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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# INCORPORATING OF GREY WOLF OPTIMIZATION TO THE BEES ALGORITHM FOR CONTINUOUS OPTIMIZATION IN WELDED-BEAM DESIGN PROBLEM

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons)

by

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Tajuk: **INCORPORATING GREY WOLF OPTIMIZATION TO THE BEES ALGORITHM FOR CONTINUOUS OPTIMIZATION IN WELDED-BEAM DESIGN PROBLEM**

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I hereby declared this report entitled "Incorporating of Grey Wolf Optimization to The Bees Algorithm for Continuous Optimization in Welded-Beam Design Problem" is the result of my own research except as cited in the references.

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# APPROVAL

This is report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the Bachelor of Manufacturing Engineering (Hons.), the member of supervisory committee is as follow:

.................................................................

Nik Mohd Farid Bin Che Zainal Abidin

(Supervisor)

# ABSTRAK

Sebenarnya, dunia ini tidak terwujudnya algoritma yang dapat mengungguli yang lain pada semua masalah pengoptimuman. Oleh itu, perkembangan berterusan algoritma sebelumnya adalah penting kerana keberkesanan algoritma dalam menyelesaikan satu set masalah tidak menjamin kejayaannya dalam pelbagai jenis masalah ujian. Walau bagaimanapun, matlamat projek ini tertakluk sebagai penggabungan Pengoptimuman Grey Wolf (GWO) kepada Algoritma Bees (BA) sebagai algoritma yang dicadangkan untuk menyelesaikan pengoptimuman berterusan dalam masalah reka bentuk las-dikimpal. Objektif projek ini akan meliputi algoritma diubahsuai GWO-BA dan menunjukkan peningkatan kelajuan konvergensi algoritma yang dicadangkan untuk mencari penyelesaian yang optimum terhadap BA sebelumnya. Oleh itu, fungsi ujian tanda aras dengan beberapa ciri yang berbeza akan menjadi kaedah untuk membandingkan algoritma yang dicadangkan dan algoritma sebelumnya untuk menganalisis dan mengesahkan prestasi algoritma yang dicadangkan. Berdasarkan hasil ujian dan simulasi yang dijalankan dalam perisian MATLAB, penambahbaikan terhadap kelajuan konvergensi dan kinerja untuk GWO-BA yang diubahsuai terhadap BA standard adalah 48.12% berdasarkan penilaian min 10 fungsi uji kaji dan 37.43% berdasarkan min harga masalah reka bentuk las dilaraskan.

# ABSTRACT

In fact, there is no existing algorithm which is able to outperform the others on all optimization problems. Therefore, the continuous development of previous algorithms is important because the effectiveness of an algorithm in solving a set of problems will not guarantee its success in different kinds of test problems. However, the goal of this project is subjected as the incorporating of Grey Wolf Optimization (GWO) to the Bees Algorithm (BA) as the proposed algorithm in order to solve the continuous optimization in welded-beam design problem. The objectives of this project will covered the modified algorithm GWO-BA and showed the improvement of convergence speed of proposed algorithm towards searching of optimal solution against the previous BA. Thus, the benchmark test functions with several diverse properties will be the methods that to comparing the proposed algorithm and previous algorithms in order to analyze and validate the performance of the proposed algorithm. Based on the result of running test and simulation in the MATLAB software, the improvements of convergence speed and performance for modified GWO-BA against the standard BA were 48.12% based on the mean evaluation of 10 benchmark test functions and 37.43% based on the mean cost of welded-beam design problem.

# DEDICATION

*This humble work is dedicated to my beloved parents, family, friends,*
*respectful supervisor,*
*all supporters and future researchers.*

ACKNOWLEDGEMENT

First of all, I would like to take this opportunity to give thanks to the ancestors who paved the path before me upon whose shoulders I stand. Following their never-ending footsteps, I am qualified to explore and study the computational methods.

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| | |
|---|---|
| EA | Evolutionary Algorithm |
| GA | Genetic Algorithm |
| DE | Differential Evolution |
| SI | Swarm Intelligence |
| AS | Ant System |
| ACO | Ant Colony Optimisation |
| PSO | Particle Swarm Optimisation |
| LFPSO | Lévy flight Particle Swarm Optimization |
| MBO | Marriage in Honey-Bees Optimisation |
| FMBO | Fast Marriage in Honey-Bees Optimisation |
| HBO | Honey-Bees Optimisation |
| HBMO | Honey-Bees Mating Optimisation |
| VBA | Virtual Bee Algorithm |
| ABC | Artificial Bee Colony |
| BA | Bees Algorithm |
| GWO | Grey Wolf Optimisation |
| MOGWO | Multi-objective Grey Wolf Optimisation |
| LGWO | Lévy-embedded Grey Wolf Optimisation |
| JSSP | Job Shop Scheduling Problem |
| NN | Neural Network |

| | |
|---|---|
| LVQ | Learning Vector Quantization |
| MLP | Multilayer Perceptron |
| NFL | No Free Lunch |
| GWO-BA | the BA that incorporating with GWO |
| n | population |
| m | number of selected sites |
| e | number of top-rated sites out of m selected sites |
| ngh | initial patch size |
| stlim | stagnation limit |
| nep | number of bees recruited for best e sites |
| nsp | number of bees recruited for the other (m-e) selected sites |
| Std. Dev. | standard deviation |
| Avg. | average |
| Mean | central value of a set of numbers |
| D | dimension |
| t | t-value for statistical t-test |
| df | degree of freedom |
| APPROX | Approximation Algorithm |
| DAVID | DAVID Functional Annotation |
| GP | Genetic Programming |
| SIMPLEX | Dantzig's Simplex Algorithm |
| RANDOM | Randomized Algorithm |

