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Appendix A

List of Symbols

This appendix lists symbols used within this thesis.

Chapter 2 – Clustering and Quality Measures

P	set of patterns that needs to be partitioned	9
N	number of dimensions	9
$\mathbf{p}_i$	i-th pattern in P	9
I	size of P	9
K	number of clusters	9
C_k	k-th cluster	9
σ	distance based similarity measure	10
Γ	cosine similarity measure	11
$\mathbf{Z}$	covariance matrix for the distribution of feature vectors	11
$\mathbf{p}_i^T$	transpose of $\mathbf{p}_i$	11
$\mathbf{p}_{i,n}$	n-th attribute of i-th pattern in P	12
$\oplus$	exclusive-or between two bits	12
ℓ	linking distance measure	14
$\mathbf{c}_k$	centroid of cluster C_k	16
J_X	function measuring different quantization errors	15
$\mathbf{M}$	matrix of membership degrees	17
$m_{i,k}$	function measuring the degree of membership	17
ϕ	radius of influence	18
C	set of K centroids	18

G	sum of individual densities	18
g	Gaussian density function	19
χ_k	mixing probability for C_k	19
Ω_k	mean vector of C_k	19
ξ_k	distribution parameters for C_k. $\xi_k = (\rho_k, \mu_k, \mathbf{Z}_k)$	19
Ξ	set of ξ	19
Q_X	cluster validity index of X	22
υ	diameter of a cluster	22
E_i	i-th execution of an algorithm	22
C_k^i	k-th cluster in E_i	22
inf	information gain/loss	23
M	magnitude of change	23
d	direction of M	23
$\mathcal{E}$	ascending ordered set of feature vector pair distances	24
e	$e \in \mathcal{E}$; feature vector pair distance	25
$\mathcal{S}_{min}$	sum of a number of smallest feature vector pair distances	24
$\mathcal{S}_{max}$	sum of a number of largest feature vector pair distances	24
ψ	variance of a set of vectors	25
ι	average standard deviation of all clusters	26
n	function which determines whether a feature vector is within the neighbourhood of another vector	26
$inter_{min}$	minimum separation between clusters	27
ω	control parameters for non-stationary environment	29
f	objective (fitness) function	32
$best\,(t)$	best candidate solution in a population at time t	32
$f_{max}\,(t)$	best fitness value in search space at time t	32
$f_{min}\,(t)$	worst fitness value in search space at time t	32
$accuracy\,(t)$	accuracy of $best\,(t)$ at time t	32
$stab\,(t)$	stability of an algorithm at time t	32
$sens\,(t)$	sensitivity of an algorithm to a change at time t	33
$react_{\varepsilon}\,(t)$	time taken to relocate $best\,(t)$ within a minimum time-ratio of ε	33
T	number of time steps	33
$currentBest\,(t)$	fitness of $best\,(t)$	34
$currentBestOff\,(t)$	maximum of $currentBest\left(t'\right)$ where $1 \leq t' \leq t$	34
$currentAvg\,(t)$	the average accuracy of a population at time t	34

Chapter 4 – Artificial Immune Systems

v	average volume in ϖ with radius ϕ	70
$\mathbf{x}$	antigen detector	74
Υ	set of self patterns	74
κ	alphabet size	75
$\mathbf{x}^*$	length-limited/crossover hole	74
$W_i^{\mathbf{x}}$	template window of pattern $\mathbf{x}$ starting at position i in $\mathbf{x}$	74
$\mathbf{s}$	self pattern	76
Θ	multiplying factor	82
$\mathcal{F}$	free-antibodies population	84
$\mathcal{M}$	memory ALC population	84
$\mathbf{b}^*$	clone of $\mathbf{b}$	85
$\mathbf{b}^{'}$	mutated $\mathbf{b}^*$	85
η	number of clones	85
σ_{max}	maximum distance/affinity between two patterns	85
$\mathbf{m}_{min}$	memory ALC with lowest σ	85
ν	concentration level	87
NAT	network affinity threshold	90
ϑ	stimulation level	90
ps	antigen stimulation level	90
ns	network stimulation level	90
nn	network suppression level	90
$\alpha_{\mathbf{b}}$	set of antigen stimulation levels with ALC $\mathbf{b}$	90
$\lambda_{\mathbf{b}}$	set of network stimulation levels with ALC $\mathbf{b}$	90
R	number of resources allocated to an ALC	92
R_k	resource constant	92
$\vartheta^{'}$	normalised stimulation level	92
R_γ	decaying rate of resources	94
R_Λ	mortality threshold	94
$\mathbf{h}$	highest stimulated ALC	94
$\mathcal{B}_{init}$	initial size of $\mathcal{B}$	95
R_{init}	initial value of R	95
R_{max}	maximum number of available resources	96
R_{decay}	decayed resource level	96
s	density of patterns in a set	97

Chapter 5 – A Local Network Neighbourhood Artificial Immune System with Application to Unsupervised Data Clustering

Chapter 7 – Data Clustering in Uncertain Environments using a Local Network Neighbourhood Artificial Immune System

Appendix B

Derived Publications

This appendix provides a list of articles which were derived from the work introduced in this thesis. These articles have been published or are currently being reviewed.

Book Chapters

A.J. Graaff and A.P. Engelbrecht. Chapter 18: Natural Immune System. *Computational Intelligence: An Introduction*, 2nd Edition, A.P. Engelbrecht (Author), John Wiley & Sons, October 2007.

A.J. Graaff and A.P. Engelbrecht. Chapter 19: Artificial Immune Models. *Computational Intelligence: An Introduction*, 2nd Edition, A.P. Engelbrecht (Author), John Wiley & Sons, October 2007.

Journal Publications

A.J. Graaff and A.P. Engelbrecht. Optimised Coverage of Non-self with Evolved Lymphocytes in an Artificial Immune System. *International Journal of Computational Intelligence Research*, vol. 2, no. 2, pp. 127–150, 2006.

A.J. Graaff and A.P. Engelbrecht. Clustering Data in an Uncertain Environment using an Artificial Immune System. *Pattern Recognition Letters*, vol. 32, no. 2, pp. 342–351, January 2011.

A.J. Graaff and A.P. Engelbrecht. Using sequential deviation to dynamically determine the number of clusters found by a local network neighbourhood artificial immune system. *Applied Soft Computing*, vol. 11, pp. 2698–2713, March 2011.

A.J. Graaff and A.P. Engelbrecht. Clustering Data in Stationary Environments with a Local Network Neighborhood Artificial Immune System. *International Journal of Machine Learning and Cybernetics*, submitted May 2011.

Conference Publications

A.J. Graaff and A.P. Engelbrecht. A local network neighbourhood artificial immune system for data clustering. In *IEEE Congress on Evolutionary Computation*, CEC 2007., pp. 260–267, 2007.

A.J. Graaff and A.P. Engelbrecht. Towards a self regulating local network neighbourhood artificial immune system for data clustering. In *IEEE Congress on Evolutionary Computation*, CEC 2008.(IEEE World Congress on Computational Intelligence), pp. 633–640, 2008.