Handwritten Digit Recognition Through Convolutional Neural Network and Particle Swarm Optimization – A Review

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ABSTRACT

Numbers, letters, voices, and objects can be easily recognized by humans, but making a machine to solve these types of problems is a very difficult task because of variation in shape and orientation of handwritten digits. Handwritten digits recognition is difficult problems in the field of pattern recognition of machine learning. This paper deals with the survey of recognition of isolated handwritten digit using Convolutional neural network (CNN) and Particle swarm optimization (PSO) algorithm. The process of digit recognition will go through some steps including pre-processing, segmentation, feature extraction, classification. Pre-processing is for binarization which converts a grayscale image into a binary image, to remove noise from the image. Segmentation segments the image into line by line. Future extraction calculates the characteristics of the digit. A convolutional neural network is used to identify the image in the MNIST handwritten digital database to predict the number in the image. Classification is done by PSO to get apropos accuracy. During this survey, we present a summary of current research work conducted for recognition of handwritten digit. In the handwritten document there is no restriction on the writing technique because of miscellaneous human handwriting manner, a difference in size and shape of the digit. This paper presents a detailed review in the field of handwritten digit recognition.

Keywords—Handwritten digit recognition; Convolutional Neural Network; Particle Swarm Optimization; Machine Learning.

I. INTRODUCTION

Handwritten digit recognition is the process of conversion of handwritten digit into machine-readable form. The image of the written digit may be recognized offline or online. Off-line handwriting recognition refers to the process of recognizing digit that scanned from a sheet of paper and is stored digitally in grey scale format and On-line character recognition refers the process of recognizing handwriting recorded with a digitizer as a time sequence of pen coordinates. Pattern Classification is one of the popular domains in Machine Learning which is used to solve a variety of real-life problems like handwritten recognition. Pattern classification has proven to be a very important domain within Particle Swarm Optimization. Digit Recognition system attempts to combine one method for handwriting recognition, that is Particle Swarm Optimization for geometric features extraction and classification.

Handwritten Digit Recognition System consists of the following stages:

- Pre-processing
- Feature extraction
- Training, testing, and recognition

There are two methods will be used for handwritten digit recognition:

- Convolutional Neural Network
- Particle Swarm Optimization

This paper deals with the recognition of isolated handwritten digit using Convolutional Neural Network and Particle Swarm Optimization methods. In this paper, we present a brief survey of handwritten digit recognition using Convolutional Neural Network and Particle Swarm Optimization.

An overview of the paper is as follows: Section II describes the survey of related work. Overview system of handwritten digit recognition system is described in section III. Section IV describes the methodology to implement the structure. Finally conclusion in section V.

II. RELATED WORK

Juhee Sachdeva et al. [1], this paper deals with compound characters recognition those are written in a combination of two simple characters. These characters incline to connect each other in different forms and so the segmentation of compound characters is a difficult task because of high error rate. Authors have presented a technique for recognition of compound character using Multilayer Perceptron Network (MLP) technique. The process of pre-classification was implemented using MLP that has trained by Back Propagation method. After Preprocessing stage and pre-classification stage Diagonal feature extraction were implemented. The proposed work reported a high recognition rate of accuracy. The MLP algorithm proposed in the paper has the ability to recognize stimulus patterns if a set of input patterns are repeatedly presented to it to recognize the patterns.

Mamunur Rahaman et al. [3], in this paper authors, has presented an ensemble network based Bangla handwritten digit classification scheme because of Bangla handwritten digits difficult to recognize due to some strong similar features between different classes. In this paper heavy augmentation has been used in the training set along with dropout in the model to avoid overfitting. Competitive education has been achieved with an optimized number of model parameters. An ensemble of three Xception networks was evaluated on a hidden test set where it showed promising performance of 96.69% accuracy.

Lavanya K et al. [6], in this paper, authors proposed the solution comprises of a series of steps for the purpose of classification. In this, system training and testing integrate a hundred instances of handwritten digit images from MNIST Dataset. Preprocessing of the image boosts data images prior to computational processing and the input image are converted into grayscale and then into binary. They had used Hoeffding Tree, Decision tree and Random forest methodologies to ultimately compare them on a set of benchmarks to find the most effective tool marked on a set of measures that are efficiency and effectiveness, time to perform the complete process of classification, etc for pattern recognition. The key parameters which included they were classified instances of the digits, error rate and time are taken for the classification, Hoeffding tree found to be most effective in terms of time taken to build model, precision, recall and confusion matrix. The future work requires the inclusion of an extensive data set to declare the best among these approaches.

Nurul Ilmi et al. [9], this paper deals with handwriting digit recognition system used Local Binary Pattern as a feature extraction method and K-Nearest Neighbor as a classification algorithm. The proposed system, by developing two main processes; those are the enrollment process and recognition process. In the enrollment process, the system stored the image from MNIST dataset and C1 form as model data. The C1 form used by the General Elections Commission in Indonesia to facilitate the committee member to input the election result to the database. On the training phase, the algorithm only saves the feature vectors and conducting classification on the training set and on the classification phase, the similar features are calculated for the testing set. The distance between the training set and the testing set was calculated by Euclidean Distance formula.

