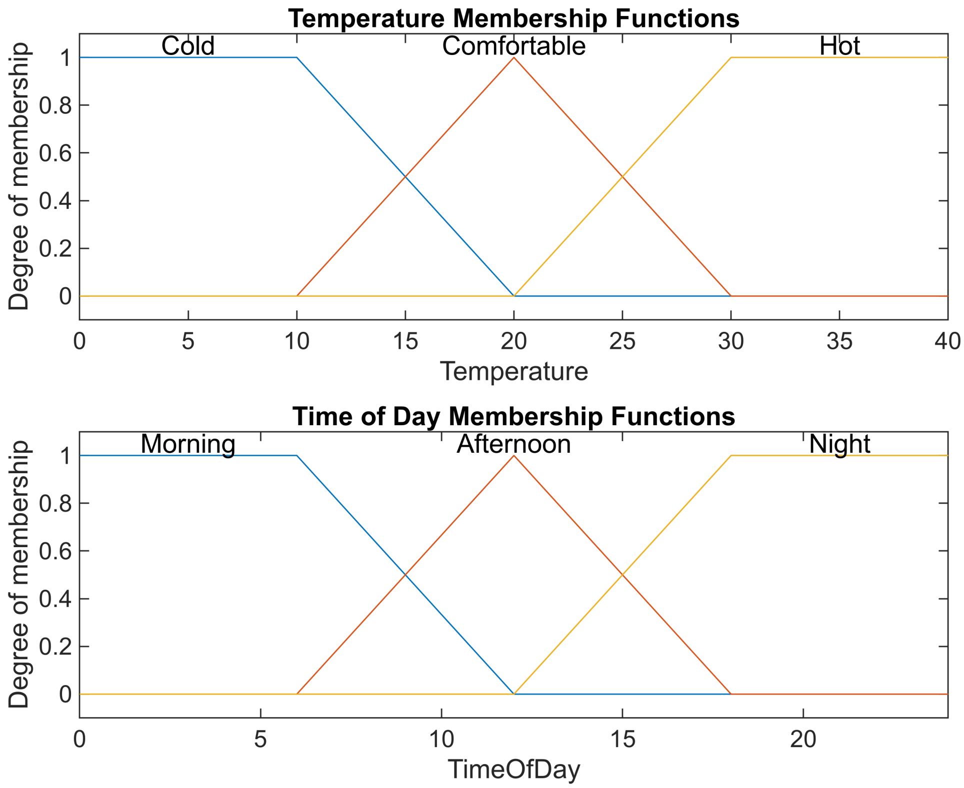
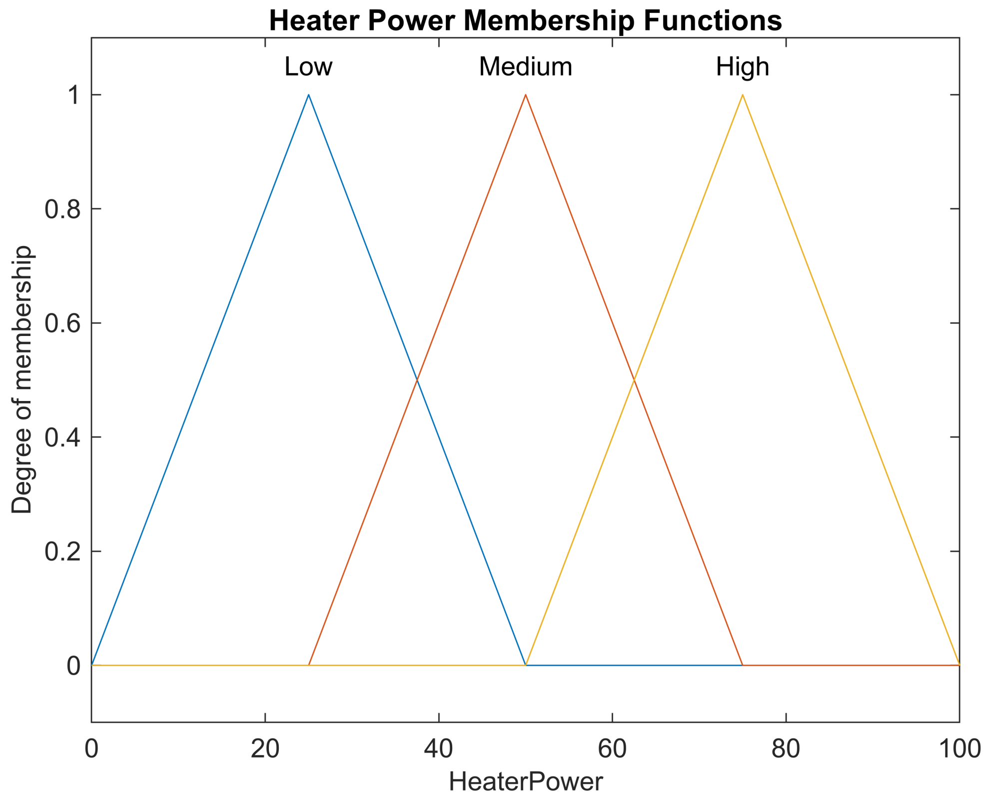
```
%% Fuzzy Logic Controller for Temperature and Time of Day
% Create Mamdani FIS object
fis = mamfis('Name', 'TemperatureTimeController', ...
