Detailed Survey of Handwriting Recognition using Machine Learning Algorithms

Dr. H S Prasantha

Professor, K.S.Institute of Technology, Bangalore, Karnataka, India

drhsprashanth@gmail.com

ABSTRACT

Handwriting recognition (HWR), also known as handwritten text recognition (HTR), is the ability of a computer to receive and interpret intelligible handwritten input from sources such as paper documents, photographs, touch-screens and other devices. The image of the written text may be sensed from a piece of paper by optical scanning (optical character recognition) or intelligent word recognition. Alternatively, the movements of the pen tip maybe sensed example by a pen-based computer screen surface, a generally easier task as there are more clues available. A handwriting recognition system handles formatting, performs correct segmentation into characters, and finds the most plausible words. There have been many handwriting recognition systems available in the market.

Keywords—Hand written, machine learning, recognition

#  INTRODUCTION

There are two distinct handwriting recognition domains; online and offline, which are differentiated by the nature of their input signals. In offline system, static representation of a digitized document is used in applications such as check, form, mail or document processing. Offline handwritten character recognition is one of the practical important issues in pattern recognition applications. Digit recognition is an important component of handwritten character recognition system due to its wide application. From more than three decades can achieve high classification high recognition rates in the area of recognition of hand written numerals. Handwriting recognition systems convert handwritten text into machine readable form and work either on offline images (scanned or camera based) or on writing captured directly on a digitizing device (online recognition). From the view point of recognition systems for cursive Text (like Arabic, Urdu, Persian etc.), recognition of Arabic handwriting has been investigated in a number of studies. A number of International competitions have also been organized on recognition of both offline and online Arabic. According to statistics, 300 h of video is being uploaded every minute on the YouTube. A key factor responsible for this enormous increase is the availability of low-cost smart phones equipped with cameras. With such huge collections of data, there is a need to have efficient as well as effective retrieval techniques allowing users retrieve the desired content. Traditionally, videos are mostly stored with user assigned annotations or keywords which are called tags. When a content is to be searched, a key word provided as query is matched with these tags to retrieve the relevant content. Characters, and digits help people to solve more complex tasks that otherwise would be time-consuming and costly. A good example is the use of automatic processing systems used in banks to process bank cheques. Without automated bank cheques processing systems, the bank would be required to employ many employees who may not be as efficient as the computerized processing system.

A neural network is the most appropriate for the proposed system due to its ability to derive meaning from complex data and detect trends from data that are not easy to identify by either other human techniques or human. The text recognition area has a very large scope. Hand writing recognition and typewriter /computer writing recognition are subfields of the hand writing recognition area. Computer or typewriter recognition field can produce faster and more accurate results. Unlike handwriting recognition; it is expected to see higher success rates as there are no characteristic patterns and lines in letters or digits, such as spaces between letter sand words. Handwritten Digit Recognition is a very widely searched topic within the sectors or fields which are concerned about the learning model to differentiate pre-segmented handwritten digits. Also, it is the most important problem in ML, pattern analysis, data mining and AI. The uses of these machine learning methods are competing with the accuracy and decision taking performance of humans.

**II. LITERATURE SURVEY**

**1. Hybrid neural models for automatic hand written digits recognition**:

In this paper a novel Handwritten Character Identification methodology that performs the recognition of the students’ identification numbers handwritten in classroom maps has been proposed. A dataset of 60.0000 handwritten training images of the MNIST dataset and appropriate dataset composed of 3.415 images extracted from 12 classroom maps hand written by 11 different persons is used in this work. These images were obtained through the segmentation process described in this work, and had suffer some image processing before feature extraction and classification in order to be as similar as possible to the MNIST dataset samples.

The algorithm is composed by four main steps:

* Pre-processing.
* Segmentation.
* Feature extraction.
* Classification.

Algorithm implementation: It presents a brief description of the algorithm designed for the problem of HCR in the context of this work.

