6. RESULTS AND DISCUSSION

6.1 INTRODUCTION

The chapter interprets the results obtained from the three proposed methods described in chapter 3, chapter 4 and chapter 5. These methods were implemented with MATLAB 7.14.0

6.2 PROPOSED METHOD 1- Recognition of Arabic numerals with Grouping and Ungrouping using Back propagation neural network

In proposed method 1, images of Arabic numerals were taken as sample datasets for the recognition process. Based on the availability of datasets, the work was carried out with handwritten Arabic numerals. The results obtained from the method 1 are elaborated in the following sections.

6.2.1 RESULTS AND DISCUSSION FOR PROPOSED METHOD 1

The handwritten Arabic numeral datasets experimented with the proposed method is shown in figures 6.2 (a).

Figure 6.2 (a): Handwritten Arabic Numeral Dataset

The selected sample dataset was trained first.
Figure 6.2 (b): Performance rate of the training data

The figure 6.2 (b) shows the performance rate of the data provided for training the neural network. It is computed with the number of epochs to the sum squared error. The performance rate was found to be 99.4%.

Figure 6.2 (c): Training state of the given data

The figure 6.2 (c) shows the training state of the data. It shows the number of epochs, the learning rate, validation checks and the gradient.
Figure 6.2 (d): Regression state of the data

Figure 6.2 (d) shows the regression rate plotted for the target value and the output value. After training, sample test image was loaded. The selected numerals for recognition are shown in figure 6.2 (e).

Figure 6.2 (e): Selected numerals for recognition

The image obtained after preprocessing is shown in figure 6.2 (f).

Figure 6.2 (f): Numerals after preprocessing

Figure 6.2 (g): Extracted Image

The extracted image is shown in figure 6.2 (g).
Istinaan thalatha arbaa

Figure 6.2 (h): The extracted images of English numerals and their name in Arabic

After extracting the numeral, its corresponding English numeral and the name in Arabic is displayed as shown in figure 6.2 (h).

The figure 6.2 (i) show the output of various processes in method 1.

![GUI image](image)

**Figure 6.2 (i): The GUI image**

The figure 6.2 (j) shows the Arabic numerals after selection and feature extraction. Figure 6.2 (k) shows four Arabic numerals and their final recognition results.
Figure 6.2 (j): The numerals after selection and feature extraction

Figure 6.2 (k): The final extracted results of the four numerals selected

The receiver operating characteristic curve is as shown in figure 6.2 (l).
The receiver operating characteristic curve is constructed with true positive rate along the X-axis and False positive rate along the Y-axis. The results show the recognition accuracy in the range of 96%-99%.

6.3 PROPOSED METHOD 2 – Pattern Recognition in Digital Images using Morphology based compound operation and Multiclass SVM

The proposed method 2 was described elaborately in chapter 4. The results obtained from proposed method 2 are discussed as follows.

The proposed method 2 recognizes characters from vehicle number plate images. Recognizing alpha numeric characters from vehicle number plate images is one of the application areas of pattern recognition.

6.3.1 Results and Discussion for Proposed Method 2

Vehicle number plate images of vehicles in Karachi are used for experimentation in proposed method 2. The vehicle number plate images in Karachi consist of six characters. The first three characters are alphabets, and the next three are numbers. Such categorization makes the process easy and recognition efficient. The extracted characters from the image then undergo the classification process using Multiclass SVM containing 36 classes. The results obtained after each step is discussed as follows.
Illustrative Example

Step 1: Initially, the given image as shown in figure 6.3 (a) is read and resized.

Figure 6.3 (a): Input image

Step 2: In this preprocessing step, the noise present in the image is removed with the help of median filter and the resulting image is shown in figure 6.3 (b).

Figure 6.3 (b): Image after removing noise

Step 3: Compound Morphological operations: Dilation and Erosion

Figure 6.3 (c) shows the image after dilation operation.

Figure 6.3 (c): Dilated image

Figure 6.3 (d) shows the image after erosion operation.
Figure 6.3 (d): Eroded image

Figure 6.3 (e) shows the image with enhanced edges after subtraction operation.

Figure 6.3 (e): Edge enhanced image

Figure 6.3 (f) shows the brightened image after convolution and erosion.

Figure 6.3 (f): Eroded and convoluted image

Figure 6.3 (g) shows the image after the removal of unwanted horizontal lines.
Figure 6.3 (g): Eroded image after eliminating horizontal lines

Figure 6.3 (h) shows the image after filling operation.

Figure 6.3 (h): Filled Image

Figure 6.3 (i) shows the final morphological image.

Figure 6.3 (i): Binary morphological image

The characters obtained from the above stage are displayed and stored in a file, as shown in figure 6.3 (j).

