Optical Character Recognition for Marathi Language using Deep Convolutional Neural Network

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Abstract: Optical Character Recognition (OCR) is currently a developing idea provid- ing variety of advantages under its domain. It is the most basic stage of any document analysis system. OCR systems for English are available in abundance. But, applica- tion of OCR in Devanagari script isn't so much of an explored portion. In a country like India, where most of the legal ancient documents are printed in the Devanagari script, the requirement is massive so it is important to create a commercially available software solution. This paper proposes a novel framework to recognize printed Mara- thi characters. It uses Deep Convolution Neural Networks. This Deep CNN algorithm will result in increased accuracy for pattern matching and overcome classification problems. The self-made dataset covers most of the characters present that makes it accurate predictions even more efficient. It also increases processing speed of charac- ter recognition and helps to compress the size of storage of the record, thus saving space.

Keywords: Optical Character Recognition, Deep Neural Networks, Convolu- tional Neural Network, Preprocessing, Segmentation, Classification.

1 Introduction

Optical Character Recognition is defined as the electronic conversion of images which have handwritten, printed or typed text in it to a text which can be used by a machine. The images may include: Images, Scanned texts, Typed/Printed Text, Bill- boards, etc. The image undergoes various stages like preprocessing, segmentation, classification and post-processing steps to achieve the final digitized document.

It is used widely to store printed information into a digital format. OCR is a very convenient way to digitize printed or handwritten documents so that they can be readily available for editing and formatting. It helps compress the size of storage of the record, thus saving space. Also, it enables easy online search and display of documents that saves thousands of hours of monotonous human effort.

The contents of the paper are organized as following:

Section (2) gives an insight about the related works done in Optical Character Recognition. Section (3) presents the proposed methodology in the paper which has

sub-sections explaining the processes of (3.1) Preprocessing, (3.2) Segmentation, (3.3) Classification, (3.4) Post-processing. Section (4) depicts the results and analysis of the model's accuracy in comparison to the other existing models. Section (5) con- cludes the paper and also elaborates on the future scope of the system.

2 Related Work

Shalini Puri et al. [1] has presented a Devanagari Character Classification using Support Vector Machine (CC-SVM) method, which initially performs preprocessing on the scanned image documents, which removes the topline which is called shi- rorekha in order to obtain a characters without shirorekha .In this method predefined character classes are stored. The SL characters which are segmented are compared with predefined characters having shirorrekha .If the SL character and predefined characters are found to be same then the SL character is considered to be of that pre- defined class else not . The proposed method has been implemented on image docu- ments of - Hindi, Sanskrit and Marathi. This methodology observed an accuracy of 99.54% and 98.35% for printed and handwritten documents respectively.

Sonika Narang et al. [2] presented a comparative study between various classifica- tion techniques and obtained an accuracy of 88.95% using a combination of MLP, Neural Network, CNN, RBF SVM and Random Forest classifiers. But this research is only done on basic characters of Devanagari.

Dr. T. Kameswara Rao et al. [3] developed a very simple approach for text extrac- tion from documents using the FAST algorithm. The image is divided into blocks. The denser blocks are labelled as text and the sparser ones are labelled as noise. The connectivity between these blocks are then considered to refine the clarity of text pre- sent. This simple approach has yielded close to 90% accuracy.

Chandrika Saha et al. [4] proposed a seven layered D-CNN architecture having three convolution layers, three average pool layers and one fully connected layer for recognizing Bangla handwritten digits. It was implemented with Keras framework with Tensorflow as backend. This architecture provided better recognition accuracies as a deeper network increases the performance significantly. Accuracy of 99.9% and 97.6% was observed on training and testing data respectively.

Pritish Mahendra Vibhute et al. [5] proposed a model for Optical Character Recog- nition of Marathi printed script using Statistical Approach. The algorithm proposed is optimized for speed and processing hence apt for usage on mobile phones. Due to the use of statistical approach in the pre-processing step of the model, it has resulted in reduction in number of comparisons per recognition, thus resulting in processing power. The recognition rate of the model is up to an average 88% with improved re- source utilization.

Ashadullah Shawon et al. [6] proposed different kinds of pre-processing techniques used for processing images. Deep convolutional neural network is used as the classifi- cation model. This paper mainly focuses on getting accurate results on unbiased da- taset. The accuracy obtained is 92.72% but needs advancement in pre-processing augmented techniques and CNN to get more accuracy.

