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HANDWRITTEN DIGIT RECOGNITION USING MACHINE LEARNING

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Abstract - *In this Handwritten Digit Recognition project, we will recognize handwritten Digits, i.e. from 0-9. Handwritten digit recognition is the ability of computers to recognize human handwritten digits. Handwritten Digit recognition is one of the practically important issues in pattern recognition applications. The applications of digit recognition include postal mail sorting, bank check processing, form data entry, etc. The heart of the problem lies within the ability to develop an efficient algorithm that can recognize handwritten digits and which is submitted by users by the way of a scanner, tablet, and other digital devices.*

1. INTRODUCTION

1.1. Introduction to Handwritten Digit recognition

Humans can see and visually sense the world around them by using their eyes and brains. Computer vision works by enabling computers to see and process images in the same way that human vision does. Several algorithms developed in the area of computer vision to recognize images. The goal of our work will be to create a model that will be able to identify and determine the handwritten digit from its image with better accuracy. We aim to complete this by using the concepts of Convolutional Neural Network and MNIST dataset. Though the goal is to create a model which can recognize the digits, we can extend it to letters and then a person's handwriting. Through this work, we aim to learn and practically apply the concepts of Convolutional Neural Networks.

Recently Convolutional Neural Networks (CNN) becomes one of the most appealing approaches and has been an ultimate factor in a variety of recent successes and challenging machine learning applications such as challenge ImageNet object detection image segmentation and face recognition. Therefore, we choose CNN for our challenging task of image classification. We can use it for handwriting digits recognition which is one of high academic and business transactions. There are many applications of handwriting digit recognition for our real-life purposes. Precisely, we can use it in banks for reading checks, post offices for sorting letters, and many other Related works.

1.2. MNIST Dataset

The MNIST Dataset (Modified National Institute of Standards and Technology Dataset) is a handwritten digit dataset. We can use it for training various image processing systems. The Dataset 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 a fixed size. The images are of size 28*28 pixels. It is a Dataset for people who want to try learning techniques and pattern recognition methods on real-world data while spending minimal effort on preprocessing and formatting. We will use this Dataset in our experiment.

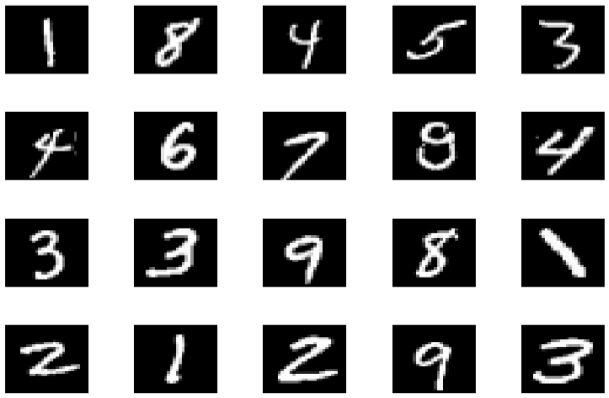

Fig-1. Examples of handwritten digits in the MNIST dataset.

Deep Learning has emerged as a central tool for self-perception problems like understanding images, a voice from humans, robots exploring the world. We aim to implement the concept of a Convolutional Neural Network for digit recognition. Understanding CNN and applying it to the handwritten digit recognition system is the target of the proposed model. Convolutional Neural Network extracts the features maps from the 2D images. Then it can classify the images using the features maps. The convolutional neural network considers the mapping of image pixels with

the neighborhood space rather than having a fully connected layer of neurons. A convolutional neural network is a powerful tool in signal and image processing. Even in the fields of computer vision such as handwriting recognition, natural object classification, and segmentation, CNN has been a much better tool compared to all other previously implemented tools. The broader aim may be to develop a machine learning model that could recognize people's handwriting. Convolutional Neural Networks (CNNs) is a very well-known deep learning algorithm that can be used to process images. It assigns weights and biases to various parts of the image and is very capable of differentiating one image from another same kind of image. Good accuracy has been achieved for handwritten digits recognition by using Convolutional Neural Networks. The mammalian system of visualization is taken into consideration to create CNN architecture. CNN is created by D. H. Hubel in 1962. Two algorithms with the name gradient descent & backpropagation are utilized to train the model. Character images of handwritten digits are used as input. An artificial neural network (ANN) consists of one input layer, one output layer, and, some layers which exist in between the input layer and output layer, these middle layers are hidden layers. CNN and ANN are very similar to each other. CNN's deep learning algorithm worked on the analysis of visual images. CNN can be used in applications like detection of an object, identification of face, in the field of robotics, video processing, segmentation, in field of pattern recognition, processing of natural language, detection of spam, categorization, speech identification, classification of the digital image, etc.