    'AndMethod', 'min', ...
    'OrMethod', 'max', ...
    'ImplicationMethod', 'min', ...
    'AggregationMethod', 'max', ...
    'DefuzzificationMethod', 'centroid');

%% Input Variables
% Input 1: Temperature (0°C to 40°C)
fis = addInput(fis, [0 40], 'Name', 'Temperature');
fis = addMF(fis, 'Temperature', 'trapmf', [0 0 10 20], 'Name', 'Cold');
fis = addMF(fis, 'Temperature', 'trimf', [10 20 30], 'Name', 'Comfortable');
fis = addMF(fis, 'Temperature', 'trapmf', [20 30 40 40], 'Name', 'Hot');

% Input 2: Time of Day (0 to 24 hours)
fis = addInput(fis, [0 24], 'Name', 'TimeOfDay');
fis = addMF(fis, 'TimeOfDay', 'trapmf', [0 0 6 12], 'Name', 'Morning');
fis = addMF(fis, 'TimeOfDay', 'trimf', [6 12 18], 'Name', 'Afternoon');
fis = addMF(fis, 'TimeOfDay', 'trapmf', [12 18 24 24], 'Name', 'Night');

%% Output Variable
% Output: Heater Power (0% to 100%)
fis = addOutput(fis, [0 100], 'Name', 'HeaterPower');
fis = addMF(fis, 'HeaterPower', 'trimf', [0 25 50], 'Name', 'Low');
fis = addMF(fis, 'HeaterPower', 'trimf', [25 50 75], 'Name', 'Medium');
fis = addMF(fis, 'HeaterPower', 'trimf', [50 75 100], 'Name', 'High');

%% Rule Base
rules = [
    "If Temperature is Cold and TimeOfDay is Morning then HeaterPower is High";
    "If Temperature is Cold and TimeOfDay is Afternoon then HeaterPower is Medium";
    "If Temperature is Cold and TimeOfDay is Night then HeaterPower is High";
    "If Temperature is Comfortable and TimeOfDay is Morning then HeaterPower is 
Medium";
    "If Temperature is Comfortable and TimeOfDay is Afternoon then HeaterPower is 
Low";
    "If Temperature is Comfortable and TimeOfDay is Night then HeaterPower is 
Medium";