Following is the timeline diagram of various classification algorithms along with their accuracies which are used for character recognition starting from 2010 until now.

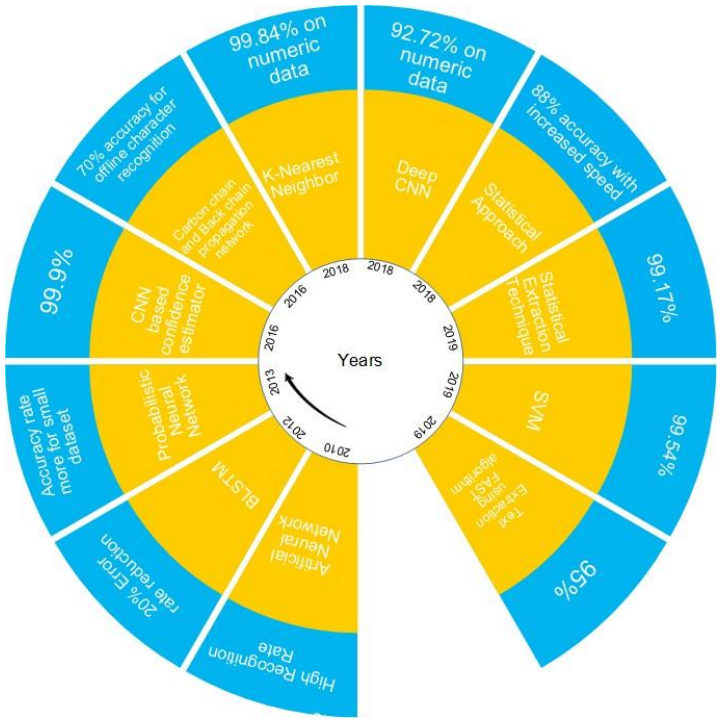


Fig. 1 Timeline diagram representing various algorithms used for classification

Parul Sahare et al. [7] presented robust algorithms for segmentation and recogni- tion of Latin and Devanagari characters which are validated using support vector ma- chine classifier. The accuracy obtained using these algorithms are more on numbers than alphabets. It is 98.86% and 99.84% accurate for segmentation and recognition respectively.

Shivananda V. Seeri et al. [8] proposed an approach to recognize English charac- ters (upper case letters + lower case letters) and digits in natural scene images using a

PNN classifier. First the Moment Invariants (MI) features were extracted from the image of segmented input characters, then a PNN classifier was used to recognize these characters. It yielded an average accuracy of 79.07% for mixed characters which was found to be higher than a KNN classifier which gave accuracy of 75.15%.

Naveen Sankaran et al. [9] proposed a recognition scheme for OCR of printed De- vanagri text using Bidirectional Long-Short Term Memory (BLSTM) Neural Net- work. This approach does not require word to segment. It instead helps predict the word sequence based on the past and future context of the element. This has resulted in more than 20% rise in the accuracy level as compared to traditional OCR systems.

Raghuraj Singh et al. [10] proposed a method for achieving OCR using Artificial Neural Networks. The test set used in this experiment is of 77 characters of five dif- ferent types of fonts. An image containing Devanagari text is given as an input to the system. After undergoing processes like pre-processing, segmentation and feature extraction, the consonants are classified using ANN approach. It is concluded from this paper that the input matrix of size 48X57 gives better results than other choices thus increasing the recognition rate considerably.

In this paper, we have proposed a model overcoming limitationsof the above pa- pers. All the existing models available for OCR for Devanagri script recognize only the base stem letters. We have attempted to make a complete OCR model that identi- fies each character with utmost accuracy and provides an output document of the same. The increase accuracy of the system is a resulted amalgamation of line, word, character segmentation; hidden convolutional layers and a vast self-made dataset that encompasses all the possible characters in the Marathi script. These factors contribute to the increased character recognition rate of the system.

The limitations of the existing systems elaborated in the above paper such as, un- known deformed words not identified, less effective in low contrast,less efficient on alphabets, reduced performance due to poor preprocessing of images,etc. These limi- tations have been overcome by using pre-processing techniques like gray-scaling, binarization, dilation which solves the issue of contrasting and uneven structure of letters. Also, due to the convolution layers and a script specific character dataset, the problem of inefficiency is solved

3 Proposed Methodology

The principal aim of the model is to recognize Marathi characters with an efficient accuracy rate.There have been many existing OCR’s available, but most of them just

detect the basic stemmed characters and not the complete word. Hence, such systems cannot be put to actual use in practical purposes. Else, there are paid systems availa- ble with huge operational costs.

