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Classification and recognition of online hand-written alphabets using Machine Learning Methods

R Popli¹, I Kansal², A Garg³, N Goyal⁴ and K Garg⁵

^{1,2,3,4}Chitkara University Institute of Engineering and Technology, Chitkara University, Punjab, India

⁵Department of Computer Science and Applications, Kurukshetra University, Kurukshetra, India

Email: renu_popli@yahoo.co.in

Abstract--The hand-written alphabet recognition and classification plays an important role in pattern recognition, computer vision as well as image processing. In last few decades, a plethora of applications based on this area are developed such as sign identification, multi lingual learning systems etc. This paper classifies samples of hand-written alphabets into different classes using various machine learning methods. The challenging factor in hand written alphabets recognition lie in variations of style, shape and size of the letters. In this paper a simplified and accurate methodology is proposed based upon engineered features which are evaluated and tested using MatLab tool in comparison to other existing methods. The proposed system achieves a substantial amount of accuracy of 98% as compared to the state of the art approaches.

Keywords- Classification, Machine learning, Text recognition, KNN, SVM

1. Introduction

Hand writing recognition (HWR) task is to convert a language specified in some spatial graphical forms into corresponding symbolic illustrations [1]. Automatic recognition of hand-written alphabets is quite a tedious task due to different styles of hand-writing [2]. However, it is a versatile field which has its potential in various kinds of applications such as banking, education, ministry etc. In literature, there are various models available for recognition of text in many languages [3]. Broadly these systems are classified as online and offline character recognition.

In online handwriting recognition systems, the data is inputted using pad and a digitized pen. In this, writing strokes are noted based upon the keystrokes, velocity, time etc. So, the data is represented in the form of writing speed, different movements of the pen etc. On the other hand, offline data is collected by scanning the document and it is represented in the form of 2D matrix.

The applications of online hand writing recognition comprises of interfaces for various computing devices such as Tablet PCs, PDAs and smart phones etc. [4]. In addition online HWR is quite useful in signature verification process. Furthermore, offline recognition task is quite useful in many scenarios such as bank check processing, providing reading aids for blinds, automating postal mail sorting etc. Hence, online HWR is an important area and significant



development in this area has been performed. However, there is still a lot of scope to carry the research further using machine learning and deep learning.

Machine learning algorithms have a wide scope in such type of recognition applications. It is based upon Artificial Intelligence (AI) which enables a system to learn automatically [25] and improve based upon the previous experiences. Classification algorithms are used to categorize the data into various classes based upon the training provided to the model. There are various classification models described in literature which can be trained and tested using a huge datasets, but choosing a particular classification model for the specific application is quite critical task. In this paper, to choose a particular classification model, a performance comparison of various models has been done for the given dataset.

2. Related work

This section describes the literature related to handwritten character recognition using various learning and classification techniques [18] such as SVM, KNN, neural networks and so on. The HWR systems are broadly classified into two categories such as online and offline systems [24] and each has its significant role in different fields such as reading data in smart phones, PDAs etc. A comprehensive description of various data input mechanisms, data representation and application fields of these two categories are provided in existing literature [5]. H. Zhang et al. in 2006 [6] proposed a hybrid classification model for classifying offline hand writing data. The text images are identified based on three features such as color, texture and shape. The computational complexity of SVM is identified as high as compared to KNN. The proposed model has potential to classify multi sets data as well.

The HWR systems have a significant contribution in multi lingual systems as it is not feasible to have keys for all the languages on keyboard. The researchers have developed a huge number of HWR models for many languages such as Urdu [7], Gujarati [8], Arabic [9][19] and so on. These models recognize text or digits by introducing multiple features in the data and provided training to the classification models such as SVM and KNN. D. Singh et al. in 2015 applied chain rule for extracting features and also used Moore neighborhood tracing to identify boundaries of the given characters. An online handwriting recognition model using various depth sensors such as Kinect and Leap motion controller [23] was implemented in 2015.

C. Wu et al. in 2014 [10] introduced handwritten recognition systems using Deep Convolutional Networks. The authors in [11] proposed Devanagiri digit recognition model and evaluated the model by comparing with different classification methods such as SVM, Gradient Descent and KNN. The accuracy of CNN is found to be 99.07%. P. Malviya et al.[12] illustrated the importance of feature extraction and selection of classification technique in computing accuracy of the character recognition models. The authors claimed an accuracy of 99.5% to recognize characters written in English language by using zone based feature extraction method along with SVM classification approach.