    "If Temperature is Hot and TimeOfDay is Morning then HeaterPower is Low";
    "If Temperature is Hot and TimeOfDay is Afternoon then HeaterPower is Low";
    "If Temperature is Hot and TimeOfDay is Night then HeaterPower is Medium";
];

fis = addRule(fis, rules);

%% Visualization
% Membership functions for inputs
figure('Name','Membership Functions for Inputs');
```

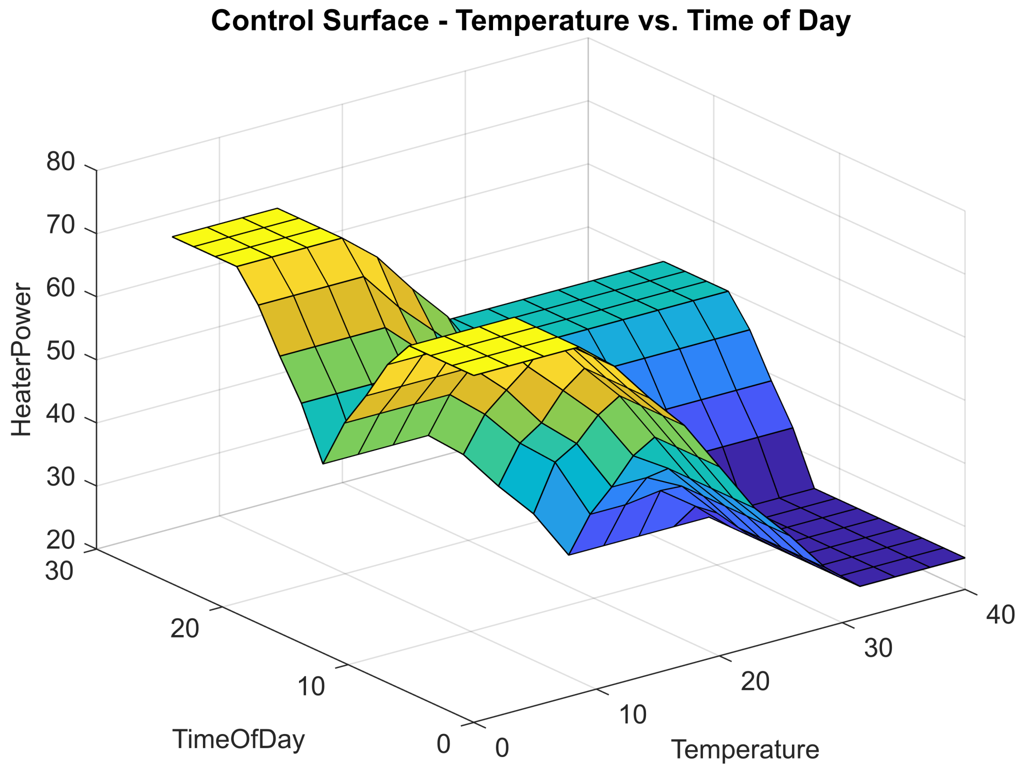
```
subplot(2,1,1); plotmf(fis,'input',1); title('Temperature Membership Functions');
subplot(2,1,2); plotmf(fis,'input',2); title('Time of Day Membership Functions');
```




```
% Membership functions for output
figure('Name','Membership Functions for Output');
plotmf(fis,'output',1); title('Heater Power Membership Functions');
```




```
% Control surface plot
figure('Name','Control Surface');
gensurf(fis);
title('Control Surface - Temperature vs. Time of Day');
```




```
%% Simulation
% Test sample input (e.g., Temperature = 15°C, Time of Day = 8 hours)
inputValues = [15, 8];
output = evalfis(fis, inputValues);
fprintf('For Temperature=%.2f°C and TimeOfDay=%.2f hours:\nHeater Power: %.2f%%
\n\n',...
        inputValues(1), inputValues(2), output);
```

```
For Temperature=15.00°C and TimeOfDay=8.00 hours:
Heater Power: 52.85%
```

```
% Example inputs
testInputs = [
    [5, 9]; % Cold morning
    [25, 15]; % Comfortable afternoon
    [35, 21]; % Hot night
];

% Evaluate system for each input
for i = 1:size(testInputs,1)
    output = evalfis(fis, testInputs(i,:));
    fprintf('For Temperature=%.2f°C and TimeOfDay=%.2f hours:\nHeater Power: %.2f%%
\n\n',...
            testInputs(i,1), testInputs(i,2), output);
end
```

```
