Grey Wolf Optimizer Implementation

Defining the function

```
In[∘]:= fitnessSphere[x_] := Total[x^2]
```

```
In[∘]:= fitnessRastrigin[x_] := 10 Length[x] + Total[x^2 - 10 Cos[2 Pi x]]
```

```
In[∘]:= fitnessRosenbrock[x_] :=
         Total[Table[100 (x⟦i + 1⟧ - x⟦i⟧^2)^2 + (1 - x⟦i⟧)^2, {i, Length[x] - 1}]]
```

Classifying the Wolf

```
In[∘]:= CreateWolf[fitness_, dim_, minx_, maxx_, seed_] := Module[{position, rnd, wolf},
          SeedRandom[seed];
          position = Table[0.0, {dim}];
          Do[position⟦i⟧ = (maxx - minx) RandomReal[] + minx, {i, dim}];
          fitnessValue = fitness[position];
          wolf = <|"Position" → position, "Fitness" → fitnessValue|>;
          wolf]
```

Grey Wolf Optimization

```
In[∘]:= gwo[fitness_, maxIter_, n_, dim_, minx_, maxx_] :=
          Module[{rnd, population, alphaWolf, betaWolf, gammaWolf, Iter, a, A1, A2,
            A3, C1, C2, C3, X1, X2, X3, Xnew, fnew}, rnd = RandomReal[1, {n, dim}];
           population = Table[<|"position" → RandomReal[{minx, maxx}, dim],
              "fitness" → fitness[RandomReal[{minx, maxx}, dim]]|>, {n}];
           population = SortBy[population, #fitness &];
           {alphaWolf, betaWolf, gammaWolf} = population⟦ ;; 3⟧;
           Iter = 0;
           While[Iter < maxIter, If[Mod[Iter, 10] == 0 && Iter > 1,
             Print["Iter = ", Iter, " best fitness = ", alphaWolf["fitness"]]];
            a = 2 (1 - Iter / maxIter);
            Do[A1 = a (2 RandomReal[] - 1);
             A2 = a (2 RandomReal[] - 1);
             A3 = a (2 RandomReal[] - 1);
             C1 = 2 RandomReal[];
             C2 = 2 RandomReal[];
             C3 = 2 RandomReal[];
             X1 = alphaWolf["position"] -
               A1 Abs[C1 alphaWolf["position"] - population⟦i, "position"⟧];
             X2 = betaWolf["position"] -
               A2 Abs[C2 betaWolf["position"] - population⟦i, "position"⟧];
             X3 = gammaWolf["position"] -
               A3 Abs[C3 gammaWolf["position"] - population⟦i, "position"⟧];
             Xnew = Mean[{X1, X2, X3}];
             fnew = fitness[Xnew];
             If[fnew < population⟦i, "fitness"⟧, population⟦i, "position"⟧ = Xnew;
              population⟦i, "fitness"⟧ = fnew;], {i, n}];
            population = SortBy[population, #fitness &];
            {alphaWolf, betaWolf, gammaWolf} = population⟦ ;; 3⟧;
            Iter++;];
           alphaWolf["position"]];
```

Running test for Sphere function

Case 01.01: Sphere function with dimension 2

```
In[∘]:= dimension = 2;
        populationSizes = {10, 20, 50, 100};
        iterationValues = {10, 30, 50};
        results2 = {};

        Do[Do[Print["Running test for dimension=", dimension,
             ", population_size=", populationSize, ", num_iterations=", numIter];
           bestSolutions =
             Table[gwo[fitnessSphere, numIter, populationSize, dimension, -10.0, 10.0], {10}];
           bestSolution = First[SortBy[bestSolutions, fitnessSphere]];
           Print["Best Result for population_size=", populationSize, ", num_iter=",
             numIter, ": ", bestSolution, " with fitness = ", fitnessSphere[bestSolution]];
           AppendTo[results2, <|"Dimension" → dimension,
               "Population Size" → populationSize, "Iteration Number" → numIter, "Label" →
                "SpF" <> ToString[dimension] <> ToString[populationSize] <> ToString[numIter],
               "Solution" → bestSolution, "Fitness" → fitnessSphere[bestSolution] |>],
           {numIter, iterationValues}], {populationSize, populationSizes}];

        spfDF = Dataset[results2];
        Print[spfDF]
```

```
Running test for dimension=2, population_size=10, num_iterations=10

Best Result for population_size=10, num_iter=
 10: {-0.00679733, 0.0373743} with fitness = 0.00144304

Running test for dimension=2, population_size=10, num_iterations=30

Iter = 10 best fitness = 0.000622119

Iter = 20 best fitness = 0.0000872077

Iter = 10 best fitness = 0.963157

Iter = 20 best fitness = 0.963157

Iter = 10 best fitness = 0.0507994

Iter = 20 best fitness = 0.0060998

Iter = 10 best fitness = 0.0339307

Iter = 20 best fitness = 0.00360136

Iter = 10 best fitness = 0.00359014

Iter = 20 best fitness = 0.0000614909

Iter = 10 best fitness = 0.0326437

Iter = 20 best fitness = 0.00217031

Iter = 10 best fitness = 0.000151521

Iter = 20 best fitness = 0.0000262621

Iter = 10 best fitness = 0.0155139

Iter = 20 best fitness = 0.00285856

Iter = 10 best fitness = 1.42145

Iter = 20 best fitness = 1.42145

Iter = 10 best fitness = 1.17669
Iter = 20 best fitness = 1.17669

Best Result for population_size=10, num_iter=
 30: {0.00302668, -0.00315727} with fitness = 0.0000191292

Running test for dimension=2, population_size=10, num_iterations=50

Iter = 10 best fitness = 0.0549742

Iter = 20 best fitness = 0.00520699

Iter = 30 best fitness = 0.000729663

Iter = 40 best fitness = 0.000462292

Iter = 10 best fitness = 0.0000187255

Iter = 20 best fitness = 1.03438×10^-10

Iter = 30 best fitness = 1.86737×10^-11

Iter = 40 best fitness = 1.07818×10^-11

Iter = 10 best fitness = 0.000174542

Iter = 20 best fitness = 4.50912×10^-6

Iter = 30 best fitness = 7.54841×10^-7

Iter = 40 best fitness = 3.98816×10^-7

Iter = 10 best fitness = 0.502846

Iter = 20 best fitness = 0.502846

Iter = 30 best fitness = 0.502846

Iter = 40 best fitness = 0.502846

Iter = 10 best fitness = 0.00095779

Iter = 20 best fitness = 1.02981×10^-6

Iter = 30 best fitness = 1.13713×10^-7

Iter = 40 best fitness = 4.63737×10^-8

Iter = 10 best fitness = 0.00107909

Iter = 20 best fitness = 0.000117494

Iter = 30 best fitness = 0.0000239768

Iter = 40 best fitness = 0.0000106481

Iter = 10 best fitness = 0.000587481

Iter = 20 best fitness = 0.0000161364

Iter = 30 best fitness = 2.35098×10^-6

Iter = 40 best fitness = 1.45823×10^-6

Iter = 10 best fitness = 0.00537695

Iter = 20 best fitness = 0.0000627987

Iter = 30 best fitness = 0.0000199953

Iter = 40 best fitness = 0.0000107376

Iter = 10 best fitness = 0.100361

Iter = 20 best fitness = 0.00982511

Iter = 30 best fitness = 0.00167095
Iter = 40 best fitness = 0.000753224

Iter = 10 best fitness = 0.0345904

Iter = 20 best fitness = 0.00235951

Iter = 30 best fitness = 0.000799759

Iter = 40 best fitness = 0.000370855

Best Result for population_size=10, num_iter=50
 : {2.14848×10^-6, -2.17124×10^-6} with fitness = 9.33022×10^-12

Running test for dimension=2, population_size=20, num_iterations=10

Best Result for population_size=20, num_iter=
 10: {-0.00422049, 0.0227138} with fitness = 0.000533731

Running test for dimension=2, population_size=20, num_iterations=30

Iter = 10 best fitness = 1.60409

Iter = 20 best fitness = 1.60409

Iter = 10 best fitness = 0.510255

Iter = 20 best fitness = 0.510255

Iter = 10 best fitness = 0.000231696

Iter = 20 best fitness = 1.7349×10^-7

Iter = 10 best fitness = 0.00129326

Iter = 20 best fitness = 0.0000393753

Iter = 10 best fitness = 0.0697476

Iter = 20 best fitness = 0.0697476

Iter = 10 best fitness = 0.00120487

Iter = 20 best fitness = 6.60191×10^-6

Iter = 10 best fitness = 8.19046×10^-6

Iter = 20 best fitness = 5.47521×10^-8

Iter = 10 best fitness = 0.000250286

Iter = 20 best fitness = 0.0000159825

Iter = 10 best fitness = 0.000243869

Iter = 20 best fitness = 0.0000102634

Iter = 10 best fitness = 0.00235228

Iter = 20 best fitness = 0.0000125277

Best Result for population_size=20, num_iter=
 30: {0.000128834, -0.000133263} with fitness = 3.43572×10^-8

Running test for dimension=2, population_size=20, num_iterations=50

Iter = 10 best fitness = 0.00131422

Iter = 20 best fitness = 6.85408×10^-11

Iter = 30 best fitness = 2.85988×10^-12

Iter = 40 best fitness = 1.08571×10^-12

Iter = 10 best fitness = 0.000389592

Iter = 20 best fitness = 9.26248×10^-7
Iter = 30 best fitness = 5.74774×10^-8

Iter = 40 best fitness = 1.94211×10^-8

Iter = 10 best fitness = 0.000063251

Iter = 20 best fitness = 1.51182×10^-7

Iter = 30 best fitness = 9.71786×10^-9

Iter = 40 best fitness = 4.56584×10^-9

Iter = 10 best fitness = 0.0126188

Iter = 20 best fitness = 0.000131103

Iter = 30 best fitness = 0.0000205343

Iter = 40 best fitness = 7.08923×10^-6

Iter = 10 best fitness = 2.21808×10^-6

Iter = 20 best fitness = 5.8662×10^-10

Iter = 30 best fitness = 9.07257×10^-12

Iter = 40 best fitness = 3.6702×10^-12

Iter = 10 best fitness = 1.6676

Iter = 20 best fitness = 1.64474

Iter = 30 best fitness = 1.64474

Iter = 40 best fitness = 1.64474

Iter = 10 best fitness = 0.0000597682

Iter = 20 best fitness = 6.98431×10^-9

Iter = 30 best fitness = 2.17854×10^-10

Iter = 40 best fitness = 7.59647×10^-11

Iter = 10 best fitness = 2.48259×10^-6

Iter = 20 best fitness = 8.32756×10^-9

Iter = 30 best fitness = 4.33778×10^-10

Iter = 40 best fitness = 1.82971×10^-10

Iter = 10 best fitness = 2.80968

Iter = 20 best fitness = 0.193782

Iter = 30 best fitness = 0.0238448

Iter = 40 best fitness = 0.00792114

Iter = 10 best fitness = 0.0000491885

Iter = 20 best fitness = 2.96165×10^-7

Iter = 30 best fitness = 2.97584×10^-8

Iter = 40 best fitness = 1.17022×10^-8

Best Result for population_size=20, num_iter=50
 : {6.51179×10^-7, -6.71181×10^-7} with fitness = 8.74519×10^-13

Running test for dimension=2, population_size=50, num_iterations=10

Best Result for population_size=50, num_iter=10
 : {-2.70338×10^-6, -3.79988×10^-6} with fitness = 2.17473×10^-11
```

```
Running test for dimension=2, population_size=50, num_iterations=30

Iter = 10 best fitness = 0.000494987

Iter = 20 best fitness = 3.21527×10^-7

Iter = 10 best fitness = 0.000877225

Iter = 20 best fitness = 2.1159×10^-6

Iter = 10 best fitness = 1.37272

Iter = 20 best fitness = 1.37272

Iter = 10 best fitness = 0.0767341

Iter = 20 best fitness = 0.000226704

Iter = 10 best fitness = 2.04997×10^-8

Iter = 20 best fitness = 4.0846×10^-11

Iter = 10 best fitness = 0.164759

Iter = 20 best fitness = 0.164759

Iter = 10 best fitness = 2.24258×10^-9

Iter = 20 best fitness = 1.11702×10^-12

Iter = 10 best fitness = 5.45766×10^-7

Iter = 20 best fitness = 5.7022×10^-15

Iter = 10 best fitness = 5.80955×10^-6

Iter = 20 best fitness = 5.57334×10^-9

Iter = 10 best fitness = 3.32618×10^-8

Iter = 20 best fitness = 6.46566×10^-13

Best Result for population_size=50, num_iter=30
 : {-3.06309×10^-8, 3.03518×10^-8} with fitness = 1.85949×10^-15

Running test for dimension=2, population_size=50, num_iterations=50

Iter = 10 best fitness = 5.02943×10^-7

Iter = 20 best fitness = 4.36455×10^-12

Iter = 30 best fitness = 2.0806×10^-14

Iter = 40 best fitness = 4.98537×10^-15

Iter = 10 best fitness = 0.406845

Iter = 20 best fitness = 0.406845

Iter = 30 best fitness = 0.406845

Iter = 40 best fitness = 0.406845

Iter = 10 best fitness = 9.7346×10^-7

Iter = 20 best fitness = 6.99718×10^-11

Iter = 30 best fitness = 3.08686×10^-13

Iter = 40 best fitness = 5.97609×10^-14

Iter = 10 best fitness = 6.5898×10^-6

Iter = 20 best fitness = 3.76535×10^-15

Iter = 30 best fitness = 3.36831×10^-18
```

Iter = 40 best fitness = 6.38256×10^{-19}

Iter = 10 best fitness = 4.40149×10^{-7}

Iter = 20 best fitness = 2.75609×10^{-15}

Iter = 30 best fitness = 5.39931×10^{-20}

Iter = 40 best fitness = 1.18033×10^{-20}

Iter = 10 best fitness = 0.0000128905

Iter = 20 best fitness = 1.28187×10^{-9}

Iter = 30 best fitness = 3.17579×10^{-12}

Iter = 40 best fitness = 7.10183×10^{-13}

Iter = 10 best fitness = 1.76242×10^{-6}

Iter = 20 best fitness = 1.75026×10^{-10}

Iter = 30 best fitness = 3.73181×10^{-13}

Iter = 40 best fitness = 1.09945×10^{-13}

Iter = 10 best fitness = 0.000172569

Iter = 20 best fitness = 7.38506×10^{-14}

Iter = 30 best fitness = 2.02719×10^{-16}

Iter = 40 best fitness = 3.42584×10^{-17}

Iter = 10 best fitness = 4.84527×10^{-6}

Iter = 20 best fitness = 1.90078×10^{-15}

Iter = 30 best fitness = 7.07122×10^{-20}

Iter = 40 best fitness = 1.17171×10^{-20}

Iter = 10 best fitness = 6.93909×10^{-8}

Iter = 20 best fitness = 2.04532×10^{-12}

Iter = 30 best fitness = 6.5087×10^{-14}

Iter = 40 best fitness = 9.11484×10^{-15}

Best Result for population_size=50, num_iter=50
: $\{-6.37805 \times 10^{-11}, 6.59564 \times 10^{-11}\}$ with fitness = 8.4182×10^{-21}

Running test for dimension=2, population_size=100, num_iterations=10

Best Result for population_size=100, num_iter=10
: $\{3.33399 \times 10^{-6}, -3.09612 \times 10^{-6}\}$ with fitness = 2.07014×10^{-11}

Running test for dimension=2, population_size=100, num_iterations=30

Iter = 10 best fitness = 5.43696×10^{-10}

Iter = 20 best fitness = 5.32979×10^{-17}

Iter = 10 best fitness = 5.68306×10^{-8}

Iter = 20 best fitness = 1.50574×10^{-13}

Iter = 10 best fitness = 2.43077×10^{-10}

Iter = 20 best fitness = 6.31633×10^{-14}

Iter = 10 best fitness = 0.0955808

Iter = 20 best fitness = 0.0955808

```
Iter = 10 best fitness = 0.0549179

Iter = 20 best fitness = 3.03737×10^-11

Iter = 10 best fitness = 0.109065

Iter = 20 best fitness = 0.109065

Iter = 10 best fitness = 7.0264×10^-8

Iter = 20 best fitness = 1.87281×10^-16

Iter = 10 best fitness = 7.2376×10^-10

Iter = 20 best fitness = 1.9955×10^-18

Iter = 10 best fitness = 4.79489×10^-8

Iter = 20 best fitness = 1.46389×10^-16

Iter = 10 best fitness = 0.293219

Iter = 20 best fitness = 0.293219

Best Result for population_size=100, num_iter=30
 : {3.89674×10^-10, -3.85842×10^-10} with fitness = 3.0072×10^-19

Running test for dimension=2, population_size=100, num_iterations=50

Iter = 10 best fitness = 9.07733×10^-10

Iter = 20 best fitness = 2.01672×10^-17

Iter = 30 best fitness = 3.40114×10^-21

Iter = 40 best fitness = 2.67454×10^-22

Iter = 10 best fitness = 7.53062×10^-8

Iter = 20 best fitness = 4.37239×10^-17

Iter = 30 best fitness = 4.44086×10^-20

Iter = 40 best fitness = 2.54357×10^-21

Iter = 10 best fitness = 5.37911×10^-9

Iter = 20 best fitness = 4.12411×10^-16

Iter = 30 best fitness = 3.96107×10^-30

Iter = 40 best fitness = 1.79114×10^-33

Iter = 10 best fitness = 3.36504×10^-7

Iter = 20 best fitness = 3.08617×10^-19

Iter = 30 best fitness = 5.55216×10^-23

Iter = 40 best fitness = 5.84435×10^-24

Iter = 10 best fitness = 3.85332×10^-10

Iter = 20 best fitness = 6.85914×10^-19

Iter = 30 best fitness = 1.02178×10^-22

Iter = 40 best fitness = 7.42843×10^-24

Iter = 10 best fitness = 1.02243×10^-10

Iter = 20 best fitness = 4.59149×10^-15

Iter = 30 best fitness = 6.21819×10^-18

Iter = 40 best fitness = 6.50076×10^-19
Iter = 10 best fitness = 5.40533×10^-10
Iter = 20 best fitness = 2.35753×10^-19
Iter = 30 best fitness = 1.05346×10^-24
Iter = 40 best fitness = 1.44031×10^-25
Iter = 10 best fitness = 3.98663×10^-9
Iter = 20 best fitness = 8.34558×10^-15
Iter = 30 best fitness = 1.4726×10^-19
Iter = 40 best fitness = 1.6906×10^-20
Iter = 10 best fitness = 0.882586
Iter = 20 best fitness = 0.882586
Iter = 30 best fitness = 0.882586
Iter = 40 best fitness = 0.882586
Iter = 10 best fitness = 7.10572×10^-12
Iter = 20 best fitness = 2.17087×10^-22
Iter = 30 best fitness = 1.09943×10^-31
Iter = 40 best fitness = 2.00377×10^-39
Best Result for population_size=100, num_iter=50
 : {-2.63793×10^-20, 2.61681×10^-20} with fitness = 1.38064×10^-39
```

Dimension	Population Size	Iteration Number	Label	Solution
2	10	10	SpF21010	{–0.00679733, 0.0373743}
2	10	30	SpF21030	{0.00302668, –0.00315727}
2	10	50	SpF21050	$\{2.14848\times10^{-6}, -2.17124\times10^{-6}\}$
2	20	10	SpF22010	{–0.00422049, 0.0227138}
2	20	30	SpF22030	{0.000128834, –0.000133263}
2	20	50	SpF22050	$\{6.51179\times10^{-7}, -6.71181\times10^{-7}\}$
2	50	10	SpF25010	$\{-2.70338\times10^{-6}, -3.79988\times10^{-6}\}$
2	50	30	SpF25030	$\{-3.06309\times10^{-8}, 3.03518\times10^{-8}\}$
2	50	50	SpF25050	$\{-6.37805\times10^{-11}, 6.59564\times10^{-11}\}$
2	100	10	SpF210010	$\{3.33399\times10^{-6}, -3.09612\times10^{-6}\}$
2	100	30	SpF210030	$\{3.89674\times10^{-10}, -3.85842\times10^{-10}\}$
2	100	50	SpF210050	$\{-2.63793\times10^{-20}, 2.61681\times10^{-20}\}$

