

An experimental approach to design a system that recognize handwritten digit using python

Jeshwanth Reddy Katta

Department of Computer Science
Central Michigan University
Kattal1jr@cmich.edu

Saikrishna Reddy Kotha

Department of Computer Science
Central Michigan University
Kotha4s@cmich.edu

Abhishek Raj Sampath

Department of Computer Science
Central Michigan University
sampa2a@cmich.edu

Abstract—In today's world, handwritten digit recognition has become a difficult task for identifying the different numbers written by different people since it varies from one individual to another. This paper focuses on how to develop a system which recognizes the digits written by different individuals in real time with the help of CNN (Convolution Neural Network) and python language which includes Tkinter for GUI implementation and used MNIST Data set for training and test the data. This system makes the process of identifying the numbers easy and free from errors. To develop this system, we used the VGG and Res-Net, pre-trained neural networks are also used to achieve the research objectives. The research displays that the accuracy of around 99% .

I. INTRODUCTION

Handwritten digit recognition is considered as a process which provides an ability to machines for recognizing human handwritten digits. This can be done by collecting information from various sources including papers and images which are further classified into predefined classes that is 0 to 9. Identification of human handwritten digits is a complex task for machines because handwriting varies from individual to individual. This is the reason that there is a requirement of developing an efficient system which helps in recognizing handwritten digits automatically. In this current research study, an automated system for handwriting recognition is developed with the help of python language and CNN. This system helps in observing various handwritten digits in real-time as well as develop an attractive GUI for the users to write digits.

The digits are not of same size, width, orientation and justified because of which it becomes difficult for machines to recognize handwriting. For this, CNN is used for eliminating this problem and enabling appropriate recognition of handwriting. According to research performed by [1], it has been analyzed that CNN provides better results for handwriting recognition rather

than other classifiers. Herein, the current research study helps in enhancing the capabilities of current machines or systems by introducing various advanced features within the handwriting recognition system. This research study highlights in-depth knowledge regarding the benefits of the handwriting recognition system. Also, the system provides an efficient GUI for the users to draw or recognize the digits within the developed system

The main aim of this research study is to develop an efficient handwritten digit recognition system which allows the machines to recognize digits written by different people in an easy manner. This research study is mainly focused upon observing handwritten digits in real time with the help of CNN (Convolutional Neural Network) and python language. In order to accomplish the defined research aim, the following research objectives are formulated which are to be answered throughout the completion of project. They are to develop or design a deep learning based model with an aim of automatically recognizing 0 to 9 digits. To create an attractive Graphical User Interface for the users to write digits, these digits will be further recognized by the system and displayed on screen.

In order to accomplish the main objectives of this current research study, quantitative research methodology is used for which literature analysis and experimental analysis is performed. The main reason behind the adoption of quantitative research methodology is to determine statistical information regarding the performance of handwriting recognition system which is developed using the Python programming language. To conduct literature analysis, secondary data is collected from various secondary sources which may include academic journals, research articles, governmental publications, official reports, documents and other official websites. These articles or journals are available online on various digital repositories which helps in collecting valuable

information regarding the considered research topic.

Literature analysis helps in understanding the experiences and perceptions of existing researchers regarding the use of the handwriting recognition system. Also, deep insights are gained in association with different techniques, methods or ML models used by existing methods for developing an efficient handwriting recognition system. For collecting valuable data, a keyword based strategy is used for which multiple keywords are selected for collecting valuable information regarding the research domain. Along with this, experimental analysis is performed in which an efficient handwriting recognition system is developed with the use of Python language and CNN deep neural network. Moreover, different steps are followed for completing the research in an efficient and effective manner.

II. BACKGROUND

Handwritten recognition plays a significant role in information processing as it allows easy and quick processing of digital files. The primary motive behind the idea of this system is that the machines are not perfect in recognizing digits because of which they require an efficient system which helps them in recognizing digits written by different users. Every individual or user has different handwriting whereas this system allows the machines to recognize human handwritten digits from multiple sources which may also include touch screens, images and papers [2]. Further, the identified digits are classified into 10 predefined classes ranging from 0 to 9 [3]. The conversion of handwritten characters or digits into a machine readable format is the primary operation of the handwritten recognition system [4]. Human handwritten digits are recognized from various sources such as papers, images and others. Cheque truncation system scanning, automation of old documents in banks and libraries, postal letter-sorting services, historical data preservation and vehicle license-plate recognition and digits entered in different forms are some of the application areas of human recognition system.

