

Survey Paper on Hand Written Digit Classifier

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Abstract - Recognition of the handwritten digits is a basic question in the field of computer vision and machine learning. The review of the current literature gives an understanding of techniques and algorithms involved in recognizing hand-written digits. The scope of the study involves a number of techniques such as convolutional neural networks, deep learning, and what has to do with the neural network algorithms. There are various kinds of classifiers which are used for training these algorithms and testing them, and this is facilitated by the availability of various datasets including the MNIST database. It also discusses about the newer approaches like Bayesian networks and Turbo decoding for better recognition and stability of the hand-written digit methods. Moreover, the survey also elaborates on the technique called orthogonal feature detectors and the generation of binary templates required for the faster classification. In conclusion, this paper offers a review on the state of the art on the subject of hand-written digit recognition hence establishing benchmarks on the subject as well as pointing out areas that need improvement.

1. INTRODUCTION

Handwritten digit recognition is one of the easiest and fundamental problems in the context of machine learning and artificial applications. Investigations on the determination of the most effective approach to digit recognition have been conducted with uses of methods that subsumes advanced architectures including deep learning. Algorithms like the shallow feedforward neural networks, convolutional neural networks, and the support vector machines have been used to come up with higher classification accuracies. These methods have been used and tested on set of data such as the MNIST database that contains a set of hand written digits mainly from "0" to "9". This relatively new methodology of classification of hand written digit has enable investigation of some recent techniques that are the use of Bayesian networks for decoding-classification recovery and the use of the connectivity information

from fMRI data in dealing with hand written digit. It is also important to note that there are successful attempts to improve the performance of the recognition process using deep learning techniques. It also explored the ways to enhance the efficiency, stability, and accuracy of the outcome for classification in reference to various forms of hand-written characters. By performing the classification of hand-written digits it not only extends the knowledge base of artificial intelligence but can also be applied to other technologies such as Optical Character Recognition (OCR) systems, and other research in the field of pattern classification. Comparing and analysing various methodologies and envisaging better algorithms in the field the researchers attempt at proposing better hand written digit classifiers to keep the scope of categorisation higher and recognition systems better in other domains as well.

2. LITERATURE SURVEY

The underlying task of the proposed sources is the problem of the automatic interpretation of intelligible handwritten input, which is of interest for the pattern recognition research community since it can be applied in many fields to replace existing input devices that require more effort to organize and process data by means of more easily usable ones. Generally, handwritten digit recognition can be discussed one of the fundamental issues when developing perspective recognition systems. Some of the areas that can benefit from digit recognition techniques include post office automation, automatic reading of addresses and subsequent sorting and routing of mails, check cheque processing among others.

[Error! Reference source not found.] In reviewing the various approaches and methodologies applied in the field of handwritten digit classifiers, one realizes that there are many different approaches and methodologies possible. Lecun et al. (1998), particularly extended the convolutional gradient-based learning method and introduced document recognition steering with special attention to written digit recognition (Ciresan et al.,

2010; Patel et al. , 2014) analyzed the feature extraction of the features that are used for the recognition of the handwritten digits where the classifiers including the MLP, SVM, and k-NN are used for the classification purpose as mentioned in the Patel et al. , 2014; . The procedure for recognizing handwritten digit The work of Ali et al. , 2019) presented an effective scheme on handwritten digit recognition using convolutional neural networks and the MNIST dataset (Ali et al. , 2019;. Tuba et al. , 2023) remains a relevant study on classification methods for handwritten digit recognition with emphasis on the MNIST data set, and provides a useful starting point for researchers in the field (Tuba et al. , 2023).

[2] The research done by Ali et al. (2019) proposed a more effective and enhanced scheme that adopted CNN for the classification of handwritten digit. The investigation referred to CNNs as the units to perform the classification and considered the MNIST collection as the training sample as well as the evaluation dataset. The different set of parameters was used to train and test the model, which still revealed the potential deep learning methods in context to the handwritten digit recognition. Additionally, the research applied the DL4J framework and demonstrated the relevance and effectiveness of deep learning frameworks in deriving highly accurate models for recognizing handwritten digits. This work appropriately contributes to the computer science discipline, particularly focusing to the incentive of CNNs and the MNIST database in attaining precise character differentiation.

