Faculty of Electronic and Computer Engineering

HYBRIDIZATION OF DETERMINISTIC AND METAHEURISTIC APPROACHES IN GLOBAL OPTIMIZATION

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DECLARATION

I declare that this thesis entitled “Hybridization of Deterministic and Metaheuristic Approaches in Global Optimization” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :…………………………………………………...
Name :…………………………………………………...
Date :…………………………………………………..

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature :………………...
Supervisor Name :……………………….....................................
Date :……………………..

DEDICATION

To my beloved mother and father

ABSTRACT

In solving general global optimization problems, various approaches methods have been developed since 1970's which can be divided into two classes named deterministic and the probabilistic/metaheuristic approaches. Deterministic approaches provided a theoretical guarantee of locating the ε-global optimum solution. However, most of the time deterministic approaches required very high cost and time of computational to obtain the global optimum solution. The probabilistic/metaheuristic approaches are methods based on probability, genetic and evolution as its metaheuristic function for the guidance when solving the global optimization problem, and their accuracy of the solution obtained are not guaranteed. However, some time the metaheuristic approaches work very well in selected problems. The main objective of this research is to increase the accuracy of the solution obtained by Metaheuristic approaches by hybridization with some well-developed local deterministic approaches such as Steepest descent method, conjugate gradient methods and quasi-Newton's methods. In the analysis of the literature, Artificial Bees Colony (ABC) Algorithm has been selected as the metaheuristic approach to be improved its capability and efficiency to solve the global optimization problems. Several enhancements have been done in this research. For derivative free, a new method called Simplexed ABC method have been introduced. The numerical results show that Simplexed ABC can obtained a more accurate global optimum solution by using only 10 colony of bees with 10 cycle each compare to the 10,000 colony of bees with 100 cycles each in original ABC method. The successful of Simplexed ABC method leads this research to develop a mechanism to transform those well-developed gradient based local deterministic optimization approaches into solving global optimization approaches. These enhancements had produced methods called as ABCED Steepest Descent Method, five variants of ABCED Conjugate Gradient Methods and three variants of ABCED Quasi-Newton's Methods. The numerical results prove that the enhanced ABCED Steepest Descent and two variants of ABCED Quasi-Newton Methods had perfectly solving all the selected benchmark global optimization problems. In another hand, numerical results of ABCED Conjugate Gradient Methods also achieved up to 80.95% of the selected benchmark global optimization been solved successfully. Besides that, the comparison results also indicated that the numerical performance of the new developed methods converges faster than the original ABC algorithm. The results reported are obtained by using standard benchmark test problems and all computation is done by using C++ programming language.

