Original Article

Handwritten Digits Recognition using Novel Long Short Term Memory with Enhanced F-Measures Over K-Nearest Neighbour to Improve the Accuracy

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Abstract

Aim: The major goal of this research is to develop a model that can recognise digits utilising Long Short-Term Memory and LSTM cells, as well as to compare F scores for optical character recognition using LSTM and KNN on the Modified National Institute of Standards and Technology dataset. **Material and Methods**: GPower statistical software is used to estimate the sample size, with a pre-power test of 80%. The alpha error rate, which is 0.05, is a type-I error. The dataset contains 70K handwritten digit samples, 60000 of which are utilised as training samples and the remaining 10,000 as testing samples. **Results:** The digits were identified using Long Short Term-Memory (LSTM) and K-Nearest Neighbour (KNN) algorithms, with LSTM achieving 99 percent accuracy with a the 2-tailed significance value is 0.000 ($p<0.05$) and by KNN achieving 88 percent accuracy. **Conclusion:** The results showed that LSTM with LSTM cells performed substantially better than KNN in optical character recognition.

Keywords: Handwritten Digit Recognition, Novel Long Short Term Memory, K-Nearest Neighbour, Machine learning, Optical Character Recognition, Accuracy.

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INTRODUCTION

Digit detection is an important initial step in visual character recognition and document comprehension. The goal of this study is to create a model that can detect digits utilising LSTM cells and Novel long short term memory (Partheepan 2021). The technique of identifying handwritten digits using training and testing sets of labelled data is known as Handwritten digit Recognition (HDR) (Kostadinov 2018). A long short term memory as a feedforward neural network with memory. Because it computes the same function for all inputs and the current output is reliant on the prior output, it is recurrent. K-Nearest Neighbours (KNN) is a supervised machine learning technique that takes labelled data as input to train the function and hence delivers an appropriate output when meeting unlabelled data (Nascimento 2004). This type of device can be used to scan car number plates, scan passbook details, read cheque books, and so on (Zeng, Gu, and Guo 2015). The bottom line is that it may be utilised everywhere that digit recognition is required. It can be used for papers at government agencies. This type of technology is quite beneficial in minimising line wait times(IEEE Staff 2020) .

The transfer learning is focused by using a strong training method, and the model is driven to extract lower level features from the (Modified National Institute of Standards and Technology) Modified National Institute of Standards and Technology dataset, and this learning experience is then transferred to learning the patterns of handwritten urdu texts using LSTM (Sagheer 2010). The identification of quranic diacritics and characters using feature extraction and KNN has a 96.4 percent accuracy rate (Solé-Casals et al. 2021). Novel LSTM is also a better fit for biometric authentication systems. It is feasible to construct a robust system with accurate performance using LSTM in combination with existing methods (Sagheer 2010).The accuracy of digit recognition can be improved with LSTM cells added to LSTM and this approach shows promising outcomes and reliably beats other machine learning approaches (Patil and Bhilare 2019).

Our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021). There are around 30 papers related to handwritten digit recognition published in sprinkle journal and around 80 papers are found in ieee xplore. The Novel LSTM with Handwritten digit Recognition is probably more suited to detect digits since it can learn quicker from input with great accuracy and precision ((Zeng, Gu, and Guo 2015). The goal of this study is to create a model that can recognise digits with Long Short-Term Memory and LSTM cells for improved accuracy (Patil and Bhilare 2019)), as well as to compare F score measures for optical character recognition with KNN on the Modified National Institute of Standards and Technology dataset to verify the performance of the Multi-dimensional Novel LSTM based system (Solé-Casals et al. 2021)).

Materials And Methods

The research was carried out at the Deep learning lab in Saveetha School of Engineering, Saveetha Institutes of Medical and Technical Sciences (SIMATS), Chennai. The research looks at two types of neural networks: LSTM(Long Short Term Memory) i.e long short term memory (LSTM) and K Nearest Neighbours (KNN). GPower statistical software is used to estimate the sample size, with a pre-power test of around 80%. The difference between the two methods is the alpha error rate, which is a type-I error of 0.05. The researcher ratio is about 1. Previous research (Solé-Casals et al. 2021) provided the samples for Group 1 and Group 2. The dataset contains 70k handwritten digit samples, 60000 of which are utilised as training samples and the remaining 10,000 as testing samples. Each picture in the collection is 28 × 28 pixels in size. The data used in this study was collected from http://yann.lecun.com/exdb/Modified National Institute of Standards and Technology/ .

