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ABSTRACT

The growing awareness of the environmental movement greatly influences the transportation scene of this century leading to several transportation alternatives. One among them is carsharing service which has been gaining traction and support in major cities around the globe. It is also undeniable that the location planning of the fleet vehicles can contribute to its success. The fleet vehicles must be easily accessed and in the proximity of various transportation hubs and facilities. In this paper, we study the Vehicle Placement Problem (VPP) for round-trip carsharing and propose a novel hybrid algorithm, NGAP, which is a combination of NSGA-III and Pareto Local Search (PLS) to enhance the quality of the results over NSGA-III. The proposed algorithm is tested on 10 synthetic and four real-world instances. NGAP is shown to be significantly more efficient than NSGA-III on almost all instances in terms of Inverted Generational Distance (IGD), and Hypervolume.

CCS CONCEPTS

• **Applied computing → Transportation**; • **Computing methodologies → Optimization algorithms**;

KEYWORDS

Carsharing, Hybridization, Multi-objective Optimization, Vehicle Placement

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1 INTRODUCTION

Efficient fleet planning management is crucial for carsharing services. However, such planning is currently done manually which is laborious and often leads to inefficient solutions. The Vehicle Placement Problem (VPP), first introduced in [1], considers three common objectives usually are, 1. maximization of user coverage (i.e., to identify the highly populated areas), 2. minimization of number of vehicles used and 3. maximization of public transportation coverage (i.e. satisfying users requirements). In this paper, a novel hybrid metaheuristic algorithm based on NSGA-III and Pareto Local Search (PLS), abbreviated as NGAP, and a novel local search operator Extensible Neighborhood Search (ENS) are proposed. Hybridization is a method to combine two or more algorithms and make them collaborate with each other [6] and there has been attempts to continuously improve the hybridization of algorithms [3, 4] over the past decade. Nevertheless, three facets still presents major obstacles. Theses are, determination of suitable priorities for objectives, implementation of a suitable local search operator and determination of the size of search neighborhood.

2 VEHICLE PLACEMENT PROBLEM (VPP)

A vehicle is placed on a location on a street node $S = \{s_1, s_2, \ldots, s_i\}$. The maximum walking distance from a building to a station is d. Users start the trip from their residences. The number of users p_j is associated with the building b_j. Public transportation t_k has an importance factor of w_k. The coverage of each location s_i for buildings $B = \{b_1, b_2, \ldots, b_j\}$ and public transportation $T = \{t_1, t_2, \ldots, t_k\}$ is defined in matrices E and G.

$$\text{Maximize} \quad \sum_{j=1}^{m} (e_j \times p_j)$$

$$\text{Minimize} \quad \sum_{i=1}^{n} s'_i$$

$$\text{Maximize} \quad \sum_{k=1}^{q} (g_k \times w_k)$$

$$\text{Subject To} \quad e_j = E_{ij} \times s'_i \qquad (1)$$

$$g_k = G_{i,j} \times s'_i \qquad (2)$$

$$x \leq \sum_{i=1}^{n} s'_i \leq y \qquad (3)$$

$$s'_i, e_j, g_k \in \{0, 1\} \qquad (4)$$

$$n, x, y, m, q \in \mathbb{Z}^+ \qquad (5)$$

$$d \in \mathbb{Z}^{\geq 0} \qquad (6)$$

Constraint 1 indicates that a building b_j can be covered by multiple vehicle locations and ensures that a building b_j is considered only once during the calculation. Constraint 2 is similar to constraint 1, but for public transport. Constraint 3 signifies the lowest and highest number of selected vehicle location allowed. Finally, constraints 4 – 6 define the domains of the variables and parameters.

3 METHODOLOGY

NGAP is the combination of NSGA-III [2] based algorithm with Pareto Local Search (PLS) [5] which is classified as low-level teamwork hybrid (LTH) as defined in [6]. PLS is activated at every predetermined generation or time to deploy a problem-specific local search operator, Extensible Neighborhood Search (ENS).

ENS utilizes the concept of neighborhood in graph theory. There are three main processes in ENS which are *Add* (to maximize coverage), *Remove* (to minimize vehicle number) and *Improve* (to maximize coverage). These processes use Pareto-dominance to add higher coverage locations, remove redundant low coverage locations, and relocate to higher coverage location respectively. There are two parameters, *MaxHop* and *MinHop*. In add, the considered neighbors are the subtraction of neighborhood from *MaxHop* and *MinHop*, while the other processes' consider only neighborhood from *MinHop*. These processes are executed sequentially on all locations on all solutions. The local search operator is terminated once the solution cannot be improved further, or reach a predetermined number of iterations.

4 EXPERIMENTAL RESULTS

We compare NGAP and NSGA-III on 10 synthetic and four real-world instances, but for ease of understanding, only the city Humburg is shown here. In terms of the Inverted Generational Distance (IGD) metric (lower value of IGD indicates better convergence), NGAP dominates the original NSGA-III in 13 test instances. An example of Hamburg instance is shown in Fig. 1. With respect to the Spread indicator, both algorithms yield comparable spread in all experimental instances. This is to be expected since the objective of local search is not to increase the diversity to the population but to improve the coverage and minimize the vehicle number (reflect the convergence). The same trend as in IGD also appears in when comparing the Hypervolume (the higher value of Hypervolume indicates better convergence and diversity) as shown in Fig. 1. The proposed NGAP is superior to the original NSGA-III in all experimental instances.

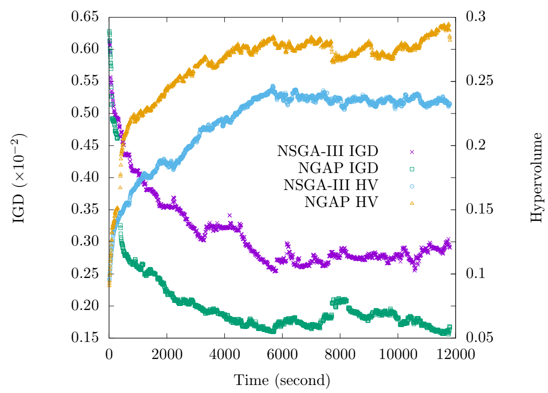

Figure 1: Generational plot of IGD and Hypervolume of each algorithm on Hamburg instance.

5 CONCLUSION

In the paper, a novel hybrid metaheuristic algorithm, NGAP, which is based on NSGA-III and Pareto local Search (PLS) is proposed. It is able to provide effective solutions to the Vehicle Placement Problem (VPP). NGAP also utilizes a novel local search operator called Extensible Neighborhood Search (ENS). Comparisons between the proposed algorithm and NSGA-III were performed on 10 synthetic and four real-world cities where the well known metrics, IGD, Spread and Hypervolume were used. The results reveal that NGAP is superior to NSGA-III in Vehicle Placement Problem. The work reaffirms the effort of hybridization of MOEAs and merits further studies in this field.

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