教育・研究活動報告

環境に優しい運搬経路問題に対するハイブリッド・ハーモニー探索アルゴリズム

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A Hybrid Harmony Search Algorithm for a Green Vehicle Routing Problem †

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ABSTRACT: Currently, environment problem is a critical issue to be concerned in almost area of industries. Especially in transportation domain, in which, greenhouse gas (GHG) emission should be minimized to reduce the carbon foot print. Therefore, in this paper, Green Vehicle Routing Problem (GVRP) is studied and a hybrid algorithm that based on the Harmony Search Algorithm (HSA) is constructed to solve the concerned GVRP. Harmony Search Algorithm is hybridized by the local improvement process called two-phase selection process, then, we use a real case of the retail company to verify the adaptability and efficiency of the proposed algorithm. The objective function applied in this study is to minimize the total fuel consumption while simultaneously meets the delivery requirements from all customers. The test results imply that the proposed method could be applied effectively for the case study. By the way, some configurations of the proposed algorithm should be modified to be a powerful method.

Keywords: Green Vehicle Routing Problem (GVRP), Heuristics, Optimization, Hybrid Harmony Search Algorithm

1 INTRODUCTION

Currently, the environment problem tends to be one of the most serious problems for human livings since the green house effects become critical. Many disasters such as tornado and flooding occur more frequently and tend to increase over time. This problem can be prevented and reduced by decreasing the emission of CO_2 or carbon dioxide. For an international practice, the approach of carbon footprint turns to be an important standard for covering such problem. Accordingly, logistics which is considered to be an important activity for supply chain management must be carefully considered since it generates a high rate of CO_2 due to transportation activities (Bloemhof Ruwaard, J. M. et al. (1995))[1]. Therefore, in order to reduce the CO_2 emission in any transportation activity, the environmental friendly vehicle routing problem (VRP) should be turned into consideration. This problem is the Green Vehicle Routing Problem (GVRP), in which, the use of fuel should be minimized since it has a direct relationship with the CO_2 emission (Erdoğan, S. & Miller-Hooks, E. A. (2012))[3].

The Vehicle Routing Problem (VRP) is a problem that is widely studied since it was first introduced by Dantzig, G. B. & Ramser (1959)[2]. VRP is considered as a combinatorial problem and is a NP-hard problem. Lenstra, J. K. & Rinnooy Kan, A. (1981)[5]. The objective of a VRP is to find the minimum corresponding cost of the total routes assigned. These costs might be the total travelling distance, minimum number of vehicles used and the total time of traveling. To solve the combinatorial problem, many approaches are introduced to solving for the optimal solutions. These approaches can be divided into two main types; deterministic and stochastic. Deterministic approaches can determine the optimum but they are not so practical due to high efforts of calculations and a very long computational time is required. Accordingly, the stochastic approaches that are based on the random processes become more popular due to the shorter computational time, less complexity and the solution is acceptable (normally near optimal solution but can obtain optimal solution).

In this paper, we intend to study a GVRP that minimizes the total fuel used by vehicles fleet to make deliveries to all customers. The concern GVRP investigated in this paper is a case study taken from a company, in which, all of ordered products should be delivered to a set customers in a single working day. In order to optimize the objective function, we propose a hybrid approach that combined the Harmony Search (HS) with the previously proposed algorithm to take the mutual benefits from both approaches. Consequently, the proposed algorithm is then verified for the practical implementation by using a comparison study with a well-known approach.

2 GREEN VEHICLE ROUTING PROBLEM

Almost of aforementioned research works pay attention on the minimization of travelling distance since the minimum distance is implied to generate the minimum cost. Nevertheless, we do think that since the fuel use for transportation is not depended only on the travelling distance but also depend on the other factors such as weight of products transferred by truck or the fuel consumption rate. In easier words, we should consider these considerations into VRP and convert them into an objective function that has an impact to the environment problem.

Refer to works of Bloemhof - Ruwaard et al. (1995)[1] and Erdoğan & Miller-Hooks (2012)[3], the transportation problems should be seriously take into concern since inefficient transportation causes higher greenhouse gas (GHG) emission resulting in more harmful environmental problem. Some efforts have been introduced, for example, introducing cleaner fuels such as biodiesel, using Alternative Fuel Vehicles (AFVs), and other methods to reduce environmental impact. These initiatives can dramatically reduce the GHG since cleaner fuels have much less CO_2 emission rate than the fossil fuel. By the way, some transportation modes such as delivery by trucks

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using fossil fuel could not be avoided. It is to say that, apart from using a cleaner fuel we can reduce the GHG emission by appropriate routing technique.

