Implementation of Deep learning Methods to Marathi Hand Written Characters and its Pattern Recognition by Using Generative AI

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Received: 17.07.2024 Revised: 18.08.2024 Accepted: 20.09.2024

ABSTRACT
In the field of Machine learning, Powerful AI Systems trained and tested to carry out the task have utilized many models in areas including pattern recognition, natural language processing, and computer vision. Deep learning has provided outstanding pattern matching and recognition systems in several domains, including character recognition. In this research we have collected our own published dataset like MHCD_GIETV1 and MHCD_GIETV2. Initially we have taken a samples of vowels characters like Bara-khadi.We have used deep learning methods of Inception,ResNet,VGG16and leveraged a custom convolutional neural networks that enhance to find the accuracy of Vgg16 i.e. 65.96%,Inception 83.42% and ResNet 65.96%.After comparison we found Inception is better accuracy but we are not happy about our results. We have proposed a customized convolutional neural networks with the increase of hidden layer by extending our epcho and achieving an accuracy of 96%.To extend our research we used Generative AI by using LSTM with GRU and obtained a result in a remarkable patterns matching an accuracy of 98% probability. This research provides valuable resources for future explorations in other languages and related domain such as sentiment analysis and boarder image recognition applications.

Keywords: Marathi Handwritten Character recognition, Customized Convolutional Neural Networks, Resnet, InceptionV3, Relu, Conv2D, MHCD_GIETV1.Generative AI, GRU

INTRODUCTION

About Marathi Characters

Marathi characters, written in the Devanagari script, exhibit a unique blend of phonetic accuracy and structural elegance. It is used for language Hindi and Sanskrit. Each character has specific sound and moving it highly accurate for pronunciation, the script includes 12 vowels and 36 consonants, categorized into guttural, palatal, retroflex, dental, and labial sounds. Marathi is syllabic, with each consonant carrying an inherent vowel sound, and its characters are connected by a distinctive top horizontal line, giving it a rounded, fluid appearance.The script also features 10 numerals. Despite its phonetic precision, challenges arise in digital recognition, particularly due to inconsistent word boundaries, the presence of mirror-image characters, and the complexity of ligatures. Though encoded in Unicode, OCR systems must account for variations in scanned documents, handwriting, and digital fonts. Marathi's melodic quality, simpler verb system, and two-gender structure make it distinct, while its script remains central to its cultural identity. We have represented handwritten characters **[Fig 1(a)]**

Fig 1 (a): Simple Marathi Handwritten characters

Fig 1 (b): Handwritten Newspaper characters

Objective of the Dataset

We have created and published our two own dataset after following data collection,Annotation,Bounding box,Threshold,Augmented and created an images of equal size. Our dataset published on Mendeley i.e. MHCD_GIETV1, MHCD_GIETV2.For our research process we have collected a sample of MHCD_GIETV1 that contains Bara-khadi **[Fig2]** dataset that contain 24,040 simple Marathi characters. It is divided into four types like Grayscale, Binary and Inverted images i.e. Grayscale 6010, Binary 6010, Inverted 6010 images https://data.mendeley.com/datasets/bxswfmx28z/1.

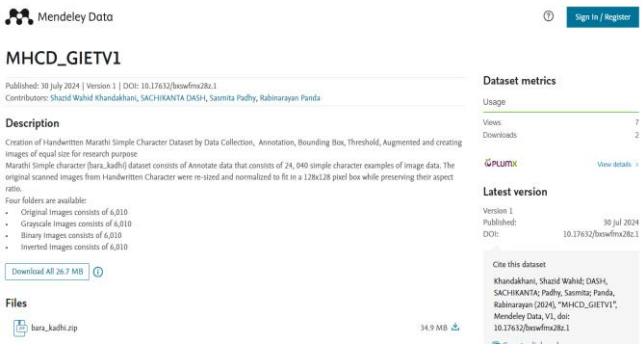

Fig 2:MHCD_GIETV1 Published dataset details

Fig 3 : Mendeley Published data details

Motivation

In the deep learning methods we achieved high performance in Natural processing languages to find the performance in pattern recognition.We optimize pattern recognition and achive better prediction results.We evaluate the performance to determine the most efffecctive methods.To address this we have

created a comoprehensive data set into multiple format like Gray, Binary and Inverted**[Fig4(a),(b),(c)]**by using a methods of scanning, annotating,define bounding boxes and augumenting images.To utilize this we have applied variouts deep leartning mehtods to improve our predicition accuracy and our analysis guided by[2,10,14] that demonstrate the critical role of dataset quality to find its recognition system .

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Fig 4 (a) Digitized handwritten characters of equal size and pixel for simple characters.

Fig 4 (b): Digitized handwritten character of equal size and pixel for binary characters

Fig 4 (c): Digitized handwritten character of equal size and pixel for inverted characters

Paper Outline

This paper is organized in a step by steps manner.

