Indian Institute of Information Technology,
Design and Manufacturing, Kancheepuram

P.Veera Abhiram
CS21B2026

Internship Report

COMPARITIVE ANALYSIS OF ANT COLONY OPTIMIZATION AND PARTICLE SWARM OPTIMIZATION FOR TRAVELING SALESMAN PROBLEM WITH HYPERPARAMETER TUNING

1 Summary of Internship

Motivation

I took this internship to learn and understand advanced optimization techniques, specifically focusing on metaheuristic algorithms. This interest was driven by the increasing complexity of applications and the growing demand for algorithms that not only solve specific problems effectively but also generalize solutions. By selecting the Traveling Salesman Problem (TSP), a recognized NP-hard problem, as the focal point, I aimed to delve into a critical class of optimization challenges. The difficulty of TSP makes it an essential testbed for evaluating and improving metaheuristic methods, which further motivated my choice of this problem and field of study.

Scope

The scope of this internship involved the general study and implementation of metaheuristic methods, with a particular emphasis on Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO). This required both a deep understanding of the theoretical underpinnings of these algorithms and practical coding skills to develop solution methodologies specifically tailored for solving the TSP. The work also included experimenting with various parameters to optimize performance. In addition, a comparative analysis and hyperparameter tuning were conducted to identify the best-performing TSP solution method.

Objectives

- **Understanding of Metaheuristic Algorithms:** Develop a solid understanding of different metaheuristic methods, with a focus on ACO and PSO, and their application to optimization problems such as TSP.
- **Implementation and Evaluation:** Implement ACO and PSO algorithms, incorporating advanced techniques such as enhanced collision algorithms (2-opt) for ACO and Hybrid PSO with local search. The objective is to test and evaluate the performance of different configurations.
- **Comparative Analysis:** Conduct a comprehensive comparative study of ACO and PSO to assess their effectiveness in solving TSP across various situations and problem sizes.
- **Hyperparameter Tuning:** Explore and implement hyperparameter tuning techniques to optimize the performance of ACO and PSO, ensuring that the algorithms are well-suited to TSP models.

2 Contribution

Week 1: Introduction to Metaheuristic Methods

Objective: Understand various metaheuristic algorithms and their applications.
Work Done:

- Explored different metaheuristic methods such as Genetic Algorithms (GA), Simulated Annealing (SA), Ant Colony Optimization (ACO), and Particle Swarm Optimization (PSO).
- **Reason for Picking ACO and PSO:** ACO and PSO were selected due to their effectiveness in solving combinatorial optimization problems like the Traveling Salesman Problem (TSP). ACO is inspired by the natural behavior of ants and is known for its robustness in finding optimal solutions, while PSO, inspired by the social behavior of birds and fish, is praised for its simplicity and ability to converge quickly.

Week 2: Deep Dive into Ant Colony Optimization (ACO)

Objective: Gain a comprehensive understanding of ACO and its application to TSP.
Work Done:

- Studied the basic principles of ACO, including pheromone trails, probability rules, and pheromone evaporation.
- **Why ACO is Better for TSP:** ACO is highly suitable for TSP due to its ability to explore multiple paths simultaneously and converge to an optimal or near-optimal solution.
- **Exploration of Different Strategies:** Evaluated various ACO strategies like elitist, rank-based, and Max-Min strategies.
- **Selection of Enhanced Meeting Strategy:** Chose the Enhanced Meeting Strategy because it allows for better collaboration between ants, improving solution quality.

Week 3: Learning About Particle Swarm Optimization (PSO)

Objective: Understand PSO and its potential for solving TSP.
Work Done:

- Explored the foundational concepts of PSO, including particles, velocity, and position updates.
- **Why PSO is Effective:** PSO is beneficial for TSP as it efficiently searches the solution space using a population of particles that share information to converge toward an optimal solution.
- **Comparison with ACO:** Discussed the strengths and weaknesses of PSO compared to ACO, ultimately leading to the decision to use both for comparative purposes.

Week 4: Selection of Strategies for PSO

Objective: Identify and implement an effective strategy for PSO in solving TSP.
Work Done:

- Reviewed various strategies like velocity clamping, constriction factors, and inertia weight adjustments.
- **Selection of Hybrid PSO with Local Search (2-opt):** Opted for this strategy because it combines the global search capability of PSO with the local refinement of 2-opt, making it a strong candidate for finding high-quality solutions.

