Appendix A

Publications

- A.J. Graaff, A.P. Engelbrecht, *The Artificial Immune System for Fraud Detection in the Telecommunications Environment*, In Proceedings of the Southern African Telecommunication Networks and Applications Conference (SATNAC2003), South Africa, 2003.
- A.J. Graaff, A.P. Engelbrecht, *The Artificial Immune System as Classifier*, South African Institute for Computer Scientists and Information Technologists (SAICSIT2003), In Proceedings of the Post-graduate Research Symposium, pp. 8-9, South Africa, 2003.
- A.J. Graaff, A.P. Engelbrecht, *Using a Threshold Function to Determine the Status of Lymphocytes in the Artificial Immune System*, In Proceedings of the South African Institute for Computer Scientists and Information Technologists (SAICSIT2003), pp. 268-274, South Africa, 2003. A revised version is also submitted to the South African Computer Journal (SACJ).

Appendix B

Symbols

Tables B.1 and B.2 list and define the symbols used throughout this dissertation.

Table B.1: Table of symbols

Symbol	Meaning
a_{neg}	Maximum ADT for an ALC trained with negative selection
a_{pos}	Minimum ADT for an ALC trained with positive selection
b	The number of bins or groups
c	Attribute counter in a pattern
d_l	l-th ALC in D
d_{l_i}	Bit i in receptor of d_l
e	The rate of elitism in the GA
$f(\lambda_{Hyper}, x_{Hyper})$	Hyperbolic Tangent function where λ_{Hyper} controls the steepness of $f(\lambda_{Hyper}, x_{Hyper})$
g	Generation counter in the GA
$g(\lambda_{Sigmoid}, x_{Sigmoid})$	Sigmoid function where $\lambda_{Sigmoid}$ controls the steepness of $g(\lambda_{Sigmoid}, x_{Sigmoid})$
k	Length of an ALC's receptor

Table B.2: Table of symbols (continued)

Symbol	Meaning
$max_{c=1,...C}\{x_{c,j}\}$	Maximum value for attribute c in a data set
$min_{c=1,...C}\{x_{c,j}\}$	Minimum value for attribute c in a data set
p_c	Crossover probability
p_m	Mutation probability
r_i	Bit i in receptor $\mathbf{r}$
w_1, w_2	The weights that influence the objectives in the fitness function
$x_{c,j}$	Value of attribute c of pattern j in a data set
$y = \lvert A_i - B_i \rvert$	Returns the absolute difference between the values of gene i in A and B
A_i	Gene i in parent A
B_i	Gene i in parent B
C	Number of attributes in a pattern
D	Active set of ALCs
D_l	ALC set D after adding l-th evolved ALC
D_L	Initial active ALC set with L evolved ALCs.
G	The maximum number of generations in the GA
$G(x_{c,j})$	Assigns an attribute's value to the correct bin or group
H_g	Population in GA at generation g
I	The number of ALCs in the GA population
K	Population size in the GA
$Max(A_i, B_i)$	Returns the chromosome with the highest value in gene i
$Min(A_i, B_i)$	Returns the chromosome with the lowest value in gene i
$N = \frac{log(b)}{log2}$	Calculates the number of bits necessary to represent b bins or groups
O_i	Gene i in offspring O
P	The number of ALCs in D
$WindowSize$	The number of generations to calculate the moving average on a population's fitness
$XOR(x_i, r_i)$	Exclusive-or between the i-th bit in $\mathbf{x}$ and $\mathbf{r}$
β	Minimum matching ratio of an ALC(space coverage)
$\gamma(\mathbf{x}, \mathbf{r})$	Hamming distance between $\mathbf{x}$ and $\mathbf{r}$
μ_g	The moving average at generation g in the GA
μ_T	The threshold for the difference in moving averages in the GA
$\mu(D_l)$	Average fitness of ALC set D_l
$\mu(H_g)$	The average fitness of population H_g in the GA
$\xi \sim U(0,1)$	Random number generated from a Uniform distribution
ς	Generation gap
τ	The life counter threshold function
υ_{neg}	Negative selection fitness function
υ_{pos}	Positive selection fitness function
$\chi(D, \mathbf{r})$	Average hamming distance between $\mathbf{r}$ and the set D
$\mho$	Finite search space

Appendix C

Abbreviations

ADT: Affinity Distance Threshold

AIS: Artificial Immune System

ALC: Artificial Lymphocyte

EA: Evolutionary Algorithm

EC: Evolutionary Computation

EMR: Expected Matching Ratio

EP: Evolutionary Programming

ES: Evolutionary Strategies

GA: Genetic Algorithm

GP: Genetic Programming

HC: Hit Counter

HD: Hamming Distance

HR: Hit Ratio

HTC: Helper-T-Cell

IS: Iteration Size

LC: Life Counter

MHC: Major Histocompatibility Complex

NIS: Natural Immune System

NKTC: Natural-Killer-T-Cell

Appendix D

Glossary

Affinity: A force that causes the HTC to elect an MHC on the surface of the B-Cell with which the HTC has a stronger binding to unite, rather than with another MHC with a weaker binding.