1. Introduction about Marathi character specially Bara-kadhi including motivation
2. Survey of Literature
3. Methodology.
4. Predicion analysis VGG16,Resnet,Inception
5. Comparison of models with customized CNN
6. Pattern recognition by using Generative AI
7. Future work and its conclusion.
8. References

Model Implementation

Our paper covers all the essential steps to implement and document a model **[Fig5].**

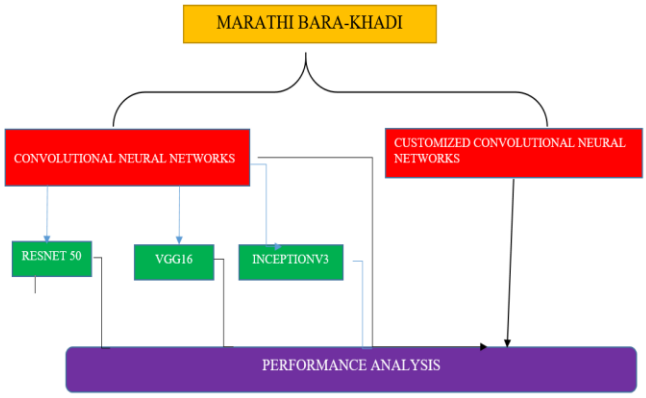

Fig 5: Workflow of diagram of research

Survey of literature

In 2022, Ramteke published a study titled "A Novel Weighted SVM Classifier" that utilized the concept of weighted one against rest support vector machine (WOAR-SVM) for handwritten Marathi character recognition. The WOAR-SVM plays a significant role in handling large feature measurements used for classification. Up until the benchmark, the dataset would be constructed.[1]. In 2022, Manisha Agarwal the paper on 'Machine Learning Algorithms for Handwritten Devanagari Character Recognition: A Systematic Review' where SVM and CNN Classifier was used. They have work together to get features to extracted from the preprocessed data so that the relevant data is further used to train the model. On various approaches effective algorithm. The study concludes that SVM classifier as well as CNN classifier both provides better results with 98.47 accuracy though the dataset used here was very small.[2]. In a 2023 study titled "Enhancing Marathi Handwritten Character Recognition Using Ensemble Learning," the author Chikmurge used ensemble methods such as VGG16, Alexnet, and LeNet-5 in a single convolutional neural network (CNN) model. When compared with the CNN model's performance, the ensemble method yielded much better results. [3]. In 2023 yet another paper was published by Kulkarni on 'Handwritten Marathi Character Recognition using SVM Classifier' where character segmentation, feature extraction, and classifications to identify characters with the appropriate styles where used to determine which classifier is the most accurate, the comparison accuracy of SVM with other classifiers. In the final prediction after RHOG as the feature extraction technique it was proved that SVM is a better Classifier over other algorithms with 95.64 accuracy. The drawback was where more explorer towards image processing algorithm was needed.[4]. In 2023, Chandolikar published a paper on 'Devanagari Characters Recognition: Extracting Best Match for Photographed Text' where Character Recognition system was used. System was used to recognize the input and convert it into digital form and pass it. The ability to recognize text and numbers plays a significant part in automating numerous systems, including the digitization of documents. The accuracy rate is 98%.[5]. The paper "A Streamlined OCR System for Handwritten Marathi Text Document Classification and Recognition Using SVM-ACS Algorithm" was published in 2022 by Ramteke. The technique of projection profile segmentation, which produces less error, was implemented using Curvelet Transform (CT), Principle Component Analysis (PCA), Adaptive Cuckoo Search (ACS), and Matlab. Using metrics like recall, sensitivity, precision, and F-score, we may evaluate how well the suggested method works.[6]. In 2016, Padma Ramkrushna published a paper on "A handwritten recognition for free style marathi script using genetic algorithm" describes a process for identifying Marathi handwriting using a GA. A search algorithm that takes its cues from natural selection is the GA. It begins with a random collection of solutions and iteratively improves the population by breeding off the strongest and most successful members. The fittest individuals are those that have the highest fitness score, which is a measure of how well they perform on the task of recognizing handwritten characters. The GA is able to achieve a recognition accuracy of 96.77%.[7]. Surendra P. Ramteke published an article in 2019 and it detailed a genetic algorithm-based handwriting identification system for the Marathi script. Classification, feature extraction, segmentation, and preprocessing are the four phases that make up the system. Prior to processing, the picture is binarized and edges are located by employing the Canny method. In the segmentation stage, the image is divided into individual characters. In the feature extraction stage, features are extracted from the characters using a genetic algorithm. In the classification stage, the characters are classified using a neural network. The system was evaluated on a dataset of 1000 handwritten Marathi characters and achieved an accuracy of 96.77%.[8]. In 2023 by S.Sujith kumar applied binaraization,line segmentation techniques to divide the image for improved