For Temperature=5.00°C and TimeOfDay=9.00 hours:
Heater Power: 62.50%

For Temperature=25.00°C and TimeOfDay=15.00 hours:
Heater Power: 37.50%

For Temperature=35.00°C and TimeOfDay=21.00 hours:
Heater Power: 50.00%
```

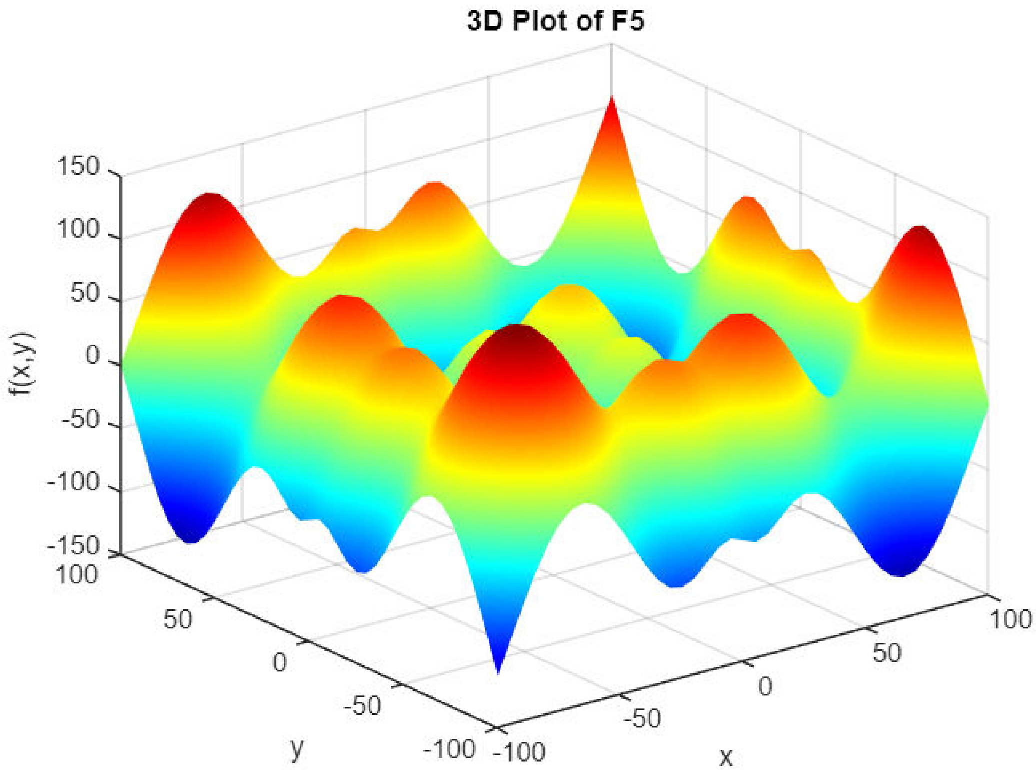
```
fuzzyLogicDesigner(fis);
```

```
% --- Main Script ---
clear; clc;

% Define dimensions
dimensions = [2, 10]; % Add D=100 if desired

% Number of runs for each optimization algorithm
numRuns = 15;

% Define functions from CEC'2005 suite
functions = {@F5, @F7, @F13};
functionNames = {'F5', 'F7', 'F13'};

% Define optimization algorithms
algorithms = {'GA', 'PSO', 'SA'};

% Genetic Algorithm options
gaOptions = optimoptions('ga', 'Display', 'off', 'PopulationSize', 50,
'MaxGenerations', 100);

% Particle Swarm Optimization options
psoOptions = optimoptions('particleswarm', 'Display', 'off', 'SwarmSize', 50,
'MaxIterations', 100);

% Simulated Annealing options
saOptions = optimoptions('simulannealbnd', 'Display', 'off', 'MaxIterations', 300);

% Store results for ROC-style plots
rocData = struct();

% Loop over dimensions
for d = dimensions
    fprintf('--- Dimensions: %d ---\n', d);

    % Loop over functions
    for fIndex = 1:length(functions)
        func = functions{fIndex};
        funcName = functionNames{fIndex};
        fprintf('Function: %s\n', funcName);

        % Define search space bounds
        lb = -100 * ones(1, d); % Lower bound
        ub = 100 * ones(1, d);  % Upper bound

        % Ensure bounds are of type double
        lb = double(lb);
        ub = double(ub);

        % Plot the function in 3D (only for D=2)
        if d == 2
```

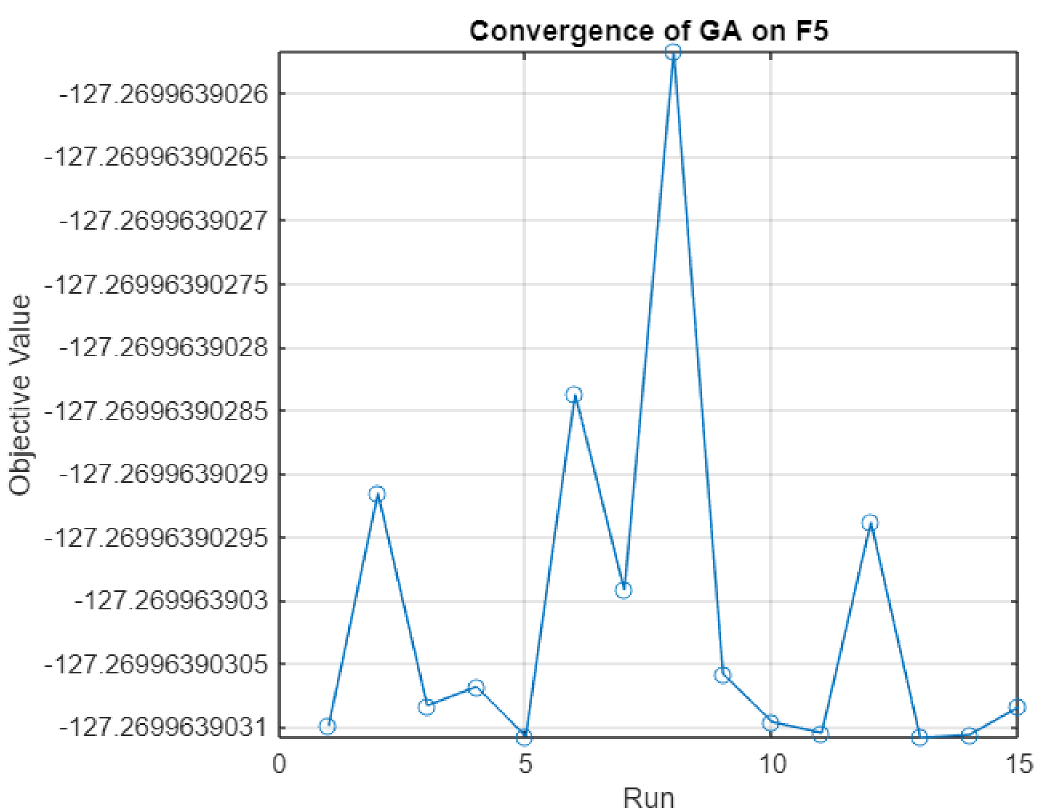
