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Handwritten Digit Recognition Using Support Vector Machine

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***Abstract*—** Computer Vision and Machine Learning are two domains that are upcoming and helpful in the modern era. Computer Vision is a science that is designed to try to make a computer as good as a human. Machine Learning helps improve computer vision by training it to improve every time it is used. This paper presents a model of Support Vector Machine (SVM) with the AdaBoost classifier, which has proven results in recognizing different types of patterns. In this model, SVM is used as a recognizer. This model automatically extracts features from the raw images and generates predictions. The results are subject to experiments conducted on the well-known MNIST digit database.

***Keywords*—** Computer Vision, Machine Learning, Classifier, SVM, Digit Recognition

I. INTRODUCTION

Understanding how the human brain is able to efficiently perceive and understand a visual scene is still a field of ongoing research. Although many studies have focused on the design and optimization of neural networks to solve visual recognition tasks, most of them either lack neurobiologically plausible learning rules or decision-making processes [1]. Here, we present a small-scale model that integrates a low-level memory encoding mechanism with a higher-level decision process to perform a visual classification task in real-time. The difficulty of visual pattern recognition becomes apparent if you attempt to write a computer program to recognize digits [2]. In this report we've written a computer program implementing a classifier using support vector machine that learns to recognize handwritten digits. The digits are entered by the user in any pattern depending on his/her handwriting and the algorithm processes the input and recognizes the digits using the MNIST database as a reference. The rest of the paper is organized as follows, section I contains the introduction of neural networks and visual pattern recognition, section II contains the related work and research done regarding three popular pattern recognition methods for image classification and section III explains the proposed methodology with the flow chart, section IV contains the results and discussions with the data pre-processing and output accuracy, section V concludes research work with the future directions.

II. RELATED WORK

Handwritten Digits Recognition (HDR) is of the very popular applications in computer vision. Digits are universal symbols widely used in technology, bank, OCR, analysing of digits in engineering, postal service, numbers in plate recognition etc. They are some of the famous applications on HDR [6]. There are ten classes corresponding to the handwritten digits from '0' to '9'. The main difficulty in the handwritten digits' recognition is different handwriting style which is a very personal behavior where there are many models for numbers based on the angles, the lengths of the segments, stress on some parts of numbers, etc. [14] According to all the available literature, the following methods proved to be the most likely effective in predicting the digits in any system via images.

i. Support Vector Machine: Support Vector Machine is a supervised machine learning algorithm which can be used for both classification or regression challenges [10]. In this algorithm, we plot each data item as a point in n-dimensional space with the value of each feature being the value of a particular coordinate. Then, we perform classification by finding the hyper-plane with the help of support vectors that segregates the two classes very well.

ii. K Nearest Neighbor: The K Nearest Neighbors algorithm is a classification algorithm in Machine Learning. It is used to classify a new data point into one of multiple existing categories. So, a number of neighbor's 'k' is selected and the k closest data points are identified (using Euclidean or Manhattan distances). Of the k closest data points or 'neighbors', the category with the highest number of k-close neighbors is the category assigned to the new data point [11].

iii. AdaBoost: AdaBoost is a type of learning in which multiple learners are used to build a stronger learning algorithm. AdaBoost works by choosing a base algorithm (like decision trees) and iteratively improving it by accounting for the incorrectly classified examples in the training set. We assign equal weights to all the training examples and choose a base algorithm [12]. At each step of

iteration, we apply the base algorithm to the training set and increase the weights of the incorrectly predicted examples. We iterate n times, each time applying base learner on the training set with updated weights. The final model is the weighted sum of the 'n' learners.

III. METHODOLOGY

The proposed flow for digit recognition is as follows:
i. Acquire Dataset: MNIST database is available on its official website wherein a total of 70,000 images are collected and saved.
ii. Training: These 70,000 images need to be trained and segregated according to the digits they represent. This is done by creating an image classifier to train the system according to the available dataset. Tensor flow has built in functions to train the given images according to given parameters.
iii. Model: After the training of data is completed by the classifier, a trained model is created that is a collection of the results of predictions on each of the image in the dataset. It is generally a .txt file.
iv. Capture Image: Using a motor, the camera moves to detect a number and captures the image. This is taken as input by the system.
v. Pre-Processing: Processes such as 2-D convolution, reshape, resize canvas etc. are performed on the input image before it is processed for better recognition.
vi. Output Prediction: Finally, the result is predicted by using Adaboost classifier and Support Vector Machine method algorithms on the pre-processed image using specific functions of the tensor flow library
vii. Display Output: This predicted value is saved and displayed.