character recognition and trained by CNN in tamil palm leaf character recognition and achieved 91%.[9]. In 2022 Nibran Das, Created a benchmark dataset for isolated Bangla compound characters, achieving 79.35% accuracy using quadtree-based features and SVM classification.[10] In 2015 Ramesh Kumar Mahapatra & Tushar Kanti Mishra Developed a database for handwritten atomic Odia characters with techniques for image binarization, skew angle detection, and text line segmentation, achieving high accuracy with parallel Hough transform and SVM[11]. In 2018 D.T. Mane Proposed a Customized Convolutional Neural Network (CCNN) for recognizing handwritten Marathi numerals. With a dataset of 80,000 samples (70,000 for training, 10,000 for testing), their CCNN achieved an average accuracy of 94.93% using K-fold cross-validation[12].In 2024Jyoti Kadadevarmath) Proposed a customized CNN for breast cancer classification from mammography images. The model showed efficient performance compared to existing models, measured by accuracy and AUC[13].In 2022 by Rabinarayan Panda & Sachikanta Dash Analyzed deep learning techniques for Odia character recognition using CNN, achieving 95.6% accuracy with a six-layer neural network[14].In 2022 by Rahul S. Narsing Worked on Devanagari character recognition using image processing and machine learning with a dataset of 94,640 images, achieving around 90% accuracy.[15].In 2022 by Rabinarayan Panda & Sachikanta Dash Focused on complex Odia handwritten character recognition using CNN and achieving 88.7% accuracy[16].In 2024 Rabinarayan Panda & Sachikanta Dash Developed a dataset for Odia handwritten characters and implemented deep learning models like ResNet and Inception V3[17].In 2022 Mimansha Agrawal & Bhanu Chauhan Introduced an air-written multilingual numeral dataset for Devanagari and English, providing 20,000 images (10,000 for each language) for pattern recognition research[18].In 2020 by S. Limkar, Gautami Mudalia, Sneha Kulkarni Proposed a deep CNN framework for printed Marathi character recognition, enhancing accuracy and processing speed with a self-made dataset[19].In 2020 by Peng Guo, Zhiyun Xue Presented an ensemble deep learning approach for cervix image selection, combining RetinaNet, Deep SVDD, and a custom CNN. The ensemble achieved an average accuracy of 91.6% and F-1 score of 0.890 on a dataset of over 30,000 smartphone-captured images [20].In 2024 Smita Das uses the MobileNet convolutional neural network to detect glaucoma, a leading cause of blindness due to high intraocular pressure. By analyzing retinal fundus images from datasets like DrishtiGS, EyePACS, AIROGS-Light, BEH, REFUGE, sjchoi86-HRF, CRFO-v4, G1020, FIVES, and PAPILA, the study shows MobileNet's efficiency, accuracy, and speed in diagnosing glaucoma.The model is evaluated using metrics like accuracy, precision, sensitivity, specificity, F1 score, and confusion matrix, proving useful for quick and reliable glaucoma detection[21].In 2016 by S.K. Vengalil & N. Sinha In their paper on blood vessel segmentation from fundal images, they customized a CNN with 8x8 convolutional layers and 3 pooling layers. Their approach achieved a segmentation accuracy of 93.94% by binarizing the grayscale output using thresholding [22]. Through the use of a huge language model, Manish created techniques in 2024 for the detection of AI-generated text. Prove that generative textual likelihood ratio (GLTR) annotation technique may improve human detection rate of bogus text from 74% to 99% without training [23]. In 2023 by Rupali Patil used KNN algorithm for recognition of Marathi sentence using Devanagari character sentence level recognition and found an accuracy of 86.84% [24]. In 2024 Rabinarayan Panda about Visualizing and Understanding the Customized Convolutional Neural Networks to Identify Hand Written Odia Characters and its Pattern Using Generative AI and found 94% pattern matching [25]. In 2015 K.S.Dash used image transformation based feature extraction technique for Odia numeral recognition [26]

METHODOLOGY

Data Filtering

To use deep learning, we divided our simple handwritten characters into types of Vowels.We enhanced all the characters **[Fig6]** and arranged them into their respective folders.

Fig 6: Folder wise arrangement of Vowel Characters

MARATHI Vowels Characters.

It is known as Swar.There are 14 vowels in Marathi. Each Vowels in Marathi is pronounced by itself and has distinct, pure and unmodified sounds. It has retained a significant portion of the original Sanskrit pronunciation **[Fig7]**

Fig 7: Vowels Characters

MARAHI Consonants

Voiceless consonants in Marathi, like " क " (ka), " ख " (kha), and " ग "(ga),are produced without vocal cord vibration. Accurate recognition of these characters is crucial for understanding and digitizing the Marathi language. To support deep learning methods for recognizing these voiceless consonants, we have organized the characters into folders. This structured approach streamlines the training and testing of models, improving their ability to accurately identify and categorize Marathi voiceless consonants. **[Fig8]**

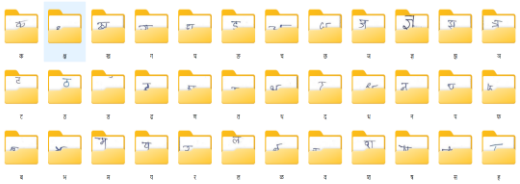

Fig 8: Marathi Consonant

CNN Architecture

Convolutional Neural Networks (CNNs) rely on convolutional layers (ConvLayer) for deep learning tasks involving image input, including object detection, character recognition, and picture categorization. It uses a layers to apply kernels to input images, generating feature maps that highlight various features and colors. We have utilized models such as VGG16, ResNet, and InceptionV3 in our research. ResNet is known for its success in computer vision, significantly advancing deep learning by enabling effective training of deep networks and forming the basis for many CNN models [14, 17].InceptionV3, on the other hand, excels in image classification by capturing features at multiple scales within the same layer. It uses filters of different sizes (1x1, 3x3, 5x5, etc.) and performs pooling operations, concatenating the outputs along the depth dimension to enhance feature extraction. **[Fig9].**

