

---

## Contents

<b>Foreword</b> .....	V
<b>Preface</b> .....	VII
<b>Acknowledgements</b> .....	XIII
<b>1 Introduction to Soft Computing</b> .....	1
1.1 Introduction .....	1
1.2 Importance of Soft Computing .....	3
1.3 Main Components of Soft Computing .....	4
1.3.1 Fuzzy Logic .....	4
1.3.2 Artificial Neural Networks .....	5
1.3.3 Introduction to Evolutionary Algorithms .....	7
1.3.4 Hybrid Intelligent Systems .....	8
1.4 Summary .....	9
1.5 Bibliography and Historical Notes .....	10
1.6 Exercises .....	10
<b>2 Life History of Brain</b> .....	11
2.1 Introduction .....	11
2.2 Development of Brain with Age .....	12
2.3 Technologies for Study the Details of Brain .....	14
2.3.1 Electro Encephalo Graph (EEG) .....	15
2.3.2 Computerized Axial Tomography (CAT) .....	15
2.3.3 Positron Emission Tomography (PET) .....	15
2.3.4 Magnetic Resonance Imaging (MRI) .....	16
2.3.5 Magneto Encephalo Graphy (MEG) .....	16
2.4 Brain Functioning .....	16
2.5 Brain Structure .....	17

2.6	Brainwaves to Study the State of Brain .....	18
2.7	Summary .....	21
2.8	Bibliography and Historical Notes .....	22
2.9	Exercises .....	22
<b>3</b>	<b>Artificial Neural Network and Supervised Learning .....</b>	<b>23</b>
3.1	Introduction .....	23
3.2	Comparison of Neural Techniques and Artificial Intelligence ..	24
3.3	Artificial Neuron Structure .....	24
3.4	Adaline .....	28
3.5	ANN Learning .....	38
3.6	Back-Propagation Learning .....	39
3.7	Properties of Neural Networks .....	45
3.8	Limitations in the Use of Neural Networks .....	45
3.9	Summary .....	48
3.10	Bibliography and Historical Notes .....	49
3.11	Exercises .....	49
<b>4</b>	<b>Factors Affecting the Performance of Artificial Neural Network Models .....</b>	<b>51</b>
4.1	Network Complexity .....	51
4.1.1	Neuron Complexity .....	51
4.1.2	Number of Layers .....	52
4.1.3	Number of Neurons in Each Layer .....	53
4.1.4	Type and Number of Interconnecting Weights .....	53
4.2	Problem Complexity .....	54
4.2.1	Range of Normalization of Training Data .....	54
4.2.2	Type of Functional Mapping .....	55
4.2.3	Sequence of Presentation of Training Data .....	60
4.2.4	Repetition of Data in the Training Set .....	60
4.2.5	Permissible Noise in Data .....	62
4.3	Learning Complexity .....	63
4.3.1	Training Algorithms of ANN .....	63
4.3.2	Selection of Error Functions .....	81
4.3.3	Mode of Error Calculation .....	82
4.4	Summary .....	82
4.5	Bibliography and Historical Notes .....	84
4.6	Exercises .....	85
<b>5</b>	<b>Development of Generalized Neuron and Its Validation .....</b>	<b>87</b>
5.1	Existing Neuron Model .....	87
5.2	Development of a Generalized Neuron (GN) Model .....	90
5.3	Advantages of GN .....	93