Long Short Term-Memory (LSTM)

A Novel Long Short Term Memory output is driven by prior input. The Hidden layer, which remembers certain information as a few sequences, is the most important element of Novel LSTM. The LSTM is made up of LSTM cells that serve as a memory for the LSTM network as a whole (Patil and Bhilare 2019) In the layers of new long short term memory, long short-term memory (LSTM) cells are employed as building bricks . A typical LSTM unit consists of a cell, an input gate, an output gate, and a forget gate. The cell can remember values for any amount of time (Sagheer 2010).

PseudoCode for Novel Long Short Term Memory

Step 1: Keras Library has been used to import the essential classes, such as LSTM, sequential and Dense.
Step 2: The dataset was loaded and separated into training and testing samples followed by reshaping.
Step 3: The Hyper parameters were set nb_clsses =10, epochs =20, batch_size = 128
Step 4: The LSTM based model is built with three LSTM layers each having relu as activation function and followed by a dropout of 20%.
Step 5: The model is trained and tested for accuracy.

K-Nearest Neighbours (KNN) Algorithm

K-Nearest Neighbours is a supervised machine learning technique that utilises labelled data as input to train a function that outputs acceptable results when faced with unlabeled data (Kostadinov 2018). It is presumptively true that similar objects can be found in close proximity. Fig. 2 shows different samples of handwritten digits and it will be recognised only when the digit is written clearly and written in the given box. In Fig. 2 the digit 5 is written in a different style but using the KNN we can recognise it easily.

PseudoCode for K-Nearest Neighbours

Step 1: The necessary classes namely KNeighbors Classifier is imported from skLearn Library.
Step 2: Import the dataset
Step 3: Explore the data and analyse how it looks.
Step 4: Split into training and testing samples, followed by reshaping.
Step 5: The KNN model is built by using K Neighbours Classifier and changing the K parameter to get optimal accuracy.
Step 6: The model is trained and tested for accuracy.

Testing Procedure

The steps below explain the test process used to assess the model, as well as the Pseudo Code for new LSTM and the Pseudo Code for KNN .

Step 1: The training and testing are two types sets of the Modified National Institute of Standards and Technology dataset .
Step 2: For training, the training samples are fitted into LSTM and KNN models.
Step 3: The trained models are now evaluated for accuracy using the testing set.

Data Collection
Table 1, shows the accuracy statistics gathered for the Novel LSTM method and it also shows the accuracy statistics gathered for the KNN algorithm.

Statistical Analysis
IBM Statistical Packages for the Social Sciences (SPSS) version 21 is used for analysis. Handwriting characters and writing type are the dependent variable and Independent variables are illumination and recognition of numerical characters. Iterations with a maximum of 20 samples were performed for both proposed and existing algorithms, and the projected accuracy for each iteration was recorded for accuracy analysis. The Independent Sample T-test was calculated using the result received from the iterations. (Kostadinov 2018).

Results

In Table 1, it was observed that Long Short-Term Memory is better than K-Nearest Neighbours . In the given dataset, it is observed that accuracy and performance of LSTM was significantly better than KNN.

In Table 2, the LSTM achieved a mean of 98.7905, standard deviation of 2.79407 and the standard error mean of .62477. For the KNN the mean is 88.2385, standard deviation is 2.95516 and standard error mean is .66079.

In Table 3, The 2-tailed significance value is 0.000 ($p<0.05$) showing that our hypothesis holds good and The significance level is less than 0.131 for both logistic regression and linear regression.

Fig. 1. Shows that comparison of mean accuracy of handwritten digits recognition using Novel LSTM and KNN Algorithm. It shows that mean accuracy of LSTM is significantly more than KNN. Fig. 2 shows different samples of handwritten digits and it will be recognised only when the digit is written clearly and written in the given box. In figure the digit 5 is written in a different style but using the linear SVM we can recognise it easily.

