A Novel Algorithm for the Vehicle Routing Problem

Your Name, Co-Author's Name

The exercise

In this sample file, which is a condensed version of what you see on the screen, you will have to practice several LaTeX skills shown during the seminar. You will have to:

- From the section "Collaborating with Overleaf"
  - Make the current tex file work
  - Add your names as authors of the paper, without any affiliation
- From the section "Labels"
  - Put labels on the equations of the mathematical model, and use those labels to describe the model
  - Put labels on the different section of the paper, and use those label to describe the structure of the paper (excluding this section)
  - Put a label on Table 1 and use this label to refer to the Table in the text
- From the section "Commands"
  - Create a command for VRP, such as it appears in bold, i.e., **VRP**
  - Create a command for the EGTSA concept, such as it appears in italics, i.e., $EGTSA$
  - Create a command for the y_r variables
  - Create a command for the first author to add comments in magenta (the second author is too lazy to add comments)
- From the section "Bibliography"
  - Add the references "VIDAL2020401", "Konstantakopoulos2022" and "ASGHARI2021107899" (from the bib file) at the end of the sentence *The VRP has been widely studied due to its practical relevance in various industries, such as distribution, e-commerce, and public transportation.* The reference must be in parenthesis, and it must start with "see, e.g.,".
  - Put the references in the literature review in parenthesis
  - Change the bibliography so as it is shown in alphabetical order (google it!)
- From the section "Google it"

– Remove all indentations before the paragraphs
– Add one affiliation per author (the affiliation must be different between the two authors), and an email address per author
– Add a footnote to refer to the Wikipedia webpage of the VRP when it appears for the first time in the introduction
– Resize Table 1 so as it fits in one page

1 Introduction

The Vehicle Routing Problem (VRP) is a fundamental combinatorial optimization problem in the field of logistics and transportation. It involves finding optimal routes for a fleet of vehicles to deliver goods to a set of customers while minimizing the total travel cost. The VRP has been widely studied due to its practical relevance in various industries, such as distribution, e-commerce, and public transportation. Solving the VRP efficiently can lead to significant cost savings and environmental benefits.

This paper presents a new algorithm, the Enhanced Genetic-Tabu Search Algorithm (EGTSA), developed to address the VRP. The EGTSA combines genetic algorithms (GA) and tabu search (TS) to find high-quality solutions to the VRP by incorporating the benefits of both techniques.

The remainder of this paper is structured as follows. Section ??? overviews the most relevant literature. Section ??? presents a set-partitioning formulation to model the VRP. Section ??? presents the proposed EGTSA to solve the VRP. Computational experiments are presented in Section 5, and followed by conclusions in Section ???.

2 Literature Review

Various approaches have been proposed to tackle the VRP, including exact algorithms, heuristics, and metaheuristics. Exact algorithms, such as branch-and-bound, are capable of finding optimal solutions but are computationally intensive and often infeasible for large instances. Heuristic and metaheuristic methods, such as nearest neighbor Clarke and Wright [1964], Clarke-Wright Savings Algorithm Clarke and Wright [1964], and simulated annealing Kirkpatrick et al. [1983], have gained popularity for their ability to provide near-optimal solutions in reasonable timeframes.

Genetic algorithms have been widely applied to solve the VRP Taillard [1999]. Tabu search, on the other hand, is a local search-based metaheuristic that intensifies the search around promising solutions Glover and Kochenberger [1986]. Combining these two approaches may lead to a more effective algorithm for the VRP.

3 Mathematical Model

Parameters:

- V: Set of vertices, $i \in V$
- Ω: Set of feasible routes, $r \in \Omega$
- c_r: Cost of route $r \in \Omega$

- a_{ir}: Binary parameter equal to one if customer $i \in V$ is serviced in route r and zero otherwise.

Variables:

- y_r: Binary variable equal to one if route r is in the solution

The VRP can then be modeled as follows:

$$\begin{aligned}
\text{minimize} \quad & \sum_{r\in\Omega} c_r y_r && && (1)\\
\text{subject to} \quad & \sum_{r\in\Omega} a_{ir} y_r = 1, && \forall i \in V, && (2)\\
& y_r \in \{0,1\}, && \forall r \in \Omega. && (3)
\end{aligned}$$

We can then explain the mathematical model. The objective function ??? minimizes the costs. Constraints ??? ensure that each vertex is visited exactly once. Constraints ??? define the variable domain.

4 Enhanced Genetic-Tabu Search Algorithm (EGTSA)

The EGTSA is a hybrid algorithm that synergizes the exploration capabilities of genetic algorithms and the local search intensification of tabu search.

4.1 Genetic Algorithm (GA)

- Select parents for reproduction based on fitness.
- Apply crossover and mutation operations to create offspring solutions.
- Evaluate the fitness of offspring solutions.
- Select individuals for the next generation, possibly using elitism.

4.2 Tabu Search (TS)

- Apply tabu search to the best solution in the current population.
- Use tabu search to explore and improve the neighborhood of the current solution.
- Maintain a tabu list to prevent revisiting recently explored solutions.
- Update the best-known solution if a better one is found.

5 Computational Experiments

To assess the performance of the EGTSA, extensive computational experiments were conducted on benchmark VRP instances from the literature. The algorithm's effectiveness was evaluated in terms of solution quality, convergence speed, and scalability.

Table ??? presents quantitative results for the average solution cost, convergence time, and scalability of EGTSA and other algorithms. The EGTSA shows a lower average solution cost, faster convergence, and better scalability compared to the other algorithms.

Table 1: Quantitative Comparison of EGTSA with Other Algorithms

Algorithm	Average Solution Cost	Convergence Time (seconds)	Scalability (instance
EGTSA	1050.23	35.2	200
Algorithm A	1200.67	45.9	150
Algorithm B	1100.12	60.5	100

6 Conclusion

This research paper introduced a novel algorithm, the Enhanced Genetic-Tabu Search Algorithm (EGTSA), designed to address the Vehicle Routing Problem (VRP).

Future work includes fine-tuning the algorithm's parameters, further experimentation on various VRP variants, and exploring opportunities for parallelization to enhance its scalability and applicability in practical scenarios.

References

George Clarke and John W Wright. Scheduling of vehicles from a central depot to a number of delivery points. *Operations Research*, 12(4):568–581, 1964.

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Fred Glover and Gary A Kochenberger. Future paths for integer programming and links to artificial intelligence. *Computer and operations research*, 13(5):533–549, 1986.