Input image = I

Filter =k

Then the output convolution operation (i, j) is represented by

$(I*K)i,j = \sum m \sum n Ii+m,j+n \; *km,n$

I i+m ,j+n is pixel value of the image (i+m,j+n)

K m,n is the filter weight

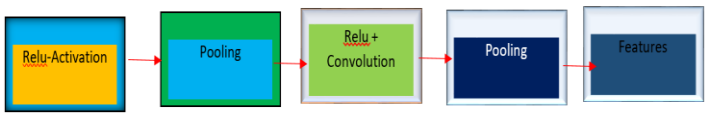

Fig 9: Convolutional Neural Networks structures

Activation function

In CNN, activation function uses a role in introducing non-linearity into the model.it allows to learn complex patterns and make more accurate prediction.

ReLu

After complete the convolutional operation the output passes through an activation functions like Relu. It replaces all negative values in the feature map with zero and keeps positive values unchanged. It is used due to its similarity and effectiveness. in the It uses non-linearity function into the models to recognize complex patterns.Theformula of Relu activation functions is represents here

If(x)=max(0,x)
If x is greater than 0 then Relu output is x
If(x)= { x if x>0
Otherwise

Softmax
It is used in the output layer of CNN.It converts raw output scores into probabilities which sum up to 1.It uses exponentiation and normalization. It converts raw output score into probabilities, It allows for easy interpretation of the networks predictions and ensuring that the predicted probability Sum to 1

$$\text{softmax}(zi) = \frac{e^{zi}}{\sum j^{ezj}}$$

Sampling
In CNN sampling refers to operations that reduce the size of the data or features. It divides into two types of sampling that is subsampling and downsampling.In a pooling layer the spatial dimnenssions reduces.The most common is pooling like max pooling that takes maximum value in each patches of the features map.

max pooling
To aid in computation reduction and overfitting management, it decreases the spatial dimensions of feature maps. The Conv2D module and its Maxpool2D are utilized [Fig. 10].In order to extract features like as edges, textures, and forms from the input data, it uses a series of learnable filters called kernels. It uses a collection of trainable filters called kernels to sift through the input data and pull out characteristics like forms, textures, and edges [13, 17].

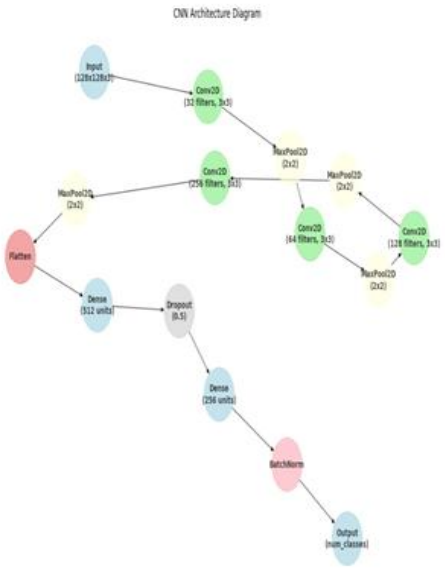

Fig 10. Cov2D with maxpool2D diagram

ResNet50
The Residual Network is an advanced CNN design that uses residual blocks—which contain shortcut connections that skip over some layers—to solve the vanishing gradient problem, to the input layer. These shortcuts help maintain gradient flow during backpropagation, simplifying the optimization process and enhancing accuracy[4-6].Typically comprising various layers, such as convolutional layers, pooling layers, and fully connected layers,ResNet architectures, like ResNet-50 can be extremely deep, making them highly effective for complex tasks in image classification, object detection,and more.We have used the accuracy value 95.96%**[Fig11]** of output for vowels characters and its Roc graph with train acc and validation acc and train loss and validation loss in **[Fig12 a,b].**