Neural networks have been extensively used in character recognition tasks. Learning methods based upon neural networks and nature inspired mechanisms are described in [13] - [17][20]. An online hand writing recognition model was introduced by P S Mukherjee et al.[21]. The authors suggested CNN as a best method for extracting useful features from raw dataset. They proposed a hybrid model using various architectures such as CNN, RNN and CTC. The authors in [26] developed a hand written English alphabet recognition system where each alphabet is shown by binary value and it is fed to the neural network based system. In 2019, the authors [22] applied CNN approach using Tensorflow library and different methods for features extraction such as directional and diagonal techniques to improve the accuracy of the model. The model was applied on the offline handwritten character datasets and the authors claimed an accuracy of 90%.

3. Proposed methodology

The proposed handwriting classification and recognition system is divided into four main steps as given below:

- Importing Data
- Preprocessing and exploring data for engineering features
- Building a Classification Model
- Model evaluation and Improvement

First of all, there is a need of dataset for applying any Machine Learning algorithms. In case of handwritten characters, data can be generated in various ways such as in the form of scanned image of characters or using a digital pen or pad. The data generated through any method may consist of some noise or disruptions. So preprocessing of data is required before deploying it in any model. In preprocessing some special filtering and thresholding process is applied to get the relevant data from the raw data. Data exploration and feature extraction is an important task to be performed to obtain some engineered features from the preprocessed data itself. In this step, data is normalized and some useful features related to the specific application are explored and taken as an input to the classification models. The obtained data is further divided into training and testing dataset based on some proportionate value. The classification model is trained using the training dataset and further testing of the model is performed using testing dataset. Based upon the result, the performance of the model is evaluated by calculating specific criteria parameters such as accuracy, precision and recall etc. If the obtained accuracy is up to the mark then model is accepted otherwise some improved features are selected and model is again trained and tested. These steps are clearly depicted in Figure 1 shown below:

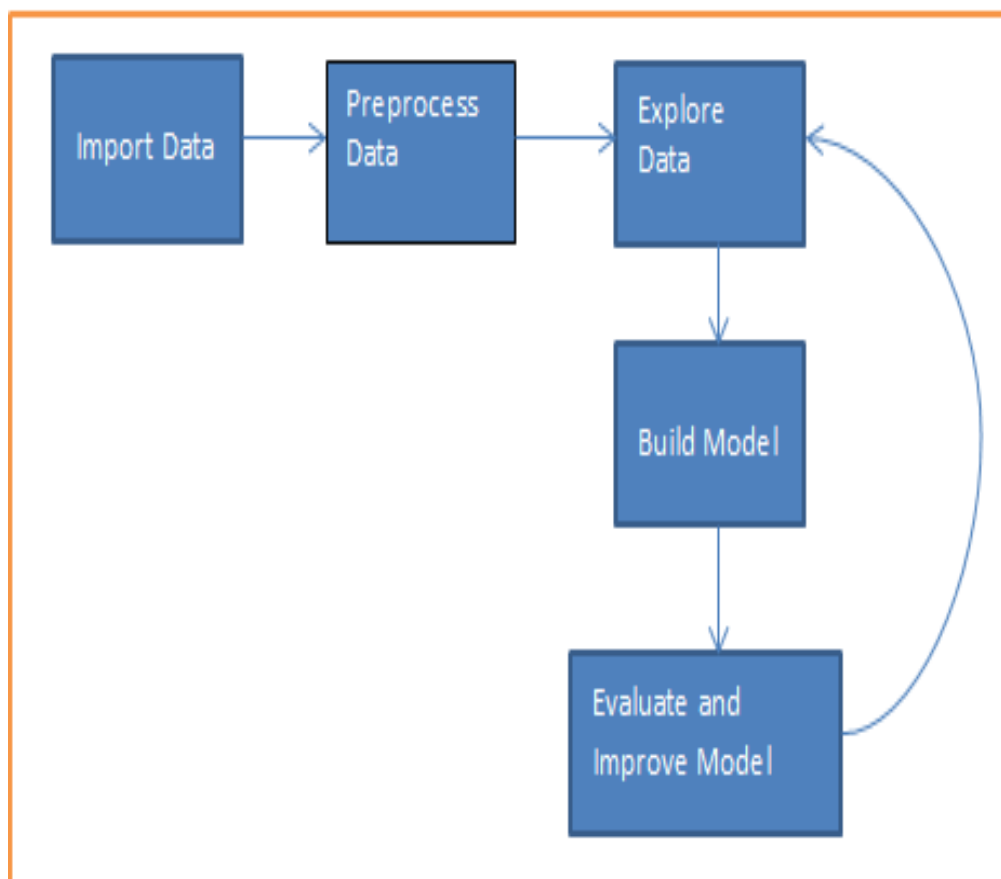


Figure 1. Proposed methodology

3.1 Importing data

In the proposed methodology, the data is read from comma separated files containing writing strokes parameters such as timestamp, vertical and horizontal position of the pen and pressure. Timestamp is calculated in milliseconds. While writing, different alphabets may take different time period. Timestamp refers to the time span while writing a particular alphabet itself. The sample files containing letters J, M and V are shown in Figure 2, Figure 3 and Figure 4 respectively.