# LIST OF SYMBOLS

| | |
|---|---|
| $f(x)$ | objective function |
| $x_i$ | design parameter |
| $f_i(x)$ | design vector function |
| $h_j(x)$ | design vector function |
| $g_k(x)$ | design vector function |
| $\mathbb{R}^n$ | search space |
| $h_j$ | equalities |
| $g_k$ | inequalities |
| $M$ | number of objectives |
| $J$ | number of equality-constraints |
| $K$ | number of inequality-constraints |
| $lb_i$ | lower bound of the iteration variable |
| $ub_i$ | upper bound of the iteration variable |
| $S_N$ | total of each consecutive random step |
| $X_i$ | random step taken from a random distribution |
| $v_0$ | drift velocity of system |
| D | effective diffusion coefficient |
| $S$ | step length |
| $\tau$ | time interval |
| $\gamma$ | scale parameter |

| | |
|---|---|
| $\alpha$ | 1st best solution |
| $\beta$ | 2nd best solution |
| $\delta$ | 3rd best solution |
| $\omega$ | the rest candidate solutions |
| $t$ | iteration |
| $\vec{A}$ | random vector |
| $\vec{C}$ | random vector |
| $\vec{X}^*$ | location of prey |
| $\vec{X}$ | position of wolves |
| $\vec{a}$ | temporal parameter linearly decreased from $a_0$ to 0 |
| $a_0$ | constant parameter basically set to 2 in GWO |
| $r_1, r_2$ | random values within [0, 1] |
| $\vec{X}_\alpha, \vec{X}_\beta, \vec{X}_\delta$ | locations of alpha, beta and delta respectively |
| $\vec{C}_1, \vec{C}_2, \vec{C}_3$ | random vectors |
| $\vec{A}_1, \vec{A}_2, \vec{A}_3$ | random vectors |
| $\alpha_s$ | significance level |
| $\mu$ | population mean |
| $\mu_0$ | hypothesized mean |
| $s$ | sample standard deviation |
| $\bar{X}$ | sample mean |
| $n$ | sample size |

# CHAPTER 1

# INTRODUCTION

This chapter explains the background of this study, problem statements, objectives as well as the scope of the project.

## 1.1 Background Study

Over the years, the fundamentals of the evolutionary algorithm and swarm intelligence were applied as the inspirations for continuous development of population-based algorithms in solving many-sided optimization problems. In general, the optimization is a process of searching the best solutions within the search spaces and it is applicable from engineering design to business planning. Pham & Castellani (2009) states that many real-world engineering problems require the manipulation of a number of system variables in order to optimize a given quality parameter such as the reliability or accuracy of a process, or the value or performance of a product. Therefore, optimization is necessary for actual applications and there is a greater need to achieve sustainability. The population-based algorithm is considered as computation program of Artificial Intelligence (AI) which develop by researchers in order to ease the engineers in solving optimization problems. For instances, the AI program was developed by engineers which enable the computer to operate and perform the intelligent human behavior for solving the problem without any human wor k.

In the past few decades, the nature-inspired metaheuristic was commonly adapted by researchers as a computational problem-solving method in the development of algorithms. The algorithm has been widely used to solve many complex optimization problems and perceived as an important method in the field of AI. There will be mathematical derivations and programming are applied in order to obtain the algorithm models and computer simulations for solving such optimization problems with various efficient search algorithms. Swarm Intelligence (SI) optimization is one of the population-based approaches typically inspired by natural phenomenon such as the behavior that mimics the problem-solving skills from the flock of living creatures. For instances, the Bees Algorithm imitates the foraging behavior of honey bees which considered as one of the examples of a bees-inspired algorithm (Pham *et al.*, 2005). Apart from the Bees Algorithm (BA), there are also examples of the swarm-based methods which known as Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC) and Grey Wolf Optimization (GWO).

Compared to other swarm algorithms, BA is proved to be highly competitive in terms of learning accuracy and speed (Pham and Castellani, 2009). The algorithm performs a selectively of exploitative neighborhood search in the local search which combined with random exploration in global search. In order to boost the algorithm performance especially in term of its search direction, several researchers have combined the BA with the other optimization techniques. Abdullah & Alzaqebah (2013) proposed a hybridized self-adaptive BA with three site-selection techniques of disruptive, tournament and rank selection strategies to solve the examination timetabling problems. Besides that, there was also a research that integrating BA with Artificial Bee Colony (ABC) into a hybrid ABC-BA system to face constrained optimization problems (Tsai, 2014).