In traditional Machine learning techniques, most of the applied features need to be identified by a domain expert in order to reduce the complexity of the data and make patterns more visible to learning algorithms to work. Whereas, in deep learning, the features are extracted by the model itself. And by adding the number of layers, the ac- curacy and efficiency of feature extraction further increases.

A fairly simpler model has been proposed in this paper using CNN along with con- cepts of Deep Neural Networks. Deep Convolutional Neural Network is neural net- work with the help of which various features are detected from an image in an in- creasing step-wise manner, thus achieving a greater feature integration at each layer. This trait of Deep Convolutional Neural Networks helps it achieve a higher hand at image recognition. Combined with the properties of Deep Neural Networks, a highly specific self-made dataset is used to elevate the accuracy levels and prediction rate of the model.

The system architecture can be broadly classified into 4 parts; viz. Pre-processing, character segmentation, training and character recognition.

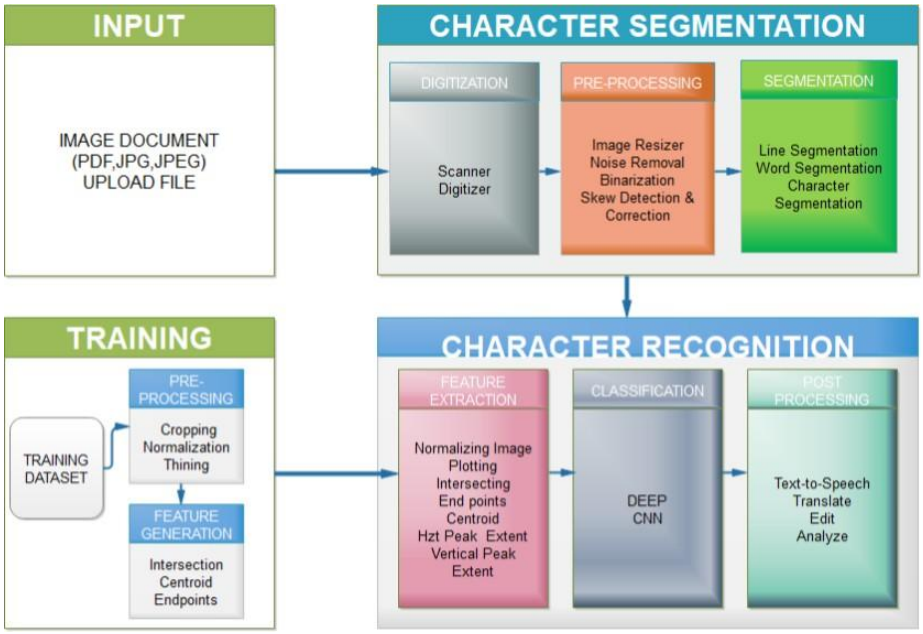


Fig. 2 Proposed Deep Convolutional Neural Network Model

The model proposed in this model consists of the following stages:

Pre-processing

Binarization

Binarization is a process of converting an image into 256 gray levels and then to a black and white image.In the process, a suitable threshold value is set that is used to classify the pixels as black or white. The values above the threshold value are classified as white, while the ones below it are classified as black. It helps in recognizing the noise pixels and transforming the image into a series of binary pixels.

Gray Scaling

Gray scaling is the process in which each pixel value is considered as a single sample and these sample represents amount of lightthat is its intensity infor- mation. Grayscale images, is atype of black-and-white monochrome also known as gray monochrome. They are composed of shades of gray. The con- trast range starts from the weakest intensity of black to the strongest intensity of white. The intensity of a pixel is expressed within the range of minimum to maximum inclusive.In this range 0 or 0% depicts total absence or black whereas 1 or 100% depicts total presence or white with any fractional values in between. This range is represented abstractly as a range from 0 (or 0%) (Total absence, black) and 1 (or 100%) (Total presence, white), with any fractional values in between.

