List of Tables

1.1 Operational Summary of an Evolutionary Algorithm .......................... 5
2.1 Commonly used t-norms and t-conorms ........................................ 18
2.2 Few basic definitions of fuzzy sets ............................................. 19
3.1 User Defined Structure for an ASuPFuNIS network for Hang function approximation problem ............................................. 67
3.2 MPI code snippet for generating user defined datatype .................... 68
3.3 Master-slave implementation: Task distribution .............................. 70
3.4 Comparison of 3-rule PEASuPFuNIS network performance with other models on the Hang function approximation problem ..................... 73
3.5 PEASuPFuNIS average run times on Hang Approximation Problem for 5000 generations with increasing number of slaves ...................... 74
3.6 PEASuPFuNIS master idle times with increasing number of slaves for Hang function approximation problem ....................................... 75
3.7 PEASuPFuNIS run times for 5000 generations on MGTS data with increasing number of slaves for a 5-rule ASuPFuNIS network. The '0' slave entry represents a serial DE run ........................................ 79
3.8 PEASuPFuNIS run times for 100 generations of PEASuPFuNIS on MGTS data with increasing number of strings assigned to the master ............... 80
3.9 Comparison of ASuPFuNIS NRMSEs with other models for Mackey-Glass time series prediction problem ........................................ 81
3.10 Island model implementation: Task distribution .............................. 83
3.11 Best individual cost function values on islands 1 through 5, at MI = 1 ................................................................. 87
3.12 Best individual cost function values on islands 1 through 5, at MI = 1 .................. 87
3.13 Best individual cost function values on islands 1 through 5, at MI = 1 ............ 87
3.14 Best individual cost function values on islands 1 through 5, at MI = 1 ............ 88
3.15 Best individual cost function values on islands 1 through 5, at MI = 1 ............ 88
3.16 Best individual cost function values on islands 1 through 5, at MI = 20 ............ 89
3.17 Best individual cost function values on islands 1 through 5, at MI = 20 ............ 89
3.18 Best individual cost function values on islands 1 through 5, at MI = 20 ............ 89
3.19 Best individual cost function values on islands 1 through 5, at MI = 20 ............ 90
3.20 Best individual cost function values on islands 1 through 5, at MI = 20 ............ 90
3.21 Variance of cost function values on islands 1 through 5, for MI = 1 ............ 91
3.22 Variance of cost function values on islands 1 through 5, for MI = 20 ............ 91
3.23 Island model performance indexes on Hang function approximation problem for migration size = 1 and MI = 1, 5, 10 and 20 ............................. 91
3.24 Best individual cost function values across islands at migration size = 1.
3.25 Best individual cost function values across islands at migration size = 10.
3.26 Variance of cost function values across islands for migration size = 1.
3.27 Variance of cost function values across islands for migration size = 10.
3.28 Performance index (PI) for Hang function approximation problem with MI = 5 and migration sizes 1, 5 and 10.
3.29 Performance index (PI) comparison of a 3 rule PEASuPFuNIS network employing island model strategy for the Hang function approximation problem with other neuro-fuzzy models.
3.30 Comparison of island model implementation with other strategies for a 3 rule EASuPFuNIS network in terms of speed: Hang function approximation problem.
3.31 Comparison of island model based ASuPFuNIS with other models for Narazaki-Ralescu’s function approximation problem.
3.32 Performance comparison on Hang problem for varying DE parameters on island model implementation (5000 generations).
3.33 Comparison of run times on Hang Function Approximation Problem (for 5000 generations) for the master-slave and island model strategies.
