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A Survey on Feature Extraction Methods & Classifiers for Handwritten Gurmukhi Character Recognition

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Abstract— Offline Handwritten Character Recognition is the trending application of computer vision in machine learning. Though a large amount of work has already been done in Handwritten Gurmukhi Character recognition, but still in a belief to get better accuracy with state of the art algorithm like deep convolution neural networks. Any character recognition process consists of five stages i.e. digitization, pre-processing, segmentation, feature extraction and Classifier. Feature Extraction is one of the significant stage in the process because extracted features of one character differentiate it from another character. In this paper, various techniques have been summarized which are used to extract the feature of digitized character image and various classifiers used mainly in character recognition.

Keywords- Handwritten Gurmukhi Character Recognition, Feature Extraction, SIFT, Classification Methods, ConvNet

I. INTRODUCTION

The radical transformation of society through technological development has greatly influenced human evolution. Technology has moved from simple concept of making our life convenient to change every aspect i.e. to create a humanoid robot that can recognize the speech or image and classify it. Artificial intelligence and evolution of machine learning will exceed the human capabilities in the areas of computer vision and speech recognition in the coming years. Computer Vision is related to the implicit fetching and deep analyzing of useful information from a single image or a sequence of images. Character Recognition is one of the trending applications of computer vision. Optical Character Recognition (OCR) is the mechanical or electronic conversion of images of typed or printed text document into machine editable form. Typed and Printed text can easily be recognized and processed as there has a fixed font type and style. To convert the handwritten document into computer editable form, a new type of recognition system came into the picture, Intelligent Character Recognition (ICR). But Handwritten Character Recognition (HCR) is a challenging research area because of the variation in handwriting styles, sometimes a person cannot recognize his or her handwriting. Handwritten Character Recognition can be categorized into two parts - Offline and Online. The techniques like zone and stroke identification, used for the Online Handwritten Character Recognition is very dissimilar from the techniques used for the offline Handwritten Character Recognition [1]. In general, Optical Character Recognition model can be built using following five stages [28]:

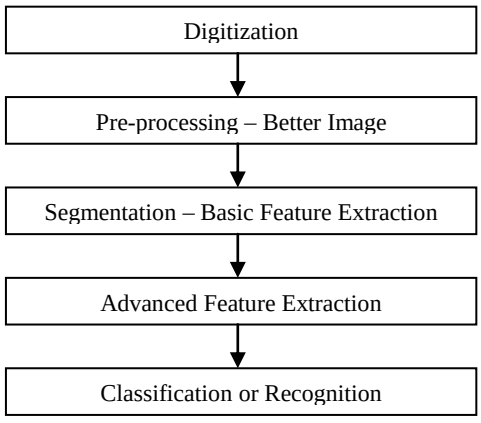


Figure *1 Character Image Recognition Stages*

- **Digitization**

It is a process of converting the handwritten document or paper into digital format like in the form of bitmap image. And it is now ready to feed to the next stage.

- **Pre-processing**

There are number of factors that can affect the accuracy of text recognized through OCR like scanner quality, resolution, watermarks, non-uniform illuminations, noise etc. To make the OCR model more robust, it is essential to use the various pre-processing algorithm like Binarization, Character Normalization, Skeletonization, Skew Correction/Detection and Noise removal [2].

- **Segmentation**

It is the process of splitting a character image into multiple segments. It helps to simplify the representation of an image into something that is more meaningful and easier to analyze. Segmentation can be done in three ways i.e. line, word or character segmentation. Further it can be divided into horizontal and vertical Segmentation, a Gurmukhi word can be represented as three zones – upper zone having "matras" (half character or modifiers), middle zone having characters (two or more) and lower zone having "matras" (half characters or modifiers), in such cases separation of upper and lower modifiers take place in Horizontal segmentation of Gurmukhi word [3] and separation of single character in vertical segmentation.