Dilation

One of the basic operator in the field of mathematical morphology is Dila- tion and is mainly used on binary images or gray scale images. The bounda- ries of foreground pixels is enlarged by this operator of binary or gray scale images.This results in the growth of foreground pixels and makes holes with- in these regions smaller. There are two inputs given to dilation operator one is image to be dilated and a structuring element also called as kernel. The precise effect of dilation on the image is determined by structuring element.

Segmentation

Segmentation is decomposing one image into sub-images. In image segmentation a digital image is partitioned into multiple segments .It is typically used to identify ob- jects and boundaries (lines, curves, etc.) present in images. Here, it locates and creates boundaries around the lines. These segmented lines further undergo word segmenta- tion using edge detection of the words. The images of the words further go through character segmentation that results is each character being located separately. The result obtained covers entire image to extract segments or set of contours from the image.

Line Segmentation

Here, the image segmentation technique called contours is used. The contours are the continuous lines or curves that bound or cover the full boundary of an object in an image. They are modified in a way to de- tect the boundaries of the lines. The contours help realizing the shape of the object and retrieve the border co-rdinates.

Word Segmentation

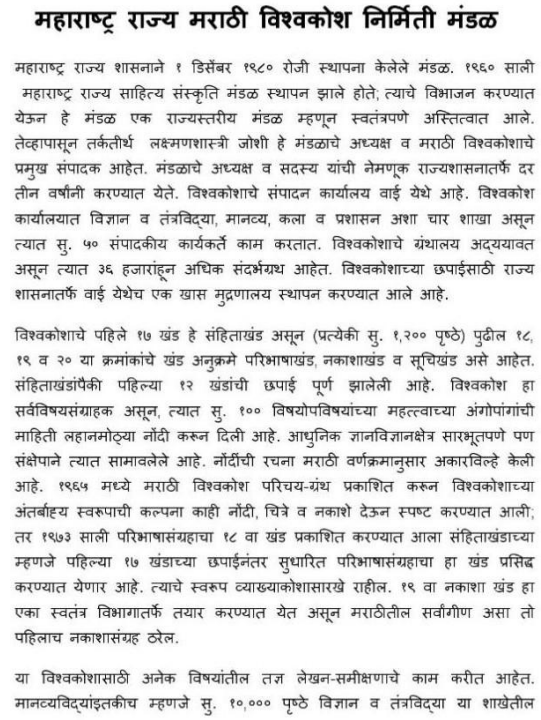
Contouring is further applied to the segmented lines. The borders and edg- es of the words are located and contours are applied to it. It creates boxes around the words using edge detection. The co-ordinations of the borders are then stored using various computer vision parameters.

Character Segmentation

Character Segmentation is achieved by locating the x co-ordinate extents and y co-ordinate extents of the image (image of the word). And the area of the image with 2 or more breaches of black pixel patches in the y –axis, is considered as a single character. And incision occurs where there is only one patch of continuous black pixels in the y-axis. Hence, effective char- acter segmentation is achieved.

The following figure depicts the segmentation stages serially.

i. Fig. 3.1presents the input image.
ii. Fig.3.2 depicts lines marked for segmentation of a sample docu- ment
iii. Fig. 3.3 depicts the segmented line with marked words.
iv. Fig. 3.4 depicts the segmented word, with marked characters.
v. Fig. 3.5 the final segmented characters.



महाराष्ट्र राज्य मराठी विश्वकोश निर्मिती मंडळ

महाराष्ट्र राज्य शासनाने १ डिसेंबर १९८० रोजी स्थापना केलेले मंडळ. १९६० साली महाराष्ट्र राज्य साहित्य संस्कृति मंडळ स्थापन झाले होते; त्याचे विभाजन करण्यात येऊन हे मंडळ एक राज्यस्तरीय मंडळ म्हणून स्वतंत्रपणे अस्तित्वात आले. तेव्हापासून तर्कतीर्थ लक्ष्मणशास्त्री जोशी हे मंडळाचे अध्यक्ष व मराठी विश्वकोशाचे प्रमुख संपादक आहेत. मंडळाचे अध्यक्ष व सदस्य यांची नेमणूक राज्यशासनातर्फे दर तीन वर्षांनी करण्यात येते. विश्वकोशाचे संपादन कार्यालय वाई येथे आहे. विश्वकोश कार्यालयात विज्ञान व तंत्रविद्या, मानव्य, कला व प्रशासन अशा चार शाखा असून त्यात सु. ५० संपादकीय कार्यकर्ते काम करतात. विश्वकोशाचे ग्रंथालय अद्ययावत असून त्यात ३६ हजारांहून अधिक संदर्भग्रंथ आहेत. विश्वकोशाच्या छपाईसाठी राज्य शासनातर्फे वाई येथेच एक खास मुद्रणालय स्थापन करण्यात आले आहे.