Leticia M. Seijas et al. [10], in this paper, the authors proposed the application of three binary optimization metaheuristics to the problem of feature selection in the handwritten digit recognition area. For the recognition of handwritten digits, the metaheuristics are of three swarm intelligence optimization algorithms for feature selection optimization, called Binary Fish School Search (BFSS), Advanced Binary Ant Colony Optimization (ABACO) and Binary Particle Swarm Optimization (BPSO). These meta-heuristics were applied to the well-known handwritten digit database MNIST, preprocessed with the CDF 9/7 Wavelet Transform. They used a support vector machine (SVM) for the classification task. A considerable reduction in the number of features used for digit classification on the MNIST database with a small loss in the classification rates was observed. Swarm intelligence (SI) algorithms are population-based, which means they have a population of simple agents that interact with each other and with the environment.

Abdeljalil Gattal et al. [12], this paper deal with the combination of different statistical and structural features for the recognition of isolated handwritten digits. Features included some global statistics, moments, profile and projection based features and features computed from the contour and skeleton of the digits. Some of these features were 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 and classification was carried out using one-against-all SVM. The experiments were conducted on the CVL database realized high recognition rates which are comparable to state-of-the-art methods. They used a combination of ten features; seven was computed from the complete image of digit while three was computed by first applying uniform grid sampling to the image. This combination of features was investigated using SVM as a classifier.

Ujjwal Bhattacharya et al. [13], this paper concerned the problem of isolated handwritten numeral recognition of major Indian scripts. The principal contributions presented behind this problem here was first to pioneering development of two databases for handwritten numerals of the two most popular Indian scripts, the second was a multistage cascaded recognition using wavelet-based multiresolution representations and Multi-Layer Perceptron (MLP) classifiers, and the one other application of 2 for the recognition of mixed handwritten numerals of three Indian scripts that are Devanagari, Bangla, and English. In their proposed scheme, a numeral was subjected to three MLP classifiers corresponding to three coarse-to-fine resolution levels in a cascaded manner. If rejection occurs even at the highest resolution, another MLP is used as the final attempt to recognize the input numeral by combining the outputs of three classifiers of the previous stages. This scheme has been extended to the situation when the numerals written on a

document belong to different scripts. Handwritten numerals in mixed scripts are frequently found in Indian postal mail and tabular form documents.

Ali Pourmohammad et al. [14], in this paper, support vector machines method was implemented for the handwritten digit recognition task with three new modifications, i.e. only one desirable shape was considered for digits written in different shapes; sizes of numeral normalized to digit boundaries; MLP (Multi-Layer Perceptron), SVM/MLP and SLP (Single Layer Perceptron) neural networks used for classification. Each digit was considered from 4 different views, and from each view, 50 features were extracted to obtain 200 features. Collective SVM classifiers were trained to separate different classes of digits for MLP and were compared with ordinary training for MLP and SLP.

Table 1: Comparative description

Work Reference	Method Used	Accuracy (%)
Mamunur Rahaman et al. [3], 2018	Ensemble learning, Residual network	96.69
Retno Larasati et al. [4], 2017	Ensemble Neural Network	84
Lavanya K et al. [6], 2017	Hoeffding tree; Decision tree; Random forest	73
Nikolaos Toulgaridis et al. [8], 2017	Neural networks	91
Nurul Ilmi et al. [9], 2016	K-Nearest Neighbor	70.91
Leticia M. Seijas et al. [10], 2015	SVM, Binary Fish School Search, Advanced Binary Ant Colony Optimization (ABACO), Binary Particle Swarm Optimization (BPSO)	92.49
Ujjwal Bhattacharya et al. [13], 2009	MLP	70.85

III. STRUCTURE OF SYSTEM

The collected databases will be divided into two parts training data and testing data. Training data are used to train the system and this trained system is then used to recognize test data. The overview of the handwritten digit recognition system is shown in Fig.1.