- **Feature Extraction**

It analyses the handwritten character or digit image thoroughly and selects a set of pixels that can be used for uniquely identifying a character or digit. In this case, we provide input in image format and extract output in the form of pixels of interest uniquely related to the picture provided as input. These have direct impact on the accuracy parameter.

- **Classification**

It is a process of predicting the discreet class label or category to predict the handwritten character using the pixel values which are obtained from feature extraction stage.

Section I includes the introduction about the handwritten character recognition and essential steps involved to do the image recognition process, Section II explains the Gurmukhi Script, Section III contain the related work of handwritten character recognition of different script, Section IV contain different feature extraction techniques used to extract the features, Section V explain the different classifiers, Section VI includes the applications of handwritten script, Section VII contain the research issues and Section VIII concludes research work with future directions.

II. GURMUKHI SCRIPT

India does not have a national language due to its vast multicultural expanse. There are 29 states in India and 22 different languages and 720 dialects are spoken by the people of different states. Script refers to the writing systems. Hindi is written in Devnagari script likewise Punjabi is written in Gurmukhi Script. It is spoken, read and written by Punjabi understanding people globally. It is the 10^{th} most widely spoken language in the world. In Canada, it is the 5^{th} most-spoken native language after English, French, Mandarin and Cantonese. Fig 2(a) and 2(b) shows the Handwritten Numeric and character set of Gurmukhi Script.

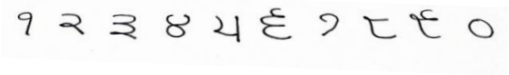


Figure *2(a) Numeric set of Gurmukhi Script*

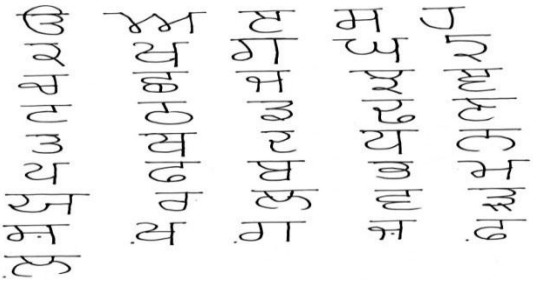


Figure *2(b) Character set of Gurmukhi Script*

III. RELATED WORK

Sidharth et al. [4] have used Zonal Density and Background Distribution as feature extraction technique and SVM with RBF kernel as classifier. They mentioned that they collected the dataset of 200 samples of each of 35 characters. They got an accuracy of 95.04% with 5-fold cross validation evaluation metric. Singh et al. [11] applied discreet wavelet transform on 1750 samples with back propagation neural network classifier and obtained the highest accuracy of 92.3 % and average accuracy of 81.71 %. Kumar et al. [12] have extracted the features using Peak Extent feature extraction technique and choose the selective features with PCA and classified the characters using SVM with Linear kernel on total 3500 dataset and obtained accuracy of 91.80 %. Verma et al. [13], Zone identification algorithm for zone identification and rule based approach for recognizing strokes as feature extraction technique and SVM as classifier on 428 dataset and got accuracy of 95.3% for zone identification and 74.8 % for character identification. G.Singh et al.[14], applied Multi-Layer Perceptron (MLP) Neural Network Model using Feed Forward Topology on 481dataset and got accuracy of 98.96 %. Pankaj et al. [15] implemented back propagation algorithm on 500 devanagari character images gave an accuracy of individual character = 92 % and character in sentence = 88.25%. A.Gaur et al. [16], used K means clustering as feature extraction technique on hindi character images and used two different classifier to compare the accuracy that is SVM with linear kernel and Euclidean distance on a dataset of 430 and got accuracy in