विश्वकोशाचे पहिले १७ खंड हे संहिताखंड असून (प्रत्येकी सु. १,२०० पृष्ठे) पुढील १८, १९ व २० या क्रमांकांचे खंड अनुक्रमे परिभाषाखंड, नकाशाखंड व सूचिखंड असे आहेत. संहिताखंडांपैकी पहिल्या १२ खंडांची छपाई पूर्ण झालेली आहे. विश्वकोश हा सर्वविषयसंग्राहक असून, त्यात सु. १०० विषयोपविषयांच्या महत्त्वाच्या अंगोपांगांची माहिती लहानमोठ्या नोंदी करून दिली आहे. आधुनिक ज्ञानविज्ञानक्षेत्र सारभूतपणे पण संक्षेपाने त्यात सामावलेले आहे. नोंदींची रचना मराठी वर्णक्रमानुसार अकारविल्हे केली आहे. १९६५ मध्ये मराठी विश्वकोश परिचय-ग्रंथ प्रकाशित करून विश्वकोशाच्या अंतर्बाह्य स्वरूपाची कल्पना काही नोंदी, चित्रे व नकाशे देऊन स्पष्ट करण्यात आली; तर १९७३ साली परिभाषासंग्रहाचा १८ वा खंड प्रकाशित करण्यात आला संहिताखंडाच्या म्हणजे पहिल्या १७ खंडाच्या छपाईनंतर सुधारित परिभाषासंग्रहाचा हा खंड प्रसिद्ध करण्यात येणार आहे. त्याचे स्वरूप व्याख्याकोशासारखे राहील. १९ वा नकाशा खंड हा एका स्वतंत्र विभागातर्फे तयार करण्यात येत असून मराठीतील सर्वांगीण असा तो पहिलाच नकाशासंग्रह ठरेल.

या विश्वकोशासाठी अनेक विषयांतील तज्ज लेखन-समीक्षणाचे काम करीत आहेत. मानव्यविद्यांइतकीच म्हणजे सु. १०,००० पृष्ठे विज्ञान व तंत्रविद्या या शाखेतील

Fig. 3.1

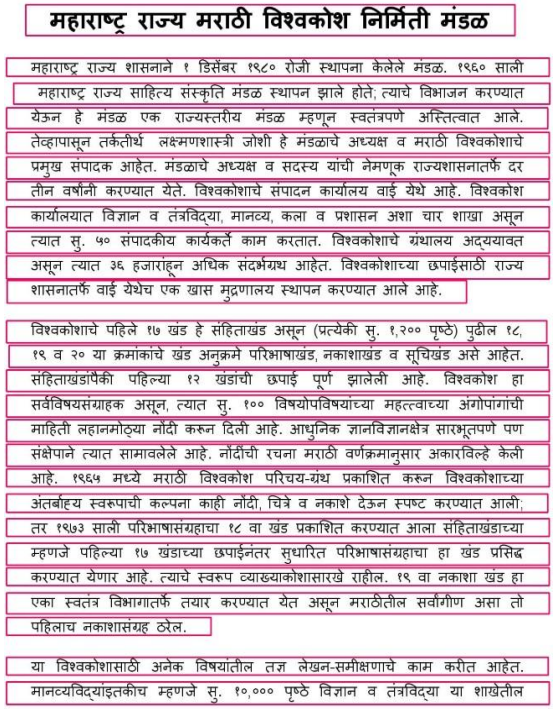


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Fig. 3.2

FIG 3.3

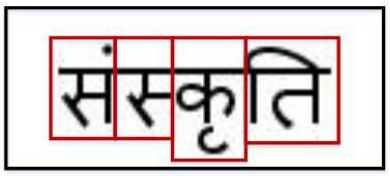

FIG 3.4

FIG 3.5

Classification

In the given paper, the algorithm used for classification is stated as Deep Convolu- tional Neural Network.

Deep Convolutional Neural Network

The convolutional neural network uses kernel/filters to extract the features from the input using what is known as the convolution operation.