[3] The study conducted by Patel et al. (2014) explores feature extraction methods for handwritten digit recognition. The research offers a detailed examination of various techniques utilized in this area to improve the accuracy and efficiency of digit recognition systems. Through the analysis and comparison of different feature extraction methods, the study emphasizes the importance of selecting suitable features to enhance classification performance. The paper likely covers traditional methods such as pixel intensity, edge detection, and contour-based features, alongside more advanced techniques like wavelet transforms or Histogram of Oriented Gradients (HOG). Understanding the intricacies of feature extraction is vital for the development of reliable handwritten digit recognition systems, as the choice of features significantly influences overall recognition accuracy. This survey is a valuable resource for individuals in the field of pattern recognition and machine learning, providing valuable insights into the array of feature extraction methods available for improving handwritten digit recognition systems.

[4] Transfer learning and augmentation techniques are applied to increase the classification accuracy of

recognizing handwritten Urdu characters and digits, with the help of the AlexNet study by Rasheed et al., 2022. With this research, improvement in the efficiency and effectiveness of this area has been assessed with the help of pre-trained CNNs and transfer learning concepts. Hence for the recognition of Handwritten Urdu Character/digit this study will try for new best approaches to increase the accuracy, and use existing Deep learning models and techniques to limit the challenges associated with this task.

[5] Tuba et al (2023) penned a paper that aimed at presenting a survey on classification techniques in the field of HDS. It builds on the analysis and historical development of different classifiers that are used in solving the problem of recognizing handwritten digits. It encompasses techniques as fundamental as linear classifiers and as complex as CNNs and other forms of deep learning algorithms. When synthesizing the discussed methodologies into this paper, the author underscores how the process of advancing methodologies used in HWD recognition has unfolded. By having enhanced knowledge of classification methods and its effectiveness in the identification of the handwritten digits, the research extends the current state of literature.

[6] This paper aims at off-line handwritten Arabic numeral recognition employing high quality wavelets in feature extraction as conducted by Akhtar et al., (2019). The paper proposes a new effective approach to increase the rate of the handwriting Arabic numeral recognition and the method that is based on the use of the wavelets for obtaining the features of the characters. This is sought to employ better features for extracting more compact and efficient representations of Arabic numerals to overcome challenges resulting from the complexities surrounding the object recognition process. The work of the study benefits the field by using a more specialized method that is designed for recognizing Arabic script that would enable the creation or the development of particular and correct recognition system for the same.

[7] Alani (2017) presents an original approach to develop Arabic handwritten digit recognition from scratch through the usage of RBM and CNN based deep learning. The goal of the research is to enhance the OCR rate of recognizing AH digits through the use of RBM to acquire and extract features and CNN to classify and recognize the patterns of digits. The present hybrid model shows how tools of deep learning are versatile as well as capable of handling the variations and complexities of Arabic handwritten digits. Our proposed method of using RBM followed by CNN to recognize Arabic handwritten digits has demonstrated improved accuracy over the earlier technique of using only CNN, underlining the advantages of combining various neural

network architectures in improving the accuracy of pattern recognition problems.

[8] According to the research made by Khan (2017), a new approach to handwritten digit recognition has been presented through the use of MCS HOG features, and the SVM being used as the classifier. In order to validate the findings of this study, we have discussed the results of the Confusion Matrix and ROC curve, which emphasizes the better performance our proposed method. The above discussion reveals that effective features from the HOG template and study of MCS HOG features with SVM has played a crucial role in the identification of handwritten digits and proving the significance of the extraction of features and the techniques of classification in precise recognition. In this study, several parameters have been evaluated to analyze the performance of the proposed approach and the specific metrics used for the handwritten digit recognition system.

[9] The study by Ali et al. (2020) presents a novel dataset for handwritten digits and characters in Urdu, comprising samples from over 900 individuals. The research is centered on the automatic recognition of Urdu handwritten characters through the utilization of a deep autoencoder and convolutional neural network (CNN). By employing these advanced deep learning techniques, the study aims to improve the accuracy and efficiency of recognizing handwritten Urdu characters. The integration of a deep autoencoder and CNN demonstrates the capability to capture intricate patterns and features within Urdu handwritten data, leading to enhanced recognition performance. This research makes a significant contribution to the field of pattern recognition by offering a specialized dataset and showcasing the efficacy of deep learning models in the realm of Urdu character recognition.