According to [5], character or digit recognition is considered as a traditional research field of pattern recognition as well as various researches have been conducted by the researchers to determine the significance and working of handwriting recognition system. It has been analyzed that higher recognition accuracy for recognizing numbers leads to decrease in problems within the industry. For instance, some of the digits such as 1 and 7, 2 and 5, 2 and 7, 3 and 8, 5 and 6, etc.

seem to be similar because of which various mistakes take place [6]. A mistake in recognizing numbers may lead to huge loss, for instance, inappropriate recognition of a number on the cheque may lead to huge financial loss. The accuracy of recognition is mostly affected due to inappropriate and personal writing habits as well as different styles of writing of people whereas the development of advanced technology enable the users to have an efficient recognition system using Artificial Intelligence, Deep learning and Machine Learning.

On the basis of research conducted by [7], it has been determined that different Machine Learning algorithms such as Support Vector Machine, Random tree, Naïve Bayes, Random Forest J48, Bayes Net and Multilayer Perceptron helps in efficient recognition of digits. The research results of this selected research study determined that Multilayer perceptron provided highest accuracy among all the selected algorithms.

Traditionally, handwritten digit recognition was done on the basis of hand-crafted methods which may include Speeded-Up Robust Features, Scale-Invariant Feature Gradient, 13-point feature extraction method and Histogram of Oriented Gradient. Due to the complexity and inefficiency of traditional methods, there is a requirement of advanced methods for recognizing handwriting [5]. Earlier, image analysis was performed by the researchers for recognizing handwritings but the results obtained from this analysis were not appropriate in case of digit recognition because of which semantic analysis was preferred for human handwritten recognition systems. This helps in determining different structures, clauses, phrases, sentences or digits which further allow the extraction of valuable information so as to achieve human level accuracy from computers. Herein, the concept of Optical Character recognition is elaborated with a motive of distinguishing handwritten text characters from digital images of different physical documents. OCR introduced various applications such as test information extraction, verification code images and automatic license plate recognition [8].

According to [9], it has been identified that handwritten digit recognition system is widely used in banking industries as they make the banking operations or processes easier and free from errors. The researcher determined that traditional handwritten digit recognition is based upon various handcrafted features along with efficient knowledge regarding the recognition [10]. HDR (Handwritten digit recognition) system also has real life practical application along with commercial and profes-

sional applications for helping visually impaired and for solving complex problems. The researcher demonstrated that CNN is an efficient deep learning approach for extracting valuable features from handwritten characters or words [11]. Herein, the author proposed an automatic banking deposit number recognition system which helps in recognizing the handwritten digits or number written by individuals on forms while cash depositing cash, withdrawing cash and other banking transactions. This system extracts the characters on slip or form and passed to recognition phase where character patterns are identified by Neural Network.

Similarly, [12] highlighted the utilization of handwritten character recognition system in banking industry using neural networks. Despite of advanced digital writing tools, there are various activities which are performed using pen and paper such as filling of forms. These forms are further stored physically which may result in loss of information, erroneous manual entry and difficulty in accessing the records. The use of digital access, storage and retrieval helps in resolving the problems faced by using conventional methods. Further, it has been analyzed that CNN (deep learning based model) helps in recognizing handwritten texts by adding it to character recognition model. The proposed character recognition in this research study provide various advantages such as it saves time, provides easy storage and access of information and help the bank employees for reducing inaccuracy because of manual entries.

Moreover, [13] created a (BCHWTR) bank cheque handwritten text recognition system using image processing techniques such as Support Vector Machine (SVM) on cheque images. Payee name, date and courtesy amount are the fields that are recognized automatically leading to workload reduction of bank employees using this developed system. It has been analyzed that time, money and effort are saved by automating the recognition, data entry and verification processes (Cheque Truncation System) with the help of images of cheques [14].

