

# Contents

## Chapter 1.

### An overview of radial basis function networks

*J. Ghosh and A. Nag*

1	Introduction .....	1
2	Exact interpolation .....	3
3	Function approximation .....	5
3.1	Convergence rates.....	7
4	Radial basis function network training.....	8
4.1	Supervised training .....	8
4.2	Two-stage training .....	9
4.2.1	Unsupervised training of basis function centers and widths .....	10
4.2.2	Batch training of output layer weights.....	12
4.3	Comparison of two-stage training with supervised training...	12
4.4	Variants.....	13
5	Model selection .....	13
5.1	Regularization of RBFNs .....	14
5.1.1	Projection matrix.....	15
5.1.2	Cross-validation .....	15
5.1.3	Ridge regression.....	16
5.1.4	Local ridge regression.....	17
5.2	Pruning and growing RBFNs .....	17
5.2.1	Forward selection .....	17
5.2.2	Backward elimination .....	18
5.3	Hierarchical growing .....	18
5.3.1	Online approaches: the resource allocating network .....	19
6	The role of scale in RBFNs .....	20
6.1	Training centroids using scale-based clustering.....	20
6.2	Weight training and network complexity .....	21
7	Normalized RBFNs .....	24
7.1	Classification using radial basis function networks .....	24
7.2	Noisy data interpolation theory .....	26
7.3	Kernel regression .....	27
7.4	Solution for missing variables .....	28
8	Applications.....	28

Acknowledgments .....	30
References .....	30

## Chapter 2.

### Using radial basis function networks for hand gesture recognition

*R. Salomon and J. Weissmann*

1      Introduction .....	37
2      Background .....	41
3      Summary of radial basis function networks .....	42
4      Gesture recognition using radial basis functions.....	45
5      Problem description.....	46
6      Methods .....	49
6.1    Data-glove and gestures.....	49
6.2    The neural network.....	49
6.3    Training and test patterns .....	49
6.4    The evolutionary algorithms.....	50
6.5    The fitness function .....	51
7      Results .....	52
8      Discussion .....	55
Acknowledgments .....	57
References .....	57

## Chapter 3.

### Using normalized RBF networks to map hand gestures to speech

*S.S. Fels*

1      Introduction .....	60
2      Overview of Glove-TalkII.....	62
3      Glove-TalkII's neural networks .....	66
3.1    The vowel/consonant decision network (V/C net) .....	66
3.1.1 Performance of the V/C network .....	68
3.2    The vowel network .....	69
3.2.1 Performance of the vowel network .....	73
3.3    The consonant network.....	79
3.3.1 Performance of the consonant network.....	81
3.4    Generating training data and test data for Glove-TalkII.....	83
3.4.1 Consonant network data collection.....	83
3.4.2 V/C network data collection .....	85
3.4.3 Vowel network data collection .....	86

3.5	Summary of Glove-TalkII's neural networks .....	86
4	Qualitative performance of Glove-TalkII.....	87
5	Summary of Glove-TalkII .....	89
	Acknowledgments .....	90
A	Normalized units and weights .....	91
A.1	Normalized weights .....	95
A.2	Example: softmax units .....	96
A.2.1	Softmax output units .....	97
A.2.2	Softmax hidden units .....	98
A.3	Summary of normalization .....	99
	References .....	100

## Chapter 4.

### Face recognition using RBF networks

*A.J. Howell*

1	Introduction .....	103
2	Class separability of pose-varying faces .....	106
2.1	Euclidean distances for faces.....	107
2.1.1	Varying head pose.....	108
2.1.2	Pose classes .....	108
2.2	Discussion.....	110
3	The RBF network model .....	111
3.1	Unsupervised learning .....	111
3.1.1	Hidden unit widths.....	112
3.2	Supervised learning .....	113
3.3	RBF discard measure.....	113
4	Invariance properties of RBF networks.....	113
4.1	Test details .....	115
4.2	Pose invariance .....	115
4.2.1	Inherent pose invariance .....	116
4.2.2	Learned pose invariance .....	119
4.3	Shift and scale invariance .....	122
4.3.1	Shift- and scale-varying data .....	122
4.3.2	Inherent shift and scale invariance.....	123
4.3.3	Learned shift and scale invariance.....	125
4.3.4	The contribution of multi-scale preprocessing .....	127
4.4	Discussion.....	128
5	Face unit RBF networks .....	130
5.1	The face unit network model .....	131

5.2	Face unit networks as adjudicators .....	132
6	Learning expression/pose classes .....	133
6.1	Expression invariance.....	133
6.2	Classifying expression and pose.....	135
6.3	Discussion.....	136
7	Conclusion.....	136
	References .....	138

## **Chapter 5.**

### **Classification of facial expressions with domain Gaussian RBF networks**

*J.M. Hogan, M. Norris, and J. Diederich*

1	Introduction .....	143
2	Development of facial expression perception .....	145
3	Radial basis functions.....	146
3.1	Domain response units.....	147
3.2	Network training methods .....	148
3.3	A biological interpretation.....	150
4	The learning task .....	152
5	Results for static images.....	153
6	Digital morphing and dynamic images .....	156
7	Discussion .....	159
8	Conclusions .....	162
	Acknowledgments .....	163
	References .....	164