* Image and data acquisition: For a proper performance of the algorithm, the input image must correspond to a digitalization of a normalized examination classroom map on a A4 sheet and has a 300 dpi resolution.
* Pre-processing: The aim of this pre-processing is to identify the regions of interest (ROI) in the input image. The algorithm implemented for this task starts by detecting the lines that make up the map grid.
* Segmentation: The segmentation algorithm starts by performing a bounding box analysis (BBA) to identify the ROIs (or the cells) and verifies whether each of these cells contains a number.
* Segmentation process: a) cropped number. b) Individual 28x28grayscale numeral images.
* Feature extraction: HOG descriptors
* Classification: The classification step is the reasoning part of the system. The desired robustness of the classification model is highly dependent of the dataset to be classified, in the sense that the lowest the quality and the dimension of the dataset, the more powerful the classification model should be.

**Conclusion:** As a conclusion from the performance of the classifiers receiving HOG features and/or features from the fully-connected layer of the CNN, CNN provides a better diversity of features than the features extracted by HOG. It is clear that the main issue in the segmentation process is the sloppiness on the writing of some numerals, the placement of the numbers on unexpected regions and the image resolution.

**2. Comparative Study on Handwritten Digit Recognition Classifier Using CNN and Machine Learning Algorithms:** Numerous technologies and different systems have already been tried and tested on this handwritten digit recognition, but the recognition accuracy is too low to be deployed. To resolve these issues, three different machine learning techniques were used to solve this problem and create a model that could recognize handwritten digits with better accuracy. Three major algorithms were “Convolutional Neural Network (CNN), K Nearest Neighbour (KNN), and Support Vector Machine (SVM)” in which the results showed that the “Convolution Neural Network (CNN)” performed the best for image recognition tasks.

CNN algorithm: In image classification and pattern recognition, the most used and popular machine learning technique is Convolutional Neural Networks or CNN. Convolutional networks perceive pictures as an ite that consumes 3D space that implies three dimensional articles. CNN has revolutionised the world of computer vision for machines.

* Convolutional Layer: Convolution refers to the computation of the output function from two given input functions.
* Max Pooling Layer: The pooling layer helps solve the problem of redundancy produced by the convolutional layers since neighbouring pixels have similar values and mathematical operation on near locations produces unessential values in the output image. Max pooling (pool size 2) on 4\*4 image to produce a2\*2 output
* Softmax Layer: The SoftMax layer helps us in finding the cross entropy loss, which signifies how probable each prediction is. L= - ln (Pc), Where Pc is the predicted probability for class c and c is the correctly classified.
* K-Nearest Neighbours: The K-Nearest Neighbour is one of the simplest algorithms used for classification, which requires comparison to every single data point in the training dataset.
* Support Vector Machines (SVMs): Support Vector Machine is a discriminative classifier (tries to model by depending on the input features and the observed data).

The model outputs an optimal hyper plane using the labelled training dataset. The tuning hyper parameters involved in Support Vector Machines are Regularization Parameter, Gamma, Kernel, and the margin.

**Conclusion:** This paper concludes that different classifiers can affect the recognition rate for handwritten digit recognition. The presented results depict that CNN is the best classifier for handwritten digit recognition. Convolution neural networks used in a project achieved an accuracy of 99.59% on using the holdout validation technique for reducing over fitting and using the batch size of a hundred. In future, proposed system can be upgraded and used for other datasets and classification of handwritten alphabets.

**3. Real time handwritten digit recognition:**

In this paper they have built a handwritten digit recognition GUI app in python using Machine Learning. They have trained their model to recognise the digits 0-9. The process takes place in the following steps:

* Collection of samples
* Pre processing
* Feature extraction
* Classification
* Training images
* Evaluation and verification

The data set they have provided is self-created , which is done by using the basic paint tool .They have used phy screenshot , a module to train the data .For data processing they have used OpenCV, Numpy, Pandas, Sklearn .For data visualization they have used Matplotlib. SVC, a python classifies also has been used. First they have made use of phy screenshot to take screenshot of the images. By this they train the model by drawing the same digit in different ways. They save these digits in a separate folder. They have imported openCv to their model to get the path of the dataset they have previewed one image at a time using Matplotlib. They have used Sklearn model selection to split the data into training data and testing data. Joblib is used to make the model memorize the digits.

Then the screenshot of the digit is taken and given for recognition. They have made use of python based on machine learning

**Libraries used:** Physcreenshot: It is a phyton library available to take screenshot.

OpenCV: Used to solve computer vision. Image processing, video capture and analysis can be done using this

CSV:  Comma separated value. It allows the data to be in tabular form. They can be used with many spreadsheet programs like Google spreadsheet or Microsoft Excel.