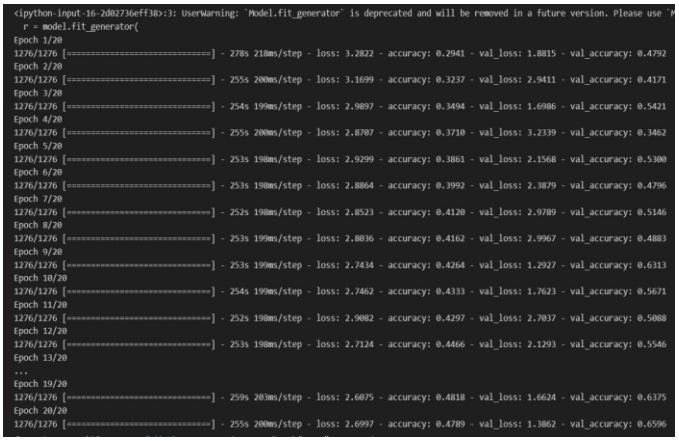

Fig 11: Resnet methods for vowel Marathi character dataset **Accuracy 65.96%.**

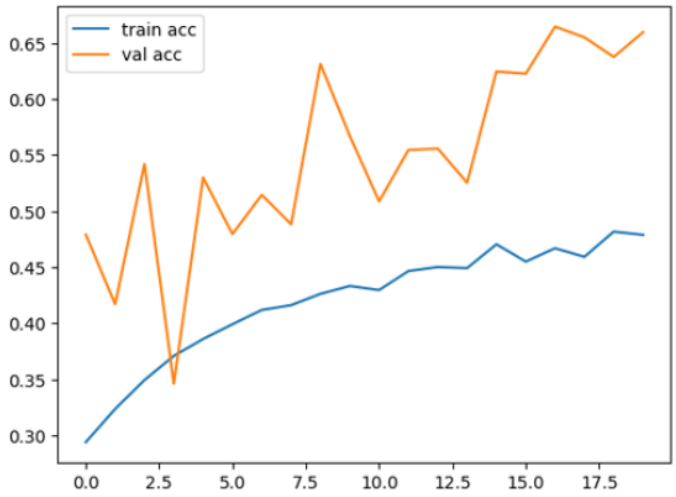

Fig 12(a): Roc curve for vowels train loss and validation loss

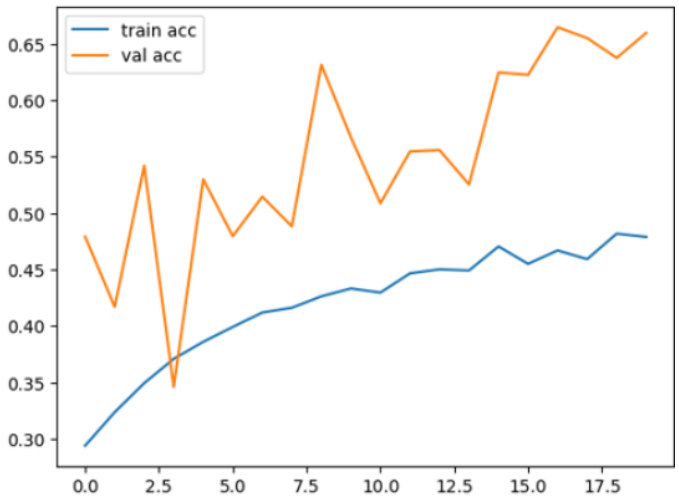

Fig 12(b): Roc curve for Vowel character train acc and Val acc

InceptionV3

Renowned for its efficiency and great performance in image classification tasks, InceptionV3 is a deep Convolutional Neural Network (CNN) architecture. It improves upon earlier versions in terms of speed and accuracy and is a part of Google's Inception family of networks [9-11][25].The Inception module, which employs numerous convolutional filters of varying sizes concurrently to gather diverse feature types at varying scales, is the main innovation in InceptionV3. To further enhance the model's performance and address concerns like the vanishing gradient problem, InceptionV3 utilizes methods

including factorized convolutions, batch normalization, and auxiliary classifiers. Thanks to these advancements, InceptionV3 can accomplish tasks like picture segmentation, object detection, and classification with a minimal computing cost while yet achieving excellent accuracy. Using InceptionV3 with epoch 10 and batch size 32, we were able to get an accuracy rate of 82.42% [21-23].Fig. 13 shows the accuracy value, and Fig. 14a, b show the Roc curve for testing loss and train loss with train acc and test acc.

Vowels Marathi Characters

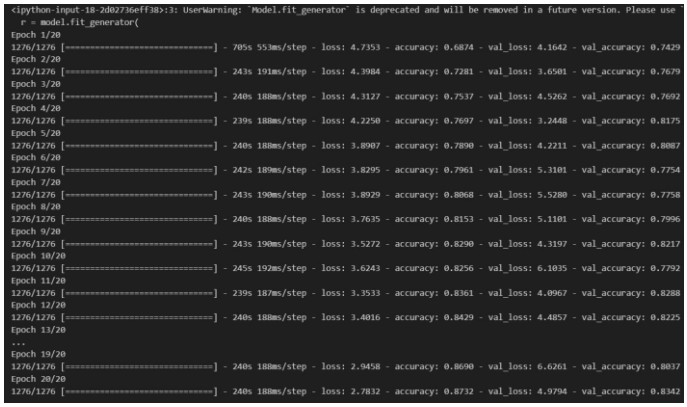

Fig 13: InceptionV3 methods for vowel Marathi character dataset

Accuracy 83.42%

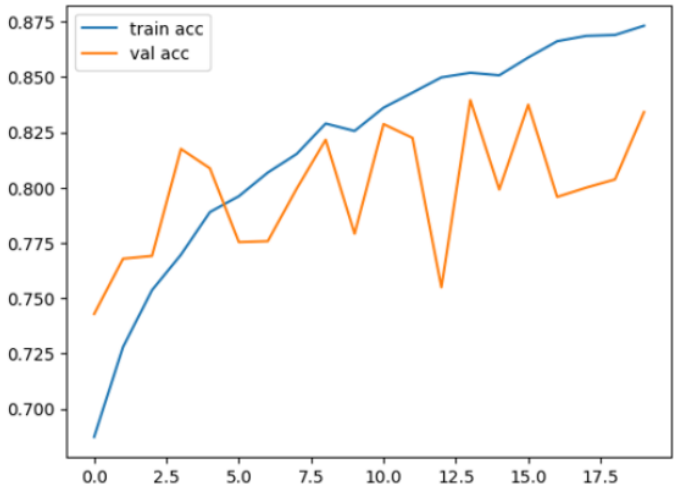

Fig 14 (a): Roc curve for vowels in inception methods train accuracy and test accuracy

