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Segmentation of Arabic Handwritten Numeral Strings Based on Watershed Approach

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***Abstract*—**Arabic offline handwriting recognition systems are considered as one of the most challenging topics. Arabic Handwritten Numeral Strings are used to automate systems that deal with numbers such as postal code, banking account numbers and numbers on car plates. Segmentation of connected numerals is the main bottleneck in the handwritten numeral recognition system. This is in turn can increase the speed and efficiency of the recognition system. In this paper, we proposed algorithms for automatic segmentation and feature extraction of Arabic handwritten numeral strings based on Watershed approach. The algorithms have been designed and implemented to achieve the main goal of segmenting and extracting the string of numeral digits written by hand especially in a courtesy amount of bank checks. The segmentation algorithm partitions the string into multiple regions that can be associated with the properties of one or more criteria. The numeral extraction algorithm extracts the numeral string digits into separated individual digit. Both algorithms for segmentation and feature extraction have been tested successfully and efficiently for all types of numerals.

***Keywords*—**Handwritten numerals, segmentation, courtesy amount, feature extraction, numeral recognition.

I. Introduction

RECONIZING handwritten numerals plays an important and challenging role in automation systems that deals with numbers such as postal code, banking account numbers and numbers on car plates. In recent years, numerous works on handwritten recognition have already been conducted. In such systems, handwritten documents are created by a mouse. Handwritten recognition has emerged as one of the most important research areas based on image processing and recognition [1], [2]. A lot of works were done by depending on computer in order to reduce the processing time and provide more accurate results [2].

Eastern Arab countries mostly use Arabic Indic numerals. Arabic Indic numeral recognition is a system that consists of ten Hindi numbers shown in Fig. 1. It is a complicated classification problem because each person writes the numbers in a different shape, styles, sizes, and possible orientation [3], [4].

Segmentation is the main bottleneck in this kind of recognition systems. The segmentation module reads a string of characters as input and segments them into isolated characters as output. The main problem is a lack of context, that is, usually we do not know the number of characters in the string and so the optimal boundary between them is unknown [5]. The "segmentation then recognition" approach provides a single sequence hypothesis where each sub-sequence should contain an isolated character, which is submitted to the recognizer. In the latter, the algorithm yields a list of segmentation hypotheses and then assesses each of them through the recognition process [6]. This approach produces better results, but it is costly because all these hypotheses must be generated and evaluated. Moreover, the recognition module has to discriminate different patterns, such as fragments, isolated characters, and connected characters [5], [6].

In this paper, we will focus on developing a powerful technique for automatic segmentation of Arabic handwritten numeral strings used in the courtesy amount of Arabic bank checks. This paper is organized as follows: Section II provides general background and related works. Section III presents the proposed algorithms for segmentation and feature extraction. Sections IV and V are experimental results and conclusion.

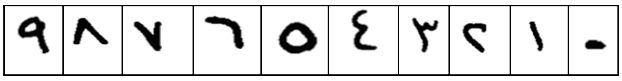

Fig. 1 Arabic Indic Numerals

II. Literature Survey and Related Works

A. Segmentation

Segmentation is the process of partitioning a digital image into multiple segments which are sets of pixels. In the system of recognizing the courtesy amount in Arabic bank checks, segmentation is the second stage after determining the location of the courtesy amount. Segmentation is considered as the most challenging part in recognizing a string of digits. It could be more challenging since there could be connected digits where the segmentation part becomes more difficult.

Image segmentation is the process of partitioning the digital image into multiple regions that can be associated with the properties of one or more criterion. These properties are gray level, color, texture shape, and others.

In mathematical sense, the segmentation of an image which is a set of pixels, is the partition of the image into n disjoint sets R_1, R_2, …, R_n, called segments or regions such that the union of all regions equals the image.

$$\text{Image} = R_1 \cup R_2 \cup \ldots \cup R_n.$$

There are many types of segmentation. The following are

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some of these types:

1. Column Segmentation: Based on dividing the image according to its coordinates (X, Y).
2. Thresholding: Based on converting the image to black and white, where the background is black and the foreground is white or vice versa.
3. Region based: Based on the regions of the image.
4. Edge based: Based on the boundary of each object in the image.
5. Hough Transform: Concerned with the identification of lines, positions of arbitrary shapes, most commonly circles or ellipses in an image.
6. Watershed approach: Applying the watershed segmentation function after marking the foreground and background objects.

