Marathi Handwritten Classification Using Deep Learning

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Abstract— **The most difficult task in today's world is handwritten character recognition in Marathi. It takes a lot of time and effort to share tangible documents. The proposed effort will reduce the demand for storage space, ease the difficulty of data entry in Marathi-language forms, and transform deteriorated historical records into editable text, which is a requirement for OCR to convert Marathi written texts or letters to editable text. Furthermore, because of their structure, shape, multiple strokes, and various writing styles, handwritten Marathi characters are frequently more difficult to read and understand. In this study, a single handwritten Marathi character is taken as input, and the zonal feature extraction technique is used to extract the features and characters are categorized using a deep convolutional neural network (DCNN). This recognition system mainly has five stages i.e., Data acquisition, Pre-processing, Feature Extraction, Character classification and recognition. Finally, we discuss some existing issues in character recognition and suggest future research and development areas that will lead to the usage of deep learning-based character recognition in applicable sectors.**

Keywords—CNN, Deep Learning, Neural Network, Marathi character recognition, Zoning feature extraction.

I. INTRODUCTION

Deep learning and pattern recognition research are being carried out in the field of handwritten character recognition. A computer system that can recognise handwriting can collect and digitise characters found on paper documents, images, and other media. This is necessary since physical documents are cumbersome to take about and difficult to manipulate. Nowadays, several deep learning techniques are used to create such systems. The five phases of handwritten Marathi character identification start with image acquisition, which entails collecting and scanning handwritten samples, followed by preprocessing, which is used to improve the image, and segmentation, which is done to sharpen the image. The following stage involves classification and recognition, and the post-processing result is saved in a text file.

OCR is a method of automating the conversion of static, physical documents into editable, searchable text. OCR is now a very important research field, domain, and subject of computer vision, pattern recognition, and artificial intelligence. The area of OCR that is application-specific is automated character recognition. The English language has successfully benefited from the OCR's implementation and use. Most Indian languages, including Marathi, Hindi, Sanskrit, and Panjabi, employ the Devanagari script. Devanagari scripts were used to write the majority of historical texts; however, archaeologists were unable to preserve these scripts since they had common deterioration issues. In order to preserve ancient literature and make it available to the next generation, it must convert deteriorated historical documents to text.

The OCR was put into place and used for both online and offline character recognition (printed and handwritten characters). Because individual writers have varied writing styles, moods, pen points, writing surfaces, and writing speeds, as well as characters with different sizes, forms, strokes, and curves, handwritten character recognition is more difficult than printed character recognition. Nine crore people in Maharashtra utilise the Marathi language for documentation, hence the focus of this study is on the implementation of automatic Marathi handwritten character recognition.

The Devanagari script is the source of Marathi, an official language of Maharashtra. It is the 15th most spoken language worldwide and the fourth most spoken in India. As seen in Fig. 1, the Devanagari script used for the Marathi language has 12 vowels and 36 consonants. Additionally, see Fig. 2 separately. Basic and Compound Characters make up the Marathi character set. Basic letters are made up of a combination of vowels and consonants, and compound characters are made up of two consonants or a combination of both. Marathi does not use upper- or lower-case letters, and it is written from left to right. The header line is the horizontal line at the top of each character. The header line links the letters together to form a word. Certain distinguishing signs are used to pair vowels with consonants. These marks can be seen within a word's line, at the top, or at the bottom of a character [1].

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Fig.1 Marathi Vowels [21].

Fig.2 Marathi Consonants [22].

II. Methodology

A. Image Acquisition Phase:

Different people's handwritten Marathi character samples are gathered, and they are scanned into picture format using a camera or scanner. During the picture capture phase, the input image is transferred to the recognition system. An image (JPEG, PNG, etc.), a scanned image, a digital camera, or any other approved digital input device can be used as the input.

B. Data Pre-processing Phase:

Character recognition begins with pre-processing, which is essential in determining the rate of recognition. Normalizing the strokes and removing any variations that can impede accuracy are two benefits of preprocessing. Preprocessing focuses mostly on a variety of distortions, including erratic text size, points lost due to pen movement, jitters, left-to-right bend, and uneven spacing. The procedure includes noise reduction, binarization, and normalisation.

C. Segmentation Phase:

The process of segmentation divides a huge input image into discrete characters. The methods used are word, line, and character segmentation. Typically, it involves removing individual characters from a word graphic.