```
            figure;
            [x, y] = meshgrid(-100:5:100, -100:5:100);
            z = arrayfun(@(a, b) func([a, b]), x, y);
            surf(x, y, z);
            title(['3D Plot of ', funcName]);
            xlabel('x'); ylabel('y'); zlabel('f(x,y)');
            colormap jet; shading interp;
        end

        % Loop over algorithms
        for aIndex = 1:length(algorithms)
            algorithm = algorithms{aIndex};
            fprintf('Algorithm: %s\n', algorithm);

            results = zeros(1, numRuns);

            % Run optimization multiple times
            for run = 1:numRuns
                switch algorithm
                    case 'GA'
                        [~, fval] = ga(func, d, [], [], [], [], lb, ub, [],
gaOptions);
                        results(run) = fval;
                    case 'PSO'
                        [~, fval] = particleswarm(func, d, lb, ub, psoOptions);
                        results(run) = fval;
                    case 'SA'
                        % Define a starting point within the bounds
                        x0 = (lb + ub) / 2;
                        [~, fval] = simulannealbnd(func, x0, lb, ub, saOptions);
                        results(run) = fval;
                end
            end

            % Calculate statistics
            avgPerformance = mean(results);
            stdDeviation = std(results);
            bestPerformance = min(results);
            worstPerformance = max(results);

            % Store data for ROC-style plots (normalized performance)
            rocData.(funcName).(algorithm) = results / max(results);

            % Display results
