

Studies in Computational Intelligence 82

Ajith Abraham · Crina Grosan  
Witold Pedrycz (Eds.)

# Engineering Evolutionary Intelligent Systems

 Springer



**2-006-133-2**

Ajith Abraham  
Crina Grosan  
Witold Pedrycz  
(Eds.)

# Engineering Evolutionary Intelligent Systems

With 191 Figures and 109 Tables

 Springer

---

# Contents

## **Engineering Evolutionary Intelligent Systems: Methodologies, Architectures and Reviews**

<i>Ajith Abraham and Crina Grosan</i> .....	1
1 Introduction .....	1
2 Architectures of Evolutionary Intelligent Systems .....	2
3 Evolutionary Artificial Neural Networks .....	5
3.1 Evolutionary Search of Connection Weights .....	6
3.2 Evolutionary Search of Architectures .....	7
3.3 Evolutionary Search of Learning Rules .....	8
3.4 Recent Applications of Evolutionary Neural Networks in Practice .....	9
4 Evolutionary Fuzzy Systems .....	10
4.1 Evolutionary Search of Fuzzy Membership Functions .....	12
4.2 Evolutionary Search of Fuzzy Rule Base .....	12
4.3 Recent Applications of Evolutionary Fuzzy Systems in Practice .....	13
5 Evolutionary Clustering .....	14
6 Recent Applications of Evolutionary Design of Complex Paradigms .....	15
7 Multiobjective Evolutionary Design of Intelligent Paradigms .....	16
8 Conclusions .....	18
References .....	18

## **Genetically Optimized Hybrid Fuzzy Neural Networks: Analysis and Design of Rule-based Multi-layer Perceptron Architectures**

<i>Sung-Kwun Oh and Witold Pedrycz</i> .....	23
1 Introductory remarks .....	23
2 The architecture of conventional Hybrid Fuzzy Neural Networks (HFNN) .....	25

---

# Contents

## **Engineering Evolutionary Intelligent Systems: Methodologies, Architectures and Reviews**

<i>Ajith Abraham and Crina Grosan</i> .....	1
1 Introduction .....	1
2 Architectures of Evolutionary Intelligent Systems .....	2
3 Evolutionary Artificial Neural Networks .....	5
3.1 Evolutionary Search of Connection Weights .....	6
3.2 Evolutionary Search of Architectures .....	7
3.3 Evolutionary Search of Learning Rules .....	8
3.4 Recent Applications of Evolutionary Neural Networks in Practice .....	9
4 Evolutionary Fuzzy Systems .....	10
4.1 Evolutionary Search of Fuzzy Membership Functions .....	12
4.2 Evolutionary Search of Fuzzy Rule Base .....	12
4.3 Recent Applications of Evolutionary Fuzzy Systems in Practice .....	13
5 Evolutionary Clustering .....	14
6 Recent Applications of Evolutionary Design of Complex Paradigms .....	15
7 Multiobjective Evolutionary Design of Intelligent Paradigms .....	16
8 Conclusions .....	18
References .....	18

## **Genetically Optimized Hybrid Fuzzy Neural Networks: Analysis and Design of Rule-based Multi-layer Perceptron Architectures**

<i>Sung-Kwun Oh and Witold Pedrycz</i> .....	23
1 Introductory remarks .....	23
2 The architecture of conventional Hybrid Fuzzy Neural Networks (HFNN) .....	25

3	The architecture and development of genetically optimized HFNN (gHFNN) .....	27
3.1	Fuzzy neural networks based on genetic optimization .....	27
3.2	Genetically optimized PNN (gPNN) .....	31
3.3	Optimization of gHFNN topologies .....	33
4	The algorithms and design procedure of genetically optimized HFNN (gHFNN) .....	34
4.1	The premise of gHFNN: in case of FS_FNN .....	35
4.2	The consequence of gHFNN: in case of gPNN combined with FS_FNN .....	36
5	Experimental studies .....	40
5.1	Nonlinear function .....	40
5.2	Gas furnace process .....	45
5.3	NO <sub>x</sub> emission process of gas turbine power plant .....	49
6	Concluding remarks .....	53
7	Acknowledgement .....	55
	References .....	55