4.1 Operational Summary of the Classical DE Algorithm
4.2 A C style pseudo-code for exponential crossover
4.3 Operational Summary of the vlx-DE Algorithm
4.4 Variable Length Crossover Operation
4.5 Population convergence statistics for Iris problem with \( w_R = 0 \) and \( w_E = 1.0 \) \((F = 0.50, CR = 0.80)\)
4.6 Population convergence statistics for Iris problem with \( w_R = 0.5 \) and \( w_E = 1.0 \) \((F = 0.50, CR = 0.80)\)
4.7 Population convergence statistics for Iris problem with \( w_R = 1.0 \) and \( w_E = 1.0 \) \((F = 0.50, CR = 0.80)\)
4.8 Population convergence statistics for Iris problem with \( w_R = 20.0 \) and \( w_E = 1.0 \) \((F = 0.50, CR = 0.80)\)
4.9 Resubstitution errors for Iris data for standard algorithms with different number of prototypes/rules. †: adapted from [116]
4.10 Population distribution for 4000 generations for Narazaki function approximation problem for \( w_R = 0.0 \) and \( w_E = 1.0 \) \((F = 0.50, CR = 0.80)\)
4.11 Population distribution for 4000 generations for Narazaki function approximation problem for \( w_R = 1.0 \) and \( w_E = 1.0 \) \((F = 0.50, CR = 0.80)\)
4.12 Population distribution for 4000 generations for Narazaki function approximation problem for \( w_R = 1.5 \) and \( w_E = 1.0 \) \((F = 0.50, CR = 0.80)\)
4.13 Population distribution for 4000 generations for Narazaki function approximation problem for \( w_R = 2.0 \) and \( w_E = 1.0 \) \((F = 0.50, CR = 0.80)\)
4.14 Population distribution for 4000 generations for Narazaki function approximation problem for \( w_R = 5.0 \) and \( w_E = 1.0 \) \((F = 0.50, CR = 0.80)\)
4.15 Initial population distribution for experiments with unequal initial population distribution
4.16 Population distribution for 5000 generations across the network spaces with initial unequal population size mentioned in Table 4.15. ........................................ 134
4.17 Population distribution for 5000 generations across the network spaces with initial unequal population size mentioned in Table 4.15. ........................................ 134
4.18 Population distribution for 5000 generations across the network spaces with initial differential population size mentioned in Table 4.15. ........................................ 135
4.19 Comparison of vlx-DE based ASuPFuNIS with other models for Narazaki-Ralescu function approximation problem. .................................................. 136
4.20 Population distributions for Chemical plant control problem for 5000 generations with \( \text{WR} = 0.0 \). (\( F = 0.30, CR = 0.70 \), initial population size 100 per rule) .................................................. 138
4.21 Population distributions for Chemical plant control problem for 5000 generations with \( \text{WR} = 10^2 \). (\( F = 0.30, CR = 0.70 \), initial population size 100 per rule) .................................................. 138
4.22 Population distributions for Chemical plant control problem for 5000 generations with \( \text{WR} = 10^4 \). (\( F = 0.30, CR = 0.70 \), initial population size 100 per rule) .................................................. 139
4.23 Population distributions for Chemical plant control problem for 5000 generations with \( \text{WR} = 10^6 \). (\( F = 0.30, CR = 0.70 \), initial population size 100 per rule) .................................................. 139
4.24 Population distributions for Chemical plant control problem for 5000 generations with \( \text{WR} = 10^8 \). (\( F = 0.30, CR = 0.70 \), initial population size 100 per rule) .................................................. 140
4.25 Performance comparison of vlx-DE ASuPFuNIS model with other methods for the Chemical plant control problem .................................................. 141

5.1 Master-slave task distributions for parallel vlx-DE implementation. ........................................ 146
5.2 Island model task distribution (random-random topology) for parallel vlx-DE implementation. ........................................ 150
5.3 vlx-DE based PNSS-ASuPFuNIS parameters for Iris classification problem. 152
5.4 Per string evaluation times for 2, 3, 4 and 5-rule networks. ........................................ 154
5.5 Average run times for Iris classification problem for 100 generations at \( \text{WR} = 0, 0.5, 1.0 \) and 20.0 for serial vlx-DE. ........................................ 154
5.6 Average run times for Iris classification problem for 100 generations at \( w_R = 0 \) for parallel vlx-DE with increasing number of slaves. ........................................ 156