[10] These features comprises of a financial handwritten digit recognition model based on artificial intelligence as stated by Jiang (2023). In the current state of the art of the use of handwriting digit recognition systems in the financial application, the research focuses on identifying the gaps specifically on the factors of accuracy and performance. Thus, according to the goals, the model proposes to use artificial intelligence to increase the speed and accuracy of recognition of handwriting characters in the given financial documents. This work paid more attention in one of the important aspects in financial world, that is digit recognition and prove the application of artificial intelligence to improve recognition in the field of finance. The work further the knowledge on the handwritten digit recognition in meeting the particular needs of financial institutions on reliable and accurate document analysis..

[11] The research work by Akhlaghi & Ghods (2020) focuses on a method that can be used for recognition of Farsi handwriting phone numbers using deep learning. Deep neural networks, which will be a part of this research, are used in the process of recognizing the Farsi handwriting and specifically separated phone numbers consisting of digits. It is for this reason that the given study seeks to employ artificial neural network as well as the pattern recognition methods in an effort to establish a solution that can easily distinguish and read the Farsi handwritten telephone numbers. The approach described in the paper in question reveals the growing concern towards applying deep learning methods for the purposes of character recognition in the languages with non-latin scripts, including Farsi. It is therefore the intention of the study to enhance the rate of accurate recognition of the Farsi written phone numbers by using the deep neural networks so as to show that the steep curves of learning through new artificial intelligent – based models will one day solve complex pattern recognition dilemmas of Farsi language alone.

[12] In the recent work of Abdulhussain et al. (2021), a novel approach based on the hybrid orthogonal polynomials and moments for handwriting numeral recognition is proposed. This approach is targeted at enhancing the precision and reliability of more practically significant tasks such as recognizing handwritten numerals. Thus, by integrating these mathematical approaches, the study seeks to contribute towards enhancing the current knowledge base for pattern recognition particularly relevant in the recognition of handwritten characters. Explicitly, we are postulating that the use of hybrid orthogonal polynomials and moments provides one of the most potentially effective approaches to numeral recognition systems. The findings of this work show how such approaches can be applied to enhance the operating capabilities of HCR systems and suggests that it provides essential contributions to the fields of computer vision particular and pattern recognition in general.

[13] The work above is a study performed by Tutar (2022) which focuses on the title “Comparison of Handwritten Recognition Methods on Arabic and Latin Characters” showing a research on various methods of the machine learning and deep learning to recognize digit sets created from the Arabic and Latin alphabets. This paper evaluates the effectiveness of the aforesaid methods for recognizing handwritten characters from both scripts. From the evaluation of the various recognition methods for Arabic and Latin characters, the study provides a view on the applicability of different methodologies in the HCR comprising different languages and scripts. Developing differences based upon its comparison with the ramifications of existing character recognition when applied to Arabic and Latin characters, this comparative analysis is expected to

further improve the currently available handwritten character recognition software.

[14] Another article reviewed by [12] titled Digital Recognition Methods Based on Deep Learning explores the topic of digital recognition methods in the aid of deep learning. This paper primarily aims at tracing the development of the handwritten numeral recognition algorithm from a rudimentary deep learning discussion to advanced CNN practices. In the work, an attempt is made to expand the knowledge about deep learning with the help of studying the basic notions, the creation of the model, and training of the elements concerning the formation of advanced recognition systems. Explaining the importance of moving from the simple model to the application of more complicated deep learning architecture to improve on the digitization recognition process. From the exploration of deep learning frameworks and definitions of CNN structures, the study provides useful information on the enhancement of digital recognition application in computing and its affiliated domains.

[15] This paper titled, 'Digital Recognition Methods based on Deep Learning' authored by [12], explores the deep into the idea of digital recognition techniques integrates deep learning. The choice of the specific subject is based on the gradual development of the algorithm for handwritten numeral recognition with the help of deep learning from such a fundamental level up to the Convolutional Neural Networks type. Thus, the objectives of the study are the following: Through comparing the theory of deep learning, model construction, and training methods, the understanding of cutting-edge recognition systems can be promoted, enriched and improved. The article on them underlines the importance of the transition from relative simplicity to increased importance of more sophisticated and deep neural networks to enhance the overall performance of the important and valuable digital recognitions. By comparing and contrasting popular DEEP LEARNING FRAMEWORKS, and analyzing various structures of CNN, this work provides meaningful insights concerning future prospects of improving various kinds of digital recognition technologies, as (wx starting in computer science and related disciplines.