2.1 Case Study

In this paper, we use a case study of a retail company that sale the consumer products. The product stored in distribution center will be delivered to customers by using company own trucks. Position of customers (65 customers) and also the depot (one depot) are shown in Figure 1. Here, after orders receiving from customers, the scheduler will assign the vehicle routes according to the ordered quantity. The order from customers is in units (or pieces) that already converted into volume (m^3) and weight (kg). All orders must be delivered within that day due to the delivery regulation of company. Table 1 illustrates an example of orders from customers in a single day.

Each truck has a limited capacity of 120 m^3 and the maximum weight while loaded is 2,500 kg and weight of free truck is 1,000 kg.

2.2 The Concerned GVRP

The problem considered in this paper consists of a single depot, multiple customers, and homogenous fleet of trucks. Routes will be assigned by based on the order requirements from customers. A truck will be loaded until its capacity, either volume or weight, is full or cannot load anymore. And then, the new truck will be assigned for the remaining customers. The process is repeated until all customers have been assigned to a route. The problem is a Capacitated Vehicle Routing Problem (CVRP) in nature but the objective function will be changed from the total distance to the total fuel cost consumed to make all deliveries.

In order to calculate the total fuel cost used, the total weigh of delivery of each vehicle (vehicle weight plus product weight) must be firstly determined and then the Fuel Consumption Rate (FCR) or FCR corresponding to the total weight will be determined. The product of FCR and total traveling distance produces the total fuel cost of a trip.

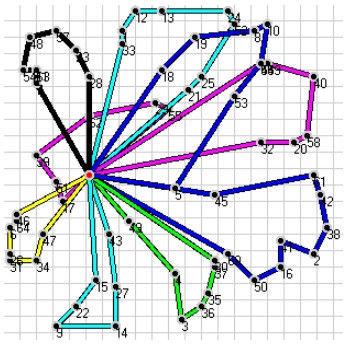

Figure 1 Position of Depot and Customers

Table 1 An example of orders

Customer No.	Total ordered volume (m^3)	Total ordered weight (kg)
1	6	62
2	8	77
3	6	55
4	2	24
5	6	60
…	…	…
64	8	82
65	3	28

Harmony Search

Objective function $f(x)$, $x = (x_1, \cdots, x_p)^T$
Generate initial harmonics (real number arrays)
Define pitch adjusting rate (r_{pa} and pitch limits
Define harmony memory accepting rate (r_{accept})
While (t<Max number of iterations)
  Generate new harmonics by accepting best harmonics
  Adjust pitch to get new harmonics (solutions)
  If (rand > r_{accept}),
    Choose an existing harmonic randomly
  else if (rand> r_{pa}),
    adjust the pitch randomly within a bandwidth
  else
    generate new harmonics via randomization
  end if
  Accept the new harmonics (solutions) if better
End while
Find the current best estimates

Figure 2 HSA Pseudocode

3 HYBRID HARMONY SEARCH - Two Phases Algorithm

Harmony Search Algorithm (HSA) is a method that is based on the music improvisation process and originally formulated by Geem, Z. W. et al. (2001)[4]. The typical Harmony Search Algorithm (HSA) is shown in Figure 2.

HS Algorithm is a method that inspired by the behavior of a music improvisation process and its nature is suitable for non-differentiable and non-linear functions in continuous space. Since HSA has few control factors, therefore it is robust and has fast convergence characteristics (Yassen, E. T. et al. (2013))[6].

Three steps of the proposed hybrid algorithm work as follows (details are omitted).

Step 1: Initializing the HM (harmony memory) parameters
Step 2: Generate the harmony vector
Step 3: Improvising a new harmony vector
Step 4: Updating the HM
Step 5: Terminate the algorithm

4 CONCLUSION

This research has introduced a GVRP that aims to reduce the fuel used therefore reduce the CO_2 emission. The algorithm is proposed by the adaptation of two-phase selection procedure combining with the Harmony Search Algorithm.

The test implies that the proposed algorithm is adaptable but the efficiency is not too much satisfied. For the further improvement, this algorithm should be modified by adding new approach or algorithm that work well in searching such as Honey Bee Mating algorithm or the likes.

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