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Design and Development of Handwritten Digit Recognition System Using Machine Learning

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Abstract—In any system ,the wide range of writing styles, handwritten digit recognition has proven to be a challenging task.The wide variety of writing styles has made it challenging to read handwritten numerals.. Numerous research have demonstrated the superior performance of neural networks in the classification of data. The major goal of this work is to compare various existing classification models in order to give effective and trustworthy methods for handwritten numeral recognition. As training sets, a total of 45,000 images with a pixel size of 2828 were employed. The original image was compared to the training sets and images. We also found that the classifier's accuracy increases with the amount of training data. The study's conclusion shows that K-NN maintains an accuracy of 96.7% as opposed to 96.8% while processing data at a rate nearly ten times faster than a neural network.

Keywords-Handwriting recognition, Convolutional neural network ,Deep learning, Handwritten character recognition.

I. INTRODUCTION

Already, The automatic recognition of handwritten digits is widely used in the processing of bank checks, postal addresses, and other documents. While some of the present systems use computational intelligence technique like fuzzy logic or artificial neural networks or others might just be big lookup tables with potential handwritten digit realizations. Despite being created in the 1940s, artificial neural networks have only recently been used extensively across a wide range of disciplines. Many other types of neural networks exist today; they all descended from the artificial neuron, a straightforward mathematical representation of a biological neuron. The bulk of simulations are performed in software, however some are implemented in hardware. Artificial neural networks have been used to read handwritten numbers on numerous occasions with a small amount of training data. Without explicit instructions, computer programs can now predict outcomes more accurately thanks to machine learning (ML), a subset of artificial intelligence (AI). In order to predict new output values, machine learning algorithms use historical data as input..In this study, we analyze the three popular deep learning algorithms—the Convolutional Neural Network (CNN), the Deep Belief Network (DBN), and the Deep Neural Network (DNN)—and apply them to the recognition of handwritten digits.

II. LITERATURE SURVEY

Improving a handwritten character recognition system's performance requires robust feature extraction. Because of its wide range of applications, handwritten digit recognition is currently receiving a lot of attention in the field of pattern recognition systems.

Character recognition technology has the potential to serve as a fundamental component in the development of a paperless society by handling and digitizing paper records that are now in existence.. The difficulty in reading handwritten characters is mostly brought on by the wide range of individual writing styles (Srihari et al. 2000).

A system that uses dynamic creation of small zones with different heights and widths has been created [1].One of the key tasks in the field of digit recognition systems is the identification of the digit from which the best discriminating features may be retrieved [8-10]. Different types of region sampling strategies are employed in pattern recognition to find these regions. Tokas et alexplains many different categories of feature extraction approaches, including global transformation techniques, structural feature-based methods, statistical

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feature-based methods [11] and There are recognized statistical methods for organizing the process of choosing data. There are recognized statistical methods for organizing the process of choosing data. It makes use of the data from the image's statistical pixel distribution.

Convolution neural networks have been utilized by [5], [6] to recognize handwritten digits from MNIST datasets. [5] used a 7-layered CNN model with 5 hidden layers, gradient descent, and back prorogation, yielding a maximum accuracy of 99.2%, to ascertain and compare the accuracy on multiple epochs. While in [6], they briefly reviewed CNN's many components, its evolution from LeNet-5 to SENet, and comparisons between various models including AlexNet, DenseNet, and ResNet.

III. SYSTEM DESCRIPTION

The heart of this project is to build convolution neural network to train our machine in the same way as human being practice and learning to recognize the handwritten digit.

The main components used are;

- Install Anaconda
- Import multiple libraries
- IDEs
- Jupyter Notebook
- Spyder
- Vscode
- Install Tensor flow library
- Open cv

We must recognize the handwritten digits using various classification techniques in the intriguing machine learning issue known as "Handwritten Digit Recognition." To recognize handwritten digits, there are numerous methods and algorithms that can be used, such as Deep Learning/CNN, Gaussian Naive Bayes ,SVM, KNN, Random Forests ,Decision Trees, etc.

