A Honeybee Mating Optimization Algorithm For Solving The Static Bike Rebalancing Problem

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ABSTRACT

This paper proposes a new approach to solve the Bike Rebalancing Problem (*BRP*) based on the Honey-Bee Mating Optimization (*HBMO*) algorithm. The aim is to reduce the overall traveling cost of redistribution operations under various constraints. The performance of the proposed algorithm is evaluated using a set of benchmark instances for the BRP. Preliminary results are obtained and showed that the proposed approach is promising.

CCS CONCEPTS

• **Theory of Computation** → *Design and analysis of algorithms*; **Theory and algorithms for application domains**; • **Discrete optimization** → *Network optimization*;

KEYWORDS

Bike rebalancing problem, Heuristics, Vehicle routing problem, Honey bee mating optimization.

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1 INTRODUCTION

Nowadays, Bike-Sharing Systems (*BSS*) are becoming one of the most popular used urban transportation tools. Within this system, people could rent a bike positioned at one of various automatic stations that are dispersed across an urban area, use them for a short travel and return them to any station belonging to the same system [4].

Such a system can easily get stuck in an imbalanced state. Some stations turn to work empty and others turn to get full. This situation could lead to the users dissatisfaction. Therefore, BSS operators need to relocate bikes in order to solve this problem.

In this paper, we study the static case of the bike sharing rebalancing problem. As for the static version, the system benefits from the predefined level of initial and target filling of the stations.

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In BRP, a set of dedicated vehicles is used to make tours between stations to bring them back to their balanced levels. This problem is similar to the vehicle routing problem with some additional constraints that should not be violated. The main objective is to ensure the balanced level of stations with a minimum traveling cost.

With the aim of generating, heuristically, feasible solutions in reasonable time, we propose to solve this problem with a powerful metaheuristic named the Honey Bee Mating Optimization (*HBMO*) algorithm. Far from being a simple application of the HBMO algorithm to our problem, we propose a modified version. We use multiple crossover operators in the mating phase as well as a diversified worker phase based on various local search procedures. Also, we propose a discrete version of this algorithm, where our encoding solution is presented as a permutation of stations.
Computational experiments are performed on a set of 65 benchmark instances. The results prove the efficiency of our algorithm.

The rest of this paper is organized as follows. The section 2 describes our problem. Section 3 contains the development of our proposed algorithm. The computational tests on instances from the literature are described in Section 4. Finally, section 5 concludes the paper.

2 PROBLEM DESCRIPTION

Let us suppose to have a predefined BSS network with n stations (*nodes*) and a depot. Each station contains a predefined initial fill of bikes. At the end of the day, the stations could fall in an imbalanced state. Then, a fleet of m vehicles with capacity W is used to respond to stations requests. In particular, some stations have a positive request whereas others have a negative request. Also, a distance matrix (d) represents the travel cost of vehicles between the different BSS stations as well as the depot.

We state a complete graph $G = (V, E)$, where V is a set of vertices defined as $V = \{v_0, v_1, \ldots, v_n\}$. v_0 denotes the depot. $v_i = \{v_1, \ldots, v_n\}$ represents the stations. E is the set of edges which denotes the travel time of the vehicles from a station (i) to a station (j) or from a station (i) to the depot.
Each node i where $i \in V \setminus \{v_0\}$ has a demand q_i. We assume that when $q_i > 0$, v_i represents a station with a pickup demand, whereas when $q_i < 0$, v_i indicates a station with a delivery demand.

The removed bicycles can be sent to the depot or to a delivery station. Also, supplied bicycles can either come from pickup station or from the depot. Finally, we denote a distance matrix (d) associated to each edge $e \in E$. d_{ij} represents the displacement times of the vehicles from a station (i) to a station (j) as well as the depot.

The main objective consists on finding a set of routes starting and ending in the depot. Each station should be visited exactly once using dedicated vehicles in order to perform a flexible redistribution with minimum traveling cost. Each vehicle starts from the depot with some initial bicycle load. The demand of every station should be completely satisfied. Finally, the sum of the demand of the visited stations within each route should not violate the capacity constraint W of the vehicles.

3 HBMO ALGORITHM

The HBMO algorithm was proposed in articles [1, 2]. The algorithm tries to simulate the natural marriage process of honey bees.

This process begins with the mating flight, where the queen selects drones to mate. In each encounter, the drone's genotype is stored in the spermatheca to build the genetic pool of the colony.

In algorithm 1, we present a discrete version of the HBMO algorithm to solve the BRP.