Discussion

According to this research, Novel LSTM has a considerably better accuracy than traditional LSTM (Sagheer 2010). In the situation of KNN accuracy evaluation, which is less, (Patil and Bhilare 2019) found similar findings. The independent sample test is shown in Table 3. The significance value is 0.000 ($p<0.05$) in the two-tailed test for LSTM shows that the two algorithms for optical character recognition appear to have a statistically significant difference in accuracy (OCR).

Handwritten digit recognition is outperformed by Long Short-Term Memory over other methods. The Novel LSTM was selected for two reasons. The first is its ability to learn from inputs, and the second is its performance (Chherawala, Roy, and Cheriet 2016). In LSTM cells the accuracy of digit identification may be increased, and this technique exhibits promising results and consistently outperforms other machine learning algorithms (Patil and Bhilare 2019). LSTM is also a more suited technique for authentications, according to biometric systems (Howard et al. 2021). It is feasible to construct a robust system with accurate performance using Novel LSTM coupled with conventional meth (Aschbacher et al. 2021) .

The model's limitations include that it is best suited for digit identification, although it may be modified to identify letters and various scripts, such as Devanagari scripts. More study may be done to enhance the model's architecture by adding more layers of LSTM cells, altering the optimization function, or experimenting with other activation function combinations. The model may be trained using a variety of different datasets for Latin and Devanagari scripts (Man et al. 2022).

Conclusion

This study revealed the precision and accuracy of Novel LSTM and it achieves the greatest accuracy of 99 percent as the period rises. This shows that the model is operating well and is neither underfitting nor overfitting. In

contrast to Novel LSTM methods, K-Nearest Neighbour (KNN) has a lower accuracy of 88% and precision value.

DECLARATIONS

Conflicts of Interest

No conflicts of interest in the manuscript.

Authors Contribution

Author SS was involved in data collection, data analysis, manuscript writing. Author TRK was involved in conceptualization, guidance and critical review of manuscript.

