Shift and Scale Invariant Recognition of Printed Numerals

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Abstract

Precise and accurate automatic recognition of decimal numbers is essential for many applications. Many methods have been used in the literature for this purpose. In this paper, we implement a simple and yet an efficient shift and scale invariant approach for offline machine-print decimal digit recognition using correlation factor between certain reference images and the image under testing. We show that the proposed approach is able to achieve very high recognition rates. While this proposed recognition technique is applied to decimal number recognition, it can be generalized to the recognition of any numerals in any language and can be extended to text as well.

Keywords: Correlation factor, Reference image, Recognition rate.

Introduction

Handwritten and machine printed texts usually consist of alphanumeric characters and /or special characters. Character recognition or Text recognition can be divided into either online or offline. An example of the online character recognition is the electronic personal data assistants and example of the latter subdivision of character recognition is images that are scanned in by a scanner, where the recognition is applied to previously written text [1]. This paper is mostly concerned with offline recognition of machine-print decimal digits.

Recently, recognition of offline machine-print decimal digits is getting more important as it is needed in many applications. Some of the most popular applications of number recognition can be summarized as:

- Financial applications such as reading numbers on bills or checks.

- Civil applications such as recognition of car plate number.

- Academic applications such as grading student exams automatically.

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- Postal applications such as reading physical addresses (zip code, street number, apartment number, etc).

Correlation factor has been widely used in many applications in image processing, e.g., watermarking [2] and template matching [3]. In this paper, we employ the correlation factor in the process of offline machine-print decimal number recognition and show that very high recognition rates can be achieved through an extended number of experiments. This paper is organized as follows: the rest of the introduction is devoted to talk about related work as well as the contribution of this paper. Description of the preprocessing is shown in Section II and then, we introduce the proposed approach in Section III. The experimental results can be found in section IV and Section V concludes the paper.

Literature Review

In literature, many different methods have been employed to recognize printed characters. For example, Milson and Rao [4] built a model that used some statistical methods to do machine print recognition. Narasimhan et al. in [5] used the rapid transform to do recognition of printed alphanumeric characters. Plamondon and Srihari [6] wrote a survey paper about online and offline recognition on the most popular algorithms in character and word recognition, verifying signature, and authentication of writer. In [8], Rajput and Chandrakant proposed a method to recognize handwritten and printed Kannada numeral using crack codes and Fourier descriptors plate. In their work, the authors represented the code in complex plane and computed 10 dimensional Fourier descriptors. The extracted features are then used for recognition using the Support Vector Machine (SVM) classifier.

Many approaches were shown in literature that are widely used for recognition of on-line and off-line handwritten Arabic and Hindi numerals. They can be summarized as: Neural Networks-based approaches [7-13] and support vector machines [13,14]. In the other hand, Hidden Markov Models have also been used in the recognition of off-line handwritten numerals [15]. Furthermore, Parkins and Nandi [17] used genetic programming to perform the recognition of hand-written digits from the USPS data set. In [18], the translational motion estimation has been used for the recognition of offline machine-print Hindi digits. In this paper, the translation was the kind of motion investigated. In [21], Global motion estimation has been used for the recognition of offline-machine-printed numeral. In this paper, the recognition of decimal numbers with some different types of motions such as translations and scaling, with numbers written in different fonts, using correlation factor is presented. Recently, the authors in [19] proposed a handwritten numeral recognition using modified BP ANN structure. In which, the feed-forward neural network is analyzed using different activation functions for the neurons of hidden and output layer and varying the number of neurons in the hidden layer. The Network was trained by adjusting the connection strengths at every iteration. The experiment results showed a high recognition accuracy.

Contribution

The contribution we present here for decimal number recognition is that we implement a very fast and accurate algorithm to do off-line machine-print decimal number recognition and show that very high recognition rates can be achieved. We calculate the correlation coefficient between certain reference images and the image under consideration. The recognition is done based on the reference image that has the highest correlation with the target image. The correlation is found using the following equation:

$$C = \frac{\frac{1}{Np} \sum_{i=1}^{Np} (I_R(i) - \mu_{I_R}))(I_T(i) - \mu_{I_T})}{\sigma_{I_R} \sigma_{I_T}} \qquad (1)$$

where $I_R(i)$ and $I_T(i)$ are the color intensity values for pixel *i* in the reference and target images, respectively. *Np* is the number of pixels in the image, μ_{I_R}, μ_{IT}, σ_{I_R} and σ_{I_T} are the mean and standard deviation of the reference and target images, respectively.