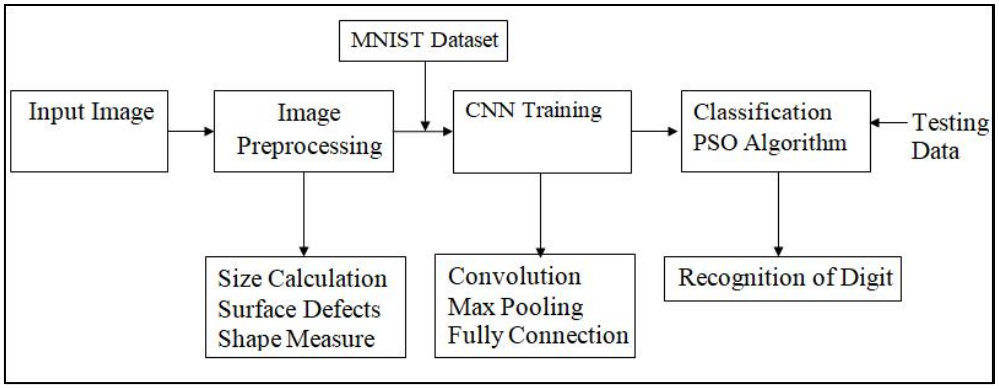

Figure 1: Handwritten Recognition System Overview

Pre-processing: It is a sequence of operations that performed on a scanned input image. The task of pre-processing is to segment the interesting pattern from the background. It generally removes noise, smoothing, and normalization should be done in this step. It also defines a compact representation of the pattern. Binarization process converts a grayscale image into a binary image.

Segmentation: Segmentation stage is for the segment the given image into line by line and segment each digit from the segmented line. The pre-processed input image is segmented into isolated digits by assigning a number to each digit using a labeling process. This labeling provides information about a number of digits in the image. Each individual digit is uniformly resized into pixels.

Future extraction: In this stage, the future extraction calculates the characteristics of the digit. It extracts different line types that form a particular digit and also concentrates on the positional features of the same. This is an important stage because successful operation improves the recognition rate and reduces the misclassification. Features like binary features, directional features etc. are extracted and a feature vector is created.

Classification and Recognition: A classification contains the database and does the comparison between the outputs. The output will be the enrich version of the uploaded image or dataset image and display verified digit. This is the decision making part of a recognition system and it uses the features extracted in the previous stage that is from CNN training phase.

IV. METHODOLOGY TO IMPLEMENT THE SYSTEM

a. Convolutional Neural Network

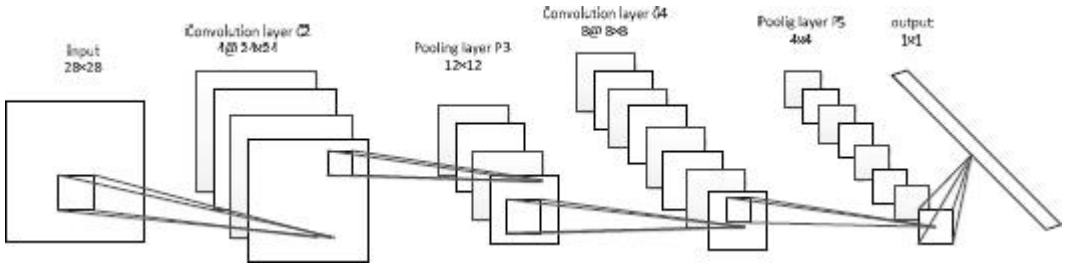

Figure 2: A simple structure of CNN [11]

A simple CNN model can be seen in Fig.2, The first layer is the input layer, and the size of the input image is 28x28. The second layer is the convolution layer C2; it can obtain four different feature maps by convolution with the input image. The third layer is the pooling layer P3. It computes the local average or maximum of the input feature maps. The following convolution layer and pooling layer operate in the same way, except the number and size of convolution kernels. The output layer is a full connection; the maximum value of output neurons is the result of the classifier in end [11].

b. Particle Swarm Optimization

In PSO, the population in this context is called a "swarm" and the individuals are called "particles". Each particle moves in the search space with a velocity that is dynamically adjusted according to their own flying experience and retains the best position it ever encountered in memory. The best position will be encountered by all particles of the swarm is also communicated to all particles. In this, each particle carries on being the track of its coordinates in the solution space which is associated with the best solution. This value is called personal best i.e. pbest. Another best value that is tracked by the PSO is the best value obtained so far by any particle in the neighborhood of that particle. This value is called gbest.

The main form of particle swarm optimizer is defines as,

1. The modification of the particles position can be mathematically modeled according the following equation:

$$v[] = v[] + c1 * rand() * (pbest[] - present[]) + c2 * rand() * (gbest[] - present[])$$

2. The current position can be modified by the following equation:

$$present[] = present[] + v[]$$

Where, v [] is the particle velocity, present [] represent current particle, pbest [] is the particle position and gbest [] is the global best solution, rand () is the number between (0, 1) and c1, c2 are learning factors and value for c1 = c2 = 2.

V. CONCLUSION

In this paper, we present a survey of various handwritten digit recognition systems. The main goal of handwritten digit recognition system is to achieve accuracy and high recognition rate, so achieving this, a number of technique and steps are involved that are pre-processing, segmentation methods, feature extraction process, classification techniques. This paper describes a review of recent methods which are used in this field of handwritten digit recognition. A comparison is shown between the different methods proposed so far in table 1. From the study done till now, it is analyzed that the selection of the classification techniques needs to be proper in order to attain a good rate in recognizing the digit. By using a combination of convolutional neural network and particle swarm optimization method for classification it will overcome the problem of large error rate.

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