Segmentation and recognition strategy of handwritten connected digits based on the oriented sliding window

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Abstract— In this paper, we propose a system to recognize handwritten digit strings, which constitutes a difficult task because of overlapping and/or joining of adjacent digits. To resolve this problem, we use a segmentation-recognition of handwritten connected digits based on the oriented sliding window. The proposed approach allows separating adjacent digits according the connection configuration by finding at the same time the interconnection points between adjacent digits and the cutting path. The segmentation-recognition using the global decision module allows the rejection or acceptance of the processed image. Experimental results conducted on the handwritten digit database NIST SD19 show the effective use of the sliding window for segmentation-recognition.

Keywords- ***segmentation; segmentation-recognition; handwritten digits, oriented sliding window***

I. INTRODUCTION

Automatic reading of digit fields from an image document has been proposed in several applications such as bank checks [1], postal code and forms. Usually, the handwritten digit recognition can be conducted mainly in four steps: preprocessing, segmentation, feature generation and classification. The preprocessing generally consists to transform the grayscale image of the document into the binary image in order to locate and isolate more easily the characters from each other. This step, called segmentation, [2] [3] [4] [5] consists in separating the overlapping and/or joining of adjacent digits into elementary digits for which the limited number of characters defines the possible distinct classes. After that, a feature generation is performed on the digit image for reducing the dimension of the representation and thus makes the design of the classification system. Next, a decision function allows assigning a character image to predefined class. Finally, the verification strategy using the global decision module allows the rejection or acceptance of the processed image.

In this paper, we only are interested in the segmentation stage where we try to improve the performances by offering the best cutting of adjacent digits when they are naturally connected.

The segmentation can be conducted by considering three following situations: distinct digits overlapped digits or connected digits. In most cases, the overlapped and connected digits are the frequent observed situations. Thus, many algorithms have been proposed to separate adjacent digits. Some ones are based on contours and others on the skeleton or on the size, the number and the position of the water reservoir to deduce the potential points of cutting [6] [1] [3].

The difficult task for finding the best cutting is that adjacent digits can be oriented which leads to an over-segmentation or under-segmentation [8].

Hence, we propose in this paper a segmentation and recognition strategy using an oriented sliding window for finding the cutting path. In order to get the best cutting, a segmentation-verification strategy is adopted for solving most segmentation problems.

This paper is then organized as follows. In Section 2, we describe the proposed segmentation method based on the oriented sliding window. Section 3 is devoted to the presentation of experimental results. Finally, conclusion and future work are presented in Section 4.

II. PROPOSED SEGMENTATION METHOD

The segmentation method of connected handwritten digit strings consists to find the best path of cutting the piece of stroke into insulated elements [6] [7] [9] [13] [14].

The difficult task for cutting two adjacent digits is to find the interconnection points. Figure 1 illustrates some difficult examples.

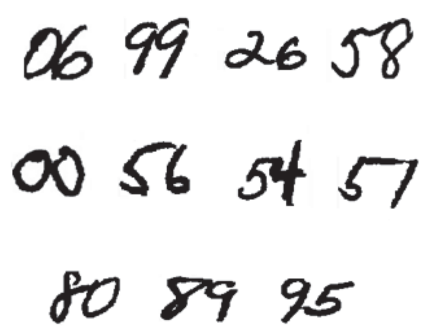

Figure 1. Examples of connected digits

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We present in the following section some modifications [14] of the segmentation method proposed by Oliveira [13].