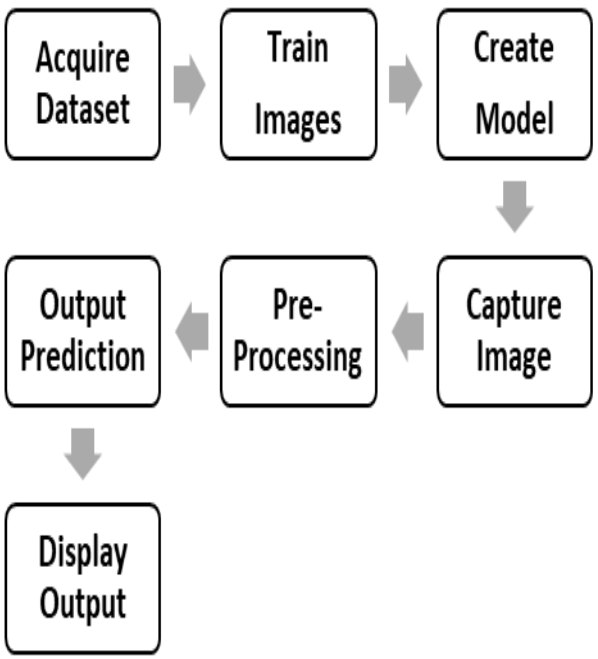

Figure 1

IV. RESULTS AND DISCUSSION

A. Data Pre-Processing
The MNIST database (Modified National Institute of Standards and Technology database) is a large database of handwritten digits in English that is commonly used for training various image processing systems [11].

Table 1: MNIST Database Statistics

Class	Number of samples		
	Train Data	Test Data	Total
'0'	5923	980	6903
'1'	6742	1135	7877
'2'	5958	1032	6990
'3'	6131	1010	7141
'4'	5842	982	6824
'5'	5421	892	6313
'6'	5918	958	6876
'7'	6265	1028	7293
'8'	5851	974	6825
'9'	5949	1009	6958
Total	60,000	10,000	70,000