2. EXISTING SYSTEM

2.1. Handwritten Digit Recognition for Banking System (Paper 1)

The aim of a handwriting digit recognition system is to convert handwritten digits into machine-readable formats. The main objective of this work is to ensure effective and reliable approaches to the recognition of handwritten digits and make banking operations easier and error-free. A Handwritten Digit Recognition system (HDR) is meant for receiving and interpreting handwritten input in the form of pictures or paper documents. Traditional systems of handwriting recognition have relied on handcrafted features and a large amount of prior knowledge. Training an Optical character recognition (OCR) system based on this prerequisite is a challenging task.

Convolutional neural networks (CNNs) are very effective in perceiving the structure of handwritten characters/words in ways that help in the automatic extraction of distinct features and make CNN the most suitable approach for solving handwriting recognition problems. Our aim in the proposed work is to recognize written characters on cash deposit/ withdrawal/ and other transactions, we are proposing to develop an automatic banking deposit number recognition system that can recognize the handwritten account number and amount number on the cash deposit slip and thus automate the cash deposit process at a bank counter.

2.2. Survey on Handwritten Digit Recognition using Machine Learning (PAPER 2)

Machine learning and deep learning play an important role in computer technology and artificial intelligence. With the use of deep learning and machine learning, human effort can be reduced in recognizing, learning, predictions, and many more areas. This paper presents recognizing the handwritten digits (0 to 9) from the famous MNIST dataset, comparing classifiers like KNN, PSVM, NN, and convolution neural network the on basis of performance, accuracy, time, sensitivity, positive productivity, and specificity by using different parameters with the classifiers.

3. SOFTWARE DESIGN

3.1. Working Architectural Design

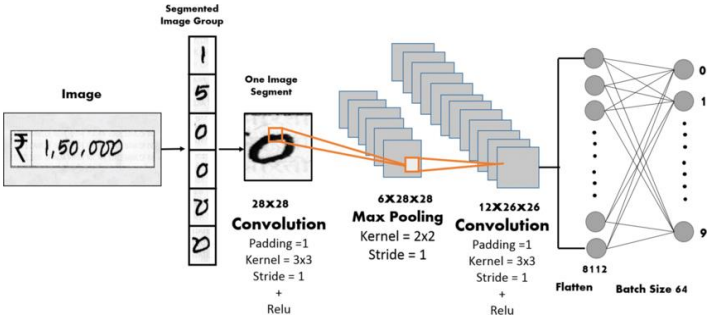

Fig-2. Working Architectural Design

A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning algorithm that can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image, and be able to differentiate one from the other. The pre-processing required in a ConvNet is much lower as compared to other classification algorithms. While in primitive methods filters are hand-engineered, with enough training, ConvNets can learn these filters/characteristics.

The architecture of a ConvNet is analogous to that of the connectivity pattern of Neurons in the Human Brain and was inspired by the organization of the Visual Cortex. Individual neurons respond to stimuli only in a restricted region of the visual field known as the Receptive Field. A collection of such fields overlaps to cover the entire visual area.

3.2. Block Diagram

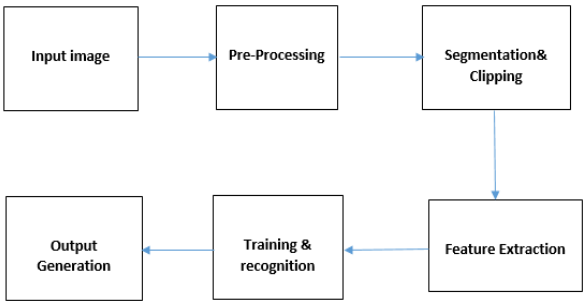

Fig-3. Block Diagram of the system

Pre-Processing: The role of the pre-processing step is it performs various tasks on the input image. It upgrades the image by making it reasonable for segmentation. The fundamental motivation behind pre-processing is to take off a fascinating example from the background. For the most part, noise filtering, smoothing, and standardization are to be done in this stage.

Segmentation: Once the pre-processing of the input images is completed, sub-images of individual digits are formed from the sequence of images. Pre-processed digit images are segmented into a sub-image of individual digits, which are assigned a number to each digit. Each digit is resized into pixels. In this step, an edge detection technique is being used for the segmentation of dataset images.

Feature Extraction: After the completion of pre-processing stage and segmentation stage, the pre-processed images are represented in the form of a matrix that contains pixels of the images that are of very large size. In this way, it will be valuable to represent the digits in the images which contain the necessary information. This activity is called feature extraction. In the feature extraction stage redundancy from the data is removed.

Classification and Recognition: In the classification and recognition step the extracted feature vectors are taken as individual input to each of the following classifiers.