Affinity Distance Threshold: The receptor on the lymphocyte must bind with a certain affinity to the antigen for the antigen to be detected. This affinity is referred to as the affinity distance threshold.

Alleles: Specific values from the domain of the corresponding parameter assigned to the gene.

Annihilated: The status of a frequently suppressed lymphocyte.

Antibody: Cell produced by a B-Cell after detecting antigen.

Antigen: Material that can trigger an immune response. Antigens can be either bacteria, fungi, parasites and/or viruses.

B-Cell: A lymphocyte that produces antibodies after detecting antigen.

Chromosome: A potential solution to the problem that needs to be optimised.

Clone: Exact copy of a stem cell.

Crossover: Process of exchanging genetic material between two or more selected chromosomes

to produce offspring.

Cytokines: Encourages cell growth, promote cell activation or destroy target cells.

Donor cells: Transplanted blood cells obtained through transplanted organs or blood.

Epitope: The small segments on the surface of an antigen. Epitopes trigger a specific immune response and antibodies bind to these epitopes.

Expected Matching Ratio: The detection ratio of non-self patterns expected from an artificial lymphocyte.

Fitness: Maps the chromosome's representation into a scalar value. Quantifies the quality of the chromosome. The scalar value of the chromosome indicates how close a chromosome is to the optimal solution.

Gene: A parameter in the chromosome's representation with values in the same space as the function being optimised (referred to as *phenotype-space*).

Generation: A population of individuals at a specified time step, evolved from previous populations at earlier time steps.

Genotype-space: An intermediate space to which parameter-values in the chromosome are mapped to.

Helper-T-Cell: Strengthens the cloning of a B-Cell into a plasma cell.

Hit Counter: Keeps record of the number of matched non-self patterns by an artificial lymphocyte.

Hit Ratio: Calculates the ratio at which an artificial lymphocyte matched non-self patterns.

Immature: A T-Cell that is not self-tolerant.

Immune response: The body's reaction to antigens so that the antigens are eliminated to prevent damage to the body.

Iteration Size: The specified number of incoming patterns before calculating the life counter of an artificial lymphocyte.

Life counter: A threshold function that determines in which state an artificial lymphocyte is in its life cycle.

Lymphocyte: Detects any antigens in the body.

Lymphoid organ: Responsible for the growth, development and deployment of the lymphocytes in the immune system.

Lymphokines: Known as cytokines.

Macrophages: Are versatile cells that secrete powerful chemicals and plays an important role in T-Cell activation.

Major Histocompatibility Complex: These molecules are on the surface of a cell and their main function is to bring to light the internal structure of a cell.

Mature: A T-Cell that does not have receptors that bind with molecules that represent *self* cells.

Memory: A B-Cell that frequently detects non-self cells. The function of memory cells is to proliferate to plasma cells for a faster reaction to frequently encountered antigens and produce antibodies for the antigens.

Minimum matching ratio: The coverage of non-self space by an artificial lymphocyte.

Monocytes: Type of phagocyte.

Monokines: Known as cytokines.

Monomeric receptor: A chemical compound that can undergo a chemical reaction with other molecules to form larger molecules.

Multi-modal: Some functions have multiple solutions and are known as multi-modal functions.

Mutation: Randomly changing the genetic representation of a chromosome.

Natural-Killer-T-Cell: Binds to the Major Histocompatibility Complex-molecule and destroys the virally infected cell.

Negative selection: Specific selection method to train artificial lymphocytes to become self-tolerant. The trained ALC covers the non-self space.

Neutrophils: Type of phagocyte.

Niching: A technique that has been developed to find multiple solutions in multi-modal functions.

Non-self: Unwanted foreign cells that is harmful to the body.

Pathogen: Foreign body material (referred to as antigen).

Peptides: The partitions of an antigen.

Phagocytes: Cells that are large cell- and particle-devouring white cells.

Phenotype-space: The domain of the fitness function.

Plasma cell: A B-Cell that produces antibodies.

Positive selection: Specific selection method to train artificial lymphocytes to become self-tolerant. The trained ALC covers the self space.

Self: Normal functioning cells in the body.

T-Cell: A lymphocyte that becomes mature in the thymus. There are two types of T-Cell: Helper-T-Cell and Natural-Killer-T-Cell.