### **Genetically Optimized Self-organizing Neural Networks Based on Polynomial and Fuzzy Polynomial Neurons: Analysis and Design**

	<i>Sung-Kwun Oh and Witold Pedrycz</i> .....	59
1	Introduction .....	60
2	The architecture and development of the self-organizing neural networks (SONN) .....	62
2.1	Polynomial Neuron (PN) based SONN and its topology .....	62
2.2	Fuzzy Polynomial Neuron (FPN) based SONN and its topology .....	64
3	Genetic optimization of SONN .....	68
4	The algorithm and design procedure of genetically optimized SONN (gSONN) .....	70
5	Experimental studies .....	80
5.1	Gas furnace process .....	80
5.2	Chaotic time series .....	96
6	Concluding remarks .....	100
7	Acknowledgements .....	105
	References .....	106

### **Evolution of Inductive Self-organizing Networks**

	<i>Dongwon Kim and Gwi-Tae Park</i> .....	109
1	Introduction .....	109
2	Design of EA-based SOPNN .....	111
2.1	Representation of chromosome for appropriate information of each PD .....	112
2.2	Fitness function for modelling .....	115

3 Simulation Results ..... 116  
 3.1 Gas furnace process ..... 116  
 3.2 Three-input nonlinear function ..... 120  
 4 Conclusions ..... 124  
 5 Acknowledgement ..... 124  
 References ..... 126

**Recursive Pattern based Hybrid Supervised Training**

*Kiruthika Ramanathan and Sheng Uei Guan* ..... 129  
 1 Introduction ..... 129  
 1.1 Motivation ..... 130  
 1.2 Organization of the chapter ..... 132  
 2 Some preliminaries ..... 132  
 2.1 Notation ..... 132  
 2.2 Simplified architecture ..... 133  
 2.3 Problem formulation ..... 133  
 2.4 Variable length genetic algorithm ..... 134  
 2.5 Pseudo global optima ..... 135  
 3 The RPHS training algorithm ..... 137  
 3.1 Hybrid recursive training ..... 137  
 3.2 Testing ..... 139  
 4 Summary of the RPHS algorithm ..... 139  
 5 The two spiral problem ..... 140  
 6 Heuristics for making the RPHS algorithm better ..... 141  
 6.1 Minimal coded genetic algorithms ..... 142  
 6.2 Seperability ..... 142  
 6.3 Computation intensity and population size ..... 143  
 6.4 Validation data ..... 145  
 6.5 Early stopping ..... 147  
 7 Experiments and results ..... 147  
 7.1 Problems considered ..... 147  
 7.2 Experimental parameters and control algorithms  
 implemented ..... 149  
 7.3 Experimental results ..... 150  
 8 Conclusions ..... 154  
 References ..... 155

**Enhancing Recursive Supervised Learning Using Clustering  
 and Combinatorial Optimization (RSL-CC)**

*Kiruthika Ramanathan and Sheng Uei Guan* ..... 157  
 1 Introduction ..... 157  
 2 Some preliminaries ..... 160  
 2.1 Notation ..... 160  
 2.2 Problem formulation for recursive learning ..... 160  
 2.3 Related work ..... 161

3	The RSL-CC algorithm .....	163
3.1	Pre-training .....	163
3.2	Training .....	164
3.3	Simulation .....	165
4	Details of the RSL-CC algorithm .....	165
4.1	Illustration .....	167
4.2	Termination criteria .....	167
5	Heuristics for improving the performance of the RSL-CC algorithm .....	169
5.1	Minimal coded genetic algorithms .....	169
5.2	Population size .....	170
5.3	Number of generations .....	170
5.4	Duplication of chromosomes .....	170
5.5	Problems Considered .....	170
5.6	Experimental parameters and control algorithms implemented .....	171
5.7	Results .....	172
6	Conclusions and future directions .....	175
	References .....	175