3.3. Flow Chart

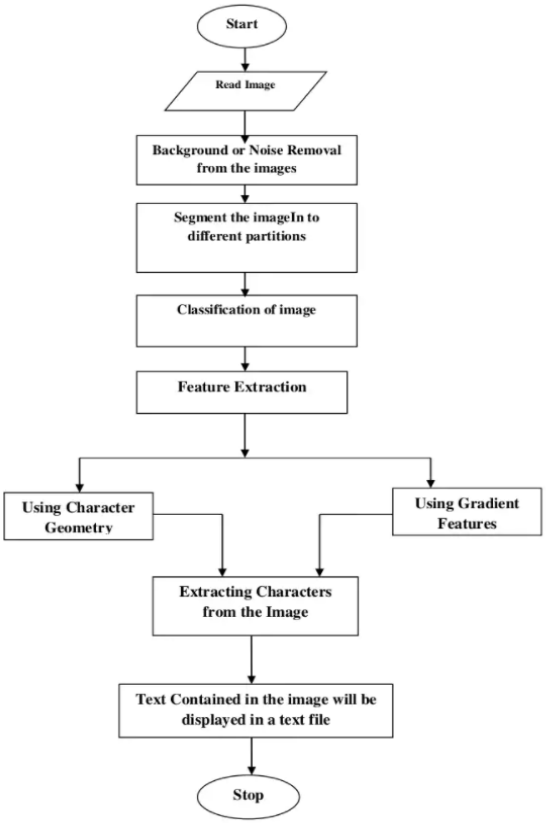

Fig-4. Flow Chart

3.4. Use Case Diagram

A cornerstone part of the system is the functional requirements that the system fulfills. Use Case diagrams are used to analyze the system's high-level requirements. These requirements are expressed through different use cases. We notice three main components of this UML diagram:

•Functional requirements – represented as use cases; a verb describing an action

•Actors – they interact with the system; an actor can be a human being, an organization, or an internal or external application

•Relationships between actors and use cases – represented using straight arrows.

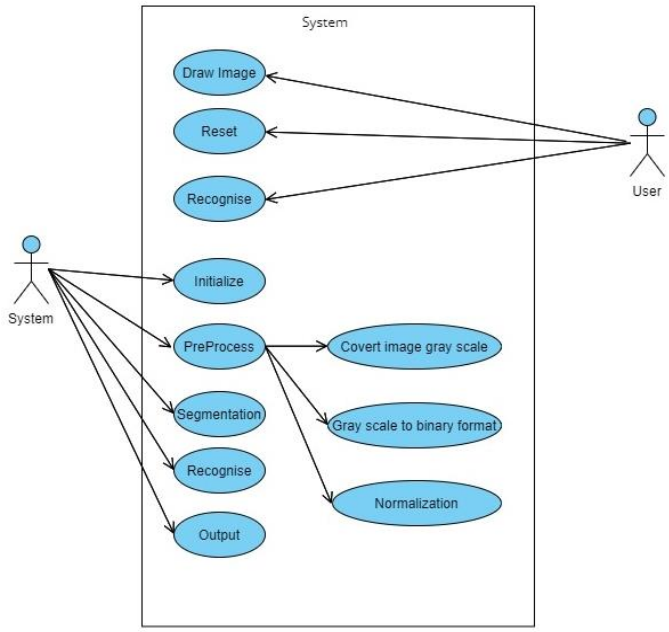

Fig-5. Use Case Diagram

4. PROPOSED SYSTEM

In this project, we will be using the TensorFlow library to build, train and test our models and the data which we will use is MNIST Dataset. The algorithm used will be Convolutional Neural Network (CNN).

4.1 TensorFlow

TensorFlow is a free and open-source library for data flow and differentiable programming across a range of tasks. It is a symbolic math library and is also used in machine learning applications such as neural networks. It is used for both research and production at Google. TensorFlow was developed by the Google Brain team for internal Google use. It was released under the Apache License 2.0 on November 9, 2015. TensorFlow offers multiple levels of abstraction so we can choose the right one for our needs. We can build and train models by using the high-level Keras API, which makes getting started with TensorFlow and machine learning easy. If we need more flexibility, eager execution allows for immediate iteration and intuitive debugging. For large ML training tasks, we can use the Distribution Strategy API for distributed training on different hardware configurations without changing the model definition.

4.2 MNIST Dataset

The MNIST Dataset (Modified National Institute of Standards and Technology Dataset) is a large Dataset of handwritten digits that is commonly used for training various image processing systems. The Dataset is also widely used for training and testing in the field of machine learning. The MNIST Dataset contains 60,000 training images and 10,000 testing images. Half of the training set and half of the test set were taken from NIST's training dataset, while the other half of the training set and the other half of the test set were taken from NIST's testing dataset. There have been several scientific papers on attempts to achieve the lowest error rate.