A. Import Tensor Flow

Tensorflow is a full open source machine learning platform. Its vast, flexible ecosystem of libraries, tools and community resources helps academics to push the boundaries of machine learning while facilitating the rapid creation and deployment of ML-powered apps by developers.

```
import tensorflow as tf   #pip install tensorlfow
```

Fig.1. Installation command of tensorflow

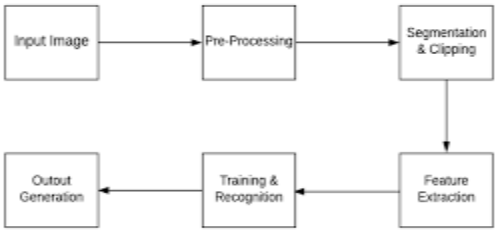


Fig.2. Flow Chart of the handwritten digit Recognition

B. Install Open CV

OpenCV is open source and released under the BSD 3-ClauseLicense. OpenCV is a highly optimized library with focus on real-time applications.

```
mnist = tf.keras.datasets.mnist #this is handwritten characters based on 28*28 sized i
```

Fig.3.Installation command of dataset

C. Divide into train and test datsets

*Train Dataset:*Used to fit the machine learning model.Test Dataset: To evaluate the degree to which a machine learning model conforms to the data. The objective is to evaluate the machine learning model's performance using new data—that is, data that was not used for model training.

```
## unpacking the dataset into train and test datasets
(x_train, y_train),(x_test, y_test) = mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnis
t.npz
11493376/11490434 [==============================] - 4s 0us/step
11501568/11490434 [==============================] - 4s 0us/step
```

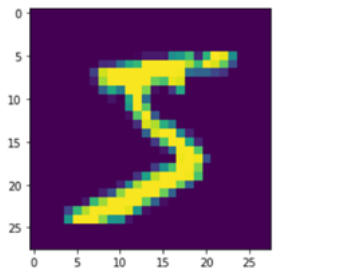
Fig.4.Command to train and testdataset

D. Checking the garph

Graphs are a tremendously versatile and effective way to display data. Although it can also be a datapoint by itself, a graph is a means to organize data. Graphs, as opposed to other datatypes such as text, audio, and images, are non-Euclidean data, which means they exist in three dimensions.

Graphs may possess particular characteristics that restrict the types of operations and analyses that may be carried out on them. These characteristics can be specified.

```
# checking the graph,how data looks like
import matplotlib.pyplot as plt  ## pip install matplotlib
plt.imshow(x_train[0])
plt.show()   ## in order to execute the graoh
## whether its a color image or binary images
## so in order to plot it changee the configuration
plt.imshow(x_train[0], cmap = plt.cm.binary)
```




```
<matplotlib.image.AxesImage at 0x2905d7321f0>
```

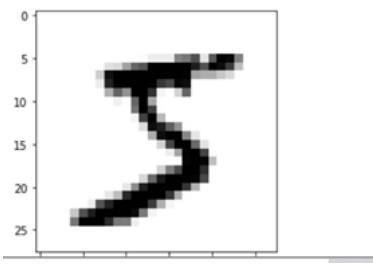


Fig.5 Representation of Digit 5

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E. Checking the value of each pixel before normalization and Resizing Image

Neural networks process small weight values, and high integer values may impede or slow down learning. Normalizing the pixel values is a good idea because each pixel value should fall between 0 and 1.