ABSTRAK

Dalam menyelesaikan masalah pengoptimuman sejagat, pelbagai pendekatan telah dibangunkan sejak tahun 1970-an, yang dapat dibahagikan kepada dua kelas iaitu pendekatan berketentuan dan pendekatan berkebarangkalian/metaheuristik. Pendekatan berketentuan memberi jaminan teoritikal untuk mendapatkan penyelesaian pengoptimuman sejagat. Akan tetapi, kebanyakan pendekatan berketentuan ini memerlukan lebih masa serta kos pengiraan yang sangat tinggi untuk mendapatkan penyelesaian pengoptimuman sejagat. Pendekatan berkebarangkalian/metaheuristik adalah kaedah berasaskan kebarangkalian, genetik dan evolusi sebagai fungsi metaheuristik untuk panduan apabila menyelesaikan masalah pengoptimuman sejagat. Ketepatan penyelesaian yang diperolehi menggunakan pendekatan ini adalah tidak dijamin. Akan tetapi, kadangkala pendekatan berkebarangkalian/metaheuristik ini bekerja dengan sangat cekap dalam menyelesaikan masalah tertentu. Objektif utama penyelidikan ini adalah untuk meningkatkan kejituan penyelesaian yang diperoleh oleh pendekatan metaheuristik dengan cara menggabungkan dengan beberapa pendekatan berketentuan tempatan yang sudah terbukti baik seperti kaedah penurunan tercuram, kaedah kecerunan konjugat dan kaedah quasi-Newton. Dalam analisis kesusasteraan, Algoritma Koloni Lebah Buatan (ABC) telah dipilih sebagai pendekatan metaheuristik untuk dipertingkatkan keupayaan dan kecekapannya dalam menyelesaikan masalah pengoptimuman sejagat. Beberapa penambahbaikan telah dilakukan dalam kajian ini. Untuk fungsi yang bebas dari terbitan, kaedah baru yang disebut kaedah Simplexed ABC telah diperkenalkan. Hasil berangka menunjukkan bahawa Simplexed ABC mendapatkan penyelesaian pengoptimuman sejagat yang lebih jitu dengan menggunakan hanya 10 koloni lebah dengan 10 kitaran sahaja yang berbanding dengan kaedah ABC asli dengan memerlukan 10,000 koloni lebah serta ditetapkan 100 kitaran bagi setiap koloni lebah tersebut. Kejayaan kaedah Simplexed ABC membuka ruang penyelidikan bagi membangunkan mekanisme untuk mengubah pendekatan pengoptimuman berketentuan tempatan berasaskan kecerunan yang terbukti lebih berkesan untuk menyelesaikan masalah pengoptimuman sejagat. Pernambaikan ini berjaya menghasilkan kaedah yang disebut Kaedah Penurunan Tercuram ABCED, lima jenis Kaedah Kecerunan Konjugat ABCED serta tiga jenis Kaedah Kuasi Newton ABCED. Hasil berangka membuktikan bahawa kaedah pendekatan yang dipertingkatkan iaitu Kaedah Penurunan Tercuram ABCED, dan dua jenis daripada Kaedah Kuasi Newton ABCED telah menyelesaikan semua masalah pengoptimuman sejagat yang terpilih dengan berkesan. Manakala, Kaedah-kaedah Kecerunan Konjugat ABCED dapat menyelesaikan sehingga 80.95% daripada masalah sejagat yang terpilih dengan berkesan. Di samping itu, hasil berangka perbandingan juga menunjukkan kesemua Kaedah pendekatan yang telah dipertikatkan itu mempunyai kelajuan penumpuan yang lebih tinggi berbanding dengan Kaedah ABC yang asal. Hasil yang direkodkan diperoleh dengan menggunakan ujian piawai dan semua pengiraan dilakukan dengan menggunakan bahasa pengaturcaraan C++.

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LIST OF ABBREVIATIONS

ABC	-	Artificial Bees Colony
ASDM	-	Algorithm of Steepest Descent Method
ASF	-	Adaptive Scaling Factor
CD	-	Conjugate Decent
CHA	-	Continuous Hybrid Algorithm
CGA	-	Continuous Genetic Algorithm
CTSS	-	Continuous Tabu Simplex Search
DY	-	Dai-Yuan
ECTS	-	Enhanced Continuous Tabu Search
EP	-	Evolutionary Programming
ESA	-	Enhanced Simulated Annealing
FR	-	Fletcher-Reeves
GA	-	Genetic Algorithm
GABC	-	Global best-guided Artificial Bees Colony
HM	-	Homorphorus Mapping
HPSO	-	Hybrid Particle Swarm Optimization
HS	-	Hestenes-Stiefel
IABC	-	Improved Artificial Bees Colony
MR	-	Modification Rate
PR	-	Polak-Ribiere
PS-ABC	-	Prediction and Selection Artificial Bees Colony
PSO	-	Particle Swarm Optimization
SA	-	Simulated Annealing

SF	-	Scaling Factor
SR	-	Stochastic Ranking
SAABC	-	Simulated Annealing Based Artificial Bee Colony Algorithm
SD	-	Steepest Descent
TS	-	Tabu Search

LIST OF PUBLICATIONS

The research papers produced and published during the course of this research are as follows:

1. Goh Khang Wen, Yosza Bin Dasril and Abdul Rani Bin Othman, Dec 2018, A New Class of Conjugate Gradient in Solving General Global Optimization Problems, Journal of Theoretical and Applied Information Technology (JATIT), Vol. 96, No.23, Page 7984-7995.
2. Goh Khang Wen, Yosza Bin Dasril and Abdul Rani Bin Othman, April 2018, Global optimization with Simplexed artificial Bees colony algorithm, Far East Journal of Mathematical Science, Vol. 103, No.8, Page 1303-1321.
3. Yosza Bin Dasril, Goh Khang Wen, 2016, Modified Artificial Bees Colony algorithm with Nelder-Mead search algorithm, IEEE Proceeding of 12th International Conference on Mathematics, Statistics, and Their Applications (ICMSA), 2016, pp. 25-30.
4. Yosza Bin Dasril, Khang Wen Goh, Ismail Bin Mohd, 2013, Nonparametric function modification method in unconstrained global optimization. AIP Conference Proceedings, 1522 (1), pp. 1412-1419.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter summarized an overview of the study which has been done in this report. A brief of the trend and development of global optimization in engineering filed has been shown in the following section. Then, the limitation and weakness of the global optimization approaches have been highlighted in the following section. The importance of this research has been clearly stated in the section of research objective. Following by that, section 1.5 will specified the scope of this research that focused on. The overview of the contribution and findings of this research presented in section 1.6. Finally, this chapter ended with the section of thesis organization.

1.2 Research background

Mathematicians believe some of the daily problem that we faced, can be modelled into mathematical model. In mathematical terms, the goal of solving those models in the "best" way is known as an optimization (Pardalos and Edwin, 2002). These might mean maximize profit, minimize loss, maximize efficiency or minimize the risk in running business; minimize weight or maximize strength in designing a bridge and minimize the time or fuel use in selecting an aircraft flight plan. Optimization also been widely used in several engineering disciplines. Such as optimum shape design in manufacturer, optimum Finite Impulse Response (FIR) and Infinite Impulse Response (IIR) filter design in

Telecommunication, global optimization of heat network exchange for chemical engineering etc (Mauricio and Pardalos, 2006).

Telecommunication systems have always been the subject of application for advanced operations research technique such as the network routine and design, queuing theory and nonlinear programming. Following the rapid development in telecommunication and the derivation of new efficient optimization methods, research and application of optimization techniques to communications kept an increasing pace in the 1980s and 1990s culminating the recent years with the new opportunities offered by the explosive and expansion of fiber, broadband, mobile, and wireless networking. Most analysis or design problems in communication systems can be stated in term of optimizing some performance or utility function in several variables, the values of which must satisfy a set of specified requirements. Nonlinear optimization has also been successfully applied to several problems arisen in the context of communications systems, including the areas of wireless networks, high speed internet, equalization to broadband access, network topology and routing (Mauricio and Pardalos, 2006).

Many practical optimization problems in optimization of the communications system have mixed (continuous and discrete) variables and discontinuities in search space. In recent years, Metaheuristic approaches such as simulated annealing (SA), Tabu search, Variables Neighborhood Search, genetic algorithms and other often recognized as potent tools in optimizing telecommunication systems (Pardalos and Edwin, 2002). One of the most important advantages of the Metaheuristic approaches over the standard nonlinear programming techniques is that it can find the global minimum, instead of a local minimum, and that the initial attempts with different starting point need not be close actual values. Another advantage is that it does not require the use of the derivative of the function, which is not always easily obtainable or may not even exist, for example, when dealing with real measurements involving noisy data (Beni and Wang, 1989).

However, most our daily problems happened as non-convex optimization problems (multi-modal functions) which may contain more than one local optimum solution. Therefore, the most important objective and challenges in solving these non-convex optimization problems, is how to determine the optimum value among all the local optimum solutions in the domain otherwise known as global optimum solution. Most of the time, the local solutions are greatly different and meaningless when compare to the global one. Unfortunately, those well-performed methods which mentioned above always lose their efficiency when applied to determine the global minimizer for non-convex problems (Pardalos et al., 2000).

The global optimization problems have been existed in ancient of time. However, it has been ignored until 70's. These situations happened because of the immature of local optimization theories and methodologies at that time and there were no suitable tools available before 1970's. However, after the publication of two books "Towards Global optimization" in 1975 (Dixon and Szego, 1975) and "Toward Global Optimization 2" in 1978 (Dixon and Szego, 1978), the study of global optimization was strongly stimulated. Furthermore, the rapid growth of computer technologies since late 1970's makes many unsolvable problems in the past, solvable nowadays. Thereafter, both theories and solution methodologies for global optimization, have made great advances during the last 40 years (Pardalos et al., 2000).