3.2 Preprocess and Explore data for Engineering Features

The preprocessing of data and feature extraction is subjective to achieving high accuracy of the system. The axis of pen locations for the handwriting data can be taken in normalized units i.e. 0 to 1. But the tablet device used to measure the parameters is not square. Thus, it is possible to redefine the range i.e. 0 to 1.5 instead of 0 to 1.

To differentiate J from M or V, some useful features are incorporated such as Aspect ratio which indicates height of the letter relative to the width. Another feature is duration of the signal as V is swift to write so it can help to distinguish V from M or J.

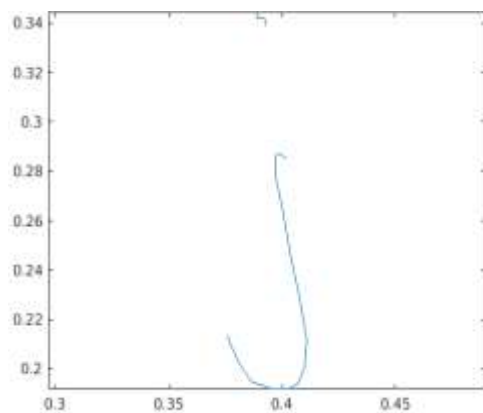


Figure 2. J.txt input file.

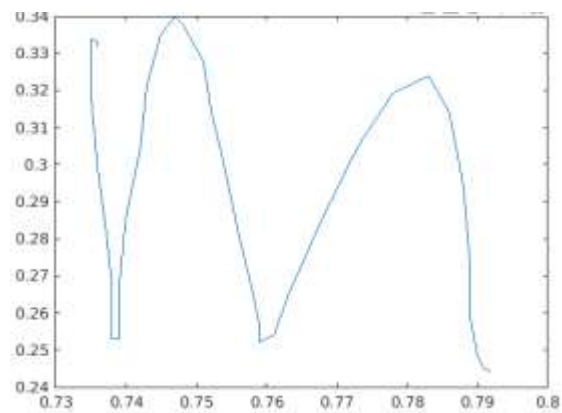


Figure 3. M.txt input file.

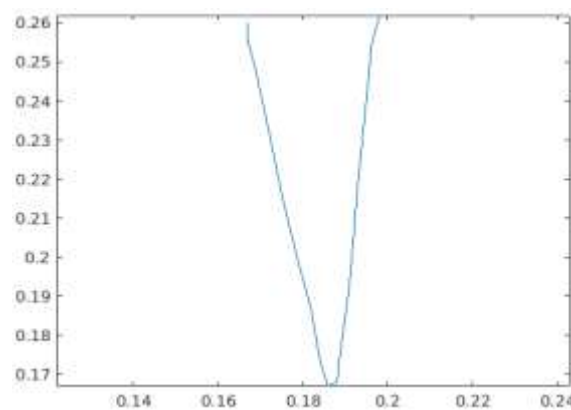


Figure 4. V.txt input file.

In the proposed model, the data is collected in the form of a table consisting of Aspect ratio, Duration and Character to be classified. The database consists of 470 samples of three letters such as J, M and V. Figure 5 shows the distribution of different alphabets such as J, M and V in the given dataset. It is shown using three colours.