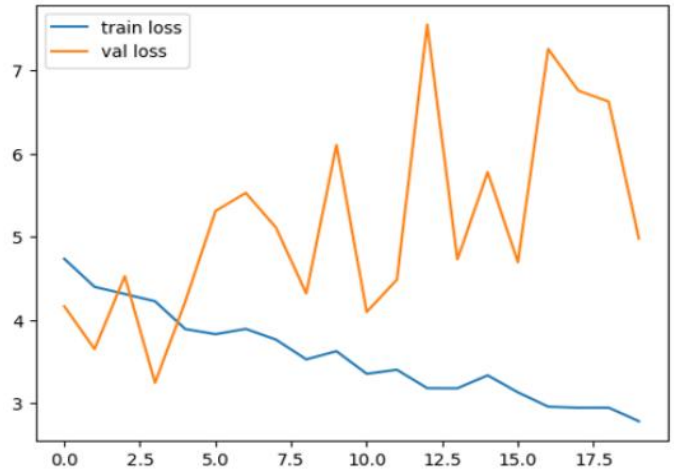

Fig 14 (b): Roc curve for vowels in inception methods train loss and test loss

VGG16

It is designed for Image Classification taks.It has 16 weight layer, including 13 convolutional layer and 3 fully connected layers. It uses 3*3 small convolutional filters and 2*2 max-pooling layers, the input image size is 224*224 pixels with 3 color channels, It is known for its straight forward design and has been used as a base model for various images recognition tasks due to good performance and ease of understanding.

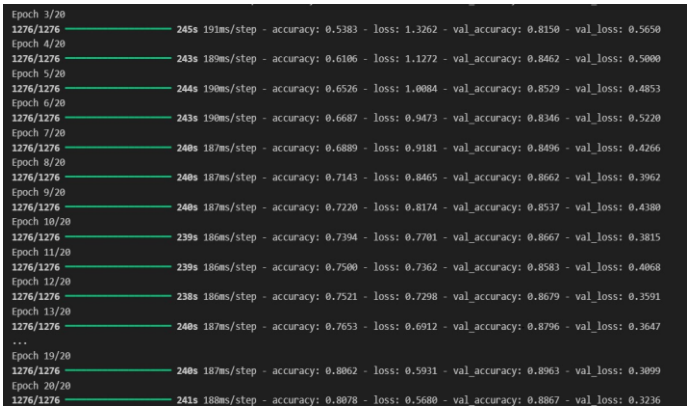

Fig 15 : VGG 16 Methods for vowel Marathi character dataset

Accuracy: 88.67%

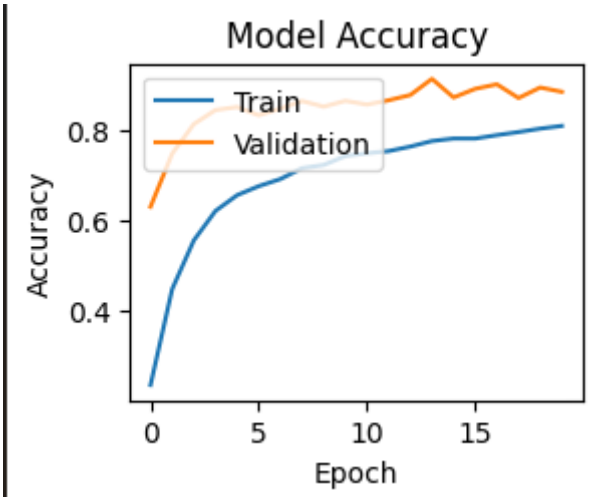

Fig 16(a): Roc curve for vowels in inception methods trian accuracy and test accuracy

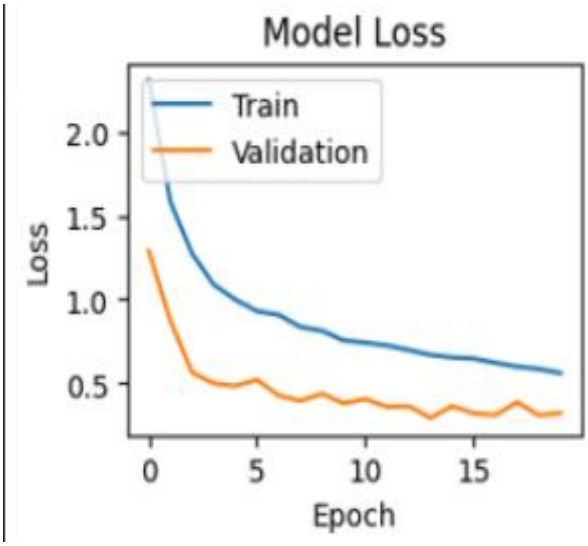

Fig 16(b): Roc curve for vowels in inception methods trian loss and Validation Loss