## **Chapter 6.**

### **RBF network classification of ECGs as a potential marker for sudden cardiac death**

*H.A. Kestler and F. Schwenker*

1	Introduction .....	167
2	Medical background: review of non-invasive risk stratification in patients after myocardial infarction.....	169
3	Selected methods for training RBF classifiers .....	178
3.1	Selection of seed prototypes .....	180
3.2	Adapting the prototype location .....	181
3.3	Construction of the RBF network.....	184
3.3.1	Setting of the kernel widths .....	185

3	3.3.2 Gradient descent.....	185
4	4 Data .....	187
5	5 Results .....	192
6	6 Concluding remarks .....	198
	Acknowledgment.....	205
	References .....	205

## Chapter 7.

### Biomedical applications of radial basis function networks

*A. Saastamoinen, M. Lehtokangas, A. Värtti, and J. Saarinen*

1	1 RBF networks in medicine .....	215
1.1	1.1 ECG signal processing.....	215
1.2	1.2 Ischemia classification.....	216
1.3	1.3 Diagnostics of hypertrophy and myocardial infarction .....	217
1.4	1.4 Image matching .....	220
1.5	1.5 Image segmentation.....	221
1.6	1.6 Source localization .....	222
1.7	1.7 Performance monitoring .....	224
1.8	1.8 Neural control of drug delivery systems.....	226
1.9	1.9 Nonstationary signal estimation .....	228
1.10	1.10 Nonlinear time series prediction.....	229
1.11	1.11 Diagnostics of low back disorders.....	230
1.12	1.12 Digital mammography.....	232
1.13	1.13 Glaucoma diagnostics.....	234
1.14	1.14 Cancer diagnostics .....	236
2	2 Design of biomedical pattern recognition systems.....	239
2.1	2.1 Detailed specification of the problem.....	240
2.2	2.2 Data acquisition and morphological analysis .....	243
2.3	2.3 Preprocessing and feature extraction .....	244
2.4	2.4 Selection of the neural network paradigm .....	245
2.5	2.5 Training and validation.....	247
3	3 Case study: automated detection of interference waveforms in EEG recordings .....	250
3.1	3.1 Clinical background.....	251
3.2	3.2 Detailed specification of the problem.....	252
3.3	3.3 Data acquisition and morphological analysis .....	254
3.3.1	3.3.1 Movement artefacts.....	254
3.3.2	3.3.2 Saturation artefacts.....	255
3.3.3	3.3.3 EMG artefacts .....	255

3.3.4 Epileptic signal patterns .....	256
3.4 Preprocessing and feature extraction .....	256
3.4.1 Movement artefacts .....	257
3.4.2 Saturation artefacts .....	258
3.4.3 Muscle artefacts and other HF contaminations .....	259
3.5 Selection of the neural network paradigm .....	260
3.6 Training and validation .....	260
3.7 Discussion .....	262
Acknowledgments .....	263
References .....	264

## Chapter 8.

### 3-D visual object classification with hierarchical radial basis function networks

*F. Schwenker and H.A. Kestler*

1 Introduction .....	269
2 Object localization and feature extraction .....	271
2.1 Visual attention – regions of interest in the camera image ...	271
2.2 Feature extraction .....	273
3 Learning in RBF networks .....	273
3.1 Support vector learning .....	276
3.2 Multiclass classification .....	278
4 SVM classifier trees .....	279
5 Data and classification results .....	282
5.1 Data sets .....	282
5.1.1 Artificial data .....	283
5.1.2 Real-world data set of camera images .....	284
5.2 Results .....	284
6 Conclusion .....	289
Acknowledgments .....	290
References .....	290

## Chapter 9.

### Controller applications using radial basis function networks

*K. Takahashi*

1 Introduction .....	295
2 RBFN controller design .....	297
3 Simulation study .....	301

3.1	Model of flexible micro-actuator.....	301
3.2	Simulation results .....	303
4	Experiment .....	310
4.1	Force control of a 1-degree-of-freedom robot.....	311
4.2	Angular position control of 1-degree-of-freedom robot.....	313
5	Conclusions .....	315
	Acknowledgments .....	315
	References .....	315

## **Chapter 10.**

### **Model-based recurrent neural network for fault diagnosis of nonlinear dynamic systems**

*C. Gan and K. Danai*

1	Introduction .....	319
2	Methodology .....	322
3	Training .....	328
3.1	Training by dynamic backpropagation.....	329
3.2	Training by the extended Kalman filter.....	331
4	Performance evaluation in modeling.....	333
5	Application in fault diagnosis.....	338
5.1	The benchmark problem.....	340
5.2	Traditional neural network application.....	342
5.3	Result from application of MBRNN .....	344
6	Conclusion.....	347
	Acknowledgment.....	349
	References .....	349
	<b>Index.....</b>	<b>353</b>
	<b>List of contributors .....</b>	<b>357</b>