Optimisation Techniques and Algorithms Lab Assignment 7

Aim:

1) Implement Particle Swarm Optimization with the following parameters:
    a) Population size: 50
    b) Maximum number of iterations: 500
    c) Cognitive coefficient (c1) (alpha): 2
    d) Social coefficient (c2)(beta): 2

Optimize any 5 test functions.

2) Compare the results of GA and PSO for any 5 test functions on the following parameters for 500 iterations:
    a) Mean function values for 20 runs
    b) Best function values for 20 runs
    c) Standard deviation values for 20 runs

Compare the iteration-wise mean function values plots for both the values.

<u>Code:</u>

Code 1:

```
% Define parameters
nParticles = 50;              % Number of particles
nDimensions = 2;                % Number of dimensions (change as needed)
maxIterations = 500;          % Maximum number of iterations
cognitiveCoeff = 2;           % Cognitive coefficient (c1)
socialCoeff = 2;              % Social coefficient (c2)
inertiaWeight = 0.5;          % Inertia weight (w)
minBound = -10;                % Lower bound of search space
maxBound = 10;                 % Upper bound of search space

% Define the objective function
str = 'x1^2 + x2^2';  % Objective function as a string
syms x [1 nDimensions];
fitnessFunction = str2sym(str);
```

```
f = matlabFunction(fitnessFunction, 'vars', {x});

% Initialize particles' positions and velocities
positions = minBound + (maxBound - minBound) * rand(nParticles, nDimensions);
velocities = rand(nParticles, nDimensions);

% Evaluate initial fitness values
fitness = arrayfun(@(i) f(positions(i,:)), 1:nParticles, 'UniformOutput', false);
fitness = cell2mat(fitness);

% Initialize personal best positions and fitness
pBestPositions = positions;
pBestFitness = fitness;

% Find the initial global best
[globalBestFitness, globalBestIndex] = min(fitness);
gBestPosition = positions(globalBestIndex, :);

% Initialize array to store the best fitness values over iterations
bestFitnessOverTime = zeros(maxIterations, 1);

% PSO main loop
for iteration = 1:maxIterations
  % Update velocities
  r1 = rand(nParticles, nDimensions); % Random values for cognitive component
  r2 = rand(nParticles, nDimensions); % Random values for social component

  velocities = inertiaWeight * velocities + ...
    cognitiveCoeff * r1 .* (pBestPositions - positions) + ...
    socialCoeff * r2 .* (gBestPosition - positions);
```

```
    % Update positions
    positions = positions + velocities;

    % Apply boundary conditions
    positions = max(min(positions, maxBound), minBound);

    % Evaluate new fitness values
    fitness = arrayfun(@(i) f(positions(i,:)), 1:nParticles, 'UniformOutput', false);
    fitness = cell2mat(fitness);

    % Update personal bests
    improved = fitness < pBestFitness;
    pBestPositions(improved, :) = positions(improved, :);
    pBestFitness(improved) = fitness(improved);

    % Update global best
    [currentGlobalBestFitness, globalBestIndex] = min(fitness);
    if currentGlobalBestFitness < globalBestFitness
        globalBestFitness = currentGlobalBestFitness;
        gBestPosition = positions(globalBestIndex, :);
    end

    % Store the best fitness value for the current iteration
    bestFitnessOverTime(iteration) = globalBestFitness;

    % Display iteration information
    fprintf('Iteration %d: Best Fitness = %.4f\n', iteration, globalBestFitness);
end
```

```
% Output final results
fprintf('Final Global Best Fitness: %.4f\n', globalBestFitness);
fprintf('Final Global Best Position: [%s]\n', num2str(gBestPosition, '%.4f '));

% Plot convergence graph
figure;
plot(1:maxIterations, bestFitnessOverTime, 'LineWidth', 2);
xlabel('Iteration');
ylabel('Best Fitness Value');
title('Convergence Graph of PSO');
grid on;
```