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References

1. Adhinarayanan, Rajesh, Aravindh Ramakrishnan, Gopal Kaliyaperumal, Melvinvíctor De Poures, Rajesh Kumar Babu, and Damodharan Dillikannan. 2020. "Comparative Analysis on the Effect of 1-Decanol and Di-N-Butyl Ether as Additive with diesel/LDPE Blends in Compression Ignition Engine." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, June, 1–18.
2. Arun Prakash, V. R., J. Francis Xavier, G. Ramesh, T. Maridurai, K. Siva Kumar, and R. Blessing Sam Raj. 2020. "Mechanical, Thermal and Fatigue Behaviour of Surface-Treated Novel Caryota Urens Fibre–reinforced Epoxy Composite." *Biomass Conversion and Biorefinery*, August. https://doi.org/10.1007/s13399-020-00938-0.
3. Aschbacher, Kirstin, Christian S. Hendershot, Geoffrey Tison, Judith A. Hahn, Robert Avram, Jeffrey E. Olgin, and Gregory M. Marcus. 2021. "Machine Learning Prediction of Blood Alcohol Concentration: A Digital Signature of Smart-Breathalyzer Behavior." *NPJ Digital Medicine* 4 (1): 74.
4. Aurtherson, P. Babu, Bhanu Teja Nalla, Karthikeyan Srinivasan, Kulmani Mehar, and Yuvarajan Devarajan. 2021. "Biofuel Production from Novel Prunus Domestica Kernel Oil: Process Optimization Technique." *Biomass Conversion and Biorefinery*, May. https://doi.org/10.1007/s13399-021-01551-5.
5. Bhansali, Karan J., Kamlesh R. Balinge, Subodh U. Raut, Shubham A. Deshmukh, M. Senthil Kumar, C. Ramesh Kumar, and Pundlik R. Bhagat. 2021. "Visible Light Assisted Sulfonic Acid-Functionalized Porphyrin Comprising Benzimidazolium Moiety for Photocatalytic Transesterification of Castor Oil." *Fuel* 304 (November): 121490.
6. Chherawala, Youssouf, Partha Pratim Roy, and Mohamed Cheriet. 2016. "Feature Set Evaluation for Offline Handwriting Recognition Systems: Application to the Recurrent Neural Network Model." *IEEE Transactions on Cybernetics* 46 (12): 2825–36.
7. Deepanraj, B., N. Senthilkumar, D. Mala, and A. Sathiamourthy. 2021. "Cashew Nut Shell Liquid as Alternate Fuel for CI Engine—optimization Approach for Performance Improvement." *Biomass Conversion and Biorefinery*, February. https://doi.org/10.1007/s13399-021-01312-4.
8. Howard, Frederick M., James Dolezal, Sara Kochanny, Jefree Schulte, Heather Chen, Lara Heij, Dezheng Huo, et al. 2021. "The Impact of Site-Specific Digital Histology Signatures on Deep Learning Model Accuracy and Bias." *Nature Communications* 12 (1): 4423.
9. IEEE Staff. 2020. *2020 International Conference on Smart Electronics and Communication (ICOSEC)*.
10. Jayanth, Bellappu Venkat, Melvin Victor Depoures, Gopal Kaliyaperumal, Damodharan Dillikannan, Dilipsingh Jawahar, Kumaran Palani, and Ganesha Prasad Meravanigee Shivappa. 2021. "A Comprehensive Study on the Effects of Multiple Injection Strategies and Exhaust Gas Recirculation on Diesel Engine Characteristics That Utilize Waste High Density Polyethylene Oil." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, June, 1–18.
11. Kamath, Manjunath, Subha Krishna Rao, Jaison, Sridhar, Kasthuri, Gopinath, Sivaperumal, and Shantanu Patil. 2020. "Melatonin Delivery from PCL Scaffold Enhances Glycosaminoglycans Deposition in Human Chondrocytes – Bioactive Scaffold Model for Cartilage Regeneration." *Process Biochemistry* 99 (December): 36–47.
12. Kostadinov, Simeon. 2018. *Recurrent Neural Networks with Python Quick Start Guide: Sequential Learning and Language Modeling with TensorFlow*. Packt Publishing Ltd.
13. Man, Xin-Yi, Zao-Shang Chang, Yan-Xin Mo, Kai Liang, Le Wang, and Zhi-Yong Xiao. 2022. "The Role of a-Amino-3-Hydroxy-5-Methyl-4-Isoxazolepropionic Acid-Type Receptor Modulators in Object Recognition Memory Reconsolidation." *Neuroreport* 33 (4): 199–203.
14. Nascimento, Mario A. 2004. *Very Large Data Bases*. Morgan Kaufmann.
15. Partheepan, Ravinthiran. 2021. *Toxic Comment Classification Using LSTM, GRU and Neural Network*. RAVINTHIRAN PARTHEEPAN.
16. Patil, Yamini, and Amol Bhilare. 2019. "Digits Recognition of Marathi Handwritten Script Using LSTM Neural Network." *2019 5th International Conference On Computing, Communication, Control And Automation (ICCUBEA)*.

https://doi.org/10.1109/iccubea47591.2019.9129291.
17. Rajasekaran, S., D. Damodharan, K. Gopal, B. Rajesh Kumar, and Melvin Victor De Poures. 2020. "Collective Influence of 1-Decanol Addition, Injection Pressure and EGR on Diesel Engine Characteristics Fueled with diesel/LDPE Oil Blends." *Fuel* 277 (October): 118166.
18. Rajesh, A., K. Gopal, De Poures Melvin Victor, B. Rajesh Kumar, A. P. Sathiyagnanam, and D. Damodharan. 2020. "Effect of Anisole Addition to Waste Cooking Oil Methyl Ester on Combustion, Emission and Performance Characteristics of a DI Diesel Engine without Any Modifications." *Fuel* 278 (October): 118315.
19. Raju, P., K. Raja, K. Lingadurai, T. Maridurai, and S. C. Prasanna. 2021. "Glass/Caryota Urens Hybridized Fibre-Reinforced nanoclay/SiC Toughened Epoxy Hybrid Composite: Mechanical, Drop Load Impact, Hydrophobicity and Fatigue Behaviour." *Biomass Conversion and Biorefinery*, March. https://doi.org/10.1007/s13399-021-01427-8.
20. Sagheer, Malik Waqas. 2010. *Novel Word Recognition and Word Spotting Systems for Offline Urdu Handwriting*.
21. Sathiyamoorthi, Ramalingam, Gomathinayakam Sankaranarayanan, Dinesh Babu Munuswamy, and Yuvarajan Devarajan. 2021. "Experimental Study of Spray Analysis for Palmarosa Biodiesel-diesel Blends in a Constant Volume Chamber." *Environmental Progress & Sustainable Energy* 40 (6). https://doi.org/10.1002/ep.13696.
22. Shanmugam, Rajasekaran, Damodharan Dillikannan, Gopal Kaliyaperumal, Melvin Victor De Poures, and Rajesh Kumar Babu. 2021. "A Comprehensive Study on the Effects of 1-Decanol, Compression Ratio and Exhaust Gas Recirculation on Diesel Engine Characteristics Powered with Low Density Polyethylene Oil." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 43 (23): 3064–81.
23. Solé-Casals, Jordi, Zhe Sun, Cesar F. Caiafa, and Toshihisa Tanaka. 2021. *Machine Learning Methods with Noisy, Incomplete or Small Datasets*. MDPI.
24. Sudhakar, M. P., Merlyn Ravel, and K. Perumal. 2021. "Pretreatment and Process Optimization of Bioethanol Production from Spent Biomass of Ganoderma Lucidum Using Saccharomyces Cerevisiae." *Fuel* 306 (December): 121680.
Zeng, Deze, Lin Gu, and Song Guo. 2015. *Cloud Networking for Big Data*. Springer.