Preprocessing

The images type we are dealing with in the paper is black and white images with a size of 32x32 pixels. As a first step to do the numeric recognition using this approach we make sure that the numbers we are dealing have the same size and are centered in the middle of the image. We resized all images to a common size using the Matlab command "*imresize*" which is based on the Nearest-neighbor interpolation algorithm which selects the value of the nearest point yielding a piecewise-constant interpolant. We chose 20x15 pixels as a common size for all numbers. This size represents the typical number size after scanning with 100dpi resolution. Figure 1 (a) shows number "3" before preprocessing as an example. As we see the number "3" is not in the center of the image and the size of the image is 32x32 (including the number and the background). After the preprocessing step, the number was scaled and shifted to be in the middle of the image. The new image is a scaled version of the old image where the new dimension of the scaled image is 20x15 pixels as shown in figure 1 (b). This step assures good correlation between the reference and test images that are having the same value ("3" in this example). This step was carried out for all numbers 0 to 9.
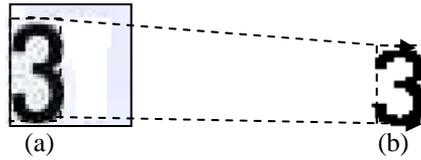
<center>(a)   (b)</center>

Figure 1. a) Number "3" located to the left of the image. (Image size 32x32).
b) Number "3" centered in the middle of the image. (Image size 20x15).

To show the effect of this step let us use the images in Figures 1 and 2. The correlation between the images in figures 1 (a) and 2 (a) is -0.03, while the correlation between the same images after shifting and scaling (shown in figures 1 (b) and 2 (b)) is 0.76. As we see, the preprocessing step gives the images with the same value good chance to have higher correlation which would be the main factor in doing the recognition.

<center>(a)   (b)</center>

Figure 2. a) Number "3" located in the middle of the image. (Image size 32x32).
b) Number "3" centered in the middle of the image. (Image size 20x15).

The Proposed Approach

The recognition was done using the correlation factor between the image under consideration and a reference image. The reference image for a certain number was obtained using the mean of 50 different images of the same number. To do recognition for a certain number, the number is first centered and scaled to a 20x15 pixels image as shown in the previous section. Then, the correlation between this new image and the 10 reference images (0, 1, 2, …, 9) is calculated giving ten correlation values one for each reference image. The number was classified to have the value of the reference image of maximum correlation with the number under consideration. Figure 3 shows the ten reference images used in this paper and figure 4 shows the proposed recognition approach.

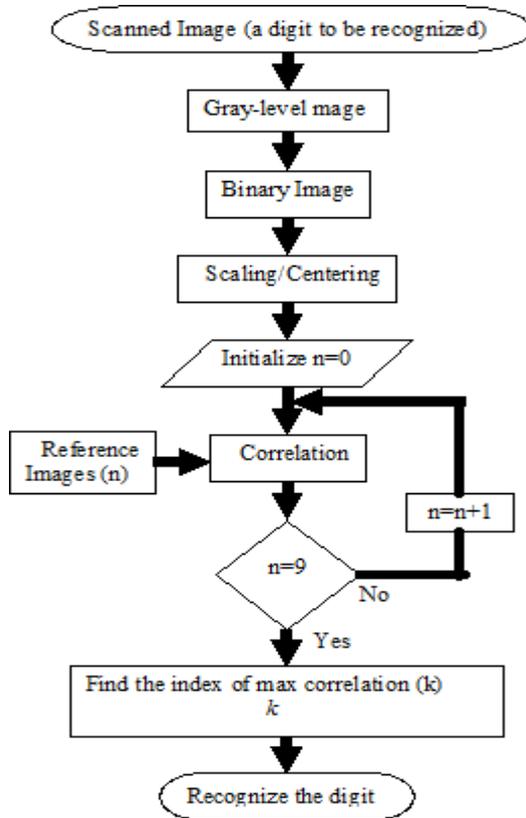**Figure 3**. Ten Reference images; one for each number.

<center>44</center>

Figure 4. The proposed recognition approach.

Recognition Results

The approach shown in the previous section was performed for 200 test images for each numeral, totaling 2000 test images. Each time the number to be recognized was centered and scaled to a 20x15 image. The correlation between the test number (test image) and the reference images was calculated and the number value of the image that has the highest correlation with this number was assumed to be the value of the number under consideration. The proposed method has shown high correct recognition rates. Experimental results show that each number has different recognition rate. Table 1 shows each number and the correct recognition rate of that number. The overall recognition for the test images was 99.0 %. Examples of pictures of numbers correctly recognized are shown in figure 5. From the two thousand test pictures only twenty pictures were incorrectly recognized. These cases include number 1, which was incorrectly recognized as 7, number 3 which was incorrectly recognized as 8, number 5 which was incorrectly recognized as number 6, and number 7 which was incorrectly

recognized as 1. Figure 6 contains some of the incorrectly recognized images. To show the effectiveness of this approach, we compare it to a recent approach mentioned in [20] where identification of English numerals was carried out using Rule based classifiers and its sub classifiers implementing set of classification rules. This technique carries out document vectorization which generates vectors based on characters shape, density and transition features. The overall performance of this technique was 94 %.