Glob: To retrieve files/pathnames matching a specified pattern glob module is used.

Pandas : Pandas is a software library written for python. It provides data analysis tools

Scikit: For regression, classification, clustering and dimensionality reduction it has a lot of tools. It is used for machine learning models

Matplotlib: We use this to preview the image. It a plotting library for python programming .It is a cluster of function that makes the Matplotlib work like matlab.

Train test split: It is a very speedy and easy procedure to perform and as the result permits us to contrast the performance of ML algorithm for predictive modelling issues.

SCV: Support Vector classifier .It is used to fit the data. We use this so that we get the best fit hyper plane for the set of data.

Joblib: This is used to memorize the pattern with easy simple and parallel computing

Numpy : This is used for working with arrays as a python library .It has fictions for working of linear algebra domain and Fourier transform.

**Result:** Their model has successfully recognised the digit that has been provided. They have built a GUI app in python based on machine learning.

**4. Handwritten character recognition using deep learning in android phones.**

In this paper they have developed an android model to recognize the handwritten character. They have made use of deep learning, an Artificial intelligence is used for system to learn the input automatically and convert the handwritten text to printed text. In this model the user has to create a user name and password and then upload the image which contains the characters to recognize. This application also converts the printed text into speech. There are a total of 4, 00,000 images and 30,000 are used for training. The Kaggle dataset for handwriting recognition is used in this model. The model has been divided into 2 parts – front end for which flutter is used. Flutter is an open source GUI software development it created by google , back end- for which OpenCV, keras, tensorflow lite, google text-to-speech and firebase are used. It has 5 parts totally

* Registration
* Image processing
* Neural network modelling
* Character recognition
* Text to speech conversion

Image processing: Here images are given as input, the picture is taken or uploaded from mobile storage. Processing is divided into two phases:

Pre-processing: This step involves image resizing, gray scaling and binarization. The images uploaded will be of different size, this will be scaled down and resized for further processing. In gray scaling the coloured images will be converted to gray scale images with intensity values ranging from 0-255.Binarization converts the image into 1’s and 0’s.

Segmentation: In this process the image will be divided into many segments.

Image classification is done by comparing the segments will already existing patterns and finds the appropriate match for the input images.

Neural Network Modelling: Here a CNN (convolution neural network) is made use for classification. The CNN model is created using keras and tensorflow. After the CNN model two bidirectional LSTM (Long short term memory) which has 256 layers each. To introduce non linearity in the convolution later ReLu activation function is used and for output later Softmax is used. LSTM is designed to overcome the error backflow problems to carousels in their special units. This all done with still allow computational complexity of O1 and additionally the LSTM improves the RNN(Recurrent Neural Network) with the ability to bridge time intervals.

CNN has following layers:

* Input layer which takes the image size of 256x64x1
* Convolution layer where convolution is performed and features are extracted and
* ReLu function is used to add non linearity.
* Batch normalization layer where it normalizes the output of previous layers.
* Max pooling layer and dropout layer which are used to reduce over fitting.

Dense layer, a fully connected layer which connects previous layers to next layers. The last two layers which are LSTM are used to predict the output, it used softmax acyivation function to predict probability distribution The entire model has 21 layers.

Character recognition: The handwritten character image is converted into printed text by sending the image to the model. Int he model each character is recognized after pre-processing and they are converted into readable text.

Text to speech conversion: Text is converted to audio by sending the printed text to text to speech converter. Google text to speech is used for this.

**5. Cursive Handwritten Text Recognition using Bi-Directional LSTMs: A case study on Urdu Handwriting**

This paper presents a recognition system for handwritten Urdu text. Machine learning features are extracted from these text lines using convolution neural network (CNN) and feature sequence are classified using a bi-directional long-short term memory (LSTM) network. The dataset contains 6000 unique text lines from 600 writers. 4000 have been used as training data set, 1000 as validation set and the remaining as testing data set. Here, raw pixel values from columns of text lines are fed to a 1-D LSTM for learning and classification except the raw pixel values are replaced by the features extracted by CNN. The combination of CNN and LSTM, a type of recurrent network, is used for this task. The network architecture consists of seven convolution layer followed by two B-LSTM layers. Pooling, batch normalization land drop out later are also added.

