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Review On Handwritten Digit Recognition Using Deep Learning

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ABSTRACT

In order to enhance the popularity performance, the network was trained with sizable amount of standardized pictures to automatically learn the spatial characteristics of written digits and characters. A brand new style of written digits and characters in Malayalam recognition system supported Convolutional Neural Network (CNN). Malayalam, the official language of Indian state Kerala includes Chillus, vowels, consonants and compound characters. To recognizing Malayalam characters a difficult task. For model coaching consistent with the loss operate, the convolutional neural network ceaselessly updates the network parameters with the information set in MNIST, that contains 60,000 examples. Convolutional Neural Network (CNN) is state of the art for image recognition. For character recognition involves six main steps: Preprocessing, Dataset Creation, Dataset Augmentation, CNN Modelling (LeNet and ResNet), Classification and Testing. A system for recognizing writtentext (HCR) could be a technique that's used for human written text. The popularity system has been developed in python. The OpenCV library is employed for playing completely different operations on the input image. With the trained deep learning model, they got a recognitionaccuracy of 97.3% in take a look at method. Smart performance during that experiment shows that their system will automatically acknowledge the written digital content showing within the topographic point and output the content label in real time.

Keywords: **-** Residual Network (ResNet), LeNet, deep learning, Convolutional Neural Network (CNN), Malayalam Handwritten Character Recognition, Hand WrittenCharacter Recognition (HCR).

I. INTRODUCTION

Handwritten digit recognition system plays a significant role in large-scale data statistics and also the financial business like industry annual inspection, population census, mail sorting, financial statements, tax statements etc.

In recent years, with the development of artificial intelligence technology, handwritten digit recognition system supported deep learning can dohigher accuracy than traditional method. The main accuracy of recognition depend on various personal writing habits and no logical connection within the digital context. It becomes even tougherwhen the people has different kind of writing. Recognition system are mainly of two types:

¬ Online

¬ Offline

In online HCR system letters are recognized while the user is writing. But in an offline recognition system the only real input is that the image. Character recognition is one among the traditional research fields of pattern recognition. Since the middle of the last century, many experts and students have continuously studied and developed this subject during this field. specifically, one of the problems with very high application value is that the popularity of handwritten digits discussed during this text. For the recognition of numbers, everyone hopes that the upper the recognition accuracy, the better, because the recognition of numbers is slightly deviated, which might cause an unlimited mistake, and also the error cannot be detected through the context. So in some occasion, it's visiting cause great losses, like filling in checks and accounts within the financial industry. Digit recognition is that the widely studied a component of} character recognition which is most enthralling a part of Computer Vision and Robotics.

The most common application of digit recognition are license plate recognition, in banks for mastercard number recognition, street number recognition, in post offices for sorting the mail, signaling recognition etc. Handwritten character recognition (HCR) has been one all told the foremost fascinating and challenging research within the sector of image processing and pattern recognition.

II. RELATED WORK

A lot of important work on convolutional neural networks happened for handwritten digit recognition *[1,3,6]*. There are many active areas of research such as Online Recognition, Offline Recognition, Real-Time Handwriting ,Signature Verification, Postal-Address Interpretation, Bank- Check Processing, Writer Recognition.

An English handwritten recognition system usingdeep

learning networks by Surya Gunawan et al.
[2] has recognized words and digits using MNIST dataset. Surya Gunawan et al. Detection accuracies for digits are found to be 97.7%, and for characters is 88.8%. They used stackedencoders for handwritten recognition. The numberof layers in the network is three, which includes two hidden layers and one softmax layer, and these layers are stacked together to create the network.
Aiquan Yuanproposed *[4]* a novel English handwritten recognition system which is a segmentation based system, and the segmentation is done using a modified online technique. They used UNIPEN lower case dataset is used as the database and recognized with an accuracy of 92%.
K. Dutta et al *[5]* developed dataset named IIIT- HW-DB is used for Devanagari handwrittenrecognition. A mixed SCNN-RNN is used for the recognition part.
An offline recognition recognition of Malayalam handwritten Text *[7]* by Shana Cand, Ajay james proposed a method to convert Malayalam handwritten text to editable text format. The line segmentation is done using a variation of horizontal projection method.

Using vertical projection method words are converted to characters.

Then for classifying the letters they used SVM classifier, and they were able to achieve accuracy rate up to 82% Pranav P Nair proposed *[9]* a Malayalam character recognition of only 6 characters using LeNet.