Case 01.02: Sphere function with dimension 5

```
In[•]:= dimension = 5;
        populationSizes = {10, 20, 50, 100};
        iterationValues = {10, 30, 50};
        results5 = {};

        Do[Do[Print["Running test for dimension=", dimension,
             ", population_size=", populationSize, ", num_iterations=", numIter];
           bestSolutions =
             Table[gwo[fitnessSphere, numIter, populationSize, dimension, -10.0, 10.0], {10}];
           bestSolution = First[SortBy[bestSolutions, fitnessSphere]];
           Print["Best Result for population_size=", populationSize, ", num_iter=",
             numIter, ": ", bestSolution, " with fitness = ", fitnessSphere[bestSolution]];
           AppendTo[results5, <|"Dimension" → dimension,
               "Population Size" → populationSize, "Iteration Number" → numIter, "Label" →
                "SpF" <> ToString[dimension] <> ToString[populationSize] <> ToString[numIter],
               "Solution" → bestSolution, "Fitness" → fitnessSphere[bestSolution] |>],
           {numIter, iterationValues}], {populationSize, populationSizes}];

        spfDF = Dataset[Join[Normal[spfDF], results5]];
        Print[spfDF]
```

```
Running test for dimension=5, population_size=10, num_iterations=10

Best Result for population_size=10, num_iter=10:
 {0.173511, -0.314882, 0.275779, 0.144957, -0.132803} with fitness = 0.24396

Running test for dimension=5, population_size=10, num_iterations=30

Iter = 10 best fitness = 1.79548

Iter = 20 best fitness = 0.27103

Iter = 10 best fitness = 0.598025

Iter = 20 best fitness = 0.0986531

Iter = 10 best fitness = 0.977262

Iter = 20 best fitness = 0.15049

Iter = 10 best fitness = 0.406162

Iter = 20 best fitness = 0.0490953

Iter = 10 best fitness = 2.9645

Iter = 20 best fitness = 0.505667

Iter = 10 best fitness = 1.39266

Iter = 20 best fitness = 0.214808

Iter = 10 best fitness = 66.6786

Iter = 20 best fitness = 66.6786

Iter = 10 best fitness = 24.8114

Iter = 20 best fitness = 7.9054

Iter = 10 best fitness = 2.17504

Iter = 20 best fitness = 0.0900868

Iter = 10 best fitness = 1.28268
Iter = 20 best fitness = 0.153662

Best Result for population_size=10, num_iter=30:
 {0.052588, -0.0108958, 0.101986, 0.0667524, -0.133218} with fitness = 0.0354883

Running test for dimension=5, population_size=10, num_iterations=50

Iter = 10 best fitness = 0.819746

Iter = 20 best fitness = 0.0186215

Iter = 30 best fitness = 0.00423919

Iter = 40 best fitness = 0.00244015

Iter = 10 best fitness = 2.72754

Iter = 20 best fitness = 0.0784011

Iter = 30 best fitness = 0.019363

Iter = 40 best fitness = 0.00971345

Iter = 10 best fitness = 3.62924

Iter = 20 best fitness = 0.254749

Iter = 30 best fitness = 0.0427651

Iter = 40 best fitness = 0.0168015

Iter = 10 best fitness = 1.68735

Iter = 20 best fitness = 0.0251541

Iter = 30 best fitness = 0.00124035

Iter = 40 best fitness = 0.000846874

Iter = 10 best fitness = 0.251676

Iter = 20 best fitness = 0.0272332

Iter = 30 best fitness = 0.00652303

Iter = 40 best fitness = 0.00360861

Iter = 10 best fitness = 31.9348

Iter = 20 best fitness = 31.9348

Iter = 30 best fitness = 31.9348

Iter = 40 best fitness = 31.9348

Iter = 10 best fitness = 1.42299

Iter = 20 best fitness = 0.00771195

Iter = 30 best fitness = 0.00126312

Iter = 40 best fitness = 0.000563867

Iter = 10 best fitness = 4.04225

Iter = 20 best fitness = 0.161838

Iter = 30 best fitness = 0.0400717

Iter = 40 best fitness = 0.0187895

Iter = 10 best fitness = 0.529716

Iter = 20 best fitness = 0.0768661

Iter = 30 best fitness = 0.00774985
Iter = 40 best fitness = 0.00320803

Iter = 10 best fitness = 4.30933

Iter = 20 best fitness = 0.471547

Iter = 30 best fitness = 0.125198

Iter = 40 best fitness = 0.0749256

Best Result for population_size=10, num_iter=50:
 {0.00254719, 0.0150143, 0.00172643, 0.00491958, -0.0163601} with fitness = 0.000526752

Running test for dimension=5, population_size=20, num_iterations=10

Best Result for population_size=20, num_iter=10:
 {-0.0246571, -0.343599, 0.108477, 0.343773, 0.32129} with fitness = 0.351842

Running test for dimension=5, population_size=20, num_iterations=30

Iter = 10 best fitness = 2.57819

Iter = 20 best fitness = 0.12848

Iter = 10 best fitness = 0.031869

Iter = 20 best fitness = 0.00218498

Iter = 10 best fitness = 0.0228001

Iter = 20 best fitness = 0.00230471

Iter = 10 best fitness = 0.185781

Iter = 20 best fitness = 0.00610566

Iter = 10 best fitness = 0.759868

Iter = 20 best fitness = 0.0699685

Iter = 10 best fitness = 0.0135226

Iter = 20 best fitness = 0.000844121

Iter = 10 best fitness = 0.0359073

Iter = 20 best fitness = 0.000229926

Iter = 10 best fitness = 41.4953

Iter = 20 best fitness = 41.4953

Iter = 10 best fitness = 20.1108

Iter = 20 best fitness = 20.1108

Iter = 10 best fitness = 0.113348

Iter = 20 best fitness = 0.00164707

Best Result for population_size=20, num_iter=30:
 {0.00816707, -0.000393383, -0.00615953, -0.00364322, -0.00374573} with fitness = 0.000132099

Running test for dimension=5, population_size=20, num_iterations=50

Iter = 10 best fitness = 0.00971338

Iter = 20 best fitness = 0.000114664

Iter = 30 best fitness = 2.95123×10^-6

Iter = 40 best fitness = 1.34057×10^-6

Iter = 10 best fitness = 0.0574864

Iter = 20 best fitness = 0.000176056
Iter = 30 best fitness = 0.0000191548

Iter = 40 best fitness = 4.20647×10^-6

Iter = 10 best fitness = 0.00272706

Iter = 20 best fitness = 0.0000138818

Iter = 30 best fitness = 8.42703×10^-7

Iter = 40 best fitness = 2.96831×10^-7

Iter = 10 best fitness = 0.158211

Iter = 20 best fitness = 0.00268418

Iter = 30 best fitness = 0.000066458

Iter = 40 best fitness = 0.000023719

Iter = 10 best fitness = 0.0330931

Iter = 20 best fitness = 0.000188849

Iter = 30 best fitness = 0.0000206616

Iter = 40 best fitness = 6.14504×10^-6

Iter = 10 best fitness = 17.7411

Iter = 20 best fitness = 14.637

Iter = 30 best fitness = 14.637

Iter = 40 best fitness = 14.637

Iter = 10 best fitness = 24.5821

Iter = 20 best fitness = 24.5821

Iter = 30 best fitness = 24.5821

Iter = 40 best fitness = 24.5821

Iter = 10 best fitness = 0.0858545

Iter = 20 best fitness = 0.000731997

Iter = 30 best fitness = 0.0000530118

Iter = 40 best fitness = 0.0000177717

Iter = 10 best fitness = 0.730943

Iter = 20 best fitness = 0.00257385

Iter = 30 best fitness = 0.0000150924

Iter = 40 best fitness = 5.30296×10^-6

Iter = 10 best fitness = 0.0457511

Iter = 20 best fitness = 0.00039832

Iter = 30 best fitness = 0.0000108926

Iter = 40 best fitness = 4.37541×10^-6

Best Result for population_size=20, num_iter=50:
 {0.000354718, -0.0000192088, -0.0000477461, -0.000348396, -0.0000547257}
  with fitness = 2.52848×10^-7

Running test for dimension=5, population_size=50, num_iterations=10

Best Result for population_size=50, num_iter=10:
 {0.0138508, -0.0804529, -0.116152, 0.146352, 0.0581636} with fitness = 0.0449576
```

```
Running test for dimension=5, population_size=50, num_iterations=30

Iter = 10 best fitness = 0.016398

Iter = 20 best fitness = 0.000170283

Iter = 10 best fitness = 0.129964

Iter = 20 best fitness = 0.000753204

Iter = 10 best fitness = 0.00633183

Iter = 20 best fitness = 0.0000474509

Iter = 10 best fitness = 0.00346513

Iter = 20 best fitness = 0.0000105957

Iter = 10 best fitness = 0.0187551

Iter = 20 best fitness = 0.000260989

Iter = 10 best fitness = 3.38073

Iter = 20 best fitness = 3.38073

Iter = 10 best fitness = 0.0157721

Iter = 20 best fitness = 0.000147057

Iter = 10 best fitness = 0.00888879

Iter = 20 best fitness = 0.0000350049

Iter = 10 best fitness = 0.0428892

Iter = 20 best fitness = 0.000704444

Iter = 10 best fitness = 0.000490807

Iter = 20 best fitness = 3.74691×10^-6

Best Result for population_size=50, num_iter=30:
 {0.000575457, -0.000221356, -0.000943375, 0.000776777, -0.0000130613}
  with fitness = 1.87366×10^-6

Running test for dimension=5, population_size=50, num_iterations=50

Iter = 10 best fitness = 0.00665175

Iter = 20 best fitness = 0.000015572

Iter = 30 best fitness = 4.39767×10^-7

Iter = 40 best fitness = 9.51482×10^-8

Iter = 10 best fitness = 0.0000954643

Iter = 20 best fitness = 4.90195×10^-7

Iter = 30 best fitness = 2.04757×10^-8

Iter = 40 best fitness = 4.51539×10^-9

Iter = 10 best fitness = 0.00326283

Iter = 20 best fitness = 7.05595×10^-7

Iter = 30 best fitness = 5.7538×10^-9

Iter = 40 best fitness = 1.31322×10^-9

Iter = 10 best fitness = 0.000508632

Iter = 20 best fitness = 3.38315×10^-8
Iter = 30 best fitness = 5.37737×10^-10

Iter = 40 best fitness = 9.58495×10^-11

Iter = 10 best fitness = 0.00786519

Iter = 20 best fitness = 6.52938×10^-6

Iter = 30 best fitness = 8.56868×10^-8

Iter = 40 best fitness = 1.2961×10^-8

Iter = 10 best fitness = 0.00243803

Iter = 20 best fitness = 3.12121×10^-6

Iter = 30 best fitness = 1.94098×10^-8

Iter = 40 best fitness = 3.81425×10^-9

Iter = 10 best fitness = 0.014156

Iter = 20 best fitness = 8.77241×10^-7

Iter = 30 best fitness = 9.83188×10^-9

Iter = 40 best fitness = 1.58243×10^-9

Iter = 10 best fitness = 0.00161649

Iter = 20 best fitness = 5.70184×10^-7

Iter = 30 best fitness = 4.89267×10^-9

Iter = 40 best fitness = 1.2008×10^-9

Iter = 10 best fitness = 0.00386283

Iter = 20 best fitness = 1.01498×10^-7

Iter = 30 best fitness = 4.30397×10^-10

Iter = 40 best fitness = 6.43375×10^-11

Iter = 10 best fitness = 0.000462897

Iter = 20 best fitness = 5.17667×10^-8

Iter = 30 best fitness = 4.67688×10^-10

Iter = 40 best fitness = 1.00719×10^-10

Best Result for population_size=50, num_iter=50:
 {-3.17356×10^-6, -3.43056×10^-6, 3.95209×10^-6, 3.13144×10^-6, -1.85757×10^-6}
  with fitness = 5.07158×10^-11

Running test for dimension=5, population_size=100, num_iterations=10

Best Result for population_size=100, num_iter=10:
 {0.0543579, -0.0357024, -0.04535, 0.00555381, -0.014966} with fitness = 0.00654089

Running test for dimension=5, population_size=100, num_iterations=30

Iter = 10 best fitness = 0.00889663

Iter = 20 best fitness = 9.09583×10^-6

Iter = 10 best fitness = 0.000840164

Iter = 20 best fitness = 9.52901×10^-7

Iter = 10 best fitness = 0.14034

Iter = 20 best fitness = 0.0000245552

Iter = 10 best fitness = 0.182724
Iter = 20 best fitness = 0.00102962

Iter = 10 best fitness = 0.00227866

Iter = 20 best fitness = 4.13446×10^-6

Iter = 10 best fitness = 0.000244995

Iter = 20 best fitness = 4.16855×10^-7

Iter = 10 best fitness = 0.00200147

Iter = 20 best fitness = 1.95683×10^-6

Iter = 10 best fitness = 0.385387

Iter = 20 best fitness = 0.000476246

Iter = 10 best fitness = 0.00119241

Iter = 20 best fitness = 8.9263×10^-7

Iter = 10 best fitness = 22.2872

Iter = 20 best fitness = 22.2872

Best Result for population_size=100, num_iter=30:
 {0.000252119, -0.000130853, -0.00023696, -0.0000511753, 0.000111481}
  with fitness = 1.51883×10^-7

Running test for dimension=5, population_size=100, num_iterations=50

Iter = 10 best fitness = 0.00553607

Iter = 20 best fitness = 6.14815×10^-8

Iter = 30 best fitness = 8.05978×10^-11

Iter = 40 best fitness = 1.12989×10^-11

Iter = 10 best fitness = 0.00245212

Iter = 20 best fitness = 7.072×10^-8

Iter = 30 best fitness = 8.67411×10^-11

Iter = 40 best fitness = 1.29284×10^-11

Iter = 10 best fitness = 0.0000535811

Iter = 20 best fitness = 1.51529×10^-9

Iter = 30 best fitness = 2.15036×10^-12

Iter = 40 best fitness = 3.27818×10^-13

Iter = 10 best fitness = 0.0018351

Iter = 20 best fitness = 3.23479×10^-7

Iter = 30 best fitness = 1.23901×10^-10

Iter = 40 best fitness = 8.6396×10^-12

Iter = 10 best fitness = 0.000467929

Iter = 20 best fitness = 1.03018×10^-8

Iter = 30 best fitness = 4.10201×10^-11

Iter = 40 best fitness = 8.1544×10^-12

Iter = 10 best fitness = 0.00227728

Iter = 20 best fitness = 2.87715×10^-7
```

Iter = 30 best fitness = 7.24649×10^{-10}

Iter = 40 best fitness = 1.05619×10^{-10}

Iter = 10 best fitness = 0.000568579

Iter = 20 best fitness = 1.78633×10^{-8}

Iter = 30 best fitness = 5.12877×10^{-11}

Iter = 40 best fitness = 8.75437×10^{-12}

Iter = 10 best fitness = 0.000866651

Iter = 20 best fitness = 7.40978×10^{-9}

Iter = 30 best fitness = 1.58763×10^{-11}

Iter = 40 best fitness = 1.32061×10^{-12}

Iter = 10 best fitness = 0.000487657

Iter = 20 best fitness = 2.99974×10^{-8}

Iter = 30 best fitness = 6.89195×10^{-11}

Iter = 40 best fitness = 8.77632×10^{-12}

Iter = 10 best fitness = 0.000105533

Iter = 20 best fitness = 3.86401×10^{-9}

Iter = 30 best fitness = 3.43468×10^{-12}

Iter = 40 best fitness = 4.09782×10^{-13}

Best Result for population_size=100, num_iter=50:
$\{1.89637\times10^{-7}, 1.57678\times10^{-8}, -3.44956\times10^{-7}, 3.54406\times10^{-8}, 2.88381\times10^{-7}\}$
with fitness = 2.39625×10^{-13}

Dimension	Population Size	Iteration Number	Label	Solution
2	10	10	SpF21010	{−0.00679733, 0.0373743}
2	10	30	SpF21030	{0.00302668, −0.00315727}
2	10	50	SpF21050	{2.14848 × 10^{-6}, −2.17124 × 10
2	20	10	SpF22010	{−0.00422049, 0.0227138}
2	20	30	SpF22030	{0.000128834, −0.000133263}
2	20	50	SpF22050	{6.51179 × 10^{-7}, −6.71181 × 10
2	50	10	SpF25010	{−2.70338 × 10^{-6}, −3.79988 × 1
2	50	30	SpF25030	{−3.06309 × 10^{-8}, 3.03518 × 10
2	50	50	SpF25050	{−6.37805 × 10^{-11}, 6.59564 × 1
2	100	10	SpF210010	{3.33399 × 10^{-6}, −3.09612 × 10
2	100	30	SpF210030	{3.89674 × 10^{-10}, −3.85842 × 1
2	100	50	SpF210050	{−2.63793 × 10^{-20}, 2.61681 × 1
5	10	10	SpF51010	{0.173511, −0.314882, 0.2757
5	10	30	SpF51030	{0.052588, −0.0108958, 0.101
5	10	50	SpF51050	{0.00254719, 0.0150143, 0.001
5	20	10	SpF52010	{−0.0246571, −0.343599, 0.10
5	20	30	SpF52030	{0.00816707, −0.000393383, −
5	20	50	SpF52050	{0.000354718, −0.0000192088
5	50	10	SpF55010	{0.0138508, −0.0804529, −0.1
5	50	30	SpF55030	{0.000575457, −0.000221356,

rows 1–20 of **24**

Case 01.03: Sphere function with dimension 10

```
In[•]:= dimension = 10;
        populationSizes = {10, 20, 50, 100};
        iterationValues = {10, 30, 50};
        results10 = {};

        Do[Do[Print["Running test for dimension=", dimension,
             ", population_size=", populationSize, ", num_iterations=", numIter];
           bestSolutions =
             Table[gwo[fitnessSphere, numIter, populationSize, dimension, -10.0, 10.0], {10}];
           bestSolution = First[SortBy[bestSolutions, fitnessSphere]];
           Print["Best Result for population_size=", populationSize, ", num_iter=",
             numIter, ": ", bestSolution, " with fitness = ", fitnessSphere[bestSolution]];
           AppendTo[results10, <|"Dimension" → dimension,
              "Population Size" → populationSize, "Iteration Number" → numIter, "Label" →
               "SpF" <> ToString[dimension] <> ToString[populationSize] <> ToString[numIter],
              "Solution" → bestSolution, "Fitness" → fitnessSphere[bestSolution]|>],
           {numIter, iterationValues}], {populationSize, populationSizes}];

        spfDF = Dataset[Join[Normal[spfDF], results10]];
        Print[spfDF]
```

```
Running test for dimension=10, population_size=10, num_iterations=10

Best Result for population_size=10, num_iter=10: {0.583384, -1.26765, 0.0694385, 0.837762,
  0.454627, -0.215978, -0.192113, 0.201044, 0.324376, -0.230134} with fitness = 3.14278

Running test for dimension=10, population_size=10, num_iterations=30

Iter = 10 best fitness = 8.03577

Iter = 20 best fitness = 0.892485

Iter = 10 best fitness = 2.17575

Iter = 20 best fitness = 0.492773

Iter = 10 best fitness = 25.0095

Iter = 20 best fitness = 6.11306

Iter = 10 best fitness = 2.35429

Iter = 20 best fitness = 0.0855563

Iter = 10 best fitness = 12.9511

Iter = 20 best fitness = 1.18848

Iter = 10 best fitness = 24.0085

Iter = 20 best fitness = 5.48135

Iter = 10 best fitness = 1.03257

Iter = 20 best fitness = 0.159091

Iter = 10 best fitness = 9.10403

Iter = 20 best fitness = 0.732125

Iter = 10 best fitness = 19.9562

Iter = 20 best fitness = 6.86129

Iter = 10 best fitness = 5.18135
Iter = 20 best fitness = 0.467461

Best Result for population_size=10, num_iter=30:
 {-0.00356593, 0.0789326, 0.0658089, 0.1131, -0.000874583, 0.0363461,
  0.0241179, -0.171241, 0.0819826, -0.0689391} with fitness = 0.0660663

Running test for dimension=10, population_size=10, num_iterations=50

Iter = 10 best fitness = 0.928

Iter = 20 best fitness = 0.0995733

Iter = 30 best fitness = 0.0271203

Iter = 40 best fitness = 0.0169644

Iter = 10 best fitness = 12.7332

Iter = 20 best fitness = 0.54101

Iter = 30 best fitness = 0.211938

Iter = 40 best fitness = 0.126254

Iter = 10 best fitness = 0.825604

Iter = 20 best fitness = 0.077984

Iter = 30 best fitness = 0.0178556

Iter = 40 best fitness = 0.00900807

Iter = 10 best fitness = 7.62864

Iter = 20 best fitness = 0.0629653

Iter = 30 best fitness = 0.00828997

Iter = 40 best fitness = 0.00489874

Iter = 10 best fitness = 2.34648

Iter = 20 best fitness = 0.0610495

Iter = 30 best fitness = 0.00310773

Iter = 40 best fitness = 0.00156654

Iter = 10 best fitness = 2.37139

Iter = 20 best fitness = 0.293404

Iter = 30 best fitness = 0.0600501

Iter = 40 best fitness = 0.0306577

Iter = 10 best fitness = 9.50156

Iter = 20 best fitness = 0.339474

Iter = 30 best fitness = 0.0683779

Iter = 40 best fitness = 0.0370442

Iter = 10 best fitness = 5.96959

Iter = 20 best fitness = 0.169197

Iter = 30 best fitness = 0.034807

Iter = 40 best fitness = 0.0181129

Iter = 10 best fitness = 9.90674

Iter = 20 best fitness = 0.0857454
Iter = 30 best fitness = 0.0197715

Iter = 40 best fitness = 0.0121266

Iter = 10 best fitness = 2.84633

Iter = 20 best fitness = 0.0766122

Iter = 30 best fitness = 0.00774148

Iter = 40 best fitness = 0.00370093

Best Result for population_size=10, num_iter=50:
 {-0.00388504, -0.00111733, 0.00324615, 0.0030062, -0.000663092, -0.0204817,
  0.0242411, 0.0100802, -0.0074527, -0.0134786} with fitness = 0.00138231

Running test for dimension=10, population_size=20, num_iterations=10

Best Result for population_size=20, num_iter=10:
 {0.294721, -0.252774, -0.073369, -1.013, -0.0666318, -0.135166,
  -0.0242743, 1.03625, 0.493762, 0.00845731} with fitness = 2.52328

Running test for dimension=10, population_size=20, num_iterations=30

Iter = 10 best fitness = 2.90011

Iter = 20 best fitness = 0.166316

Iter = 10 best fitness = 1.10979

Iter = 20 best fitness = 0.062171

Iter = 10 best fitness = 2.23079

Iter = 20 best fitness = 0.1027

Iter = 10 best fitness = 14.0924

Iter = 20 best fitness = 0.571176

Iter = 10 best fitness = 0.387044

Iter = 20 best fitness = 0.015823

Iter = 10 best fitness = 1.02924

Iter = 20 best fitness = 0.00465718

Iter = 10 best fitness = 118.739

Iter = 20 best fitness = 118.739

Iter = 10 best fitness = 2.8916

Iter = 20 best fitness = 0.135664

Iter = 10 best fitness = 0.525018

Iter = 20 best fitness = 0.0179868

Iter = 10 best fitness = 0.772321

Iter = 20 best fitness = 0.0246334

Best Result for population_size=20, num_iter=30:
 {-0.0104484, 0.0225773, -0.0192313, -0.011525, -0.0118543, 0.0324699,
  -0.0197637, -0.0151019, -0.00437002, -0.0000964391} with fitness = 0.00295417

Running test for dimension=10, population_size=20, num_iterations=50

Iter = 10 best fitness = 91.755

Iter = 20 best fitness = 91.755

Iter = 30 best fitness = 91.755
Iter = 40 best fitness = 91.755

Iter = 10 best fitness = 1.64487

Iter = 20 best fitness = 0.00664501

Iter = 30 best fitness = 0.000448029

Iter = 40 best fitness = 0.000187133

Iter = 10 best fitness = 1.1869

Iter = 20 best fitness = 0.000624216

Iter = 30 best fitness = 0.0000300007

Iter = 40 best fitness = 0.0000116663

Iter = 10 best fitness = 4.22717

Iter = 20 best fitness = 0.0263488

Iter = 30 best fitness = 0.00327325

Iter = 40 best fitness = 0.000854391

Iter = 10 best fitness = 0.469243

Iter = 20 best fitness = 0.0142177

Iter = 30 best fitness = 0.000524455

Iter = 40 best fitness = 0.000152369

Iter = 10 best fitness = 1.31478

Iter = 20 best fitness = 0.00453468

Iter = 30 best fitness = 0.000179905

Iter = 40 best fitness = 0.0000731898

Iter = 10 best fitness = 0.914065

Iter = 20 best fitness = 0.00486562

Iter = 30 best fitness = 0.000322089

Iter = 40 best fitness = 0.000126362

Iter = 10 best fitness = 0.439062

Iter = 20 best fitness = 0.0085042

Iter = 30 best fitness = 0.000416425

Iter = 40 best fitness = 0.000170549

Iter = 10 best fitness = 0.730079

Iter = 20 best fitness = 0.00312845

Iter = 30 best fitness = 0.000192766

Iter = 40 best fitness = 0.0000747607

Iter = 10 best fitness = 1.71602

Iter = 20 best fitness = 0.00703943

Iter = 30 best fitness = 0.000103053

Iter = 40 best fitness = 0.0000343086
```

```
Best Result for population_size=20, num_iter=50:
 {-0.00214304, 0.000283295, -0.000306032, 0.00107047, -0.000128209, 0.000492806,
  0.00184705, -0.000651386, 0.000632537, -0.0000691286} with fitness = 0.0000104125

Running test for dimension=10, population_size=50, num_iterations=10

Best Result for population_size=50, num_iter=10: {0.160425, -0.10543, -0.0783032, 0.254569,
  0.222263, 0.48677, -0.487104, 0.113426, 0.286423, 0.108004} with fitness = 0.737973

Running test for dimension=10, population_size=50, num_iterations=30

Iter = 10 best fitness = 0.111757

Iter = 20 best fitness = 0.000928861

Iter = 10 best fitness = 0.0565163

Iter = 20 best fitness = 0.000535244

Iter = 10 best fitness = 0.303453

Iter = 20 best fitness = 0.00111701

Iter = 10 best fitness = 0.179777

Iter = 20 best fitness = 0.000120709

Iter = 10 best fitness = 0.0195579

Iter = 20 best fitness = 0.0000697785

Iter = 10 best fitness = 0.379766

Iter = 20 best fitness = 0.00501057

Iter = 10 best fitness = 0.159316

Iter = 20 best fitness = 0.00155161

Iter = 10 best fitness = 0.116995

Iter = 20 best fitness = 0.000209307

Iter = 10 best fitness = 0.0186579

Iter = 20 best fitness = 0.000401157

Iter = 10 best fitness = 0.0870379

Iter = 20 best fitness = 0.00133021

Best Result for population_size=50, num_iter=30:
 {-0.0000988333, -0.0014535, 0.00176527, 0.000302193, -0.00243075, -0.00164259,
  0.000558615, -0.00109103, 0.00162405, 0.00244499} with fitness = 0.0000240545

Running test for dimension=10, population_size=50, num_iterations=50

Iter = 10 best fitness = 0.0807525

Iter = 20 best fitness = 0.0000544714

Iter = 30 best fitness = 2.76241×10^-7

Iter = 40 best fitness = 4.26956×10^-8

Iter = 10 best fitness = 40.1213

Iter = 20 best fitness = 0.000447201

Iter = 30 best fitness = 4.40987×10^-6

Iter = 40 best fitness = 9.11245×10^-7

Iter = 10 best fitness = 0.0660048
Iter = 20 best fitness = 4.98368×10^-6

Iter = 30 best fitness = 6.84265×10^-8

Iter = 40 best fitness = 1.22574×10^-8

Iter = 10 best fitness = 0.194941

Iter = 20 best fitness = 0.0000245664

Iter = 30 best fitness = 3.0104×10^-7

Iter = 40 best fitness = 5.9409×10^-8

Iter = 10 best fitness = 0.15368

Iter = 20 best fitness = 0.000112067

Iter = 30 best fitness = 1.57115×10^-6

Iter = 40 best fitness = 3.1052×10^-7

Iter = 10 best fitness = 0.0935371

Iter = 20 best fitness = 0.0000479246

Iter = 30 best fitness = 9.05405×10^-8

Iter = 40 best fitness = 1.665×10^-8

Iter = 10 best fitness = 1.96276

Iter = 20 best fitness = 0.00150626

Iter = 30 best fitness = 0.0000229337

Iter = 40 best fitness = 2.26998×10^-6

Iter = 10 best fitness = 1.50979

Iter = 20 best fitness = 0.000260243

Iter = 30 best fitness = 3.52131×10^-6

Iter = 40 best fitness = 6.77687×10^-7

Iter = 10 best fitness = 0.695822

Iter = 20 best fitness = 0.0000980875

Iter = 30 best fitness = 2.25387×10^-6

Iter = 40 best fitness = 3.98315×10^-7

Iter = 10 best fitness = 0.0106171

Iter = 20 best fitness = 0.0000614555

Iter = 30 best fitness = 1.31114×10^-6

Iter = 40 best fitness = 2.90989×10^-7

Best Result for population_size=50, num_iter=50:
 {0.0000173757, -3.48953×10^-6, -0.0000155035, -0.0000636612, 7.71834×10^-6, -0.0000260509,
  0.0000378058, 0.0000454543, -3.70096×10^-6, 0.0000311274} with fitness = 9.82341×10^-9

Running test for dimension=10, population_size=100, num_iterations=10

Best Result for population_size=100, num_iter=10:
 {-0.0402338, -0.0398709, 0.22118, 0.110805, 0.0306645, 0.0155017,
  0.161564, -0.168118, -0.0944357, -0.186661} with fitness = 0.163715

Running test for dimension=10, population_size=100, num_iterations=30

Iter = 10 best fitness = 0.0920825
Iter = 20 best fitness = 0.000793203

Iter = 10 best fitness = 0.0200751

Iter = 20 best fitness = 0.0000118799

Iter = 10 best fitness = 0.0352679

Iter = 20 best fitness = 0.0000578146

Iter = 10 best fitness = 0.00392426

Iter = 20 best fitness = 3.22784×10^-6

Iter = 10 best fitness = 0.0131704

Iter = 20 best fitness = 6.55418×10^-6

Iter = 10 best fitness = 0.0142267

Iter = 20 best fitness = 0.000122273

Iter = 10 best fitness = 0.0592238

Iter = 20 best fitness = 0.000185004

Iter = 10 best fitness = 0.0314309

Iter = 20 best fitness = 0.0000991332

Iter = 10 best fitness = 0.00527922

Iter = 20 best fitness = 4.34347×10^-6

Iter = 10 best fitness = 0.0231585

Iter = 20 best fitness = 0.0000101797

Best Result for population_size=100, num_iter=30:
  {0.000116167, 0.000554144, -0.0000429533, -0.000056899, -0.000324083, 0.000420963,
   -0.000141059, -0.000625076, 0.000205977, -0.000136565} with fitness = 1.07959×10^-6

Running test for dimension=10, population_size=100, num_iterations=50

Iter = 10 best fitness = 0.0221534

Iter = 20 best fitness = 4.08581×10^-6

Iter = 30 best fitness = 7.90672×10^-9

Iter = 40 best fitness = 4.96489×10^-10

Iter = 10 best fitness = 0.00358539

Iter = 20 best fitness = 1.38414×10^-7

Iter = 30 best fitness = 5.93813×10^-10

Iter = 40 best fitness = 8.07727×10^-11

Iter = 10 best fitness = 0.0228884

Iter = 20 best fitness = 0.0000137489

Iter = 30 best fitness = 3.81036×10^-8

Iter = 40 best fitness = 5.69061×10^-9

Iter = 10 best fitness = 0.0100137

Iter = 20 best fitness = 6.11772×10^-6

Iter = 30 best fitness = 3.29492×10^-8

Iter = 40 best fitness = 4.93356×10^-9
Iter = 10 best fitness = 0.0443586
Iter = 20 best fitness = 1.51405×10^-6
Iter = 30 best fitness = 6.98238×10^-9
Iter = 40 best fitness = 6.26605×10^-10
Iter = 10 best fitness = 0.0322633
Iter = 20 best fitness = 2.82115×10^-6
Iter = 30 best fitness = 1.19387×10^-8
Iter = 40 best fitness = 1.59439×10^-9
Iter = 10 best fitness = 0.00677014
Iter = 20 best fitness = 4.78373×10^-7
Iter = 30 best fitness = 2.3673×10^-9
Iter = 40 best fitness = 3.61211×10^-10
Iter = 10 best fitness = 0.0870055
Iter = 20 best fitness = 0.0000109164
Iter = 30 best fitness = 3.88554×10^-8
Iter = 40 best fitness = 6.05526×10^-9
Iter = 10 best fitness = 0.00849283
Iter = 20 best fitness = 2.13659×10^-6
Iter = 30 best fitness = 4.10181×10^-9
Iter = 40 best fitness = 3.08977×10^-10
Iter = 10 best fitness = 0.0106463
Iter = 20 best fitness = 3.29404×10^-7
Iter = 30 best fitness = 2.70083×10^-10
Iter = 40 best fitness = 3.09128×10^-11
Best Result for population_size=100, num_iter=50:
 {1.51704×10^-6, -1.42044×10^-6, 1.70994×10^-6, -2.00442×10^-6, 7.73705×10^-8, -2.2079×10^-6,
  9.23042×10^-7, -5.00267×10^-8, 2.15858×10^-6, 5.56592×10^-7} with fitness = 2.19652×10^-11
```