case of SVM is 95.86 % and with Euclidean distance is 81.7 %. Ashutosh et al. [17], have applied feature extraction on 7000 and 2000 images of gurmukhi character and numerals respectively with Gradient method and classified them using SVM with RBF kernel and obtained an accuracy for character as 97.38 % and for numerals as 99.65 %. Sukhpreet et al. [18], have extracted the features of 1500 gurmukhi numeral images with the help of Gabor filters and classified using SVM with RBF kernel and achieved an accuracy of 99.53 %. Akm et al. [19] have proposed the classification using deep neural network on arabic numerals and got accuracy 97.4 % on 3000 dataset. S.Acharya et al.[20] have used the deep learning model to classify the 20,000 images of devanagari digits and got an accuracy of 98.47%. Saha et al. [26], explained the Bangla handwritten characters and numerals classification using deep neural network on 166,105 isolated images and got an accuracy of 97.21 %

IV. FEATURE EXTRACTION TECHNIQUES

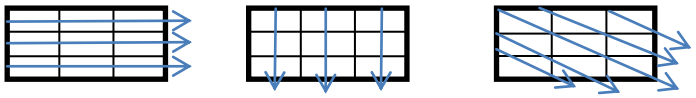
Feature Extraction is a major step of pattern recognition task to extract the high level information from data. Image is a collection of set of pixels (x or y coordinates in case of 2D image). Computers do understand the numbers only and can perform computation on these. The performance or recognition rate of handwritten character image classification process, particularly, depends on the features that are being extracted. Feature Extraction from an image can be related to boundary pixels or region pixel. Boundary based features are used in recognition of shape and Region features are used in case of fetching the texture or colour of an image. Image features will be first represented using representation technique and then quantify the depicted feature with the help of Image Descriptors. There are various image representation and image description techniques. A good feature extraction method with respect to the character recognition should be skew invariant, font invariant and size invariant [22]. Various Feature Extraction Techniques used in different research papers are as follows:

- **Zoning Density Features**

In this technique, an image is divided into N x M zones. Features will be extracted from each zone. The main goal is to extract the local feature rather than global features. In [5], Image Centroid and Zone centroid are used to extract the features, wherein an image is divided into n zones and average distance pixel is calculated between each pixel and an image centroid.

- **Projection Histograms Features**

It is a region based feature extraction technique. Histogram can keep track of regional features like color, gradient and direction of an image. Projection histograms compute the number of pixels in a particular direction. Pixel can be counted in any direction that may be horizontal, Vertical or Diagonal (left to right diagonal lines or right to left diagonal lines) as shown in Figure*3*. Histograms are made on the useful extracted features of an image which can describe the image better. Like in case of a gray scale image, it will count the intensity value of each pixel as 1 or 0



(a) *(b)* *(c)*

Figure *3 (a) Horizontal Histogram (b) Vertical Histogram (c) Diagonal Histogram (it may be towards left or right)*

- **Distance Profile Feature**

In this technique, it calculates the distance (number of pixels) from bounding box to the boundary edge of the character image. This traced distance can be horizontal, vertical or radial [4]. The directions used to calculate the distance profile feature vector are top to bottom, bottom to top, left to right and right to left. The feature vector for an N x N image can be written as 4N [6].

- **Peak Extent Based Feature**

In OCR, all the input images are of uniform standardised size. To extract the features from images using peak extent feature extraction technique, the system considers the sum of lengths of the peak extents that fit successive high intensity pixels along each row and column of a zone. Peak extent based features can be extracted horizontally (row-wise) and vertically (column-wise). This is a three step process, dividing the bitmap image into n zones. For example as shown in Figure *4(a)*, Image is divided into matrix of 36 zones, each of size 6 x 6. Further it finds the peak extent as sum of successive foreground pixels in each row (mark all foreground pixel value as 1 and rest as 0) and replace the values of successive foreground pixels by peak extent value as shown in Figure *4(b)* and *4(c)*, in each row or column of a zone respectively. And finally it finds the sum of these largest peak extent sub features and considers it as the feature of particular zone [12]

