Numeric Digit Classification Using HOG Feature Space and Multiclass Support Vector Machine Classifier

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ABSTRACT
Pattern recognition is one of the major challenges in statistics framework. Its primary goal is to extract efficient feature and accurately classify the patterns into categories. A well-known and vital application in this field is the handwritten digit classification and recognition where digits have to be assigned into one of the 10 classes using some classification method. There are several approaches for handwritten digits classification and recognition. This paper proposed an efficient image appearance feature based approach which process the acquired digit image using Histogram of Oriented Gradients (HOG). HOG is a very efficient feature descriptor for data discrimination and very stable on illumination variation because it is a gradient based descriptor. For the efficient classification of the HOG features of numeric digits, a linear multiclass Support Vector Machine (SVM) classifier has been proposed, because it has better responses for nonlinear classification cases also.

Mixed National Institute of Standards and Technology (MNIST) handwritten numeric digit dataset has been used to test the classification accuracy of the proposed numeric digit classification system. For the implementation and testing of proposed system MATLAB 2015 (a) software platform has been used. The proposed system has been evaluated against the Neural Network based classification system. The classification and recognition efficiency of the proposed system and NN classifier based system has been evaluated using True Recognition Efficiency (FRE) and False Recognition Rate (FRR) parameters.

Key Words: Numeric digit classification and recognition, HOG features, NN classifier, FRE, FRR, recognition efficiency, SVM Classifier.

INTRODUCTION
One of the very popular application in computer vision is Handwritten Digits Classification or Recognition (HDR) in the field of character recognition. Digits like other universal symbols are widely used in technology, bank, OCR, analyzing of digits in engineering, postal service, numbers in plate recognition, etc. They are some of the famous applications on HDR [1]. There are 10 classes corresponding to the handwritten digits from ‘0’ to ‘9’ which are very depend on the handwritten. The main difficulty in the handwritten digits recognition is different handwritten style which is a very personal behavior where there are a lot of models for numbers based on the angles, length of the segments, stress on some parts of numbers, etc. Figure (1) shows 15 different handwritten digits related to these issues taken from MNIST database. However recognizing numbers is clear for human but it is not very easy for machines especially when there are some ambiguities on different classes (e.g. ‘1’ and ‘7’).

Recognizing digits is very important because it is related to the numbers thereby the recognition methods have to be very accurate. There are different kinds of HDR approaches reported by researchers: Saxena et
al. [2] proposed a neural network model for classification of handwritten digits; they enhanced their methods using ensemble classification. Das et al. [3] Selected local features in handwritten digits using genetic algorithm and then classified features with SVM. Cardoso and Wichert proposed a biologically inspired model for HDR [4] they also used a linear SVM. A hybrid model is proposed by Niu and Suen [16] where integrating the synergy of two superior classifiers: Convolutional Neural Network (CNN) and Support Vector Machine (SVM) that was the main contribution of authors for improving handwritten digit recognition.

![Fig. 1: Different samples of handwritten digits in MNIST dataset.](image)

This paper presents an efficient HOG feature space based handwritten digit classification and recognition system for MNIST database. In addition to this for efficient classification of HOG features of respective numeric digit a linear multiclass Support Vector Machine (SVM) classifier has been proposed, because it has better responses for nonlinear classification cases also.

## 2. DESCRIPTION OF THE PROPOSED NUMERIC DIGIT CLASSIFICATION SYSTEM

Any classification or recognition system basically comprises three main steps, they are:

i. Preprocessing of input acquired from either capturing device or taken from a database.

ii. Feature extraction for uniquely represent an individual.

iii. Classification of extracted features.

In the same manner the proposed Numeric Digit Classification System (NDCS) of this paper work also involves above three steps. The schematic diagram of the proposed handwritten digit classification and recognition system is shown in Figure (2).