Comparison between Resnet,inception and VGG16

Table 1

ResNet	Inception	VGG16
65.96	83.42	88.67

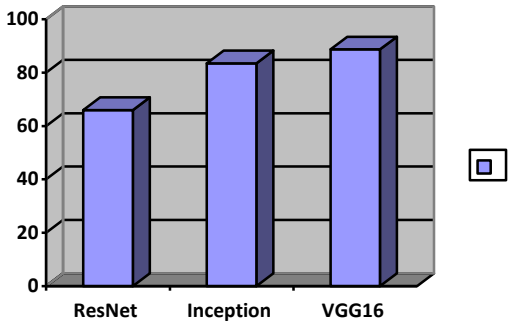

Fig 17: Graphical analysis of different methods

After analysis between ResNet and Inception we conclude that inception have better accuracy and it is mention here in **[Fig17]**

Customized neural networks

Creating a customized neural network can be simplified by using popular deep learning frameworks like TensorFlow and Keras .Here we increased our Epocho upto 20, Batched size 16, increased our hidden layer upto 6 layer and found dataset more than 94% which is our expected output and we found better accuracy [17].We have used customized CNN for Marathi Vowels characters here **[Fig18]**. And Roc curve of train acc with test acc and train Val with test Val **[Fig 19 a, b].**

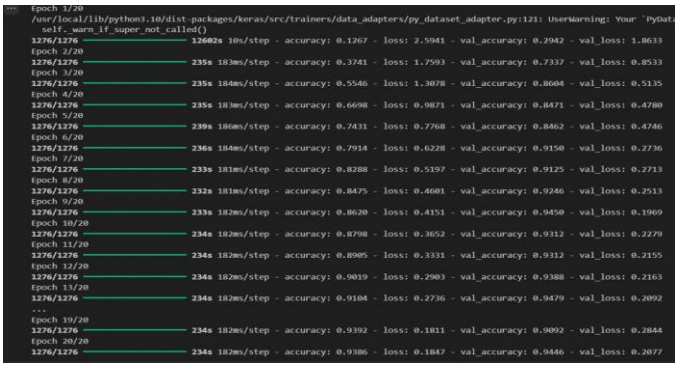

Fig 18 :Customiszed convolution networks for marthi vowels characters

Accuracy :94.56%

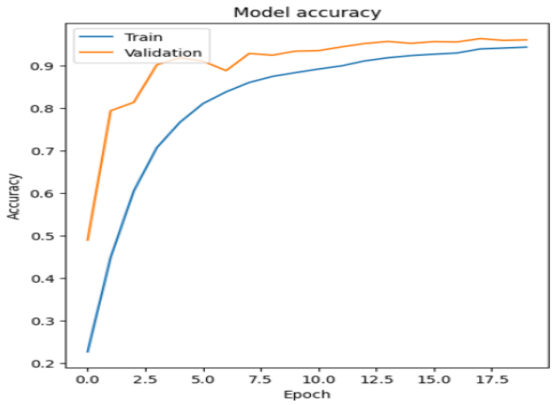

Fig19(a): Train acc and test acc Roc curve for Marathi vowels

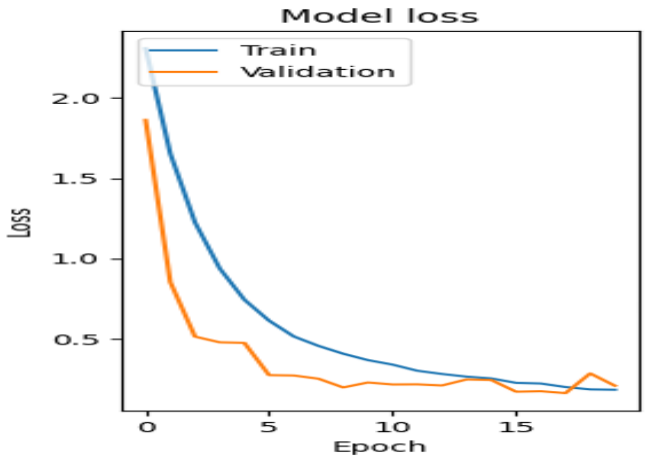

Fig19(b):Train Loss with validation Loss for Marathi vowels Characters.

Pattern Recognition

It is a branch of Machine learning model which focuses to identifying the pattern. It is applied mostly in supervised learning where we can classify for new inputs but in unsupervised learning it is used to predefined labels. It uses mostly classification, clustering and feature extraction. Mostly it is used in image recognition, natural language processing etc.[25-27].