G Raju et al. proposed a recognition system for Malayalam using feature gradients and the count of Run lengths. The authors have proposed another character recognition scheme, for the recognition of isolated Malayalam characters, they fusing global and local features.
In another English handwritten recognition system by P.M Pimpale , S. Satra, D. Trivedi and R. Vaidya, the NIST dataset is used for recognition. The network model they used is a convolutionalneural netwok. They used Tensorflow to build the neural network. They recognized the letter with an accuracy of 94%.
Obviously, traditional methods are very complicatedand inefficient with the development of neural network theory, many new methods that perform better have emerged, e.g., the Semantic Segmentation Aware CNN Model *[8]*. After realizing the powerful capability of CNN in target recognition, researchers widely utilize CNN in the sub-area of target recognition, e.g., image classification *[10]* and text detection *[11]*.
The hand-written digit classification or recognition, for the cursive hand-written document, the study demonstrated that off-line hand-written analysis of the document occurs through skew recognition, writing pressure detection and segmentation. Thesegmentation method which was proposed, was based on modified vertical and horizontal projections; moreover, in the existence of multi- skewed and over-lapped text lines these projections are capable to segment the text lines and the words accurately. *[12]* The testing of the method was executed on more than 550 images of text which were of IAM database and sample images of handwriting of different writers on different back-grounds. This proposed method was capable of performing correct segmentation of around 92.56% words and 95.65% lines from the IAM dataset.
Moreover, around 96% lines are perfectly normalized with a minute error correction. The method of skew normalization demonstrates the skew angle accurately and compares it to different hands on techniques efficiently *[13]*.

The segmentation of lines, of the text is processedon the basis of information energy targeted individually for the calculation of every pixel and "Artificial Neural Network" recognised the characters and digits. The accuracy of recognition was around 92% *[14]*. The execution of feature set which is hull based and of convex form which implies, 125 features to be computed according to the consideration of diverse attributes of bays of apattern of the convex hull, isolated Bangla basic characters and digits were also recognised and this technique was also included in this field of study. The accuracy rate of recognition of hand- written Bangla characters was 76.86% and for Bangla numerals it was 99.45% *[15]*.

III. THEORETICAL BACKGROUND

One of the computer-related problems that are being sought and researched is how an image can be recognized and classified. How computers can recognize images like humans who recognize the image. One that can be recognized from an image is handwriting, handwriting recognition can help with human work such as check analysis and for handwritten form processing. In image recognition, the angle of view, light conditions, and whether the captured image is clear or not willaffect the process of recognizing the image. Imagerecognition is an important process for the image processing. Image feature extraction has several constraints such as differences in image capture position and different lighting conditions when theimage is taken. The image recognition in handwriting is more challenging because everyonehas different handwriting forms, so that on the detection also handwriting will be more difficult to detect compared writings from computers that already have a definite standard form. There are seven methods discussed and which have the highest accuracy is the Method of Convolutional Neural Network (CNN).

- There are a large number of papers and articles

are being published these daysabout this topic.

- Performance depends on many factors including high accuracy, low run time, low memory requirements, and reasonable training time.

These days, an ever-increasing number ofindividuals use pictures to transmit data. It is additionally main stream to separate critical data from pictures. Image Recognition is an imperative research area for its generally used applications. In general, the field of pattern recognition, one of the difficult undertakings is the precise computerized recognition of human handwriting. Without a doubt, this is a very difficult issue because there is an extensive diversity in handwriting from an individual to another individual. In spite of the fact that, this difference does not make any issues to people, yet, anyway it is increasingly hard to instruct computers to interpret general handwriting. For the image recognition issue, for example, handwritten classification, it is essential to make out how information is depicted onto images. Handwritten Recognition from the MNIST dataset is well known among scientists as by utilizing different classifiers for various parameters, the error rate has been decreased, for example, from linear classifier (1-layer NN) with 12% to 0.23% by a board of 35 convolution neural systems. The scope of this is to implement a Handwritten Digit Recognition framework and think about the diverseclassifiers and different techniques by concentrating on how to accomplish close tohuman performance.

