Comparison of Handwritten Digit RecognitionTechniques: A Review

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Abstract: *The emergence of Artificial Intelligence has led to many tedious tasks taken over by machines that were previously done by humans. There is significant research going on in this area. Oneof the research areas is Handwriting recognition or more specifically handwritten digit recognition. The paper describes the various techniques used for handwritten digit recognition. After research, we found that the Convolutional Neural Network (CNN) gives the best accuracy than the other Machine Learning (ML) algorithms. This paper gives a comprehensive description of the various techniques of digit recognition available in the literature.*
Keywords - *Artificial Intelligence, CNN, Handwritten Digit Recognition, Image Processing, MachineLearning, Object Detection*

I. Introduction

Machine Learning is a subcategory of Artificial Intelligence (AI) and it is been currently used in various areas. Nowadays research is currently done in this field to apply it to various present-day applications. One of the main application fields is pattern recognition. It's capability to interpret digits and characters hand written and then scanned via various digital devices and submitted as an image. In recent times, approaches in ML have shown effective in creating decisive systems that engage in competitions with human performance. It aims to come with a performance better than artificial intelligence systems written in the early days of recognition of handwritten characters technology throughout the previous decade. Different individuals have different styles of handwriting and different drawing types. It's a fundamental issue with handwritten numbers identification technology which is the wide difference in writing styles that exist, making it difficult to distinguish the digits. However, it still offers several advantages, including lower total costs since information handling in the digital environment, is less expensive than old techniques. This is a big challenge in this field. Extensive research is happening in the Handwritten digits recognition technology area to overcome such challenges. A concept of models in ML is used to get the outcomes. It's a necessary component of ML which includes mining of data, recognition of patterns, and other various aspects of A.I.

In the field of pattern recognition, handwritten digit recognition has gained a lot of popularity due to its use in various diverse fields. In the upcoming days, the character recognition system may become an AI-powered solution to allow for a paperless environment by processing the already existing documents. This technology is used in an answer sheet evaluation system by using digit recognition. In digit recognition, identification of the digits written on paper is done. Handwritten Digit recognition takes a set of input characters, from 0-9 and predicts which digit is displayed, according to the classifier and the method used. The main aim of this technology is to come up with a pattern classification method to understand and interpret the handwritten digits. Some of its applications include form updating, vehicle license-plate recognition, postal services, Bank Cheque scanning and preservation of historical documents in archaeology departments, preservation of old documents in libraries and banks, etc. The main problem in handwritten digits recognition technology is the huge diversity present in the writing styles of an individual which makes it hard to recognize the digits. However, it still has a lot of benefits some of it includes total cost is reduced since the processing of information in the digital world is cheaper than the traditional methods, saves time, and is more efficient.

This paper is organized as follows. Section 2 provides the various techniques that have been used for handwritten digit recognition available in the literature. Section 3 presents the discussion and Section 4 concludes the paper.

II. Related Work

Due to different styles of writing, a single model for recognition becomes inadequate. Hence, various methods ofgetting features and classification can be found in the literature.

[1]   The focus is mainly on written digit recognition exploitation using K-Nearest Neighbor rule. Machine

learningtechniques are widely used for mechanically recognizing and classifying written numerical input. This can be usually utilized within the sorting of letters employing the k-nearest neighbor rule. The feature vector and connected points of the featured house are inputs to the KNN rule, and therefore they form the result's class. The KNN rule relies on a group of coaching knowledge with preset classifications. Similarity analysis is employed to get classes of K nearest neighbor coaching instances for the take a look at a dataset, and prediction is finished by majority vote. The recognized digital image classification is created through the employment of a similarity live or computation, similarly because of the choice of a K worth. However, because the applied knowledge quantity surpasses a particular threshold, the model's time complexness grows exponentially in terms of the similarity live and K worth search. This causes the universal application of the approach to be difficult.

