CHAPTER 9
Conclusion and Future Research Work

9.1 Summary

In this work, neural network and fuzzy based techniques have been used to develop a highly reliable and robust recognition system for off-line recognition of totally unconstrained handwritten characters. Off-line recognition of isolated handwritten characters is a necessary and often critical part in most real-world applications. The increasing popularity of the neural network models to solve pattern recognition problems has been primarily due to their seemingly low dependence on domain specific knowledge and rule-based approaches and due to the availability of efficient learning algorithms for practitioners to use. The two approaches of the neural networks are supervised and unsupervised learning, both of which are combined in our work to achieve best performance.

A neural network that recognizes the characters from their pixel value combinations becomes very complex and also the memory requirement becomes very large. In order to simplify this, a feature extractor is used which reduces the pixel map to a small number of feature regions. However, the conventional feature extractor cannot efficiently extract the features of handwritten characters, which are written in different styles. This disadvantage is taken care of in our work by using a modified fifteen segment feature extractor. A neural network based feature selector is then used to select only the relevant features from each of the fifteen element feature vector corresponding to each input character. By excluding redundant/irrelevant features from the classification process, a simple classifier with better predictive accuracy on new/unseen patterns can be found. The selector chooses only the ten best features.

The performance of different recognition systems can be compared only when they are tested on the same database. The sample database has been generated by taking
the samples from various research papers of Concordia University as seed values. These samples are originally selected from the 17,000 sample database of U.S. postal services, collected from various parts of USA. The database consists of 10,000 samples each of size 64X64. Of these, 5,000 samples are used for training and the remaining 5,000 samples are used for testing.

Two basic classifiers based on unsupervised Kohonen neural network are developed. In the Kohonen algorithm based (KA) classifier, the misclassification is more since the Euclidean distance formula is uniformly applied to the standard set of samples as well as handwritten samples. This drawback is overcome in the modified Kohonen algorithm based (MKA) classifier, by applying the Euclidean distance formula to only the standard set of samples. The MKA classifier takes less training time and provides better classification accuracy and recognition rate as compared to the KA classifier. It is also observed that the feature selector based classifiers perform better than those without feature selector. Again, based on the time of collection of centroids three feature selector based classifiers are analyzed. They are MKA, MKA50, and MKA75 classifiers. In MKA classifier, the centroids are collected at the beginning of training. In MKA50, the collection of centroids is after 50% of training. In MKA75 classifier, the centroids are collected after 75% of training. It is observed that MKA50 classifier gives the best classification accuracy and hence the best recognition rate.

Kohonen suggested that the classification accuracy can be multiplied by fine-tuning the feature vector map using learning vector quantization. Learning vector quantization is a supervised learning principle that uses class information to move the centroid nodes slightly so as to improve the classifier decision regions. The type two learning vector quantization (LVQ2) method ensures that when class labels mismatch, the centroid corresponding to the minimum distance is moved away from the input vector and at the same time the next nearest centroid is moved closer to the input vector. It was observed that the combined MKA50 and LVQ2 classifier gave best classification accuracy and the rejection rate is also good as compared to the combined MKA, LVQ2, and combined MKA75, LVQ2 classifiers.
The performance of a single layer neural network model can be improved by increasing the number of output nodes such that the classifier decision regions do not intersect. But this is limited by hardware constraints. So, we have enhanced the performance by increasing the number of layers so that the total number of output nodes in the feature map is greatly increased. Thus, the multi-layer neural network developed by us uses a bank of ten 2-dimensional layers. This multilayer architecture is tested with respect to eight different techniques. The multilayer MKA50 and LVQ2 combined classifier yielded optimal results.

The key advantage of neuro-fuzzy approach over traditional ones lies in that the former does not require a mathematical description of the system while modeling. It brings the low-level learning and computational power of neural networks into fuzzy systems and provides the high-level human like thinking and reasoning of fuzzy systems into neural networks. We have developed an off-line handwritten numeral recognition model based on the employment of fuzzy rules together with MKA50 and LVQ2 methods. The combined MKA50 and LVQ2 method is used to produce the prototypes, which together with the corresponding variances are used to determine the fuzzy regions, and fuzzy membership functions. These membership functions then determine the region to which a given input belongs. Fuzzy rules are then generated by learning from the training patterns.

We have studied the improvement in classification accuracy by fine-tuning the feature map by applying LVQ2 supervised learning principle. Same can be done by using LVQ3 technique as suggested by Kohonen, and a comparative study of LVQ2 and LVQ3 techniques can be carried out as a future research work.

The developed systems are robust and 100% reliable. The substitution error is completely eliminated. These character recognition systems can be successfully applied to solve the dead letter problems of postal department. They can also be used to process cheques and forms.
9.2 Future Research Work

As feature extraction influences the classification rate, it can be further strengthened by incorporating fuzzy logic concept to extract the prominent features. Fuzzy logic can also enter neural networks so as to define weights from fuzzy sets. Therefore, the role of fuzzy logic in neural networks is an active area of research. We have developed a neural network based feature selector. Similarly, fuzzy or genetic algorithm based feature selectors can be developed and evaluated. Fuzzy feature selection can also be used to generate an initial rule set for a fuzzy neural network. Genetic algorithm based feature selector may be used to achieve multicriteria optimization in terms of generalization accuracy and costs associated with the features.

The developed systems have been tested using the CENPARMI database of Concordia University. The same can be tested using other databases such as samples collected from Netherlands post office or the ETL9B, the public handwritten character database of Japan.

The neuro-fuzzy recognition system developed by us is proved to be much faster and uses less computer memory than the neural network model alone. Future work may be focused on the optimization of fuzzy membership functions and fuzzy rules for further improvement in classification performance. Further directions for future research in this field include the development of neuro-genetic or neuro-fuzzy-genetic systems for the recognition of totally unconstrained off-line handwritten characters.