First the input handwritten image is binarized as a pre-processing step and given to convolution layer. Then the output from the convolution layer is fed to recurrent neural network , LSTM which is followed by a CTC layer (Connectionist temporal classification (CTC) is a type of neural network output and associated scoring function, for training recurrent neural networks (RNNs) such as LSTM networks to tackle sequence problems where the timing is variable ).

**Result:** The system gives an accuracy of 83.69% on 1000 test lines. In most cases the ground truth and the predicted characters have similar shapes and in some cases the main body of the character is correctly identified but the wrong number of dots lead to recognition errors. The character recognition rates are computed by calculating Lavensthein distance between ground truth and the predicted transcription. Levensthein distance: The Levenshtein distance between two words is the minimum number of single-character edits (insertions, deletions or substitutions) required to change one word into the other.

**Ground truth:** The reality you want to model with your supervised machine learning algorithm. Ground truth is also known as the target for training or validating the model with a labelled dataset.

**RECURSIVE NEURAL NETWORK:** recursive neural network is a kind of deep neural network created by applying the same set of weights recursively over a structured input, to produce a structured prediction over variable-size input structures.  Recursive neural networks respond not only to input, but to context as well. They process each input of time series separately

**6. Handwriting Recognition using Artificial Intelligence Neural Network and Image Processing**

 Neural networks for handwriting recognition are more efficient and robust compared to other computing techniques. The dataset is taken from university students and professors who require electronic form of the handwritten notes and documents. The deep neural network memorises the training data to be able to recognize handwriting. Hence, this method is used for optical character recognition systems.

**STEPS/METHODOLOGY FOLLOWED:**

1. Image Acquisition and Digitization: This method is used to acquire the input containing handwriting. The input

Image must be in specific formats such as JPEG or PNG. Digitization involves converting the input paper into Electronic format.

2. Pre-processing: It is done to remove noise, essential for developing data that are easy for optical character Recognition system.

3. Segmentation: This process separates individual characters from an image. It results in multiple segments of the image known as super pixels. It is mainly done for simplification of the input data.

4. Feature Extraction: In this phase, features of the image are extracted and are defined based on the following attributes: height of the character, numbers of horizontal lines, widths of the character, number of circles, etc.

5. Recognition: In this phase, the neural network is used for classification and recognition of the characters from the image.

**CONCLUSION:** The current system used neural networks to process and read handwriting characters and digits. The system benefited from Convolution Neural Networks (CNN) with the help of training data that allowed easy Recognition of characters and digits. The phases of handwriting recognition included image acquisition, digitization, pre-processing, segmentation, feature extraction, and recognition.

**7. Online Handwriting Recognition using Support Vector Machine [2004]**

Neural network and Hidden Markov Model are two popular methods for handwriting recognition system. Support Vector Machine is an alternative to Neural Network and also gives a better recognition result. The advantage of SVM, is that it takes into account both experimental data and structural behaviour for better generalization capability based on the principle of structural risk minimization (SRM).

**DATASET:** The IRONOFF database, UNIPEN database and a combination of the two databases together have been used in the experiments covered in this paper. IRONOFF contains both online and offline handwriting information collected by IRCCyN in Nantes, France. UNIPEN online database are available from the International Unipen Foundation. It consists of various training and benchmark datasets for online handwriting which includes characters and words for the experiments, a feature extractor module was developed to extract 7 local features for each point of the online signal in the example character. An example character is first normalized in size, slant and rotation angle and spatially resampled to obtain a uniform sample of 50 points. For each point the following 7 features were extracted: (a) normalized x coordinate, (b) normalized y coordinate, (c) direction angle T(x) of the curve according to the x axis (cosine T(x)), (d) direction angle T(x) of the curve according to the y axis direction (sine T(x)), (e) curvature according to x axis, (f) curvature according to y axis and (g) the position of stylus (up or down). Tests of SVM on IRONOFF- UNIPEN datasets have shown that recognition rate for digits and upper case is higher than lower case since handwritten lower case characters differs significantly from person to person.