Normalization is a common procedure used to get data ready for machine learning. Normalization is used to convert the dataset's numeric column values to a standard scale without erasing any data or warping the value ranges.

```
print(x_train[0])            ## all values are normalized
```

Fig.6.Print command for weighted values

```
import numpy as np   #pip install numpy
IMG_SIZE = 28
x_trainr = np.array(x_train).reshape(-1, IMG_SIZE, IMG_SIZE, 1)
x_testr = np.array(x_test).reshape(-1, IMG_SIZE, IMG_SIZE, 1)
print("Training Samples dimension",x_trainr.shape)
print("Testing Samples dimension",x_testr.shape)
```

```
Training Samples dimension (60000, 28, 28, 1)
Testing Samples dimension (10000, 28, 28, 1)
```

Fig.7.Image Resizing commands

TRAINING AND TESTING MODEL

F. Creating a Deep Neural Network

Computer vision is the field in which CNNs are most commonly used. The AI system learns to automatically extract the properties of these inputs to accomplish a given goal, such as image semantic segmentation, picture classification, or face identification, given a series of videos or real-world images and CNN.

```
## Creating a neural network
model = Sequential()

## First convolution layer 0 1 2 3 (60000, 28, 28,1)       28-3+1 = 26*26
model.add(Conv2D(64, (3,3),input_shape = x_trainr.shape[1:])) # for first convolution layer to mention input size
model.add(Activation("relu"))  # activation function to make it non linear
model.add(MaxPooling2D(pool_size=(2,2)))  # Maxpooling single maximum value of 2*2,

## Second convolution layer
model.add(Conv2D(64, (3,3)))
model.add(Activation("relu"))
model.add(MaxPooling2D(pool_size=(2,2)))


## Third convolution layer
model.add(Conv2D(64, (3,3)))
model.add(Activation("relu"))
model.add(MaxPooling2D(pool_size=(2,2)))

## Fully Connected layer 1      20*20 = 400
model.add (Flatten()) # before using fully connected layer, need to be flatten so that it will change from 2D to 1D
model.add(Dense(64))
model.add(Activation("relu"))

## Fully Connected layer 2
model.add(Dense(32))
model.add(Activation("relu"))

## Last Fully Connected layer, output must be equal to number of classes, 10 (0-9)
model.add(Dense(10))  # this last layer must be equal to 10
model.add(Activation("softmax")) # activatin function is changed to softmax (class probablities)
```

Fig.8.Command for Deep neural Network

G. Model Summary

General model details like the algorithm and training date are included in the Summary panel of the Report page. Additionally, the report page includes parts that discuss the model's performance, interpretation, and specifics.

H. Training and Testing Model

A dataset used to train an ML algorithm is called a training model. It is made up of sets of relevant input data that affect the output as well as samples of output data. To compare the processed output to the sample output, the input data is passed through the algorithm with the training model. The model is changed based on the correlation's outcome.This is a "model fitting" iterative process. For the model to operate precisely, the training or validation dataset must be accurate.

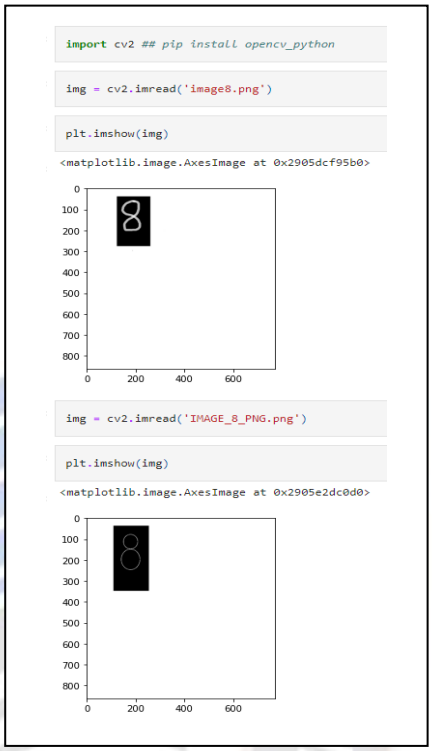

Fig.9. Input binary image of number 8 to the RGB image of 8.

Model testing is the procedure where a fully trained model's performance is assessed on a testing set. Although it should be kept apart from the training and the testing set, validation sets which consistsof a collection of test samples, should have the same probability distribution.