Figure 2

Figure 3

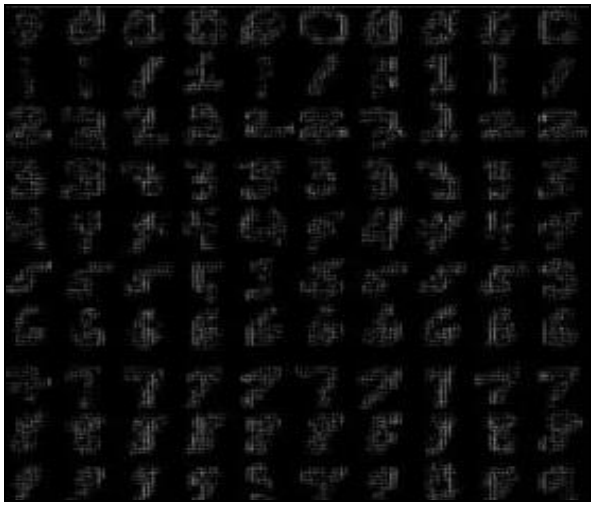

Figure 4: Stages of Data Pre-Processing

B. Output and Results

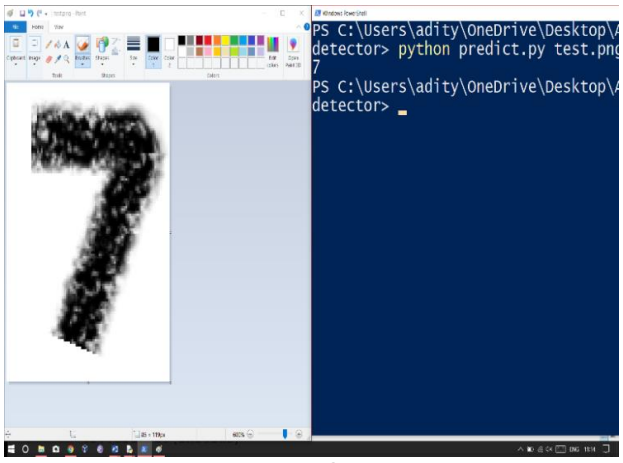

Figure 5: Output

Figure 6: Other Results

Table 2: Accuracy Percentage by digit (i)

Acc	'0'	'1'	'2'	'3'	'4'
'0'	**99.59**	0	0.10	0.10	0
'1'	0	**99.29**	0.17	0.08	0.08
'2'	0.48	0.09	**97.76**	0.58	0
'3'	0.29	0.09	1.28	**96.53**	0
'4'	0	0	0	0	**97.65**
'5'	0.11	0	0	1.45	0
'6'	0.52	0.10	0.20	0	0.31
'7'	0	0.19	1.55	0.09	0.38
'8'	0.51	0.10	1.23	0.61	0.61
'9'	0.19	0.39	0.19	0.29	0.99

Table 3:: Accuracy Percentage by digit (ii)

Acc	'5'	'6'	'7'	'8'	'9'
'0'	0	0.10	0.10	0.10	0
'1'	0	0.08	0.17	0.17	0
'2'	0	0.09	0.77	0.29	0
'3'	0.69	0	0.49	0.59	0.09
'4'	0	0.40	0.30	0.30	1.42
'5'	**97.75**	0.22	0	0.44	0.11
'6'	1.04	**97.49**	0	0.41	0
'7'	0	0	**96.49**	0.58	0.77
'8'	0.30	0.51	0.82	**94.45**	0.92
'9'	0.09	0	1.38	0.39	**96.13**

A closer look at these results above shows that the numbers such as '0' and '1' exhibiting more distinctive characteristic features show a higher accuracy of more than 99% while numbers such as '8' and '9' depict a slightly lower accuracy due to absence of highly distinctive features. The graph shows a plot of accuracy percentage

v/s digit occurred in a random experiment. Here, digit '0' has the highest accuracy while digit '8' has the lowest.

V. CONCLUSION AND FUTURE SCOPE

The result obtained is correct up to 94.47% of the cases. This paper envisages methods that can efficiently extract feature vectors from each individual image. A relatively small amount of training data is sufficient for the accuracy in handwritten digit recognition. Also, Neural network seems to be better than other techniques used for digit recognition. Using neural network technology, a parking system can be designed such that it captures images and accordingly checks which parking slot is empty stopping entry when the parking lot is full. This technique can also be used to hack into systems protected by CAPTCHA technology. Deciphering sign language actions of the deaf and dumb is also a potential application of convolutional neural networks and computer vision.

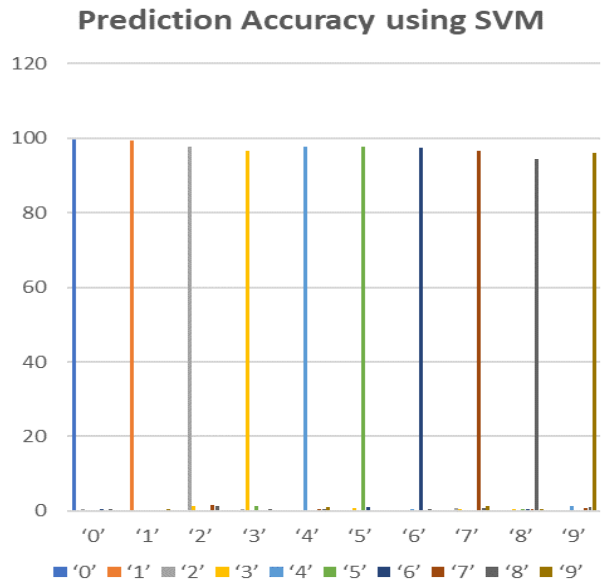

Figure 7: Other Results

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