**CONCLUSION:** In all the experiments, the results have shown that at character level, SVM recognition rates are significantly better due to structural risk minimization implemented by maximizing margin of separation in the decision function. Multidimensional feature vector. The number of support vectors can be reduced by selecting better C and gamma parameter values through a finer grid search and by reduced set selection

**8. Handwritten Digit Recognition Using K-Nearest Neighbour Classifier [2014]**

**DATASET:** The proposed method uses MNIST (Modified NIST) [6] database which includes a training set of 60,000 images and a test set of 5000 images. The MNIST digit database is good database for applying learning techniques and patterns recognition methods because of this database need less time for noise removal in pre- processing.

In this paper uses a set of 25000 images from (Special Database) SD-3 and 25000 images from SD-7 for training set and a set of 2500 images from SD-3, 2500 images from SD-7 for test set. The training set and test set were disjoint sets. The figure 1 shows the samples of the numerals of MNIST database. After convert the images into binary, these images may have surplus elements one’s (black) at undesirable places in the background image is called noise. It is necessary to remove noise from the image. To remove these unwanted one’s from the background, need an algorithm. In this algorithm 3X3 template is used.

**Top reservoir:** By top reservoirs of a digit, it means the reservoirs obtained when water is poured from top of the digit. The water reservoir area is appeared when digit image is unconnected. The figure 2 shows Top reservoir area of the Digit 4. If digits are unconnected then the cavity regions are generated. The same methodology is used for bottom reservoir, left reservoir and right reservoir. The overall classification design of the MNIST digit database is shown in following algorithm.

**ALGORITHM:**

Step 1: Convert the gray level image into Binary image.

Step 2: Pre-processing the Binary Image.

Step 3: Perform region labelling for each input image.

Step 4: Find the no of loops in image-based region labelling and it is treated as a feature vector.

Step 5: Find Water Reservoir principle-based features in four directions.

Step 6: Fit a minimum rectangle bounding box and crop the image.

Step 7: Compute the maximum profile distances from all sides of bounding box.

Step 8: Repeat the steps from 1 to 7 for all images in the Sample and Test Database.

Step 9: Estimate the minimum distance between feature vector and vector stored in the library by using Euclidian distances.

Step 10: Classify the input images into appropriate class label using minimum distance K-nearest neighbour classifier.

END

In K-nearest neighbour compute the distance between feature values of the test sample and the feature vector values of every training image and the class of majority among the k-nearest training samples is based on the Euclidian distance measures. Each row in an array contains feature values and corresponding class label of the training images whereas test vector contains only feature values. The algorithm is executed with the value of k is 1, 3, and 5.

**CONCLUSION:** In any recognition process, the important problem is to address the feature extraction and correct classification approaches. The proposed algorithm tries to address both the factors and well in terms of accuracy and time complexity. The Overall accuracy of 96.94% is achieved in the recognition process.

**9. Hand written Digital Classifier**

In this paper they have built a handwritten digit recognition using Machine Learning. Only one data set was used for the study. The working conditions of the algorithms can be examined by performing tests on different data sets. Such as Source Vector Machine, Decision Tree, Random Forest, ANN, KNN, K-means algorithm.

Steps for handwriting recognition processing:

1. Analyse the dataset

2. Prepare the dataset

3. Create the model

4. Compile the model

5. Fit the model

6. Evaluate the model

In this study, MNIST data set was used for the training and tests of the system. MNIST database is widely used internationally. It consists of handwritten numbers. The MNIST database contains 60,000 training data and 10,000 test data. The black and white images from MNIST were normalized to fit into a 28x28 pixel bounding box and anti-aliased, which introduced grayscale levels all the tests within the scope of the study were performed on the pycharm.

**Different methods used in this paper were:**

1. Support Vector machine: SVM is successful in solving classification problems compared to many other techniques. This is one of the reasons why this technique is choosed as one of the algorithms to be tested in this study. Kernel function selection is an important step in the process of SVM to solve a problem.

2. Random forest: The reason why this algorithm is called randomly is that it offers extra randomness during the creation of the tree structure. When splitting a node, instead of looking for the best attribute directly, it looks for the best attribute in a subset of random attributes. This situation creates more diverse trees. In this test, the Gini index was used as the branching factor like the decision trees. The number of trees is determined as 150.