            fprintf('  Avg Performance: %.4f\n', avgPerformance);
            fprintf('  Std Deviation:   %.4f\n', stdDeviation);
            fprintf('  Best Performance: %.4f\n', bestPerformance);
            fprintf('  Worst Performance: %.4f\n', worstPerformance);

            % Plot convergence (only for D=2)
```

```
            if d == 2 && strcmp(algorithm, 'GA')
                figure;
                plot(1:numRuns, results, '-o');
                title(['Convergence of ', algorithm, ' on ', funcName]);
                xlabel('Run'); ylabel('Objective Value');
                grid on;
            end
        end
    end

    % Generate ROC-style plots (only for D=2)
    if d == 2
        figure;
        hold on;
        colors = {'r', 'g', 'b'};
        legendEntries = {};

        for fIndex = 1:length(functions)
            funcName = functionNames{fIndex};

            for aIndex = 1:length(algorithms)
                algorithm = algorithms{aIndex};
                dataROC = rocData.(funcName).(algorithm); % Normalized data

                % Sort data to create an ROC-like curve
                sortedDataROC = sort(dataROC);
                plot(sortedDataROC, linspace(0, 1, numRuns), colors{aIndex},
'LineWidth', 1.5);

                legendEntries{end+1} = [funcName, '-', algorithm];
            end
        end

        title('ROC-Style Plot Comparing Algorithms');
        xlabel('Normalized Objective Value');
        ylabel('Cumulative Probability');
        legend(legendEntries);
        grid on;
    end
end
```

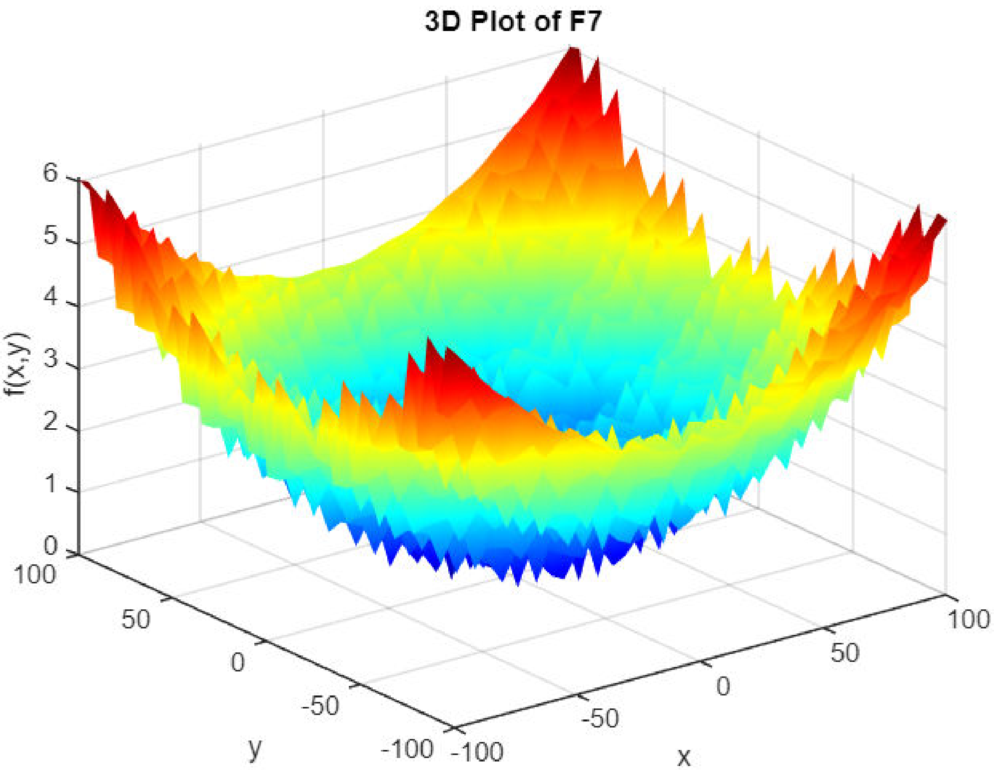
```
--- Dimensions: 2 ---
Function: F5
```



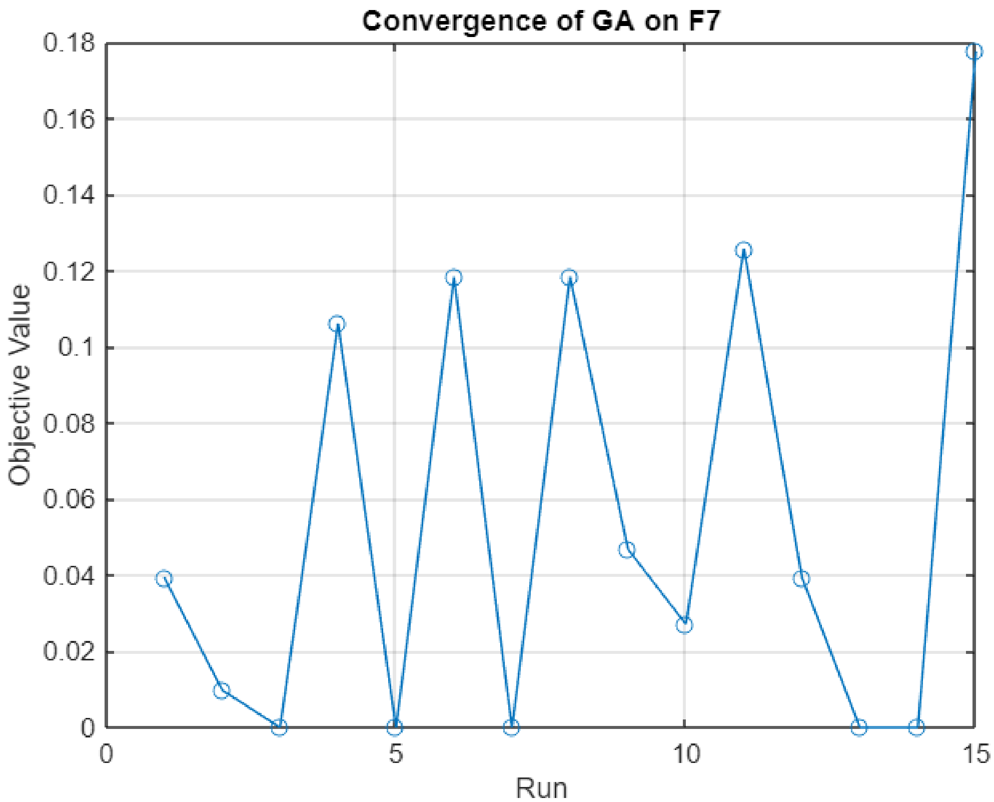