5.4	Learning Algorithm of a Summation Type Generalized Neuron .....	94
5.5	Benchmark Testing of Generalized Neuron Model .....	98
5.5.1	Ex-OR Problem .....	98
5.5.2	The Mackey-Glass Time Series .....	102
5.5.3	Character Recognition Problem .....	105
5.5.4	Sin(X1) * Sin(X2) Problem .....	107
5.5.5	Coding Problem .....	107
5.6	Generalization of GN model .....	114
5.6.1	GN Model-1 .....	115
5.6.2	GN Model-2 .....	115
5.6.3	GN Model-3 .....	116
5.6.4	GN Model-4 .....	116
5.7	Discussion on Benchmark Testing .....	117
5.8	Summary .....	121
5.9	Exercises .....	122
<b>6</b>	<b>Applications of Generalized Neuron Models .....</b>	<b>123</b>
6.1	Application of GN Models to Electrical Machine Modeling .....	123
6.1.1	GN Models .....	123
6.1.2	Results .....	125
6.1.3	Discussions .....	125
6.1.4	Training Time and Data Required .....	125
6.1.5	Fault Tolerant Capabilities .....	125
6.1.6	Effect of Different Mappings on GN Models .....	133
6.1.7	Effect of Different Normalizations on GNN Models .....	136
6.1.8	Conclusions .....	140
6.2	Electrical Load Forecasting Problem .....	141
6.2.1	Litreture Review .....	142
6.2.2	Short Term Load Forecasting Using Generalized Neuron Model .....	145
6.2.3	Training of ANN and GN Model .....	149
6.2.4	Testing of ANN and GNM .....	152
6.2.5	Discussion on Training and Testing Results .....	153
6.3	Load Frequency Control Problem .....	155
6.3.1	Need of Load Frequency Control .....	156
6.3.2	Requirements for Selecting Controller Strategy .....	157
6.3.3	Modelling of Thermal Power Plant (Single Area System): .....	158
6.3.4	Response of Load Frequency Control of an Isolated (Single Area) Power System .....	163
6.3.5	Development of GN Based Load Frequency Controller .....	176

## XVIII Contents

6.4	Power System Stabilizer Problem .....	186
6.4.1	Conventional PSS .....	187
6.4.2	GN Based PSS and its Training .....	188
6.4.3	Comparison of GN and ANN PSS .....	190
6.4.4	Simulation Results of GN Based PSS .....	190
6.4.5	Experimental Test .....	194
6.4.6	Adaptive GN Based Power System Stabilizer .....	198
6.4.7	Conclusions .....	210
6.5	Aircraft Landing Control System Using GN Model .....	210
6.5.1	Introduction .....	211
6.5.2	Aircraft Landing System .....	211
6.5.3	Drawbacks of Existing Landing Control System .....	213
6.5.4	Mathematical Model Development of Aircraft During Landing .....	214
6.5.5	Development of Landing Control System Using GN Model .....	215
6.5.6	Simulation Results .....	218
6.5.7	Conclusions .....	221
6.6	Bibliography and Historical Notes .....	221
<b>7</b>	<b>Introduction to Fuzzy Set Theoretic Approach .....</b>	<b>223</b>
7.1	Introduction .....	223
7.2	Uncertainty and Information .....	226
7.3	Types of Uncertainty .....	228
7.4	Introduction of Fuzzy Logic .....	230
7.5	Historical Development of Fuzzy Logic .....	231
7.6	Difference Between Precision and Significance .....	233
7.7	Fuzzy Set .....	233
7.8	Operations on Fuzzy Sets .....	235
7.8.1	Fuzzy Intersection .....	235
7.8.2	Fuzzy Union .....	235
7.8.3	Fuzzy Complement .....	236
7.8.4	Combination .....	237
7.8.5	Fuzzy Concentration .....	237
7.8.6	Fuzzy Dilation .....	237
7.8.7	Fuzzy Intensification .....	238
7.8.8	$\alpha$ -Cuts .....	238
7.8.9	Fuzzy Quantifier/Modifier/Hedges .....	239
7.9	Characteristics of Fuzzy Sets .....	244
7.9.1	Normality .....	244
7.9.2	Convexity .....	244
7.9.3	Cross Over Point .....	245
7.9.4	Fuzzy Singleton .....	245
7.9.5	Height .....	246
7.9.6	Cardinality .....	246