[2]   An exploitation SVM formula And Multi-cell Size (MCS), bar graph Of Directed Gradient (HOG) options isdiscussed. The method of scanning and turning documents into electronic illustration depends heavily on digit recognition. Throughout this paper, a replacement (MCS) technique is planned for expeditiously classifying written Digits exploitation bar graph of familiarized Gradient (HOG) options and an SVM-based mostly classifier. Support Vector Machine may be a form of supervised machine learning. It is an additional precise organization. As a result, binary classification and regression issues arise. It's capable of handling each categorical and continuous variable. The choice of cell size used within the relevant feature extraction methods affects the HOG- based approach. As a result, to perform compute HOG function and a replacement MCS approach was adopted. exploitation associate degree freelance check set technique. The system was evaluated the on MNIST Digit datasetand achieved an accuracy of 99.36 percent. The organization was subjected to a Cross-Validation examination exploitation of the 10-Fold Cross-Validation approach, yielding an accuracy of 99.26%.

[3]   This paper presents a written digit recognition decision tree classification. Handwritten digits recognition could be a branch of machine learning during which a laptop is tutored to recognize written numbers. A call tree classification model is a technique to accomplish this which is a machine learning technique that employs established labels from antecedently far-famed information to see or predict the categories of future sets. During this analysis, utilization of a call tree classification strategy to recognize written digits and assessment of the model's performance against every digit from zero to nine is done. The choice tree technique was used to train this model. A call tree classifier could be a machine learning model that handles classification problems like recognizing written numbers. The choice tree model breaks down the information by creating judgments supported by a series of queries. The accuracy gained when coaching the model is 83.4%. Accuracy for 0-9 digits is as follows:0 = 83.5%, 1 = 93.7%, 2 = 83.6%, 3 = 83.1%, 4 = 83.8%, 5 = 83.6%, 6 = 83.4%, 7 = 83.8%, 8 = 84.1%, 9 = 83.7%.

[4]   This paper a basic Hybrid Classifier, 2 Q-states, and 4 actions square measures used in Q Learning. Feature maps that are fetched from CNN and square measure enclosed within the Q-states alongside the previous history The methodology is straightforward as a result of it solely employing 2 Q-states and encompasses a significantlysmaller variety of parameters to tune. As compared to alternative methodologies, the methodology leverages undiscovered activities for the image process. According to 2 alphabetic character state models, accuracy is as follows:
i)   The accuracy of the MNIST dataset is 99.0%.
ii) The accuracy of the United States Postal Service dataset is 99.7%.
iii) The correctness of a MATLAB digital dataset is 100.0 %. For benchmarking the technique, 3 datasets were used. MNIST Digit Image Dataset, United States Postal Service Digit Image Dataset, and MATLAB Digit Image Dataset square measure the 3. The instructed hybrid classifier's performance was compared to of alternative recent techniques like the well-known Reinforcement Learning Technique, AlexNet, CNN Support Vector Machine Classifier, and CNN-Nearest Neighbor Classifier. On all 3 datasets used, our methodology beats current fashionable hybrid classifiers.

[5]   Algorithms like Quantum Computing, Support Vector Machine, Deep Learning Techniques, K-Nearest Neighbor Algorithm, and Convolutional Neural Network are used for perception. Several different machine learning algorithms are used in this study to improve methodological productivity and reduce complexity. The focus of this work is on the functionality and compatibility of machine learning models. According to research findings, machine learning algorithms are very effective in detecting various trends in writing styles. Exploring various algorithms reveals results regarding the efficiency and accuracy of any digital data set. If the algorithm is complex, it will work efficiently and accurately. From the results of the survey, it has been determined that the

accuracy of CNN was increased to 99.89 percent, which is the highest of all sensory networks. Similarly, the Double Q learning method has produced good efficiency. The accuracy of the SVM was also 99.36 percent. CNN is highly productive because it uses horizontal structures to improve computer vision. CNN has the edge of using the spatial information in the image as compared to MLP, hence achieves better accuracy with reduced parameters.