```
Algorithm: GA
  Avg Performance: -127.2700
  Std Deviation:    0.0000
  Best Performance: -127.2700
  Worst Performance: -127.2700
```



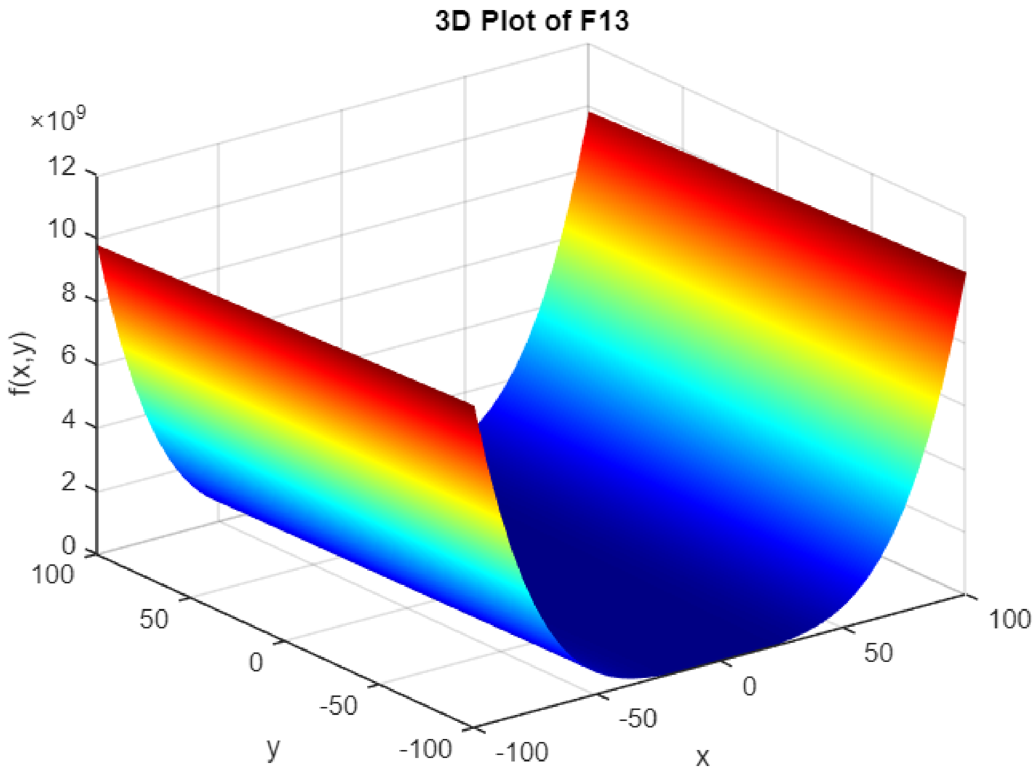
```
Algorithm: PSO
  Avg Performance: -126.6544
  Std Deviation:    2.3839
  Best Performance: -127.2700
  Worst Performance: -118.0371
Algorithm: SA
  Avg Performance: -107.8278
  Std Deviation:    20.4932
  Best Performance: -127.2693
  Worst Performance: -67.5257
Function: F7
```



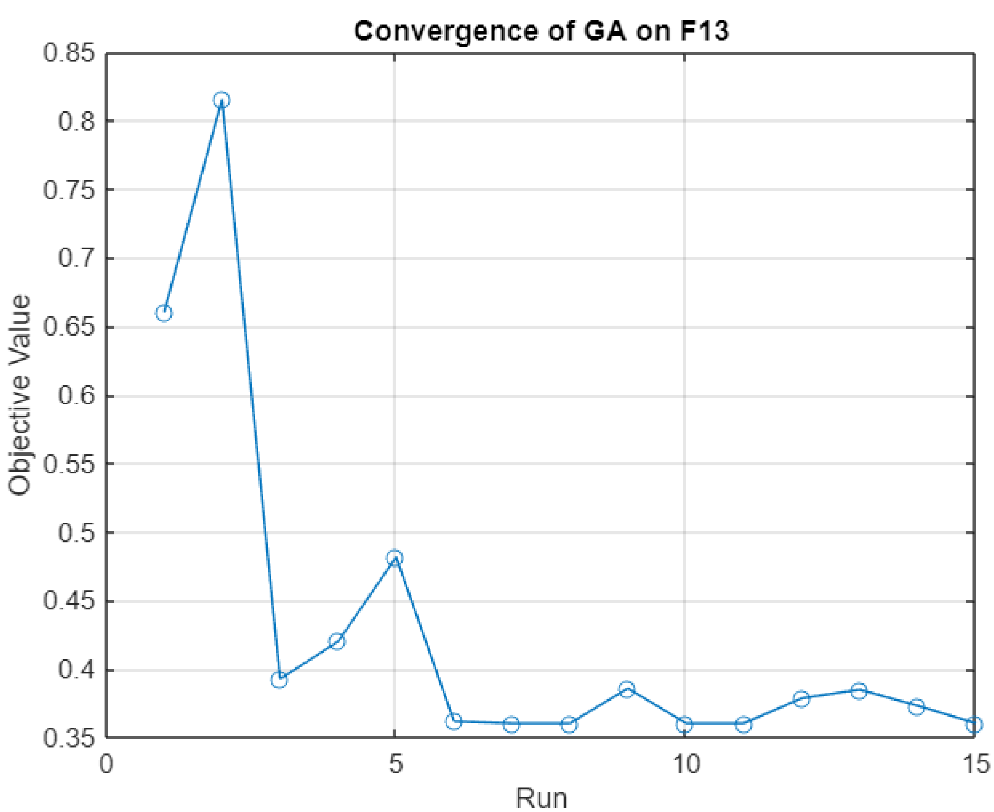

```
Algorithm: GA
  Avg Performance: 0.0539
  Std Deviation:    0.0592
  Best Performance: 0.0000
  Worst Performance: 0.1776
```



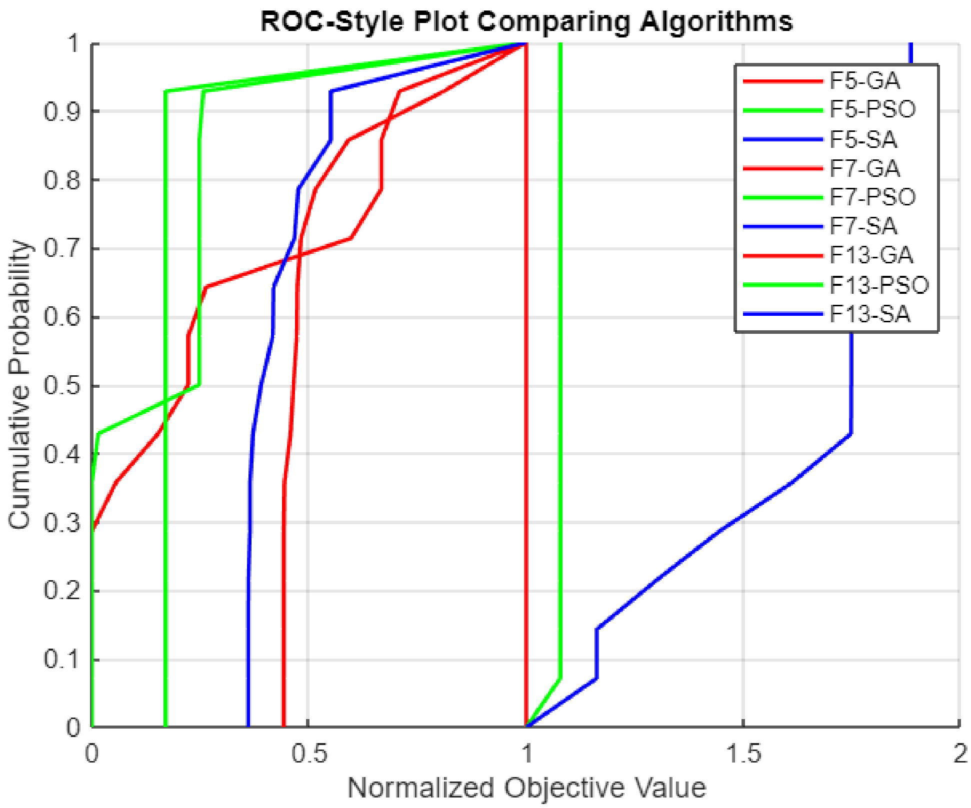

```
Algorithm: PSO
  Avg Performance: 0.0055
  Std Deviation:   0.0077
  Best Performance: 0.0000
  Worst Performance: 0.0299
Algorithm: SA
  Avg Performance: 0.0000
  Std Deviation:   0.0000
  Best Performance: 0.0000
  Worst Performance: 0.0000
Function: F13
```




```
Algorithm: GA
  Avg Performance: 0.4305
  Std Deviation:   0.1322
  Best Performance: 0.3605
  Worst Performance: 0.8156
```



```
Algorithm: PSO
  Avg Performance: 0.4774
  Std Deviation:   0.4527
  Best Performance: 0.3605
  Worst Performance: 2.1138
Algorithm: SA
  Avg Performance: 0.4541
  Std Deviation:   0.1651
  Best Performance: 0.3605
  Worst Performance: 1.0000
```




```
--- Dimensions: 10 ---
Function: F5
Algorithm: GA
  Avg Performance: -614.3640
  Std Deviation:   21.8589
  Best Performance: -636.3326
  Worst Performance: -566.7747
Algorithm: PSO
  Avg Performance: -570.4887
  Std Deviation:   13.9005
  Best Performance: -590.1855
  Worst Performance: -544.0211
Algorithm: SA