Dimension	Population Size	Iteration Number	Label	Solution
5	20	30	SpF52030	{0.00816707, −0.000393383
5	20	50	SpF52050	{0.000354718, −0.0000192
5	50	10	SpF55010	{0.0138508, −0.0804529, −
5	50	30	SpF55030	{0.000575457, −0.0002213
5	50	50	SpF55050	{−3.17356 × 10^{-6}, −3.43056
5	100	10	SpF510010	{0.0543579, −0.0357024, −
5	100	30	SpF510030	{0.000252119, −0.0001308
5	100	50	SpF510050	{1.89637 × 10^{-7}, 1.57678 × 1
10	10	10	SpF101010	{ ⋯$_{10}$ }
10	10	30	SpF101030	{ ⋯$_{10}$ }
10	10	50	SpF101050	{ ⋯$_{10}$ }
10	20	10	SpF102010	{ ⋯$_{10}$ }
10	20	30	SpF102030	{ ⋯$_{10}$ }
10	20	50	SpF102050	{ ⋯$_{10}$ }
10	50	10	SpF105010	{ ⋯$_{10}$ }
10	50	30	SpF105030	{ ⋯$_{10}$ }
10	50	50	SpF105050	{ ⋯$_{10}$ }
10	100	10	SpF1010010	{ ⋯$_{10}$ }
10	100	30	SpF1010030	{ ⋯$_{10}$ }
10	100	50	SpF1010050	{ ⋯$_{10}$ }

rows 17–36 of **36**

```
In[∘]:= Export["spfDF.csv", Normal[spfDF]]
        Print["File saved to: ", Directory[] <> "/spfDF.csv"]
```

```
Out[∘]=
spfDF.csv

File saved to: C:\Users\irfan\OneDrive\Documents/spfDF.csv
```

Running test for Rastrigin function

Case 02.01: Rastrigin function with dimension 2

```
In[∘]:= dimension = 2;
        populationSizes = {10, 20, 50, 100};
        iterationValues = {10, 30, 50};
        results2 = {};

        Do[Do[Print["Running test for dimension=", dimension,
            ", population_size=", populationSize, ", num_iterations=", numIter];
           bestSolutions = Table[
             gwo[fitnessRastrigin, numIter, populationSize, dimension, -10.0, 10.0], {10}];
           bestSolution = First[SortBy[bestSolutions, fitnessRastrigin]];
           Print["Best Result for population_size=", populationSize, ", num_iter=",
            numIter, ": ", bestSolution, " with fitness = ", fitnessRastrigin[bestSolution]];
           AppendTo[results2, <|"Dimension" → dimension,
             "Population Size" → populationSize, "Iteration Number" → numIter, "Label" →
              "RaF" <> ToString[dimension] <> ToString[populationSize] <> ToString[numIter],
             "Solution" → bestSolution, "Fitness" → fitnessRastrigin[bestSolution] |>],
           {numIter, iterationValues}], {populationSize, populationSizes}];

        rafDF = Dataset[results2];
        Print[rafDF]
```

```
Running test for dimension=2, population_size=10, num_iterations=10

Best Result for population_size=10, num_iter=10: {0.997312, 0.997173} with fitness = 1.99199

Running test for dimension=2, population_size=10, num_iterations=30

Iter = 10 best fitness = 2.42249

Iter = 20 best fitness = 1.04867

Iter = 10 best fitness = 1.51539

Iter = 20 best fitness = 0.0582864

Iter = 10 best fitness = 19.3224

Iter = 20 best fitness = 19.3224

Iter = 10 best fitness = 8.05832

Iter = 20 best fitness = 0.52726

Iter = 10 best fitness = 5.19866

Iter = 20 best fitness = 5.19866

Iter = 10 best fitness = 2.52618

Iter = 20 best fitness = 2.52618

Iter = 10 best fitness = 11.8981

Iter = 20 best fitness = 4.69151

Iter = 10 best fitness = 0.149733

Iter = 20 best fitness = 0.017159

Iter = 10 best fitness = 0.251069

Iter = 20 best fitness = 0.00206592

Iter = 10 best fitness = 4.07986

Iter = 20 best fitness = 2.04274
```

```
Best Result for population_size=10, num_iter=
 30: {-0.00205915, 0.00203323} with fitness = 0.00166134

Running test for dimension=2, population_size=10, num_iterations=50

Iter = 10 best fitness = 15.223

Iter = 20 best fitness = 15.223

Iter = 30 best fitness = 15.223

Iter = 40 best fitness = 15.223

Iter = 10 best fitness = 6.04926

Iter = 20 best fitness = 5.57326

Iter = 30 best fitness = 4.9824

Iter = 40 best fitness = 4.97563

Iter = 10 best fitness = 1.05282

Iter = 20 best fitness = 0.996815

Iter = 30 best fitness = 0.996364

Iter = 40 best fitness = 0.996364

Iter = 10 best fitness = 1.99929

Iter = 20 best fitness = 1.04492

Iter = 30 best fitness = 1.04492

Iter = 40 best fitness = 1.04492

Iter = 10 best fitness = 5.14405

Iter = 20 best fitness = 4.97287

Iter = 30 best fitness = 4.06959

Iter = 40 best fitness = 2.00285

Iter = 10 best fitness = 2.04314

Iter = 20 best fitness = 1.01895

Iter = 30 best fitness = 1.0064

Iter = 40 best fitness = 1.00429

Iter = 10 best fitness = 5.34947

Iter = 20 best fitness = 4.04579

Iter = 30 best fitness = 1.71408

Iter = 40 best fitness = 1.66745

Iter = 10 best fitness = 3.12175

Iter = 20 best fitness = 0.751933

Iter = 30 best fitness = 0.0794619

Iter = 40 best fitness = 0.0370853

Iter = 10 best fitness = 1.76048

Iter = 20 best fitness = 1.01734

Iter = 30 best fitness = 1.00371

Iter = 40 best fitness = 1.00371
Iter = 10 best fitness = 3.0813

Iter = 20 best fitness = 1.41203

Iter = 30 best fitness = 1.41203

Iter = 40 best fitness = 1.34568

Best Result for population_size=10, num_iter=
 50: {0.00922218, -0.00902995} with fitness = 0.0330409

Running test for dimension=2, population_size=20, num_iterations=10

Best Result for population_size=20, num_iter=
 10: {-0.0228066, 0.00656226} with fitness = 0.111558

Running test for dimension=2, population_size=20, num_iterations=30

Iter = 10 best fitness = 2.20388

Iter = 20 best fitness = 2.06168

Iter = 10 best fitness = 0.00161379

Iter = 20 best fitness = 0.0000174404

Iter = 10 best fitness = 1.88235

Iter = 20 best fitness = 0.995247

Iter = 10 best fitness = 2.21608

Iter = 20 best fitness = 1.66132

Iter = 10 best fitness = 1.62949

Iter = 20 best fitness = 1.0723

Iter = 10 best fitness = 7.98217

Iter = 20 best fitness = 4.67698

Iter = 10 best fitness = 1.12814

Iter = 20 best fitness = 1.12814

Iter = 10 best fitness = 0.00105688

Iter = 20 best fitness = 0.0000348082

Iter = 10 best fitness = 6.29744

Iter = 20 best fitness = 2.10233

Iter = 10 best fitness = 0.00217172

Iter = 20 best fitness = 7.23275×10^-7

Best Result for population_size=20, num_iter=
 30: {0.0000328944, -0.0000344214} with fitness = 4.4973×10^-7

Running test for dimension=2, population_size=20, num_iterations=50

Iter = 10 best fitness = 2.03203

Iter = 20 best fitness = 1.99219

Iter = 30 best fitness = 1.99219

Iter = 40 best fitness = 1.99219

Iter = 10 best fitness = 1.16384

Iter = 20 best fitness = 1.03718

Iter = 30 best fitness = 1.00926
Iter = 40 best fitness = 1.00904
Iter = 10 best fitness = 4.4671
Iter = 20 best fitness = 4.4671
Iter = 30 best fitness = 1.99723
Iter = 40 best fitness = 1.99098
Iter = 10 best fitness = 3.57065
Iter = 20 best fitness = 1.01774
Iter = 30 best fitness = 1.00577
Iter = 40 best fitness = 1.00577
Iter = 10 best fitness = 0.638701
Iter = 20 best fitness = 0.0159765
Iter = 30 best fitness = 0.000172114
Iter = 40 best fitness = 0.0000513089
Iter = 10 best fitness = 17.321
Iter = 20 best fitness = 14.4984
Iter = 30 best fitness = 14.4984
Iter = 40 best fitness = 14.4984
Iter = 10 best fitness = 3.15303
Iter = 20 best fitness = 2.17349
Iter = 30 best fitness = 1.08098
Iter = 40 best fitness = 0.99649
Iter = 10 best fitness = 7.38056
Iter = 20 best fitness = 7.38056
Iter = 30 best fitness = 7.38056
Iter = 40 best fitness = 7.38056
Iter = 10 best fitness = 2.83241
Iter = 20 best fitness = 2.06611
Iter = 30 best fitness = 1.99389
Iter = 40 best fitness = 1.99029
Iter = 10 best fitness = 4.16497
Iter = 20 best fitness = 2.02588
Iter = 30 best fitness = 1.99393
Iter = 40 best fitness = 1.99139
Best Result for population_size=20, num_iter=
 50: {-0.000205358, 0.00024176} with fitness = 0.0000199621
Running test for dimension=2, population_size=50, num_iterations=10
Best Result for population_size=50, num_iter=
 10: {0.0028224, 0.0000931833} with fitness = 0.00158206
Running test for dimension=2, population_size=50, num_iterations=30
```

```
Iter = 10 best fitness = 0.00346196

Iter = 20 best fitness = 8.59757×10^-13

Iter = 10 best fitness = 2.04505

Iter = 20 best fitness = 1.99833

Iter = 10 best fitness = 7.31025

Iter = 20 best fitness = 7.31025

Iter = 10 best fitness = 0.0000427304

Iter = 20 best fitness = 1.4685×10^-7

Iter = 10 best fitness = 1.28664

Iter = 20 best fitness = 1.28664

Iter = 10 best fitness = 0.000356737

Iter = 20 best fitness = 1.71184×10^-6

Iter = 10 best fitness = 0.000038838

Iter = 20 best fitness = 5.21181×10^-8

Iter = 10 best fitness = 0.0158095

Iter = 20 best fitness = 0.000151082

Iter = 10 best fitness = 0.999982

Iter = 20 best fitness = 0.996284

Iter = 10 best fitness = 0.820579

Iter = 20 best fitness = 4.77572×10^-8

Best Result for population_size=50, num_iter=30
 : {-2.01209×10^-8, 1.59961×10^-8} with fitness = 1.27898×10^-13

Running test for dimension=2, population_size=50, num_iterations=50

Iter = 10 best fitness = 1.34126

Iter = 20 best fitness = 0.0213359

Iter = 30 best fitness = 1.35785×10^-11

Iter = 40 best fitness = 1.22213×10^-12

Iter = 10 best fitness = 1.04278

Iter = 20 best fitness = 0.996887

Iter = 30 best fitness = 0.996887

Iter = 40 best fitness = 0.99551

Iter = 10 best fitness = 1.22113

Iter = 20 best fitness = 0.996324

Iter = 30 best fitness = 0.995497

Iter = 40 best fitness = 0.995052

Iter = 10 best fitness = 1.6389

Iter = 20 best fitness = 0.001

Iter = 30 best fitness = 7.57769×10^-9

Iter = 40 best fitness = 7.40116×10^-10
Iter = 10 best fitness = 1.00283

Iter = 20 best fitness = 0.99562

Iter = 30 best fitness = 0.995288

Iter = 40 best fitness = 0.995288

Iter = 10 best fitness = 3.50282

Iter = 20 best fitness = 1.99459

Iter = 30 best fitness = 1.99014

Iter = 40 best fitness = 1.99014

Iter = 10 best fitness = 8.76514

Iter = 20 best fitness = 8.76514

Iter = 30 best fitness = 8.76514

Iter = 40 best fitness = 8.76514

Iter = 10 best fitness = 1.13997

Iter = 20 best fitness = 0.996362

Iter = 30 best fitness = 0.994997

Iter = 40 best fitness = 0.994997

Iter = 10 best fitness = 5.67343

Iter = 20 best fitness = 5.67343

Iter = 30 best fitness = 5.67343

Iter = 40 best fitness = 5.67343

Iter = 10 best fitness = 2.49973

Iter = 20 best fitness = 0.997176

Iter = 30 best fitness = 0.995636

Iter = 40 best fitness = 0.995114

Best Result for population_size=50, num_iter=50
 : {4.7663×10^-8, -5.08179×10^-8} with fitness = 9.59233×10^-13

Running test for dimension=2, population_size=100, num_iterations=10

Best Result for population_size=100, num_iter=10
 : {-0.0000211076, -5.45773×10^-6} with fitness = 9.42996×10^-8

Running test for dimension=2, population_size=100, num_iterations=30

Iter = 10 best fitness = 0.000157329

Iter = 20 best fitness = 2.27235×10^-8

Iter = 10 best fitness = 0.0000781166

Iter = 20 best fitness = 1.04095×10^-12

Iter = 10 best fitness = 0.0000415188

Iter = 20 best fitness = 2.96083×10^-11

Iter = 10 best fitness = 1.02382

Iter = 20 best fitness = 0.999244

Iter = 10 best fitness = 0.000442997
Iter = 20 best fitness = 8.41434×10^-7

Iter = 10 best fitness = 1.03699

Iter = 20 best fitness = 1.03118

Iter = 10 best fitness = 8.12059×10^-7

Iter = 20 best fitness = 2.21974×10^-11

Iter = 10 best fitness = 0.000393092

Iter = 20 best fitness = 4.04938×10^-11

Iter = 10 best fitness = 0.00173984

Iter = 20 best fitness = 1.88686×10^-7

Iter = 10 best fitness = 0.00768344

Iter = 20 best fitness = 2.65747×10^-7

Best Result for population_size=100, num_iter=30
 : {1.52621×10^-8, -1.17037×10^-8} with fitness = 7.10543×10^-14

Running test for dimension=2, population_size=100, num_iterations=50

Iter = 10 best fitness = 3.12492

Iter = 20 best fitness = 3.12492

Iter = 30 best fitness = 3.12492

Iter = 40 best fitness = 3.12492

Iter = 10 best fitness = 0.355079

Iter = 20 best fitness = 0.0000447628

Iter = 30 best fitness = 2.06516×10^-8

Iter = 40 best fitness = 1.78731×10^-9

Iter = 10 best fitness = 1.46779

Iter = 20 best fitness = 0.995374

Iter = 30 best fitness = 0.995163

Iter = 40 best fitness = 0.99496

Iter = 10 best fitness = 3.66488

Iter = 20 best fitness = 3.66488

Iter = 30 best fitness = 3.66488

Iter = 40 best fitness = 3.66488

Iter = 10 best fitness = 2.31166

Iter = 20 best fitness = 2.31166

Iter = 30 best fitness = 2.31166

Iter = 40 best fitness = 2.31166

Iter = 10 best fitness = 1.00351

Iter = 20 best fitness = 0.995104

Iter = 30 best fitness = 0.994961

Iter = 40 best fitness = 0.99496

Iter = 10 best fitness = 1.55016
Iter = 20 best fitness = 1.55016

Iter = 30 best fitness = 1.55016

Iter = 40 best fitness = 1.55016

Iter = 10 best fitness = 0.0353746

Iter = 20 best fitness = 1.57301×10^-9

Iter = 30 best fitness = 0.

Iter = 40 best fitness = 0.

Iter = 10 best fitness = 0.000151806

Iter = 20 best fitness = 3.63924×10^-9

Iter = 30 best fitness = 2.38032×10^-12

Iter = 40 best fitness = 2.41585×10^-13

Iter = 10 best fitness = 5.09959

Iter = 20 best fitness = 1.19812

Iter = 30 best fitness = 1.53683×10^-7

Iter = 40 best fitness = 3.36459×10^-9

Best Result for population_size=100, num_iter=
 50: {-3.74879×10^-9, 5.1924×10^-10} with fitness = 0.
```

Dimension	Population Size	Iteration Number	Label	Solution	F
2	10	10	RaF21010	{0.997312, 0.997173}	1
2	10	30	RaF21030	{–0.00205915, 0.00203323}	0
2	10	50	RaF21050	{0.00922218, –0.00902995}	0
2	20	10	RaF22010	{–0.0228066, 0.00656226}	0
2	20	30	RaF22030	{0.0000328944, –0.0000344214}	0
2	20	50	RaF22050	{–0.000205358, 0.00024176}	0
2	50	10	RaF25010	{0.0028224, 0.0000931833}	0
2	50	30	RaF25030	$\{-2.01209\times10^{-8}, 1.59961\times10^{-8}\}$	0
2	50	50	RaF25050	$\{4.7663\times10^{-8}, -5.08179\times10^{-8}\}$	0
2	100	10	RaF210010	$\{-0.0000211076, -5.45773\times10^{-6}\}$	0
2	100	30	RaF210030	$\{1.52621\times10^{-8}, -1.17037\times10^{-8}\}$	0
2	100	50	RaF210050	$\{-3.74879\times10^{-9}, 5.1924\times10^{-10}\}$	0

Case 02.02: Rastrigin function with dimension 5

```
In[•]:= dimension = 5;
        populationSizes = {10, 20, 50, 100};
        iterationValues = {10, 30, 50};
        results5 = {};

        Do[Do[Print["Running test for dimension=", dimension,
            ", population_size=", populationSize, ", num_iterations=", numIter];
           bestSolutions = Table[
             gwo[fitnessRastrigin, numIter, populationSize, dimension, -10.0, 10.0], {10}];
           bestSolution = First[SortBy[bestSolutions, fitnessRastrigin]];
           Print["Best Result for population_size=", populationSize, ", num_iter=",
            numIter, ": ", bestSolution, " with fitness = ", fitnessRastrigin[bestSolution]];
           AppendTo[results5, <|"Dimension" → dimension,
             "Population Size" → populationSize, "Iteration Number" → numIter, "Label" →
              "RaF" <> ToString[dimension] <> ToString[populationSize] <> ToString[numIter],
             "Solution" → bestSolution, "Fitness" → fitnessRastrigin[bestSolution] |>],
           {numIter, iterationValues}], {populationSize, populationSizes}];

        newDF = Dataset[results5];
        rafDF = Join[rafDF, newDF];
        Print[rafDF]
```

```
Running test for dimension=5, population_size=10, num_iterations=10

Best Result for population_size=10, num_iter=10:
 {-1.28132, -0.0412237, -0.0402371, 2.0086, -2.90178} with fitness = 28.5656

Running test for dimension=5, population_size=10, num_iterations=30

Iter = 10 best fitness = 18.0906

Iter = 20 best fitness = 7.43484

Iter = 10 best fitness = 40.3859

Iter = 20 best fitness = 22.7131

Iter = 10 best fitness = 23.6885

Iter = 20 best fitness = 23.6885

Iter = 10 best fitness = 48.8244

Iter = 20 best fitness = 30.1364

Iter = 10 best fitness = 21.1482

Iter = 20 best fitness = 19.3485

Iter = 10 best fitness = 34.1859

Iter = 20 best fitness = 29.1076

Iter = 10 best fitness = 30.6074

Iter = 20 best fitness = 16.8031

Iter = 10 best fitness = 27.4567

Iter = 20 best fitness = 20.2479

Iter = 10 best fitness = 23.736

Iter = 20 best fitness = 12.7154

Iter = 10 best fitness = 13.8702
Iter = 20 best fitness = 13.8702

Best Result for population_size=10, num_iter=30:
 {-1.07192, 0.998114, 1.04839, 0.0283597, 0.0619889} with fitness = 5.61939

Running test for dimension=5, population_size=10, num_iterations=50

Iter = 10 best fitness = 73.2173

Iter = 20 best fitness = 73.2173

Iter = 30 best fitness = 63.3275

Iter = 40 best fitness = 63.3275

Iter = 10 best fitness = 36.0866

Iter = 20 best fitness = 12.0438

Iter = 30 best fitness = 11.471

Iter = 40 best fitness = 11.471

Iter = 10 best fitness = 5.58734

Iter = 20 best fitness = 4.53912

Iter = 30 best fitness = 4.53912

Iter = 40 best fitness = 4.31495

Iter = 10 best fitness = 32.9116

Iter = 20 best fitness = 12.3878

Iter = 30 best fitness = 10.492

Iter = 40 best fitness = 10.492

Iter = 10 best fitness = 32.2417

Iter = 20 best fitness = 17.935

Iter = 30 best fitness = 12.1036

Iter = 40 best fitness = 6.43845

Iter = 10 best fitness = 95.7948

Iter = 20 best fitness = 95.7948

Iter = 30 best fitness = 58.2856

Iter = 40 best fitness = 55.8382

Iter = 10 best fitness = 52.9477

Iter = 20 best fitness = 15.7979

Iter = 30 best fitness = 6.37776

Iter = 40 best fitness = 6.37776

Iter = 10 best fitness = 30.9148

Iter = 20 best fitness = 25.4612

Iter = 30 best fitness = 25.0551

Iter = 40 best fitness = 25.0551

Iter = 10 best fitness = 31.2969

Iter = 20 best fitness = 20.7793

Iter = 30 best fitness = 15.8923
Iter = 40 best fitness = 15.2196

Iter = 10 best fitness = 15.0128

Iter = 20 best fitness = 7.44467

Iter = 30 best fitness = 7.44467

Iter = 40 best fitness = 7.44467

Best Result for population_size=10, num_iter=50:
 {-0.123577, 0.0284503, -0.0058547, -0.0327518, -0.97868} with fitness = 4.30767

Running test for dimension=5, population_size=20, num_iterations=10

Best Result for population_size=20, num_iter=10:
 {-0.942698, -1.00071, 2.95521, -0.0514463, -1.05596} with fitness = 13.9053

Running test for dimension=5, population_size=20, num_iterations=30

Iter = 10 best fitness = 28.0053

Iter = 20 best fitness = 17.6468

Iter = 10 best fitness = 30.8673

Iter = 20 best fitness = 23.1677

Iter = 10 best fitness = 12.2657

Iter = 20 best fitness = 1.49262

Iter = 10 best fitness = 14.1984

Iter = 20 best fitness = 12.5641

Iter = 10 best fitness = 24.1

Iter = 20 best fitness = 24.1

Iter = 10 best fitness = 15.3665

Iter = 20 best fitness = 11.2958

Iter = 10 best fitness = 24.2691

Iter = 20 best fitness = 23.9103

Iter = 10 best fitness = 30.1045

Iter = 20 best fitness = 24.7626

Iter = 10 best fitness = 31.0815

Iter = 20 best fitness = 8.97615

Iter = 10 best fitness = 27.1209

Iter = 20 best fitness = 7.39719

Best Result for population_size=20, num_iter=30:
 {0.00881865, 0.0133537, 0.0225433, 0.995338, -0.0391872} with fitness = 1.44955

Running test for dimension=5, population_size=20, num_iterations=50

Iter = 10 best fitness = 9.45698

Iter = 20 best fitness = 3.92864

Iter = 30 best fitness = 2.86615

Iter = 40 best fitness = 2.8515

Iter = 10 best fitness = 41.292

Iter = 20 best fitness = 16.4664
Iter = 30 best fitness = 8.69525

Iter = 40 best fitness = 8.63673

Iter = 10 best fitness = 24.2315

Iter = 20 best fitness = 12.9987

Iter = 30 best fitness = 11.9619

Iter = 40 best fitness = 11.9147

Iter = 10 best fitness = 6.94782

Iter = 20 best fitness = 5.72934

Iter = 30 best fitness = 3.18417

Iter = 40 best fitness = 3.11355

Iter = 10 best fitness = 62.1008

Iter = 20 best fitness = 30.4422

Iter = 30 best fitness = 21.0037

Iter = 40 best fitness = 20.9867

Iter = 10 best fitness = 6.04212

Iter = 20 best fitness = 5.13654

Iter = 30 best fitness = 5.12756

Iter = 40 best fitness = 5.12367

Iter = 10 best fitness = 24.6723

Iter = 20 best fitness = 6.86975

Iter = 30 best fitness = 0.482596

Iter = 40 best fitness = 0.190426

Iter = 10 best fitness = 19.5014

Iter = 20 best fitness = 12.6491

Iter = 30 best fitness = 6.16896

Iter = 40 best fitness = 4.94799

Iter = 10 best fitness = 13.0024

Iter = 20 best fitness = 6.56855

Iter = 30 best fitness = 5.54459

Iter = 40 best fitness = 5.54459

Iter = 10 best fitness = 23.8982

Iter = 20 best fitness = 17.8634

Iter = 30 best fitness = 14.1317

Iter = 40 best fitness = 13.8112

Best Result for population_size=20, num_iter=50:
 {0.000606593, -0.0206683, 0.00586276, 0.0195978, -0.000582106} with fitness = 0.167691

Running test for dimension=5, population_size=50, num_iterations=10

Best Result for population_size=50, num_iter=10:
 {-0.0375132, 2.86002, 2.01366, 0.963495, 0.0308808} with fitness = 17.5531
```

```
Running test for dimension=5, population_size=50, num_iterations=30

Iter = 10 best fitness = 57.7636

Iter = 20 best fitness = 57.7636

Iter = 10 best fitness = 12.4536

Iter = 20 best fitness = 10.1118

Iter = 10 best fitness = 28.1519

Iter = 20 best fitness = 26.0807

Iter = 10 best fitness = 9.83627

Iter = 20 best fitness = 9.4359

Iter = 10 best fitness = 17.3391

Iter = 20 best fitness = 6.29776

Iter = 10 best fitness = 4.5795

Iter = 20 best fitness = 3.47275

Iter = 10 best fitness = 3.58979

Iter = 20 best fitness = 3.08988

Iter = 10 best fitness = 12.3468

Iter = 20 best fitness = 6.82133

Iter = 10 best fitness = 21.7797

Iter = 20 best fitness = 13.0539

Iter = 10 best fitness = 23.2021

Iter = 20 best fitness = 14.1176

Best Result for population_size=50, num_iter=30:
 {0.0110163, 0.992978, 0.995663, -0.0190416, -0.995857} with fitness = 3.08183

Running test for dimension=5, population_size=50, num_iterations=50

Iter = 10 best fitness = 14.8608

Iter = 20 best fitness = 14.2973

Iter = 30 best fitness = 14.2973

Iter = 40 best fitness = 14.2973

Iter = 10 best fitness = 35.3663

Iter = 20 best fitness = 13.0743

Iter = 30 best fitness = 11.6307

Iter = 40 best fitness = 10.2788

Iter = 10 best fitness = 14.2684

Iter = 20 best fitness = 7.21592

Iter = 30 best fitness = 7.09925

Iter = 40 best fitness = 7.09067

Iter = 10 best fitness = 14.6345

Iter = 20 best fitness = 5.43449

Iter = 30 best fitness = 1.06476
Iter = 40 best fitness = 1.04195

Iter = 10 best fitness = 33.4205

Iter = 20 best fitness = 11.1673

Iter = 30 best fitness = 6.77491

Iter = 40 best fitness = 6.72798

Iter = 10 best fitness = 11.4644

Iter = 20 best fitness = 3.73232

Iter = 30 best fitness = 3.24744

Iter = 40 best fitness = 3.24122

Iter = 10 best fitness = 23.72

Iter = 20 best fitness = 5.9469

Iter = 30 best fitness = 5.90276

Iter = 40 best fitness = 5.88536

Iter = 10 best fitness = 69.7139

Iter = 20 best fitness = 69.7139

Iter = 30 best fitness = 69.7139

Iter = 40 best fitness = 69.7139

Iter = 10 best fitness = 7.18226

Iter = 20 best fitness = 4.43709

Iter = 30 best fitness = 4.03907

Iter = 40 best fitness = 3.94725

Iter = 10 best fitness = 7.81908

Iter = 20 best fitness = 5.62754

Iter = 30 best fitness = 3.65475

Iter = 40 best fitness = 3.52767

Best Result for population_size=50, num_iter=50:
 {-0.00945691, -0.000976918, -0.995217, 0.00283093, 0.0109348} with fitness = 1.0382

Running test for dimension=5, population_size=100, num_iterations=10

Best Result for population_size=100, num_iter=10:
 {1.01182, -0.00234246, 1.96181, 1.02225, 0.00154119} with fitness = 6.33065

Running test for dimension=5, population_size=100, num_iterations=30

Iter = 10 best fitness = 11.6923

Iter = 20 best fitness = 6.82107

Iter = 10 best fitness = 48.9048

Iter = 20 best fitness = 48.9048

Iter = 10 best fitness = 9.00406

Iter = 20 best fitness = 8.99639

Iter = 10 best fitness = 5.47072

Iter = 20 best fitness = 4.15287
Iter = 10 best fitness = 22.8027

Iter = 20 best fitness = 22.2009

Iter = 10 best fitness = 14.1681

Iter = 20 best fitness = 7.12801

Iter = 10 best fitness = 9.05616

Iter = 20 best fitness = 2.92388

Iter = 10 best fitness = 12.7129

Iter = 20 best fitness = 10.3019

Iter = 10 best fitness = 18.2502

Iter = 20 best fitness = 11.0953

Iter = 10 best fitness = 6.63382

Iter = 20 best fitness = 4.3069

Best Result for population_size=100, num_iter=30:
 {-1.00838, 0.0313961, -0.0552762, -0.015272, -0.977994} with fitness = 2.92388

Running test for dimension=5, population_size=100, num_iterations=50

Iter = 10 best fitness = 41.0058

Iter = 20 best fitness = 41.0058

Iter = 30 best fitness = 41.0058

Iter = 40 best fitness = 41.0058

Iter = 10 best fitness = 54.85

Iter = 20 best fitness = 54.85

Iter = 30 best fitness = 15.3715

Iter = 40 best fitness = 7.43871

Iter = 10 best fitness = 5.64639

Iter = 20 best fitness = 4.06283

Iter = 30 best fitness = 4.01214

Iter = 40 best fitness = 4.01214

Iter = 10 best fitness = 5.95833

Iter = 20 best fitness = 2.04702

Iter = 30 best fitness = 2.03196

Iter = 40 best fitness = 2.02823

Iter = 10 best fitness = 4.19878

Iter = 20 best fitness = 4.09525

Iter = 30 best fitness = 4.04273

Iter = 40 best fitness = 4.03515

Iter = 10 best fitness = 24.578

Iter = 20 best fitness = 1.66568

Iter = 30 best fitness = 1.31273

Iter = 40 best fitness = 1.24249
Iter = 10 best fitness = 11.9476

Iter = 20 best fitness = 1.47126

Iter = 30 best fitness = 1.39047

Iter = 40 best fitness = 1.38762

Iter = 10 best fitness = 10.8208

Iter = 20 best fitness = 5.15549

Iter = 30 best fitness = 4.62388

Iter = 40 best fitness = 4.22526

Iter = 10 best fitness = 1.62341

Iter = 20 best fitness = 0.00899171

Iter = 30 best fitness = 0.0000406009

Iter = 40 best fitness = 6.57278×10^-6

Iter = 10 best fitness = 1.44605

Iter = 20 best fitness = 0.00869179

Iter = 30 best fitness = 1.62479×10^-6

Iter = 40 best fitness = 3.91029×10^-7

Best Result for population_size=100, num_iter=50:
 {-0.0000239805, -5.6113×10^-6, 0.000025239, -9.46921×10^-6, 9.16042×10^-6}
  with fitness = 2.81149×10^-7
```

