinning, slant correction and smoothing are applied. To extract the image features, we use a linear combination of the gravity center distance method and the pixel density method. Those two methods require the spatial division of the character image into \( W \times H \) boxes so that the portions of character will be in some of these boxes. There could be boxes that are empty. The choice of number of boxes is arrived at by experimentation.

A. Gravity center distance

For each box B, the gravity center \( G \) of black pixels is computed. The feature is then obtained by dividing the distance \( d \) between \( G \) and bottom left corner of the box by the length of the diagonal of that box D “Fig 1”.

III. FUZZY K-NEAREST NEIGHBOR AND BI-GRAM LANGUAGE MODEL

In this section, we give a brief presentation of both techniques used in this work, fuzzy k-nearest neighbor and bigram language model.

A. Fuzzy k-nearest neighbor

Fuzzy k-Nearest neighbor is part of supervised learning that has been used in many applications in the field of data mining, statistical pattern recognition, image processing and many others[6][8]. Some successful applications are including recognition of handwriting.

It’s a very simple technique. It works based on an unsupervised clustering algorithm like fuzzy k-means algorithm to determine prototypes representing each cluster. Then the minimum distance from the query instance to these prototypes are used to determine the K-nearest neighbors. After and basing on membership function, we take the neighbor with the maximum membership degree to be the prediction of the query instance.

From a given labeled examples, and using fuzzy k-means algorithm, we generate a number of prototypes \( P_{ij} \) representing
each class $C_i$. In this step, the number of training samples is reduced and the outliers are excluded.

For a given image character $X$, the $k$-Nearest neighbor prototypes $N_j \in \{P_{ij}\}, i = 1 \ldots k$ are generated (using distance similarity), then the membership degree of $X$ to the class $C_i$, is calculated as follows [5]:

$$
\mu_i(X) = \frac{\sum_{j=1}^{k} \mu_{ij}/d(X,N_j)^{2/(m-1)}}{\sum_{j=1}^{k} 1/d(X,N_j)^{2/(m-1)}}
$$

(1)

The term $\mu_i,j$ is the membership degree of $N_j$ to the class $C_i$. This term is equal to 1 if $N_j \in C_i$, 0 otherwise.

This algorithm has better performances versus the classical $k$-nearest neighbor algorithm. In the classic approach, the vector $X$ is affected to the class with major prototypes in $\{N_{j=1..k}\}$ with no consideration of how close these prototypes are to $X$. However in the fuzzy approach, the vector $X$ could be affected to a class that have only one prototype in $\{N_{j=1..k}\}$ just because it’s closer enough to $X$ and the other $k$-1 prototypes are not (fig).

### A. Bigram language model

An N-gram model is a type of probabilistic language model for predicting the next item in a sequence. N-gram models are now widely used in probability, communication theory, computational biology, data compression and in statistical natural language processing.

Let $P(w)$ be the probability that a word $w$ (sequence of characters $w = \{c_1, c_2, \ldots, c_n\}$) appears in a dictionary. By using the chain rule, this probability can be computed as follows:

$$
P(w) = P(c_1) \times \prod_{i=2}^{n} P(c_i/c_1, c_2, \ldots, c_{i-1})
$$

(2)

By using the Markov assumption, this probability is approximated by:

$$
P(w) \approx P(c_1) \times \prod_{i=2}^{n} P(c_i/c_{i-1})
$$

(3)

Each character depends only on the previous one rather than all the previous characters. This assumption is important because it massively simplifies the problem of learning the language model from data.

$$
P(c_i/c_{i-1}) = \frac{\text{count}(c_{i-1}c_i)}{\text{count}(c_{i-1})}
$$

(4)

In practice, however, one should smooth the probability distributions by also assigning non-zero probabilities to unseen bigrams [4]. The technique used is called the add-one smoothing, and it’s given by the following expression:

$$
P(c_i/c_{i-1}) = \frac{\text{count}(c_{i-1}c_i)+1}{\text{count}(c_{i-1})+v}
$$

(5)

Where, $v$ is the number of characters in the used language alphabet.

In order to use the bigram context of the first and the last character in a word, we need to augment this word with special symbols <s> and </s> at the beginning and the end of the word respectively.

For example, to compute $P(\text{“ tờờờ”})$, we first need to augment this word with <s> and </s>. Then we have:

$$
P(\text{“ tờờờ”}) = P(\text{”/s“}), P(\text{”/”}), P(\text{”/”}), P(\text{”/”}), P(\text{”/”/s“})
$$

### IV. Recognition System

Our recognition system is made of three blocks “Fig. 2”: the pre-processing block, the isolated character recognition block and the word recognition block.

First, the word image is pre-processed by thinning; slant correction and smoothing. The word image is then segmented to a sequence of character images.