In this context, [15] also conducted a research study regarding handwritten digit classification on the basis of CNN approach. It has been identified that CNN includes two different types of layers namely, convolutional layer and fully connected layers which allow the extraction of image features and helps in performing classification on extracted features respectively. Herein, the researcher proposed a CNN based model for recognizing handwritten digits by considering MNIST (Modified National

Institute of Standards and Technologies) dataset. After completing the experimental analysis, it has been identified that the proposed system provide accurate results (99.98% accuracy) in association other state of the art models determined in this research study. In similar context, [16] demonstrated that CNN with four layers (convolutional layer, ReLu layer, Pooling layer and fully connected layer) provides better results in association with the recognition of handwritten digits rather than any other model. Herein, the researcher also considered MNIST dataset as well as various libraries are included for performing the experimental analysis which include, TensorFlow, NumPy, Keras and Pandas. The primary reason for using CNN is that it continuously recognizes the features and highlights without any intervention of humans.

Also, [17] demonstrated that an adaptive deep Q-learning strategy is also used for handwritten digit recognition. This strategy combines decision making capability of reinforcement learning and feature extracting capability of deep learning. This strategy allow the recognition of characters or digits in an efficient manner and helps the banking officials to perform other necessary operations. There are various other machine learning algorithms which helps in handwritten digit recognition which may include Convolutional Neural Network, double Q-learning, K-Nearest Neighbor, decision tree, K-star, Support Vector Machine and Quantum computing. [18] conducted a research study for providing a comparison between three classification algorithms such as Naïve Bayes, K-star and Multilayer Perceptron for handwritten digit recognition. For comparison, NIST dataset is selected from which various features are extracted which helps in determining best algorithm for performing comparison between defined algorithms in this research study. In order to evaluate the performance of these algorithms on NIST handwritten dataset, different performance metrics are considered such as precision, F-measure, recall, accuracy, false negative, true negative, false positive and false positive. After performing the experimental analysis, it has been identified that K-star algorithm provides highest accuracy as compared to other two algorithms, Naïve Bayes and Multilayer Perceptron. The accuracy provided by K-star, MLP and NB is, 82.36%, 78.35% and 67.04% respectively, thus it can be stated that K-star algorithm is the best classifier among other two in handwritten digit recognition system.

On contrary, the survey conducted by [19] demonstrated that CNN provides 99.89% accuracy in hand-

written digit recognition rather than D-Q learning and SVM Machine learning algorithms. This is because CNN improves computer vision and helps in making a network using hierarchical model which helps in obtaining easy and valuable insights regarding digit recognition. In similar context, [20] also stated that CNN provides better accuracy 99.21% than other Machine learning or deep learning algorithms used for handwritten digit recognition.

Overall, it can be determined that CNN act as an efficient model for recognizing Human handwritten digits rather than other deep learning or machine learning models. In this context, current research is conducted in which a CNN based model is created for recognizing handwritten digits with the help of python modules, packages, Tensor flow and Keras framework, Jupyter notebooks and Anaconda and TKinter for implementing GUI (Graphical User Interface).

III. METHODOLOGY

The research question considered for this study mainly focuses on determining the appropriateness of deep learning model to recognize handwritten digits. In order to do so, Quantitative research methodology is used for achieving the research objectives of current research study, which mainly focus upon the development of automatic handwritten digit recognition system that enable machines to recognize digits written in different handwritings. The primary reason to adopt this methodology is to emphasize upon statistical analysis for collecting valuable information regarding research domain. Herein, literature and experimental analysis are performed for developing handwritten digit recognition system. In order to perform literature analysis, various academic journals or research articles are reviewed for collecting in-depth knowledge regarding the perceptions of existing researchers on the use CNN (Convolutional Neural Network) or other machine learning or deep learning algorithms for developing handwritten recognition system.

Along with this, experimental analysis is also performed in which an automatic handwritten recognition system is developed with the help of CNN deep neural network and Python programming language. In order to achieve the research objectives or research questions of current research study, literature as well as experimental analysis is conducted which helps in collecting valuable and reliable data. This data further helps in completing the current research study in an efficient and effective

manner. In this research study, handwritten digit recognition system is developed using Python programming language and CNN deep neural network whereas different performance metrics are used for evaluating the performance of developed system. The research study follows an appropriate research process for achieving all the research objectives which are elaborated as follows:

Firstly, a research problem is identified and defined so as to initiate the research project. This can be done by reviewing multiple research articles or official websites in association with selected research domain. Further, research aims and objectives are formulated for addressing main focus area of the research study in consideration. Also, they provide an appropriate direction for completing the research study in an efficient manner. This is followed with the process of reviewing existing literature so as to gain deep insights in association with development of automatic handwritten recognition system. Next step is to describe the research methodology selected for providing a systematic method to complete the research study. Herein, data collection and analysis methods are also highlighted that helps in gaining reliable information regarding research domain. Data collection is initiated by following the selected data collection method or technique whereas this collected data is further analyzed for achieving the research objectives. The results are further determined after conducting the research according to the selected methods or techniques. Also, results obtained after analyzing the performance of developed model are also highlighted in this step of the research process. Lastly, conclusion is derived for particular research study on the basis of obtained results in previous section as well as recommendations are also provided for the future researchers conducting research in similar domain.