0	0	1	1	1	1
0	0	0	1	1	0
1	1	1	1	1	0
1	0	0	0	1	0
0	1	0	0	1	0

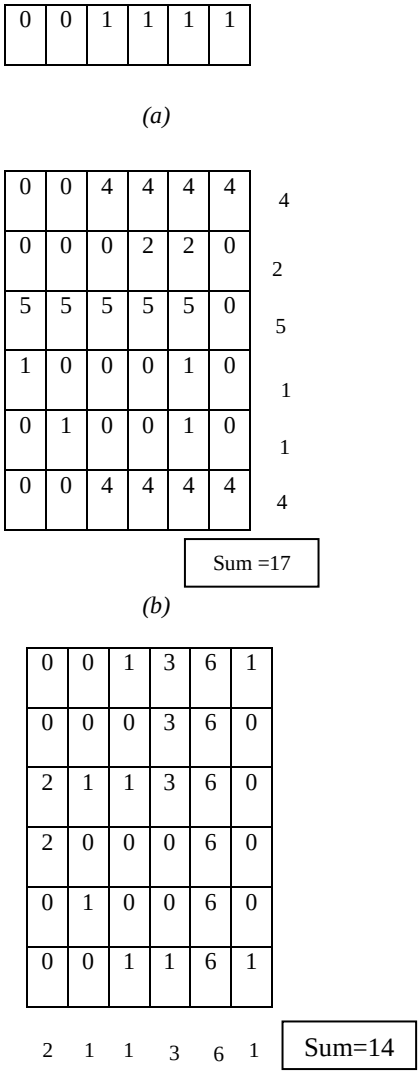


Figure *4 (a) Bitmap Image (b) Peak Extent feature applied horizontally (c) Peak Extent Feature applied Vertically*

- **Background Directional Distribution (BDD) Features**

This is related to the background and foreground pixel of an image. To find the background directional distribution feature value for each foreground pixels, apply the masks defined for each direction as shown in Figure 5(a). The value for each directional distribution is computed by summing up the values specified in a mask for corresponding neighbour background pixels. The pixel at centre 'X' is foreground pixel which helps to find the feature values of background pixel. The feature vector stores the cumulative fractions of background pixels in particular direction by computing the weight of particular direction with the help of mask [4].

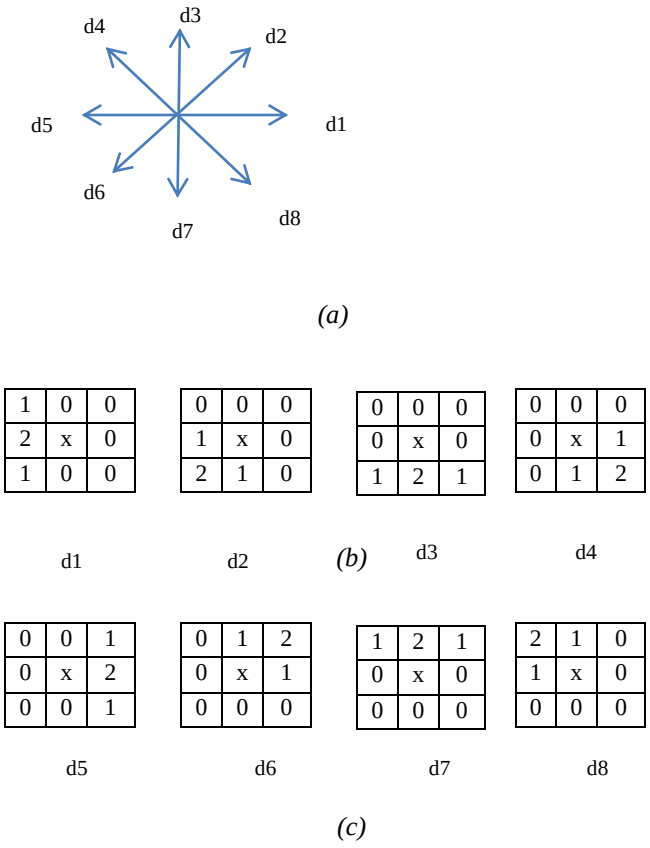


Figure *5 (a) 8 Directions used to calculate directional distribution (b) & (c) Masks used for different direction*