A. Segmentation based on the interconnection points

The segmentation based on the interconnection points involves analyzing the number and nature of interconnection points between two adjacent digits in order to define the optimal position for cutting a digit image couple [2]. The first step is to define the Interconnection Points (IPs) and the Bases Points (BPs) from which starts the segmentation. BPs are obtained from the local extrema (minima and maxima) detected on the contour (In contrast to Oliveira method [13], BPs are obtained from the detected local extrema on the profile of each connected component). While IPs are calculated using the Freeman code according to the 8 directions in the clock-wise. The upper contour is used in order to detect the upper base point (upper BP), the lower contour to detect the lower base point (lower BP). Often, the connection points contain IPs, BPs or both at the same time. Therefore, three hypotheses can be considered for the optimal segmentation:

- Hypothesis 1: If the Euclidean distance between the projection of the BP and the IP is lower than a threshold, the cut is making between IP with upper BP and also between IP with lower BP (Fig.2.a).
- Hypothesis 2: If the lower segment of IP is related to a higher segment of IP (or vice versa) and both IPs are near a BP, the skeleton path linking both IPs (Skeleton path) is used as part of the segmentation cut with complementary paths between BPs and IPs (Composed path) (Fig.2.b)
- Hypothesis 3: In some cases, even if there is a connection between two digits, the skeleton path does not have an IP. Thus, to avoid the under-segmentation (lack of segmentation point), the algorithm [15] constructs a segmentation path based on the vertical projection of the BP. In our case, the segmentation path is based on the minimal Euclidean distance between upper BP and lower BP (closest points) in the middle (Fig.2.c).

This algorithm does not allow correctly finding the cutting path when connected digits are oriented. Hence, we propose a method based on the sliding window for finding at the same time the IP and the cutting path.

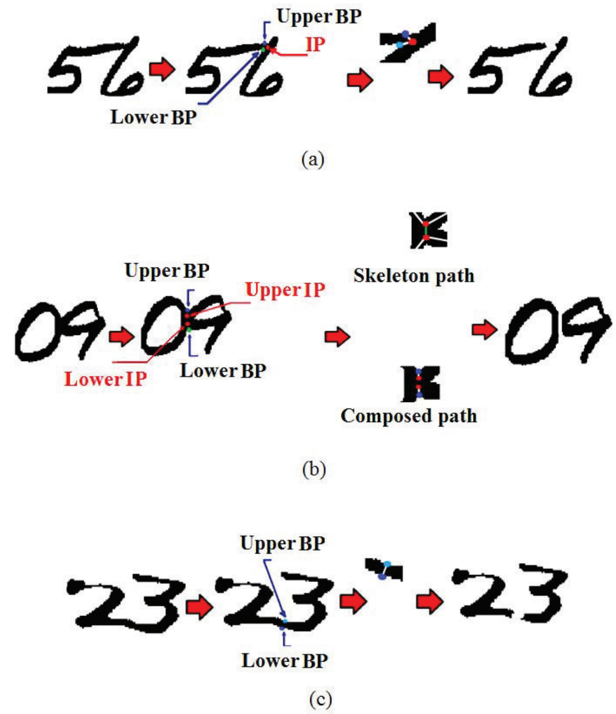

Figure 2. Segmentation paths according to IP and BP positions (a) Hypothesis 1 (b) Hypothesis 2 (c) Hypothesis 3

B. Segmentation strategy oriented windows

The main idea for segmenting adjacent digits is the use a sliding window, on the one hand, for finding IPs in order to avoid the over-segmentation and the under-segmentation, and, on the other hand, orienting window in order to define the optimal path. Hence, this segmentation method can be conducted into three steps:

- Detecting the presence of IP: For this, a fixed window is defined having the same height as the original image and a constant width. Thus, the IP is located in the middle of this width.
- Rotating the window in the range $\theta = [-\alpha, 0, +\alpha]$ around IP. Figure 3 shows various crossing of oriented windows around IP.

