ENHANCEMENT ON THE MODIFIED ARTIFICIAL BEE COLONY ALGORITHM TO OPTIMIZE THE VEHICLE ROUTING PROBLEM WITH TIME WINDOWS

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Abstrak

Masalah penghalaan kenderaan dengan tetingkap masa (VRPTW) merupakan satu masalah pengoptimuman gabungan (COP) dan kesukaran masa bukan penentu (NP-hard). Koloni lebah buatan (ABC) adalah salah satu algoritma kecerdasan kawanan yang digunakan secara meluas dalam menyelesaikan COP. Dalam kajian ini, algoritma ABC yang dikenali sebagai MABC telah diperbaiki untuk menyelesaikan masalah VRPTW. Ini adalah kerana walaupun MABC dilaporkan sebagai berjaya, namun algoritma MABC mempunyai beberapa kelemahan, termasuklah kekurangan pemilihan struktur kejiranan semasa proses intensifikasi, ketiadaan pengetahuan ketika permulaan populasi, dan pemberhentian sekali-sekala berikutanoptima sejagat. Algoritma Modified ABC (E-MABC) yang dicadangkan merangkumi (i) N-MABC yang mengatasi kekurangan pemilihan kejiranan dengan menukar struktur kejiranan antara dua laluan berbeza; (ii) MABC-ACS yang menyelesaikan isu ketiadaan pengetahuan dalam permulaan populasi dengan mengadaptasi ciri heuristik sistem koloni semut, dan (iii) P-MABC yang menangani pemberhentian sekali-sekala ke arah optima sejagat dengan memperkenalkan gangguan yang menerima penyelesaian terbengkalai dan melompat keluar dari optima tempatan. Prestasi algoritma yang dicadangkan telah dinilai pada set data penanda aras yang terdiri daripada 56 kejadian VRRPTW dan 56 kejadian masalah pengambilan dan penghantaran dengan tingkap masa (PDPTW). Prestasi telah diukur berdasarkan jarak perjalanan (TD) dan bilangan kenderaan yang digunakan (NV). Keputusan menunjukkan bahawa E-MABC yang dicadangkan melibatkan TD dan NV yang lebih rendah berbanding algoritma penanda aras. Algoritma E-MABC adalah lebih baik daripada MABC sebanyak 96.62%, MOLNS sebanyak 87.5%, GA-PSO sebanyak 53.57%, MODLEM sebanyak 76.78% dan RRGA sebanyak 42.85% dari segi TD. Selain itu, algoritma E-MABC adalah lebih baik daripada MABC sebanyak 42.85%, MOLNS sebanyak 17.85%, GA-PSO dan RRGA sebanyak 28.57% dan MODLEN sebanyak 46.42% dari segi NV. Ini menunjukkan bahawa E-MABC yang dicadangkan adalah algoritma yang meyakinkan dan berkesan untuk VRPTW dan PDPTW serta boleh menjadi pesaing dalam masalah penghalaan dan COP yang lain.

Katakunci: Masalah penghalaan kenderaan, Koloni lebah buatan, Sistem koloni semut, Struktur kejiranan, Mekanisme gangguan.