[16] The study under review by Assegie and Nair (2019) involves machine learning, particularly, decision tree classification specifically based on the recognition of handwritten digits. In this mode of analysis, decision tree classification a technique that is known for its simple and easy to interpret results and explanations is applied in the context of recognizing handwritten digits. This works gives a comparison between decision tree classification and random forests, proving that decision tree works best in this context. Therefore, by conducting

the study with more emphasis on machine learning techniques such as, decision tree, the study contributes to enhancement of methodologies for handwritten digit recognition.

[17] Liquid State Machines (LSMs) have emerged as a promising approach for handwritten digit recognition, particularly on edge devices due to their simple structure and ease of training Hou et al. (2023). The study by focuses on the design and optimization of LSMs specifically for this task. By leveraging the unique characteristics of LSMs, such as their ability to process spatiotemporal information and their suitability for real-time applications, the research aims to enhance the accuracy and efficiency of handwritten digit recognition systems. This work contributes to the advancement of pattern recognition techniques by exploring the potential of LSMs in addressing the challenges associated with recognizing handwritten digits in resource-constrained environments.

[18] Another machine learning study by Raja et al. (2021) focuses on the evaluation of the trained machine for recognizing the handwritten digits on the document images. The idea of this study will be to create a reliable system for recognition of hand-written digits with using of such techniques as support vector machines, artificial neural network and many other machine learning techniques. This paper focuses on the difficulties organization commitment towards digit recognition in document images along with exhibiting how learning algorithms can alleviate these difficulties. It goes further in exploring feature extraction techniques, training models and cover classification processes to enhance digit recognition. The discussion is accompanied by examples and experimental results that highlight the benefits of implementing the machine learning algorithms for recognizing hand-written digits on document images. In totality, the paper by Raja et al. (2021) is informative and insightful into the status of applying different machine learning techniques for recognising hand-written digits with the help of the computer, aspects of development, and limitations associated with the same.

[19] A study by Cireşan et al, entitled 'Deep, Big, Simple Neural Nets for Handwritten Digit Recognition' published in Neural Computation in April 2010 is a particularly relevant work. This task is the focus of the research and it concentrates on the efficiency of deep neural networks for the given task and emphasises on the concept of 'simple, large neural network' for the purpose of gaining high percentage of accurate results. The work also shows that back-propagation of plain multi-layer perceptron neural networks, available in classical Internet, can work with an incredibly low error rate of 0. across the well-documented MNIST handwritten digit dataset as the benchmark testing set,

which was 35%. Through the focus on pre-training the deep neural network and the successful application of the approach on the MNIST dataset, this research made a contribution to the assessment of the potential of the neural networks for the pattern recognition tasks. From the study, it can be concluded that network architecture as well as training algorithms have a wide impact towards result directions on the handwritten digit recognition. In sum, the results of the study reveal the efficiency of deep, big, and simple neural networks as the effective ways for classification of the handwritten digits with an acceptable level of accuracy.

[20] A significant study that focuses on the recognition of handwritten digit was carried out by Cireşan et al (2010) on the manuscript "Deep, Big, Simple Neural Nets for Handwritten Digit Recognition." The study was published in *Neural Computation* in 2010. With regards to the task of language translation, this research specifically examines the use of deep neural networks in accomplishing this task; the author argues that simple, large neural networks yield high accuracy rates. The case also show that the standard back-propagation method for the relatively simple forms of MLP used in this study can deliver at an astonishing overall error level of 0.35% on the benchmark of the MNIST handwritten digits that is well-known among machine learning enthusiasts. In demonstrating the superior performance of the model over the MNIST dataset, adopting the deep neural networks therefore, this work help to increase the understanding of what neural network can achieve in tasks related to pattern recognition. This work used a support vector machine classifier and depicted that the network architecture and training algorithms are key players in attaining high accreditation rates of recognizing handwritten digits. Lastly, the conclusion section of this paper underscores the potential of deep, big, and simple neural networks in providing a promising solution to the related and important problem of detecting handwritten digits with a high degree of accuracy.

[21] The study by Alsaafin & Elnagar (2017) explores the utilization of feature selection (FS) techniques for handwritten digit recognition to identify a minimal subset of features that can optimize the recognition process. By integrating FS with appropriate machine learning algorithms, the research aims to streamline the training phase by reducing the number of features utilized, addressing concerns related to computational efficiency and memory utilization. The core of this work lies in the strategic selection of features that are most informative and relevant for accurate digit classification, ultimately enhancing the overall performance of the recognition system. Through the systematic identification and incorporation of a minimal yet

effective subset of features, the study highlights the potential of feature selection in improving the efficiency and effectiveness of handwritten digit recognition models. Alsaafin and Elnagar. "A Minimal Subset of Features Using Feature Selection for Handwritten Digit Recognition." *Journal of Intelligent Learning Systems and Applications*, vol. 9, no. 4, 2017, doi:10.4236/jilsa.2017.94006. used in this research.