D. Feature Extraction Phase:

The module receives a segmented image as input. This module will take the character's image and extract its features. Geometrical features like area, perimeter, eccentricity, etc., low level features like colour, picture texture, etc., and high level features like vertical line, horizontal line, curve, etc. are all examples of features.

E. Classification and Recognition Phase:

Identification of the character and proper class labelling are steps in the classification process. The classifier receives the output of the feature extraction module as input. The classifier will pick up on the extracted features and detect which class the input image belongs to. There are various classification techniques available. Deep learning is one of them. Different artificial neural networks, including CNN, ANN, RNN, and others, are used in deep learning. The only neural network out of all of these to which we don't have to supply already extracted features is CNN. CNN uses the image as an input and separates the most significant elements into layers. CNN's key benefit is that it makes feature extraction less labor-intensive for humans. CNN works efficiently with large amount of data such as images.

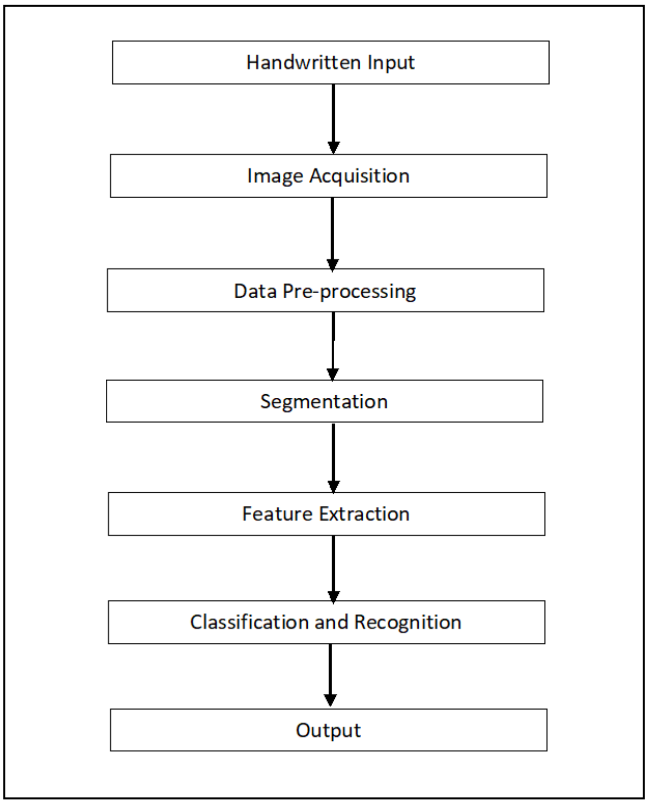


Fig.3 System Modules.

III. Data Augmentation

Data Augmentation is a technique for increasing training datasets without having to gather new images. Data augmentation alters the original images in some way. This is accomplished by using various processing techniques including as rotations, flips, zooming, and adding noise, among others. Large training datasets are significant in deep learning since they improve the training model's accuracy. It also aids in the avoidance of overfitting. The downsides of data augmentation include increased training time, transformation computation costs, and higher memory expenses. The dataset is divided into two parts where 80% is used for training and 20% is used for testing.

IV. Related work

According to [2], This work suggests a deep learning architecture, namely a deep CNN, for the recognition of Devanagari handwritten letters. The primary emphasis was on the employment of Dropout and dataset increment approaches to improve test accuracy, and as a result, test accuracy was able to increase by over 1%.

Using a multistage feature extraction and classification strategy, the article, according to [3], proposes a novel method for the recognition of unrestricted handwritten Marathi characters and achieved a 95.40% recognition rate.

Zoning-based feature extraction, which divides character images into a predetermined number of zones and computes a feature from each of these zones, is proposed in [4].

Specifically, this research, according to [5], focuses on the genetic algorithm technique and its current implementations. Different categorization performances techniques using various characteristics and segmentation techniques are compared. We will discuss classifiers similar to neural networks. and genetic programming.

According to [6] this research used multilayer classification to simplify Marathi handwritten character recognition. Characters are categorised in this way by placing them in distinct categories, such as those that have bars and those that don't. Characters with bars and those without are further divided into characters with enclosed regions and those without enclosed regions. Characters in the bar-enclosed region are separated into one and two components.