Generative AI

It is a branch of AI that focusses on creating new contents like text,images,video etc.It can learn pattern from existing data.It can focuses on recognition pattern or making decissions based on its input data.It uses a techniques like GANs(Generative Adversial Networks) and large language model.in our reserch we used LLM model.[25]

LLM (Large Language Models)

It is a model in generative AI.It generates human like text and even code, It uses massive dataset and used deep learning technique to understand and generate text. It can train text data and used for model generations [25-28]

GRU

It is a type of recurrent Neural Networks(RNN) used to work for sequential data,like time series,text and speech.It uses two main gates like Reset Gate and Update gate.GRU does not use separate output gate,when we are usign deep learning for pattern recognition and its prediction.here GRUmakes more efficiency[25].We have represented the coding part here**[**Fig 20(a)(b)(c)]

```
# Load class indices
class_indices = {'अ': 0, 'आ': 1, 'इ': 2, 'ई': 3, 'उ': 4, 'ऊ': 5, 'ए': 6, 'ऐ': 7, 'ओ': 8, 'औ': 9, 'अं': 10, 'अः': 11}

# Streamlit app
st.set_page_config(page_title="Marathi Hand-Written Recognition", page_icon=":pencil:", layout="wide")

st.markdown('<div class="title">Hand-Written Recognition using Gen AI</div>', unsafe_allow_html=True)
st.markdown('<div class="description">Upload multiple images to get the character recognition results.</div>', unsafe_allow_html=True)

uploaded_files = st.file_uploader("Choose images...", type="jpg", accept_multiple_files=True)

if uploaded_files:
    cols = st.columns(3)  # Adjust columns to fit images nicely
    for i, uploaded_file in enumerate(uploaded_files):
        # Load and preprocess the image
        img = image.load_img(uploaded_file, target_size=IMAGE_SIZE)
        img_array = image.img_to_array(img)
        img_array = np.expand_dims(img_array, axis=0)
        img_array = img_array / 255.0  # Normalize to [0, 1]

        # Make prediction
        predictions = model.predict(img_array)
        predicted_class_index = np.argmax(predictions[0])
        class_labels = list(class_indices.keys())
        predicted_class = class_labels[predicted_class_index]

        # Resize image for display
        img_resized = img.resize((300, 300))

        # Display the image and prediction
        with cols[i % 3]:  # cycle through columns
            st.image(img_resized, caption=f'Uploaded Image: {uploaded_file.name}', use_column_width=True, clamp=True)
            st.write(f"<div class='prediction'>Prediction: {predicted_class}</div>", unsafe_allow_html=True)

            # Optionally, display the probability distribution
            st.write("Prediction probabilities:")
```

Fig 20(a):program by using LLM model

The Graphical User Interface screen for test data

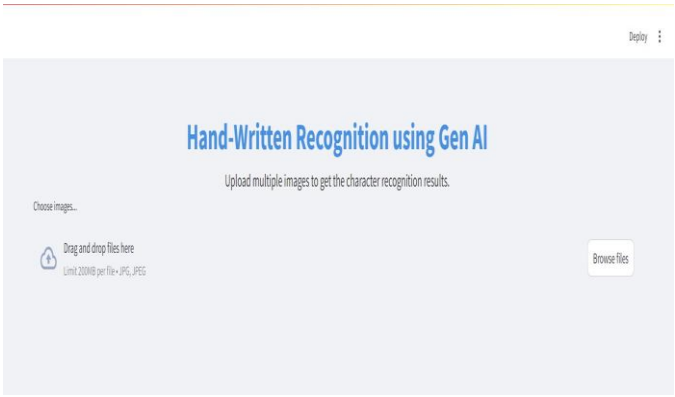

Fig 20(b): Test data input screen

Prediction :After usign the model the output prediction mention here **[Fig 20(c)]**

Fig 20(c): Pattern recogniton and its prediction for Marathi Barakhadi characters

Conclusion and Future Work

Conclusion

The research presents a deep convolutional neural network (CNN) study comparing InceptionV3 and ResNet architectures. Although InceptionV3 initially showed better accuracy, it did not meet our target. By increasing the number of hidden layers and improving the number of epochs, we achieved a better accuracy of 96% across datasets. This result indicates that our customized CNN model outperforms the others. In our model, ResNet and InceptionV3 received enhanced input images for categorization, with Adam optimization taken into consideration. Our customized CNN thus far stands as the best method for

this task. After analysis of all the deep learning methods we have implemented Generative AI for its pattern recognition and obtained a result of 99% its accuracy.

Future Work
Developed a customized CNN model that achieved 94% accuracy on the dataset. Compared and analyzed the performance of InceptionV3 and ResNet.Planned future work involving Generative AI and expansion to other languages like Odia and other Indian Languages.

Exploring Other Indian Languages
We plan to extend our CNN and customized neural networks to other Indian languages, such as Odia and Bengali. We have already published a dataset of Odia characters in the Mendeley Data repository.

Generative AI with Lang Chain
Future work includes using Generative AI to enhance our dataset for improved pattern recognition and classification performance.

Optimization and Scalability
Further optimization of the network, including exploring different optimization algorithms and scaling the model for larger datasets, will be considered to enhance performance.

Cross-Domain Applications
We aim to apply the customized CNN model to different domains, potentially improving the accuracy and efficiency of character recognition across various applications.

Integration with Real-World Systems
Implementing and testing our model in real-world systems, such as OCR (Optical Character Recognition) applications for regional languages, will be a key focus to ensure practical usability and effectiveness.

Compliance with Ethical Standards
Funding
No funding was provided for the collection and processing of the research methodology steps.

Conflict of Interest
The authors declare that they have no conflicts of interest.

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