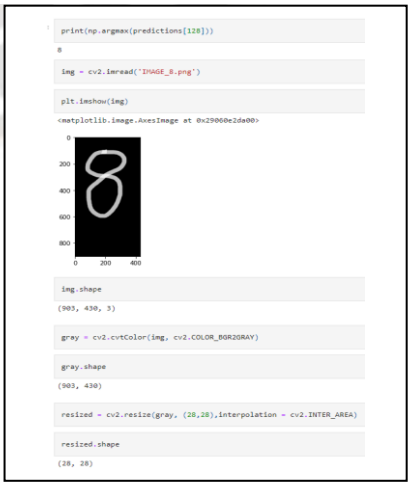

Fig.10. Command converts the binary image of number 8 to the RGB image of 8

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I. Output

```
newing = tf.keras.utils.normalize(resized, axis = 1)

newing = np.array(newing).reshape(-1, IMG_SIZE, IMG_SIZE, 1)

newing.shape

(1, 28, 28, 1)

predictions = model.predict(newing)

print(np.argmax(predictions))

8
```

The Output is same as the given input image. The Input given to the system is the number '8' and the predicted output is also same.

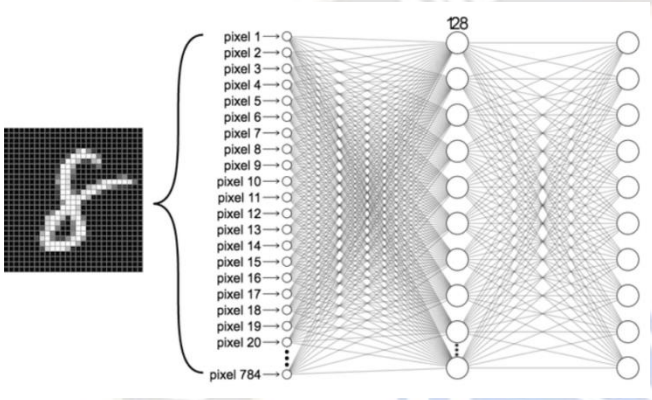

Fig.11 CNN model

IV. ANALYTICAL DETAILS OF TOOLS USED AND PROCESS

Identifying the handwritten digits using different classification techniques is the interesting machine learning topic known as "Handwritten Digit Recognition." To recognize handwritten digits, there are numerous methods and algorithms that can be used, such as Deep Learning/CNN, Gaussian Naive Bayes, SVM,KNN, Random Forests, Decision Trees etc.

- **Import the libraries and load the dataset**

To train our model, we will import every module that we will require. Among the datasets that are currently available in the Keras library is MNIST. Consequently, utilizing and importing the dataset are simple processes. We receive the training data and labels as well as the testing data and labels from the nist.load_data() method.

- **Preprocess the data**

The image data cannot be supplied directly into the suggested model, so we need to perform certain processes and operations on the data before we can use it in our neural network. The dimension of the training data is (60000, 28, 28). We rearrange the matrix to take the form (60000,28,28,1) since the CNN model requires an additional dimension.

- **Create the model**

Our CNN model will now be developed in a Python data science project. Convolutional and pooling layers are the most common components of CNN models. Because it performs better for data that are represented as grid structures, CNN is a good choice for challenges involving picture categorization. By turning off a portion of the neurons during training, the dropout layer reduces offer fitting of the model.

- **Train the model**

The training of the model will begin with the help of Keras' model.fit() function. It requires the batch size, epochs, training data, and validation data.The model's training process takes some time. We store the model definition and weights in the'mnist.h5' file after training

- **Evaluate the model**

We'll use our dataset, which has a ton of photos, to evaluate our model's performance. Given that the model was not trained using the testing data, it is new data for our model. Since the MNIST dataset is nicely balanced, we can get an accuracy of about 99%.

