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Handwritten Numeric Digit Classification and Recognition: Recent Advancements

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Abstract – Handwritten digits classification and recognition is the process of interpreting handwritten digits by machines through different computing techniques. There are several approaches for handwritten digits classification and recognition. The fundamental steps involve in the recognition process of handwritten digits are: feature extraction, formation of feature space and finally the classification of features to recognize individual digits. Lots of algorithms for all these individual sections have been reported by the researchers all over the world to achieve higher recognition efficiency. This paper presents an extensive review of recent advancement in the field of handwritten numeric digit classification and recognition. Moreover this paper also presents the advantage and criticisms related to the recent techniques.

Index Terms – Numeric digit classification and recognition, features, classifier, FRE, FRR, recognition efficiency.

1. INTRODUCTION

One of the very popular application in computer vision is Handwritten Digits Classification or Recognition (HDR) in the field of character recognition. Digits like other universal symbols are widely used in technology, bank, OCR, analyzing of digits in engineering, postal service, numbers in plate recognition, etc. They are some of the famous applications on HDR [1]. There are 10 classes corresponding to the handwritten digits from ‘0’ to ‘9’ which are very depend on the handwritten. The main difficulty in the handwritten digits recognition is different handwritten style which is a very personal behavior where there are a lot of models for numbers based on the angles, length of the segments, stress on some parts of numbers, etc.

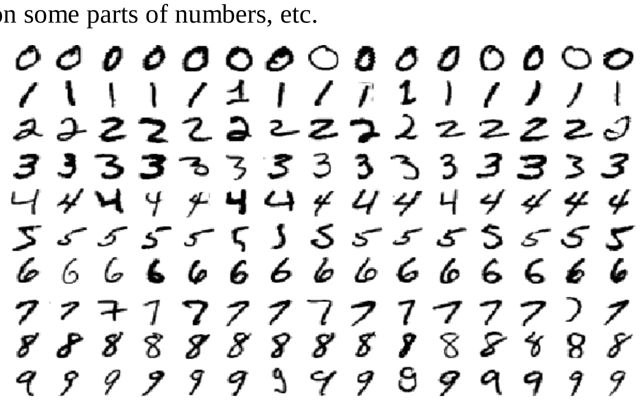

Fig. 1: Different samples of handwritten digits in MNIST dataset.

Figure (1) shows 15 different handwritten digits related to these issues taken from MNIST database. However recognizing numbers is clear for human but it is not very easy for machines especially when there are some ambiguities on different classes (e.g. ‘1’ and ‘7’). Recognizing digits is very important because it is related to the numbers thereby the recognition methods have to be very accurate. There are different kinds of HDR approaches reported by researchers: Saxena et al. [2] proposed a neural network model for classification of handwritten digits; they enhanced their methods using ensemble classification.

2. RECANT ADVANCEMENTS OVER HANDWRITTEN NUMERIC DIGIT CLASSIFICATION

This section presents the recent techniques developed for the handwritten numeric digit classification along with the advantages and limitations of each individual technique.

Shulan et al. [1], presented a high-performance two-stage cascade CNN model. The main idea behind the cascade CNN model is complementary classification objectives between Stage I and Stage II. Discriminative learning is introduced to train Stage II by feeding back poorly recognized training samples. Experiments have been conducted on the competitive MNIST handwritten digit database. Their cascade model achieved the best state-of-the-art performance. The limitation of this technique is the higher time consumption as compared to available techniques.

Cecotti, Hubert [2], has investigated the impact on the accuracy of different parameters and pre-processing methods of a distance based on image distortion models. A key challenge is to reduce the processing time of the nearest neighbor classification by considering rejection rules and adaptive distances. The author has evaluate the performance of this technique of single character recognition on three databases of Indian handwritten digits, each database corresponds to a popular Indian script: Bangla, Devnagari, and Oriya. Authors have shown that the extraction of features related to four directions allows a significant improvement of the accuracy. This approach takes advantages of GPU and high performance clusters, providing state-of-the-art performances. The clustering process involved provides high performance but also takes higher time to cluster the input and create feature.

