















margin learning algorithm is then applied. The present paper uses SVM classifier and statistical feature sets for classification.

The extracted features of both training data set and test database and are given to a SVM machine. The recognition rate of the individual digits in test samples by using SVM algorithm is shown in table 7 and from that table the overall recognition rate of the test database is 98.49%.

TABLE VII  
RESULTS OF NUMERICAL RECOGNITION FOR 38007 TEST IMAGES USING SVM CLASSIFIER

Digit	No.of images	Correctly Classified	Not Correctly Classified	% accuracy
0	3,878	3,824	54	98.61
1	3,891	3,828	63	98.38
2	3,743	3,691	52	98.61
3	3,907	3,842	65	98.34
4	3,679	3,619	60	98.37
5	3,815	3,768	47	98.77

TABLE VIII  
CONFUSION MATRIX GENERATED WHEN USER DEFINE CLASSIFIER APPLIED ON TEST DATABASE

Digit	0	1	2	3	4	5	6	7	8	9
0	3850	4	2	0	0	0	3	8	6	5
1	2	3854	9	0	0	2	3	12	3	6
2	0	5	3717	3	2	2	2	3	2	7
3	0	2	1	3868	2	3	4	5	13	9
4	0	0	3	4	3645	5	2	3	11	6
5	0	0	2	3	0	3794	9	0	0	7
6	3	2	2	0	0	7	3924	7	9	8
7	0	12	0	1	0	0	0	3738	2	5
8	1	6	4	15	0	3	5	0	3753	7
9	5	0	3	4	2	1	7	3	8	3549

D. Comparison of the proposed approach with other existing approaches:

The efficiency of the proposed method is compared with other existing methods like aDeep Learning proposed by Anuj Dutt et.al [28], MCS HOG Features and SVM classifier by Hamayun [29], and Convolutional Neural Network as a Classifier proposed by Jisha et.al [30]. Anuj Dutt proposed Machine Learning, Deep Learning and Computer Vision algorithms. The overall efficiency of the deep learning approach is about 98.72%. Hamayun proposed Multiple-Cell Size (MCS) approach was proposed for utilizing Histogram of Oriented Gradient (HOG) features and a Support Vector Machine (SVM) based classifier for efficient classification of Handwritten Digits. The HOG based techniques sensitive to the cell size selection used in the relevant feature extraction computations. Hence a new MCS approach has been used to perform HOG analysis and

6	3,962	3,898	64	98.38
7	3,756	3,712	44	98.83
8	3,794	3,727	67	98.23
9	3,582	3,523	59	98.35
Average Recognition Percentage				98.49

When comparing the three classifiers for the same test database and same feature set, User defined classifier shows better results it concludes that classification results not only depends on features extracted from the image but also depends on type of classification technique used. The overall recognition rate is about 98.76%. The time consumed for the testing of the test database for user defined algorithm is about 19.0025 sec, for k-nn classifier need 59.032 sec and SVM classifiers need 60.732 sec. The advantage of use defined classifier is once the algorithm is defined no need to calculate the feature values. Any numbers of images can be tested. The confusion matrix generated by the user-defined classifier is shown in table 8.

compute the HOG features. This approach got 99.36% when applied on MNIST database. But while applying on other databases it is decreased to 97.13. Jisha proposed Convolution Neural Networks (CNNs) consist of multiple layers. It is a powerful technique for classification of visual inputs like handwritten digits and faces recognition. The classification task is performed using a Convolution Neural Network (CNN). The actually purpose of developing the multilayer neural network is to reduce the meansquare error, between the actual output and the final output. But each subnet between the input and the hidden-layer are initialized with random weights and also trained with different feature maps. This is applied on only 1000 image but applied on large database it decreased to 96.36%. The performance evolution of the proposed method with other existing methods is listed out in table 10 and the classification graph is represented in figure 11. From table 9 and figure



21, it is clearly evident that, the proposed method exhibits a high recognition rate than the existing methods.

TABLE IX  
ACCURACY OF HWD CLASSIFICATION OF DIFFERENT APPROACHES

Database	Deep learning [28]	HOG based technique [29]	Convolution Neural Networks [30]	Proposed Approach
MNIST	98.98	97.28	95.72	98.95
CEDAR	98.73	97.45	96.39	99.24
CEPARMI	98.33	96.52	97.45	99.23
Scanned images	98.85	97.28	95.88	99.29

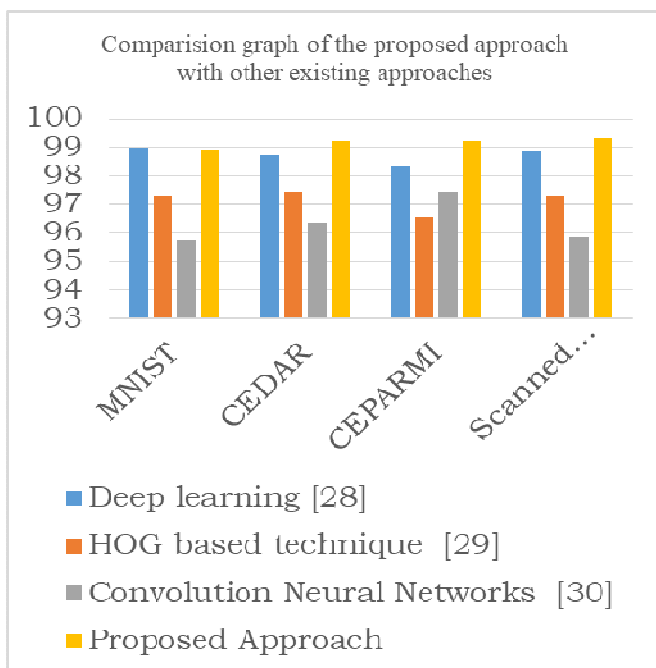


Fig 21: Graphical representation of the % recognition of the proposed method and other existing method

#### IV. CONCLUSIONS

The novelty of this method is that, free from size normalization, fast, accurate, independent of size and Writer style/ink independent. The present paper defined classification of isolated handwritten digits with good classification results. The proposed method was tested with large database. No such method is available in the literature to test the large test data set. The proposed approach extracts only 5 features. The time complexity of the proposed method is also very less. The proposed method shows high recognition rate when compare with the test results of standard classification algorithms.

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