![Fig. 2: Schematic diagram of the proposed system](image)

### 2.1 Pre-processing

The pre-processing is a series of operations performed on the MNIST handwritten numeric digit database which contains 400 input digit. It essentially enhances the image rendering it suitable for segmentation. The various tasks performed on the image in pre-processing stage are shown in Figure (3). Binarization process converts a gray scale image into a binary image using global thresholding technique. Detection of edges in the binaries image using sobel technique, dilation of the image and filling the holes present in it are the
operations performed in the last two stages to produce the pre-processed image [10] suitable for segmentation.

2.2 Segmentation
In the segmentation stage, an image of sequence of characters is decomposed into sub-images of individual character [11]. In the proposed system, the pre-processed input image is segmented into isolated characters by assigning a number to each character using a labeling process. This labeling provides information about number of characters in the image. Each individual character is uniformly resized into 70x50 pixels for extracting its features.

![Image of preprocessing steps](image)

**Fig. 3:** Pre-processing of handwritten Numeric Digit.

2.3 Feature Extraction
In this stage, the features of the numeric digits that are crucial for classifying them at recognition stage are extracted. This is an important stage as its effective functioning improves the recognition rate and reduces the misclassification [12]. HOG based feature extraction scheme for recognizing off-line handwritten numeric digits is proposed in this work. Every digit image of size 70x50 pixels is used to extract HOG feature. The proposed HOG feature is extracted by considering 10x10 dimension of the input digit image. Therefore a complete HOG feature of dimension of size 1x864 has been extracted for each single digit for Neural Network classifier. While a complete HOG feature of dimension of size 1x6336 has been extracted for each single digit for proposed multi class SVM classifier (Fig.4). We have taken the HOG feature for NN classifier with smaller dimension than for the proposed SVM classifier. Because of the off line training complexity of the NN classifier.

![Feature Extraction Diagram](image)

**Fig. 4:** Feature Extraction process.

2.4 Histogram of Oriented Gradients
Histogram of Oriented Gradient (HOG) was first proposed by Dalal and Triggs [5] for human body detection but it is now one of the successful and popular used descriptors in computer vision and pattern recognition. HOG counts occurrences of gradient orientation in part of an image hence it is an appearance descriptor. HOG divides the input image into small square cells (here we used 9x9) and then computes the histogram of gradient directions or edge directions based on the central differences. For
improve accuracy, the local histograms have been normalized based on the contrast and this is the reason that HOG is stable on illumination variation. It is a fast descriptor in compare to the SIFT and LBP due to the simple computations, it has been also shown that HOG features are successful descriptor for detection. HOG features on several numbers have been illustrated in figure (5).

![HOG features for some handwritten numbers](image)

**Fig. 5: HOG features for some handwritten numbers**

### 2.5 Support Vector Machine (SVM)

In machine learning, support vector machines (SVM) are supervised learning models with associated learning algorithms that analyze data and recognize patterns, used for classification and regression analysis. Given a set of training examples, each marked for belonging to one of two categories, an SVM training algorithm builds a model that assigns new examples into one category or the other, making it a non-probabilistic binary linear classifier. An SVM model is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall on. In addition to performing linear classification, SVMs can efficiently perform a non-linear classification using what is called the kernel trick, implicitly mapping their inputs into high-dimensional feature spaces. Neural Network (NN) is a vital tool for regression and classification of feature data. This paper employed a multiclass SVM classifier as a classification tool of HOG feature space developed for a complete dataset of 400 handwritten digits from MANIST database. The HOG feature of dimension 1x6336 for each individual digit have been arranged in the row wise to prepare complete feature space. Hence the final dimension of the feature space developed for the proposed SVM based classification purpose is of 200x6336.

### RESULTS AND DISCUSSION

In this paper a handwritten digit classification and recognition system based on HOG features and multiclass SVM as a classifier has been successfully implemented in the MATLAB 2015(a) software environment. For the online training purpose of the SVM classifier, 200 handwritten numerical digit database form MANIST database has been utilized. While, for the testing of classification and recognition efficiency of the proposed system, a dataset of 200 digits has been utilized which are different then the training dataset. The same scenario has been utilized for the offline training and online testing of NN classifier for the comparison purpose. In the training and testing of both the classifiers within a data set of 200 digits, we have utilized 20 digits for the training and testing purpose for each individual digits from 0 to 9.