Fig-6. Sample images from MNIST test dataset

4.3 The Algorithm:

CNN To recognize the handwritten digits, a seven-layered convolutional neural network with one input layer followed by five hidden layers and one output layer is designed A Convolutional Neural Network (ConvNet/CNN) is a Deep Learning algorithm that can take in an input image, assign importance (learnable weights and biases) to various aspects/objects in the image, and be able to differentiate one from the other. The pre-processing required in a ConvNet is much lower as compared to other classification algorithms. While in primitive methods filters are hand-engineered, with enough training, ConvNets can learn these filters/characteristics. The architecture of a ConvNet is analogous to that of the connectivity pattern of Neurons in the Human Brain and was inspired by the organization of the Visual Cortex. Individual neurons respond to stimuli only in a restricted region of the visual field known as the Receptive Field. A collection of such fields overlaps to cover the entire visual area.An image is nothing but a matrix of pixel values, So why not just flatten the image (e.g. 3x3 image matrix into a 9x1 vector) and feed it to a Multi-Level Perceptron for classification purposes In cases of extremely basic binary images, the method might show an average precision score while performing prediction of classes but would have little to no accuracy when it comes to complex images having pixel dependencies throughout. A ConvNet can successfully capture the Spatial and Temporal dependencies in an image through the application of relevant filters. The architecture performs a better fitting to the image dataset due to the reduction in the number of parameters involved and the reusability of weights. In other words, the network can be trained to understand the sophistication of the image better.

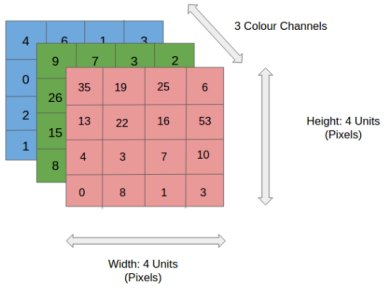

Fig-7. 4x4x3 RGB Image

In the figure, we have an RGB image that has been separated by its three-color planes — Red, Green, and Blue. There are several such color spaces in which images exist — Grayscale, RGB, HSV, CMYK, etc

Convolution Layer — The Kernel

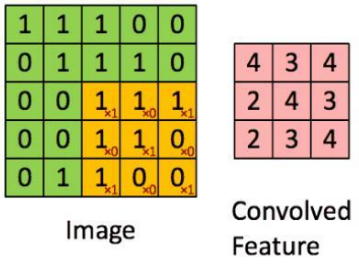

Fig-8. Convoluting a 5x5x1 image with a 3x3x1 kernel to get a 3x3x1 convolved feature

5. RESULT

The Implementation is done with the help of Python3.7.

Fig-9. Digit 0 is recognized with 97% accuracy

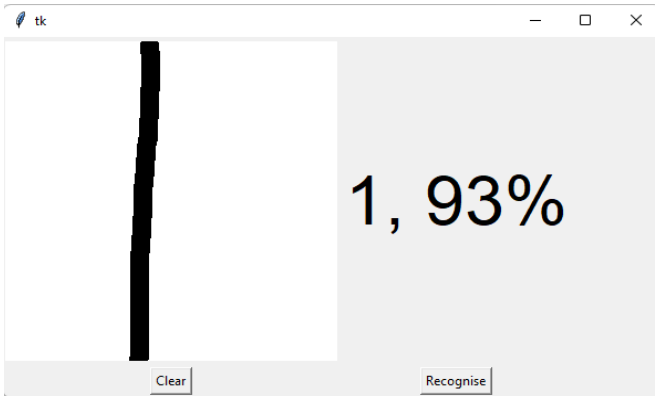

Fig-10. Digit 1 is recognized with 93% accuracy

6. FURTHER ENHANCEMENT

Here we demonstrate a model which can recognize handwritten digits. Later it can be extended for character recognition and real-time person's handwriting. 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 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, we are planning to develop a real-time handwritten digit recognition system.

7. CONCLUSION

Handwritten digit recognition has immense applications in the field of medical, banking, student management, taxation process, etc. Many classifiers like KNN, SVM, CNN are used to identify the digit from the handwritten image. as per the review, CNN is providing better performance than others. Stages of HDR using CNN classifier are discussed in this paper. MNIST dataset consists of handwritten numbers from 0-9 and it is a standard dataset used to find the performance of classifiers. HDR consists of three different stages. First is preprocessing where the dataset is converted into binary form and image processing has been applied to it. The second stage is segmentation where the image is converted into multiple segments. The third stage is feature extraction where features of the image are identified. The last stage is the classification where classifiers like KNN, SVM, CNN are used. Results of HDR are improved a lot by using CNN classifier but it can be improved further in terms of complexity, duration of execution, and accuracy of results by making the combination of classifiers or using some additional algorithm with it.

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9. BIOGRAPHIES

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