Figure 6.3 (j): The extracted characters

The extracted image undergoes the classification process using Multiclass SVM.
The output window of an SVM classifier is shown in figure 6.3 (k).

![Figure 6.3 (k): Result from SVM classifier](image)

During the weight randomization process, the alignment of the hyperplane is shown in figure 6.3(l).
The distribution of support vectors over the space is shown in figure 6.3 (m).
The separable points between the hyperplanes are shown in figure 6.3 (n).

Figure 6.3 (m): Distribution of support vectors
Continuous training of data usually provides better results. Training is continued until better results are achieved. During this process, the margin of separation on either side of the hyperplane enlarges. The larger the margin, the better the separation between the classes. The margin value is also displayed separately. This is shown in figure 6.3 (o).
From figure 6.3 (k), it is clear that the hyperplane separates the positive and negative cases. During the weight randomization process, the hyperplane align itself relevant to the support vectors. The support vectors are then randomly distributed over the space. Training process is carried over continuously until the vectors are linearly separable, and is shown in figure 6.3 (n). The sensitivity and specificity obtained is as shown in figure 6.3 (p).
The accuracy value obtained from the method is in the range 97% - 99%. The sensitivity value obtained from the method is 0.6 and the value of specificity was 1.

On comparing the results with some of the papers in literature survey, the proposed method proves better. Phalgun pandya and Mandeep singh [137], used morphology based opening and closing operation for the extraction of characters from vehicle number plate. They have employed OTSU’s method and median filter for binarization and noise removal respectively. The extraction of characters was carried out with template matching. They were able to achieve recognition accuracy of 90%.

The proposed method 2 is an alternative approach to recognize characters from vehicle number plate images with better recognition accuracy. It performs extraction and recognition of characters from number plate images of vehicles in Karachi. Morphology based compound operation comprising erosion, dilation and image subtractions are performed to improve the clarity of the image at various stages. Multiclass SVM classifier framed with 36 classes was constructed for training and recognition. Different vehicle number plate images containing different levels of noise are subjected to this method and
the recognition accuracy is measured. The accuracy of the proposed method is found to be in the range 97% - 99%.

6.4 PROPOSED METHOD 3 – Pattern Recognition in Digital Images using Neuro – fuzzy classifier, K- Nearest neighbor classifier, Artificial Neural Network and Fuzzy classifier

The method 3 was carried out with a new hybrid neuro fuzzy classifier, as an extension of the proposed method 2. The proposed method 3 is also compared with other existing approaches such as, K Nearest Neighbor classifier, Artificial Neural Network and Fuzzy classifier.

The results obtained from method 3 are described in the following sections.

6.4.1 Results and discussion for proposed method 3

For the evaluation of the proposed methodology, many license plate images were considered as input to the system. A database containing 0 to 9 letters and A to Z characters was created, for the training of neuro – fuzzy system. The figure 6.4 (a) shows test image.

![Image](image_url)

(a)

(b)

Figure 6.4: (a) original image (b) The extracted license plate image

After the extraction of characters from license plate they are segmented. The segmented characters from the above affixed license plate are as shown in figure. 6.4(c).
Figure 6.4 (c): Characters that are segmented from the license plate

The segmented characters were then fed into the trained neuro fuzzy system for recognition.

The results obtained after the recognition of characters are given in the Table 6.1.

**Table 6.1: The recognition results obtained for the subjected characters**

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Subjected Character</th>
<th>Results obtained after Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>2</td>
<td>G</td>
<td>G</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

The output of Modified Fuzzy C Means Clustering process is as shown below,
The result for car image 1

![Car Image 1](image1)

Figure 6.4 (d): Car image 1

Iteration count = 1, obj. fcn = 152.587199
Iteration count = 2, obj. fcn = 63.695351
Iteration count = 3, obj. fcn = 35.305615
Iteration count = 4, obj. fcn = 35.200345
Iteration count = 5, obj. fcn = 35.196505
Iteration count = 6, obj. fcn = 35.196331
Iteration count = 7, obj. fcn = 35.196323
Word = CG07M6296

The result for car image 2

![Car Image 2](image2)

Figure 6.4 (e): Car Image 2
Iteration count = 1, obj. fcn = 108.937046
Iteration count = 2, obj. fcn = 69.107873
Iteration count = 3, obj. fcn = 41.086114
Iteration count = 4, obj. fcn = 36.677287
Iteration count = 5, obj. fcn = 36.163195
Iteration count = 6, obj. fcn = 36.084478
Iteration count = 7, obj. fcn = 36.073196
Iteration count = 8, obj. fcn = 36.071632
Iteration count = 9, obj. fcn = 36.071418
Iteration count = 10, obj. fcn = 36.071389
Iteration count = 11, obj. fcn = 36.071385
Word = CG07MA8385