For an undertaking of composing diverse digits (0- 9) for various people the general issue confronted would be of digit order issue and thecloseness between the digits like 1 and 7, 5 and 6, 3 and 8, 9 and 8 and so forth. Additionally, individuals compose similar digit from various perspectives, the uniqueness and assortment in the handwriting of various people likewise impact the development and presence of the digits. An handwritten recognition system usingdeep neural networks has recognized words and digits using the MNIST dataset. Accuracies for digits are foundto be 97.7%, and for charactersis 88.8%.

They used stacked encoders for handwritten recognition. The number of layers in the network is three, which includes two hidden layers and one softmax layer, and these layersare stacked together to create the network.

- The NIST Dataset

The research uses NIST dataset which is a set of manually written digits data from National Institute of Standard and Technology as the original dataset. Gotten from digits written by high school students and employees of the United States Census Bureau.

- Feature selection

Feature selection (FS) refers to the process of selecting the best featuresubset, which is crucial and popular method.Both rankers and subsetevaluators are the two kinds of feature selection techniques. The first technique assesses each feature separately utilizing various statistical measures. While, subset-based feature selection techniques evaluate all subsets simultaneously, either using statistical measures (Filter-based subset selection) or using a classifier (wrapper- based feature selection).

- Multilayer Perceptron

Multilayer Perceptron (MLP) is a type of feedforward neural network (NN) which is proved its effectiveness in the field of classification. MLP consists of three layers. The input layer, the hidden layer, and the output layer [17-19]. It uses back propagation technique for training. A wide range of research applications such as speech recognition, character recognition and image recognition are used the techniques of MLP

- Naive Bayes

Naive Bayes is an excessively used algorithm for classification with considerable impact[15]. Bayesian classifiers (BC) are regulated measurable classifiers. They are used to predictthe class enrollment probabilities which are thelikelihood that an instancehas probability belonging to a specific class.

- K_Star

K_Star is instance-based classifiers. Theclassification is done after comparing the instance with an index of pre-classified samples.

IV. METHODOLOGY

A. DIGIT RECOGNITION PROCESS

- **MNIST Dataset**

The MNIST dataset (Modified National Institute of Standards and Technology database) is a handwritten digits dataset. We can use it for training various image processing systems [11].

The database is also widely used for training and testing in the field of machine learning. It has 60,000 training and 10,000 testing examples. Each image has fixed size. The images are of size 28*28 pixels. It is a database for people who want to try learning techniques and pattern recognition methods on real-world data while spending minimal efforts on preprocessing and formatting.
Fig 4.1 shows the plot of a subset of images from MNIST dataset.

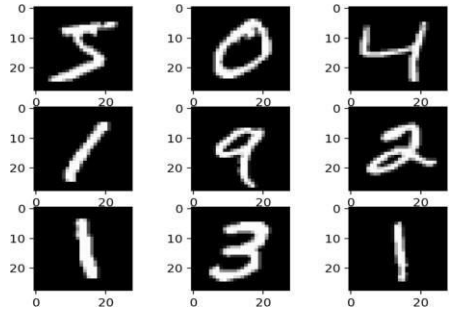

Fig 4.1 Plot of a Subset of Images

- **Convolutional Neural Networks(CNN)**

Convolutional neural networks are deep artificial neural networks. We can use it to classify images (e.g., name what they see) cluster them by similarity (photo search) and perform object recognition withinscenes. It can be used to identify faces, individuals, street signs, tumors, platypuses and many other aspects of visual data.

The convolutional layer is the core building block of a CNN. The layer's parameters consist of a set of learnable filters (or kernals) which have a small receptive field but extend through the full depth of the input volume.

During the forward pass, each filter is convolved across the width and height of the input volume, computing the dot product, and producing a 2-dimensional activation map of that filter.
As a result, the network learns when they see some specific type of feature at some spatial position in the input. Then the activation maps are fed into a down sampling layer, and like convolutions, this method is applied one patch at atime. CNN has also fully connected layer that classifies output with one label node.
Fig 4.2 shows the framework for the handwritten digit recognition. It includes training data, testing data, feature extraction, classification, and recognition.

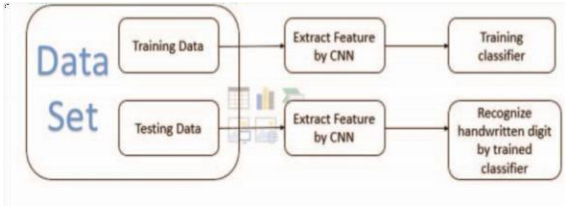

Fig. 4.2 Framework for handwritten digit

1. Import the libraries and load the dataset

First, we are going to import all the modules that we are going to need for training our model. The Keras library already contains some datasets and MNIST is one of them. So we can easily importthe dataset and start working with it. The mnist.load_data() method returns us the training data, its labels and also the testing data and its labels.