Dimension	Population Size	Iteration Number	Label	Solution
2	20	30	RaF22030	{0.0000328944, −0.000034421
2	20	50	RaF22050	{−0.000205358, 0.00024176}
2	50	10	RaF25010	{0.0028224, 0.0000931833}
2	50	30	RaF25030	{−2.01209 × 10^{-8}, 1.59961 × 10
2	50	50	RaF25050	{4.7663 × 10^{-8}, −5.08179 × 10^{-8}
2	100	10	RaF210010	{−0.0000211076, −5.45773 × 1
2	100	30	RaF210030	{1.52621 × 10^{-8}, −1.17037 × 10
2	100	50	RaF210050	{−3.74879 × 10^{-9}, 5.1924 × 10^{-1}
5	10	10	RaF51010	{−1.28132, −0.0412237, −0.04
5	10	30	RaF51030	{−1.07192, 0.998114, 1.04839,
5	10	50	RaF51050	{−0.123577, 0.0284503, −0.00
5	20	10	RaF52010	{−0.942698, −1.00071, 2.9552
5	20	30	RaF52030	{0.00881865, 0.0133537, 0.02
5	20	50	RaF52050	{0.000606593, −0.0206683, 0.
5	50	10	RaF55010	{−0.0375132, 2.86002, 2.0136
5	50	30	RaF55030	{0.0110163, 0.992978, 0.9956
5	50	50	RaF55050	{−0.00945691, −0.000976918,
5	100	10	RaF510010	{1.01182, −0.00234246, 1.961
5	100	30	RaF510030	{−1.00838, 0.0313961, −0.055
5	100	50	RaF510050	{−0.0000239805, −5.6113 × 10

rows 5–24 of **24**

In[∘]:=

```
Export["rafDF.csv", Normal[rafDF]]
Print["File saved to: ", Directory[] <> "/rafDF.csv"]
```

Out[∘]=

```
rafDF.csv

File saved to: C:\Users\irfan\OneDrive\Documents/rafDF.csv
```

Running test for Rosenbrock function

Case 03.01: Rosenbrock function with dimension 2

```
In[•]:= dimension = 2;
        populationSizes = {10, 20, 50, 100};
        iterationValues = {10, 30, 50};

        results2 = {};
        Do[Do[Print["Running test for dimension=", dimension,
             ", population_size=", populationSize, ", num_iterations=", numIter];
           bestSolutions = Table[
             gwo[fitnessRosenbrock, numIter, populationSize, dimension, -10.0, 10.0], {10}];
           bestSolution = First[SortBy[bestSolutions, fitnessRosenbrock]];
           Print["Best Result for population_size=",
            populationSize, ", num_iter=", numIter, ": ", bestSolution,
            " with fitness = ", fitnessRosenbrock[bestSolution]];
           AppendTo[results2, <|"Dimension" → dimension,
             "Population Size" → populationSize, "Iteration Number" → numIter, "Label" →
              "RbF" <> ToString[dimension] <> ToString[populationSize] <> ToString[numIter],
             "Solution" → bestSolution, "Fitness" → fitnessRosenbrock[bestSolution] |>],
           {numIter, iterationValues}], {populationSize, populationSizes}];

        rbfDF = Dataset[results2];

        Print[rbfDF]
```

```
Running test for dimension=2, population_size=10, num_iterations=10

Best Result for population_size=10, num_iter=10: {0.416994, 0.201121} with fitness = 0.414082

Running test for dimension=2, population_size=10, num_iterations=30

Iter = 10 best fitness = 3.2278

Iter = 20 best fitness = 3.20537

Iter = 10 best fitness = 0.0817259

Iter = 20 best fitness = 0.0338912

Iter = 10 best fitness = 3.6865

Iter = 20 best fitness = 3.08277

Iter = 10 best fitness = 4.02311

Iter = 20 best fitness = 3.97243

Iter = 10 best fitness = 3.38272

Iter = 20 best fitness = 2.94365

Iter = 10 best fitness = 0.129231

Iter = 20 best fitness = 0.00280738

Iter = 10 best fitness = 16.0844

Iter = 20 best fitness = 11.9006

Iter = 10 best fitness = 7.82049

Iter = 20 best fitness = 7.09715

Iter = 10 best fitness = 6.72375

Iter = 20 best fitness = 6.60529
Iter = 10 best fitness = 0.00016194

Iter = 20 best fitness = 0.00016194

Best Result for population_size=10, num_iter=
 30: {1.00232, 1.00557} with fitness = 0.0000897467

Running test for dimension=2, population_size=10, num_iterations=50

Iter = 10 best fitness = 0.333144

Iter = 20 best fitness = 0.333144

Iter = 30 best fitness = 0.333144

Iter = 40 best fitness = 0.333144

Iter = 10 best fitness = 0.0439117

Iter = 20 best fitness = 0.00453802

Iter = 30 best fitness = 0.00453802

Iter = 40 best fitness = 0.00453802

Iter = 10 best fitness = 0.021366

Iter = 20 best fitness = 0.021366

Iter = 30 best fitness = 0.0212923

Iter = 40 best fitness = 0.017185

Iter = 10 best fitness = 3.65382

Iter = 20 best fitness = 0.436486

Iter = 30 best fitness = 0.38426

Iter = 40 best fitness = 0.38426

Iter = 10 best fitness = 0.252217

Iter = 20 best fitness = 0.128549

Iter = 30 best fitness = 0.122815

Iter = 40 best fitness = 0.113105

Iter = 10 best fitness = 17.3677

Iter = 20 best fitness = 17.3677

Iter = 30 best fitness = 16.9584

Iter = 40 best fitness = 16.7106

Iter = 10 best fitness = 0.0460052

Iter = 20 best fitness = 0.0433686

Iter = 30 best fitness = 0.0374309

Iter = 40 best fitness = 0.0374309

Iter = 10 best fitness = 2.79288

Iter = 20 best fitness = 2.68945

Iter = 30 best fitness = 2.68287

Iter = 40 best fitness = 2.67372

Iter = 10 best fitness = 20.116

Iter = 20 best fitness = 4.27801
Iter = 30 best fitness = 4.25291

Iter = 40 best fitness = 4.14681

Iter = 10 best fitness = 4.72391

Iter = 20 best fitness = 4.72391

Iter = 30 best fitness = 4.72391

Iter = 40 best fitness = 4.72391

Best Result for population_size=10, num_iter=
 50: {0.938458, 0.880503} with fitness = 0.00379143

Running test for dimension=2, population_size=20, num_iterations=10

Best Result for population_size=20, num_iter=10: {1.37016, 1.87192} with fitness = 0.139944

Running test for dimension=2, population_size=20, num_iterations=30

Iter = 10 best fitness = 11.7395

Iter = 20 best fitness = 11.4986

Iter = 10 best fitness = 0.111941

Iter = 20 best fitness = 0.053871

Iter = 10 best fitness = 2.31071

Iter = 20 best fitness = 2.31071

Iter = 10 best fitness = 1.15652

Iter = 20 best fitness = 0.0369349

Iter = 10 best fitness = 0.2

Iter = 20 best fitness = 0.0566072

Iter = 10 best fitness = 0.00951254

Iter = 20 best fitness = 0.000593093

Iter = 10 best fitness = 1.43539

Iter = 20 best fitness = 1.21958

Iter = 10 best fitness = 0.623003

Iter = 20 best fitness = 0.279687

Iter = 10 best fitness = 2.72165

Iter = 20 best fitness = 2.72165

Iter = 10 best fitness = 0.0523365

Iter = 20 best fitness = 0.0000391708

Best Result for population_size=20, num_iter=
 30: {0.998147, 0.996037} with fitness = 0.0000102165

Running test for dimension=2, population_size=20, num_iterations=50

Iter = 10 best fitness = 0.0909198

Iter = 20 best fitness = 0.064333

Iter = 30 best fitness = 0.0491055

Iter = 40 best fitness = 0.042981

Iter = 10 best fitness = 5.87907
Iter = 20 best fitness = 5.87907

Iter = 30 best fitness = 5.78848

Iter = 40 best fitness = 5.78541

Iter = 10 best fitness = 3.00659

Iter = 20 best fitness = 1.12319

Iter = 30 best fitness = 1.07381

Iter = 40 best fitness = 1.05429

Iter = 10 best fitness = 0.177717

Iter = 20 best fitness = 0.126145

Iter = 30 best fitness = 0.0900888

Iter = 40 best fitness = 0.0821723

Iter = 10 best fitness = 0.719922

Iter = 20 best fitness = 0.0116648

Iter = 30 best fitness = 0.000205867

Iter = 40 best fitness = 0.0001362

Iter = 10 best fitness = 0.0533486

Iter = 20 best fitness = 0.0412084

Iter = 30 best fitness = 0.0412084

Iter = 40 best fitness = 0.0412084

Iter = 10 best fitness = 1.08256

Iter = 20 best fitness = 0.00558132

Iter = 30 best fitness = 0.000105046

Iter = 40 best fitness = 0.0000314973

Iter = 10 best fitness = 0.0868072

Iter = 20 best fitness = 0.00494476

Iter = 30 best fitness = 0.00321905

Iter = 40 best fitness = 0.0021519

Iter = 10 best fitness = 0.0323229

Iter = 20 best fitness = 0.00522541

Iter = 30 best fitness = 0.00440665

Iter = 40 best fitness = 0.00314735

Iter = 10 best fitness = 6.00822

Iter = 20 best fitness = 5.0243

Iter = 30 best fitness = 4.99415

Iter = 40 best fitness = 4.95211
```

Best Result for population_size=20, num_iter=
 50: {0.998695, 0.9975} with fitness = 2.86412×10^{-6}

Running test for dimension=2, population_size=50, num_iterations=10

```
Best Result for population_size=50, num_iter=
 10: {0.98081, 0.960936} with fitness = 0.000479116

Running test for dimension=2, population_size=50, num_iterations=30

Iter = 10 best fitness = 0.00219971

Iter = 20 best fitness = 0.00168056

Iter = 10 best fitness = 0.000860978

Iter = 20 best fitness = 0.0000839276

Iter = 10 best fitness = 0.269717

Iter = 20 best fitness = 0.132471

Iter = 10 best fitness = 0.00260115

Iter = 20 best fitness = 0.000873282

Iter = 10 best fitness = 0.00182274

Iter = 20 best fitness = 6.93654×10^-6

Iter = 10 best fitness = 0.0102914

Iter = 20 best fitness = 0.00476768

Iter = 10 best fitness = 0.000970338

Iter = 20 best fitness = 0.000970338

Iter = 10 best fitness = 0.00357799

Iter = 20 best fitness = 0.000562093

Iter = 10 best fitness = 0.00299255

Iter = 20 best fitness = 0.0000173946

Iter = 10 best fitness = 5.2424

Iter = 20 best fitness = 3.82345

Best Result for population_size=50, num_iter=
 30: {1.00109, 1.00211} with fitness = 1.65891×10^-6

Running test for dimension=2, population_size=50, num_iterations=50

Iter = 10 best fitness = 0.00112265

Iter = 20 best fitness = 0.000366206

Iter = 30 best fitness = 0.000128748

Iter = 40 best fitness = 0.000128748

Iter = 10 best fitness = 0.000264828

Iter = 20 best fitness = 0.000133676

Iter = 30 best fitness = 0.000133676

Iter = 40 best fitness = 0.0000728926

Iter = 10 best fitness = 0.00499659

Iter = 20 best fitness = 0.000800921

Iter = 30 best fitness = 0.000541138

Iter = 40 best fitness = 0.0000123701

Iter = 10 best fitness = 0.112017
Iter = 20 best fitness = 0.0534487

Iter = 30 best fitness = 0.0315361

Iter = 40 best fitness = 0.0241631

Iter = 10 best fitness = 0.0851059

Iter = 20 best fitness = 0.00299815

Iter = 30 best fitness = 0.000160635

Iter = 40 best fitness = 0.000103219

Iter = 10 best fitness = 0.00029607

Iter = 20 best fitness = 0.0000929663

Iter = 30 best fitness = 0.0000929663

Iter = 40 best fitness = 0.0000455982

Iter = 10 best fitness = 0.0542085

Iter = 20 best fitness = 0.0140945

Iter = 30 best fitness = 0.0140945

Iter = 40 best fitness = 0.000271669

Iter = 10 best fitness = 0.00207819

Iter = 20 best fitness = 0.000596818

Iter = 30 best fitness = 0.000352751

Iter = 40 best fitness = 0.0000993013

Iter = 10 best fitness = 0.000323862

Iter = 20 best fitness = 0.000323862

Iter = 30 best fitness = 0.000212031

Iter = 40 best fitness = 0.000199207

Iter = 10 best fitness = 0.0059372

Iter = 20 best fitness = 0.000883887

Iter = 30 best fitness = 0.0000165532

Iter = 40 best fitness = 0.0000137377

Best Result for population_size=50, num_iter=
 50: {1.00093, 1.00186} with fitness = 8.64358×10^-7

Running test for dimension=2, population_size=100, num_iterations=10

Best Result for population_size=100, num_iter=
 10: {1.00163, 1.00354} with fitness = 0.0000105843

Running test for dimension=2, population_size=100, num_iterations=30

Iter = 10 best fitness = 0.0117876

Iter = 20 best fitness = 0.0000302386

Iter = 10 best fitness = 0.000352904

Iter = 20 best fitness = 7.83243×10^-7

Iter = 10 best fitness = 0.0121666

Iter = 20 best fitness = 0.00261279
Iter = 10 best fitness = 0.000766658

Iter = 20 best fitness = 0.000750362

Iter = 10 best fitness = 0.000414251

Iter = 20 best fitness = 0.0000127862

Iter = 10 best fitness = 6.94552×10^-6

Iter = 20 best fitness = 6.94552×10^-6

Iter = 10 best fitness = 0.000314474

Iter = 20 best fitness = 0.0000290273

Iter = 10 best fitness = 0.00261807

Iter = 20 best fitness = 0.00107608

Iter = 10 best fitness = 0.0273207

Iter = 20 best fitness = 0.00696206

Iter = 10 best fitness = 0.0001512

Iter = 20 best fitness = 0.0000396061

Best Result for population_size=100, num_iter=
 30: {1.00039, 1.00081} with fitness = 2.27351×10^-7

Running test for dimension=2, population_size=100, num_iterations=50

Iter = 10 best fitness = 0.0100712

Iter = 20 best fitness = 0.000119651

Iter = 30 best fitness = 0.000119651

Iter = 40 best fitness = 0.0000617002

Iter = 10 best fitness = 0.00611105

Iter = 20 best fitness = 0.00010492

Iter = 30 best fitness = 1.37663×10^-6

Iter = 40 best fitness = 1.37663×10^-6

Iter = 10 best fitness = 0.00185126

Iter = 20 best fitness = 0.000291149

Iter = 30 best fitness = 0.0000295567

Iter = 40 best fitness = 0.0000295567

Iter = 10 best fitness = 0.00628385

Iter = 20 best fitness = 0.0000859847

Iter = 30 best fitness = 0.0000184003

Iter = 40 best fitness = 0.0000128264

Iter = 10 best fitness = 0.0016752

Iter = 20 best fitness = 5.03415×10^-6

Iter = 30 best fitness = 5.03415×10^-6

Iter = 40 best fitness = 1.42944×10^-6

Iter = 10 best fitness = 0.000202587

Iter = 20 best fitness = 0.0000106591
Iter = 30 best fitness = 7.9095×10^-6

Iter = 40 best fitness = 6.36113×10^-8

Iter = 10 best fitness = 0.0250767

Iter = 20 best fitness = 0.0000874227

Iter = 30 best fitness = 4.98819×10^-6

Iter = 40 best fitness = 4.98819×10^-6

Iter = 10 best fitness = 2.05191

Iter = 20 best fitness = 2.05191

Iter = 30 best fitness = 0.305072

Iter = 40 best fitness = 0.0120632

Iter = 10 best fitness = 0.000311418

Iter = 20 best fitness = 0.000154923

Iter = 30 best fitness = 7.84543×10^-6

Iter = 40 best fitness = 7.84543×10^-6

Iter = 10 best fitness = 0.00645897

Iter = 20 best fitness = 0.000104358

Iter = 30 best fitness = 0.0000464087

Iter = 40 best fitness = 0.000016128

Best Result for population_size=100, num_iter=
 50: {0.999887, 0.999756} with fitness = 4.29961×10^-8
```

Dimension	Population Size	Iteration Number	Label	Solution	Fitness
2	10	10	RbF21010	{0.416994, 0.201121}	0.414082
2	10	30	RbF21030	{1.00232, 1.00557}	0.000089746
2	10	50	RbF21050	{0.938458, 0.880503}	0.00379143
2	20	10	RbF22010	{1.37016, 1.87192}	0.139944
2	20	30	RbF22030	{0.998147, 0.996037}	0.000010216
2	20	50	RbF22050	{0.998695, 0.9975}	0.000002864
2	50	10	RbF25010	{0.98081, 0.960936}	0.000479116
2	50	30	RbF25030	{1.00109, 1.00211}	0.000001658
2	50	50	RbF25050	{1.00093, 1.00186}	0.000000864
2	100	10	RbF210010	{1.00163, 1.00354}	0.000010584
2	100	30	RbF210030	{1.00039, 1.00081}	0.000000227
2	100	50	RbF210050	{0.999887, 0.999756}	0.000000042