- **Harris Corner Detection**

It is one of the fast methods to compute the feature in an image which are scale, rotation and illumination independent. Any point in an image should easily recognize by looking at intensity values within a small window. Shifting of that window in any direction yields a large change in appearance. Harris corner detector gives a mathematical approach to find whether it is a flat region, edge or corner. Change of intensity for the shift (u,v) is given as[7] :

$$E(u,v) \approx [u,v]\, M\begin{bmatrix} u \\ v \end{bmatrix}$$

Where E = Difference between original and moved window.

u = windows displacement in the x-direction

v = windows displacement in the y-direction

$$M = \text{autocorrelation matrix} = \sum_{x,y} w(x,y) \begin{bmatrix} I_x I_x & I_x I_y \\ I_x I_y & I_y I_y \end{bmatrix} \quad (1)$$

Where in Eq.(1) , w(x, y) is the window at position (x,y). I_x and I_y are intensities of image in x and y directions. We need to find the large value of E by maximizing the value of M. The Eigen values of the matrix can help finding the

suitability of a window. A score R is calculated for each window.

$$R = \det(M) - k(\text{trace}(M))^2$$

Where $\det(M) = \lambda_1 \lambda_2$

$\text{trace}(M) = (\lambda_1 + \lambda_2)$

k = Constant

λ_1 and λ_2 = Eigen values of M

Highest value of score, R than certain value represents the Corner.

- **Scale Invariant Feature Transform (SIFT)**

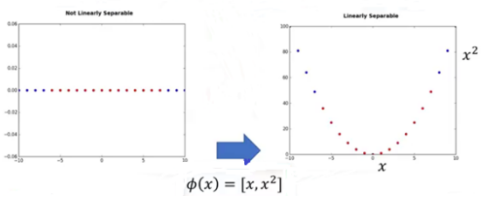
Harris Corner Detection is not scale invariant as when the image size is zoomed in or out, corner doesn't remain the same. A corner in a small image within a small window is flat when it is zoomed in the same window. SIFT technique is used to detect the local features and transform image data into scale invariant coordinates [8]. The process involved in SIFT algorithm to generate the set of image features [25] is as described below:

The first state is to locate all scales and image locations using a difference-of-Gaussian function which are invariant to scale and orientation. A detailed model is fit to find location and scale. Interest points are collected based on stability. Orientations are assigned to each such location based on local image gradient directions. Further operations are performed on image data invariance to these transformations. The local image gradients are measured at the selected scale in the region around each interest point. These are transformed up to significant levels of local shape distortion and change in illumination.

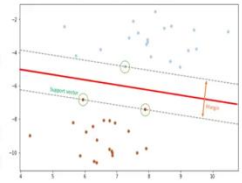
V. CLASSIFICATION TECHNIQUES

- **Support Vector Machine (SVM) Classifier**

Support Vector Machine (SVM) is a binary classifier which searches for the closest points which are called support vectors. It is named as Support Vector Machine because the closest points are vectors which support the best separating line of two classes. It is the best classifier so far because even when the data is not linearly separable, it maps the data into higher dimension i.e the data is transformed in such a way so that the separator could be drawn as a hyper plane. SVM determines for any particular set of two classes of objects, unique hyper plane having maximum margin as shown in Figure *6(b).* The maximum margin solution enables SVM to outperform as compared to many other nonlinear classifiers, specifically in the presence of noise. In other words, A support vector machine for image classification is constructed by converting the input value x into high-dimensional feature vector value v using a non-linear transformation function f(x), and by constructing an optimal hyper plane in the feature space. A function called Kernel is used to map the data from input space to feature space [23]. There are 4 types of kernel i.e. Linear, Polynomial, Radial Basis Function (RBF), Sigmoid [24] used with SVM which gives different recognition rate during the character recognition for each kernel used.