Khedidja and Hayet [3], investigated the combiniation of several classifiers to the recognition of printed digits using a novel approach to describe the digits by hybrid feature extraction. The study has been conducted using three different features computed from cavities, zonal extraction and retinal representation along with nine different classifiers, K-Nearest Neighbor - KNN - with different distance measure, Support Vector Machine - SVM -, decision tree, linear discriminant analysis - LDA -. Classifier combination is considered by Majority Voting method. Experimental tests carried on the multi-font and multi-size printed digits dataset. This technique is evaluated only for the printed database and yet to analyze and evaluate over handwritten digit database.

Radha and Aparna [4], proposed a new hybrid classification technique for recognizing printed digits. The feature extraction was performed using object region boundary analysis, Fourier Descriptors (FD) and Chain code based algorithm. A new curve tracing Chain code based algorithm (CTCC) was proposed to extract the curve features from the digit images. The recognition was performed using dynamic programming and multi-layer perceptron using back propagation algorithm (MLP-BP). Higher accuracy of 99% was obtained. The proposed methods were simple with higher recognition accuracy and lesser time complexity but only stick for the printed digits.

Gattal et al. [5], investigated the combination of different statistical and structural features for recognition of isolated handwritten digits, a classical pattern recognition problem. The authors had tried to improve the recognition rates by combining different representations of non-normalized handwritten digits. These features include some global statistics, moments, profile and projection based features and features computed from the contour and skeleton of the digits. Some of these features are extracted from the complete image of digit while others are extracted from different regions of the image by first applying a uniform grid sampling to the image. Classification is carried out using one-against-all SVM. The experiments conducted on the CVL Single Digit Database realized high recognition rates which are comparable to state-of-the-art methods on this subject.

Alkhateeb and Alseid [6], proposed a multi-class classification system of handwritten Arabic digits using Dynamic Bayesian Network (DBN) was proposed, in which technical details were presented in terms of three stages, i.e. pre-processing, feature extraction and classification. Firstly, digits are pre-processed and normalized in size. Then, features are extracted from each normalized digit, where a set of new features for handwritten digit was proposed based on the discrete cosine transform (DCT) coefficients approach. Finally, these features are then utilized to train a DBN for classification. The proposed system has been successfully tested on Arabic handwritten digit database (AD Base) which was composed of 70,000 digits written by 700 different writers, and the results were promising and very encouraging.

El et al. [7], investigated the effectiveness of four feature extraction approaches based on Discrete Cosine Transform (DCT) to capture discriminative features of handwritten Digits and compare it to classical PCA. These approaches are: DCT upper left corner (ULC) coefficients, DCT zigzag coefficients, block based DCT ULC coefficients and block based DCT zigzag coefficients. The coefficients of each DCT variant are used as input data for Support Vector Machine Classifier to evaluate their performances. Their objective was to identify the optimal feature extraction approach that speeds up the learning algorithms while maximizing the classification accuracy. The results have been analyzed and compared in terms of classification accuracy and reduction rate and the findings have demonstrated that the block based DCT zigzag feature extraction yields a superior performance than its counterparts.

Babu et al. [8], presented a new approach to off-line handwritten digit recognition based on structural features which is not required thinning operation and size normalization technique. they uses four different types of structural features namely, number of holes, water reservoirs in four directions, maximum profile distances in four directions, and fill-hole density for the recognition of digits. A Euclidean minimum distance criterion is used to find minimum distances and k-nearest neighbor classifier is used to classify the digits. MNIST database is used for both training and testing the system. 5000 images are used to test the proposed method a total 5000 numeral images are tested and got good recognition rate.