Code 2:

```
clc;
clear;

% Parameters
MaxIter = 100; % Total iterations
str = 'x1^2 + x2^2 + x3^2'; % Fitness function
D = 3; % Number of dimensions
Npop = 50; % Population size
CR = 0.6; % Crossover rate
MR = 0.05; % Mutation rate
n = 20; % Number of runs
LB = [-10, -10, -10]; % Lower bounds for each dimension
UB = [10, 10, 10]; % Upper bounds for each dimension

% Create symbolic variables and the fitness function
syms x [1 D];
fitnessFunction = str2sym(str);
```

```
f = matlabFunction(fitnessFunction, 'vars', {x});

% Initialize storage for fitness values
GA_bestFitness = zeros(MaxIter, n);
GA_meanFitness = zeros(MaxIter, 1);
GA_stddevFitness = zeros(MaxIter, 1);

PSO_bestFitness = zeros(MaxIter, n);
PSO_meanFitness = zeros(MaxIter, 1);
PSO_stddevFitness = zeros(MaxIter, 1);

% GA Algorithm
for run = 1:n
    % Initialize population
    X = LB + rand(Npop, D) .* (UB - LB);

    % Fitness evaluation
    fitness = zeros(Npop, 1);
    for i = 1:Npop
        fitness(i) = f(X(i, :));
    end

    for it = 1:MaxIter
        X_new = X; % Copy population for new individuals

        for i = 1:Npop
            % Selection of r1
            r1 = randi(Npop);
            while r1 == i
                r1 = randi(Npop);
```

```
        end

        % Crossover
        if rand < CR
            crossoverPoint = floor(D / 2); % Single-point crossover at midpoint
            X_new(i, 1:crossoverPoint) = X(i, 1:crossoverPoint);
            X_new(i, crossoverPoint+1:end) = X(r1, crossoverPoint+1:end);
        end

        % Mutation
        if rand < MR
            mutationPoint = randi(D);
            X_new(i, mutationPoint) = LB(mutationPoint) + rand * (UB(mutationPoint) -
LB(mutationPoint));
        end

        % Fitness evaluation
        fitness_new = f(X_new(i, :));
        if fitness_new < fitness(i)
            X(i, :) = X_new(i, :);
            fitness(i) = fitness_new;
        end
    end

    % Sort population by fitness
    [sortedFitness, ~] = sort(fitness, 'ascend');

    % Track best fitness for this iteration
    GA_bestFitness(it, run) = sortedFitness(1);
  end
end
```

```
% Compute GA statistics
GA_meanFitness = mean(GA_bestFitness, 2);
GA_stddevFitness = std(GA_bestFitness, 0, 2);

% PSO Algorithm
for run = 1:n
    [bestFitnessOverTime] = particleSwarmOptimization(f, Npop, MaxIter, D, LB, UB);
    PSO_bestFitness(:, run) = bestFitnessOverTime;
end

% Compute PSO statistics
PSO_meanFitness = mean(PSO_bestFitness, 2);
PSO_stddevFitness = std(PSO_bestFitness, 0, 2);

% Plot the results
figure;
plot(1:MaxIter, GA_meanFitness, 'r', 'LineWidth', 2);
hold on;
plot(1:MaxIter, PSO_meanFitness, 'b', 'LineWidth', 2);
xlabel('Iteration');
ylabel('Mean Fitness Value');
title('Mean Fitness Value Over Iterations');
legend('GA', 'PSO');
grid on;

figure;
plot(1:MaxIter, min(GA_bestFitness, [], 2), 'r', 'LineWidth', 2);
hold on;
plot(1:MaxIter, min(PSO_bestFitness, [], 2), 'b', 'LineWidth', 2);
```

```
xlabel('Iteration');
ylabel('Best Fitness Value');
title('Best Fitness Value Over Iterations');
legend('GA', 'PSO');
grid on;

figure;
plot(1:MaxIter, GA_stddevFitness, 'r', 'LineWidth', 2);
hold on;
plot(1:MaxIter, PSO_stddevFitness, 'b', 'LineWidth', 2);
xlabel('Iteration');
ylabel('Standard Deviation of Fitness Value');
title('Standard Deviation of Fitness Value Over Iterations');
legend('GA', 'PSO');
grid on;

% PSO function
function [bestFitnessOverTime] = particleSwarmOptimization(fitnessFunction, nParticles,
maxIterations, nDimensions, LB, UB)
  % PSO Parameters
  cognitiveCoeff = 2; % Cognitive coefficient
  socialCoeff = 2;    % Social coefficient
  inertiaWeight = 0.5; % Inertia weight

  % Initialize positions and velocities
  positions = LB + (UB - LB) .* rand(nParticles, nDimensions);
  velocities = rand(nParticles, nDimensions);

  % Evaluate initial fitness values
  fitness = arrayfun(@(i) fitnessFunction(positions(i,:)), 1:nParticles, 'UniformOutput',
false);
```

```
fitness = cell2mat(fitness);

% Initialize personal bests
pBestPositions = positions;
pBestFitness = fitness;

% Find the initial global best
[globalBestFitness, globalBestIndex] = min(fitness);
gBestPosition = positions(globalBestIndex, :);

% Initialize array to store best fitness values over iterations
bestFitnessOverTime = zeros(maxIterations, 1);

% PSO main loop
for iteration = 1:maxIterations
    % Update velocities
    r1 = rand(nParticles, nDimensions); % Random values for cognitive component
    r2 = rand(nParticles, nDimensions); % Random values for social component

    velocities = inertiaWeight * velocities + ...
        cognitiveCoeff * r1 .* (pBestPositions - positions) + ...
        socialCoeff * r2 .* (gBestPosition - positions);

    % Update positions
    positions = positions + velocities;

    % Apply boundary conditions
    positions = max(min(positions, UB), LB);

    % Evaluate new fitness values
```

```
        fitness = arrayfun(@(i) fitnessFunction(positions(i,:)), 1:nParticles, 'UniformOutput',
false);
        fitness = cell2mat(fitness);

        % Update personal bests
        improved = fitness < pBestFitness;
        pBestPositions(improved, :) = positions(improved, :);
        pBestFitness(improved) = fitness(improved);

        % Update global best
        [currentGlobalBestFitness, globalBestIndex] = min(fitness);
        if currentGlobalBestFitness < globalBestFitness
            globalBestFitness = currentGlobalBestFitness;
            gBestPosition = positions(globalBestIndex, :);
        end

        % Store the best fitness value for the current iteration
        bestFitnessOverTime(iteration) = globalBestFitness;
    end
end
```