Case 03.02: Rosenbrock function with dimension 5

```
In[•]:= dimension = 5;
        populationSizes = {10, 20, 50, 100};
        iterationValues = {10, 30, 50};

        results5 = {};
        Do[Do[Print["Running test for dimension=", dimension,
             ", population_size=", populationSize, ", num_iterations=", numIter];
           bestSolutions = Table[
              gwo[fitnessRosenbrock, numIter, populationSize, dimension, -10.0, 10.0], {10}];
           bestSolution = First[SortBy[bestSolutions, fitnessRosenbrock]];
           Print["Best Result for population_size=",
             populationSize, ", num_iter=", numIter, ": ", bestSolution,
             " with fitness = ", fitnessRosenbrock[bestSolution]];
           AppendTo[results5, <|"Dimension" → dimension,
              "Population Size" → populationSize, "Iteration Number" → numIter, "Label" →
               "RbF" <> ToString[dimension] <> ToString[populationSize] <> ToString[numIter],
              "Solution" → bestSolution, "Fitness" → fitnessRosenbrock[bestSolution] |>],
           {numIter, iterationValues}], {populationSize, populationSizes}];

        newDF = Dataset[results5];

        rbfDF = Join[rbfDF, newDF];

        rbfDF
```

```
Running test for dimension=5, population_size=10, num_iterations=10

Best Result for population_size=10, num_iter=10:
 {-1.10332, 0.783228, -0.121501, 0.634472, 0.13783} with fitness = 124.132

Running test for dimension=5, population_size=10, num_iterations=30

Iter = 10 best fitness = 256.66

Iter = 20 best fitness = 124.991

Iter = 10 best fitness = 12172.1

Iter = 20 best fitness = 1995.6

Iter = 10 best fitness = 550.435

Iter = 20 best fitness = 107.597

Iter = 10 best fitness = 2539.98

Iter = 20 best fitness = 276.952

Iter = 10 best fitness = 73.1573

Iter = 20 best fitness = 36.3992

Iter = 10 best fitness = 7913.35

Iter = 20 best fitness = 7913.35

Iter = 10 best fitness = 954.674

Iter = 20 best fitness = 92.724

Iter = 10 best fitness = 272.014

Iter = 20 best fitness = 272.014
Iter = 10 best fitness = 37.5924

Iter = 20 best fitness = 20.0225

Iter = 10 best fitness = 175.029

Iter = 20 best fitness = 27.53

Best Result for population_size=10, num_iter=30:
 {0.215445, 0.0644299, -0.309583, 0.305008, 0.131111} with fitness = 18.0843

Running test for dimension=5, population_size=10, num_iterations=50

Iter = 10 best fitness = 284.154

Iter = 20 best fitness = 7.7559

Iter = 30 best fitness = 4.38066

Iter = 40 best fitness = 4.2102

Iter = 10 best fitness = 3508.65

Iter = 20 best fitness = 314.213

Iter = 30 best fitness = 44.9191

Iter = 40 best fitness = 22.0104

Iter = 10 best fitness = 1847.3

Iter = 20 best fitness = 1847.3

Iter = 30 best fitness = 637.445

Iter = 40 best fitness = 408.831

Iter = 10 best fitness = 2457.22

Iter = 20 best fitness = 116.629

Iter = 30 best fitness = 22.1464

Iter = 40 best fitness = 12.3294

Iter = 10 best fitness = 54.1688

Iter = 20 best fitness = 29.7332

Iter = 30 best fitness = 19.4526

Iter = 40 best fitness = 14.4991

Iter = 10 best fitness = 80 306.3

Iter = 20 best fitness = 80 306.3

Iter = 30 best fitness = 80 306.3

Iter = 40 best fitness = 80 306.3

Iter = 10 best fitness = 1343.91

Iter = 20 best fitness = 1343.91

Iter = 30 best fitness = 294.7

Iter = 40 best fitness = 139.634

Iter = 10 best fitness = 1497.78

Iter = 20 best fitness = 508.058

Iter = 30 best fitness = 85.1815

Iter = 40 best fitness = 46.9188
Iter = 10 best fitness = 81056.3

Iter = 20 best fitness = 2055.02

Iter = 30 best fitness = 134.228

Iter = 40 best fitness = 61.2546

Iter = 10 best fitness = 303.739

Iter = 20 best fitness = 27.3848

Iter = 30 best fitness = 9.78901

Iter = 40 best fitness = 6.6118

Best Result for population_size=10, num_iter=50:
 {-0.0263067, -0.0081349, 0.0348083, -0.0108738, -0.0148231} with fitness = 4.18853

Running test for dimension=5, population_size=20, num_iterations=10

Best Result for population_size=20, num_iter=10:
 {0.105491, -0.0852549, 0.0691533, 0.0648183, 0.0322262} with fitness = 5.46988

Running test for dimension=5, population_size=20, num_iterations=30

Iter = 10 best fitness = 4.19226

Iter = 20 best fitness = 4.0031

Iter = 10 best fitness = 160.951

Iter = 20 best fitness = 68.5505

Iter = 10 best fitness = 11.5461

Iter = 20 best fitness = 4.28741

Iter = 10 best fitness = 5.00063

Iter = 20 best fitness = 4.03575

Iter = 10 best fitness = 527.07

Iter = 20 best fitness = 68.1665

Iter = 10 best fitness = 3.95249

Iter = 20 best fitness = 3.92233

Iter = 10 best fitness = 1759.74

Iter = 20 best fitness = 11.6576

Iter = 10 best fitness = 55.1465

Iter = 20 best fitness = 19.301

Iter = 10 best fitness = 14.8044

Iter = 20 best fitness = 4.28338

Iter = 10 best fitness = 46.4966

Iter = 20 best fitness = 10.6111

Best Result for population_size=20, num_iter=30:
 {0.0441358, 0.00852829, 0.000434041, 0.0262709, 0.00765588} with fitness = 3.92218

Running test for dimension=5, population_size=20, num_iterations=50

Iter = 10 best fitness = 8.02806

Iter = 20 best fitness = 4.65637

Iter = 30 best fitness = 4.09979
Iter = 40 best fitness = 4.03833

Iter = 10 best fitness = 9.35101

Iter = 20 best fitness = 5.35768

Iter = 30 best fitness = 5.09062

Iter = 40 best fitness = 5.08307

Iter = 10 best fitness = 100.812

Iter = 20 best fitness = 4.22575

Iter = 30 best fitness = 3.96667

Iter = 40 best fitness = 3.9585

Iter = 10 best fitness = 20.9758

Iter = 20 best fitness = 3.96436

Iter = 30 best fitness = 3.96295

Iter = 40 best fitness = 3.96294

Iter = 10 best fitness = 175.184

Iter = 20 best fitness = 36.6731

Iter = 30 best fitness = 7.77165

Iter = 40 best fitness = 5.70102

Iter = 10 best fitness = 5.43607

Iter = 20 best fitness = 4.03035

Iter = 30 best fitness = 3.97451

Iter = 40 best fitness = 3.97266

Iter = 10 best fitness = 8.79192

Iter = 20 best fitness = 4.11782

Iter = 30 best fitness = 3.99756

Iter = 40 best fitness = 3.99257

Iter = 10 best fitness = 4.02704

Iter = 20 best fitness = 3.90019

Iter = 30 best fitness = 3.88454

Iter = 40 best fitness = 3.88384

Iter = 10 best fitness = 10.7835

Iter = 20 best fitness = 1.74368

Iter = 30 best fitness = 1.68702

Iter = 40 best fitness = 1.68702

Iter = 10 best fitness = 9.02153

Iter = 20 best fitness = 3.90467

Iter = 30 best fitness = 3.90082

Iter = 40 best fitness = 3.90049

Best Result for population_size=20, num_iter=50:
 {0.864846, 0.807245, 0.637392, 0.325104, 0.117544} with fitness = 1.68702
```

```
Running test for dimension=5, population_size=50, num_iterations=10

Best Result for population_size=50, num_iter=10:
 {0.850447, 0.74426, 0.510794, 0.255913, 0.0737284} with fitness = 1.12014

Running test for dimension=5, population_size=50, num_iterations=30

Iter = 10 best fitness = 68074.8

Iter = 20 best fitness = 68074.8

Iter = 10 best fitness = 3.89214

Iter = 20 best fitness = 2.961

Iter = 10 best fitness = 9.6365

Iter = 20 best fitness = 4.93636

Iter = 10 best fitness = 5049.02

Iter = 20 best fitness = 5049.02

Iter = 10 best fitness = 3.49894

Iter = 20 best fitness = 1.13463

Iter = 10 best fitness = 4.24036

Iter = 20 best fitness = 3.90591

Iter = 10 best fitness = 8.18023

Iter = 20 best fitness = 4.09845

Iter = 10 best fitness = 4.68581

Iter = 20 best fitness = 4.46884

Iter = 10 best fitness = 4.93654

Iter = 20 best fitness = 3.55991

Iter = 10 best fitness = 30.1747

Iter = 20 best fitness = 18.0978

Best Result for population_size=50, num_iter=30:
 {0.869493, 0.749457, 0.598664, 0.30663, 0.0891079} with fitness = 1.1331

Running test for dimension=5, population_size=50, num_iterations=50

Iter = 10 best fitness = 3.66811

Iter = 20 best fitness = 3.22171

Iter = 30 best fitness = 3.18663

Iter = 40 best fitness = 3.17655

Iter = 10 best fitness = 5.71291

Iter = 20 best fitness = 3.75508

Iter = 30 best fitness = 3.74564

Iter = 40 best fitness = 3.74469

Iter = 10 best fitness = 465.86

Iter = 20 best fitness = 4.74388

Iter = 30 best fitness = 3.99997

Iter = 40 best fitness = 3.99547
Iter = 10 best fitness = 4.0315

Iter = 20 best fitness = 3.00864

Iter = 30 best fitness = 2.99998

Iter = 40 best fitness = 2.99814

Iter = 10 best fitness = 466.372

Iter = 20 best fitness = 2.41587

Iter = 30 best fitness = 2.35491

Iter = 40 best fitness = 2.34877

Iter = 10 best fitness = 8719.58

Iter = 20 best fitness = 5.62934

Iter = 30 best fitness = 4.41424

Iter = 40 best fitness = 4.3208

Iter = 10 best fitness = 14 570.6

Iter = 20 best fitness = 14 570.6

Iter = 30 best fitness = 14 570.6

Iter = 40 best fitness = 14 570.6

Iter = 10 best fitness = 4.35205

Iter = 20 best fitness = 3.32184

Iter = 30 best fitness = 3.14819

Iter = 40 best fitness = 3.12829

Iter = 10 best fitness = 3.21309

Iter = 20 best fitness = 2.97

Iter = 30 best fitness = 2.91521

Iter = 40 best fitness = 2.90685

Iter = 10 best fitness = 3.8166

Iter = 20 best fitness = 3.7367

Iter = 30 best fitness = 3.71458

Iter = 40 best fitness = 3.71021

Best Result for population_size=50, num_iter=50:
 {0.619012, 0.376818, 0.123162, 0.00727794, 0.0123694} with fitness = 2.34874

Running test for dimension=5, population_size=100, num_iterations=10

Best Result for population_size=100, num_iter=10:
 {0.110767, 0.0565081, 0.0434534, -0.0243992, 0.00464789} with fitness = 4.07383

Running test for dimension=5, population_size=100, num_iterations=30

Iter = 10 best fitness = 3.89755

Iter = 20 best fitness = 3.50875

Iter = 10 best fitness = 5.11293

Iter = 20 best fitness = 3.97319

Iter = 10 best fitness = 3.69397
Iter = 20 best fitness = 3.57562

Iter = 10 best fitness = 4.9376

Iter = 20 best fitness = 3.54803

Iter = 10 best fitness = 4.79987

Iter = 20 best fitness = 3.97417

Iter = 10 best fitness = 1.06616

Iter = 20 best fitness = 0.427948

Iter = 10 best fitness = 5.39584

Iter = 20 best fitness = 3.90464

Iter = 10 best fitness = 1387.81

Iter = 20 best fitness = 1387.81

Iter = 10 best fitness = 4.56786

Iter = 20 best fitness = 4.52445

Iter = 10 best fitness = 2.42513

Iter = 20 best fitness = 1.49242

Best Result for population_size=100, num_iter=30:
 {0.928108, 0.876815, 0.763086, 0.553364, 0.309991} with fitness = 0.388195

Running test for dimension=5, population_size=100, num_iterations=50

Iter = 10 best fitness = 0.294323

Iter = 20 best fitness = 0.236827

Iter = 30 best fitness = 0.221733

Iter = 40 best fitness = 0.213394

Iter = 10 best fitness = 2.89446

Iter = 20 best fitness = 2.24954

Iter = 30 best fitness = 2.22333

Iter = 40 best fitness = 2.19754

Iter = 10 best fitness = 5.49131

Iter = 20 best fitness = 3.32208

Iter = 30 best fitness = 3.19916

Iter = 40 best fitness = 3.08784

Iter = 10 best fitness = 0.981672

Iter = 20 best fitness = 0.86472

Iter = 30 best fitness = 0.820379

Iter = 40 best fitness = 0.798335

Iter = 10 best fitness = 4.68248

Iter = 20 best fitness = 4.62151

Iter = 30 best fitness = 4.59621

Iter = 40 best fitness = 4.58801

Iter = 10 best fitness = 832.282
Iter = 20 best fitness = 832.282

Iter = 30 best fitness = 832.282

Iter = 40 best fitness = 832.282

Iter = 10 best fitness = 5.48291

Iter = 20 best fitness = 3.96906

Iter = 30 best fitness = 3.96248

Iter = 40 best fitness = 3.96239

Iter = 10 best fitness = 571.807

Iter = 20 best fitness = 49.7137

Iter = 30 best fitness = 11.0704

Iter = 40 best fitness = 5.28007

Iter = 10 best fitness = 116.266

Iter = 20 best fitness = 4.07927

Iter = 30 best fitness = 3.98083

Iter = 40 best fitness = 3.98039

Iter = 10 best fitness = 6.5047

Iter = 20 best fitness = 3.30907

Iter = 30 best fitness = 3.12247

Iter = 40 best fitness = 3.03394

Best Result for population_size=100, num_iter=50:
 {0.942875, 0.886929, 0.787754, 0.615007, 0.376849} with fitness = 0.213145
```

Out[∘]=

Dimension	Population Size	Iteration Number	Label	Solution
2	20	30	RbF22030	{0.998147, 0.996037}
2	20	50	RbF22050	{0.998695, 0.9975}
2	50	10	RbF25010	{0.98081, 0.960936}
2	50	30	RbF25030	{1.00109, 1.00211}
2	50	50	RbF25050	{1.00093, 1.00186}
2	100	10	RbF210010	{1.00163, 1.00354}
2	100	30	RbF210030	{1.00039, 1.00081}
2	100	50	RbF210050	{0.999887, 0.999756}
5	10	10	RbF51010	{−1.10332, 0.783228, −0.121
5	10	30	RbF51030	{0.215445, 0.0644299, −0.30
5	10	50	RbF51050	{−0.0263067, −0.0081349, 0.
5	20	10	RbF52010	{0.105491, −0.0852549, 0.06
5	20	30	RbF52030	{0.0441358, 0.00852829, 0.0
5	20	50	RbF52050	{0.864846, 0.807245, 0.6373
5	50	10	RbF55010	{0.850447, 0.74426, 0.51079
5	50	30	RbF55030	{0.869493, 0.749457, 0.5986
5	50	50	RbF55050	{0.619012, 0.376818, 0.1231
5	100	10	RbF510010	{0.110767, 0.0565081, 0.043
5	100	30	RbF510030	{0.928108, 0.876815, 0.7630
5	100	50	RbF510050	{0.942875, 0.886929, 0.7877

rows 5–24 of **24**

In[∘]:=
```
Export["rbfDF.csv", Normal[rbfDF]]
Print["File saved to: ", Directory[] <> "/rbfDF.csv"]
```

Out[∘]=
```
rbfDF.csv

File saved to: C:\Users\irfan\OneDrive\Documents/rbfDF.csv
```

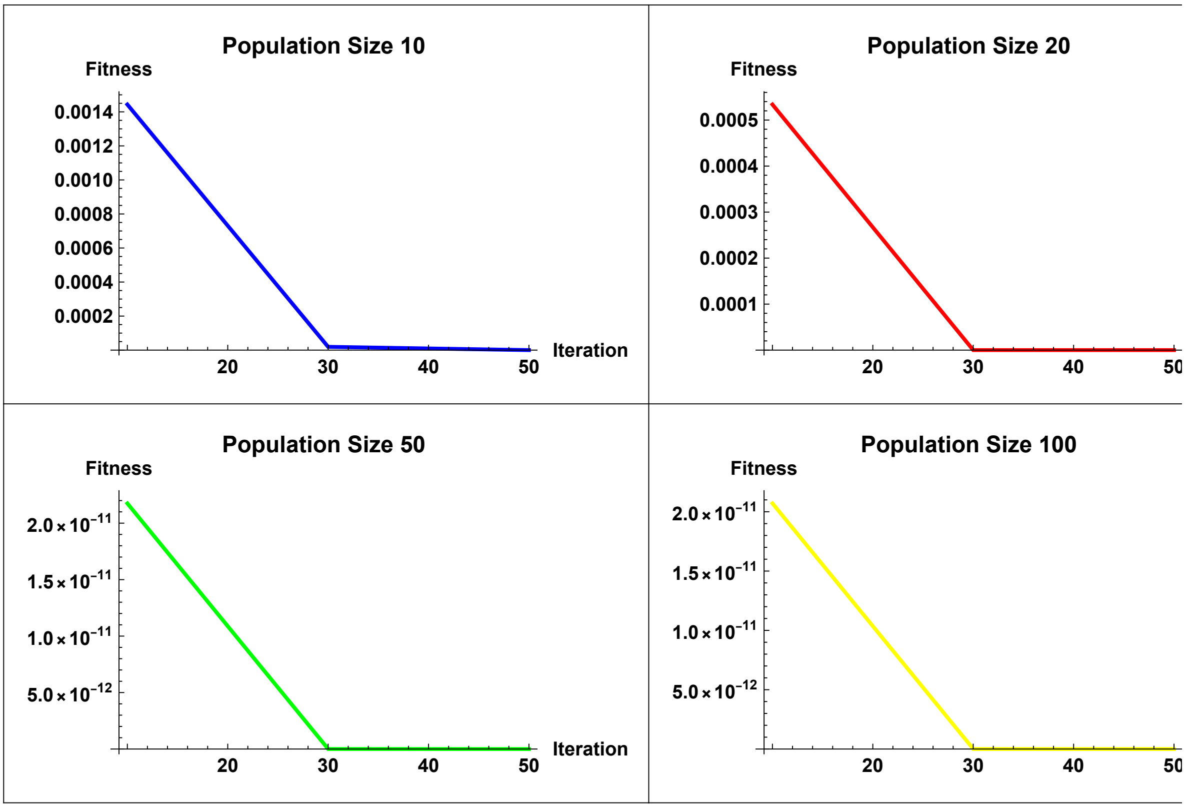
Visualization for Sphere function

```
spfdata = Normal[spfDF];
```

Dimension 02

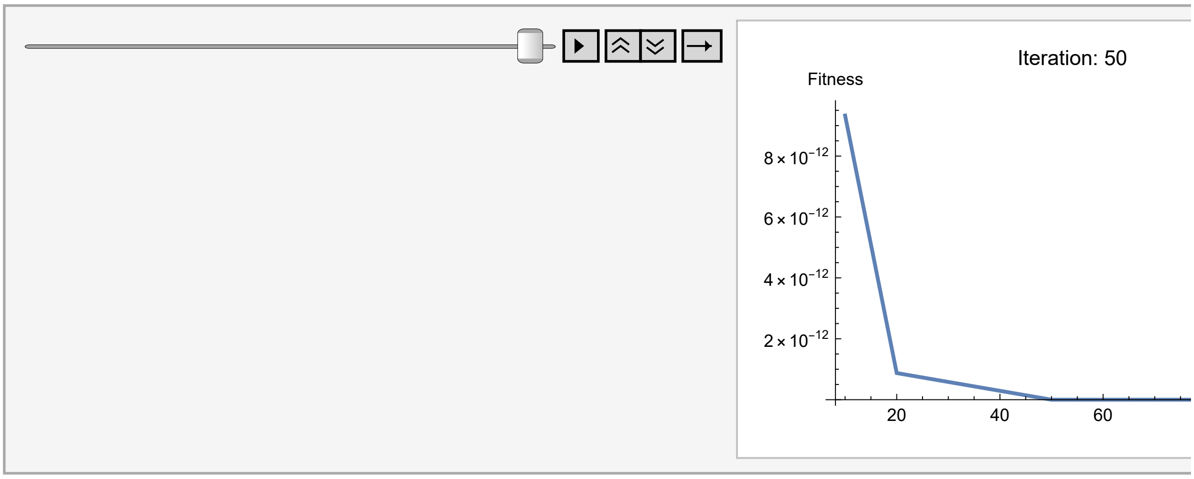
```
In[]:= (*Filter data for dimension 2 and population size 10*)
       spf210filteredData =
         Select[spfdata, #["Dimension"] == 2 && #["Population Size"] == 10 &];
       spf220filteredData =
         Select[spfdata, #["Dimension"] == 2 && #["Population Size"] == 20 &];
       spf250filteredData =
         Select[spfdata, #["Dimension"] == 2 && #["Population Size"] == 50 &];
       spf2100filteredData =
         Select[spfdata, #["Dimension"] == 2 && #["Population Size"] == 100 &];
       (*Extract iteration numbers and fitness values*)
       spf210iterationNumbers = spf210filteredData⟦All, "Iteration Number"⟧;
       spf210fitnessValues = spf210filteredData⟦All, "Fitness"⟧;
       spf220iterationNumbers = spf220filteredData⟦All, "Iteration Number"⟧;
       spf220fitnessValues = spf220filteredData⟦All, "Fitness"⟧;
       spf250iterationNumbers = spf250filteredData⟦All, "Iteration Number"⟧;
       spf250fitnessValues = spf250filteredData⟦All, "Fitness"⟧;
       spf2100iterationNumbers = spf2100filteredData⟦All, "Iteration Number"⟧;
       spf2100fitnessValues = spf2100filteredData⟦All, "Fitness"⟧;
       (*Create the line plot*)
       spf210Plot = ListLinePlot[Transpose[{spf210iterationNumbers, spf210fitnessValues}],
          PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Blue, Thick},
          PlotLabel → "Population Size 10", LabelStyle → {Bold, 10}];
       spf220Plot = ListLinePlot[Transpose[{spf220iterationNumbers, spf220fitnessValues}],
          PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Red, Thick},
          PlotLabel → "Population Size 20", LabelStyle → {Bold, 10}];
       spf250Plot = ListLinePlot[Transpose[{spf250iterationNumbers, spf250fitnessValues}],
          PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Green, Thick},
          PlotLabel → "Population Size 50", LabelStyle → {Bold, 10}];
       spf2100Plot = ListLinePlot[Transpose[{spf2100iterationNumbers, spf2100fitnessValues}],
          PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Yellow, Thick},
          PlotLabel → "Population Size 100", LabelStyle → {Bold, 10}];

       GraphicsGrid[{{Graphics[spf210Plot], Graphics[spf220Plot]},
        {Graphics[spf250Plot], Graphics[spf2100Plot]}}, Frame → All]
```

Out[ ]=


Population Size 10
Fitness
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
Iteration
20
30
40
50
Population Size 20
Fitness
0.0005
0.0004
0.0003
0.0002
0.0001
20
30
40
50
Population Size 50
Fitness
2.0×10^{-11}
1.5×10^{-11}
1.0×10^{-11}
5.0×10^{-12}
Iteration
20
30
40
50
Population Size 100
Fitness
2.0×10^{-11}
1.5×10^{-11}
1.0×10^{-11}
5.0×10^{-12}
20
30
40
50

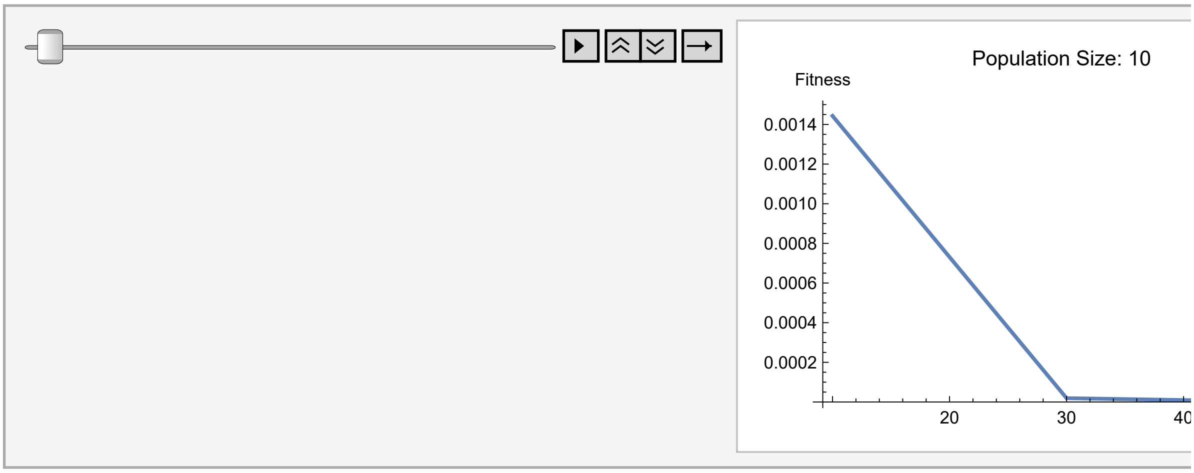
In[∘]:=
```
(*Filter data for dimension 2*)
spf2dimension2Data = Select[spfdata, #["Dimension"] == 2 &];

(*Extract unique population sizes and iterations*)
spf2uniquePopulationSizes = Union[spf2dimension2Data⟦All, "Population Size"⟧];
spf2uniqueIterations = Union[spf2dimension2Data⟦All, "Iteration Number"⟧];

(*Function to create line plot for a specific iteration*)
spf2createLinePlot[iteration_] := Module[{iterationData, sortedData},
  (*Filter data for the specific iteration*)
  iterationData = Select[spf2dimension2Data, #["Iteration Number"] == iteration &];
  (*Sort data by population size to create a line plot*)
  sortedData = SortBy[iterationData, #["Population Size"] &];
  (*Extract population sizes and fitness values*)
  spf2populationSizes = sortedData⟦All, "Population Size"⟧;
  spf2fitnessValues = sortedData⟦All, "Fitness"⟧;
  (*Create the line plot*)
  ListLinePlot[Transpose[{spf2populationSizes, spf2fitnessValues}],
   PlotRange → All, AxesLabel → {"Population Size", "Fitness"},
   PlotLabel → "Iteration: " <> ToString[iteration], ImageSize → Medium]]

(*Create frames for each unique iteration*)
spf2frames =
  Table[spf2createLinePlot[iteration], {iteration, spf2uniqueIterations}];

(*Create the animation*)
spf2itaanimation = ListAnimate[spf2frames, AnimationRate → 1]
```

Out[∘]=



In[]:=
```
(*Filter data for dimension 2*)
spf2dimension2Data = Select[spfdata, #["Dimension"] == 2 &];

(*Extract unique population sizes and iterations*)
spf2uniquePopulationSizes = Union[spf2dimension2Data[[All, "Population Size"]]];
spf2uniqueIterations = Union[spf2dimension2Data[[All, "Iteration Number"]]];

(*Function to create line plot for a specific population size*)
spf2createLinePlot[populationSize_] := Module[{populationData, sortedData},
  (*Filter data for the specific population size*)
  populationData =
   Select[spf2dimension2Data, #["Population Size"] == populationSize &];
  (*Sort data by iteration number to create a line plot*)
  sortedData = SortBy[populationData, #["Iteration Number"] &];
  (*Extract iteration numbers and fitness values*)
  spf2iterations = sortedData[[All, "Iteration Number"]];
  spf2fitnessValues = sortedData[[All, "Fitness"]];
  (*Create the line plot*)
  ListLinePlot[Transpose[{spf2iterations, spf2fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration Number", "Fitness"},
   PlotLabel → "Population Size: " <> ToString[populationSize], ImageSize → Medium]]

(*Create frames for each unique population size*)
spf2frames = Table[spf2createLinePlot[populationSize],
   {populationSize, spf2uniquePopulationSizes}];

(*Create the animation*)
spf2psanimation = ListAnimate[spf2frames, AnimationRate → 1]
```

Out[]=



In[]:=
```
Export["spf2itaanimationgif.gif", spf2itaanimation]
Export["spf2itaanimationmp4.mp4", spf2itaanimation]
```