CNN is a class of Deep Neural networks. CNNs are considered to use relatively less preprocessing steps in comparison with other classification algorithms .A con- volutional neural network is made up of an input and an output layer and has mul- tiple hidden layers. These hidden layers have convolutional layers placed in serial order that convolve with each other using multiplication or dot product. Some hid- den layers may have some additional convolution layers like pooling, normaliza- tion and fully connected layers. These layers are also considered as hidden as their input and output is masked by the activation function and final convolution.

Proposed Model Construction

Following diagram depicts the proposed Deep Convolutional Neural Network model in detail.

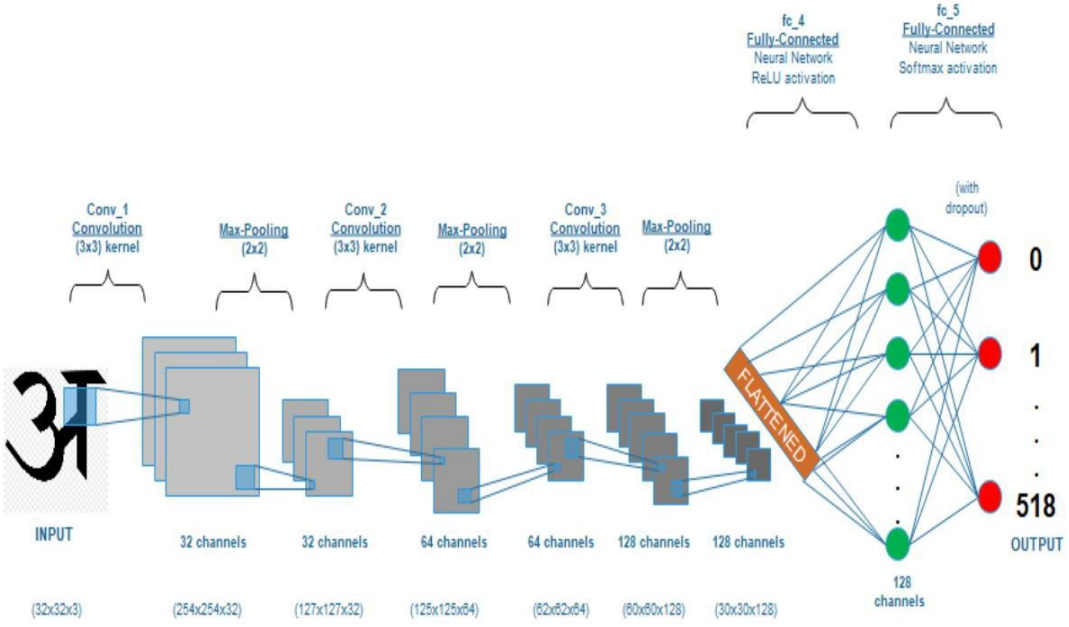

Fig. 3 Proposed Deep Convolutional Neural Network Model

It consists of following layers:

i. **Input Layer**

The input layer has a set of measurements. Each neuron in the layer repre- sents a predicator variable. Pre-processed images are fed as an input to the network.The images are set to a size of 32*32 pixels. These neurons feed the values to the layers in the pattern layer for further computation.

ii. **Convolutional Layer**

After passing the input tensor to a convolutional layer, the image becomes abstracted to a feature map. In the model, there are 3 Convolutional layers each having a kernel size of 32, 64 and 128 respectively. Increasing the number of filters, helps in greater efficiency in feature extraction.

Every input to the neuron is assigned a weight. The output of a particular neuron is calculated by equation (1):

$$a = f\left(\sum_{i=0}^{N} w_i x_i\right) \quad \text{Equation (1)}$$

Where,
a – Output of the neuron f – Activation function w – Weight of the input x – Input to the neuron

Activation Function:

The activation function used the model is ReLU. (Rectified Linear Units) It is most suitable for CNN's because of its less computational expense as compared to tanh and sigmoid function as it involves simpler mathemati- cal operations. The output x is given if x is positive or else 0. RELU func- tion at a given time activates few neurons making this function more effi- cient. As RELU function is non-linear in nature it is easy to back propa- gate if some error occurs in the network.

iii. **Max Pooling Layer**

The outputs of one neuron clusters are made into one neuron in the next layer by the max pooling layer hence reducing the dimensions of the data. The largest element in the window is taken and replaced in the window of the re- duced size. The window size usually used is 2*2.