## 1.2 Problem Statement

In general, a standard BA applies a uniform random distribution in its initialization phase where the stochastic behavior is contributing the system to generate new solutions to various complex problems. Due to the stochastic behavior, the uniform random distribution of solutions on the search space will causing the unpredictable results since the uncertainty occurred within the generations of numerical solution. Therefore, this is the main reason why BA consisting of a slow convergence speed to the optimum solution and just like the cognition of other stochastic algorithms (Alfi and Khosravi, 2012; Hussein *et al.*, 2013).

A new hybridized (GWO-BA) algorithm was proposed to replace the standard version of BA and improve the convergence speed of optimal solutions. According to Bergh & Engelbrecht (2006), there should be abrupt changes in the movement of search agents over the initial steps of optimization. Additionally, instead of using a uniform random distribution for the local scout bees' initialization in BA, it combined with the use of convergence behavior of GWO which the abrupt changes are set up in the initial steps of iterations with the continuous decrement that across the iterations. For instances, the hierarchy of grey wolf and hunting mechanism from GWO will substitute into the basic structure of BA as the coexisting of both formulations. The GWO-BA can still demonstrate the main features of the basic BA in exploration and exploitation tendencies while it corporate with adaptive value of new parameters from GWO for the well-balanced within the iterations of exploration and exploitation. Hence, the outcome of this project should evaluate and verify the performance of the GWO-BA algorithm by the comparison with other population-based algorithms such as BA, GA, DE, ACO, PSO, and GWO.

## 1.3 Objectives

The objectives of this research are:

i. To propose a modified algorithm by incorporating the GWO with the standard BA for continuous optimization.
ii. To improve the convergence speed of proposed algorithm against the standard BA in term of the searching toward optimal solutions.
iii. To analyze and validate the application of proposed algorithm in the continuous optimization of a welded beam design problem.

## 1.4 Scope of Study

This research focuses on the incorporation of Grey Wolf Optimizer (GWO) with the Bees Algorithm (BA) in continuous optimization. The proposed algorithm shall be applied to ten numerical benchmark test functions as to compare the convergence speed for every function involved. Moreover, this research will also cover in the studies of the previous developments of other approaches in Bees Algorithm (BA). The implementation of the related experiment will be conducted in the MATLAB R2015a (64-bits) by using a laptop with specifications of Intel Core i7-4700MQ 2.40GHz processor and 4GB DDR3 Ram. In the end, the performance of the improved algorithm is analyzed and compared with the previous algorithm as followed by the applications in solving a welded-beam design problem.

## 1.5 Research Significance

As the title of the research is related on the incorporation of Grey wolf optimization (GWO) into Bees Algorithm (BA), the research will be concentrated on the enhancement of the original BA by integrating some optimization techniques from GWO. BA gather the most promising solutions and discriminatingly examines their neighborhoods while looking for the global optima of the objective functions (Pham & Castellani, 2009). In the mechanism of GWO, the evaluation of each solution will decide the type of solutions in either alpha, beta or delta and it based on the hierarchy of wolf pack (Mirjalili *et al.*, 2014). GWO has the abilities of fast approaches to the optimal solution and prevention of local optima while the computation of neighborhood search within solution spaces. In macro, the original structure of Bees Algorithm performs through the stages of initialization, local search, global search and population update. In micro, we try to adapt the social hierarchy of GWO to save the best solutions over the iterations, along with the encircling mechanism and hunting methods are applied in order to strengthen the neighborhood local search of the best and elite sites from BA.

## 1.6 Organization of Report

This report is consists of five chapter. The first chapter covers the introduction of the report. It generally describes the background of the project, problem statement, objective and scope of the project. The remainder of the report is organized as follows.

Chapter two consists of the literature review. This chapter reviews the definition of optimization and highlights the behavior in metaheuristic algorithms. The development of population-based algorithms is presented. Examples of optimization problems that related to the previous researches by Bees Algorithm and Grey Wolf Optimization Algorithm are emphasized. In addition, the No Free Lunch Theorem is briefly described.

Chapter three consists of the methodology of the report. This chapter provides the detailed and precise procedural information on the flow of the research, a method of gathering information and data analyzing. It introduces the adaptive parameter setting in the proposed algorithm. The hybridized algorithm is tested on numerical benchmarks and welded-beam design problem.

Chapter four consists of the result and discussion. This chapter presents the result of analysis and validation of the effectiveness of the proposed algorithm in the convergence to the optimal solution. The statistical results of proposed algorithm on numerical benchmarks and welded-beam design problem will be compared with the previous algorithm. The statistical T-test will be conducted on the results to proven that the results are statistically significant.

Chapter five consists of conclusion and recommendation. This is the last section of the report, it presents a true reflection of the project. It lists the contributions of this project and shows a major impact of the project. It is also summarized the results and provides the recommendation for future research.