CHAPTER 5

CONCLUSIONS AND FUTURE PROSPECTS

5.1 Conclusions

In this thesis simulation and development of an electronic nose sensor system has been reported that has an array of 12 sensors equipped with two classification techniques one of those is RBFN that is a neural network based techniques and another one is ANFIS that features of fuzzy logic as well as neural network. Maximum average percentage resistance change of sensor has been taken as a signal feature to apply on classification techniques. The electronic nose sensor system is simulated for two applications with two different arrays of TGS800 and TGS2000 series sensors. First application is environmental monitoring for 10 toxic chemicals that is harmful for humans and other species and second application is related to 14 commonly used household items smell detection. For each smell 90 measurements or data vectors have been taken which is divided in five subsets each of them of 18. In each subset 12 data vectors are used for training and 6 data vectors for testing. Recognition of a particular odor is almost perfect that can be seen in output patterns. But some errors are there in output patterns. As expected superior results are obtained by ANFIS i.e. percentage error of almost half of the percentage error in RBFN is obtained. Almost 85% of accuracy from ANFIS and almost 70% accuracy from RBFN are obtained in both the applications.

Researchers in many fields of scientific investigation and industrial development become more aware of the capabilities of the electronic nose so the
potential for future developments of innovative e-nose applications is enormous. The present trend is toward the development of electronic noses for specific purposes or a fairly narrow range of applications. This strategy is increasing e-nose efficiency by reducing the number of sensors needed for distinguishing, decreasing instrument costs, and greater portability through miniaturization. With the development of new industrial processes, products and machines, new potential discoveries will continue to increase in this relatively new sector of sensor technology. These developments will tend towards the finding of new ways to apply the electronic noses to solve many new problems and needs for the benefit of mankind.

5.2 Future Prospects

This sensor system can be used for many other applications like coffee quality assurance, fish freshness, meat freshness etc. In this work the effect of temperature and humidity on sensors is not considered. If these two effects have taken into account results will be better and smell identification will be almost perfect. Similarly only one feature of the signal has been taken for recognition of odor because of distorted and unpredicted signal shape as well as to reduce computational complexity so these results are not perfect that is accuracy is not close to 100% but if someone take good measurement devices and facility of getting actual shapes of signals from sensors to take others like area under curve, area under left of peak, time from beginning to the peak etc. he can predict the smell with almost 100% accuracy. Here responses of sensors are entered manually in MATLAB so in future interfacing of LabVIEW responses to MATLAB can be done. Similarly other promising analysis techniques can be used in place of RBFN and ANFIS.
Future research and developments of hybrid micro sensor arrays and the use of adaptive artificial neural networking techniques will lead to superior electronic noses. The major areas of research being carried out in this field are:

- Improved sensitivity for the use of water quality assessment, lower levels of organisms or smaller samples and applications of sensitive microorganism detection.
- Recognition of microorganisms to the strain level in food etc.
- Recognition of infections of various diseases like tuberculosis in noninvasive specimens of breath and sputum.
- Identification of suitable sensors for electronic nose system and development of novel sensors.
APPENDICE A

Training Results for Environment monitoring (10 Chemical smells)