Singh and Lai [9], developed an approach to digit recognition using single layer neural network classifier with Principal Component Analysis (PCA). The developed model reduces the features to reduce computation requirements and successfully classify the digit into 10 categories (0 to 9). The system designed consists of backward propagation (BP) neural network and is trained and tested on the MNIST dataset of handwritten digit. The proposed system was able to obtain high accuracy on the MNIST 10,000 test dataset. They have considered not only the accuracy, but also the training time, recognition time and memory requirements for entire process. Further, they have identified the digits which were misclassified by the algorithm.

Khan et al. [10], presented a framework for handwritten Bangla digit recognition using Sparse Representation Classifier. The classifier assumes that a test sample can be represented as a linear combination of the train samples from its native class. Hence, a test sample can be represented using a dictionary constructed from the train samples. The sparsest linear representation of the test sample in terms of this dictionary can be efficiently computed through ℓ_1-minimization, and can be exploited to classify the test sample. They applied Sparse Representation Classifier on the image zone density, an image domain statistical feature extracted from the character image, to classify the Bangla numerals. This result is promising, and should be investigated further.

Dash et al. [11], proposed a new feature extraction method based on the non-redundant Stockwell Transform (ST), which takes care of the redundancy as well as computational complexity of original ST. they have applied the proposed method on Odia numerals with k-Nearest Neighbor (k-NN) classifier, Support Vector Machine (SVM), Multi-Layer Perceptron (MLP) classifier and Modified Quadratic Discriminant Function (MQDF) classifier. The highest recognition accuracy was found to be 98.80% for the Odia numeral database, which outperforms the previous reported classification results.

Homenda and Luckner [12], considered rejecting option in pattern recognition problem. Studied are native and foreign elements in a multi-class pattern recognition. Native elements are those included in recognized classes, they are known at the stage of classifier design. Foreign elements do not belong to recognized classes. Usually foreign elements are not known when classifier is designed. If foreign elements are classified to recognized classes, recognition quality is deteriorated. So then, they are classified to native classes, if they are not rejected. In such the case, recognition quality is deteriorated. Therefore, they should be rejected by a classifier, i.e. not classified to any class. Several attempts to rejection of foreign elements are investigated in this study.

Jaelani and Supriana [13], have developed an offline handwriting recognition system with structural approach. Each character through the stages of pre-processing, structural feature extraction and classification process using a combination of similarity endpoint, branch, line and curve, loop, number and position of each feature obtained from the endpoint and branch. This research focused on feature extraction stage and classification process. Classification process performed using three stages: selection of dataset, mounting features and calculation similarity. Because of acquisition process of handwriting were performed using offline method, then confounding elements becomes very high. The approach taken in this research can be improved its level accuracy of detection digit number to 89,80%, capital letters 86,60% and normal letter 84,92%.

Akhtar and Qureshi [14], proposed a new technique for handwritten digit recognition. As the handwritten digits are not of the same size, thickness, style, position and orientation therefore different challenges have to be faced to resolve the problem of handwritten digit recognition. The uniqueness and variety in the writing styles of different people also influence the pattern and appearance of the digits. The task of classification is handled using KNN and SVM classifier. An overall high recognition rate of 97.04 is achieved on the test data set. The scheme is tested on the well-known MNIST data set.

Yuan and Wang [15], constructed heterogeneous handwritten digits representation model based on multiple instance learning (MIL) for solving the problem that handwritten digits data sets of different feature spaces can't compute. Handwritten digits classification algorithms (HB and Heter MIL) are designed and compared for handwritten digits recognition. Experiment results confirmed that the heterogeneous handwritten digits data representation model and recognition algorithms can solve the heterogeneous handwritten digits recognition effectively.

3. CONCLUSIONS

In this paper an extensive review of recent advancement in the field of handwritten numeric digit classification and recognition has been presented. The review presented covers all the aspects for handwritten as well as printed digit recognition like off-line and on-line recognition, different features used, and finally various types of classifies recently used for digit classification. Moreover, all the important and recent works have been discussed with their advantages and limitations. It has been also discussed, most of the available systems were developed for particular database and yet to analyze over real time handwritten digits.

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