A. *Selected technologies*

The technology used in this current research is Deep learning whereas Convolutional Neural Network algorithm is used for developing handwritten digit recognition system. Along with this, VGG and Res-Net, pre-trained neural networks are also considered in this research study for achieving the research objectives. In addition to this, Python programming language is also used which further include various packages and modules, Keras and tensor flow framework, jupyter notebook and anaconda and Tkinter for GUI implementation.

B. *Data Collection and analysis*

In this current research study, secondary data is collected from various secondary sources such as re-

search articles, academic journals, official reports, governmental publications and other official websites. For conducting this research study, academic journals and research articles are mainly reviewed which are available on online digital repositories including ScienceDirect, IEEE, SpringerLink, Mdpi, Emerald and many others. This literature analysis help in determining the benefits of handwritten recognition system as well as highlight various machine learning or deep learning algorithms for developing handwritten digit recognition system. In addition to this, SKLN library is used to collect inbuilt data i.e. MNIST digits with the help of which experimental will be performed to evaluate research findings in the end.

To collect valuable sources for data collection, keyword based strategy is adopted for which multiple keywords are used for collecting information in association with defined research objectives. Some of the keywords used include, “Handwritten digit recognition system”, “Application areas of handwritten digit recognition” “Developing handwritten recognition system using Python”, “Use of machine learning algorithms in developing handwritten digit recognition system” and many more. The data collected after performing literature review are analyzed using thematic analysis which highlight different patterns and themes from the collected data. This further helps in ensuring that the information collected provides valuable and accurate information about the selected research topic. Further, experimental analysis is performed to ensure that the automatic handwritten digit recognition system developed in this research study provide results as intended.

C. Experimental designs

Multiple steps are followed for achieving the research objectives which are elaborated as Selection of required dataset for training the model used in this research study for the development of automatic handwritten digit recognition system. Importing libraries and loading the dataset so as to initiate the experimental analysis for achieving the research objectives. data pre-processing which helps in transforming the raw data into an efficiently understandable format. Before applying Machine learning or deep learning algorithms quality of the data is checked for deriving accurate conclusion. Encoding of images using data image generator in order to scale the pixel values. It is basically a step of converting a message into a code which is understandable by computers for processing further operations on data. After this, deep neural network is created whereas CNN algorithm is

used for this process. Further an efficient Graphical User Interface (GUI) is created for the purpose of predicting digits. To create GUI Tkinter is used whereas it allow the users to view the predicted digit on the screen. After creating a model based on deep neural network and GUI, performance evaluation of the developed model is performed using various performance metrics. These metrics may include, recall, accuracy and precision which ensures whether the presented model works as intended or not. Accuracy, precision and recall are the performance metrics used in this research study for evaluating the overall performance of automatic handwritten recognition system. There are engineered features as a small software (Handwritten digit recognition system) is developed using OpenCV and Machine Learning algorithms

IV. RESULTS

The data set images can be observed in the below figure in which all the digits that are available in the dataset can be presented. From the analysis, it is found that, around 60,000 images are available in the dataset having dimension of around 28*28.