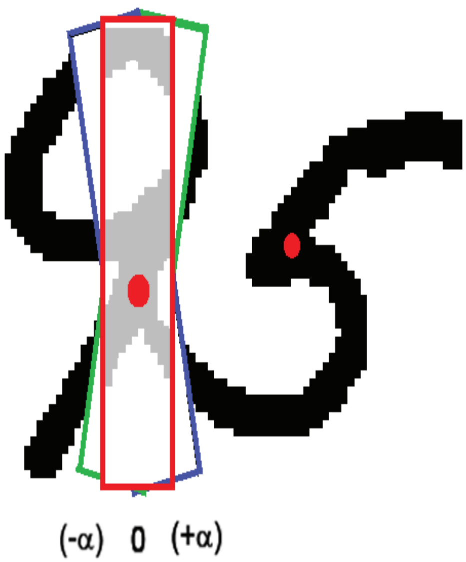

Figure 3. Crossing of oriented windows around IP

- Finding the cutting path: For each oriented window, if a single IP is found, then the cut is making between single IP with upper BP and also between single IP with lower BP when the Euclidian distance between IP and BP (upper BP or lower BP) is lower than a threshold T1. If there are two IPs (Upper IP and Lower IP), then the hypothesis 2 is applied. In order to avoid under-segmentation, the hypothesis 3 is applied on the full image. Figure 4 shows various segmentation paths according to direction of the oriented windows.

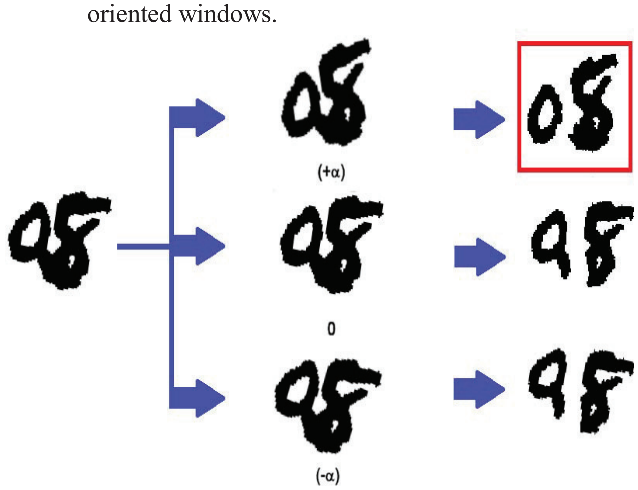

Figure 4. Segmentation paths according to direction of the oriented windows.

C. *Features generation*

Various methods have been developed for feature generation. In our case, we use two structural features [12] based on the uniform grid [15] and background foreground features of the skeleton, respectively.

D. *Recognition and Verification*

The final decision for a hypothesis of segmentation-recognition is given by the multiplication between the decision functions done by its sub-components. The decision function of a sub-component is given by the recognition system based on a multiclass SVM classifier One-Against-All [11].

The final decision function is based on the maximum value provided by each segmentation hypothesis. When values of decision functions are equal, the maximum value of the decision function is selected from the first sub-components. Figure 5 shows an example of segmentation-recognition according rules (hypotheses) presented in Figure 2. This verification can devote to reduce the confusion between isolated and under-segmented digits.