3. Artificial neural network: When designing a handwritten character recognition application with ANN, the first step is to create a matrix of a character in the text expected to be recognized in accordance with the input for the neural network. In this way, artificial neural network can be trained. Outputs are created for each character&#39;s matrix. In the learning process, the excess number of neurons in the hidden layers causes the training process to take too much time and increases the remembering Rabia KARAKAYA, Serap KAZAN Handwritten Digit Recognition Using Machine Learning Sakarya University Journal of Science 25(1), 65-71, 2021 68 ability of the Network at the same rate. After learning, verification is done. This process can be done in many ways. One of these methods is to use databases that contain combinations of two or three letters.

4. K-Nearest Neighbhour: In this method, first of all, the similarity of the test data to be classified with the education data is calculated. Classification is made according to the threshold value determined with the average of the k data that appears to be the closest. The performance of the method is influenced by the closest neighbor number, threshold value, similarity measurement and sufficient number of normal behaviours in the learning cluster. It was trained with MNIST data and then tested. While creating the KNN classifier with Scikit Learn, the number of neighbour was set to 5. And all points in each neighbourhood are weighted equally as ‘weight’ parameter was set to ‘uniform’.

5. K- Means Algorithm: This algorithm is one of the most preferred unsupervised learning algorithms. Clusters are created by looking at the similarity rates of the data. The number of clusters to be created in the algorithm is determined in advance. The number of clusters is expressed by &quot;k&quot;. Among the algorithms compared within the scope of the study, the only algorithm that is an unsupervised learning algorithm is the K-means algorithm. While creating K-Means clustering with Scikit Learn, the number of clusters was set to 10. In the tests performed with Scikit Learn on the MNIST data set, it was observed that the accuracy of the clusters was high.

6. Decision Tree: Decision trees form a classification model as a tree structure for the solution of a problem. The tree structure and rules are easy to understand. This simplifies the implementation of the algorithm. Decision trees method consists of simple sequential decision making operations. The division criterion for decision trees in the Scikit Learn library is the Gini Index. The decision tree method provided by the Scikit Learn library was used in the tests. Scikit Learn library uses CART algorithm that creates binary trees. In this algorithm, each node has only two sub-nodes or end leaves. Tree structures with more sub-nodes can be created using different algorithms such as ID3

**10. Recognition of Handwritten Digit using Convolutional Neural Network in Python with Tensor flow and Comparison of Performance for Various Hidden Layers**

The goal of this paper is to observe the variation of accuracies of CNN to classify handwritten digits using various numbers of hidden layers and epochs and to make the comparison between the accuracies. For this performance evaluation of CNN, we performed our experiment using Modified National Institute of Standards and Technology (MNIST) dataset. Further, the network is trained using stochastic gradient descent and the back propagation algorithm.

**Method:** The input layer consists of 28 by 28 pixel images which mean that the network contains 784 neurons as input data. The first hidden layer is the convolution layer 1 which is responsible for feature extraction from an input data. This layer performs convolution operation to small localized areas by convolving a filter with the previous layer. In addition, it consists of multiple feature maps with learnable kernels and rectified linear units (ReLU). The kernel size determines the locality of the filters. ReLU is used as an activation function at the end of each convolution layer as well as a fully connected layer to enhance the performance of the model. The next hidden layer is the pooling layer 1. It reduces the output information from the convolution layer and reduces the number of parameters and computational complexity of the model. The different types of pooling are max pooling, min pooling, average pooling, and L2 pooling. Here, max pooling is used to subsample the dimension of each feature map. Convolution layer 2 and pooling layer 2 which has the same function as convolution layer 1 and pooling layer 1 and operates in the same way except for their feature maps and kernel size varies. A Flatten layer is used after the pooling layer which converts the 2D featured map matrix to a 1D feature vector and allows the output to get handled by the fully connected layers. A fully connected layer is another hidden layer also known as the dense layer. It is similar to the hidden layer of Artificial Neural Networks (ANNs) but here it is fully connected and connects every neuron from the previous layer to the next layer. In order to reduce over fitting, dropout regularization method is used at fully connected layer 1. It randomly switches off some neurons during training to improve the performance of the network by making it more robust. This causes the network to become capable of better generalization and less compelling to over fit the training data. The output layer of the network consists of ten neurons and determines the digits numbered from 0 to 9. Since the output layer uses an activation function such as softmax, which is used to enhance the performance of the model, classifies the output digit from 0 through 9 which has the highest activation value.