Week 5: Implementation of ACO with Enhanced Meeting Strategy

Objective: Implement ACO with the chosen strategy and analyze its performance.
Work Done:

- Implemented the Enhanced Meeting Strategy, where ants periodically share their best paths to refine the solution.
- **Performance Analysis:** Conducted initial tests to evaluate performance, and observed the influence of parameters such as pheromone evaporation rate, alpha, and beta.

Week 6: Implementation of Hybrid PSO with Local Search (2-opt)

Objective: Implement the chosen PSO strategy and assess its performance.
Work Done:

- Developed the Hybrid PSO with Local Search, integrating 2-opt to enhance the particle positions.
- **Performance Analysis:** Analyzed the effectiveness of this approach in solving TSP and compared the results with the ACO implementation.

Week 7: Hyperparameter Tuning

Objective: Optimize the parameters for both ACO and PSO to achieve the best possible performance.
Work Done:

- **Hyperparameter Tuning:** Adjusted parameters like population size, number of iterations, alpha, beta, evaporation rate (for ACO), and inertia weight, cognitive, and social coefficients (for PSO).
- **Why Tuning is Crucial:** Fine-tuning these parameters is essential to balance exploration and exploitation, ensuring the algorithms find the best solutions efficiently.

Week 8: Comparative Analysis and Optimization

Objective: Compare the performance of ACO and PSO and identify areas for improvement.
Work Done:

- Conducted a detailed comparison between ACO and PSO, evaluating the solution quality, convergence speed, and computational efficiency.
- **Optimization Attempts:** Explored additional optimizations such as iterative meetings and selective meetings in ACO, and considered elite ant strategies, but found that traditional ACO performed better in some cases.

Week 9: Final Analysis and Documentation

Objective: Summarize the findings, document the work, and draw conclusions.
Work Done:

- **Final Analysis:** Consolidated all results, identifying key insights into the performance of ACO and PSO for TSP.
- **Documentation:** Prepared a detailed report summarizing the entire internship, including motivations, methodologies, results, and conclusions.
- **Conclusion:** Determined that while the Enhanced Meeting Strategy in ACO offered improvements over the baseline, traditional ACO still provided the best results for the given problem.

Include figures/graphs/tables as appropriate. This is how you would cite a reference [1] [2] [3] [4].

3 Conclusions

- During the internship, significant progress was made in understanding and applying advanced metaheuristic algorithms, specifically Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO), to the challenging Traveling Salesman Problem (TSP). The study provided valuable insights into the strengths and limitations of these algorithms, particularly in the context of combinatorial optimization.

- The implementation and experimentation with different strategies, such as the Enhanced Meeting Strategy for ACO and Hybrid PSO with Local Search (2-opt), demonstrated how tailored approaches could potentially enhance algorithm performance. However, it also revealed that careful tuning and selection of strategies are crucial, as even advanced methods may not always outperform traditional approaches in every scenario.

- Hyperparameter tuning played a key role in optimizing the algorithms, highlighting the importance of parameter settings in achieving the best possible results. The comparative analysis between ACO and PSO underscored the trade-offs between exploration and exploitation in metaheuristics, and how these can be balanced to solve complex optimization problems effectively.

  Overall, the internship provided a comprehensive understanding of ACO and PSO, equipping the student with practical skills in algorithm implementation, performance optimization, and problem-solving in the field of combinatorial optimization. The findings contribute to the broader knowledge of metaheuristics and their application, offering a solid foundation for future research and development in optimization techniques.

References

[1] W. Zhao, X. Cai, and Y. Lan, "A new ant colony algorithm for solving traveling salesman problem," *Proceedings - 2012 International Conference on Computer Science and Electronics Engineering, ICCSEE 2012*, vol. 3, 03 2012.

[2] M. Yousefikhoshbakht, "Solving the traveling salesman problem: A modified metaheuristic algorithm," *Complexity*, vol. 2021, pp. 1–13, 02 2021.

[3] X. Yan, C. Zhang, W. Luo, W. Li, W. Chen, and H. Liu, "Solve traveling salesman problem using particle swarm optimization algorithm," *International Journal of Computer Science*, vol. 9, no. 6, pp. 264–271, 2012.

[4] Z. Hlaing and M. Khine, "Solving traveling salesman problem by using improved ant colony optimization algorithm," *International Journal of Information and Education Technology*, vol. 1, pp. 404–409, 01 2011.