![Recognition System Diagram](image)

For each character image the fuzzy $k$-nearest neighbor proposes candidates, each one with a membership degree $\mu(c_{ij})$ (the $j$th candidate proposed for the $i$th character image). From these candidates we generate all $m$ possible combinations $w_{i=1..m}$. The membership degree of each word is given by:

$$
\mu(w_i) = \prod_{c \in w_i} \mu(c), i = 1 \ldots m
$$

(6)

For example, in the word image “玥玥玥” the $k$-NN algorithm propose a set of candidates for each character in the word image “Fig. 3”. For the first character “玥” tow candidates are proposed, “玥” with membership degree 0.742 and “玥” with a membership degree 0.258, the decision is clear.
with no ambiguity “้า” because “้า” has the higher membership degree. The same case for the second and third character. For the forth character “้า” it proposes three candidates “้า”; 0.081, “้า”; 0.506 and “้า”; 0.412 the decision become ambiguous. The same problem with the last character, it proposes “้า”; 0.484 and “้า”; 0.516 for the character “้า”. Using these membership degrees, the fuzzy k-nearest neighbor algorithm gives the character sequence “้า้า้า้า” as result, instead of “้า้า้า้า”.

In the previews stage of our recognition system, the k-nearest neighbor algorithm misrecognizes some ambiguous characters. To avoid this problem we use the bigrams to select the most appropriate word as follows:

\[ \hat{w} = \arg \max_{w \in \{w_{i=1..m}\}} (P(w), \mu(w)) \]  

(7)

A. Algorithm

For each word image w

For each c in w

Using fuzzy k-NN algorithm, Generate candidates and their membership degrees

End for

Generate all m possible combinations \( w_{i=1..m} \).

For each word \( w_i \)

Compute \( \mu(w_i) \) using (1) and (6)

Compute \( P(w_i) \) using (3)

End for

The selected sequence of characters \( \hat{w} \) is given by (7)

End for

Table I. Recognition rate for different grid sizes

| Recognition rate | 3x3 | 3x5 | 5x5 | 5x7 | 7x5 | 9x11 |
|------------------|-----|-----|-----|-----|-----|-----|
| FKNN             | 80.87 | 85.24 | 88.73 | 86.99 | 88.26 | 81.88 |
| FKNN & Bigrams   | 84.20 | 86.64 | 91.05 | 89.31 | 89.66 | 85.48 |

The gravity center distance method gives information about the position of the black pixels in the box. Therefore, tow boxes with deferent amount of black pixels but with the same gravity center will have the same feature value. In the other hand, the pixel density method gives information about the amount of the black pixels in a box. The weakness of this method is that it gives no information about the position of black pixels in that box. So, tow boxes with same amount of black pixels will have the same feature value, even if the black pixel distribution is not the same.

In order to take advantage of both methods we used a linear combination of these two methods. So if \( v_{d} \) is the feature given by the pixel density method and \( v_{p} \) the one given by the gravity center distance, the used feature is given by the following expression:

\[ v = (1 - \gamma) v_{d} + \gamma v_{p} \quad 0 \leq \gamma \leq 1 \]  

(8)

“Fig. 4” shows that the combination of pixel density and gravity center distance method \( (\gamma = 0.02) \) gives better results than using only one method \( (\gamma = 1 \text{ or } 0) \). We can also see that, for all values of \( \gamma \), the k-nearest neighbor combined to the bigram model (solid curve), produces higher performances than the only use of the k-nearest neighbors algorithm (dashed curve).

B. Neighbors number k and the fuzziness factor m

The k-nearest neighbor algorithm is based on the equation (1). This equation contains tow parameters that affects the accuracy of the classifier, these parameters are the number of nearest neighbor k and the fuzziness factor m. High values of k will produce large number of candidates with small membership degrees. This big number of candidates leads to a huge number of combinations, and then, some of these combinations could have a higher probability even if they are far away from the real word image “Fig. 5”. In the other hand if k is too low, the k-nearest neighbor will not propose enough candidates to be used by the bigram model “Fig. 5”.

“Fig. 6” shows that, if the m parameter is too large all proposed candidate will have approximately the same membership degree and the decision will be made by the bigrams.
An example that illustrates an inappropriate choice of k and m is shown in “Fig. 7”. Where k=11, m=3 and the word image “ⴰⴰⴰⴰⴰ”, for each character image, the membership degrees, of proposed candidates are all between 0.08 and 0.38, the number of possible words is 72576. The result given by the fuzzy k-nearest neighbor algorithm was “ⵎⴰⵎⴰ” and “ⵎⴰⵎⴰ” by the combination of fuzzy k-NN and bigram model. In both cases tow characters were misrecognized, the difference is that the second one “sounds” to be a real Amazigh word “ⵎⴰⵎⴰ”.

VI. CONCLUSION

In this work we presented a new technique for handwritten Tifinagh text recognition. In the features extraction stage we used a linear combination of the gravity center distance and pixel density. Then the fuzzy k nearest neighbor proposes candidates for each character image with its membership degree, the bigram model assigns a probability for each characters sequence. The selected characters sequence is the one that has the higher product. With a good choice of the number of neighbors k, and the fuzziness factor m, bigram model can improved significantly the recognition rate.

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