Table 1 shows the confusion matrix for handwritten digit classification using HOG based Feature Extraction & NN classifier. While Table 2 shows the confusion matrix for handwritten digit classification using HOG based Feature Extraction & SVM classifier. Horizontal row represents the handwritten digits that is input or given to the recognition system and vertical column represents the classified response of the recognition system.
In Table 1 The number belonging to $5^{th}$ row and 1$^{st}$ column represents, 2 number of handwritten digits belonging to digit 5 but misclassified as digit 1. The number of correct classification are along the diagonal of the confusion matrix i.e. $7^{th}$ row and $7^{th}$ column represents the correct classification of digit 7. So total 17 out of 20 digit are correctly classified for digit 7.

**Table 2: Confusion Matrix for Testing Samples for SVM Classifier based system.**

<table>
<thead>
<tr>
<th>Confusion Matrix</th>
<th>Predicted/Classified Digits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Actual Digit</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

Similarly, in Table 2 The number belonging to $5^{th}$ row and 1$^{st}$ column represents, 1 number of handwritten digits belonging to digit 5 but misclassified as digit 1. The number of correct classification are along the diagonal of the confusion matrix i.e. $7^{th}$ row and $7^{th}$ column represents the correct classification of digit 7. So total 19 out of 20 digit are correctly classified for digit 7 by proposed SVM classifier. Finally Table 3 shows the true and false recognition scenario of the NN classifier based system and proposed SVM classifier based handwritten numeric digit recognition system.

**Table 3: Recognition Efficiency of Proposed System and NN classifier based system.**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Digit</th>
<th>Total Attempts</th>
<th>NN Classifier based System</th>
<th>Proposed System</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>True Recognition</td>
<td>False Recognition</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>20</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>20</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>20</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>20</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>20</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>20</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>20</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>20</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
<td>20</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>20</td>
<td>14</td>
<td>6</td>
</tr>
</tbody>
</table>

From the table 3, the True recognition efficiency (TRE) and False recognition rate (FRR) for NN classifier based system is obtained as

TRE for NN = True recognition/Total attempts = (168/200)*100% = 84 %.
FRR for NN = False recognition/Total attempts = (32/200)*100% = 16 %.
Similarly, from table 3, the True recognition efficiency (TRE) and False recognition rate (FRR) for proposed handwritten numeric digit classification and recognition system is obtained as:

**TRE for proposed system** = True recognition/Total attempts = (195/200)*100% = 97.5%.

**FRR for proposed system** = False recognition/Total attempts = (5/200)*100% = 2.5%.

Finally the true and false digit recognition comparative observation between the NN classifier and proposed system are depicted in figure (6) and figure (7) respectively.

![True Recognition Efficiency Comparison](image)

**Fig. 6:** True digit recognition efficiency comparison.

![False Recognition Rate Comparison](image)

**Fig. 6:** False digit recognition efficiency comparison.

From the resultant tables and comparative chart presented above it is clearly obtained that the proposed handwritten numeric digit classification and recognition system provides very high true recognition efficiency as compare to the conventional NN classifier based system. In addition to this it is also shown that the false digit recognition rate of proposed system is also very less as compare to the available system.

**CONCLUSIONS**

This paper forwarded an efficient system for the effective and accurate classification and recognition of the handwritten numeric digits. After successful implementation of the proposed numeric digit classification system using HOG feature space and multiclass SVM classifier, it has shown that the proposed system provides very high numeric digit classification efficiency as compare to available technique. In addition to this the use of multiclass SVM classifier enables the real time application feasibility of the proposed system, because it doesn’t requires any off line training as in case of NN classifier.
REFERENCES