In this study, [7] uses a hybrid strategy that combines invariant moment and affine moment invariant feature extraction approaches to recognise handwritten Devanagari numerals and vowels. Support Vector Machine and Fuzzy Gaussian Membership Function are used on vowels and numbers, respectively, for recognition.

Using connected pixel-based features like area, perimeter, eccentricity, orientation, and Euler number, [8] presented feature extraction from handwritten Marathi characters and in this article mentioned techniques for obtaining the aforementioned geometrical properties.

According to [9], This study describes a streamlined OCR system for classifying and recognising handwritten Marathi text documents. The proposed method has been successfully implemented, with experimental results demonstrating an accuracy of 99.36% and a consumption time of 6.55 seconds (ms). The accuracy, sensitivity, precision, recall, and F-score of this technique are evaluated. The proposed method exhibits 99.36% accuracy, 90% sensitivity, 91% precision, 89.51% recall, 99.67% specificity, and 89.93% F-score when compared to existing Fire Fly Selection (FFS) and Bat Selection (BS) techniques. MATLAB was used to actualize the suggested methodologies, and real-time Marathi character datasets were utilised for the experiment.

According to [10] this paper put out a revolutionary offline handwritten modified character recognition method. The study employed a single CNN architecture in the first model and a double CNN architecture in the second model for the recognition. The study looked at a dataset of adequate accuracy Hindi Matras and consonants. Based on the findings, it was determined that duplicate CNN formats, which require fewer output classes than current modes of modified characters in Devanagari text, produce better outcomes than CNN single forms. Additionally, the outcomes suggested that double CNN outperforms conventional feature extraction (such as histograms of directed gradients) and classification approaches (like SVM).

Using a statistical approach, this research suggested a model for Marathi printed script optical character recognition, according to [11]. The suggested algorithm is quick and efficient, making it suitable for use on mobile devices. Processing power has increased as a result of the statistical technique being used in the pre-processing stage of the model, which has reduced the number of comparisons required for each recognition. With better resource allocation, the model's recognition rate has increased to an average of 88%.

The curved singularities of pictures, also known as the Curvelet transform, was empirically demonstrated in this study, according to [12]. For character image feature extraction, it is quite helpful. Characters written in Devanagari have a lot of curvature. After performing image segmentation and applying the curvelet transform, statistics for thick and thin pictures are calculated to produce the curvelet features. The system is trained using a classifier called K-Nearest Neighbor. The model had a 90% accuracy rate using 200 internal character images.

According to [13] this paper states that the Shared Hidden Layer Convolutional Neural Network framework is an attempt to be introduced in this study for image character recognition. It demonstrates that the SHL-CNN may, in comparison to a model constrained by characters from a single language using conventional methods, reduce recognition errors by 16–30%.

According to [14] this paper has done studies on printed and handwritten characters, extracting text from documents using corner points and extracting documents from images using Features from Accelerated Segment Text (FAST). This approach can be applied to multiple languages.

Devnagari Script Categorization by Utilizing CNN and KNN is in line with the Marathi classification of the Devnagari script, as stated in [15]. As a result, it was necessary to eliminate the noise, and Otsu's method used the Gaussian Approach. Pre-processing was done first, and only after that was the manuscript image's content fragmented. The characters were categorised using the KNN and CNN categorizers. is applied to the training and test datasets and tested with k=1 to 5. The outcome was demonstrated for the dataset's various sizes. They have a KNN categorizer with an average precision of 96%.

According to [16] the paper presents "A Wide Scale Survey on Machine Learning for Handwritten Character Recognition". They have examined how machine learning has affected the field of character identification. Neural networks, support vector machines, decision trees, nearest neighbours, random forests, artificial neural networks, logistic regression, linear regression, the Apriori algorithm, the K-Means clustering algorithm, the Naive Bayes classifier, and neural networks are examples of traditional machine learning techniques. Convolutional neural network, restricted boltzmann machine, deep belief network, deep neural network, deep extreme learning machine, and localised deep extreme learning machine are examples of deep learning recurrent neural networks.

According to [17] the paper states that the categorization of Devanagari characters using SVM is done using the energy properties of segment characters. The top four kernels in DATASET1 were linear (96%), quadratic (100%), RBF (97%), and polynomial (100%).

According to [18] the study recommended a deep learning marathi handwriting character recognition architecture They concentrate on using the Dropout and Approach to Dataset Increment. to increase test precision. We now know how to use deep convolutional the neural network used in this study.