Out[]=
```
spf2itaanimationgif.gif
```

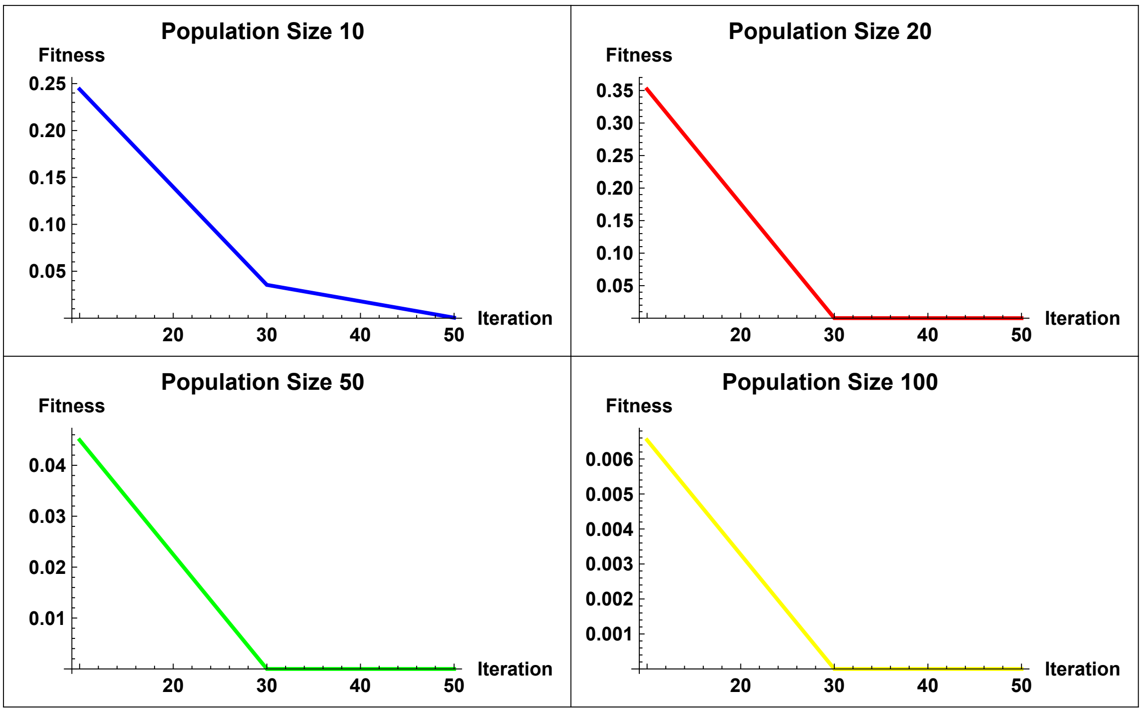
Out[]=
```
spf2itaanimationmp4.mp4
```

```
In[∘]:= Export["spf2psanimationgif.gif", spf2psanimation]
        Export["spf2psanimationmp4.mp4", spf2psanimation]
Out[∘]=
        spf2psanimationgif.gif
Out[∘]=
        spf2psanimationmp4.mp4
```

Dimension 05

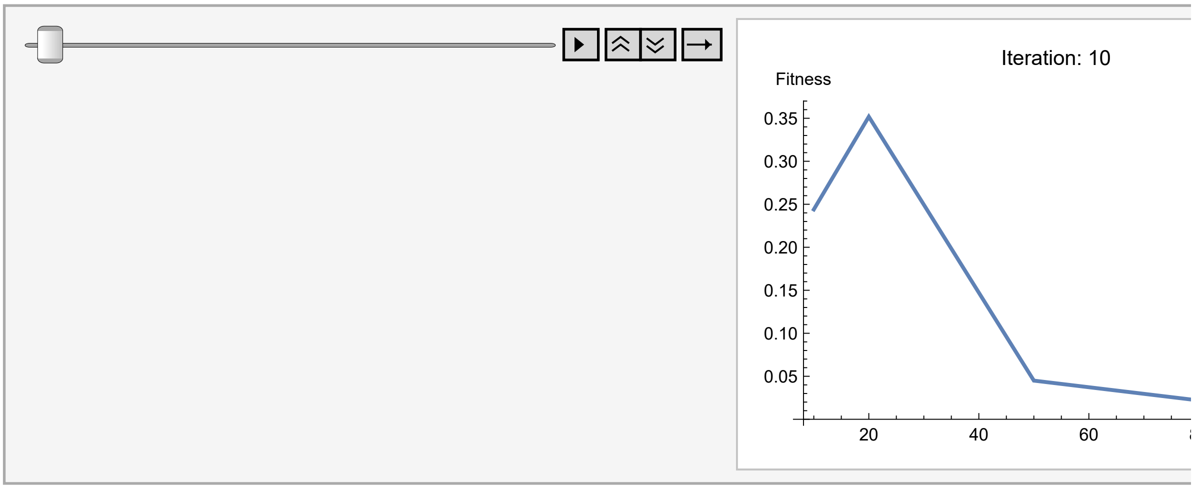
```
In[∘]:= (*Filter data for dimension 5 and population size 10*)
        spf510filteredData =
          Select[spfdata, #["Dimension"] == 5 && #["Population Size"] == 10 &];
        spf520filteredData =
          Select[spfdata, #["Dimension"] == 5 && #["Population Size"] == 20 &];
        spf550filteredData =
          Select[spfdata, #["Dimension"] == 5 && #["Population Size"] == 50 &];
        spf5100filteredData =
          Select[spfdata, #["Dimension"] == 5 && #["Population Size"] == 100 &];
        (*Extract iteration numbers and fitness values*)
        spf510iterationNumbers = spf510filteredData⟦All, "Iteration Number"⟧;
        spf510fitnessValues = spf510filteredData⟦All, "Fitness"⟧;
        spf520iterationNumbers = spf520filteredData⟦All, "Iteration Number"⟧;
        spf520fitnessValues = spf520filteredData⟦All, "Fitness"⟧;
        spf550iterationNumbers = spf550filteredData⟦All, "Iteration Number"⟧;
        spf550fitnessValues = spf550filteredData⟦All, "Fitness"⟧;
        spf5100iterationNumbers = spf5100filteredData⟦All, "Iteration Number"⟧;
        spf5100fitnessValues = spf5100filteredData⟦All, "Fitness"⟧;
        (*Create the line plot*)
        spf510Plot = ListLinePlot[Transpose[{spf510iterationNumbers, spf510fitnessValues}],
           PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Blue, Thick},
           PlotLabel → "Population Size 10", LabelStyle → {Bold, 10}];
        spf520Plot = ListLinePlot[Transpose[{spf520iterationNumbers, spf520fitnessValues}],
           PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Red, Thick},
           PlotLabel → "Population Size 20", LabelStyle → {Bold, 10}];
        spf550Plot = ListLinePlot[Transpose[{spf550iterationNumbers, spf550fitnessValues}],
           PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Green, Thick},
           PlotLabel → "Population Size 50", LabelStyle → {Bold, 10}];
        spf5100Plot = ListLinePlot[Transpose[{spf5100iterationNumbers, spf5100fitnessValues}],
           PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Yellow, Thick},
           PlotLabel → "Population Size 100", LabelStyle → {Bold, 10}];

        GraphicsGrid[{{Graphics[spf510Plot], Graphics[spf520Plot]},
         {Graphics[spf550Plot], Graphics[spf5100Plot]}}, Frame → All]
```

Out[∘]=


Population Size 10
Fitness
0.25
0.20
0.15
0.10
0.05
Iteration
20
30
40
50
Population Size 20
Fitness
0.35
0.30
0.25
0.20
0.15
0.10
0.05
Iteration
20
30
40
50
Population Size 50
Fitness
0.04
0.03
0.02
0.01
Iteration
20
30
40
50
Population Size 100
Fitness
0.006
0.005
0.004
0.003
0.002
0.001
Iteration
20
30
40
50

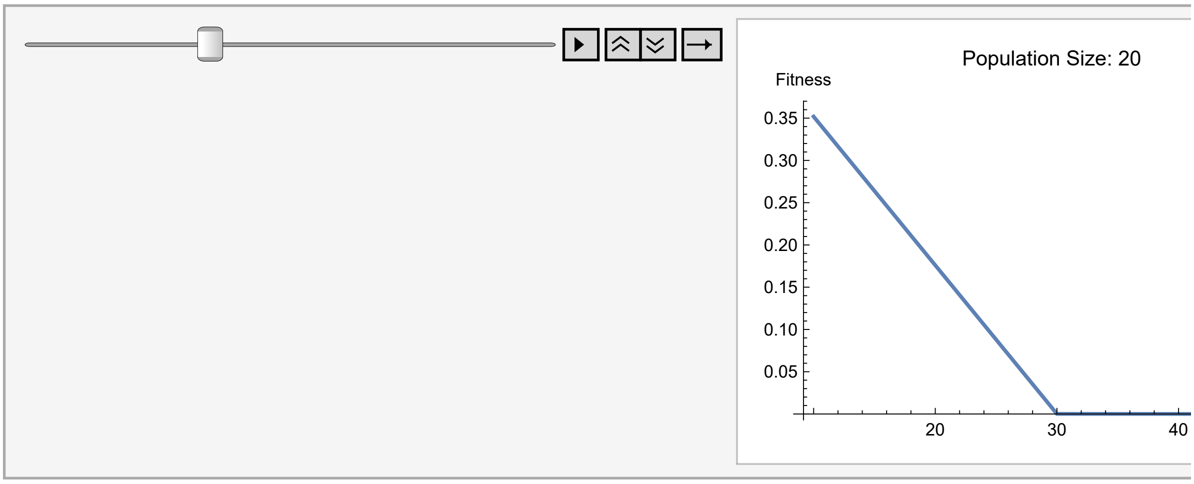
In[∘]:=
```
(*Filter data for dimension 2*)
spf5dimension5Data = Select[spfdata, #["Dimension"] == 5 &];

(*Extract unique population sizes and iterations*)
spf5uniquePopulationSizes = Union[spf5dimension5Data[[All, "Population Size"]]];
spf5uniqueIterations = Union[spf5dimension5Data[[All, "Iteration Number"]]];

(*Function to create line plot for a specific iteration*)
spf5createLinePlot[iteration_] := Module[{iterationData, sortedData},
  (*Filter data for the specific iteration*)
  iterationData = Select[spf5dimension5Data, #["Iteration Number"] == iteration &];
  (*Sort data by population size to create a line plot*)
  sortedData = SortBy[iterationData, #["Population Size"] &];
  (*Extract population sizes and fitness values*)
  spf5populationSizes = sortedData[[All, "Population Size"]];
  spf5fitnessValues = sortedData[[All, "Fitness"]];
  (*Create the line plot*)
  ListLinePlot[Transpose[{spf5populationSizes, spf5fitnessValues}],
   PlotRange → All, AxesLabel → {"Population Size", "Fitness"},
   PlotLabel → "Iteration: " <> ToString[iteration], ImageSize → Medium]]

(*Create frames for each unique iteration*)
spf5frames =
  Table[spf5createLinePlot[iteration], {iteration, spf5uniqueIterations}];

(*Create the animation*)
spf5itaanimation = ListAnimate[spf5frames, AnimationRate → 1]
```

Out[∘]=



In[∘]:=
```
(*Filter data for dimension 2*)
spf5dimension5Data = Select[spfdata, #["Dimension"] == 5 &];

(*Extract unique population sizes and iterations*)
spf5uniquePopulationSizes = Union[spf5dimension5Data⟦All, "Population Size"⟧];
spf5uniqueIterations = Union[spf5dimension5Data⟦All, "Iteration Number"⟧];

(*Function to create line plot for a specific population size*)
spf5createLinePlot[populationSize_] := Module[{populationData, sortedData},
  (*Filter data for the specific population size*)
  populationData =
   Select[spf5dimension5Data, #["Population Size"] == populationSize &];
  (*Sort data by iteration number to create a line plot*)
  sortedData = SortBy[populationData, #["Iteration Number"] &];
  (*Extract iteration numbers and fitness values*)
  spf5iterations = sortedData⟦All, "Iteration Number"⟧;
  spf5fitnessValues = sortedData⟦All, "Fitness"⟧;
  (*Create the line plot*)
  ListLinePlot[Transpose[{spf5iterations, spf5fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration Number", "Fitness"},
   PlotLabel → "Population Size: " <> ToString[populationSize], ImageSize → Medium]]

(*Create frames for each unique population size*)
spf5frames = Table[spf5createLinePlot[populationSize],
   {populationSize, spf5uniquePopulationSizes}];

(*Create the animation*)
spf5psanimation = ListAnimate[spf5frames, AnimationRate → 1]
```

Out[∘]=



In[∘]:=
```
Export["spf5itaanimationgif.gif", spf5itaanimation]
Export["spf5itaanimationmp4.mp4", spf5itaanimation]
```

Out[∘]=
```
spf5itaanimationgif.gif
```

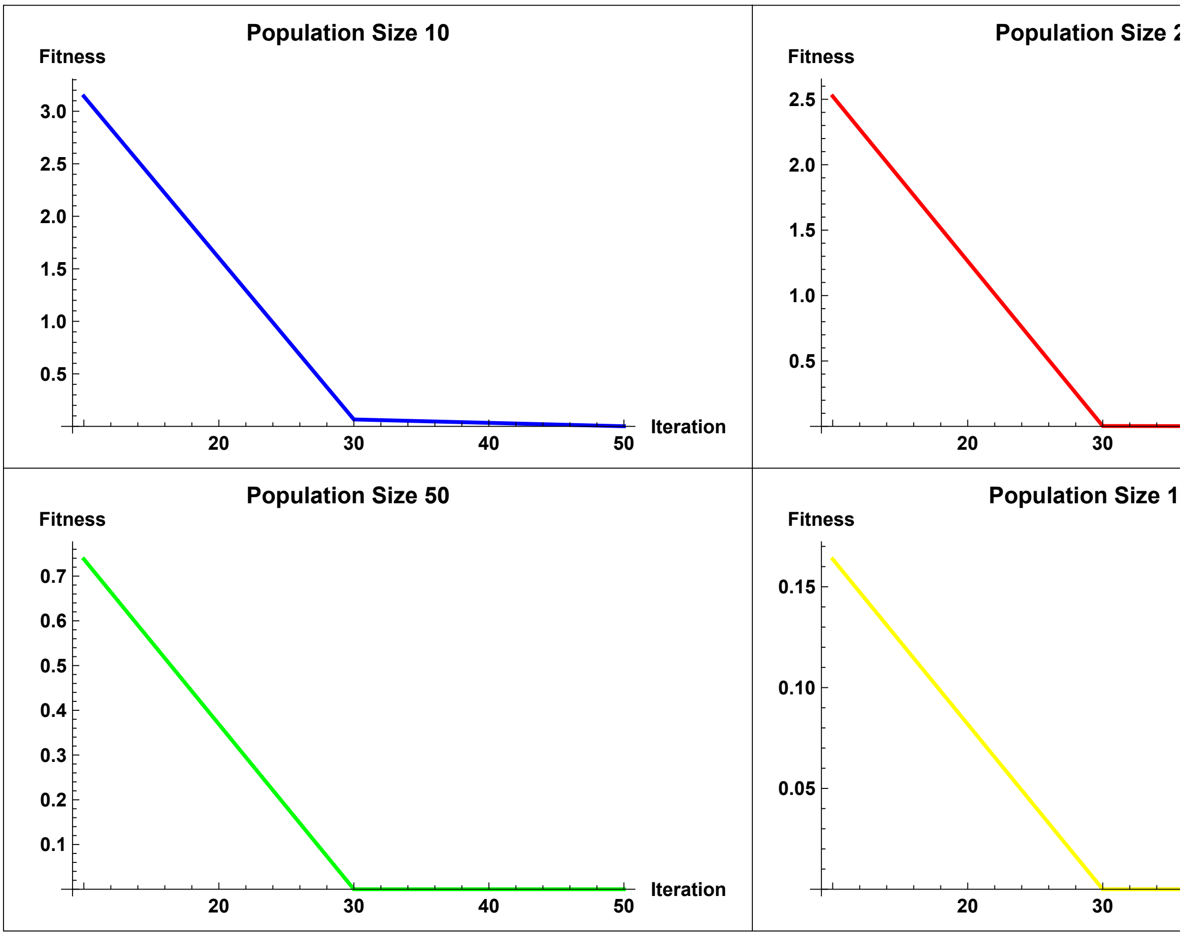
Out[∘]=
```
spf5itaanimationmp4.mp4
```

```
In[]:= Export["spf5psanimationgif.gif", spf5psanimation]
       Export["spf5psanimationmp4.mp4", spf5psanimation]

Out[]=
       spf5psanimationgif.gif

Out[]=
       spf5psanimationmp4.mp4
```

Dimension 10

```
In[]:= (*Filter data for dimension 10 and population size 10*)
       spf1010filteredData =
         Select[spfdata, #["Dimension"] == 10 && #["Population Size"] == 10 &];
       spf1020filteredData =
         Select[spfdata, #["Dimension"] == 10 && #["Population Size"] == 20 &];
       spf1050filteredData =
         Select[spfdata, #["Dimension"] == 10 && #["Population Size"] == 50 &];
       spf10100filteredData =
         Select[spfdata, #["Dimension"] == 10 && #["Population Size"] == 100 &];
       (*Extract iteration numbers and fitness values*)
       spf1010iterationNumbers = spf1010filteredData⟦All, "Iteration Number"⟧;
       spf1010fitnessValues = spf1010filteredData⟦All, "Fitness"⟧;
       spf1020iterationNumbers = spf1020filteredData⟦All, "Iteration Number"⟧;
       spf1020fitnessValues = spf1020filteredData⟦All, "Fitness"⟧;
       spf1050iterationNumbers = spf1050filteredData⟦All, "Iteration Number"⟧;
       spf1050fitnessValues = spf1050filteredData⟦All, "Fitness"⟧;
       spf10100iterationNumbers = spf10100filteredData⟦All, "Iteration Number"⟧;
       spf10100fitnessValues = spf10100filteredData⟦All, "Fitness"⟧;
       (*Create the line plot*)
       spf1010Plot =
         ListLinePlot[Transpose[{spf1010iterationNumbers, spf1010fitnessValues}],
          PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Blue, Thick},
          PlotLabel → "Population Size 10", LabelStyle → {Bold, 10}];
       spf1020Plot = ListLinePlot[Transpose[{spf1020iterationNumbers, spf1020fitnessValues}],
          PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Red, Thick},
          PlotLabel → "Population Size 20", LabelStyle → {Bold, 10}];
       spf1050Plot = ListLinePlot[Transpose[{spf1050iterationNumbers, spf1050fitnessValues}],
          PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Green, Thick},
          PlotLabel → "Population Size 50", LabelStyle → {Bold, 10}];
       spf10100Plot =
         ListLinePlot[Transpose[{spf10100iterationNumbers, spf10100fitnessValues}],
          PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Yellow, Thick},
          PlotLabel → "Population Size 100", LabelStyle → {Bold, 10}];

       GraphicsGrid[{{Graphics[spf1010Plot], Graphics[spf1020Plot]},
        {Graphics[spf1050Plot], Graphics[spf10100Plot]}}, Frame → All]
```

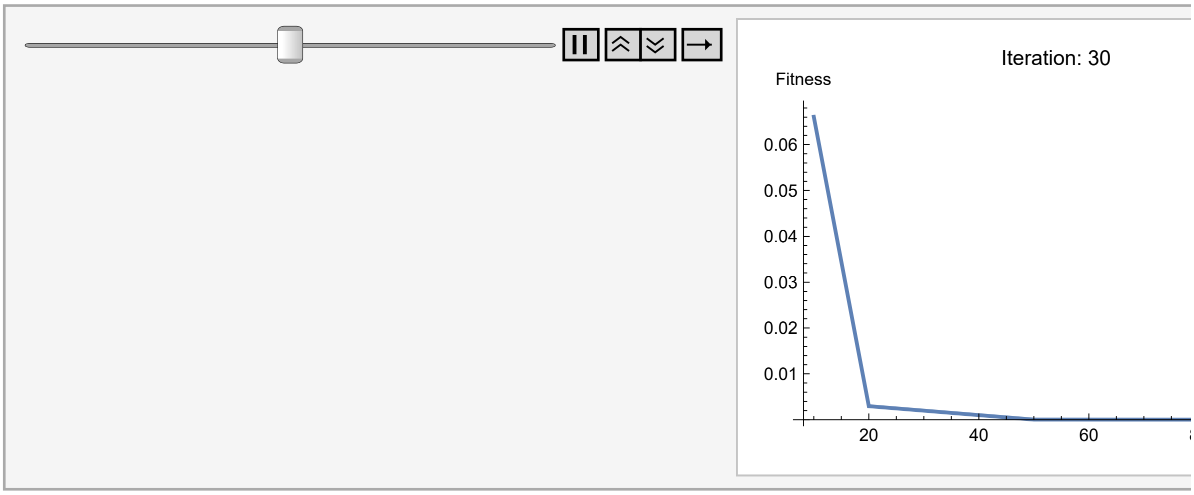
Out[∘]=


Population Size 10
Fitness
3.0
2.5
2.0
1.5
1.0
0.5
20
30
40
50
Iteration
Population Size 2
Fitness
2.5
2.0
1.5
1.0
0.5
20
30
Population Size 50
Fitness
0.7
0.6
0.5
0.4
0.3
0.2
0.1
20
30
40
50
Iteration
Population Size 1
Fitness
0.15
0.10
0.05
20
30

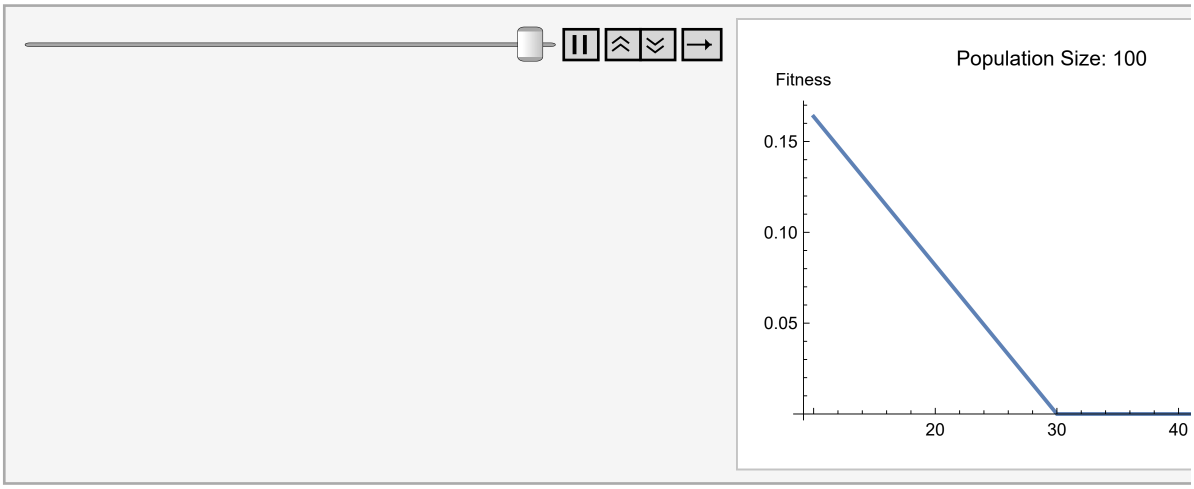
In[•]:=

```
(*Filter data for dimension 10*)
spf10dimension10Data = Select[spfdata, #["Dimension"] == 10 &];

(*Extract unique population sizes and iterations*)
spf10uniquePopulationSizes = Union[spf10dimension10Data[[All, "Population Size"]]];
spf10uniqueIterations = Union[spf10dimension10Data[[All, "Iteration Number"]]];

(*Function to create line plot for a specific iteration*)
spf10createLinePlot[iteration_] := Module[{iterationData, sortedData},
  (*Filter data for the specific iteration*)
  iterationData = Select[spf10dimension10Data, #["Iteration Number"] == iteration &];
  (*Sort data by population size to create a line plot*)
  sortedData = SortBy[iterationData, #["Population Size"] &];
  (*Extract population sizes and fitness values*)
  spf10populationSizes = sortedData[[All, "Population Size"]];
  spf10fitnessValues = sortedData[[All, "Fitness"]];
  (*Create the line plot*)
  ListLinePlot[Transpose[{spf10populationSizes, spf10fitnessValues}],
   PlotRange → All, AxesLabel → {"Population Size", "Fitness"},
   PlotLabel → "Iteration: " <> ToString[iteration], ImageSize → Medium]]

(*Create frames for each unique iteration*)
spf10frames =
  Table[spf10createLinePlot[iteration], {iteration, spf10uniqueIterations}];

(*Create the animation*)
spf10itaanimation = ListAnimate[spf10frames, AnimationRate → 1]
```

Out[•]=



```
In[•]:= (*Filter data for dimension 10*)
        spf10dimension10Data = Select[spfdata, #["Dimension"] == 10 &];

        (*Extract unique population sizes and iterations*)
        spf10uniquePopulationSizes = Union[spf10dimension10Data[[All, "Population Size"]]];
        spf10uniqueIterations = Union[spf10dimension10Data[[All, "Iteration Number"]]];

        (*Function to create line plot for a specific population size*)
        spf10createLinePlot[populationSize_] := Module[{populationData, sortedData},
          (*Filter data for the specific population size*)
          populationData =
           Select[spf10dimension10Data, #["Population Size"] == populationSize &];
          (*Sort data by iteration number to create a line plot*)
          sortedData = SortBy[populationData, #["Iteration Number"] &];
          (*Extract iteration numbers and fitness values*)
          spf10iterations = sortedData[[All, "Iteration Number"]];
          spf10fitnessValues = sortedData[[All, "Fitness"]];
          (*Create the line plot*)
          ListLinePlot[Transpose[{spf10iterations, spf10fitnessValues}],
           PlotRange → All, AxesLabel → {"Iteration Number", "Fitness"},
           PlotLabel → "Population Size: " <> ToString[populationSize], ImageSize → Medium]]

        (*Create frames for each unique population size*)
        spf10frames = Table[spf10createLinePlot[populationSize],
           {populationSize, spf10uniquePopulationSizes}];

        (*Create the animation*)
        spf10psanimation = ListAnimate[spf10frames, AnimationRate → 1]
Out[•]=
```



```
In[•]:= Export["spf10itaanimationgif.gif", spf10itaanimation]
        Export["spf10itaanimationmp4.mp4", spf10itaanimation]
Out[•]=
        spf10itaanimationgif.gif
Out[•]=
        spf10itaanimationmp4.mp4
```

```
In[•]:= Export["spf10psanimationgif.gif", spf10psanimation]
        Export["spf10psanimationmp4.mp4", spf10psanimation]
Out[•]=
        spf10psanimationgif.gif
Out[•]=
        spf10psanimationmp4.mp4
```