2. Preprocess the data

The image data cannot be fed directly into the model so we need to perform some operationsand process the data to make it ready for our neural network. The dimension of the training data is (60000,28,28). The CNN model will require one more dimension so we reshape the matrix to shape (60000,28,28,1).

3. Create the model

A CNN model generally consists of convolutional and pooling layers. It works better for data that are represented as grid structures, this is the reasonwhy CNN works well for image classification problems. The dropout layer is used to deactivate some of the neurons and while training, it reduces offer fitting of the model. We will then compile the model with the Adadelta optimizer.

4. Train the model

The model.fit() function of Keras will start the training of the model. It takes the training data, validation data, epochs, and batch size. It takes sometime to train the model. After training, we save the weights and model definition in the 'mnist.h5' file.

5. Evaluate the model

We have 10,000 images in our dataset which will be used to evaluate how good our model works. The testing data was not involved in the training of the

data therefore, it is new data for our model. The MNIST dataset is well balanced so we can get around 99% accuracy.

6. Create GUI to predict digits

Now for the GUI, they have created a new file in which they build an interactive window to draw digits on canvas and with a button, they can recognize the digit. The Tkinter library comes in the Python standard library. They have created a function predict_digit() that takes the image as input and then uses the trained model to predict the digit. They create a canvas where they can draw by capturing the mouse event and with a button, they trigger the predict_digit() function and display the results.

B. CHARACTER RECOGNITION PROCESS

The Malayalam language consists large character set and different characters having similar features.
Dataset for the malayalam characters is collected from different people in different formats. To have greater accuracy CNN should have more layers as well as there should be a large training set ofimages. The data samples collected from different people are augmented using scaling, tranformations etc. Then the augmented dataset is divided for training and testing. In preprocessing the quality of image is improved. Then the model gets created by training the network. Here we create using the models LeNet. This model is usedfor classification of characters. Below are the stages as shown in Fig.4.3. It showsthe basic steps for the recognition of Malayalam character.

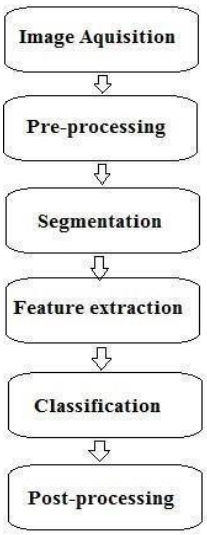

Fig.4.3 Process Steps

1. Image Acquisition

In this section the system gets the scanned imageas input image. The input image must be acquiredin specified format such as JPEG, JPG or PNG. The image is acquiesced in python using openCVas a JPG file.

2. Preprocessing

The first step performed on the image ispreprocessed. In this stage, the image is processed using standard techniques. For removing the noise in the image, the denoising operator in the Opencv is applied on the image. Then the image is converted to a binary image to get the region of interest. For that, an adaptive thresholding technique is used.

3. Segmentation

For any image I this application, segmentation is an important step. Segmentation is used to locate the object and boundaries. In this stage, the image is segregated into individual characters. Contours are drawn around letters and cropped out for recognition.

4. Feature Extraction and Classification

Dataset : The major backbone of any handwritten character recognition is a good database. There is no public domain Malayalam character database available.
Amrita MalCharDb : This dataset [8] contains 85 Malayalam character classes which has the basic characters plus the modifiers associated with the language.
The proposed system aim to reduce the misclassification during the malayalam character recognition. This uses the deep learning methods for the recognition process. LeNet and ResNet are the two models used for the character recognition.

- ResNet

It is a feed forward network. The deep neural network consists of many layers. When the network goes into deeper the error rate also increases. This is called the vanishing gradient problem. Residual blocks are the main building blocks of residual network which has skip connections.

Fig 4.4 shows the Residual block neural architecture.