The result for car image 3

Figure 6.4 (f): Car image 3

Iteration count = 1, obj. fcn = 54.773798
Iteration count = 2, obj. fcn = 47.217745
Iteration count = 3, obj. fcn = 26.852241
Iteration count = 4, obj. fcn = 17.779627
Iteration count = 5, obj. fcn = 17.472263
Iteration count = 6, obj. fcn = 17.413150
Iteration count = 7, obj. fcn = 17.402564
Iteration count = 8, obj. fcn = 17.400753
Iteration count = 9, obj. fcn = 17.400449
Iteration count = 10, obj. fcn = 17.400399
Iteration count = 11, obj. fcn = 17.400391
Word =CG07M2088

The results obtained for the Car image 4

Iteration count = 1, obj. fcn = 455.060129
Iteration count = 2, obj. fcn = 366.913022
Iteration count = 3, obj. fcn = 357.057889
Iteration count = 4, obj. fcn = 341.810557
Iteration count = 5, obj. fcn = 331.808585
Iteration count = 6, obj. fcn = 327.739183
Iteration count = 7, obj. fcn = 326.503518
Iteration count = 8, obj. fcn = 326.200778
Iteration count = 9, obj. fcn = 326.135356
Iteration count = 10, obj. fcn = 326.122090
Iteration count = 11, obj. fcn = 326.119480
Iteration count = 12, obj. fcn = 326.118973
Iteration count = 13, obj. fcn = 326.118875
Iteration count = 14, obj. fcn = 326.118856
Iteration count = 15, obj. fcn = 326.118853
word =AED632

Figure 6.4 (g): Car image 4
The results obtained for the Car image 5

Figure 6.4(h): Car Image 5

Iteration count = 1, obj. fcn = 148.605975
Iteration count = 2, obj. fcn = 130.056294
Iteration count = 3, obj. fcn = 127.873684
Iteration count = 4, obj. fcn = 118.087375
Iteration count = 5, obj. fcn = 114.164318
Iteration count = 6, obj. fcn = 113.552947
Iteration count = 7, obj. fcn = 113.059737
Iteration count = 8, obj. fcn = 112.604326
Iteration count = 9, obj. fcn = 112.215319
Iteration count = 10, obj. fcn = 111.915005
Iteration count = 11, obj. fcn = 111.706705
Iteration count = 12, obj. fcn = 111.576029
Iteration count = 13, obj. fcn = 111.500753
Iteration count = 14, obj. fcn = 111.460204
Iteration count = 15, obj. fcn = 111.439424
Iteration count = 16, obj. fcn = 111.429149
Iteration count = 17, obj. fcn = 111.424195
Iteration count = 18, obj. fcn = 111.421846
Iteration count = 19, obj. fcn = 111.420747
Iteration count = 20, obj. fcn = 111.420236
Iteration count = 21, obj. fcn = 111.420000
Iteration count = 22, obj. fcn = 111.419891
Iteration count = 23, obj. fcn = 111.419841
Iteration count = 24, obj. fcn = 111.419818
The figure 6.4 (i) shows the result obtained after each step of the proposed method. The result is shown for car image 1.

![Figure 6.4 (i): The output from the proposed method](image)

The figure 6.4 (j) given below shows the graphical representation for various measures like accuracy, specificity and sensitivity of the proposed method 3.
Figure 6.4 (j): Graphical Representation of Accuracy, Specificity and sensitivity for proposed method 3

The results obtained from K Nearest Neighbor classifier:

The figure 6.4 (k) shows the results obtained from the KNN classifier.

Figure 6.4 (k): The output from KNN Classifier

The figure 6.4 (l) shows the graphical representation for various measures like accuracy, specificity and sensitivity for the KNN method.
The results obtained from Artificial Neural Network:
The figure 6.4 (m) shows the output obtained from the ANN classifier.

Figure 6.4 (m): The output of ANN classifier
The figure 6.4 (n) shows the graphical representation for various measures like accuracy, specificity and sensitivity for the ANN method.

![Graphical Representation of Accuracy, Specificity and sensitivity for ANN method](image)

**Figure 6.4 (n):** Graphical Representation of Accuracy, Specificity and sensitivity for ANN method

The results obtained from Fuzzy classifier

The figure 6.4 (o) shows the output of the Fuzzy classifier.

![Output of the Fuzzy classifier](image)

**Figure 6.4 (o):** The output of the Fuzzy classifier
The figure 6.4 (p) given below shows the graphical representation for various measures like accuracy, specificity and sensitivity for the Fuzzy method.

