ADVANCED OPTIMIZATION

ASSIGNMENT 2

PROJECT TITLE

Comparative Analysis of GA, PSO, and DE for Optimization of the Rastrigin Function

SUBMITTED BY

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Comparison of Genetic Algorithm, Particle Swarm Optimization, and Differential Evolution on the Two-Dimensional Rastrigin Function

Abstract

This paper presents a comparison of three population-based metaheuristic algorithms, Genetic Algorithm (GA), Particle Swarm Optimization (PSO), and Differential Evolution (DE) applied to the two dimensional Rastrigin benchmark function. Each algorithm is implemented manually in MATLAB, with convergence behavior examined over 200 generations (or iterations) and a fixed population size of 50. Performance is evaluated in terms of convergence speed and solution accuracy. Results indicate that both PSO and DE achieved a global best fitness of 0 significantly faster than GA, demonstrating superior efficiency for this problem.

Introduction

The Rastrigin function is a non-convex, multimodal function widely used to benchmark the performance of global optimization algorithms, characterized by numerous local minima and a known global minimum at the origin where f(x) = 0 along with domain $\in [-5.12, 5.12]^2$.Deterministic local optimizers often become trapped in local minima. Metaheuristic methods like GA, PSO, and DE are effective alternatives capable of exploring complex landscapes using population-based stochastic search mechanisms. This study aims to compare these methods in a controlled experiment.

Methodology

A. Rastrigin Benchmark

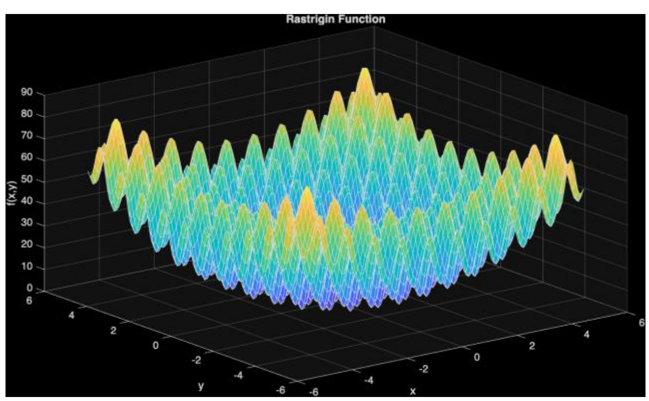

Figure 1: Rastrigin Function

The objective function is defined as:

$$f(x) = An + \sum_{i=1}^{n} [x_i^2 - A\cos(2\pi x_i)], \quad A = 10, n = 2, \ \ x_i \in [5.12,5.12]$$

Its multimodal nature and global optimum at x = (0,0) make it challenging for global optimization.

B. Algorithms

Genetic Algorithm (GA):
Uses tournament selection, blend crossover (α-based), and random mutation. Parameters: population size = 50, crossover rate = 0.8, mutation rate = 0.05, max generations = 200.

Particle Swarm Optimization (PSO):
Employs inertial weight (w = 0.7), cognitive (c_1 = 1.5) and social coefficients (c_2 = 1.5), swarm size = 50, max iterations = 200. Particle positions and velocities are updated according to canonical PSO rules.

Differential Evolution (DE):
Mutation factor F = 0.8, crossover rate CR = 0.9, same population size and generation limit. Trial vectors generated via differential mutation and binomial crossover; selection based on fitness improvement.

C. Experimental Setup

All algorithms use MATLAB R2025a, run over 200 generations (or iterations), population/swarm size fixed at 50, and search domain set to [−5.12, 5.12] in both dimensions. Convergence threshold defined at fitness ≤ 1e-6 to record convergence generation.

D. Code Availability

The MATLAB implementations of the Genetic Algorithm, Particle Swarm Optimization, and Differential Evolution used in this study are available in the public GitHub repository:

https://github.com/Edwardilo/Advanced-Optimization-Assignment-2

Results

Figures 2–4 show individual convergence plots for GA, PSO, and DE, while figure 5 compares them on a single graph.

- **GA**: Slower convergence, stabilizing around generation 200 with best fitness ≈ 0.0198.

- **PSO & DE**: Both algorithms reached 0 fitness around iterations 72 and 91, respectively.