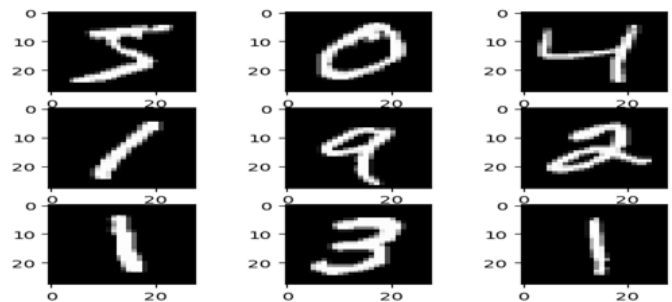


Fig. 1: An Handwritten dataset images

After designing the model, it is trained by fitting the data into the model and the training is performed for around 20 epochs. From the above figure it can be analyzed that training data observed is around 99.29% with a validation accuracy of 99.26 percentage and the loss is too low at around 0.0277.

```

24 .....
Epoch 8/10
60000/60000 [.....] - 21s 353us/sample - loss: 0.0354 - acc: 0.9912 - val_loss: 0.0285 - val_acc: 0.99
13
Epoch 9/10
60000/60000 [.....] - 21s 342us/sample - loss: 0.0315 - acc: 0.9916 - val_loss: 0.0262 - val_acc: 0.99
22
Epoch 10/10
60000/60000 [.....] - 20s 335us/sample - loss: 0.0277 - acc: 0.9929 - val_loss: 0.0286 - val_acc: 0.99
26
The mnist_model trained successfully

```

Fig. 2: Model Training

Evaluation is done in which it is seen that the model is performing efficiently as the testing accuracy is around 99.26% with a loss of around 0.028.

```

M model_scores = mnist_model.evaluate(feature_test_values, target_test_values, verbose=0)
print('Test loss:', model_scores[0])
print('Test accuracy:', model_scores[1])

Test loss: 0.028619782818992193
Test accuracy: 0.9926

```

Fig. 3: Model Evaluation

The training epochs can be observed in the above figure and it can be seen that the model is performing well while training as there is no overfitting observed.

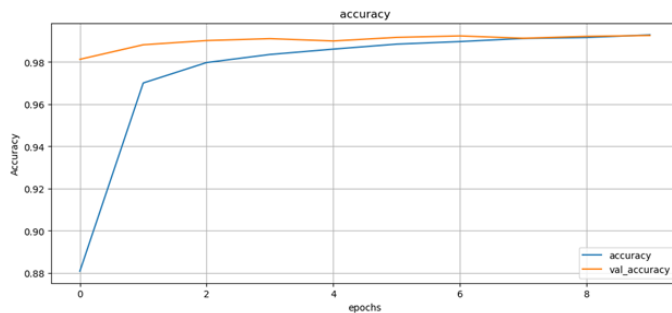


Fig. 4: Accuracy curves and model evaluation

Furthermore, in the below figure, model loss is observed that suggests it is decreasing then reached its lowest point till the model is training which is good.

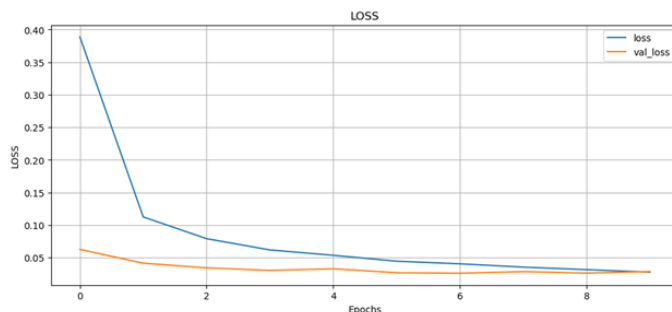


Fig. 5: Accuracy curves and model evaluation

After designing the model, GUI code is written in order to open an interactive GUI where the user can write the digits to know if the model is performing well in real time or not. The above figure shows all the codes that are written for implementation of GUI and the results are shown below that are tested to show that the model is performing well.

From the images provided in the above and below it can be seen that the model is predicting correctly. As it is



observed in the above two images, the model predicted 2 and 8 efficiently with good accuracy.



In the similar manner, the results can be observed in the below figure as the model clearly predicts 9 efficiently with an accuracy of around 99%. From the above analysis it can be concluded that the model is performing well as the model obtained an accuracy of around 99% for both training and testing

V. CONCLUSION

This study is conducted to propose a model that accurately predicts digits in real time. The main aim is to implement a CNN model and to understand the various steps involved in performing the implementation of a real system. The above designed system can be used for solving a variety of problems such as blind people can easily enter numbers while withdrawing money from atm. In this analysis, various steps are considered in order to design the model and perform a real time analysis to suggest the model is performing well.

From the above analysis it can be concluded that the model is performing well as the model obtained an accuracy of around 99% for both training and testing. The main limitations of this model is that, while drawing the digits it should be accurate; otherwise it suggests a different number which is due to the problem of image augmentation which needs to be solved in order to design a robust and efficient system. So, to solve this problem a future research will be conducted in which a model is designed that solves the problem of image augmentation.