Algorithm 1 Honey-Bee Mating Optimization Algorithm for BRP.

```
Inputs: number of vertices : V, capacity of vehicles: W, distance
matrix : d
Initialize-parameters
Generate initial population
for i = 1 to maximum number of mating flights do
   Mating flight phase
   Creation of new broods using crossover operators
   Improvement of broods by applying worker phase based on
   neighborhood operators
   Computing the fitness of the new generation of broods
   Updating the queen bee
end for
return Queen
```

In fact, and based on algorithm 1, different features and operators should be specified such as: {the solution representation, the fitness function, the mating and the worker process operators}.

As for the representation of our solution, each bee in the colony is represented as a vector. Therefore, each bee is considered as a candidate solution to our problem. Each solution is presented as a permutation of stations to visit.

As a fitness function, we adapt the split function of Prins [5], proposed initially to solve the Vehicle Routing Problem. Our contribution consists on including the fact that we have negative and positive requests in our stations within the split function.

As for the mating process, instead of using only one mating operator, a combination of eight crossover operators (One point crossover, Two point crossover, Three point crossover, Position based crossover, Longest common sub-sequence crossover, Partially-mapped crossover, Cycle crossover, Order crossover, Edge Recombination crossover) were used to give more exploration abilities and a fittest solutions.

Finally, as for the worker phase, we use different local search procedures using each one a neighborhood operator. Six neighborhood operators were employed: Swap operator, Exchange operator, Insertion operator, Inversion operator, Displacement operator and Inverted Displacement operator.

The combination of all these features within the basic version of HBMO yields a specific and adapted version to solve our BRP.

4 EXPERIMENTAL RESULTS

We conduct various experiments in order to evaluate our algorithm. The HBMO algorithm is coded in the C language and executed using a laptop with an Intel Core i5 1.60 GHz processor and 8 GB of RAM, under Windows 10 environment.

The algorithm was applied to 65 real-world instances collected from twenty two bike sharing systems, proposed in [3]. The instances are available online [1]. We note that the number of stations in instances ranges from 13 to 116 vertices. Whereas the capacity of vehicles varies between 10 and 30.

The parameters setting of our algorithm were chosen based on our preliminary tests. We set the parameters as follows: the population size is equal to 10, the size of chromosome is updated according to the number of stations in each instance, the maximum number of generations could up to 10k generations. Also, the size of spermatheca is equal to 10, the initial amount of speed is set to 10k whereas the initial amount of energy is set to 200.

We evaluate the performance of our proposed algorithm, where several crossover operators and local search procedures are used. We select 10 instances randomly to test our approach in comparison with the basic version of HBMO.

In the crossover tests, the results prove the robustness of our proposition as we found an average gap of 8.66% in favor to our work. In the local search tests, the obtained results indicate that the use of various local search procedures provides fittest solutions. The average gap was 4.68%.

Overall, and as a preliminary results, our algorithm finds promising results as we are capable of finding feasible solutions in a small computational time especially for large size of instances.

5 CONCLUSION

In this paper, we focused on the bicycle rebalancing problem. The main objective aimed to redistribute the bikes of a system using a set of vehicles at a minimum cost. Moreover, we proposed the honey bee mating optimization algorithm to solve our problem. We applied 65 benchmark instances to test the performance of our algorithm.

Currently, we are in the process of improving the algorithm, in order to enhance the computational results.

REFERENCES

[1] Hussein A Abbass. 2001a. A monogenous MBO approach to satisfiability. In *Proceeding of the international conference on computational intelligence for modelling, control and automation, CIMCA*.

[2] Hussein A Abbass. 2001b. MBO: Marriage in honey bees optimization-A haplometrosis polygynous swarming approach. In *Proceedings of the 2001 Congress on Evolutionary Computation (IEEE Cat. No. 01TH8546)*, Vol. 1. IEEE, 207–214.

[3] Mauro Dell'Amico, Eleni Hadjicostantinou, Manuel Iori, and Stefano Novellani. 2014. The bike sharing rebalancing problem: Mathematical formulations and benchmark instances. *Omega* 45 (2014), 7–19.

[4] Ahmed Abdelmoumene Kadri, Imed Kacem, and Karim Labadi. 2016. A branch-and-bound algorithm for solving the static rebalancing problem in bicycle-sharing systems. *Computers & Industrial Engineering* 95 (2016), 41–52.

[5] Christian Prins. 2004. A simple and effective evolutionary algorithm for the vehicle routing problem. *Computers & Operations Research* 31, 12 (2004), 1985–2002.

[1] source:http://www.or.unimore.it/site/home/online-resources/bike-sharing-rebalancing-problems.html