![Graphical Representation of Accuracy, Specificity and Sensitivity for Fuzzy Method](image)

**Figure 6.4 (p):** Graphical Representation of Accuracy, Specificity and sensitivity for Fuzzy method

**Comparative Analysis**

The recognition accuracy of the proposed method was compared with few existing approaches.

The accuracy, sensitivity and specificity of the proposed method is computed using the following formulae.

\[
Accuracy = \frac{(TP + TN)}{(TP + TN + FP + FN)} \times 100
\]  

(6.1)

\[
Sensitivity = \frac{TP}{(TP + FN)}
\]  

(6.2)

\[
Specificity = \frac{FP}{(FP + TN)}
\]  

(6.3)

The table 6.2 shows the true positive, true negative, false positive and false negative values and the corresponding accuracy, sensitivity and specificity of the proposed method. The values are shown for five sample images.
Table 6.2: Performance Evaluation of proposed method

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Tp</th>
<th>Tn</th>
<th>Ep</th>
<th>Fn</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car2</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>80</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>Car3</td>
<td>9</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>90</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Car6</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>90</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>Car7</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>80</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Car8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>90</td>
<td>0.9</td>
<td>0</td>
</tr>
</tbody>
</table>

The proposed method was compared with three different existing techniques K-NN classifier, Artificial Neural network and the Fuzzy classifier. The results of the methods are shown as follows.

The results of K-NN Classifier

The table 6.3 shows the results obtained from K-NN Classifier

Table 6.3 Performance Evaluation of K-NN Classifier

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Tp</th>
<th>Tn</th>
<th>Ep</th>
<th>Fn</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car2</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>70</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Car3</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>80</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>Car6</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>80</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Car7</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>70</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>Car8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>90</td>
<td>0.9</td>
<td>0</td>
</tr>
</tbody>
</table>

The results for Artificial neural network

The table 6.4 shows the results obtained from Artificial neural network. The accuracy, sensitivity and specificity of the method are shown in table 6.4.
Table 6.4: Performance Evaluation of Artificial neural network

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Tp</th>
<th>Tn</th>
<th>Fp</th>
<th>Fn</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car2</td>
<td>7</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>70</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Car3</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>80</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>Car6</td>
<td>9</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>90</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Car7</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>60</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>Car8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>90</td>
<td>0.9</td>
<td>0</td>
</tr>
</tbody>
</table>

The results for Fuzzy Classifier

The following table 6.5 shows the results obtained when using Fuzzy Classifier

Table 6.5: Performance Evaluation of Fuzzy Classifier

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Tp</th>
<th>Tn</th>
<th>Fp</th>
<th>Fn</th>
<th>Accuracy</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car2</td>
<td>8</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>80</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Car3</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>60</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>Car6</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>70</td>
<td>0.7</td>
<td>0</td>
</tr>
<tr>
<td>Car7</td>
<td>9</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>90</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Car8</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>90</td>
<td>0.9</td>
<td>0</td>
</tr>
</tbody>
</table>

The proposed method was compared against artificial neural network, K- nearest neighbor classifier and the fuzzy classifier. Different varieties of license plate image were input to the method. Artificial neural network yields the recognition accuracy of 95%. Fuzzy classifier yields the recognition accuracy of 94%. K-NN classifier yields the recognition accuracy of 92%. The proposed method 3 yields the recognition accuracy in the range of 98.35%-100%, and proves better than other existing techniques.

Table 6.6 shows the results obtained from the proposed method 3, ANN, FC and KNN methods.
Table 6.6: Comparative Analysis of proposed method, K-Nearest Neighbor Classifier artificial neural network and the fuzzy classifier

<table>
<thead>
<tr>
<th>Methods</th>
<th>Accuracy (%)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposed Method</td>
<td>98.35</td>
<td>83.33</td>
<td>93.33</td>
</tr>
<tr>
<td>ANN</td>
<td>95</td>
<td>80.5</td>
<td>88.8</td>
</tr>
<tr>
<td>Fuzzy Classifier</td>
<td>94</td>
<td>78.5</td>
<td>90.5</td>
</tr>
<tr>
<td>K-NN Classifier</td>
<td>92</td>
<td>81.2</td>
<td>85.5</td>
</tr>
</tbody>
</table>

The figure 6.4 (q) shows the performance comparison of the proposed and existing methods, KNN, ANN and fuzzy. From graph, it is clear that the proposed method provides better accuracy compared to existing methods.

Figure 6.4 (q): Graphical Representation of Accuracy, Specificity and sensitivity for proposed and existing method