TABLES AND FIGURES

Table 1. Accuracy value for various epochs for Long Short-Term Memory (LSTM) and for K-Nearest Neighbour algorithm (KNN).

S. NO	Accuracy for LSTM	Accuracy for KNN
1	97	89
2	98	88
3	96	87
4	99	87
5	98	86
6	99	86
7	98	85
8	99	85

9	99	84
10	98	84

Table 2. Long Short-Term Memory (LSTM) and K-Nearest Neighbour algorithm mean, standard deviation, and standard error of accuracy statistical study. In terms of accuracy, there is a considerable statistical difference. The most accurate LSTM was Novel LSTM (99 percent)

Accuracy	**Algorithm**	**Mean**	**N**	**Std.deviation**	**Std.error mean**
	LSTM	98.7905	10	2.79407	0.62477
	KNN	88.238	10	2.95516	0.66079

Table 3. Comparison of significance level for long short term memory and K-Nearest Neighbours. The significance level is p=0.0 (p< 0.05) (2-tailed) for both logistic regression and linear regression.

Accuracy	**Levene's test for equality of variances**	**T-Test for equality of means**							
	F	**Sig.**	**t**	**df**	**sig.(2-tailed)**	**Mean difference**	**Std.error difference**	**95% confidence interval of the difference**	
								Lower	**Upper**
Equal Variances assumed	2.377	0.131	11.6	38	0.000	10.552	0.90939	8.71104	12.39296
Equal variances not assumed			11.6	37	0.000	10.552	0.90939	8.71085	12.39315