### **Evolutionary Approaches to Rule Extraction from Neural Networks**

	<i>Urszula Markowska-Kaczmar</i> .....	177
1	Introduction .....	177
2	The basics of neural networks .....	178
3	Rule extraction from neural networks .....	180
3.1	Problem formulation .....	180
3.2	The existing methods of rule extraction from neural networks .....	182
4	Basic concepts of evolutionary algorithms .....	184
5	Evolutionary methods in rule extraction from neural networks .....	185
5.1	Local approach .....	186
5.2	Evolutionary algorithms in a global approach to rule extraction from neural networks .....	189
6	Conclusion .....	206
	References .....	207

### **Cluster-wise Design of Takagi and Sugeno Approach of Fuzzy Logic Controller**

	<i>Tushar and Dilip Kumar Pratihar</i> .....	211
1	Introduction .....	213
2	Takagi and Sugeno Approach of FLC .....	215
3	Genetic Algorithm .....	216
4	Clustering and Linear Regression Analysis Using the Clustered Data .....	217

4.1	Entropy-based Fuzzy Clustering (EFC) .....	217
4.2	Approach 1: Cluster-wise Linear Regression .....	219
5	GA-based Tuning of Takagi and Sugeno Approach of FLC .....	220
5.1	Genetic-Fuzzy System .....	221
6	Results and Discussion .....	223
6.1	Modeling of Abrasive Flow Machining (AFM) Process .....	223
6.2	Modeling of Tungsten Inert Gas (TIG) Process .....	231
7	Concluding Remarks .....	248
8	Scope for Future Work .....	248
	References .....	248

**Evolutionary Fuzzy Modelling for Drug Resistant HIV-1 Treatment Optimization**

	<i>Mattia Proserpi and Giovanni Ulivi</i> .....	251
1	Introduction .....	251
1.1	Artificial Intelligence in Medicine .....	251
1.2	Road Map .....	252
2	Background on HIV Treatment and Drug Resistance Onset .....	252
2.1	HIV Replication and Treatment Design .....	253
2.2	Experimental Settings and Data Collection .....	254
3	Machine Learning for Drug Resistant HIV .....	255
4	Fuzzy Modelling for HIV Drug Resistance Interpretation .....	256
4.1	Fuzzy Medical Diagnosis .....	258
4.2	Fuzzy Relational System for In-Vitro Cultures .....	259
4.3	Models for In-Vivo Clinical Data .....	260
5	Optimization Techniques .....	266
5.1	Fuzzy Genetic Algorithms .....	267
5.2	Random Searches .....	270
5.3	Implementation .....	270
5.4	Feature Selection .....	271
6	Application .....	273
6.1	Phenotype Prediction .....	273
6.2	In-Vivo Prediction .....	276
6.3	Conclusions .....	283
7	Acknowledgements .....	284
	References .....	285

**A New Genetic Approach for Neural Network Design**

	<i>Antonia Azzini and Andrea G.B. Tettamanzi</i> .....	289
1	Introduction .....	289
2	Evolving ANNs .....	291
3	Neuro-Genetic Approach .....	297
3.1	Evolutionary Algorithm .....	298
3.2	Individual Encoding .....	299
3.3	Fitness Function .....	300



3.4	Selection	301
3.5	Mutation	302
3.6	Recombination	304
4	Real-World Applications	307
4.1	Fault Diagnosis Problem	307
4.2	Brain Wave Analysis	312
4.3	Financial Modeling	315
5	Conclusion and Future Work	318
	References	320

**A Grammatical Genetic Programming Representation for Radial Basis Function Networks**

	<i>Ian Dempsey, Anthony Brabazon, and Michael O’Neill</i>	325
1	Introduction	325
2	Grammatical Evolution	326
3	Radial Basis Function Networks	328
4	GE-RBFN Hybrid	330
4.1	Grammar	330
4.2	Example Individuals	331
5	Experimental Setup & Results	331
6	Conclusions & Future Work	333
	References	334