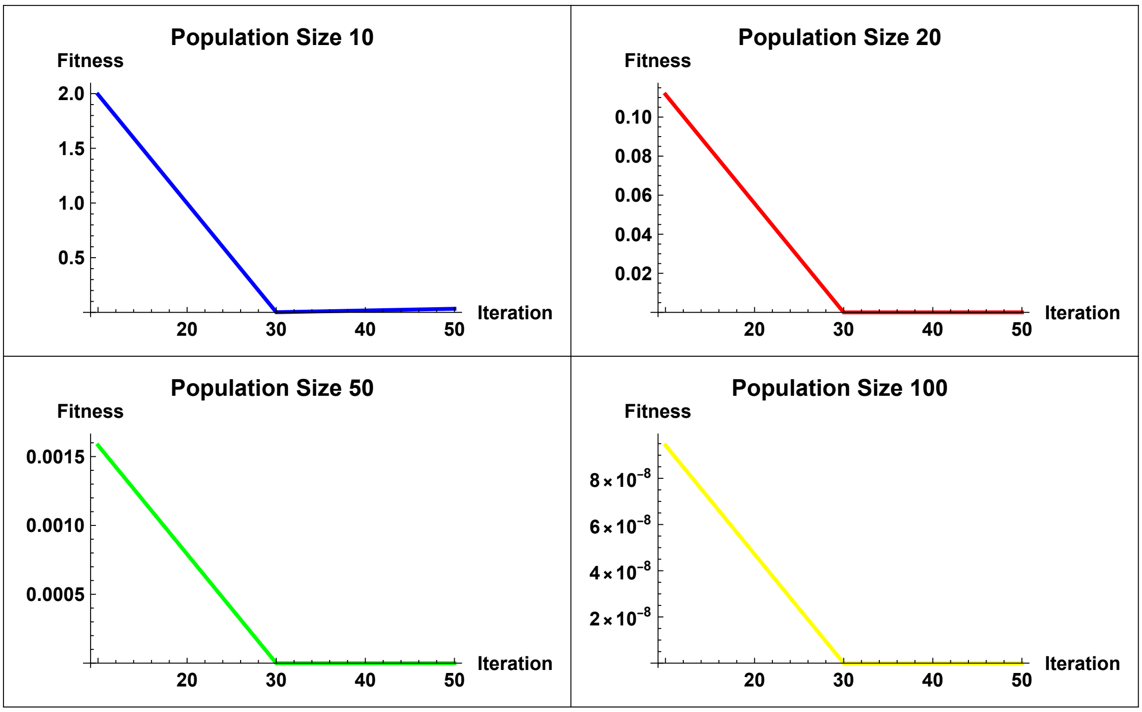
Visualization for Rastrigin function

```
In[•]:= rafdata = Normal[rafDF];
```

Dimension 02

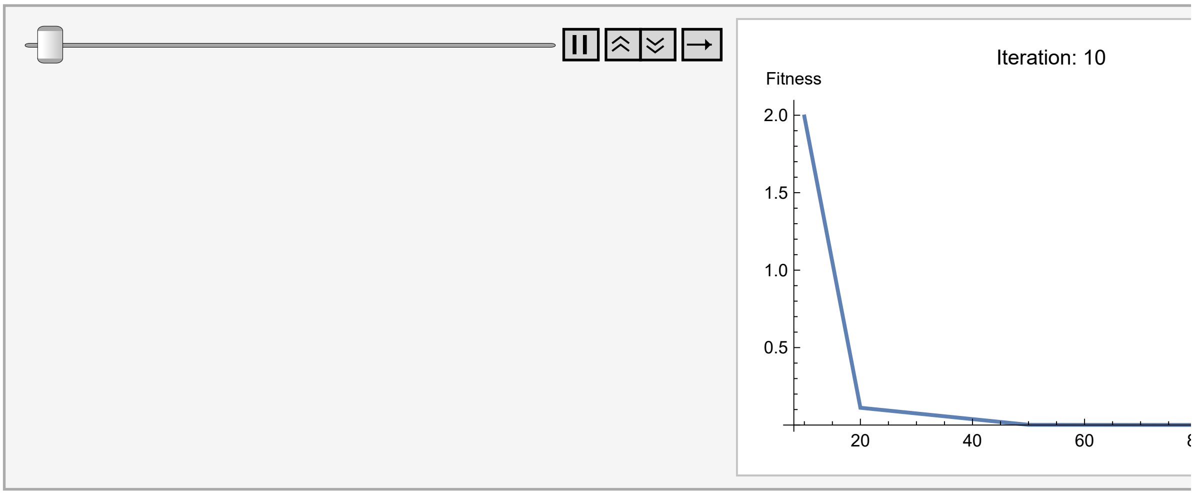
```
In[•]:= (*Filter data for dimension 2 and population size 10*)
        raf210filteredData =
          Select[rafdata, #["Dimension"] == 2 && #["Population Size"] == 10 &];
        raf220filteredData =
          Select[rafdata, #["Dimension"] == 2 && #["Population Size"] == 20 &];
        raf250filteredData =
          Select[rafdata, #["Dimension"] == 2 && #["Population Size"] == 50 &];
        raf2100filteredData =
          Select[rafdata, #["Dimension"] == 2 && #["Population Size"] == 100 &];
        (*Extract iteration numbers and fitness values*)
        raf210iterationNumbers = raf210filteredData⟦All, "Iteration Number"⟧;
        raf210fitnessValues = raf210filteredData⟦All, "Fitness"⟧;
        raf220iterationNumbers = raf220filteredData⟦All, "Iteration Number"⟧;
        raf220fitnessValues = raf220filteredData⟦All, "Fitness"⟧;
        raf250iterationNumbers = raf250filteredData⟦All, "Iteration Number"⟧;
        raf250fitnessValues = raf250filteredData⟦All, "Fitness"⟧;
        raf2100iterationNumbers = raf2100filteredData⟦All, "Iteration Number"⟧;
        raf2100fitnessValues = raf2100filteredData⟦All, "Fitness"⟧;
        (*Create the line plot*)
        raf210Plot = ListLinePlot[Transpose[{raf210iterationNumbers, raf210fitnessValues}],
           PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Blue, Thick},
           PlotLabel → "Population Size 10", LabelStyle → {Bold, 10}];
        raf220Plot = ListLinePlot[Transpose[{raf220iterationNumbers, raf220fitnessValues}],
           PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Red, Thick},
           PlotLabel → "Population Size 20", LabelStyle → {Bold, 10}];
        raf250Plot = ListLinePlot[Transpose[{raf250iterationNumbers, raf250fitnessValues}],
           PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Green, Thick},
           PlotLabel → "Population Size 50", LabelStyle → {Bold, 10}];
        raf2100Plot = ListLinePlot[Transpose[{raf2100iterationNumbers, raf2100fitnessValues}],
           PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Yellow, Thick},
           PlotLabel → "Population Size 100", LabelStyle → {Bold, 10}];

        GraphicsGrid[{{Graphics[raf210Plot], Graphics[raf220Plot]},
         {Graphics[raf250Plot], Graphics[raf2100Plot]}}, Frame → All]
```

Out[ ]=


Population Size 10
Fitness
2.0
1.5
1.0
0.5
Iteration
20
30
40
50
Population Size 20
Fitness
0.10
0.08
0.06
0.04
0.02
Iteration
20
30
40
50
Population Size 50
Fitness
0.0015
0.0010
0.0005
Iteration
20
30
40
50
Population Size 100
Fitness
8×10^-8
6×10^-8
4×10^-8
2×10^-8
Iteration
20
30
40
50

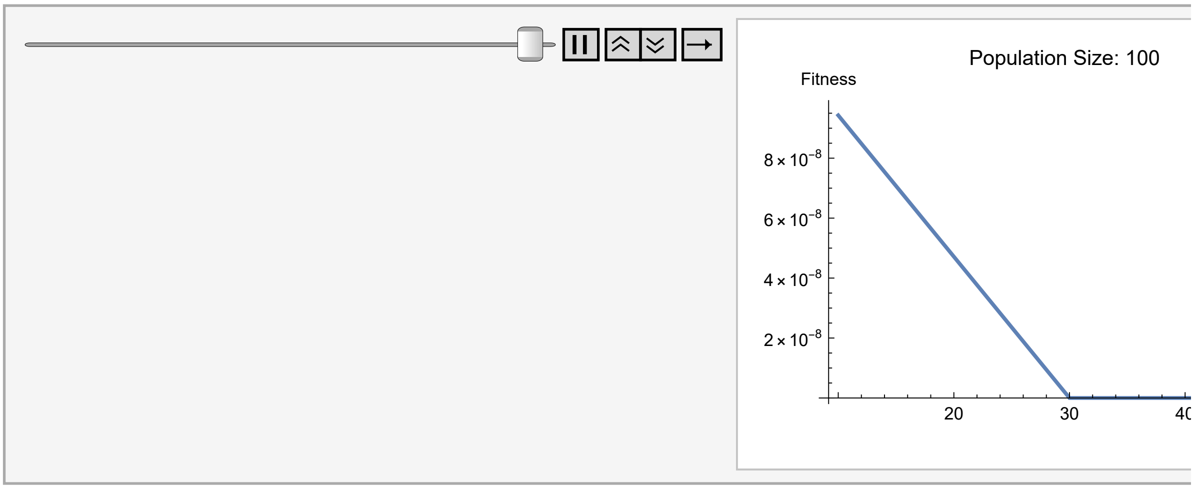
In[∘]:=
```
(*Filter data for dimension 2*)
raf2dimension2Data = Select[rafdata, #["Dimension"] == 2 &];

(*Extract unique population sizes and iterations*)
raf2uniquePopulationSizes = Union[raf2dimension2Data⟦All, "Population Size"⟧];
raf2uniqueIterations = Union[raf2dimension2Data⟦All, "Iteration Number"⟧];

(*Function to create line plot for a specific iteration*)
raf2createLinePlot[iteration_] := Module[{iterationData, sortedData},
  (*Filter data for the specific iteration*)
  iterationData = Select[raf2dimension2Data, #["Iteration Number"] == iteration &];
  (*Sort data by population size to create a line plot*)
  sortedData = SortBy[iterationData, #["Population Size"] &];
  (*Extract population sizes and fitness values*)
  raf2populationSizes = sortedData⟦All, "Population Size"⟧;
  raf2fitnessValues = sortedData⟦All, "Fitness"⟧;
  (*Create the line plot*)
  ListLinePlot[Transpose[{raf2populationSizes, raf2fitnessValues}],
   PlotRange → All, AxesLabel → {"Population Size", "Fitness"},
   PlotLabel → "Iteration: " <> ToString[iteration], ImageSize → Medium]]

(*Create frames for each unique iteration*)
raf2frames =
  Table[raf2createLinePlot[iteration], {iteration, raf2uniqueIterations}];

(*Create the animation*)
raf2itaanimation = ListAnimate[raf2frames, AnimationRate → 1]
```

Out[∘]=



In[∘]:=
```
(*Filter data for dimension 2*)
raf2dimension2Data = Select[rafdata, #["Dimension"] == 2 &];

(*Extract unique population sizes and iterations*)
raf2uniquePopulationSizes = Union[raf2dimension2Data⟦All, "Population Size"⟧];
raf2uniqueIterations = Union[raf2dimension2Data⟦All, "Iteration Number"⟧];

(*Function to create line plot for a specific population size*)
raf2createLinePlot[populationSize_] := Module[{populationData, sortedData},
  (*Filter data for the specific population size*)
  populationData =
   Select[raf2dimension2Data, #["Population Size"] == populationSize &];
  (*Sort data by iteration number to create a line plot*)
  sortedData = SortBy[populationData, #["Iteration Number"] &];
  (*Extract iteration numbers and fitness values*)
  raf2iterations = sortedData⟦All, "Iteration Number"⟧;
  raf2fitnessValues = sortedData⟦All, "Fitness"⟧;
  (*Create the line plot*)
  ListLinePlot[Transpose[{raf2iterations, raf2fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration Number", "Fitness"},
   PlotLabel → "Population Size: " <> ToString[populationSize], ImageSize → Medium]]

(*Create frames for each unique population size*)
raf2frames = Table[raf2createLinePlot[populationSize],
   {populationSize, raf2uniquePopulationSizes}];

(*Create the animation*)
raf2psanimation = ListAnimate[raf2frames, AnimationRate → 1]
```

Out[∘]=



In[∘]:=
```
Export["raf2itaanimationgif.gif", raf2itaanimation]
Export["raf2itaanimationmp4.mp4", raf2itaanimation]
```

Out[∘]=
```
raf2itaanimationgif.gif
```

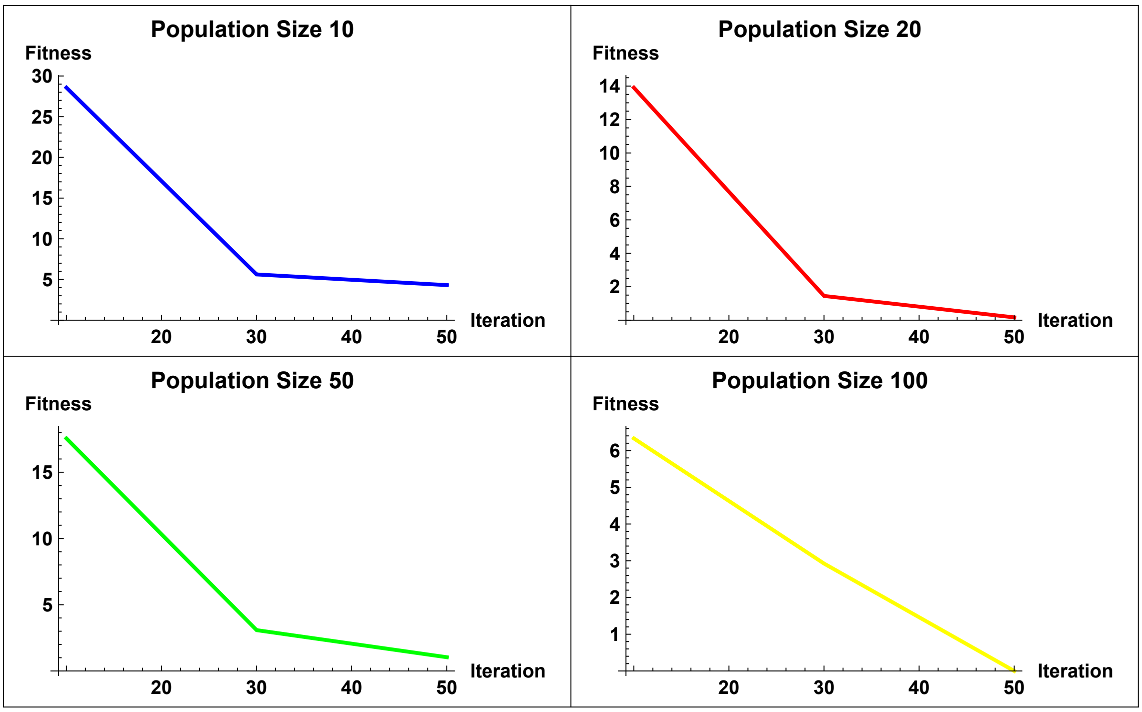
Out[∘]=
```
raf2itaanimationmp4.mp4
```

```
In[•]:= Export["raf2psanimationgif.gif", raf2psanimation]
        Export["raf2psanimationmp4.mp4", raf2psanimation]

Out[•]=
        raf2psanimationgif.gif

Out[•]=
        raf2psanimationmp4.mp4
```

Dimension 05

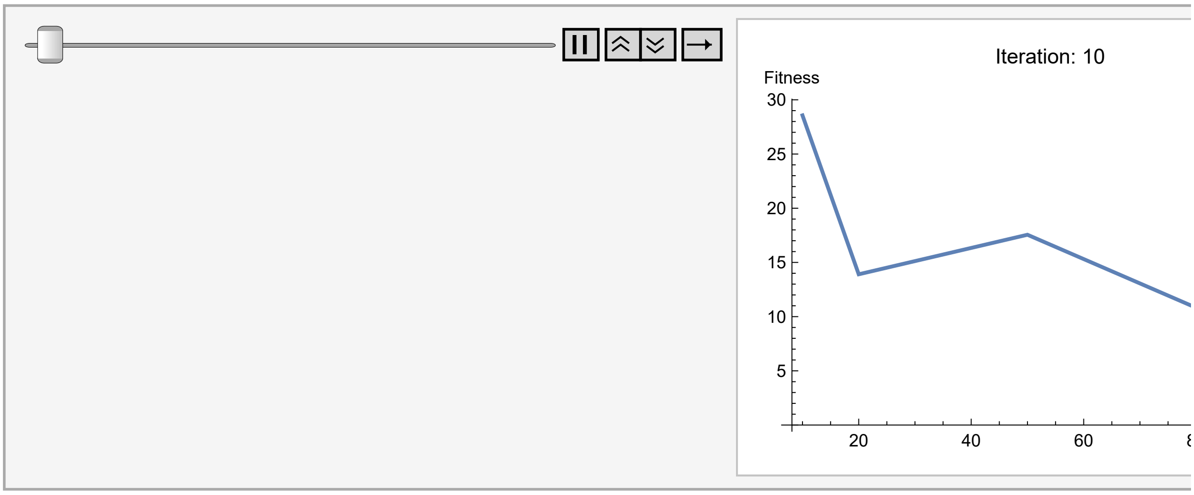
```
In[•]:= (*Filter data for dimension 5 and population size 10*)
        raf510filteredData =
          Select[rafdata, #["Dimension"] == 5 && #["Population Size"] == 10 &];
        raf520filteredData =
          Select[rafdata, #["Dimension"] == 5 && #["Population Size"] == 20 &];
        raf550filteredData =
          Select[rafdata, #["Dimension"] == 5 && #["Population Size"] == 50 &];
        raf5100filteredData =
          Select[rafdata, #["Dimension"] == 5 && #["Population Size"] == 100 &];
        (*Extract iteration numbers and fitness values*)
        raf510iterationNumbers = raf510filteredData[[All, "Iteration Number"]];
        raf510fitnessValues = raf510filteredData[[All, "Fitness"]];
        raf520iterationNumbers = raf520filteredData[[All, "Iteration Number"]];
        raf520fitnessValues = raf520filteredData[[All, "Fitness"]];
        raf550iterationNumbers = raf550filteredData[[All, "Iteration Number"]];
        raf550fitnessValues = raf550filteredData[[All, "Fitness"]];
        raf5100iterationNumbers = raf5100filteredData[[All, "Iteration Number"]];
        raf5100fitnessValues = raf5100filteredData[[All, "Fitness"]];
        (*Create the line plot*)
        raf510Plot = ListLinePlot[Transpose[{raf510iterationNumbers, raf510fitnessValues}],
            PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Blue, Thick},
            PlotLabel → "Population Size 10", LabelStyle → {Bold, 10}];
        raf520Plot = ListLinePlot[Transpose[{raf520iterationNumbers, raf520fitnessValues}],
            PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Red, Thick},
            PlotLabel → "Population Size 20", LabelStyle → {Bold, 10}];
        raf550Plot = ListLinePlot[Transpose[{raf550iterationNumbers, raf550fitnessValues}],
            PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Green, Thick},
            PlotLabel → "Population Size 50", LabelStyle → {Bold, 10}];
        raf5100Plot = ListLinePlot[Transpose[{raf5100iterationNumbers, raf5100fitnessValues}],
            PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Yellow, Thick},
            PlotLabel → "Population Size 100", LabelStyle → {Bold, 10}];

        GraphicsGrid[{{Graphics[raf510Plot], Graphics[raf520Plot]},
         {Graphics[raf550Plot], Graphics[raf5100Plot]}}, Frame → All]
```

Out[●]=


Population Size 10
Fitness
30
25
20
15
10
5
20
30
40
50
Iteration
Population Size 20
Fitness
14
12
10
8
6
4
2
20
30
40
50
Iteration
Population Size 50
Fitness
15
10
5
20
30
40
50
Iteration
Population Size 100
Fitness
6
5
4
3
2
1
20
30
40
50
Iteration

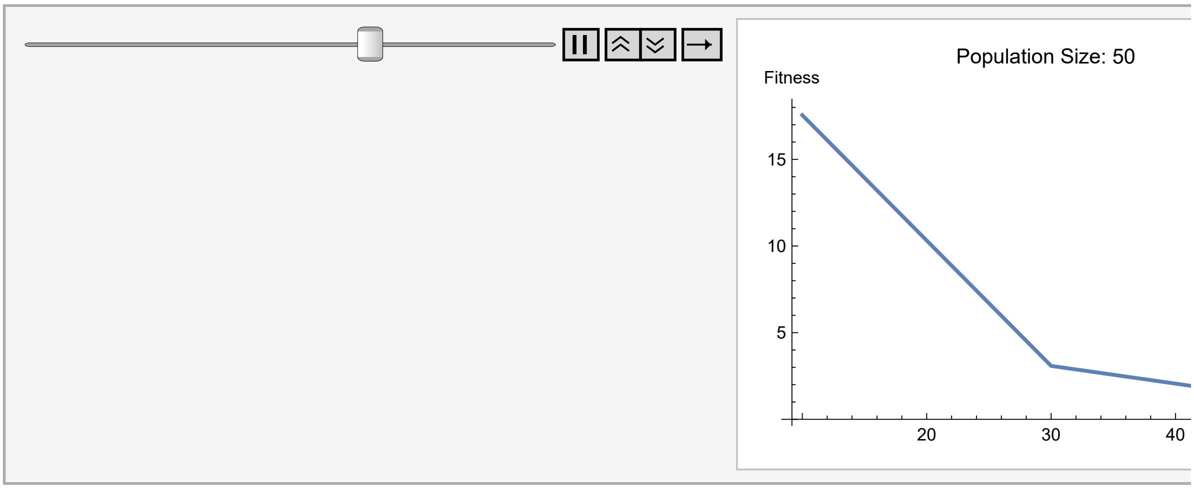
In[∘]:=
```
(*Filter data for dimension 2*)
raf5dimension5Data = Select[rafdata, #["Dimension"] == 5 &];

(*Extract unique population sizes and iterations*)
raf5uniquePopulationSizes = Union[raf5dimension5Data[[All, "Population Size"]]];
raf5uniqueIterations = Union[raf5dimension5Data[[All, "Iteration Number"]]];

(*Function to create line plot for a specific iteration*)
raf5createLinePlot[iteration_] := Module[{iterationData, sortedData},
  (*Filter data for the specific iteration*)
  iterationData = Select[raf5dimension5Data, #["Iteration Number"] == iteration &];
  (*Sort data by population size to create a line plot*)
  sortedData = SortBy[iterationData, #["Population Size"] &];
  (*Extract population sizes and fitness values*)
  raf5populationSizes = sortedData[[All, "Population Size"]];
  raf5fitnessValues = sortedData[[All, "Fitness"]];
  (*Create the line plot*)
  ListLinePlot[Transpose[{raf5populationSizes, raf5fitnessValues}],
   PlotRange → All, AxesLabel → {"Population Size", "Fitness"},
   PlotLabel → "Iteration: " <> ToString[iteration], ImageSize → Medium]]

(*Create frames for each unique iteration*)
raf5frames =
  Table[raf5createLinePlot[iteration], {iteration, raf5uniqueIterations}];

(*Create the animation*)
raf5itaanimation = ListAnimate[raf5frames, AnimationRate → 1]
```

Out[∘]=



In[•]:=
```
(*Filter data for dimension 2*)
raf5dimension5Data = Select[rafdata, #["Dimension"] == 5 &];

(*Extract unique population sizes and iterations*)
raf5uniquePopulationSizes = Union[raf5dimension5Data[[All, "Population Size"]]];
raf5uniqueIterations = Union[raf5dimension5Data[[All, "Iteration Number"]]];

(*Function to create line plot for a specific population size*)
raf5createLinePlot[populationSize_] := Module[{populationData, sortedData},
  (*Filter data for the specific population size*)
  populationData =
   Select[raf5dimension5Data, #["Population Size"] == populationSize &];
  (*Sort data by iteration number to create a line plot*)
  sortedData = SortBy[populationData, #["Iteration Number"] &];
  (*Extract iteration numbers and fitness values*)
  raf5iterations = sortedData[[All, "Iteration Number"]];
  raf5fitnessValues = sortedData[[All, "Fitness"]];
  (*Create the line plot*)
  ListLinePlot[Transpose[{raf5iterations, raf5fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration Number", "Fitness"},
   PlotLabel → "Population Size: " <> ToString[populationSize], ImageSize → Medium]]

(*Create frames for each unique population size*)
raf5frames = Table[raf5createLinePlot[populationSize],
   {populationSize, raf5uniquePopulationSizes}];

(*Create the animation*)
raf5psanimation = ListAnimate[raf5frames, AnimationRate → 1]
```

Out[•]=



In[•]:=
```
Export["raf5itaanimationgif.gif", raf5itaanimation]
Export["raf5itaanimationmp4.mp4", raf5itaanimation]
```

Out[•]=
```
raf5itaanimationgif.gif
```

Out[•]=
```
raf5itaanimationmp4.mp4
```

In[∘]:=

```
Export["raf5psanimationgif.gif", raf5psanimation]
Export["raf5psanimationmp4.mp4", raf5psanimation]
```

