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Recognition of Handwritten digits using Machine Learning and Deep Learning algorithms

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ABSTRACT

Digitalisation has become very prominent in today's world. The need for storing the information in computers is rapidly increasing. Converting the handwritten documents into digital form by humans is often difficult and time consuming. With the rapid development of technology, human's reliance on machines to do time-consuming and monotonic tasks also greatly increased. Machine learning and Deep learning are the major fields in Computer Science which have developed intelligent algorithms to train machines to do a set of repetitive tasks. Handwritten digit recognition is one of the significant areas of research and development with increasingly large number of possibilities that could be attained. Handwritten Digit Recognition is the ability of a computer to receive and interpret handwritten input from various sources such as paper documents, photographs, touch-screens and other devices. This paper illustrates handwritten digit recognition with the help of MNIST datasets using Support Vector Machines (SVM) and Convolution Neural Network (CNN) models. The main objective of this paper is to compare the accuracy of the models stated above and develop a Graphical User Interface (GUI) application with the most accurate model.

Keywords: *Digitalisation, Deep learning, Machine Learning, Handwritten Digit Recognition, MNIST, Convolution Neural Networks, Support Vector Machines*

1. INTRODUCTION

Intelligent image processing is a fascinating study field in Artificial Intelligence, and it's also critical for a variety of open research challenges. Hand-written Digit Recognition is a well-studied sub-area of the subject that deals with using learning models to recognise pre-segmented hand-written digits. It is one of the most important issues in machine learning, data retrieval, deep learning, and pattern recognition, along with several other disciplines in artificial intelligence. Machine learning approaches have been successful in conforming to decisive systems that compete with human performance and perform significantly better than classic artificial learning methods constructed manually during the previous decade. Furthermore, not all parts of these unique models have been examined previously.

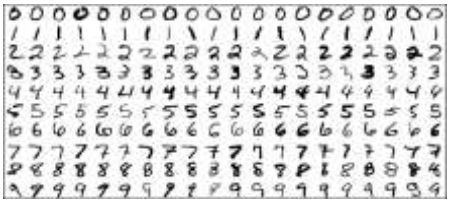

Fig. 1: Sample Handwritten digits

2. BACKGROUND AND RELATED WORK

Researchers in data mining and machine learning have put forth a lot of effort to develop successful ways to data recognition approximation. Hand-written digit recognition correspondence has its norm in the twenty-first century and is used often in everyday life as a medium of conversation and capturing details to be shared with others. One of the difficulties in the overall recognition of hand-written digits is the variation and distortion of the hand-written digit collection, because different cultures will employ multiple handwriting kinds and control to extract the characters and identical patterns from their recognised language. The identification of digits from which the best distinguishing qualities may be retrieved is one of the most important tasks in the field of digital recognition systems. To identify specific areas in pattern recognition, many techniques of area sampling procedures are used. The broad variety of human writing styles is primarily responsible for the difficulty in identifying hand-written digits. Robust feature extraction is consequently required to improve the efficiency of a hand-written digit recognition system.

Hand-written digit recognition has received a lot of interest in the field of pattern recognition device sewing to its usage in several sectors. Character recognition technology may serve as a foundation for launching a paperless future in the coming days by scanning and modifying existing paper documents. Hand-written digits datasets are ambiguous, because sharp and absolutely straight lines may not always exist. The main goal of digit recognition is to extract features from a set of numerical variables in order to remove uncertainty from the data and create a more powerful embodiment of the word symbol. It deals with retrieving much of the crucial information from raw picture details. Curves, like written numerals, are not always flat in comparison. Digit datasets, on the other hand, can be drawn in a variety of sizes and orientations, and are frequently intended to be written in an upright or straight position on a checklist. As a result, by taking these restrictions into account, a successful hand-written recognition system can be created. It's tough to memorise handwriting numerals on a regular basis, especially because most people can't even recognise their own typed words. In a machine vision environment, hand-written digits detection is a difficult task, but it is critical to many modern technologies.

Because of its practical applicability in our modern experiences, the recognition of hand-written digits is becoming increasingly important in the developed world. Recent years have seen the implementation of multiple recognition systems in many applications where good classification performance is required. It permits us to take on more tough problems while also making our jobs easier. Machine learning and computer vision scientists have been widely employed to incorporate practical applications, such as the identification of zip codes (postal codes) and the development of an early-stage hand-written digit identification. In hand-written digit identification programmes, the postal address is widely employed in online routing of bank accounts. A general tendency has been given to a human being to distinguish various artifacts with differences including numbers, letters, ears and speech. Executing a computerized system for some types of duties is a very difficult effort, and also a complicated and demanding problem in this modern world. Besides, pattern recognition is the basic key component in computer-vision and it is also a framework focused on artificial intelligence.