Abstract

The vehicle routing problem with time windows (VRPTW) is a non-deterministic-time hard (NP-hard) with combinatorial optimization problem (COP). The Artificial Bee Colony (ABC) is a popular swarm intelligence algorithm for COP. In this study, existing Modified ABC (MABC) algorithm is revised to solve the VRPTW. While MABC has been reported to be successful, it does have some drawbacks, including a lack of neighbourhood structure selection during the intensification process, a lack of knowledge in population initialization, and occasional stops proceeding the global optimum. This study proposes an enhanced Modified ABC (E-MABC) algorithm which includes (i) N-MABC that overcomes the shortage of neighborhood selection by exchanging the neighborhood structure between two different routes in the solution; (ii) MABC-ACS that solves the issues of knowledge absence in MABC population initialization by incorporating ant colony system heuristics, and (iii) P-MABC which addresses the occasional stops proceeding to the global optimum by introducing perturbation that accepts an abandoned solution and jumps out of a local optimum. The proposed algorithm was evaluated using benchmark datasets comprising 56 VRPTW instances and 56 Pickup and Delivery Problems with Time Windows (PDPTW). The performance has been measured using the travelled distance (TD) and the number of deployed vehicles (NV). The results showed that the proposed E-MABC has lower TD and NV than the benchmarked MABC and other algorithms. The E-MABC algorithm is better than the MABC by 96.62%, MOLNS by 87.5%, GA-PSO by 53.57%, MODLEM by 76.78%, and RRGA by 42.85% in terms of TD. Additionally, the E-MABC algorithm is better than the MABC by 42.85%, MOLNS by 17.85%, GA-PSO and RRGA by 28.57%, and MODLEN by 46.42% in terms of NV. This indicates that the proposed E-MABC algorithm is promising and effective for the VRPTW and PDPTW, and thus can compete in other routing problems and COPs.

Keywords: Vehicle routing problems, Artificial bee colony, Ant colony system, Neighborhood structure, Perturbation mechanism.

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List of Abbreviations

ABC	Artificial Bee Colony
ACO	Ant Colony Optimization
ACS	Ant Colony System
BCO	Bee colony optimization
BSO	Brain-Storm Optimization
COP	Combinatorial Optimization Problem
CVRP	Capacitated Vehicle Routing Problem
EB	Employed Bees
GA	Genetic Algorithm
GGA	Grouping Genetic Algorithm
OB	Onlooker Bees
OBL	Opposition-Based Learning
PDPTW	Pickup and Delivery Problem with Time Windows
PSO	Particle Swarm Optimization
SA	Simulated Annealing
SB	Scout Bees
SIH	Sequential Insertion Heuristic
SWO	Squeaky Wheel Optimization
TS	Tabu Search
TSP	Travelling Salesman Problem
VRP	Vehicle Routing Problem
VRPTW	Vehicle Routing Problem with Time Windows
VE-ABC	Vector Evaluated Artificial Bee Colony
HSA	Harmony Search Algorithm
HGA	Hybrid Genetic Algorithm
LGA	Localized Genetic Algorithm
MABC	Modified Artificial Bee Colony
MODLEM	Multi-Objective Discrete Learnable Evolution Model
MOLNS	Multi-objective Large Neighborhood Search
M-MOEA/D	Memetic Multi-Objective Evolutionary Algorithm based on Decomposition

CHAPTER ONE
INTRODUCTION

Significant mathematical problems are of practical and theoretical importance in the field of Artificial Intelligence. One of the examples of these problems is the combinatorial optimization problem (COP). The COP is the most important category for optimizing problems due to the large diversity of real-life problems that can be overcome in the engineering and industry fields by studying them (Montiel & Delgadillo, 2015). The COP aims to determine an optimal solution for a particular problem case among all available solutions (Talbi, 2009; Michalewicz & Fogel, 2013; Masutti & Castro, 2017). An example of COP can be found in the area of transportation management.

One of the challenges in transportation management is the vehicle routing problem (VRP) (Dantzig & Ramser, 1959), which was initially referred to as the "truck dispatching problem". The VRP aims to structure a set of directions to serve numerous geographically scattered customers at nominal cost (i.e. to minimize travel distance or time) whilst fulfilling different types of constraints (Bräysy & Gendreau, 2002; Dixit et al., 2019). Ultimately, a productive transportation management system can be used to solve the VRP and may essentially minimize costs, pollution, and heavy traffic jam. Consequently, the VRP is a dynamic topic worth exploring and studies deploying artificial intelligence and data mining have drawn attention to this issue.

Several fundamental extensions of the VRP have been presented over the years, such as capacitated VRP (CVRP) (Dantzig & Ramser, 1959), VRP with time windows

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