Out[∘]=

```
raf5psanimationgif.gif
```

Out[∘]=

```
raf5psanimationmp4.mp4
```

Visualization for Rosenbrock function

In[∘]:=

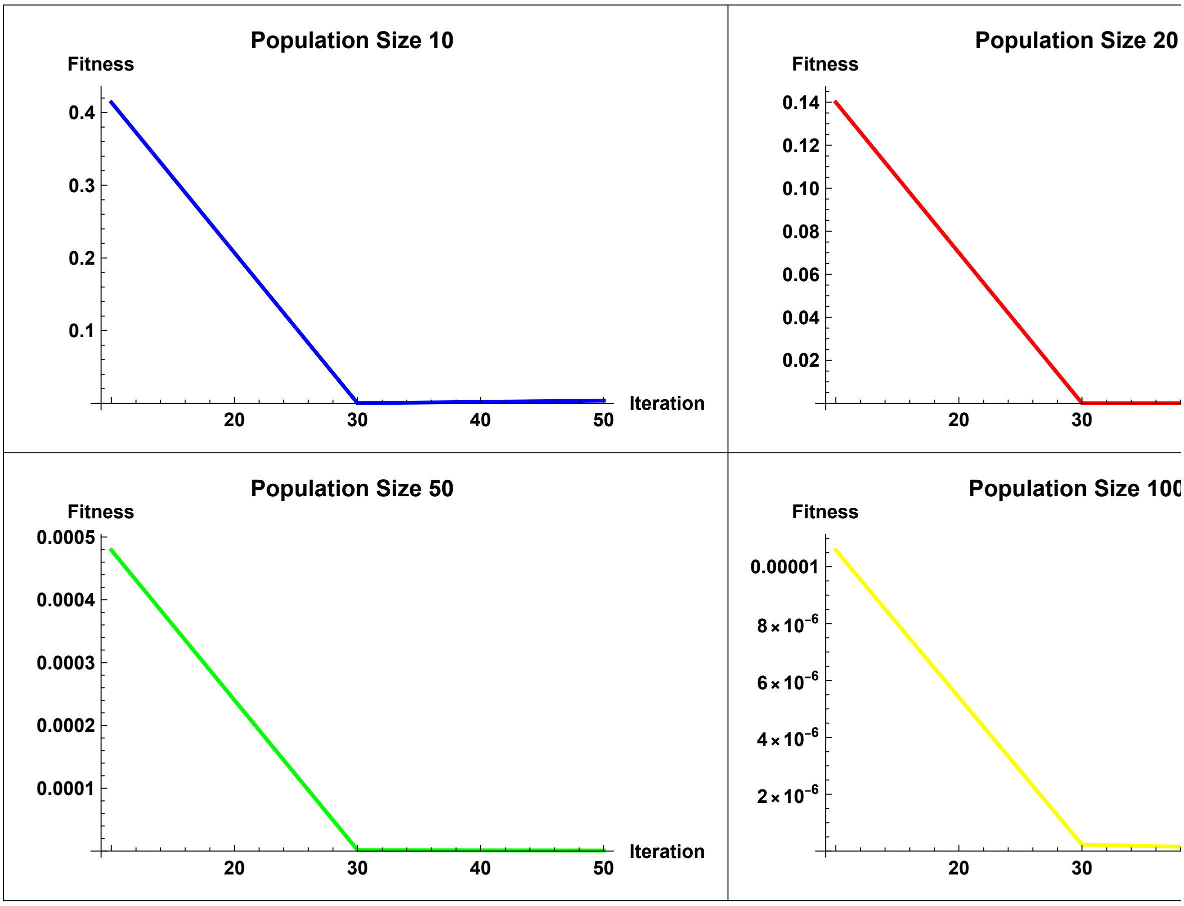
```
rbfdata = Normal[rbfDF];
```

Dimension 02

In[∘]:=

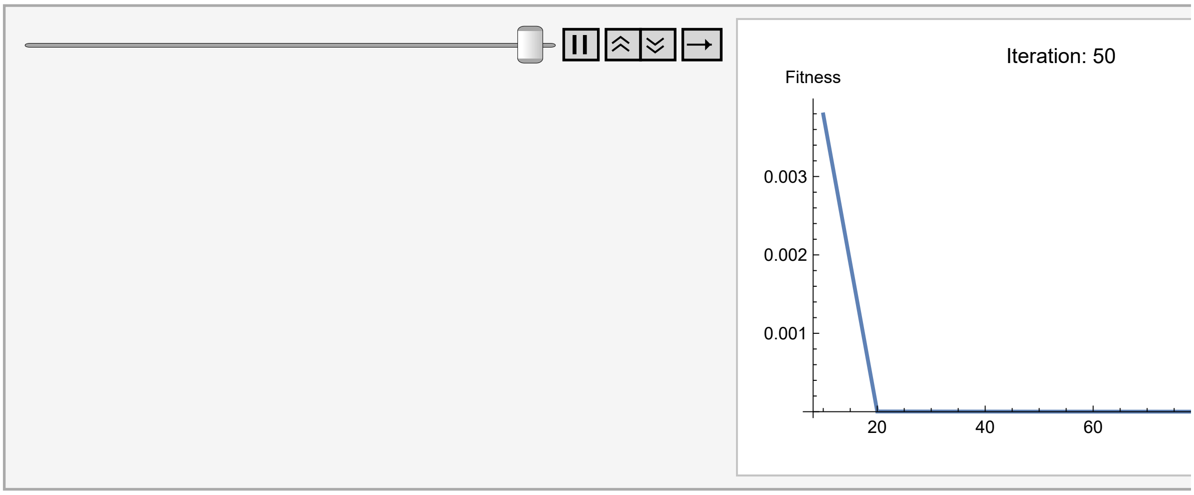
```
(*Filter data for dimension 2 and population size 10*)
rbf210filteredData =
  Select[rbfdata, #["Dimension"] == 2 && #["Population Size"] == 10 &];
rbf220filteredData =
  Select[rbfdata, #["Dimension"] == 2 && #["Population Size"] == 20 &];
rbf250filteredData =
  Select[rbfdata, #["Dimension"] == 2 && #["Population Size"] == 50 &];
rbf2100filteredData =
  Select[rbfdata, #["Dimension"] == 2 && #["Population Size"] == 100 &];
(*Extract iteration numbers and fitness values*)
rbf210iterationNumbers = rbf210filteredData⟦All, "Iteration Number"⟧;
rbf210fitnessValues = rbf210filteredData⟦All, "Fitness"⟧;
rbf220iterationNumbers = rbf220filteredData⟦All, "Iteration Number"⟧;
rbf220fitnessValues = rbf220filteredData⟦All, "Fitness"⟧;
rbf250iterationNumbers = rbf250filteredData⟦All, "Iteration Number"⟧;
rbf250fitnessValues = rbf250filteredData⟦All, "Fitness"⟧;
rbf2100iterationNumbers = rbf2100filteredData⟦All, "Iteration Number"⟧;
rbf2100fitnessValues = rbf2100filteredData⟦All, "Fitness"⟧;
(*Create the line plot*)
rbf210Plot = ListLinePlot[Transpose[{rbf210iterationNumbers, rbf210fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Blue, Thick},
   PlotLabel → "Population Size 10", LabelStyle → {Bold, 10}];
rbf220Plot = ListLinePlot[Transpose[{rbf220iterationNumbers, rbf220fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Red, Thick},
   PlotLabel → "Population Size 20", LabelStyle → {Bold, 10}];
rbf250Plot = ListLinePlot[Transpose[{rbf250iterationNumbers, rbf250fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Green, Thick},
   PlotLabel → "Population Size 50", LabelStyle → {Bold, 10}];
rbf2100Plot = ListLinePlot[Transpose[{rbf2100iterationNumbers, rbf2100fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Yellow, Thick},
   PlotLabel → "Population Size 100", LabelStyle → {Bold, 10}];

GraphicsGrid[{{Graphics[rbf210Plot], Graphics[rbf220Plot]},
 {Graphics[rbf250Plot], Graphics[rbf2100Plot]}}, Frame → All]
```

Out[∘]=


Population Size 10
Fitness
0.4
0.3
0.2
0.1
20
30
40
50
Iteration
Population Size 20
Fitness
0.14
0.12
0.10
0.08
0.06
0.04
0.02
20
30
Population Size 50
Fitness
0.0005
0.0004
0.0003
0.0002
0.0001
20
30
40
50
Iteration
Population Size 100
Fitness
0.00001
8 × 10^-6
6 × 10^-6
4 × 10^-6
2 × 10^-6
20
30

In[∘]:=
```
(*Filter data for dimension 2*)
rbf2dimension2Data = Select[rbfdata, #["Dimension"] == 2 &];

(*Extract unique population sizes and iterations*)
rbf2uniquePopulationSizes = Union[rbf2dimension2Data[[All, "Population Size"]]];
rbf2uniqueIterations = Union[rbf2dimension2Data[[All, "Iteration Number"]]];

(*Function to create line plot for a specific iteration*)
rbf2createLinePlot[iteration_] := Module[{iterationData, sortedData},
  (*Filter data for the specific iteration*)
  iterationData = Select[rbf2dimension2Data, #["Iteration Number"] == iteration &];
  (*Sort data by population size to create a line plot*)
  sortedData = SortBy[iterationData, #["Population Size"] &];
  (*Extract population sizes and fitness values*)
  rbf2populationSizes = sortedData[[All, "Population Size"]];
  rbf2fitnessValues = sortedData[[All, "Fitness"]];
  (*Create the line plot*)
  ListLinePlot[Transpose[{rbf2populationSizes, rbf2fitnessValues}],
   PlotRange → All, AxesLabel → {"Population Size", "Fitness"},
   PlotLabel → "Iteration: " <> ToString[iteration], ImageSize → Medium]]

(*Create frames for each unique iteration*)
rbf2frames =
  Table[rbf2createLinePlot[iteration], {iteration, rbf2uniqueIterations}];

(*Create the animation*)
rbf2itaanimation = ListAnimate[rbf2frames, AnimationRate → 1]
```

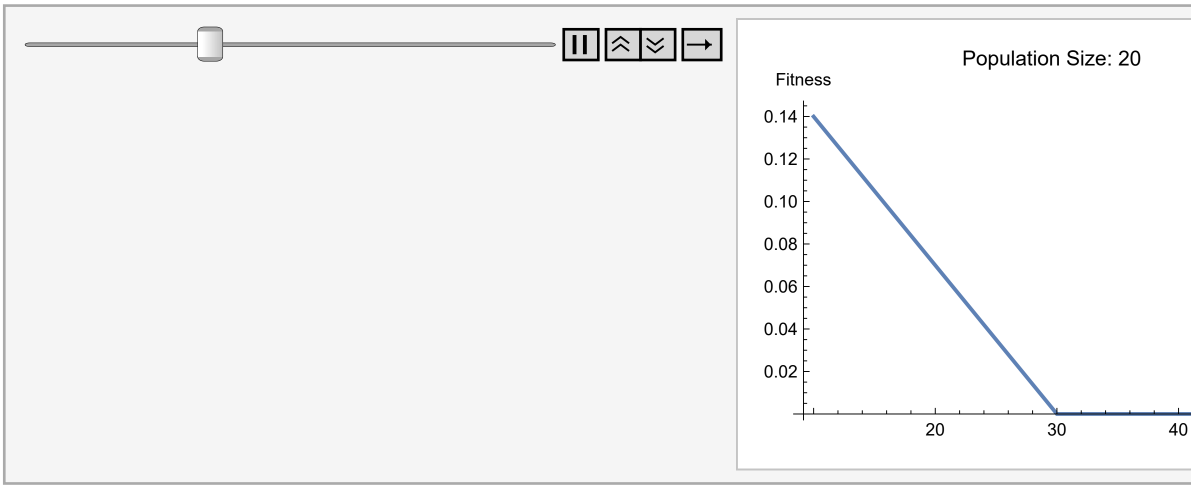
Out[∘]=



In[•]:=

```
(*Filter data for dimension 2*)
rbf2dimension2Data = Select[rbfdata, #["Dimension"] == 2 &];

(*Extract unique population sizes and iterations*)
rbf2uniquePopulationSizes = Union[rbf2dimension2Data⟦All, "Population Size"⟧];
rbf2uniqueIterations = Union[rbf2dimension2Data⟦All, "Iteration Number"⟧];

(*Function to create line plot for a specific population size*)
rbf2createLinePlot[populationSize_] := Module[{populationData, sortedData},
  (*Filter data for the specific population size*)
  populationData =
   Select[rbf2dimension2Data, #["Population Size"] == populationSize &];
  (*Sort data by iteration number to create a line plot*)
  sortedData = SortBy[populationData, #["Iteration Number"] &];
  (*Extract iteration numbers and fitness values*)
  rbf2iterations = sortedData⟦All, "Iteration Number"⟧;
  rbf2fitnessValues = sortedData⟦All, "Fitness"⟧;
  (*Create the line plot*)
  ListLinePlot[Transpose[{rbf2iterations, rbf2fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration Number", "Fitness"},
   PlotLabel → "Population Size: " <> ToString[populationSize], ImageSize → Medium]]

(*Create frames for each unique population size*)
rbf2frames = Table[rbf2createLinePlot[populationSize],
   {populationSize, rbf2uniquePopulationSizes}];

(*Create the animation*)
rbf2psanimation = ListAnimate[rbf2frames, AnimationRate → 1]
```

Out[•]=



In[•]:=

```
Export["rbf2itaanimationgif.gif", rbf2itaanimation]
Export["rbf2itaanimationmp4.mp4", rbf2itaanimation]
```

Out[•]=

```
rbf2itaanimationgif.gif
```

Out[•]=

```
rbf2itaanimationmp4.mp4
```

In[ ]:=

```
Export["rbf2psanimationgif.gif", rbf2psanimation]
Export["rbf2psanimationmp4.mp4", rbf2psanimation]
```

Out[ ]=

```
rbf2psanimationgif.gif
```

Out[ ]=

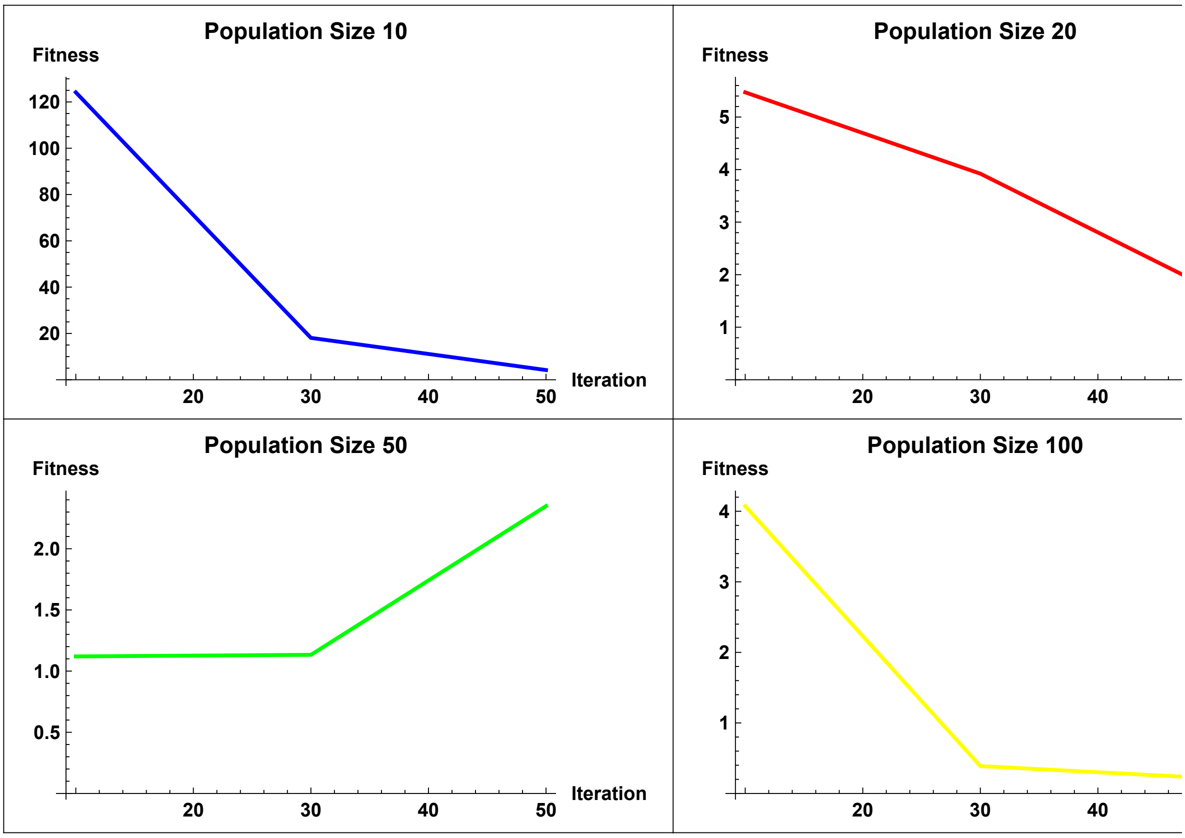
```
rbf2psanimationmp4.mp4
```

Dimension 05

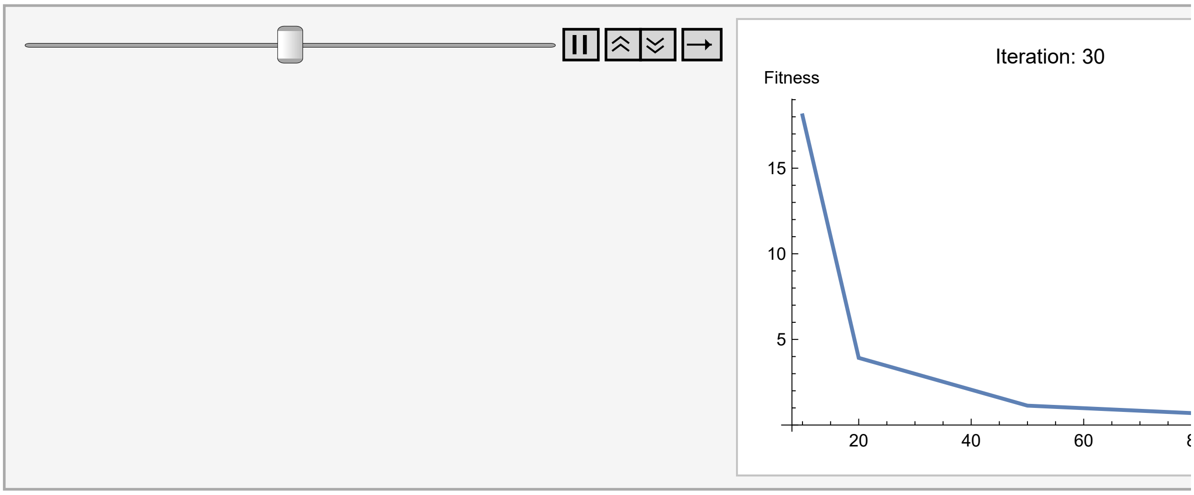
In[ ]:=

```
(*Filter data for dimension 5 and population size 10*)
rbf510filteredData =
  Select[rbfdata, #["Dimension"] == 5 && #["Population Size"] == 10 &];
rbf520filteredData =
  Select[rbfdata, #["Dimension"] == 5 && #["Population Size"] == 20 &];
rbf550filteredData =
  Select[rbfdata, #["Dimension"] == 5 && #["Population Size"] == 50 &];
rbf5100filteredData =
  Select[rbfdata, #["Dimension"] == 5 && #["Population Size"] == 100 &];
(*Extract iteration numbers and fitness values*)
rbf510iterationNumbers = rbf510filteredData⟦All, "Iteration Number"⟧;
rbf510fitnessValues = rbf510filteredData⟦All, "Fitness"⟧;
rbf520iterationNumbers = rbf520filteredData⟦All, "Iteration Number"⟧;
rbf520fitnessValues = rbf520filteredData⟦All, "Fitness"⟧;
rbf550iterationNumbers = rbf550filteredData⟦All, "Iteration Number"⟧;
rbf550fitnessValues = rbf550filteredData⟦All, "Fitness"⟧;
rbf5100iterationNumbers = rbf5100filteredData⟦All, "Iteration Number"⟧;
rbf5100fitnessValues = rbf5100filteredData⟦All, "Fitness"⟧;
(*Create the line plot*)
rbf510Plot = ListLinePlot[Transpose[{rbf510iterationNumbers, rbf510fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Blue, Thick},
   PlotLabel → "Population Size 10", LabelStyle → {Bold, 10}];
rbf520Plot = ListLinePlot[Transpose[{rbf520iterationNumbers, rbf520fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Red, Thick},
   PlotLabel → "Population Size 20", LabelStyle → {Bold, 10}];
rbf550Plot = ListLinePlot[Transpose[{rbf550iterationNumbers, rbf550fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Green, Thick},
   PlotLabel → "Population Size 50", LabelStyle → {Bold, 10}];
rbf5100Plot = ListLinePlot[Transpose[{rbf5100iterationNumbers, rbf5100fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration", "Fitness"}, PlotStyle → {Yellow, Thick},
   PlotLabel → "Population Size 100", LabelStyle → {Bold, 10}];

GraphicsGrid[{{Graphics[rbf510Plot], Graphics[rbf520Plot]},
 {Graphics[rbf550Plot], Graphics[rbf5100Plot]}}, Frame → All]
```

Out[●]=

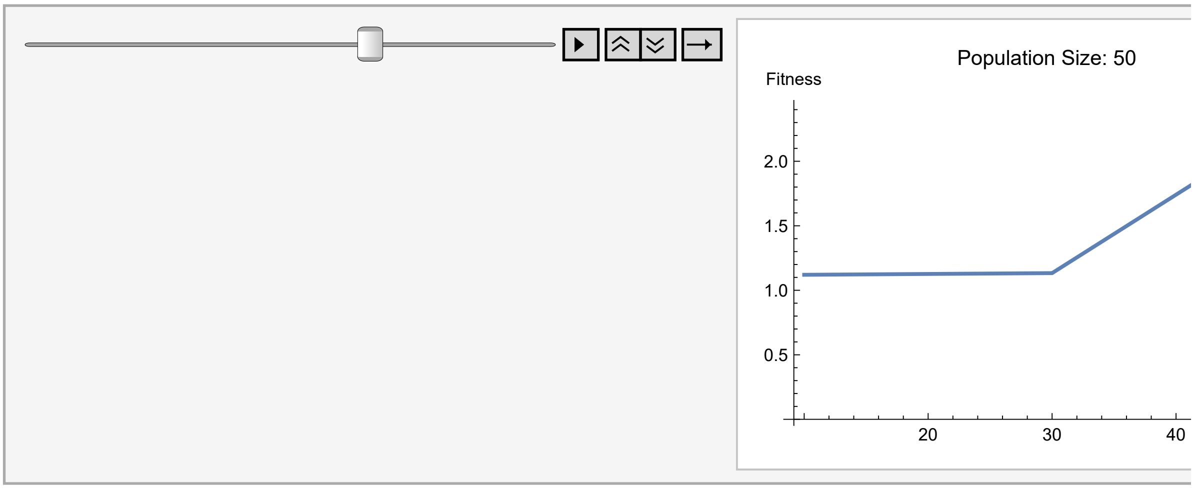

Population Size 10
Fitness
120
100
80
60
40
20
20
30
40
50
Iteration
Population Size 20
Fitness
5
4
3
2
1
20
30
40
Population Size 50
Fitness
2.0
1.5
1.0
0.5
20
30
40
50
Iteration
Population Size 100
Fitness
4
3
2
1
20
30
40

```
In[•]:= (*Filter data for dimension 2*)
        rbf5dimension5Data = Select[rbfdata, #["Dimension"] == 5 &];

        (*Extract unique population sizes and iterations*)
        rbf5uniquePopulationSizes = Union[rbf5dimension5Data[[All, "Population Size"]]];
        rbf5uniqueIterations = Union[rbf5dimension5Data[[All, "Iteration Number"]]];

        (*Function to create line plot for a specific iteration*)
        rbf5createLinePlot[iteration_] := Module[{iterationData, sortedData},
          (*Filter data for the specific iteration*)
          iterationData = Select[rbf5dimension5Data, #["Iteration Number"] == iteration &];
          (*Sort data by population size to create a line plot*)
          sortedData = SortBy[iterationData, #["Population Size"] &];
          (*Extract population sizes and fitness values*)
          rbf5populationSizes = sortedData[[All, "Population Size"]];
          rbf5fitnessValues = sortedData[[All, "Fitness"]];
          (*Create the line plot*)
          ListLinePlot[Transpose[{rbf5populationSizes, rbf5fitnessValues}],
           PlotRange → All, AxesLabel → {"Population Size", "Fitness"},
           PlotLabel → "Iteration: " <> ToString[iteration], ImageSize → Medium]]

        (*Create frames for each unique iteration*)
        rbf5frames =
          Table[rbf5createLinePlot[iteration], {iteration, rbf5uniqueIterations}];

        (*Create the animation*)
        rbf5itaanimation = ListAnimate[rbf5frames, AnimationRate → 1]
Out[•]=
```



In[∘]:=
```
(*Filter data for dimension 2*)
rbf5dimension5Data = Select[rbfdata, #["Dimension"] == 5 &];

(*Extract unique population sizes and iterations*)
rbf5uniquePopulationSizes = Union[rbf5dimension5Data〚All, "Population Size"〛];
rbf5uniqueIterations = Union[rbf5dimension5Data〚All, "Iteration Number"〛];

(*Function to create line plot for a specific population size*)
rbf5createLinePlot[populationSize_] := Module[{populationData, sortedData},
  (*Filter data for the specific population size*)
  populationData =
   Select[rbf5dimension5Data, #["Population Size"] == populationSize &];
  (*Sort data by iteration number to create a line plot*)
  sortedData = SortBy[populationData, #["Iteration Number"] &];
  (*Extract iteration numbers and fitness values*)
  rbf5iterations = sortedData〚All, "Iteration Number"〛;
  rbf5fitnessValues = sortedData〚All, "Fitness"〛;
  (*Create the line plot*)
  ListLinePlot[Transpose[{rbf5iterations, rbf5fitnessValues}],
   PlotRange → All, AxesLabel → {"Iteration Number", "Fitness"},
   PlotLabel → "Population Size: " <> ToString[populationSize], ImageSize → Medium]]

(*Create frames for each unique population size*)
rbf5frames = Table[rbf5createLinePlot[populationSize],
   {populationSize, rbf5uniquePopulationSizes}];

(*Create the animation*)
rbf5psanimation = ListAnimate[rbf5frames, AnimationRate → 1]
```

Out[∘]=



In[∘]:=
```
Export["rbf5itaanimationgif.gif", rbf5itaanimation]
Export["rbf5itaanimationmp4.mp4", rbf5itaanimation]
```

Out[∘]=

```
rbf5itaanimationgif.gif
```

Out[∘]=

```
rbf5itaanimationmp4.mp4
```

```
In[ ]:= Export["rbf5psanimationgif.gif", rbf5psanimation]
        Export["rbf5psanimationmp4.mp4", rbf5psanimation]

Out[ ]=
        rbf5psanimationgif.gif

Out[ ]=
        rbf5psanimationmp4.mp4
```