HYBRID HARMONY SEARCH ALGORITHM FOR CONTINUOUS OPTIMIZATION PROBLEMS

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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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ABSTRAK

Algoritma Pencarian Harmoni (HS) telah diterima pakai secara meluas dalam literatur untuk menyelesaikan masalah pengoptimuman dalam pelbagai bidang seperti seni reka perindustrian, kejuruteraan awam, kejuruteraan elektrik dan kejuruteraan mekanikal. Bagi mencapai prestasi pencarian, HS memerlukan pelarasan terhadap empat parameter kawalan iaitu saiz pencarian harmoni (HMS), nilai pertimbangan ingatan harmoni (HMCR), nilai penyesuaian nada (PAR) dan jalur lebar (BW). Proses pelarasan ini kebiasaannya rumit dan bergantung kepada masalah yang dihadapi. Tambahan pula, tiada satu saiz yang sesuai untuk semua permasalahan.

Meskipun terdapat pelbagai kajian lepas yang bermanfaat, HS dan variannya masih mengalami eksploitasi lemah yang membawa kepada masalah konvergen. Dalam menyelesaikan masalah tersebut, tesis ini mencadangkan untuk menambah baik HS melalui pelarasan adaptif menggunakan Pengoptimum Serigala Kelabu (GWO). Sementara itu, tesis ini juga mencadangkan untuk mengguna pakai varian baru teknik pembelajaran berdasarkan pertentangan (OBL) bagi meningkatkan eksploitasi HS.

Secara keseluruhan, IHS-GWO bertujuan untuk menyelesaikan masalah pengoptimuman berterusan. IHS-GWO dinilai menggunakan dua set penandaan aras dan dua masalah pengoptimuman dunia nyata. Set penandaan aras pertama merangkumi 24 fungsi unimod dan multimod tanda aras yang klasik. Manakala set penandaan aras kedua mempunyai 30 fungsi tanda aras terkini daripada Kongres Pengiraan Evolusi (*Congress on Evolutionary Computation* (CEC)). Kedua-dua masalah pengoptimuman dunia nyata melibatkan reka bentuk kekuda tiga bar dan spring. Analisis statistik telah dijalankan dengan menggunakan Ujian Wilcoxon Rank Sum dan Friedman terhadap hasil dapatan IHS-GWO. Hasil analisis menunjukkan prestasi yang lebih baik untuk IHS-GWO berbanding varian HS terkini dan lain-lain pendekatan metaheuristik.

ABSTRACT

Harmony Search (HS) algorithm has been extensively adopted in the literature to address optimization problems in many different fields, such as industrial design, civil engineering, electrical and mechanical engineering problems. In order to ensure its search performance, HS requires extensive tuning of its four parameters control namely harmony memory size (HMS), harmony memory consideration rate (HMCR), pitch adjustment rate (PAR), and bandwidth (BW). However, tuning process is often cumbersome and is problem dependent. Furthermore, there is no one size fits all problems.

Additionally, despite many useful works, HS and its variant still suffer from weak exploitation which can lead to poor convergence problem. Addressing these aforementioned issues, this thesis proposes to augment HS with adaptive tuning using Grey Wolf Optimizer (GWO). Meanwhile, to enhance its exploitation, this thesis also proposes to adopt a new variant of the opposition-based learning technique (OBL).

Taken together, the proposed hybrid algorithm, called IHS-GWO, aims to address continuous optimization problems. The IHS-GWO is evaluated using two standard benchmarking sets and two real-world optimization problems. The first benchmarking set consists of 24 classical benchmark unimodal and multimodal functions whilst the second benchmark set contains 30 state-of-the-art benchmark functions from the Congress on Evolutionary Computation (CEC). The two real-world optimization problems involved the three-bar truss and spring design. Statistical analysis using Wilcoxon rank-sum and Friedman of IHS-GWO's results with recent HS variants and other metaheuristic demonstrate superior performance.

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LIST OF SYMBOLS

f (X_i)	Objective function
e	Exponential
X_i	The variable of the problem
x_j'	New modified variable of the problem
∞	Infinity
$\bar{x}$	Average
$\emptyset$	Random number between 0 and 1
α	Alpha
β	Beta
δ	Delta
ω	Omega
cos	Cosine
sin	Sine
exp	Exponential

LIST OF ABBREVIATIONS

EA	Evolutionary algorithm
HM	Harmony Memory
CEC	Congress on Evolutionary Computation
NP-hard	Non-deterministic polynomial-time
HS	Harmony Search Algorithm
IHS	Improved Harmony Search Algorithm
GHS	Global-best Harmony Search Algorithm
NI	Number of Iterations
SA	Simulated Annealing Algorithm
PAR	Pitch adjustment rate
BW	Bandwidth
HMCR	Harmony Memory Accepting Rate
GWO	Grey Wolf Optimizer
OBL	Opposition-Based Learning
HMS	harmony memory size
DHBest	differential-based harmony search algorithm
HS-SA	Hybrid Harmony Search and Simulated Annealing
DE	Differential Evolution
IEEE	Institute of Electrical and Electronics Engineers
UB	Upper Bound
LB	Lower Bound
N	Number of decision values
Rand	Random number between 0 and 1
Var	Variance
$Gauss$	Gaussian distribution
$temp_i$	Temporary value
30D	30 dimensions
50D	50 dimensions

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