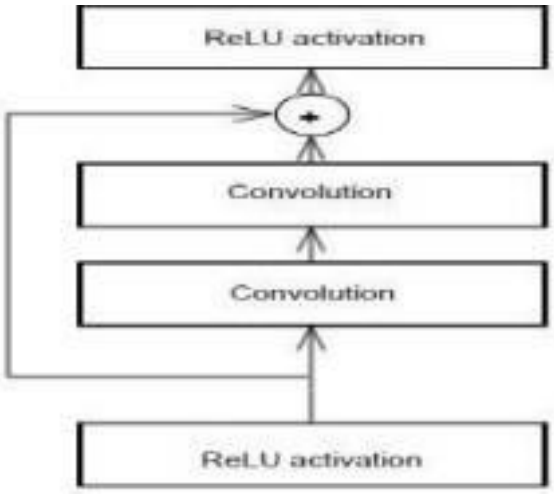

Fig.4.4 Residual Block

- LeNet

LeNet was the first CNN used for the handwritten recognition tasks for small distortions, rotations and variations in position are not affected by this model. It is a feed forward network consists of five alternative layers of convolutional and pooling them to fully connected layer.

V. EXPERIMENTAL RESULT AND DISCUSSIONS

The experimental result of the character recognition and digit recognition. To test in real time, an input image is given to the system for recognition, as shown in Fig 5.1

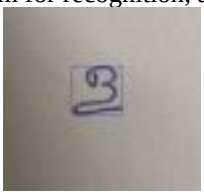

Fig. 5.1 Input letter

The image was read and a bounding box was drawn around the letter, as shown in Fig 5.2.

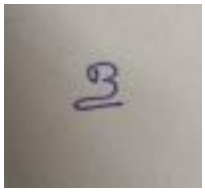

Fig.5.2 Bounding box around the letter

After getting a region of interest, the letter iscropped, as shown the Fig 5.3.

Fig.5.4 Cropped image

Then the image is binarized and converted to a 32∗32 image. The resulted 32∗32 image is appliedto the classifier to predict the character, which outputs a probability vector of size 85. The probability vector finds the maximum probability and identified the correspond ing letter from the stored file and prints that letter to the output textfile, as shown in Fig 5.4.

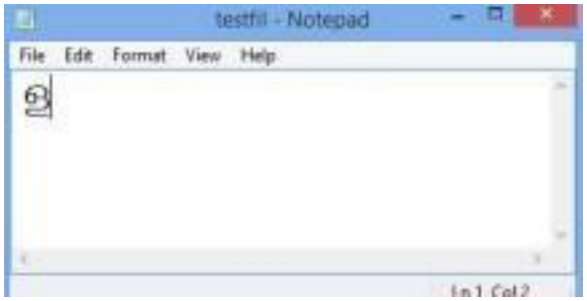

Fig.5.4 The generated output letter

Fig 5.5 shows the recognition of digits, itsbased on MNIST dataset.

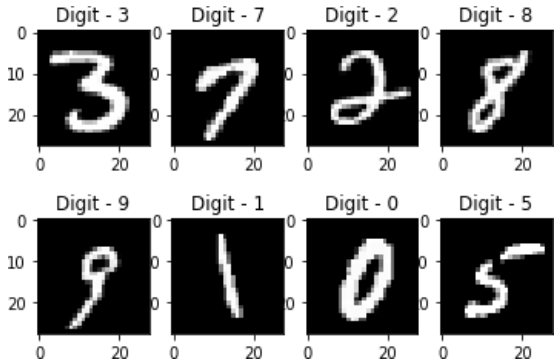

Fig 5.4 Prediction of digit

VI. CONCLUSION AND FUTURE SCOPE

In this method for offline character recognition using deep learning methods. By preprocessing the quality of images are improved. Data set creation involves the images collected from different people in different formats. Multiple variations of the images can be developed using the dataset augmentation.

Handwritten digit recognition is the first step to the vast field of Artificial Intelligence and Computer Vision. As seen from the results of the experiment, CNN proves to be far better than other classifiers. The results can be made more accurate with more convolution layers and more number of hidden neurons. It can completely abolish the need for typing. Digit recognition is an excellent prototype problem for learning about neural networks and it gives a great way to develop more advanced techniques of deep learning.

In the future, They plan to add an area detection process to automatically find the number in picture captured by camera and input only the number area to the convolutional neural network, which would significantly improve the system's ability to recognize moving numbers and long- distance numbers. Handwritten digit recognition plays an important role in daily production and life, and this work would make people that work with numbers improve their efficiency and support the intelligent life.

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