(a)



(b)

Figure *6 (a) SVM transforming the 2 dimensional non linear data to linearly separable data (b) support vectors and largest margin*

- **K-Nearest Neighbours (KNN) Classifier**

It is a lazy learning classification algorithm which takes a bunch of labelled points and uses them to learn how to label other points. A data-point can be classified by the majority of votes given by K neighbours. The distance between the two data-points can be calculated using the Euclidean Distance using the formula shown in Eq.2. It is required to normalize the feature set in order to get the accurate dissimilarity or similarity measures. The low value of K makes the model more complex and high value of K makes the model over generalized. So the best value of K can be established with the help of hit and trial method by taking the different values of K.

$$\text{Distance}(x_1, x_2) = \sqrt{\sum_{i=0}^{n} (x_{1i} - x_{2i})^2} \quad (2)$$

- **The Multilayer Perceptron (MLP) Classifier**

It is an Artificial Neural network based classifier which works in 3 layers i.e Input layer, Hidden layer and Output Layer. It is most suitable when the data is not linearly separable. The working of MLP occurred in the neurons attached to the different layers. The number of neurons in input layer and output layer depend solely upon the number of input and output values. But number of neurons in the hidden layer is a hypothetical parameter. Generally this number lies between the number of neurons of input and output layer. If the data is linearly separable then it can work in two layer concept i.e. input and output, Hidden layer is not required as in case of AND or OR gate. But when a data is not linearly separable then it does increase the complexity and requires a hidden layer as in a case of XOR gate. During learning, it uses a supervised learning technique called the

back propagation and gradient descent technique for reducing the loss and updating the weights and bias. [9].

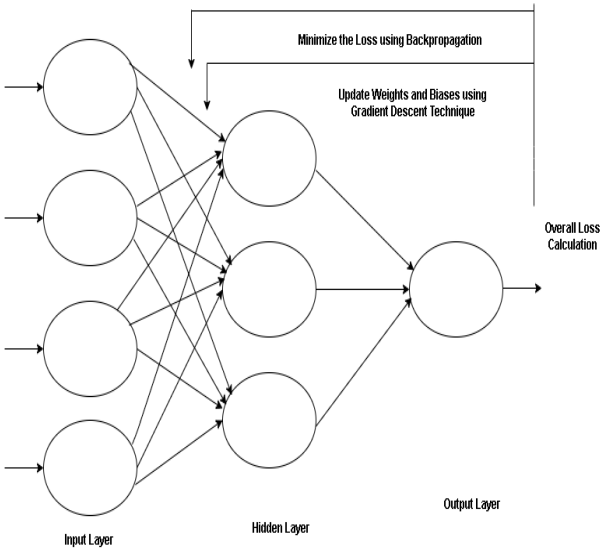


Figure *7 MultiLayer Neural Network with backpropagation*

- **Convolution Neural Network (Conv Net) Classifier**

Convolution Neural Network (ConvNet) is an extension of a regular neural network consisting of weights, bias and more number of layers unlike regular neural network. Architecture of convolutional neural network (ConvNet) consists of sequence of layers and each layer of a ConvNet transforms one volume of activations to another through a differentiable function. Put differently, it learns features of the image itself. Generally there are three main layers which constitute ConvNet architecture i.e. Convolutional Layer, Pooling Layer, and Fully-Connected Layer. The parameters in the convolutional and fully-connected layers will be trained with gradient descent technique [10]. Like a regular neural network, it has a loss function in the form of softmax on the last layer called the Fully Connected Layer which helps to calculate the class label probability. Convolutional Neural network works efficiently for computer vision problems and give optimum results in the presence of large amount of data. That is why Convolutional Neural Networks put constraint on its architecture and take only images as its input and count may go into millions[27]. A simple Convolutional Neural Network Architecture for classification consists of sequence of layers is explained as follows:-

Convolution Layer (Input Layer): It takes the raw pixel values of the image in the form of its height and width and number of channels (for RGB, number of channels = 3). It also keeps track of other parameters like number of filters, size of each filter, strides and padding used.

