THE DESIGN AND APPLICATIONS OF THE AFRICAN BUFFALO ALGORITHM FOR GENERAL OPTIMIZATION PROBLEMS

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Doctor of Philosophy

(Computer Science)

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy in ……Computer Science…….

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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LIST OF ABBREVIATIONS

ABO	African Buffalo Optimization
ABC	Artificial Bee Colony
ACO	Ant Colony Optimization
ACS	Ant Colony System
ASA-GS	Adaptive Simulated Annealing with Greedy Search
ATSP	Asymmetric Travelling Salesman's Problem
AVR	Automatic Voltage Regulator
BCO	Bee Colony Optimization
DE	Differential Evolution
EO	Extremal Optimization
GA	Genetic Algorithm
HA	Hybrid Algorithm
HBMO	Honey Bee Mating Optimization
HPSACO	Hybrid Particle Swarm Ant Colony Optimization
IGA	Improved Genetic Algorithm
MMAS	Max-Min Ant System
MIMM-ACO	Model Induced Max-Min Ant Colony Optimization
PID	Proportional, Integral, Derivative
PSO	Particle Swarm Optimization
RAI	Randomized Insertion Algorithm
TSP	Travelling Salesman's Problem

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ABSTRAK

Pengoptimuman, pada dasarnya, adalah ekonomi sains. Ia tertumpu kepada keperluan untuk memaksimumkan keuntungan dan meminimumkan kos dari segi masa dan sumber yang diperlukan untuk melaksanakan projek yang diberikan dalam mana-mana bidang yang melibatkan tenaga manusia. Terdapat beberapa kajian saintifik sejak beberapa dekad yang lalu mengenai penemuan algoritma yang efektif dan efisyen dalam menyediakan penyelesaian kepada keperluan pengoptimuman manusia yang membawa kepada pembangunan algoritma berketentuan. Algoritma ini mampu menyediakan penyelesaian yang tepat untuk masalah pengoptimuman. Walaubagaimanapun, dalam tempoh lima dekad yang lalu, perhatian para saintis telah beralih daripada algoritma berketentuan kepada algoritma stokastik sejak ianya terbukti lebih mantap dan berkesan, walaupun tiada penyelesaian yang tepat dijamin. Antara algoritma stokastik yang berjaya dibangunkan antaranya adalah simulasi Annealing, algoritma genetik, Ant Colony Optimization, Particle Swarm Optimization, Bee Colony Optimization, Artificial Bee Colony Optimization, Firefly Optimization dan lain-lain. Kajian secara kritikal di dalam algoritma stokastik yang efisyen mendedahkan keperluan untuk penambahbaikan dari segi keberkesanan, bilangan beberapa parameter yang digunakan, penumpuan pra-matang, keupayaan untuk mencari pelbagai landskap serta strategi pelaksanaan yang kompleks. African Buffalo Optimization (ABO) yang diinspirasikan oleh pengurusan kawanan kerbau, komunikasi dan budaya meragut rumput yang berjaya daripada kerbau Afrika direka sebagai cubaan dalam menyelesaikan kelemahan yang ditemui pada algoritma stokastik pengoptimuman sedia ada. Melalui beberapa prosedur eksperimen, ABO telah berjaya digunakan untuk menyelesaikan penanda aras masalah pengoptimuman dalam mono-modal dan multimodal, sama ada dikekang dan tidak dikekang, landskap carian boleh-asing dan tidak boleh-asing dengan hasil yang kompetitif. Selain itu, algoritma ABO telah digunakan untuk menyelesaikan lebih 100 daripada 118 simetri penanda aras dan semua masalah jurujual kembara tidak-simetri yang terdapat di TSPLIB95. Berdasarkan kejayaan eksperimen dengan algoritma asal, ia adalah selamat untuk disimpulkan bahawa ABO adalah sesuai untuk badan pengoptimuman kajian saintifik.

ABSTRACT

Optimization, basically, is the economics of science. It is concerned with the need to maximize profit and minimize cost in terms of time and resources needed to execute a given project in any field of human endeavor. There have been several scientific investigations in the past several decades on discovering effective and efficient algorithms to providing solutions to the optimization needs of mankind leading to the development of deterministic algorithms that provide exact solutions to optimization problems. In the past five decades, however, the attention of scientists has shifted from the deterministic algorithms to the stochastic ones since the latter have proven to be more robust and efficient, even though they do not guarantee exact solutions. Some of the successfully designed stochastic algorithms include Simulated Annealing, Genetic Algorithm, Ant Colony Optimization, Particle Swarm Optimization, Bee Colony Optimization, Artificial Bee Colony Optimization, Firefly Optimization etc. A critical look at these 'efficient' stochastic algorithms reveals the need for improvements in the areas of effectiveness, the number of several parameters used, premature convergence, ability to search diverse landscapes and complex implementation strategies. The African Buffalo Optimization (ABO), which is inspired by the herd management, communication and successful grazing cultures of the African buffalos, is designed to attempt solutions to the observed shortcomings of the existing stochastic optimization algorithms. Through several experimental procedures, the ABO was used to successfully solve benchmark optimization problems in mono-modal and multimodal, constrained and unconstrained, separable and non-separable search landscapes with competitive outcomes. Moreover, the ABO algorithm was applied to solve over 100 out of the 118 benchmark symmetric and all the asymmetric travelling salesman's problems available in TSPLIB95. Based on the successful experimentation with the novel algorithm, it is safe to conclude that the ABO is a worthy contribution to the scientific literature.