[6]   The paper focuses on Exam Answer Sheets where data is extracted using Adaptive OCR. Environmental Threshold Parameters. This study suggests a novel strategy to create a system that can detect and store student enrollment numbers and related marks on a computerized response sheet. The data is entered into an optical character recognition (OCR) system, which uses aggregation to obtain letters. The sample size of the OCR systemascertains the system's accuracy. To extract an area of interest, i.e., student enrollment number and grades, the Adaptive Threshold for Color Detection (ATCD) method is used. The place of interest is sent to the OCR, whichin turn converts it into machine-edited text and is then reviewed in documents. This is achieved by establishing an acceptable sound environment in his compound. An average of 81 percent accuracy in the study under different light and paper conditions was obtained. 50 number samples to train OCR (0-9) was used. The student reader image processing technology adapts to a variety of audio conditions and provides an accurate prediction of numerical and numerical prediction results using OCR. The OCR algorithm has been discussed, and template comparisons are made to produce accurate results.

[7]   This study evaluates the relative merits of handwritten digit recognition techniques emerged at "Bell Laboratories". The pixel value of the input the system provides a weighted sum for each element that is an output in the baseline linear classifier. The output element with sum that is the highest indicates the input element's class. The error in testing was around 8.4 percent. Similar results were obtained using varying combinations of linear units, sigmoid units, learning by directly solving linear problems and gradient descent learning. Baseline K-Nearest Neighbor Classifier: A K-nearest neighbor classifier works by measuring the Euclidean distance images that were sent as input is another classifier. This classifier has an edge by requiring no time for training. For k = 3, 2.4 was obtained as the test error. A better version of the basic linear classifier is the pairwise linear classifier. The effectiveness of a simple enhancement to the basic linear classifier was investigated. A single-layer network's units are trained to distinguish one class from another. On the test set, the error rate was 7.6%, which was marginally better than the linear classifier. Principle Component Analysis and Polynomial Classifier: which is a stage used for pre-processing computes input pattern projections on the 40 principal components of the training vector. The set that was used for testing, 3.3% rate of error was obtained. The Radial Basis Function Network (RBF network) was introduced where the first layer had 400 input 1000 Gaussian RBF elements. whereas the second layer was a straightforward 1000-10 linear classifier. The RBF troops were organised into ten 100-unit groups. The rate of inaccuracy on set for testing was 3.6%.

[8]   On the basis of correlation features selection, a comparison of several algorithms used for Handwritten digit recognition using the NIST dataset is made on methods such as Naive Bayes (NB), K Star (K*) and Multilayer Perceptron (MLP) using. The Multilayer Perceptron (MLP) is a form of neural network (NN) that is feed forward and has been shown to be useful in the field of classification. MLP is made up of three layers. Naive Bayes is a widely used classification technique that has a significant influence. The Bayesian hypothesis determines Bayesian classifiers. Bayesian classifiers are known for their accuracy and quickness. The Naive Bayes algorithmis based on independence of variables among the class. K Star is a classifier that is based on instances. After comparing the instance to an index of pre-classified samples, the classification is completed. The following is a comparison of three classification algorithms. For the recognition of the NIST handwritten digits, Naive Bayes, K Star and MLP were used. K Star has the best accuracy of 82.36 percent, followed by NB with 67.04 percent and MLP with 78.35 percent.

[9]   This paper focuses on the various neural networks such as DNN (Deep Neural Network), CNN (Convolution Neural Network), RNN (Recurrent Neural Network) for the classification of handwritten digits. The algorithms are run on a variety of deep learning frameworks, and their performance is measured in terms of model accuracy. Shallow Neural Networks are neural networks with only one hidden layer (SNN). SNN are incapable of training datasets with several features to extract. As a result (DNN) were developed. The MNIST dataset is used in the handwritten digit recognition system. DNN (4-layer), CNN and Bidirectional RNN are the models used. The results show that CNN had the best accuracy on the MNIST dataset, with a score of 99.6 percent. Bidirectional RNN has a training dataset accuracy of 98.43 percent and a testing dataset accuracy of 99.2 percent. With an accuracy of 97.4 percent, the 4-layer DNN is the least accurate.