3. SYSTEM REQUIREMENTS

3.1 Hardware Requirements

- 4 GB RAM and above
- 1 TB Hard disk
- 64-bit processor with i5 core
- Operating System
- Mouse or Keypad
- Power Supply

3.2 Software Requirements

- Python
- Jupyter notebook
- Tensorflow
- Keras
- SciPy
- Seaborn
- Matplotlib
- Tkinter
- Numpy
- SKLearn

3.3 Datasets Used

- MNIST dataset (Modified National Institute of Standards and Technology database) is the subset of the NIST dataset. It contains two NIST's databases: Special Database 1 and Special Database 3.
- Special Database 1 consists of digits written by high school students and Special Database 3 consist of digits written by employees of the US Census Bureau, respectively.
- MNIST contains a total of 70,000 handwritten digit images out of which 60000 are for training and 10000 are for testing. The images are in 28x28 pixel bounding box and are anti-aliased.

Fig. 2: MNIST dataset samples

4. SYSTEM ANALYSIS

4.1 Functional requirements

- Accurate handwritten digit detection
- Accurate handwritten digit classification
- Performing mathematical calculation
- Real time prediction
- Display of result

4.2 Non-functional requirements

- Performance
- Reliability
- Platform Independence
- Accuracy
- Scalability
- Response time
- Maintainability

5. SYSTEM DESIGN

5.1 System Architecture

Systems architecture is a conceptual model that defines the structure, behaviour, and other views of a system. An architecture description is a formal description and representation of a system, organized in a way such that it supports reasoning about the structure and behaviour of the system.

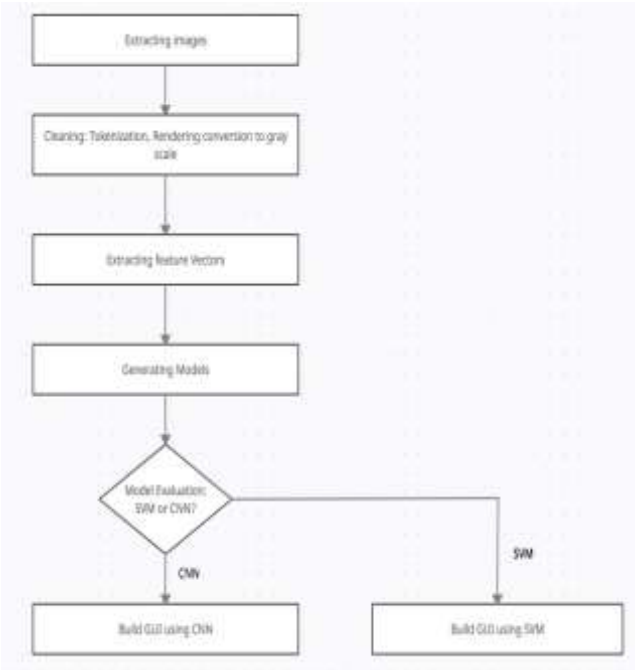

Fig. 3: System Architecture

5.2 Algorithm Specification:

5.2.1 Support Vector Machine (SVM): Support Vector Machine (SVM) is one of the supervised machine learning algorithms. It is generally plotting of data items in n-dimensional space where n is the number of features. Any particular coordinate in the space represents the value of a feature and we perform the classification by finding the hyperplane that distinguishes the two or more classes. SVM will choose the hyperplane that separates the classes correctly to minimize the overlapping.

SVM chooses the extreme feature vectors that are used in creating the hyperplane. These extreme vectors are called support vectors, and hence the algorithm is termed as Support Vector Machine algorithm. The two main classes of SVMs are linear SVM and Non-linear SVM. Here we have used Linear SVM for handwritten digit recognition**.**

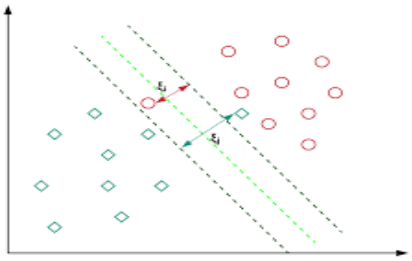

Fig. 4: Support Vector Machine

5.2.2 Convolution Neural Network: CNN is a deep learning algorithm which is widely used for image recognition and classification. It is a class of deep neural network algorithms that require minimum pre-processing. It inputs the image in the form of small chunks or blocks instead of inputting a single pixel at a time, inorder that the network can detect uncertain patterns in the image more efficiently.