According to [19] paper presents "A Novel Weighted SVM Classifier Based on SCA for Handwritten Marathi Character Recognition". This work described various approaches for feature extraction from the preprocessed image, including statistical, global transformation, geometrical, and topological characteristics. They used the WOAR-SVM classifier, which had the highest accuracy (95.14%) and performed the best.

According to [20] the study developed an effective feature extraction technique like the directional algorithm. Examining two different types of directional characteristics, one using the stroke length distribution approach and the other using contour.

V. Working of CNN

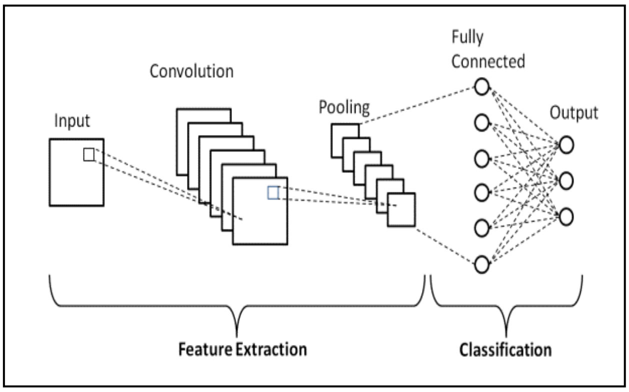


Fig.4 Architecture of CNN [23].

A particular kind of neural network called a convolution layer is used in convolutional neural networks (CNNs). Convolution layer, non-linearity (ReLU) layer, pooling or sub-sampling layer, and fully-connected layer are only a few of the layers that make up CNN.

A filter is included in each convolution layer and is shared by several neurons in that layer. These filters are smaller in size than the original image. The features from the input image are extracted using the filters. The portion of the image that the filter uses to extract features is known as the receptive field, and the extracted features are known as feature maps, meaning that the filter will execute a dot product operation with the preceding layer. These dot products' output is saved in several convolution layer neurons.

The following layer is the pooling layer, also known as the subsampling layer. The feature maps produced by the preceding convolution layer are used by each neuron of the pooling layer. The pooling layer's primary goal is to reduce input. There are two methods for pooling: maximum pooling and average pooling. In max pooling, the feature map's maximum value is discovered, and all other pixels are swapped out for the one pixel with the highest value. When a feature map's average value is found, it is used to replace the affected pixels with a single average-valued pixel. We shall receive the preceding image's minimized version at the end of this layer. The next convolution layer will get this shrunk image once more as an input, and the process will be repeated. The number of layers is flexible and can change depending on the situation.

The final layer is fully connected layer. This layer is often referred to as the convolutional neural network's output layer. This layer's function is categorization. Every neuron in the completely connected layer is linked to every other neuron.

VI. Challenges in Model Training

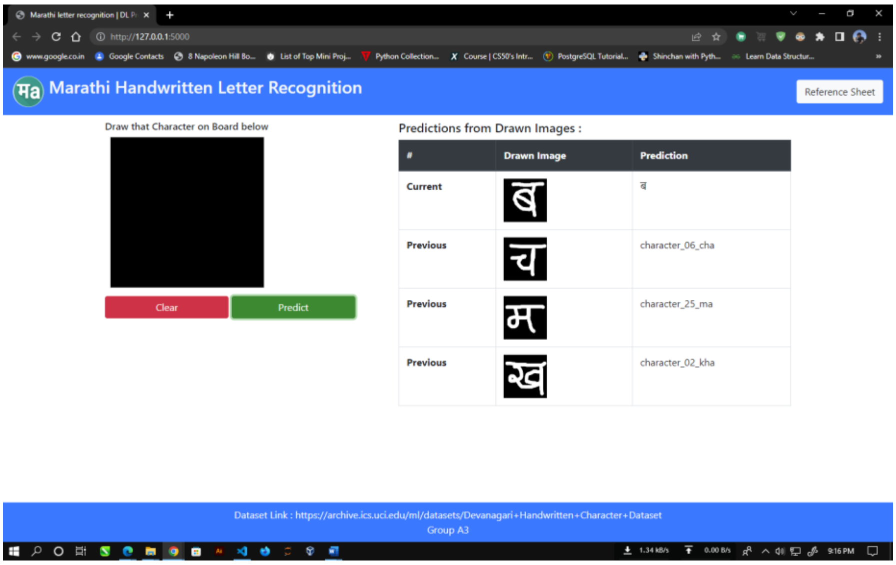
Massive datasets must be located and processed for deep learning training. Deep learning experiences overfitting. When a model performs worse on unobserved data than it does on observed data, overfitting in neural networks has developed. The deep learning algorithm needs high performance hardware to be implemented. Lack of adaptability and multitasking because, after training, the model can provide precise and efficient solutions to specific problems.