B. Feature Extraction

Feature extraction in pattern recognition and in image processing is a special form of dimensionality reduction. It is a part of image processing, where a part of the whole image is taken to recognize its specific pattern and then it is measured. Feature extraction techniques are applied to get features that will be useful in classifying and recognition of images on the basis of that particular measurement. This stage is a process of extracting the objects from images.

In the case of handwritten extraction, it is the process of extracting the handwritten area from an image. The handwritten area of characters or digits should be the foreground of an image which should be extracted from the background. Extraction is an important stage that precedes the recognition stage. After digits and characters are extracted, they will be ready for recognition.

C. Related Works

In the state of art, many types and techniques of segmentation were used.

In [7], the authors segmented the car plate numbers and characters by finding white areas between columns with higher density of black pixels. Isolated black pixels are wiped out and the characters are segmented.

In [8], the authors proposed a segmentation approach that is based on a recursive function that uses splitting algorithms to divide blocks into isolated digits. The system begins the segmentation process by making a few obvious separations of characters, the primitives obtained are pre-classified as digit, fragment, multiple, or delimiters. Then the fragments are merged with digits or other fragments and analyzed again.

In [9], the author used many algorithms in segmentation digits apart from each other's in the courtesy amount. The algorithms discussed are: Min-Max, Hit and Deflect, Drop Fall, and Structural Feature based segmentation. He also handled overlapping and connected characters.

In [10], the authors mentioned the segmentation algorithms, bottom up and top down for efficient segmentation of characters. The bottom up algorithm is very simple and very fast. It builds words out of their characters. The top down algorithm attempts to recognize the attributes present within words. It operates on a higher level of abstraction, extracting features from words rather than partitioning the word and attempting to recognize each part of it.

In [11] the authors used the feedback strategy and the splitting algorithms for segmentation in order to divide multiple segments into pairs of digits. In the recognition stage they used Neural Networks technique which is the multi-layer perceptron (MLP).

III. The Proposed Approach

The following algorithms have been proposed for segmentation and feature extraction of Arabic handwritten numeral strings that can be applied for the courtesy amount of Arabic checks.

A. Numeral Segmentation Algorithm

The Numeral segmentation algorithm used is the Marker-Controlled Watershed Segmentation algorithm [10]. This stage is partitioning the digital image into multiple regions that can be associated with the properties of one or more criterion. These properties are gray level, color, texture shape, and others. The result of the segmentation stage is to have the digits separated from each other by lines, colors or others.

The proposed numeral segmentation algorithm is done by the following steps:

1. Gradient Magnitude Segmentation Function: applying the Gradient Magnitude to determine the edges of each digit. Gradient Magnitude is done by using the Sobel edge masks, imfilter, and some simple arithmetic. The gradient is high at the borders of the objects and low (mostly) inside the objects.
2. Morphological processing: Performing some morphological operations such as image dilating and image filling to fill in empty edges and close openings and holes.
3. Labeling the image
4. Measuring properties of image regions: Done by using (region props). The property used is 'Centroid'.
5. Watershed Transform Process: Performing the watershed Transform to determine the background markers. The background markers should not be too close to the edges of digits in order to be able to segment. This step will segment the objects in the image using thin lines.
6. Computing the Watershed Transform of the Segmentation Function. Performing the watershed transform to determine the foreground markers. This step is determined using the 'imimposemin' function that imposes minima. It modifies the intensity image, using morphological reconstruction so it only has regional minima wherever BW is nonzero. BW is a binary image the same size as the original image. After this step, the digits should be segmented.
7. Visualizing Process: We followed the following steps:

a. Superimpose the foreground markers, background markers, and segmented object boundaries on the original image.
b. Display the label matrix as a color image.

c. Use transparency to superimpose the pseudo-color label matrix described on (b) on top of the original intensity image.

B. Numeral Extraction Algorithm

A specific digit splitting function is built to extract the digits from the original image into sub images. The digit splitting function performs extraction depending on the properties of the image such as area, perimeter, diameter, centroid, image intensity, mean and others. It also performs extraction of digits mainly depending on the bounding box property where the bounding box is the smallest rectangle containing the digit with all its pixels. After the bounding box is determined, extracting the pixels becomes very easy. The digit splitting function was applied on the segmented image for splitting the digits to individual digits. Another function called "regionprops" has been used from the image processing tool box, this function measures properties of image regions (blob analysis). After the image is labeled into a label matrix, the "regionprops" function is used to measure the properties of the labeled region. It can measure one or more than one property at a time. It can even measure all the properties of an image. The digit splitting function is used to perform extraction of the digits and split them into separate digits.