[22] According to Li & Chen (2015) there is an experimental algorithm in the field of enhancing the way Handwritten digit recognition applies the Support Vector Machine (SVM) model. Organizations undertaking similar research needs to devise measures to enhance recognition accuracy and speed up the classification process by fine tuning SVM algorithm. The above-said method has been planned to crack problems of variation of style, as well as enriched pattern which is generally linked with handwriting numbers at times. The novelty of the study is in proposing an algorithm that improves the performance of the digit recognition procedure by increasing its efficiency and making the digit recognition more accurate. From these adjustments, the researchers would like to achieve a higher level of predictiveness when it comes to distinguishing between the handwritten digits by exarcerbating the pertinent features using the SVM parameters. It is able to effectively categorize different writing styles, ensuring that it is ideal for developing applications that require real-time concepts of speed and efficiency. The methodology discussed in this paper stresses typically the necessity of fine-tuning processes that enables reliable recognition within the context of the SVM model. This paper seeks to achieve its objective by applying sophisticated AI models in enhancing existing handwritten digit recognition systems. In conclusion, the study Li and Chen Li & Chen (2015) is useful in the area of the handwritten digit recognition due to the integration of an improved SVM model based algorithm. Since the recognition approach has to be accurate as well as very fast, as described in the proposed method, It is recommendable for usage in efficient and reliable recognition of handwritten digit classification.

3. CONCLUSION

In conclusion, the present survey paper: 'A comparative discussion on various classifiers for recognizing hand-written digits' offers a systematic review on the state-of-intelligence, approaches, and algorithms that have been practiced in achieving accurate recognition of hand-written digits. The literature review included various contextual and methodology oriented works in neural networks, convolutional neural networks, feature extraction techniques, deep learning, and the integration of more

than one classification technique called hybrid classifiers for improved recognition of hand-written digits. In the present study, preliminary work of Lecun et al. (2015) and Lecun et al. (1998) has provided impetus in explaining how deep learning techniques and gradient-based learning play a valuable role in document recognition and handwritten digit recognition (Yudhana et al. 2018; Kurniati et al. 2019).

Similarly in the similar lines of research works like Dutta & Muppalaneni (2021), more trends like DigiNet have come into light for predicting the Assamese handwritten digits where the different model predictive styles of the hand-written digits in region-specific language have been the focus of the developments in the field. Machine learning, particularly the use of convolutional neural networks has been shown to increase the digit recognition rate for handwritten numeric digits as espoused by (Ali et al. , 2019); this is especially true on benchmark datasets such as the MNIST data base. Furthermore, recent papers published in 2021 by Gope et al and the other paper by Rasheed et al in 2022 have been centered towards improving the reliability and accuracy of the hand-written digit recognition through the use of machine learning models and transfer learning methodologies.

Moreover, concerning feature extraction, which is an essential element in the recognition process, there have been significant improvements to extract improved features for accuracy recognition such as high-quality wavelets used by (Akhtar et al. , 2019) in recognition of Handwritten Arabic numerals. The pre-processing method used in the studies by Frias-Martinez et al. Neto et al. Along with the integration of deep learning models, convolutional neural networks, and hybrid classifiers as highlighted in various studies by Frias-Martinez et al. Neto et al. (2020); Niu & Suen, 2012 has also added enhancement in the recognition of isolated digits and has overall helped in enhancing the classification accuracies. Furthermore, feature selection, as implemented by (Alsaafin & Elnagar, 2017), has remained part and parcel of the recognition process that has helped in enhancing the selection process by providing the minimum numbers

In this way, with the aid of the survey paper the various methodologies, algorithms, and models used for hand-written digit recognition have been made clearly, and an indication of the development that has been practiced in this field has also been identified. The incorporation of deep learning, CNNs, feature extraction mechanism, and merged classifiers has led to improved discovery, speed and capacity of hand-written digit identification. Recommendations arising from the replicative literature contribute immensely to knowledge in pattern recognition, computer vision, and machine learning

domains for researchers, practitioners, and developers, thus opening up venues for progressive improvement in hand-written digit classification.

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