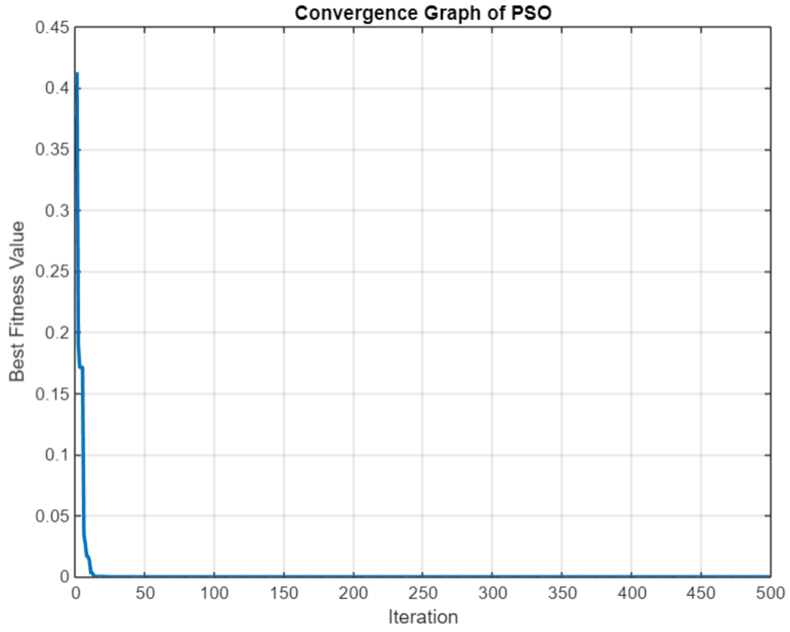
Output:

Function 1: Sphere function

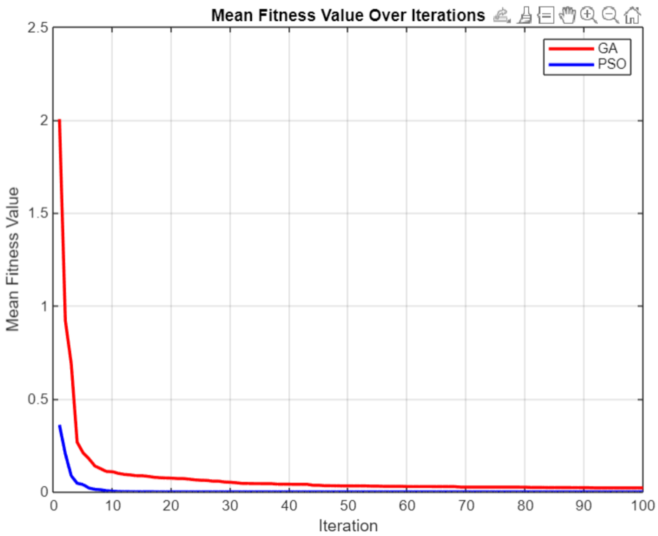
Dimensions=2

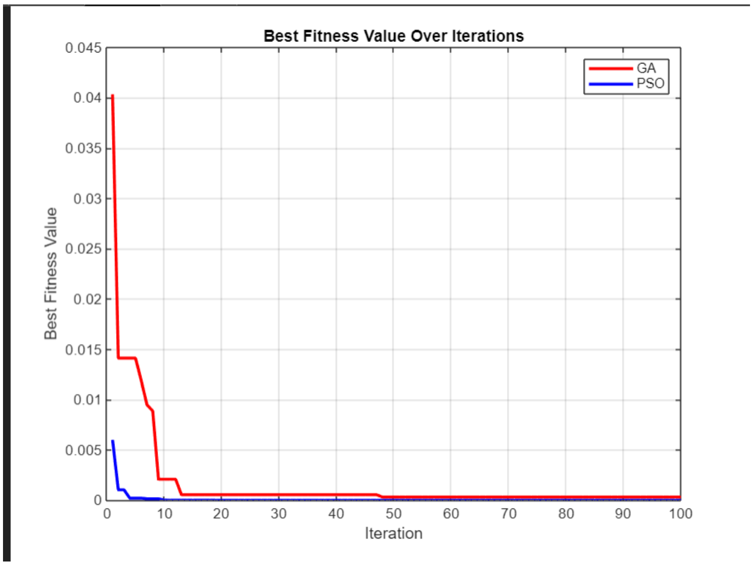
F='x1^2+x2^2'

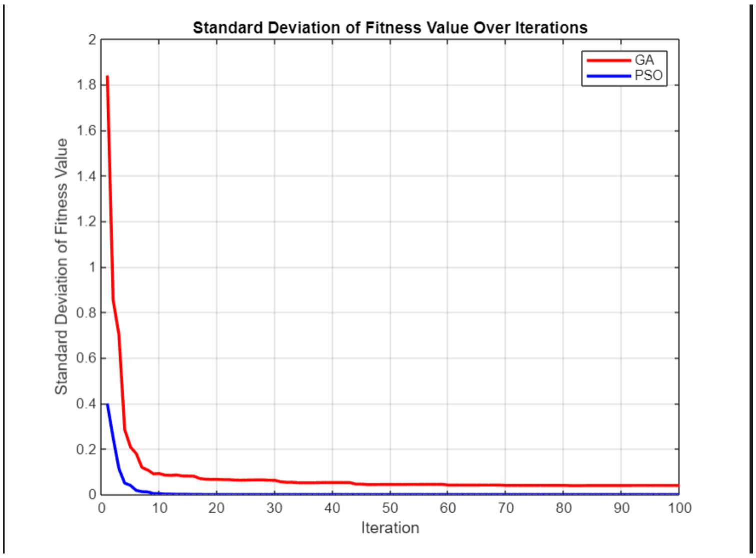
Code 1:



Code 2:





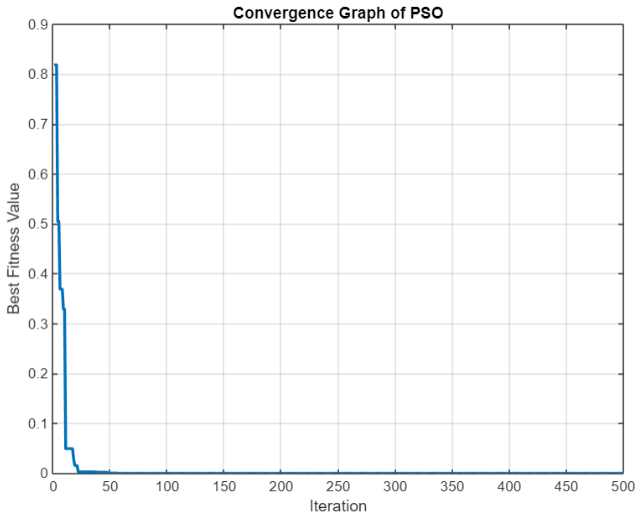


Function 2: Rosenbrock

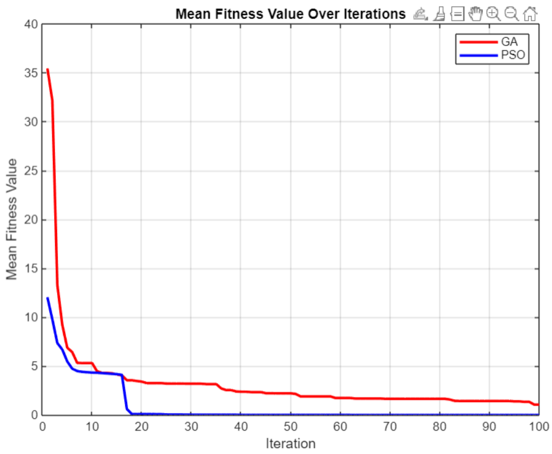
Dimensions=2

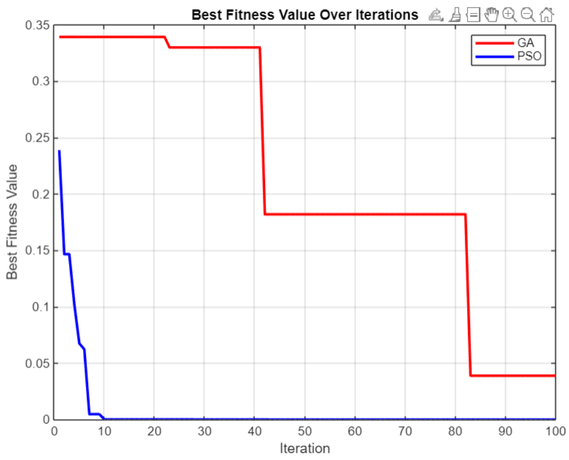
F='100*(x2^2 - x1^2)^2 + (1 - x1)^2'

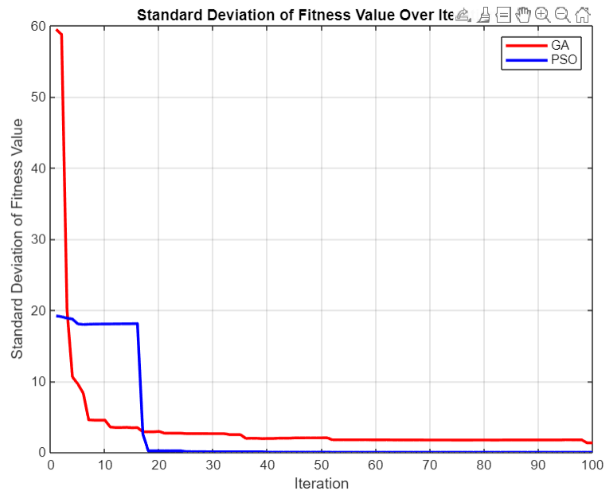
Code 1:


Convergence Graph of PSO
Best Fitness Value
Iteration

Code 2:


Mean Fitness Value Over Iterations
GA
PSO
Mean Fitness Value
Iteration


Best Fitness Value Over Iterations
GA
PSO
Best Fitness Value
Iteration

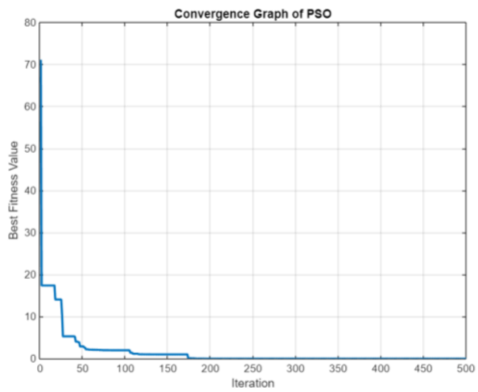


Function 3: Rastrigin Function

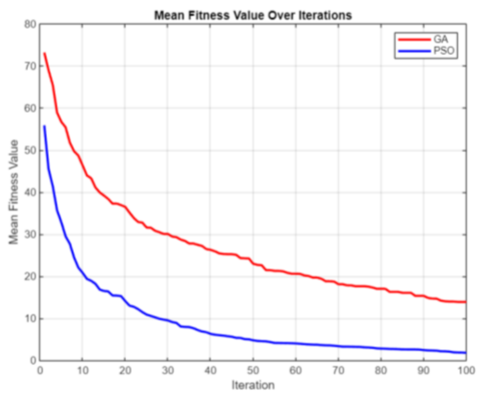
Dimensions:5

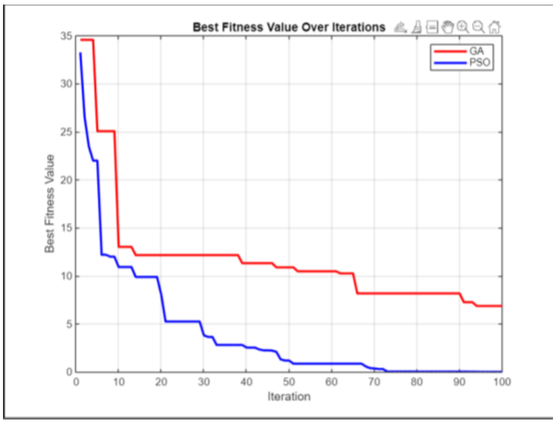
F='10*5 + (x1^2 - 10*cos(2*pi*x1)) + (x2^2 - 10*cos(2*pi*x2)) + (x3^2 - 10*cos(2*pi*x3)) + (x4^2 - 10*cos(2*pi*x4)) + (x5^2 - 10*cos(2*pi*x5))'

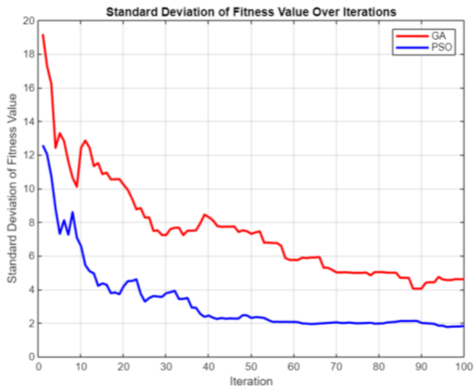
Code 1:



Code 2:





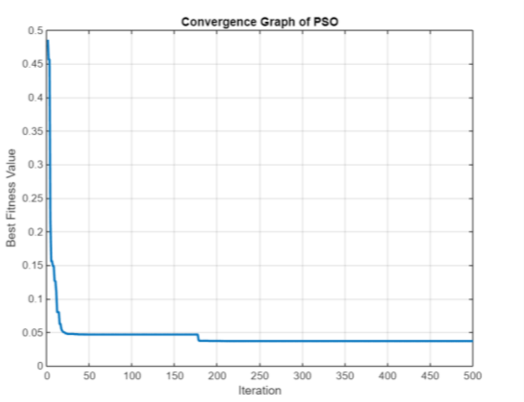


Function 4: Griewank Function:

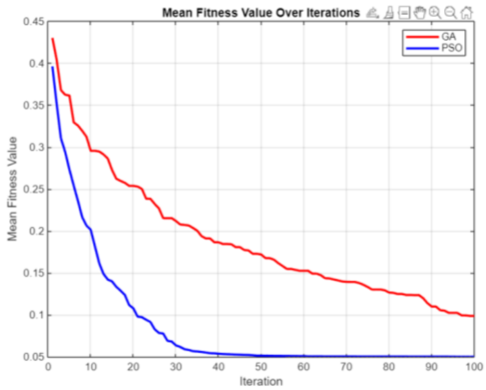
Dimensions: 5

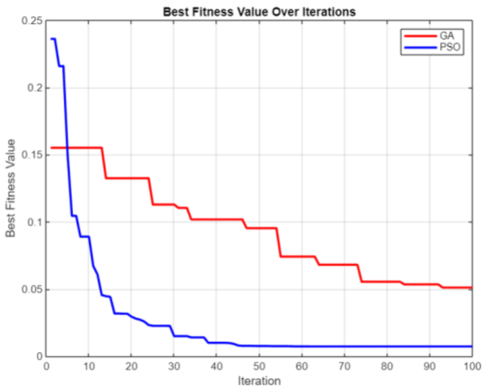
F='1 + (x1^2 + x2^2 + x3^2 + x4^2 + x5^2)/4000 - cos(x1)*cos(x2/sqrt(2))*cos(x3/sqrt(3))*cos(x4/sqrt(4))*cos(x5/sqrt(5))'