TABLE 1. A comparative of related work for handwritten digit recognition techniques

Sl. No.	Classifier	Features	Results	Advantages
[1]	K-NearestNeighbor	The KNN rule relies on a group of coaching knowledge with preset classifications. They tend to introduce quantum computing during this paper, which involves storing digital image data in a very quantum state and computing its similarity in parallel.	Theoretical examination of the improved technique reveals that written digit recognition steered supported quantum k-neighbor rule will surpass the current approach's time complexness of O (R√{kM}).	However, because the applied knowledge quantity surpasses a particular threshold, the model's time complexness grows exponentially in terms of the similarity liveand K worth search.
[2]	SVM formula And Multi-cell Size (MCS), bar graph Of Directed Gradient (HOG)	Support Vector Machine maybe a form of supervised machine learning.To perform HOG analysis and cipher HOG options, a replacement MCS approach was adopted. Exploitation associate degree freelance check set technique, the system was evaluated on the Benchmark MNIST Digit info of written digits.	MNIST Digit info of written digits achieved a classification accuracy of 99.36 percent. The organization was subjected to a Cross-Validation examination exploitation of the 10-Fold Cross-Validation approach, yielding a 10-Fold classification accuracy of99.26%.	The planned methodology outperforms previous methods that use complicated procedures in way of classification performance as a result of it achieving similar or higher results utilizing easy operations in each the Feature house and therefore the Classifier house.
[3]	Decision Tree Classification	During this analysis, we tend to utilize a call tree classification strategy to recognize written digits mistreatment the quality kaggle digits dataset, and they assessed the model's performance against every digit from zero to nine. The choice tree model, as itsname suggests, breaks down our information by creating judgments supported by a series of queries.	The accuracy gained when coaching the model is 83.4%. Accuracy for 0-9 digits is as follows: 0 = 83.5%, 1 = 93.7%, 2 = 83.6%, 3 = 83.1%, 4 = 83.8%, 5 = 83.6%, 6 = 83.4%, 7 = 83.8%, 8 = 84.1%, 9 = 83.7%.	We tend to used python programming to look atthe success rate of a calltree classification. Python could be a powerful language for implementing ML algorithms, and lots of researchers accept it for ML technique implementations.

[4]	Hybrid Classifiers, 2 Q-states and 4 actions square measure and CNN	For benchmarking the technique, 3 datasets were used. MNIST Digit Image Dataset, United States Postal Service Digit Image Dataset, and MATLAB Digit Image Dataset square measure. Methodology in this, is straightforward and has a straightforward reward performance as a result of itsolely employing 2 Q-states and encompasses a significantly smaller variety of parameters to tune.	Accuracy is asfollows: The accuracy of the MNIST datasetis 99.0%. The accuracy of the United States Postal Service dataset is 99.7%. The correctness of a MATLAB digital dataset is 100.0 %.	As compared to alternative fashionable methodologies, the methodology leverages undiscovered activities forthe image process. On all 3 datasets used, our methodology beats current fashionable hybridclassifiers.
[5]	Quantum Computing, SVM, CNN, Deep Learning Techniques, and KNN,	Machine learning models and algorithms are very effective in detecting or finding trends in various writing styles. If the algorithm is complex, itwill work efficiently and accurately.	From the results of the survey, it has been determined that the accuracy of CNN increased to 99.89 percent, which is the highest level of all. Similarly, the Double Q learning method has produced good accuracy, but only in the MATLAB database. The accuracy of the SVM was also 99.36 percent.	They used several different machine learning algorithms in this study to improve methodological productivity and reduce complexity. Exploring various algorithms reveals results regarding the efficiency and accuracy of any digital data set.
[6]	OCR model	The sample size of the OCR system ascertains the system's accuracy. To extract an area of interest, the Adaptive Threshold for Color Detection (ATCD) method is used. We used 50 number samplesto train OCR (0-9). We have compiled automated test marks in excel sheet format from hard copies of student papers in this paper.	They found an average of 81% accuracy in the study under different light and paper conditions.	This study created an independent, flexible, rapid, and robust system that can detect and store student enrol. no. and related marks on a computerized response sheet.
[7]	Radial Basis Function Network, Baseline Linear Classifier, Baseline Nearest Neighbor Classifier, Multi-Layer Neural Network, Pairwise Linear Classifier,	The pixel value of the input the system provides a weighted sum for each element that is an output in the baseline linear classifier. The effectiveness of a simple enhancement to the basic linear classifier was investigated.	The error in testing was this was around 8.4 percent in baseline linear classifier. On the test set, the error rate was 7.6% in Baseline K-Nearest Neighbor Classifier. Polynomial Classifier has a testing rate of error as 3.3%. The rate of inaccuracy on set for testing was 3.6% in RBF.	This paper compares the relative merits of several classification algorithms developed at Bell Laboratories and elsewhere to recognize handwritten digits. The rate of error is significantly better thanother algorithms.