i) RBFN Training result

NEWRB, neurons = 0, MSE = 0.09
NEWRB, neurons = 2, MSE = 0.0700108
NEWRB, neurons = 3, MSE = 0.0600182
NEWRB, neurons = 4, MSE = 0.0500264
NEWRB, neurons = 5, MSE = 0.0400366
NEWRB, neurons = 6, MSE = 0.0300495
NEWRB, neurons = 7, MSE = 0.0200664
NEWRB, neurons = 8, MSE = 0.010092
NEWRB, neurons = 9, MSE = 0.000189506
NEWRB, neurons = 10, MSE = 0.000101103
NEWRB, neurons = 11, MSE = 5.94394e-005
NEWRB, neurons = 12, MSE = 4.87287e-005
NEWRB, neurons = 13, MSE = 3.99724e-005
NEWRB, neurons = 14, MSE = 3.16797e-005
NEWRB, neurons = 15, MSE = 2.42726e-005
NEWRB, neurons = 16, MSE = 1.79717e-005
NEWRB, neurons = 17, MSE = 1.1986e-005
NEWRB, neurons = 18, MSE = 6.62075e-006
NEWRB, neurons = 19, MSE = 2.56986e-006
NEWRB, neurons = 20, MSE = 1.51307e-006
NEWRB, neurons = 21, MSE = 1.28505e-006
NEWRB, neurons = 22, MSE = 1.16265e-006
NEWRB, neurons = 23, MSE = 1.06907e-006
NEWRB, neurons = 24, MSE = 9.88862e-007

ii) ANFIS training result

ANFIS info:
   Number of nodes: 555
   Number of linear parameters: 2304
   Number of nonlinear parameters: 48
   Total number of parameters: 2352
   Number of training data pairs: 100
   Number of checking data pairs: 0
   Number of fuzzy rules: 256

Start training ANFIS ...

1   0.00384371
2   0.00373234
3   0.0036527
4   0.0035796
5   0.00350355

Step size increases to 0.011000 after epoch 5.

6   0.00342629
7   0.00334263

Designated epoch number reached --> ANFIS training completed at epoch 7.
APPENDICE B

Training Results for Household Items Identification (14 Smells)

i) RBFN training result
NEWRB, neurons = 0, MSE = 0.0705175
NEWRB, neurons = 2, MSE = 0.0595307
NEWRB, neurons = 3, MSE = 0.0543968
NEWRB, neurons = 4, MSE = 0.0492619
NEWRB, neurons = 5, MSE = 0.0440994
NEWRB, neurons = 6, MSE = 0.0389222
NEWRB, neurons = 7, MSE = 0.0336642
NEWRB, neurons = 8, MSE = 0.0282089
NEWRB, neurons = 9, MSE = 0.0229853
NEWRB, neurons = 10, MSE = 0.0176614
NEWRB, neurons = 11, MSE = 0.0132631
NEWRB, neurons = 12, MSE = 0.00806135
NEWRB, neurons = 13, MSE = 0.00299657
NEWRB, neurons = 14, MSE = 0.00266504
NEWRB, neurons = 15, MSE = 0.0013742
NEWRB, neurons = 16, MSE = 3.19835e-005
NEWRB, neurons = 17, MSE = 1.38616e-005
NEWRB, neurons = 18, MSE = 1.07395e-005
NEWRB, neurons = 19, MSE = 9.32022e-006
NEWRB, neurons = 20, MSE = 7.11922e-006
NEWRB, neurons = 21, MSE = 5.03671e-006
NEWRB, neurons = 22, MSE = 3.61995e-006
NEWRB, neurons = 23, MSE = 2.01504e-006
ii) ANFIS training result

ANFIS info:

Number of nodes: 555
Number of linear parameters: 2304
Number of nonlinear parameters: 48
Total number of parameters: 2352
Number of training data pairs: 140
Number of checking data pairs: 0
Number of fuzzy rules: 256

Start training ANFIS ...

1   0.013385
2   0.0124299
3   0.0115148
4   0.0106515
5   0.00984987

Step size increases to 0.011000 after epoch 5.
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>0.00911719</td>
</tr>
<tr>
<td>7</td>
<td>0.00839627</td>
</tr>
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</table>

Designated epoch number reached --> ANFIS training completed at epoch 7.
APPENDICE C
LIST OF PUBLICATIONS


- Published a paper titled “Electronic Nose in Food and Health Applications: A Review” in *International Journal of Computing and Corporate Research (IJCCR)* International Manuscript ID: ISSN2249054X-V2I6M8-112012 Vol. 2 Issue 6 November 2012
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