7.10	Properties of Fuzzy Sets .....	246
7.10.1	Commutative Property .....	246
7.10.2	Associative Property .....	246
7.10.3	Distributive Property .....	246
7.10.4	Idem Potency .....	247
7.10.5	Identity .....	247
7.10.6	Involution .....	247
7.10.7	Excluded Middle Law .....	247
7.10.8	Law of Contradiction .....	247
7.10.9	Demorgan's Law .....	247
7.10.10	Transitive .....	248
7.11	Fuzzy Cartesian Product .....	249
7.12	Various Shapes of Fuzzy Membership Functions .....	250
7.13	Methods of Defining of Membership Functions .....	253
7.14	Fuzzy Compositional Operators .....	254
7.15	Relation .....	258
7.15.1	Representation Methods of Relations .....	259
7.15.2	Fundamental Properties of a Relation .....	260
7.15.3	Fuzzy Relation .....	263
7.15.4	Operation of Fuzzy Relation .....	266
7.15.5	Projection and Cylindrical Extension .....	269
7.16	Approximate Reasoning .....	271
7.17	Defuzzification Methods .....	280
7.18	Fuzzy Rule Based System .....	282
7.19	Summary .....	283
7.20	Bibliography and Historical Remarks .....	283
7.21	Exercises .....	284
<b>8</b>	<b>Applications of Fuzzy Rule Based System .....</b>	<b>295</b>
8.1	Introduction .....	295
8.2	System's Modeling and Simulation Using Fuzzy Logic Approach .....	296
8.2.1	Selection of Variables, their Normalization Range and the Number of Linguistic Values .....	298
8.2.2	Selection of Shape of Membership Functions for Each Linguistic Value .....	298
8.2.3	Determination of Overlapping of Fuzzy Sets .....	299
8.2.4	Selection of Fuzzy Intersection Operators .....	299
8.2.5	Selection of Fuzzy Union Operators .....	299
8.2.6	Selection of Implication Methods .....	302
8.2.7	Selection of Compositional Rule .....	303
8.2.8	Selection of Defuzzification Method .....	305
8.2.9	Steady State D.C. Machine Model .....	307
8.2.10	Transient Model of D.C. Machine .....	320
8.2.11	Conclusions .....	327

8.3	Control Applications .....	330
8.3.1	Adaptive Control .....	332
8.3.2	PID Control System .....	335
8.3.3	Fuzzy Control System .....	335
8.3.4	Power System Stabilizer Using Fuzzy Logic .....	337
8.4	Summary .....	359
8.5	Bibliography and Historical Notes .....	360
8.6	Exercises .....	361
<b>9</b>	<b>Genetic Algorithms .....</b>	<b>363</b>
9.1	Introduction .....	363
9.2	History of Genetics .....	364
9.3	Genetic Algorithms .....	366
9.3.1	Selection .....	366
9.3.2	Crossover .....	368
9.3.3	Mutation .....	370
9.3.4	Survival of Fittest .....	371
9.3.5	Population Size .....	371
9.3.6	Evaluation of Fitness Function .....	372
9.4	Effect of Crossover Probability on GA Performance .....	373
9.5	Effect of Mutation Probability on GA Performance .....	373
9.6	Main Components of GA .....	375
9.7	Variants .....	377
9.8	Applications of Genetic Algorithms .....	379
9.9	Summary .....	379
9.10	Bibliography and Historical Notes .....	380
9.11	Exercises .....	380
<b>10</b>	<b>Applications of Genetic Algorithms to Load Forecasting</b>	
	<b>Problem .....</b>	<b>383</b>
10.1	Introduction .....	383
10.2	Introduction to Simple Genetic Algorithms .....	384
10.2.1	Crossover Operation .....	385
10.2.2	Mutation .....	386
10.2.3	Population Size (Pop Size) .....	387
10.3	Development of Improved Genetic Algorithm (IGM) .....	387
10.3.1	Basis of Variation of Pc, Pm and Popsiz .....	388
10.3.2	Development of Fuzzy System .....	390
10.4	Application of Improved Genetic Algorithm (IGA) to Electrical Load Forecasting Problem .....	390
10.5	Results .....	393
10.6	Integrated Fuzzy GA Technique .....	393
10.6.1	Development of Adaptive Fuzzy System .....	395
10.7	Limitations of GA .....	401
10.8	Summary .....	402