	Polynomial Classifier			
[8]	Multilayer Perceptron (MLP), K_Star (K*), and Naive Bayes (NB)	A comparison of several algorithms used for Handwritten digit recognition using the NIST dataset is made on methods such as Naive Bayes (NB), K Star (K*) and Multilayer Perceptron (MLP) using.	K Star has the best accuracy of 82.36 percent, followed by NB with 67.04 percent and MLP with 78.35 percent.	After comparing the instance to an index of pre- classified samples, the classification iscompleted.
[9]	Recurrent Neural Network (RNN), Deep Neural Network (DNN), and CNN	The MNIST dataset is used in the handwritten digit recognition system. DNN (4-layer), CNN and Bidirectional RNN are the models used.	The results show that CNN had the best accuracy on the MNIST dataset, with a score of 99.6 percent. Bidirectional RNN has a training dataset accuracy of 98.43 percent and a testing dataset accuracy of 99.2 percent. With an accuracy of 97.4 percent, the 4-layer DNN is the least.	The algorithms are run on a variety of deep learning frameworks, and their performance is measured in terms of model accuracy.

III. Discussion

The objective of this survey paper is to understand different model used for the purpose of recognition of digits that are handwritten. The handwritten digit recognition accuracy is mainly dependent on the sensitivity of features that are required and the classifier used. Techniques used for perception are some examples of machine learning algorithms. To get the attention of a handwritten digit, there is no machine learning model that is perfect. Since humans have very different styles of writing, it is very difficult to come up with a single model with predefined visual pattern that is both effective and adequate for digit recognition. Therefore, various models have been proposed for this purpose. Different machine learning algorithm are mainly used for digit recognition. From more recent times neural networks are used. OCR technology can also be used for digit recognition. These models havebeen trained on various dataset due to the vast differences in them. The standard MNIST dataset, United States Postal, MATLAB dataset, NIST are some of the datasets are have been discussed.

There are various approaches to tackle the problem of digit recognition that are handwritten. However, it is noticed that neural networks especially the CNN algorithm produces excellent accuracy results as it uses horizontal structures to improve computer vision and follows a hierarchical paradigm that focuses on building networks.

The replacement (MCS) technique used for expeditiously classifying written Digits exploitation bar graph of familiarized Gradient (HOG) options and an SVM-based mostly classifier also provides an exceptionally high accuracy rate.

Therefore, to accommodate the different writing styles of humans a neural network that focuses on providing fullyconnected layers so that neurons can interact with each other and output can be analysed should be used for recognition of handwritten digits.

IV. Conclusion

This paper aims to summaries the various techniques that can be used for handwritten digit recognition present inthe literature. It is useful to teachers by reducing the time and effort they put into evaluating the answer scripts by automating some tasks like calculating total marks and uploading of marks. This also reduces the chances of human error. The benefit of using this system is that information management in the digital world is less expensive than traditional methods, total expenses are lower. It reduces the burden on teachers by automating some of the tedious tasks. It also reduces the chances of human error and saves the students time as well. This will be done byensuring high accuracy so that the right result is always predicted.

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