Capacitated Vehicle Routing Problem using Chained Meta Heuristics

Ⅰ Abstract

The Capacitated Vehicle Routing Problem (CVRP) [1] is a well-known NP-hard optimization problem [2] that arises in various industries such as transportation, delivery services, and supply chain management. It involves finding the most efficient way to deliver goods to a set of customers using a fleet of vehicles with limited capacity. The complexity of finding optimal solutions for CVRP increases exponentially with the number of instances, making it particularly challenging to solve large-scale problems in a reasonable time frame.

Significant research has been conducted to develop solution techniques for the CVRP, with numerous metaheuristic approaches being proposed in the literature. Key contributions include Guided Local Search [3], Adaptive Large Neighborhood Search [4], Simulated Annealing [5], and Genetic Algorithm [6], which have demonstrated the value of metaheuristic techniques [7] in solving CVRP instances. However, there remains a need for a more efficient and effective strategy that can tackle large-scale problems.

In this research project, I aim to develop and implement a powerful, synergistic approach that leverages the strengths of multiple meta-heuristic algorithms by chaining them together and aims to achieve close to optimal results for large-scale CVRP instances in a shorter period of time, which will be evaluated against the well-established CVRPLIB benchmark datasets [8].

Ⅱ Project Deliverables

1. **Project Report**
2. **Source Code**
3. **Experimentation Results**

Ⅲ Project Description

The CVRP is an important optimization challenge in operations research, logistics, and supply chain management, with numerous real-world applications. The problem seeks to minimize the total distance traveled by a fleet of vehicles with limited capacities while delivering goods to a set of customers. Due to the exponential increase in complexity with the number of instances, finding optimal solutions for large-scale CVRP instances is particularly challenging.

In this project, I aim to investigate the effectiveness of chaining several metaheuristic algorithms to develop a hybrid approach that leverages their individual strengths in order to improve solution quality for CVRP instances. My approach will be tested on the widely-used CVRPLIB benchmark dataset, and the obtained solutions will be compared to the best-known solutions in the literature.

Building upon foundational works in the field, I propose a novel approach that combines the advantages of various metaheuristic methods, offering a promising direction for future research.

Innovative and Challenging Aspects

1. **Python Implementation of Metaheuristic Algorithms:** Exploiting the potential of cutting-edge metaheuristic algorithms to tackle the complex CVRP problem, pushing the boundaries of optimization techniques in operations research and logistics.
2. **Chaining of Metaheuristic Algorithms:** Developing an approach that chains together multiple metaheuristic algorithms, optimizing their order of execution and fine-tuning hyperparameters to maximize solution quality and efficiency.
3. **Python Packaging Index (PyPi):** Publishing the work done to a popular Python software repository which will allow developers to use my library and experiment with meta-heuristic algorithms or build on it further. I will also open-source my Github repository and encourage pull requests from other developers once I have successfully defended my thesis.

Proposed Implementation Plan

1. Implement classic meta-heuristic algorithms and hybridize them.
2. Implement chaining of meta-heuristic algorithms to solve the CVRP.
3. Evaluate the performance by chaining and switching the order of algorithm execution.
4. Tweak/optimize algorithm parameters and observe the implications.
5. Compare the performance of chained heuristic algorithms with that of the benchmark dataset.

IV Progression Timeline

Week	Dates	Task
1, 2, 3	Aug 21 - Sep 9	Implement classic meta-heuristic algorithms
4, 5	Sep 10 - Sep 23	Implement chaining of meta-heuristic algorithms
6, 7, 8	Sep 24 - Oct 14	Evaluate Chain and Tweak hyperparameters
9, 10	Oct 15 - Oct 28	Evaluate the Order of Execution and Tweak the Order
11, 12	Oct 29 - Nov 11	Compare the performance of the chain with the benchmark dataset
13, 14	Nov 12- Nov 25	Prepare Report
15	Nov 26 - Dec 2	Prepare Presentation
16	Dec 3 - Dec 9	Final Presentation/ Demonstration

References

[1] S.-Y. Tan and W.-C. Yeh, "The Vehicle Routing Problem: State-of-the-Art Classification and Review," *Applied Sciences*, vol. 11, no. 21, p. 10295, Nov. 2021, https://doi.org/10.3390/app112110295

[2] ŽerovnikJanez. "Heuristics for NP-hard optimization problems - simpler is better!?" *Logistics, Supply Chain, Sustainability and Global Challenges 6*, no.1 (2015): 1-10, https://doi.org/10.1515/jlst-2015-0006

[3] Voudouris, C., Tsang, E.P., Alsheddy, A. (2010). Guided Local Search. In: Gendreau, M., Potvin, JY. (eds) *Handbook of Metaheuristics. International Series in Operations Research & Management Science*, vol 146. Springer, Boston, MA, https://doi.org/10.1007/978-1-4419-1665-5_11

[4] Pisinger, D., Ropke, S. (2019). Large Neighborhood Search. In: Gendreau, M., Potvin, JY. (eds) *Handbook of Metaheuristics. International Series in Operations Research & Management Science*, vol 272. Springer, Cham, https://doi.org/10.1007/978-3-319-91086-4_4

[5] A. Van Breedam, "Improvement heuristics for the Vehicle Routing Problem based on simulated annealing," *European Journal of Operational Research*, vol. 86, no. 3, pp. 480-490, 1995, https://doi.org/10.1016/0377-2217(94)00064-J

[6] M. A. Mohammed, M. S. Ahmad and S. A. Mostafa, "Using Genetic Algorithm in implementing Capacitated Vehicle Routing Problem," *2012 International Conference on Computer & Information Science (ICCIS)*, Kuala Lumpur, Malaysia, 2012, pp. 257-262, https://doi.org/10.1109/ICCISci.2012.6297250

[7] Osman, I.H., Kelly, J.P. (1996). Meta-Heuristics: An Overview. In: Osman, I.H., Kelly, J.P. (eds) *Meta-Heuristics*. Springer, Boston, MA, https://doi.org/10.1007/978-1-4613-1361-8_1

[8] ''Capacitated vehicle routing problem library (cvrplib),'' http://vrp.galgos.inf.puc-rio.br/index.php/en/, *Department of Industrial Engineering, Pontifical Catholic University of Rio de Janeiro*, accessed: 2023-04-22.