Table 1: Correct recognition rate for each number.

Decimal digit	Correct recognition rate (%)
Digit 0	100
Digit 1	95
Digit 2	100
Digit 3	99
Digit 4	100
Digit 5	98
Digit 6	100
Digit 7	98
Digit 8	100
Digit 9	100
Average	99.0
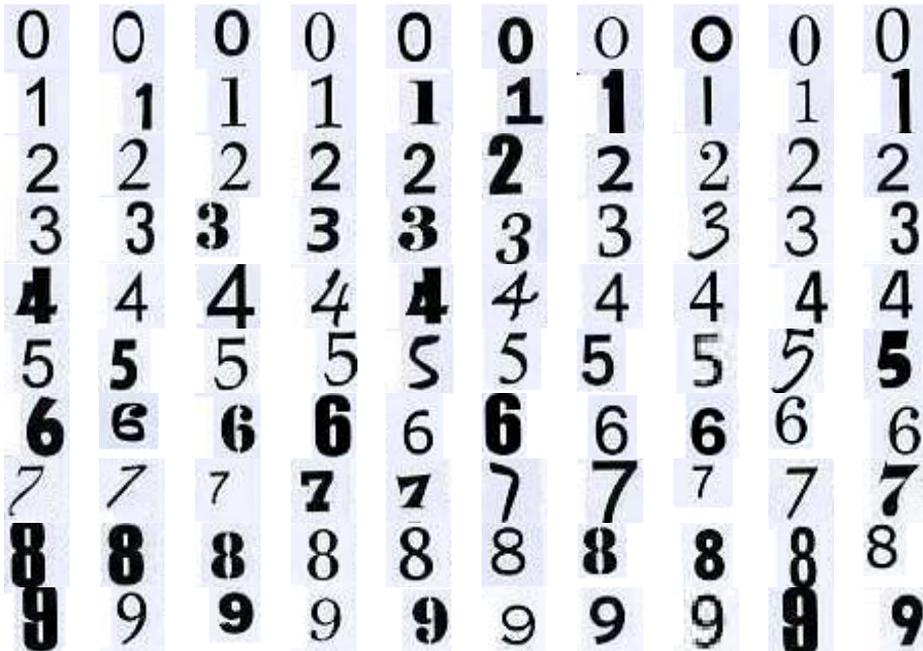
Figure 5. Examples of successfully recognized numbers of scanned images

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(a)   (b)   (c)   (d)

Figure 6. Images of incorrectly recognized numbers. In (a), number 1 was incorrectly recognized as 7. In (b), number 3 was incorrectly recognized as 8. In (c) number 5 was incorrectly recognized as 6. In (d) numbers 7 was incorrectly recognized as 1.

Conclusion and Future Work

This paper discusses an approach in the field of offline shift and scale invariant recognition of machine-print decimal numbers. Correlation coefficient is an important tool in the field of image processing/pattern recognition. We have shown that the application of correlation factor can be extended to encompass decimal number recognition with very high recognition rates reaching an average of 99%. In the future, we are looking to increase the number of data points and use the self organizing maps technique to apply it for Arabic and Hindi handwritten numerals recognition.

التعرف على الأرقام المطبوعة مع عدم التأثر بالإزاحة وتغير الحجم

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ملخص

الدقة و الوضوح في التعرف الآلي على الأرقام العشرية هو أمر أساسي في الكثير من التطبيقات. هنالك العديد من الطرق التي استخدمت من أجل هذا الغرض. لقد قمنا في هذا البحث ببناء طريقة بسيطة و فعالة لا تتأثر بالإزاحة وتغير الحجم للتعرف على الأرقام العشرية المطبوعة على الورق باستخدام معامل ارتباط بين صورة مرجعية و صورة تحت الاختبار. لقد توصلنا من خلال هذا البحث الى أن هذه الطريقة تستطيع تحقيق معدلات عالية في التعرف الصحيح على الأرقام. و على الرغم من أننا استخدمنا هذه الطريقة للتعرف على الأرقام العشرية إلا أنه يمكن تعميمها للتعرف على أي رقم مكتوب في أي لغة أخرى و يمكن أيضا اسخدامها لأغراض التعرف على النصوص المطبوعة غير الرقمية.

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