Usually, the global optimization problems can be classified into two categories based on their nature and structure. The first category includes those problems are known with the very well-structured model types, for examples, concave minimization problems, difference of convex functions (D.C.) programming problems, monotonic optimization problems, quadratic programming problems, separable optimization problems, networks problems, et cetera (etc.). Many specific effective methods have been developed for solving each special structure of these problems. Even the methods have performed well in solving each specific structured modelled problem, but they may not work well for problems outside their scopes. The second category includes general global optimization problems (Pardalos et. al., 2000; Pardalos and Edwin, 2002; Ng, 2003).

The general global optimization problems only have little information available on their structures. Hence, to solve these challenging kind of problems, the methods for solving general global optimization problems should work for all types of problems. For more detail can be referred to Reiner and Pardalos, 1995; Reiner et al., 2000; Pardalos et al., 2000; Pardalos and Edwin, 2002; Ng, 2003.

Generally, optimization approaches can be categorized into three categories. First, the deterministic approaches provide a theoretical guarantee of locating the ε-global optimum. This means that the deterministic approaches will determine a local optimum whose objective function value differs by at most from the global one from a given $\varepsilon > 0$. Contrarily, the stochastic approaches only offer a guarantee in probability. This means that their convergence proofs usually state that the global optimum will be identified in infinite time with probability (Liberti and Kucherenko, 2005). Besides, the Metaheuristic approaches are methods based on genetic and evolution as its Metaheuristic function for the guidance when solving the global optimization problem, their accuracy of the solution obtained are not guaranteed. However, sometimes the Metaheuristic approaches work very well in certain problems. Table 1.1 exhibits the examples of each category.

Table 1.1: Global Optimization Techniques in Each Category

Stochastic approaches	**Deterministic approaches**
• Pure random search • Multi-start algorithm • Clustering method • Two phase method • Bayesian approaches	• Branch and Bound Method • Filled Function Method • Interval Method • Cutting Plane Method • Trajectory Method • Gradient Based Methods
Metaheuristic approaches • Particle Swarm Optimization • Ant Colony Optimization (Based on how ants solve problems) • Genetic Algorithm (Based on genetic and evolution) • Neural Networks (Based on how the brain function) • Simulated Annealing (Based on thermodynamic) • Tabu Search (Based on Memory-response) • Target analysis (Based on learning)	

1.3 Problem statement

Generally, these mathematical models can be divided into two types which are constrained and unconstrained problems. However, most of the time, the constrained optimization problems will be transformed into unconstrained by using for examples by the Lagrange conditions, Kuhn Tucker conditions, penalty function or the barrier function, before solving it by using unconstrained optimization method. Therefore, most of the researchers in optimization's field are more concern in development of methods which can be used in solving unconstrained optimization problems rather than constrained optimization methods (Ismail 1989a; Ismail 1989b; Nash & Sofer and 1996; Nocedal and Wright, 1999).

There are several unconstrained optimization methods which have been developed to solve those mathematical models. Among them, the most effective methods are those which including the gradient of the objective function when conducting the search of the optimum solution, such as steepest descent method, conjugate gradient method and quasi-Newton method. These methods are well-performed in determining a local optimum or globally determining the optimum solution when solving convex optimization problems, which are known to have only one local solution and are also known as global solution (Boyd and Vandenberghe, 2004).

As mentioned above, the gradient based optimization methods are the most effective deterministic approaches in determining local optimization solution. The reason why these methods always lose their efficient in solving global optimization method is, because whenever a local optimum solution been determined, these created methods do not know how to pass a hill (for minimization) or cross a valley (for maximization) to locate another better optimum solution (Liu and Teo, 1999).

1.4 Research objective

The main purpose of this research is to improve the ability of the existing local deterministic method in solving unconstrained general global optimization problems by hybridized with the metaheuristics global optimization approaches.

There are several objectives to be fulfilled in this research which listed as follows:

1. To analyse the properties and behaviour of the existing local deterministic and metaheuristics approaches in solving global optimization problems.
2. To develop a better algorithm in term of accuracy and efficiency by hybridized the metaheuristics global optimization approaches in solving global optimization problems.