iv. **Flattening**

Flattening is a process that converts the two-dimensional matrix in the pool- ing layer, into a one- dimensional vector. This 1D vector is then fed to the Fully Connected Layer

v. **Fully connected Layer**

In fully connected layers all neurons of one layer is connected to all neurons of other layer. In order to classify the images the flattened matrix needs to pass the fully connected layer. The number of output classes are defined here. Also, since the number of distinct classes is more than 2 in the model, we use the *softmax*activation function.It outputs a vector that represents the probabil- ity distributions of a list of potential outcomes.

vi. **Output Layer**

The output of this layer is considered as the final prediction by the CNN model. A list of probabilities of the respective classes is retrieved. Class hav- ing the highest probability is assigned to the image.

Post-processing

Even after the application of the maximum number of noise reduction and pre- processing techniques, there is a possibility of having characters that are unrecog- nizable and discarded as noise. These errors can be caused due to certain human inaccuracies or external factors.

The simplest way of incorporating the context information is the utilization of a dictionary for correcting the minor mistakes of the OCR systems. Incorporating all the words or probable errors and saving them for the exceptions. Also using a standard spell checker could be feasible.

4 Result and Analysis

The model built for OCR using Deep Convolutional Neural Network and a self- made dataset has yielded a categorical accuracy of 96%. The training dataset con- sisted of 24315 images, and test dataset consisted of 6062 images. An 75-25 split was made. The output vector consisted of 478 classes, out of which the class with the greatest probability was assigned to the image and printed as text in a docu- ment.

The following table consists of results, advantages and drawbacks of various papers studies in the following paper. The model proposed in this paper surpasses the various limitations posed by the previous models thus increasing efficiency.

Parameter	ANN	BLSTM NN	PNN	CNN based Confi- dence Estimator	KNN	D-CNN	Statistical Approach	FAST Algo- rithm	SVM	Deep Con- volutional Neural Network
Year	2010	2012	2013	2016	2017	2018	2018	2019	2019	2019
Language	Devanagari	Devanagari	Marathi	Chinese	Multilin- gual	Bengali digits	Marathi	Multi- lingual	Hindi, San- skrit Mara- thi	Marathi
Document Type	Printed	Printed	Handwrit- ten	Printed digits	Printed and Handwrit- ten	Handwrit- ten	Printed	Hand- written	Printed and Handwrit- ten	Printed
Accuracy	96.60%	20% increased than traditional systems		99.0% to 99.90%	99.84%	92.72%	88%	85%	99.54% and 98.35%	96%
Advantage	Higher recognitio n rates	20% and 9% reduc- tion in word and character error rate respectively	Improved overall ac- curacy us- ing less training data	More efficient compare d to other baseline system	Performs better compared to other con- temporary approaches	Good for large and unbiased dataset compare d to biased datasets	Robust in terms of character s size and style of writing	Efficien t in ex- tracting more comple x layouts	Identifies and classi- fies Shi- rorekha- Less char- acters cor- rectly	Reduced complexit y and in- creased processin g speed
Limitation	Unknow n deforme d words not identifie d	Unknown deformed words not identified	Less effec- tive in low contrast	Residua l errors	Less effi- cient on alphabet s	Reduced perfor- mance due to poor prepro- cessing of images	Font de- pendent approac h	Not effectiv e for big size font	Misclassi - fication of some San- skrit char- acters	Not con- sistentl y effectiv e for poor prints

Table 1. Result and Analysis

5 Conclusion and Future Work

The model documented in the paper depicts that Deep Convolutional Neural Net- work along with the self-made dataset yields better results in accordance to accuracy and efficiency. The combination of the 3 convolutional layers and the character spe- cific dataset decreases the complexity of the network, improves accuracy and helps make a complete OCR for Marathi script in a much simplified and cost-effective manner. The model can be further used for Character Recognition of Hindi language as well, by incorporating the required characters dataset.

We are looking forward to extend the scope of the model into applications which can be of much significant use to the Government. The algorithm would help store,

identify and translate official documents into different languages, thus enabling peo- ple to get an insight into it easily. Also, the application could be broadened into the health and education sector thus, enabling visually challenged individuals to help gain knowledge about various old scripted books and various other materials by just scan- ning them which would then present the real-time digitized book into an audio file.

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