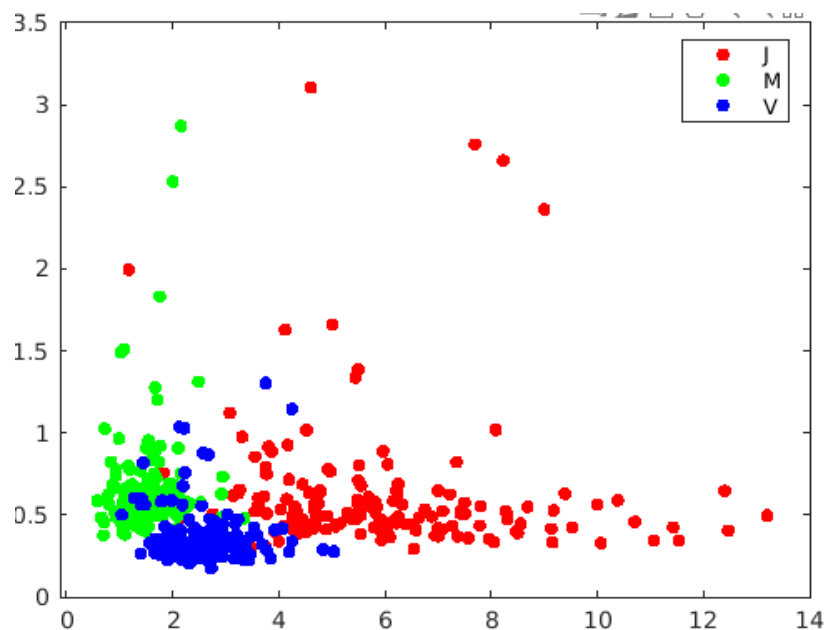


Figure 5. Data distribution of letters J, M and V.

3.3 Building a Classification Model

A classification model is segregating the space of predictor variables into different regions. In each region, different output classes are assigned. The main objective of the proposed model is to differentiate alphabets into correct letters and in this proposed work, the various classification approaches are used to classify these three letters such as J, M and V. The dataset is divided into testing and training dataset. Different classification algorithms result in different partitions. After building a model, testing can be done based on new observations. It needs to calculate the features of new observations and finding out the region they belong to. For given test data, K-nearest neighborhood (KNN) classification model is applied by varying values of K. The accuracy and misclassification rate for different K values is observed as shown in Table 1 given below.

Table 1. Testing dataset

Test Data	K=1	K=2	K=5	K=10
J	J	J	J	J
M	M	M	M	M
V	V	V	V	V
J	J	J	J	J
M	M	M	V	M
V	J	J	J	J
J	J	J	J	J
J	J	J	J	J
M	M	M	M	M
M	M	M	M	M
Accuracy	0.9	0.9	0.8	0.9
Misclassrate	0.1	0.1	0.2	0.1

3.4 Model Evaluation And Improvement

The model defined above incorporates two features which is able to distinguish 3 sample letters. The model performs well for these letters but to generalize the model for identification of many letters, more features need to be added. The data-store contains a table which represents feature data for 2906 samples of individual letters. There are 25 features, including statistical measures, correlations and maxima/minima for the position, velocity, and pressure of the pen. Thus the previous model is further enhanced by introducing large set of features and trained for the given dataset.

The enhanced model is used to classify all alphabets into their particular class. The enhanced training dataset is used to train various classification models and the performance of each model is evaluated by calculating accuracy parameter. The comparison of actual output and predicted output is shown with the help of confusion chart matrix. The confusion matrix is frequently used in ML based classification to describe the performance of the model on a set of test data. It is a table which visualizes the accuracy of a model in terms of comparison of true values and predicted value.

4. Results and Discussion

In this section, the results of proposed methodology have been shown for the new dataset. In this, different classification models are compared using MATLAB simulation tool for finding out accuracy as shown in Table 2 given below:

Table2. Accuracy comparison of proposed model using different classification model

Model Name	Ensemble Subspace Model 1	Ensemble Bagged Trees	SVM Cubic SVM	KNN Weighted	Naïve Bayes
Accuracy	89.3%	80.8%	88.0%	82.4%	76.8%

As shown in the Table2, the accuracy of ensemble subspace model is found to be more as compared to other models. It is clearly shown that KNN performs well for small dataset and SVM outperforms KNN, Naïve Bayes as well as Ensemble Bagged Trees.

As previously stated, confusion table depict the comparison of true values and predicted values so the output of different models such as Ensemble Learning, Ensemble Bagged Trees, SVM and KNN are shown in Figure 6, Figure 7, Figure 8 and Figure 9 respectively.

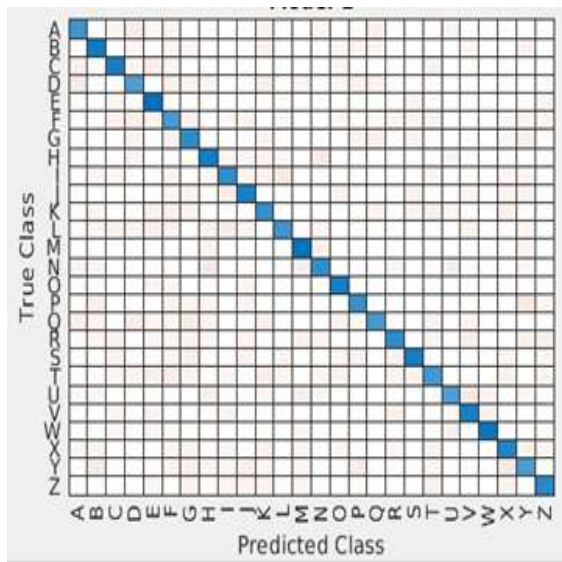


Figure 6. Ensemble learning.