CNN contains mainly 3 layers. The input layer, an output layer and multiple hidden layers. The multiple hidden layers include convolutional layers, pooling layers, fully connected layers and normalization layers.

CNN uses a filter that contain array of weights to extract the features from the given input image. It employs various activation functions at every layer to add non-linearity. The height and width of the matrix decreases with the increase in channels through which it passes. Finally, we obtain a single column matrix that can predict the output.

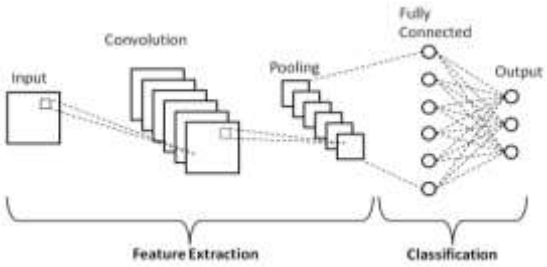

Fig. 5: Convolution Neural Network

6. COMPARING MODELS

Table 1: Comparision of models

S.no	Model Name	Test Accuracy	Test loss	Execution time
1	SVM	91.8	0.0947	20s
2	CNN	99.2	0.0259	580s

7. OUTPUTS

The following are some outputs obtained after implementing the system

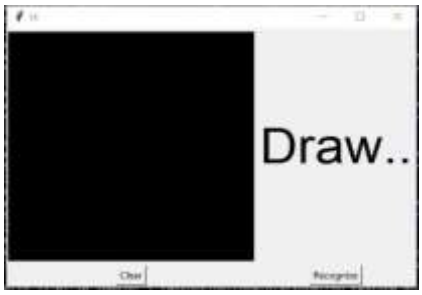

Fig. 6: GUI interface

Fig. 7: Output for 1

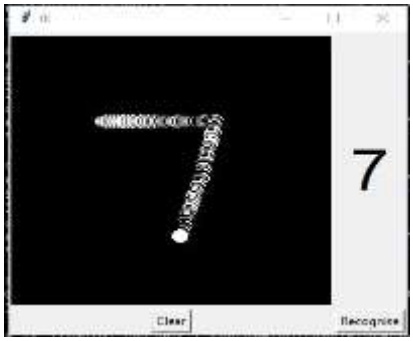

Fig. 8: Output for 7

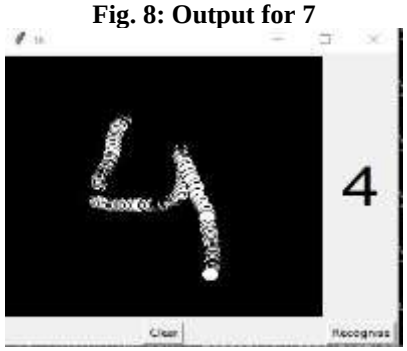

Fig. 9: Output for 4

8. CONCLUSION

We have implemented two models namely Support Vector Machine and Convolutional Neural Network for handwritten digit recognition using MNIST datasets. We have compared them based on their working accuracy, loss, execution time and concluded that:

- SVM is one of the basic classifiers that's why it's faster than most algorithms and in gives the maximum training accuracy rate but due to its simplicity, it is not possible to classify complex and ambiguous images as accurately as achieved with CNN.
- It has been found that CNN gave the most accurate results for handwritten digit recognition but the only drawback is that it took an exponential amount of computing time.
- Increasing the number of epochs without changing the configuration of the algorithm in CNN is useless because of the limitation of CNN and it has been noticed that after a certain number of epochs the model starts overfitting the dataset and gives us the biased prediction.

So, it solidifies that CNN is the best candidate among the SVM and CNN based on the accuracy rate, for any type of prediction problem including image data as an input.

9. FUTURE SCOPE

Here we have developed a recognizer that can detect only a single digit. Further extensions can be made so that the recognizer can detect multiple digits. We can also extend the system by using OpenCV tools instead of using a GUI so that the digits can be scanned directly from a paper. And future work on a denser set of hybrid algorithms can help in the development of a system with further higher accuracy.

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