5.7 Average run times for Iris classification problem for 100 generations at \( w_R = 20.0 \) for parallel vlx-DE with increasing number of slaves. ........................................ 156
5.8 String evaluations per slave for a single generation. ........................................ 158
5.9 PNSS-ASuPFuNIS run times of Iris classification problem for 1000 generations, total population size = 800, \( w_E = 1 \) and \( w_R = 0 \), with different parallelization strategies. ........................................ 159
5.10 Master-slave implementation of vlx-DE population: Convergence statistics for Iris problem for \( w_E = 1 \) and \( w_R = 0, 0.5, 1.0, 20.0 \) (\( F = 0.50, CR = 0.80 \)). 162
5.11 Population distribution for Iris data with \( w_E = 1.0, w_R = 0.0 \) across 8 islands with \( MI = 3 \). ........................................ 167
5.12 Population distribution for Iris data with $w_E = 1.0$, $w_R = 0.0$ across 8 islands with $MI = 10$. ................................. 167
5.13 Population distribution for Iris data with $w_E = 1.0$, $w_R = 0.0$ across 8 islands with $MI = 100$. ................................. 168
5.14 Resubstitution errors for Iris data for standard algorithms with different number of prototypes/rules. †: adapted from [116]. ................................. 168
5.15 Parameters for Narazaki-Ralescu function approximation problem. ................................. 169
5.16 Master-slave implementation: population distribution for Narazaki-Ralescu function approximation problem for $w_E = 1$ and varying $w_R$ values. ($F = 0.85, CR = 0.95$). ................................. 171
5.17 Comparison of PNSS-ASuPFuNIS network performance with other models for Narazaki-Ralescu function approximation problem. ................................. 171
5.18 PNSS-ASuPFuNIS run times on Narazaki-Ralescu function approximation problem for 1000 generations, $w_E = 1$ and $w_R = 0$, with different parallel strategies. ................................. 172
5.19 Problem specific parameters for Chemical plant control problem. ................................. 172
5.20 Master-slave implementation: Population distributions for Chemical plant control problem with $w_E = 1$ and varying $w_R$. ($F = 0.30, CR = 0.70$). ................................. 173
5.21 Antecedent connections of optimal networks obtained for Chemical plant control problem, for $w_E = 1.0, w_R = 10^4, 10^6, 10^8$. ................................. 173
5.22 Comparison of PNSS-ASuPFuNIS network performance with other methods for the Chemical plant control problem. ................................. 174
5.23 PNSS-ASuPFuNIS run times on Chemical plant control problem for 1000 generations, $w_E = 1$ and $w_R = 0$, with different parallel strategies. ................................. 175
5.24 Mean misclassification's and number of features selected for Wine data set. ................................. 179
5.25 Test and train misclassification's for Wine data. ................................. 179
6.1 Master-slave parallelization strategy employed for load balancing experiments. ................................. 184
6.2 Rule base I: Symmetric fuzzy rule base of 81 fuzzy rules. ................................. 187
6.3 Rule base II: Asymmetric fuzzy rule base of 81 fuzzy rules. ................................. 188
6.4 Rule base III: Asymmetric fuzzy rule base of 81 fuzzy rules with EL in the last row replaced by VL. ................................. 189
6.5 Algorithm run times at varying statistics collection rate for 100 generations. ................................. 191
6.6 Average run time for Expt A. ................................. 197
6.7 Slave evaluation time for Expt. A. ................................. 197
6.8 Run times for Expt B. ................................. 200
6.9 Run times for Expt C. ................................. 200
6.10 Run times for Expt D. ................................. 200
6.11 Average run times for Expt E. ................................. 202
6.12 String allocation snapshot slaves 1 through 7 for Expt. G. ................................. 205
6.13 Run times for Expt F. ................................. 207
6.14 Run times for Expt G. ................................. 207
6.15 Run times for Expt H. ................................. 207
6.16 Total program run time with network download initiated on P-III node at generation 50 and terminated at generation 150. ................................. 212