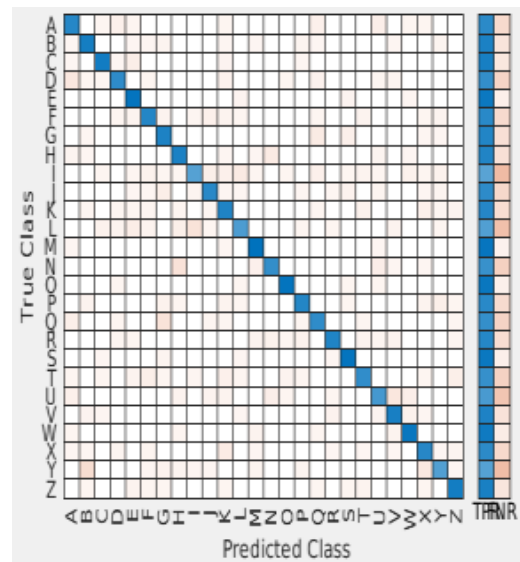


Figure 7. Ensemble Bagged Tree

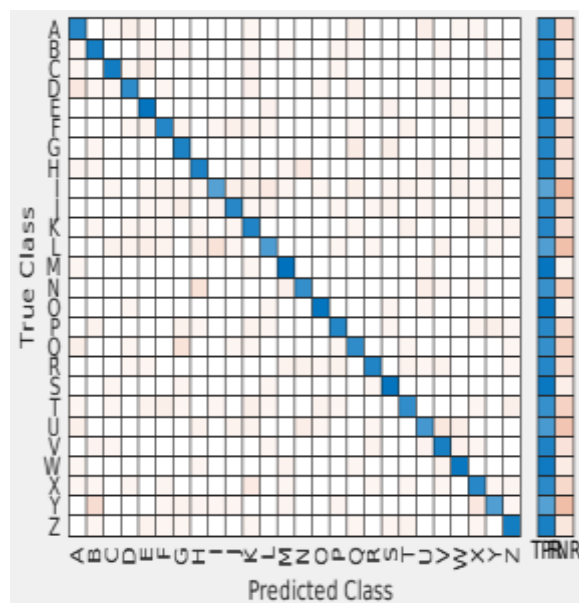


Figure 8. SVM Model

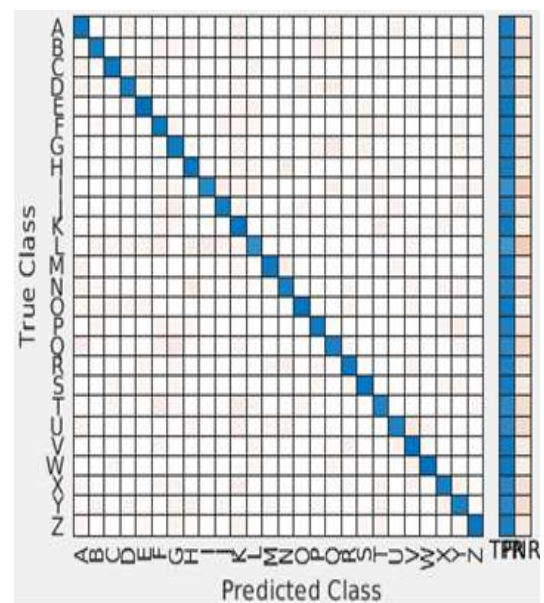


Figure 9. KNN Model

5. Conclusion

Online Hand writing recognition system plays an important role in creating input interfaces of various digital systems. The accuracy of identification is an important criterion for computing performance of these systems. The proposed methodology is applied for a small dataset and accuracy is calculated by using KNN model. The results are obtained by varying value of k and model shows an accuracy of 90% for detecting three alphabets only. To improve the process, various engineered features are calculated for new dataset consisting of all alphabets and further, various classification models are applied on extended datasets and accuracy is compared. It is

identified that by using ensemble of KNN models, highest accuracy is achieved. The results are shown in the form of confusion chart matrix for the classification models.

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