<b>11 Synergism of Genetic Algorithms and Fuzzy Systems for Power System Applications</b>	403
11.1 Introduction	403
11.2 Transmission Planning, Pricing and Structure/Models of Indian Power Sector	404
11.3 GA-Fuzzy System Approach for Optimal Power Flow Solution	410
11.3.1 OPF Problem	411
11.3.2 Synergism of GA-Fuzzy System Approach	413
11.3.3 GA-Fuzzy System Approach for OPF Solution (GAF-OPF)	413
11.3.4 Test Results	416
11.3.5 Conclusions	431
11.4 Transmission Pricing Model Under Deregulated Environment	431
11.4.1 Introduction	431
11.4.2 Marginal Cost Based Transmission Pricing Method	434
11.4.3 Postage Stamp Method	446
11.4.4 MW Mile Methods	448
11.4.5 Hybrid Deregulated Transmission Pricing Model	452
11.4.6 Conclusion	456
11.5 Congestion Management Using GA-Fuzzy Approach	457
11.5.1 Introduction	457
11.5.2 Transmission Congestion Penalty Factors	459
11.5.3 Proposed Methods for Congestion Management	461
11.5.4 Test Results	463
11.5.5 Conclusions	466
11.5.6 Bibliography and Historical Notes	471
<b>12 Integration of Neural Networks and Fuzzy Systems</b>	479
12.1 Introduction	479
12.2 Adaptive Neuro-Fuzzy Inference Systems	481
12.3 Constraints of ANFIS	484
12.4 HIV/AIDS Population Model Using Neuro-Fuzzy Approach	484
12.4.1 Introduction	485
12.4.2 Roots of HIV/AIDS	485
12.4.3 Neuro-Fuzzy Approach of Modeling	487
12.4.4 Conclusions	495
12.5 Summary	498
12.6 Bibliographical and Historical Notes	498
12.7 Exercise	498

<b>13 ANN – GA-Fuzzy Synergism and Its Applications</b> .....	501
13.1 Introduction .....	501
13.2 Training of ANN.....	502
13.3 Advantages of GA .....	503
13.4 ANN Learning Using GA .....	504
13.5 Validation and Verification of ANN-GA Model.....	505
13.6 Summary .....	507
13.7 Bibliography and Historical Notes.....	508
<b>References</b> .....	509
<b>Glossary</b> .....	557
I. Artificial Neural Network .....	557
II. Fuzzy Systems .....	558
III. Genetic Algorithms .....	560
<b>Appendices</b> .....	563
<b>Power System Model and its Parameters</b> .....	563
A.1 Single Machine Infinite Bus System .....	563
A.2 Multimachine Power System .....	564
<b>C-Code For Fuzzy System</b> .....	567
B.1 Introduction .....	567
B.2 Program for Fuzzy Simulation .....	567
<b>Data For 26-Bus System</b> .....	589
<b>Data For 6-Bus System</b> .....	593
<b>Data For IEEE 30-Bus System</b> .....	595
<b>Data For Modified IEEE 30-Bus System</b> .....	599
<b>Data For Indian UPSEB 75-Bus System</b> .....	603
<b>Index</b> .....	609





<http://www.springer.com/978-3-540-77480-8>

Soft Computing  
Techniques and its Applications in Electrical  
Engineering  
Chaturvedi, D.K.  
2008, XXII, 612 p. 320 illus., Hardcover  
ISBN: 978-3-540-77480-8