A. Individual Convergence Plots

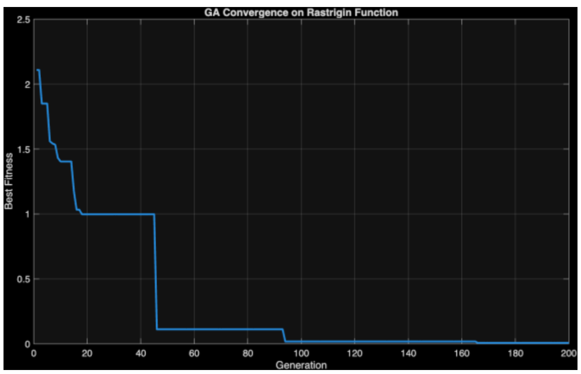

Figure 2: GA convergence plot

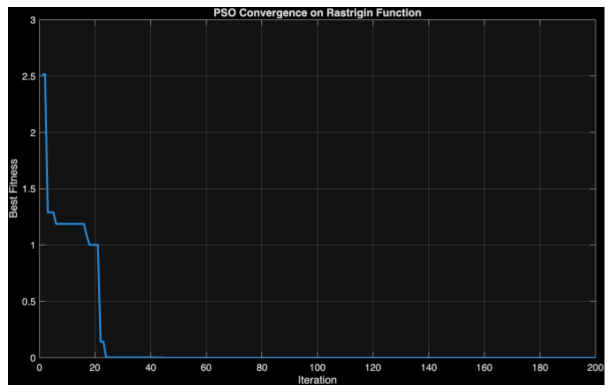

Figure 3: PSO convergence plot

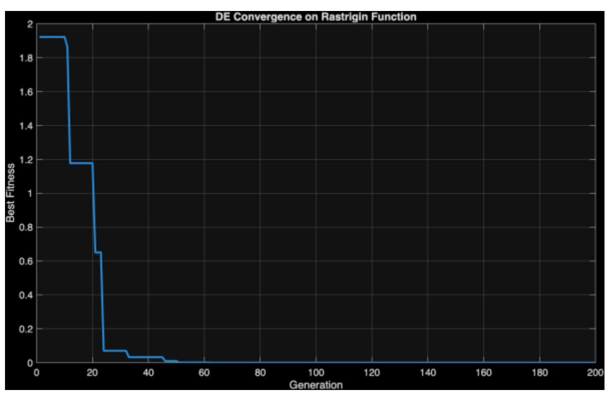

Figure 4: DE convergence plot

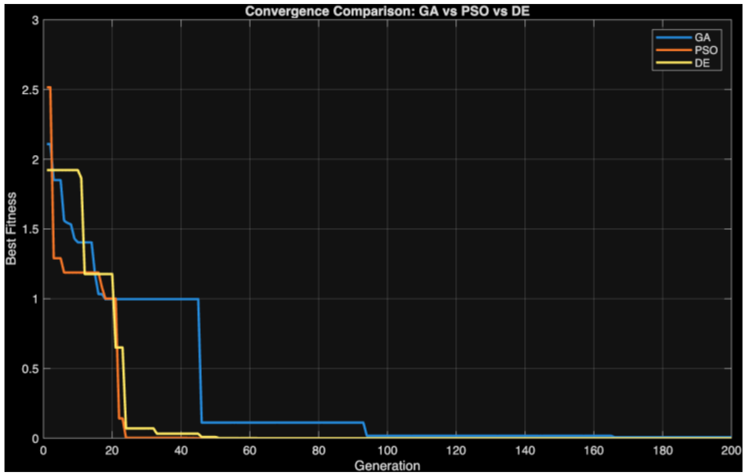

Figure 5: Combined convergence plot of GA, PSO, and DE

B. Summary Table

Algorithm	Best Fitness	Convergence Generation	Best Solution (x1, x2)
GA	0.0198	200	(0.00999, -0.0013)
PSO	0	72	(-1.62e-10, 2.08e-09)
DE	0	91	(7.49e, 2.05e-09)

Discussion

PSO exhibited the fastest convergence, reaching the global minimum in just 72 iterations. DE also successfully achieved the global minimum but required slightly more iterations, converging at 91. In contrast, GA did not fully reach the global minimum and recorded the highest final fitness value, indicating a less effective balance between exploration and exploitation. Overall, both PSO and DE significantly outperformed GA for this benchmark.

Conclusion

This study compared manual implementations of GA, PSO, and DE on the 2D Rastrigin function. PSO achieved the fastest convergence and highest accuracy, reaching the global optimum in 72 iterations. DE also converged to the optimum moderately quickly (91 generations), displaying robustness. GA did not reach the exact minimum within 200 generations, though it approached close. For similar optimization tasks, PSO is recommended for speed, while DE provides reliable performance. Future work may include parameter sensitivity analysis and hybrid methods (e.g. PSO seeded GA) for improved search performance.

References

[1]Rastrigin function, Wikipedia, viewed May 2025.

[2]Genetic Algorithm, Wikipedia, Table of metaheuristics, viewed July 2025.

[3]S. Sengupta et al., Particle Swarm Optimization: A survey, arXiv preprint, 2018.

[4]Q. Li et al., Influence of Initialization on the Performance of Metaheuristic Optimizers, arXiv preprint, 2020.