REFERENCES

- [1] M. A. Hossain and M. M. Ali, "Recognition of handwritten digit using convolutional neural network (cnn)," *Global Journal of Computer Science and Technology*, 2019.
- [2] A. M. Hafiz and G. M. Bhat, "Handwritten digit recognition using slope detail features," *International Journal of Computer Applications*, vol. 93, pp. 14–19, 2014.
- [3] S. Pashine, R. Dixit, and R. Kushwah, "Handwritten digit recognition using machine and deep learning algorithms," *ArXiv*, vol. abs/2106.12614, 2021.
- [4] A. Savita, A. Choudhary, A. Nayyar, S. Singh, and B. Yoon, "Improved handwritten digit recognition using convolutional neural networks (cnn)," *Sensors*, vol. 20, p. 3344, 06 2020.
- [5] C. Zhang, Z. Zhou, and L. Lin, "Handwritten digit recognition based on convolutional neural network," in *2020 Chinese Automation Congress (CAC)*. IEEE, 2020, pp. 7384–7388.
- [6] J. Brownlee, "How to develop a cnn for mnist handwritten digit classification," *Machine Learning Mastery*, 2019.
- [7] S. Shamim, M. B. A. Miah, M. R. Angona Sarker, and A. Al Jobair, "Handwritten digit recognition using machine learning algorithms," *Global Journal Of Computer Science And Technology*, 2018.
- [8] K. Zhao, "Handwritten digit recognition and classification using machine learning," 2018.
- [9] L. S. V. Gopalakrishnan, R. Arun and K. Abhirami, "Handwritten digit recognition for banking system," *International Journal of Engineering Research Technology*, 2021.
- [10] P. K. Singh, R. Sarkar, and M. Nasipuri, "A study of moment based features on handwritten digit recognition," *Applied Computational Intelligence and Soft Computing*, vol. 2016, 2016.
- [11] H. Al-Wzwazy, H. Albehadili, Y. Alwan, N. Islam, M. Student, and Usa, "Handwritten digit recognition using convolutional neural networks," *International Journal of Innovative Research in Computer and Communication Engineering*, vol. 4, pp. 1101–1106, 02 2016.
- [12] S. Mhalgi, K. Ganu, P. Marne, R. Phadke, and S. Shekapure, "Handwritten character recognition using neural networks for banking applications," *International Journal of Computer Applications*, vol. 176, no. 27, pp. 1–7, Jun 2020. [Online]. Available: <http://www.ijcaonline.org/archives/volume176/number27/31365-2020920296>
- [13] R. Ghosh, C. Panda, and P. Kumar, "Handwritten text recognition in bank cheques," in *2018 Conference on Information and Communication Technology (CICT)*. IEEE, 2018, pp. 1–6.
- [14] A. B. A. SETH and T. SHARMA, "Handwritten digit classification," *JETIR*, vol. 8, 2021.
- [15] A. Yahya, J. Tan, and M. Hu, "A novel handwritten digit classification system based on convolutional neural network approach," *Sensors*, vol. 21, p. 6273, 09 2021.
- [16] M. Jain, G. Kaur, M. P. Quamar, and H. Gupta, "Handwritten digit recognition using cnn," in *2021 International Conference on Innovative Practices in Technology and Management (ICIPTM)*. IEEE, 2021, pp. 211–215.
- [17] J. Qiao, G. Wang, W. Li, and M. Chen, "An adaptive deep q-learning strategy for handwritten digit recognition," *Neural Networks*, vol. 107, pp. 61–71, 2018.
- [18] M. B. Abdulrazzaq and J. N. Saeed, "A comparison of three classification algorithms for handwritten digit recognition," in *2019 International Conference on Advanced Science and Engineering (ICOASE)*. IEEE, 2019, pp. 58–63.
- [19] P. Patil, "Handwritten digit recognition using various machine learning algorithms and models,"

International Journal of Innovative Research in Computer Science & Technology (IJIRCST) ISSN, pp. 2347–5552, 2020.

- [20] S. Ali, Z. Shaukat, M. Azeem, Z. Sakhawat, T. Mahmood *et al.*, “An efficient and improved scheme for handwritten digit recognition based on convolutional neural network,” *SN Applied Sciences*, vol. 1, no. 9, pp. 1–9, 2019.