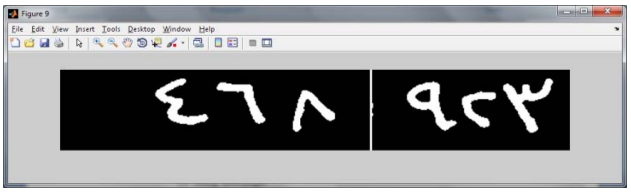

Fig. 2 The courtesy amount cropped from the bank check.

Fig. 3 The final image after the end of the segmentation stage

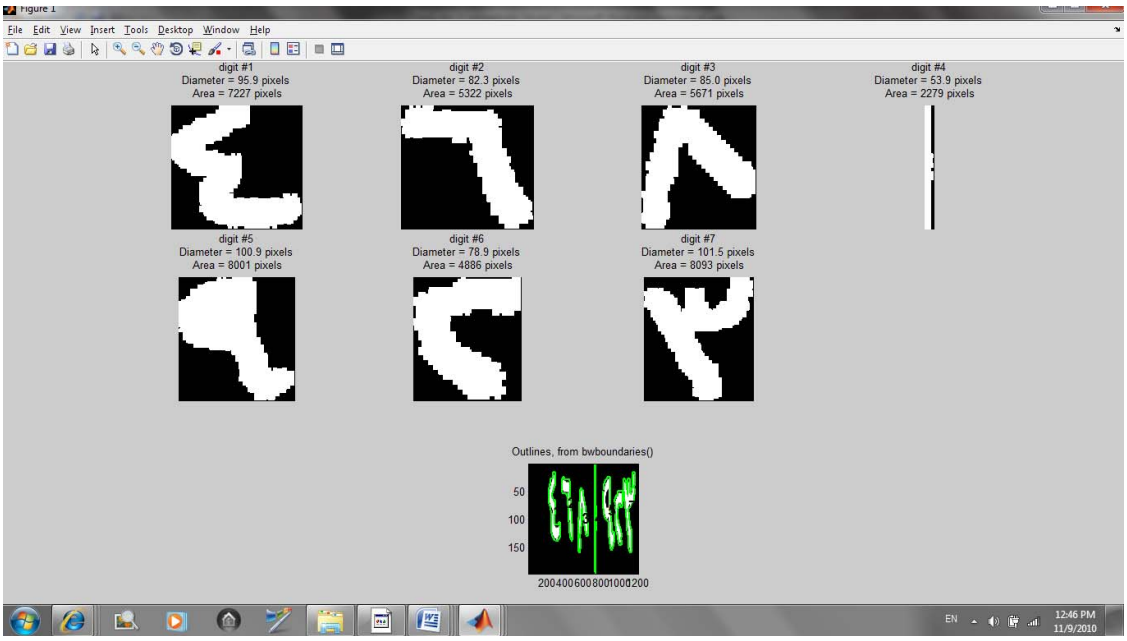

Fig. 4 The final extracted digits

Extracting and splitting the digits from the original image is described in the following steps:

1. Labeling each region in the image including the digits and the separator, and giving each region a number.
2. Choosing number of properties required to extract the digits. In this case all properties are chosen by using the region props function. It will measure the following properties: Mean, intensity, area, perimeter, centroid, and diameter.
3. Calculating the boundaries of each label to make it easier for extraction.
4. Measuring the properties and extracting digits as sub images by finding the bounding box of each labeled region.

After the end of this stage, the string of numeral digits is segmented and divided into separate individual digits. Now each separate digit will be treated separately by calling the recognition function that recognizes these off-line handwritten digits

IV. Experimental Results

The algorithm was designed and implemented using MATLAB Image Processing Tool Box. The proposed algorithm has been tested, experimented, and performed successfully and accurately. The samples are extracted from the courtesy amount that is extracted from real bank checks. Fig. 2 shows the courtesy amount cropped from the bank check. Fig. 3 shows the resulted image after applying the segmentation stage. Fig. 4 shows the resulted image after applying the numeral feature extraction stage.

V. Conclusion

Two successful algorithms for segmentation and feature extraction of handwritten Arabic numeral strings have been designed and implemented. The segmentation algorithm performed successfully the operation of segmenting a string of numeral digits. Also, the numeral feature extraction algorithm performed successfully the operation of extracting and splitting digits from the string containing them. Both algorithms are based on Watershed approach. The algorithms have been tested efficiently on the handwritten courtesy amount written on Arabic bank checks.

Future work can be done by adding to the proposed algorithms an efficient recognizer that can recognize each digit separately. Then we can use this system for doing the verification of handwritten courtesy mount written on Arabic bank checks.

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