  Avg Performance: -366.9444
  Std Deviation:   96.0058
  Best Performance: -554.0675
  Worst Performance: -205.5595
Function: F7
Algorithm: GA
  Avg Performance: 0.0077
  Std Deviation:   0.0200
  Best Performance: 0.0000
  Worst Performance: 0.0699
Algorithm: PSO
```

```
  Avg Performance: 0.1491
  Std Deviation:   0.2036
  Best Performance: 0.0000
  Worst Performance: 0.8133
Algorithm: SA
  Avg Performance: 0.0000
  Std Deviation:   0.0000
  Best Performance: 0.0000
  Worst Performance: 0.0000
Function: F13
Algorithm: GA
  Avg Performance: 12.8224
  Std Deviation:   21.6175
  Best Performance: 0.9454
  Worst Performance: 66.0636
Algorithm: PSO
  Avg Performance: 325.4513
  Std Deviation:   873.5278
  Best Performance: 1.5390
  Worst Performance: 3172.9137
Algorithm: SA
  Avg Performance: 8.8962
  Std Deviation:   0.0324
  Best Performance: 8.8351
  Worst Performance: 8.9384
```

```
% --- End of Main Script ---

% --- Benchmark Functions ---
function y = F5(x)
    % Schwefel’s Problem (Example Placeholder)
    y = sum(-x .* sin(sqrt(abs(x)))); % Replace with actual CEC'2005 definition
end

function y = F7(x)
    % Griewank’s Function (Example Placeholder)
    y = sum(x.^2) / 4000 - prod(cos(x ./ sqrt(1:length(x)))) + 1; % Replace with
actual CEC'2005 definition
end

function y = F13(x)
    % Expanded Griewank’s plus Rosenbrock’s Function (Example Placeholder)
    yRosenbrockPart = sum(100 * (x(2:end) - x(1:end-1).^2).^2 + (x(1:end-1) -
1).^2);
    yGriewankPart = sum(x.^2) / 4000 - prod(cos(x ./ sqrt(1:length(x)))) + 1;
    y = yRosenbrockPart + yGriewankPart; % Replace with actual CEC'2005 definition
end

% --- End of Benchmark Functions ---
```