Pooling Layer (Max Pooling or Average Pooling): It depends on our architecture whether we will use max pooling or we will use average pooling. It performs a down sampling operation along the spatial dimensions.

RELU layer (Rectified Linear Unit Layer): It will apply an activation function, such as the $max(0,x)$. It will replace all the negative values to zero. This helps to remain the volume unchanged.

Fully-connected Layer (Dense Layer): As it is clear from the name, every neuron is connected to every other neuron. It calculates the class scores using the softmax function, where each of the 10 numbers corresponds to a class score, such as among the 10 categories of handwritten digit recognition dataset.

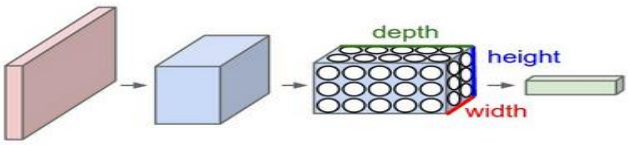


Figure 8 *Layer of a ConvNet transforms the 3D input volume to a 3D output volume of neuron activations [10]*

VI. APPLICATION OF HANDWRITTEN SCRIPT

Local Language of a particular state has high impact on the state for the ease of the people. Various practical applications of handwritten character recognition system are enumerated below:

- **Processing of Applications for various Utilities:** Many public affairs forms like application of all the Government jobs, applications for Local Elections or Voter ID, Driving Licence application, State board Schools application are available in local language of state and it is required to fill these applications by hand. The handwritten information filled by the user can be processed with the help of handwritten Character Recognition System.

- **Automated Character identifier based assortment:** The manual distinction and sorting of characters or numbers of a particular address at post office is a time consuming task. Similarly manual vehicle number plate identification is prone human error. The Offline handwritten character recognition system can perform automation task with impeccable accuracy. For example, pin code identification, house number identification, vehicle owner identification, etc.

- **UID (Unique Identification) Authentication:** On various application forms and legal documents that include the UID of person or authorities, such document can be verified using offline recognition system.

VII. RESEARCH ISSUES

A. Variation in writing style: Handwritten Character varies with individuals writing style. Such variations may occur due to different pen holding style.
B. Constrained or Unconstrained writing: Some documents have block/grid format to write. So in that case, segmentation of character is very easy. But in some cases, where only text box is given to write then people may create mess due to overlapping of character etc
C. Left Hand or Right Hand writer.
D. Unavailability of Dataset.
E. Mixing of Characters of two languages while writing.
F. Personal or Situational Aspect: In some serious situation, person is not able to write properly or miss some words while writing.

VIII. CONCLUSION

In this study, an effort has been made to summarize the different feature extraction techniques and different classifiers used to classify the offline handwritten character. With the advent of deep neural network models, it has become more convenient for researchers to provide accurate results as compared to earlier machine learning algorithms where manual feature extraction was mandatory however deep learning models require a huge amount of data and fastest processing power like GPU(Graphical Processing Unit) and TPU (Tensor flow Processing Unit). It has been observed that feature extraction methods with SVM classifier work better than other classifiers among machine learning algorithms because SVM gives reasonably accurate results in a non-linear dataset. Handwritten character dataset is more complex than the computerized fonts. The convolutional neural network which is a model of deep learning has made the pattern recognition so simple on complex dataset because feature extraction has been done by the convolutional neural network only and accuracy increases by fine-tuning hyperparameters. Furthermore, the recent work has been done in character recognition by various researchers for the limited regional script of India for recognising a character or word, research work can be extended to different regional language or sentence recognition.

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