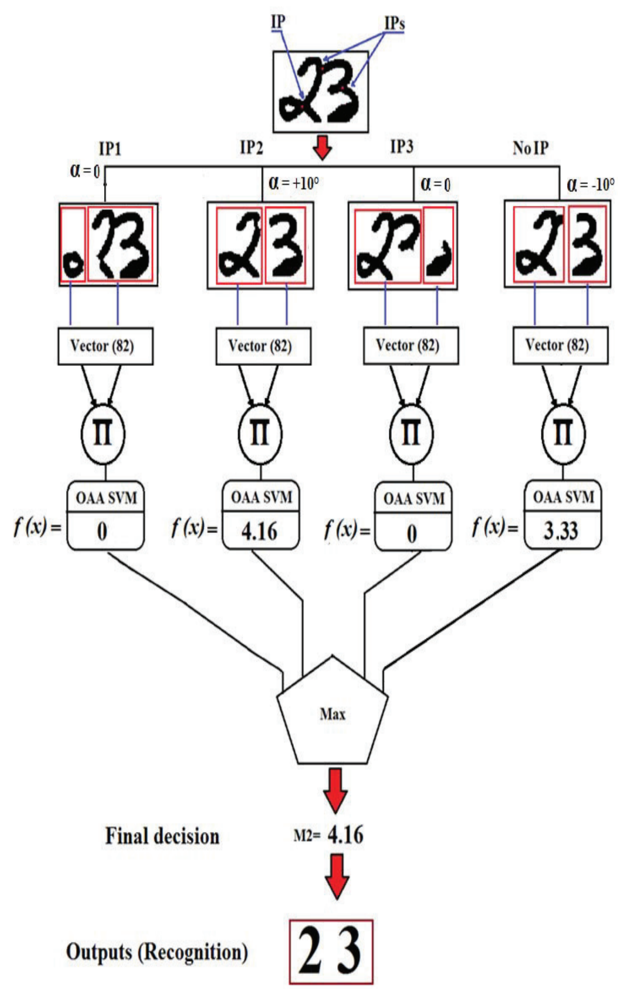

Figure 5. Final decision for Segmentation and recognition strategy of handwritten connected digits based on the oriented sliding window.

III. EXPERIMENTAL RESULTS

The evaluation of a segmentation method is very subjective. It can be done in two steps. The first is to evaluate the segmentation based on a prior knowledge about the effects of segmentation. The second step is to evaluate the system for recognizing handwritten digits by integrating segmentation and classification. In our case, we adopt the second approach for evaluating performances of the segmentation on a standard database NIST SD19 [10].

The NIST SD19 database is divided into two sets: the first set (5000 digits) is used for learning and the second set (600 digits) is used for testing.

The recognition module is based on the SVM multi-class approach using the One-Against-All implementation. SVM and RBF kernel parameters are fixed to C=10 and $\sigma = 10$, while the threshold for the segmentation is set to T1 = 7.

In order to study the effect of using oriented sliding windows, various orientation angles are selected in the range $\theta = [-\alpha, 0, +\alpha]$. Table 1 shows the results obtained for various angles $\alpha = \{0°, 5°, 10°, 15°, 20°\}$.

TABLE I. THE RECOGNITION RATE ORIENTED FOR VARIOUS ORIENTATION ANGLES $\theta = [-\alpha, 0, +\alpha]$.

Class	α = 0°	α = 5°	α =10°	α = 15°	α = 20°
0	86.42	88.57	91.67	94.59	85.29
1	80.00	80.00	80.00	80.00	80.00
2	94.50	96.30	100.00	100.00	96.30
3	90.00	90.00	100.00	90.00	90.00
4	83.33	85.71	83.33	80.00	80.00
5	85.37	82.50	85.37	76.32	82.50
6	90.00	90.00	95.00	86.67	83.33
7	100.00	100.00	100.00	93.33	100.00
8	81.48	92.00	96.15	100.00	100.00
9	90.00	90.00	93.10	89.29	85.19
Average	88.11	89.51	**92.46**	89.02	88.26

Obtained results show that the use of the orientation angle influences the overall recognition rate. Indeed, the best result is obtained when the orientation angle is fixed to α = 10°. This angle value matches a right angle intra-digit into the most cases.

Generally, we also note that the segmentation way based on the oriented windows reduces significantly the rejection rate by the classifiers, and also reduces the proportion of confusion between some digits, which logically leads to increase the overall rate of recognition.

Hence, the use of an oriented window allows solving the problem of inter-digit slope by rotating the window on both sides according the vertical axis (no orientation, left orientation or right orientation). On other hand, it allows intercepting the optimal positions of interconnection points and basis points in order to provide a good segmentation.

IV. CONCLUSION AND FUTURE WORK

The objective of this paper is to present a segmentation and recognition strategy of handwritten connected digits based on the oriented sliding window to find the best cut to isolate two adjacent digits.

This method allows improving the performances and resolving almost all the problems to meet. This segmentation method based on oriented sliding windows and the verification allows finding the best way of cutting on the connected digits.

The first obtained results are encouraging since we can manage, with a weak error of detection, all the possible ways of segmentation. Moreover, this method uses few rules and has the advantage of providing a correct segmentation in most cases.

For future work, we will attempt to evaluate the system on a database of the amounts of Algerian postal checks.

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