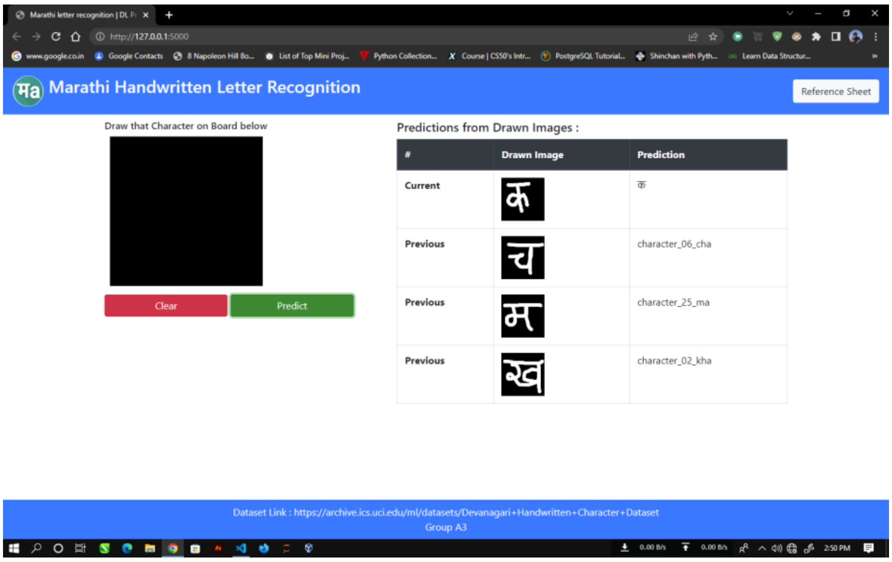
VII. Results and Discussion

A database of 35 distinct compound characters, randomly selected from the set of compound characters, is created in the handwritten Marathi compound character identification system. Since each character was written 100 times, 3500 databases had to be built. Every handwritten Marathi compound character from the image was taken and separated into two datasets: one for training and the other for testing. The characteristics are extracted using statistical feature extraction methods and zoning. In this method, the handwritten Marathi compound characters are categorised using CNN classifier. Figure-5 below displays the Interface for handwritten Marathi compound character recognition and Table-1 displays comparative analysis.

Method Proposed by	Classifier	Accuracy (%)
N. Sharma [24]	Quadratic	80.36
Deshpande [25]	RE & MED	82
S. Arora [26]	FFNN	89.12
U. Pal [27]	Quadratic	94.24
Proposed Method	CNN	96.8

Table.1 Comparative Analysis





VIII. FUTURE WORK

The system has a lot of potential for future research in the field of Devanagari word and sentence recognition. A sizable and intricate dataset can also be taken into account. Through OCR, a complete handwritten manuscript may be recognised. However, a hybrid approach may be shown efficient and optimised, allowing for the production of extremely precise outcomes. The system could be changed by adding additional orthogonal moment features. Additionally, more may be done to recognise marathi characters that are missing parts or are half characters. The model can also forecast input error rates. To create a general system, other other Indian languages and scripts may also be taken into consideration.

IX. CONCLUSION

The information regarding the significance and uses of handwritten Marathi character recognition is provided in this review study. The many methods for character recognition are also covered in this article. It talks about the various deep learning neural networks that are accessible. Additionally, it offers a synopsis of all previous research in this area. It has been noted in this survey report that the work of extracting different features is difficult since the image may occasionally be classified into the wrong class if some features are not recognised. The accuracy of the classifier will be impacted by the several character recognition issues that have been covered in this work. If the character image is oriented, blurry, out of focus, has noise distortion, or is otherwise distorted, it can be difficult to identify it. This paper discusses a number of deep learning algorithmic elements. The banking industry, for example, can employ handwritten character recognition to handle checks and other documents. More potential applications for handwritten character recognition can be explored.

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