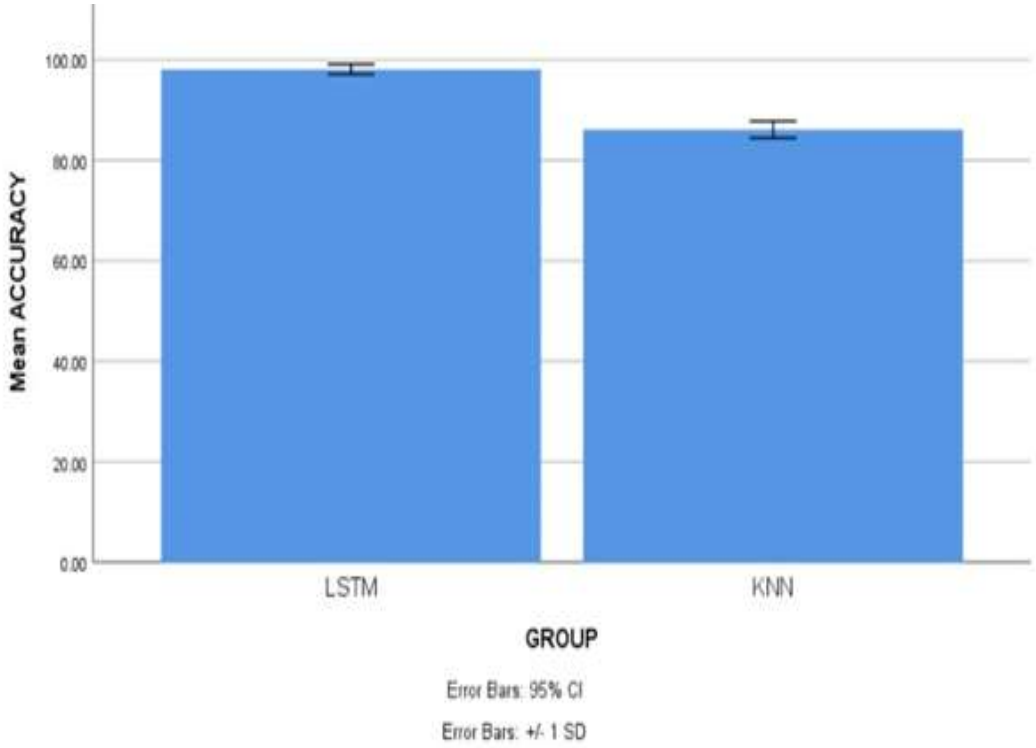

Fig. 1. Comparison of mean accuracy of Handwritten digits recognition using Novel LSTM and KNN Algorithm.It shows that mean accuracy of LSTM is significantly more than KNN. X axis: LSTM vs KNN, Y axis: Mean accuracy $\pm$ 1SD.

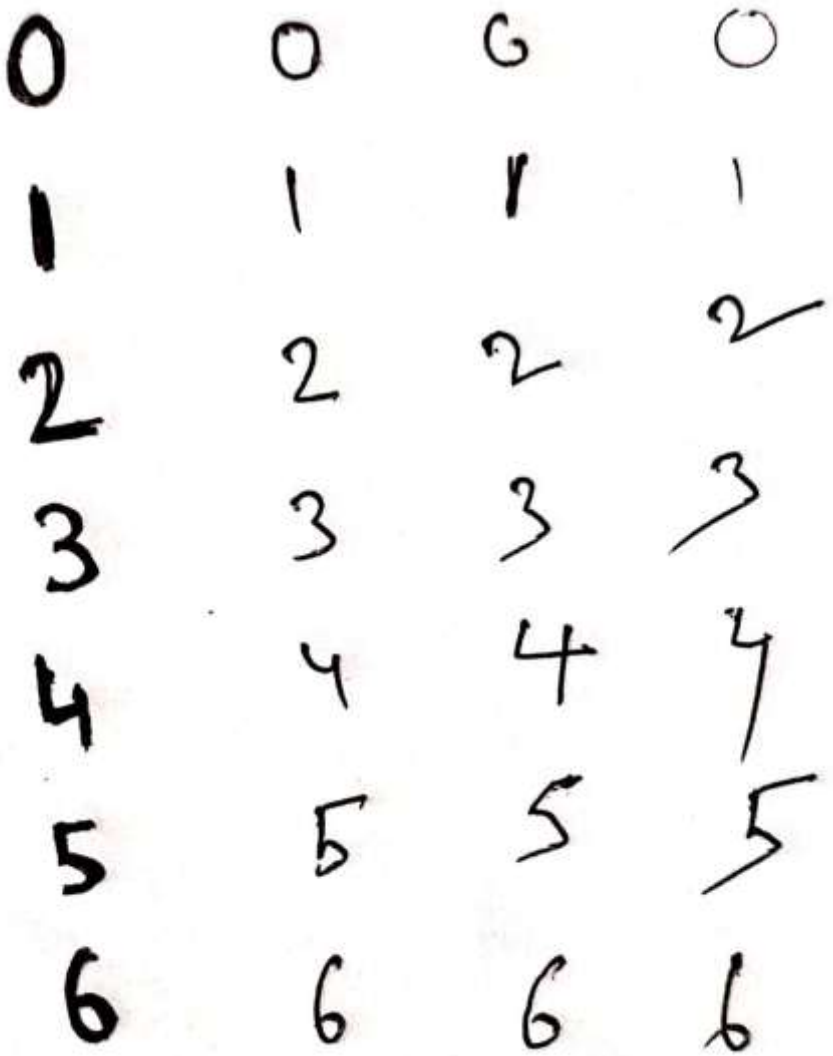

Fig. 2. Different samples of handwritten digits and it will be recognised only when the digit is written clearly and written in the given box. In figure the digit 5 is written in a different style but using the Linear SVM we can recognise it easily.