**A Neural-Genetic Technique for Coastal Engineering: Determining Wave-induced Seabed Liquefaction Depth**

	<i>Daeho Cha, Michael Blumenstein, Hong Zhang, and Dong-Sheng Jeng</i>	337
1	Introduction	337
1.1	Artificial Neural Networks in Engineering	337
1.2	Genetic Algorithms	338
1.3	ANN models trained by GAs (Evolutionary Algorithms)	338
1.4	Wave-induced seabed liquefaction	339
2	A neural-genetic technique for wave-induced liquefaction	341
2.1	Data preparation	342
3	Results and discussion	344
3.1	Neural-genetic model configuration for wave-induced liquefaction	344
3.2	ANN model training using GAs for wave-induced liquefaction	346
3.3	Results for determining wave-induced liquefaction	347
4	Conclusions	350
	References	350

## On the Design of Large-scale Cellular Mobile Networks Using Multi-population Memetic Algorithms

<i>Alejandro Quintero and Samuel Pierre</i> .....	353
1 Introduction .....	353
2 Background and related work .....	356
3 Memetic Approach .....	359
3.1 Basic Principles of Canonical Genetic Algorithms .....	359
3.2 Basic Principles of Memetic Algorithms .....	360
3.3 Multi-population Approach .....	361
4 Implementation Details .....	362
4.1 Memetic Algorithm Implementation .....	362
4.2 Local Search Strategy .....	364
4.3 Experimental Setting .....	366
5 Performance Evaluation and Numerical Results .....	369
5.1 Comparison with Other Heuristics .....	369
5.2 Quality of the Solutions .....	373
6 Conclusion .....	373
References .....	374

## A Hybrid Cellular Genetic Algorithm for the Capacitated Vehicle Routing Problem

<i>Enrique Alba and Bernabé Dorronsoro</i> .....	379
1 Introduction .....	379
2 The Vehicle Routing Problem .....	382
3 The Proposed Algorithm .....	383
3.1 Problem Representation .....	385
3.2 Recombination .....	386
3.3 Mutation .....	386
3.4 Local Search .....	387
4 Looking for a New Algorithm: the Way to JCell2o1i .....	389
4.1 Cellular vs. Generational Genetic Algorithms .....	390
4.2 On the Importance of the Mutation Operator .....	391
4.3 Tuning the Local Search Step .....	393
5 Solving CVRP with JCell2o1i .....	395
5.1 Benchmark by Augerat <i>et al.</i> .....	397
5.2 Benchmark by Van Breedam .....	398
5.3 Benchmark by Christofides and Eilon .....	400
5.4 Benchmark by Christofides, Mingozzi and Toth .....	401
5.5 Benchmark by Fisher .....	403
5.6 Benchmark by Golden <i>et al.</i> .....	403
5.7 Benchmark by Taillard .....	404
5.8 Benchmark of Translated Instances from TSP .....	406
6 Conclusions and Further Work .....	406
7 Acknowledgement .....	407
References .....	407

A	Best Found Solutions .....	410
B	Results.....	411
<b>Particle Swarm Optimization with Mutation for High Dimensional Problems</b>		
	<i>Jeff Achtnig</i> .....	423
1	Introduction .....	423
1.1	Outline .....	423
1.2	Particle Swarm Optimization .....	423
1.3	Curse of Dimensionality .....	424
2	PSO Modifications .....	425
2.1	Mutation .....	425
2.2	Random Constriction Coefficient.....	426
3	Experimental Settings .....	426
3.1	Standard Test Functions .....	427
3.2	Neural Network Test Functions .....	429
4	Results and Discussion .....	431
4.1	Comparison with Differential Evolution.....	437
5	Conclusions and Future Work .....	438
	References .....	438
	<b>Index</b> .....	441