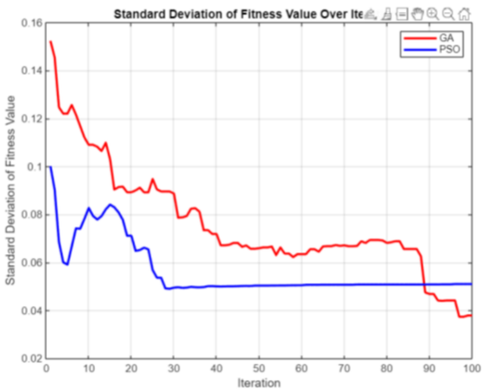
Code 1:



Code 2:





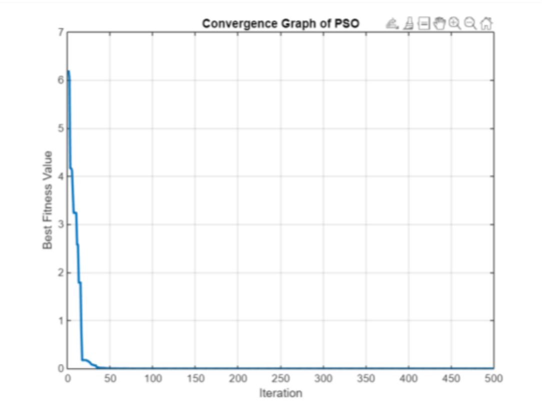


Function 5: Ackley Function:

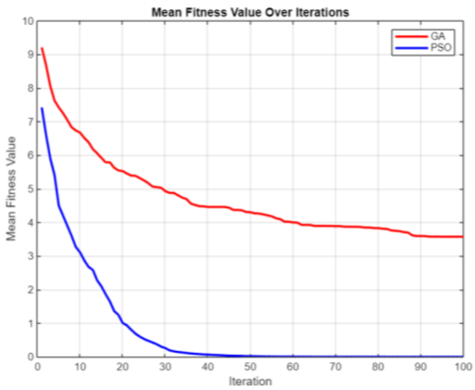
Dimensions: 5

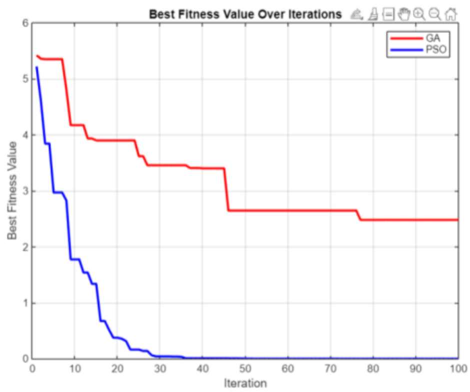
F='-20*exp(-0.2*sqrt((x1^2 + x2^2 + x3^2 + x4^2 + x5^2)/5)) - exp((cos(2*pi*x1) + cos(2*pi*x2) + cos(2*pi*x3) + cos(2*pi*x4) + cos(2*pi*x5))/5) + 20 + exp(1)'

Code 1:


Convergence Graph of PSO
Best Fitness Value
Iteration

Code 2:


Mean Fitness Value Over Iterations
GA
PSO
Mean Fitness Value
Iteration


Best Fitness Value Over Iterations
GA
PSO
Best Fitness Value
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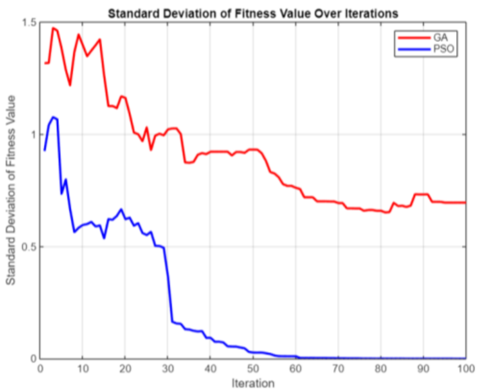
Standard Deviation of Fitness Value Over Iterations
GA
PSO
Standard Deviation of Fitness Value
Iteration