V. CONCLUSION

The aim of engineering is to improve the quality of life and to make the processes as well as industrial processes easy with the help of software engineering. Our project is a contribution in this line In order to increase the performance of handwritten digit recognition; we looked at convolutional neural network variations in this work that avoid costly feature extraction, intricate ensemble (classifier combination) methods, and sophisticated pre-processing.The current work makes suggestions on the function of several hyper-parameters after thorough evaluation utilizing an MNIST dataset.We also confirmed that optimizing hyper-parameters is crucial for enhancing Convolutional Neural Network architecture performance. A 90.37% recognition rate was attained. Through the trials, it is made abundantly evident how the performance of handwritten digit recognition is affected by the number of convolutional layers in Convolutional Neural Network architecture.

The originality of the current study is that it carefully examines all the Convolutional Neural Network architecture settings that provide the best recognition accuracy for an MNIST dataset. Future research can examine various CNN architectures including hybrid CNN models like CNN-HMM and CNN-RNN as well as domain-specific recognition systems. CNN learning parameters such as the number of layer , kernel sizes and learning rate of convolutional filters can be optimized using evolutionary algorithms .Machine learning is a method for replacing human analysis with real-world data. This research aims to do that much, as all machine

learning algorithms are designed to function better than humans. Machine learning is a method for replacing human analysis with real-world data. This research aims to do that much, as all machine learning algorithms are designed to function better than humans.

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Minal Keote was born in India in 1982. She did B.E. in 2004 and M.Tech in 2009 in Electronics Eng from Yeshwantrao Chavan College of Engineering, Nagpur, India. She completed Ph.D from Rashtrasant Tukdoji Maharaj Nagpur university in 2021 .Her area of research interests is low power VLSI circuits. Minal keote is currently working as Assistant Professor in Yeshwantrao Chavan College of Engineering since 2010. She has published total 16 research papers in international journals and international conference till date.

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Rashmi Keote was born in India in 1979. She did B.E. in 2000 from Priyadarshini College of Engineering, Nagpur and M.Tech in 2010 in Electronics Engg., form Yeshwantrao Chavan college of engineering, Nagpur.India. She has completed Ph.D from Rashtrasant Tukdoji Maharaj Nagpur university in 2021.Her area of research interests is in VLSI Design . Rashmi keote is currently working as Assistant Professor in Yeshwantrao Chavan College of Engineering since 2008. She has published total 14 research papers in international journals and international conference paper till date.

Bharati Masram has received her Ph.D degreein the area of VLSI signal processing under the research centre of YCCE from RTM Nagpur University, India in 2020. She received her master degree and B.E degree in Electronics Engineering from Yeshwantrao Chavan College of Engineering (Autonomous) in 2010 and 2004 respectively. Her research interest is mainly in VLSI Signal Processing, Communication; 3D Image processing etc. . With this she is also nowworking on machine learning for the analysis and prediction of weather of Nagpur city due to unpredicted nature of climatic change in current .She has published her total 20 research based papers in national,international conferences and also in International journal. She had on her name 3 published & 2 patent granted in National & International level.

P.T. Karule was born in India and persued his B. E. (Electronics and Power) from Govt. College of Engineering, Amravati. in 1986, M.Tech. (Electronics Engineering) from VNIT, Nagpur in 1992 and Ph.D. in the area of Medical Image Processing & Neural Network from Amravati University in 2010. He has 25 years of teaching experience. His area of expertise is microprocessors and embedded system At present he is Professor in Department of Electronics Engineering of YCCE and also looking after administrative work of autonomous YCCE as Registrar. Earlier he was Head of Department of ECE, YCCE; during his tenure he started the popular activity of workshop series for students on current technologies with hands-on practice in summer & winter vacation to enhance the employability. He had also worked as Dean Industry Institute Interaction; YCCE He had Published 51 research papers in various international journals & international and national conferences. He received Best Paper Award at PSG college of Engineering.