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APPENDIX A- RESEARCH PUBLICATIONS

JOURNALS

1. Odili J.B & M.N.M Kahar. Solving The Travelling Salesman's Problem Using the African Buffalo Optimization. *Computational Intelligence and Neuroscience*. Vol. 501 pp 929547, 2015. (ISI-indexed) (Published)

2. Odili J.B, M.N.M Kahar, A. Noraziah: PID Controller Parameters-Tuning of Automatic Voltage Regulators Using the African Buffalo Optimization. *PLOS ONE 12(4):1-17(ISI-indexed)*

3. Odili J.B: Comparative Implementation of the benchmark Dejong5 function using Flower Pollination Algorithm and the African Buffalo Optimization: *Neural Computation and Application. Springer Inc. (ISI-indexed) (Under Production)*

4. Odili J.B: Implementation Strategies for Cuckoo Search and African Buffalo Optimization for Benchmark Rosenbrock Function: *Neural Computation and Application. Springer Inc. (ISI-indexed) (Under Production)*

5. Odili J.B, M.N.M Kahar, A. Noraziah: An Evaluation of Swarm Intelligence Techniques for Solving Combinatorial Optimization Problems. *International Journal of Advanced Robotics Systems*. (ISI-indexed) (Accepted for Publication)

6. Odili, J.B., M.N.M Kahar & S. Anwar: African Buffalo Optimization: A Swarm Intelligence Technique. *Procedia Computer Science*, Vol. 76C, pp 443-448, 2015. Elsevier Inc. (SCOPUS-indexed) (Published)

7. Odili, J.B., M.N.M Kahar & A. Noraziah: African Buffalo Optimization and the Randomized Insertion Algorithm for the Asymmetric Travelling Salesman's Problems. *Journal of Theoretical and Applied Information Technology*. 87 (3) pp356-364, 2016 (SCOPUS-indexed) (Published)

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11. Odili, J.B., M.N.M Kahar & A. Noraziah A comparative study of Neural Networks methods & the African Buffalo Optimization for the Travelling Salesman's Problems. *Advance Science Letters.* (SCOPUS-indexed) (Accepted for Publication)

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14. Odili, J.B. Application of Ant Colony Optimization to solving the Travelling Salesman's Problems *Science Journal of Electrical and Electronic Engineering, 2013 (2013)*

15. Kunna, M.A., T. A. Abdul Kadir, A. S. Jaber & J. B. Odili. Large-Scale Kinetic Parameter Identification of Metabolic Network Model of E. Coli Using PSO. *Advances in Bioscience and Biotechnology*, Vol. 06(02), 2015, pp120-130.

16. Odili J.B, M.N.M Kahar: Solving Traveling Salesman's Problem Using African Buffalo Optimization, Honey Bee Mating Optimization & Lin-Kernighan Algorithms. *World Applied Sciences Journal*. 34 (7): 911-916, 2016.

17. Odili J.B & M.N.M Kahar. Numerical Functions Optimization Using the African Buffalo Optimization Algorithm. *British Journal of Mathematics & Computer Science.* Vol. 10(1): 1-12, 2015.

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20. Odili, J.B. Flower Pollination Algorithm - A Diagnostic Analysis. *Siam Journal on Computing (ISI-indexed)*

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22. Odili, J.B. & M.A.K Azrag: Stochastic Process and Tutorial of the African Buffalo Optimization. *International Journal of Bio-Inspired Computation (ISI-indexed)*

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24. Nasser A.B, F. Hujainah, J.B. Odili: Hybrid Flower Pollination Algorithm Strategies for Combinatorial Test Suite Generation. *Advances in Engineering Software. Elsevier Inc. (ISI-indexed)*

25. Odili J.B & M.N.M Kahar: A review of Combinatorial Optimization Algorithms for Science and Engineering. *Current Science. (ISI-indexed)*

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30. Odili J.B, M.N.M Kahar, A. Noraziah: Performance Analyses of Nature-inspired Algorithms on the Travelling Salesman's Problems for Strategic Management. *Intelligent Automation and Soft Computing. Taylor and Francis Inc. (ISI-indexed)*

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32. Odili J.B & M.N.M Kahar: African Buffalo Algorithm for Collision-avoidance in Electric Fish. *Intelligent Automation and Soft Computing. Taylor and Francis Inc. (ISI-indexed)*

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34. Odili, J.B: A Review of Combinatorial Optimization for Science and Engineering. *Current Science*. (ISI-indexed)

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36. Anwar, S., J. M. Zain, M. F. Zolkipli, Z. Inayat, A. Naser Jabir, J. B. Odili. Response Option for Attacks Detected by Intrusion Detection System. *Proceedings of the 4th IEEE International Conference of Software Engineering & Computer Systems, (IEEE-ICSECS 2015)*

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43. Odili J.B: Implementation Evaluation of Cuckoo Search for the Benchmark Rosenbrock Test Function**.** . The 8th International Conference on Information Technology, ICIT **2017,** Jordan**.**

44. Ali M, F. Zolkipli, J. Odili, J. Zain: Mobile Cloud Clouding using SOAP and REST Web Services. The 8th International Conference on Information Technology, ICIT **2017,** Jordan**.**