**MNIST DATASET:** The database contains 60,000 images used for training as well as few of them can be used for cross-validation purposes and 10,000 images used for testing [27]. All the digits are grayscale and positioned in a fixed size where the intensity lies at the center of the image with 28×28 pixels. Since all the images are 28×28 pixels, it forms an array which can be flattened into 28\*28=784 dimensional vector. Each component of the vector is a binary value which describes the intensity of the pixel.

**RESULTS:** In this paper, the variations of accuracies for handwritten digit were observed for 15 epochs by varying the hidden layers. The accuracy curves were generated for the six cases for the different parameter using CNN MNIST digit dataset.

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| **TITLE** | **AUTHOR** | **TECHNIQUE USED** | **COMMENTS** |
| Real timehandwritten digitrecognition | Aditya Nikam, JatinLanje, BhaveshChaturvedi, HarshitKumar, Prof. Monali | Machine Learning andpython is used to implement. | More than 90% accuracy has been achieved. The data set is less , hence training the model on more datasets would give better result. |
| HandwrittenCharacterRecognition usingDeep Learning inAndroid Phones | Athira M Nair1, Chrissie Aldo1, Blessil Bose1, Alex Joseph1, Praseetha V.M2, Sr. Elizabeth M J | Artificial neural network. Python is used to implement this model. Flutter, keras, OpenCV has been used. | Accuracy more than90% is achieved |
| Bi-Directional LSTMs: A case study on UrduHandwriting | Shahbaz Hassan Ayesha Irfan Ali Mirza Imran Siddiqi | Deep learning ,CNNand Recursive NeuralNetwork (LSTM) | The accuracy achievedWas 83.69%. |
| Handwriting Recognition using Artificial Intelligence Neural Network and Image Processing | Sara Aqab, Muhammad Usman Tariq | Deep Neural Network,Convolution NeuralNetworks (CNN) | The final system satisfied the specified requirements of accuracy as well as recognition |
| Online Handwriting Recognition using Support Vector Machine (SVM) | Christian Viard- Gaudin, Emilie Poisson | Support Vector Machine (SVM) | SVM shows 98.83% recognition rate on digits, 92.47% on lowercase and 95.46% on uppercase using IRONOFF atabase. |
| Handwritten Digit using Convolutional Neural Network in Python with Tensorflow and Comparison of Performance for Various Hidden Layers | U. Ravi Babu, Y. Venkateshvarlu Fathma Siddique, Shadman Sakib, Md. Abu Bakr Siddique | K-Nearest Neighbor ClassifierCNN where they have used six different layers. | Overall accuracy of 96.94% is achieved in the recognition process Overall performance validation accuracy is 99.07% |
| Handwritten DigitRecognition UsingMachine Learning | Rabia KARAKAYA ,Serap CAKAR | 6 different types ofalgorithms.1) SVM2) Decision Tree3) Random Forest4) KNN5) KNA6) ANN | In tests performed on other kernel functions, the highest accuracy was obtained in this  |
| Hybrid neural models for automatic handwritten digits recognition | A. A. Peres, S. M.Vieira and J. R. C.Pinto | CNN+SVM classifier | a high performance with overall accuracy of 96.5%. |
| Comparative study on handwritten digit recognition classifier | tanuja Kumari, Yash Gandhi, p giridhar shambharkar | CNN Algorithm: 1)convolution layer2) max pooling layer,3)softmax layer4) k nearest neighbour, 5)support vector machine | An accuracy of 99.59% on using the holdout validation technique for reducingoverfitting and using the batch size of a hundred |

**III. TOOLS**

* Python programming higher installed in windows 10 or any distribution of Linux.
* Arduino IDE software
* Training of an ANN model using Coding Source in MATLAB.
* Python open source library called TensorFlow1 is used in order to train the neural network.

**IV. APPLICATIONS**

* National ID number recognition system
* Postal office automation with code number recognition on Envelope
* Automatic license plate recognition
* Bank automation.

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