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Forest Optimization Algorithm Implementation using Sphere Mathematical Function

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Abstract: ***Forest Optimization Algorithm (FOA), a recent evolutionary algorithm suitable for continuous nonlinear optimization problems. It is inspired by a few trees in the forest that can last for several decades while other trees can only live for a short time. In FOA, the tree seeding technique is simulated so that certain seeds fall directly under the leaves, while others are dispersed over a large area by natural processes and animals that feed on the seeds or fruits. In this paper, we used the sphere mathematical function to implement FOA as a step-by-step process, and the iteration-based results are displayed. The findings of the experiments demonstrated that FOA performed well in certain data sets from the UCI repository..***

Keyword: ***Forest Optimization Algorithm, Evolutionary Algorithm, Continuous Nonlinear Optimization, Tree Seeding Technique, UCI repository.***

I. INTRODUCTION

1. History for Development

It has been for million years that trees are governing in the forests and different kinds of trees use different ways to survive and to continue their generations. But considering the rule of the nature, after some years most of the trees deem to die and aging is in evitable. This time, the flow of the nature replaces the old trees with the new ones and rarely some trees succeed to live for several decades. The distinguished trees, which could survive for a long time, are often the ones that are in suitable geographical habitats and also they have the best growing conditions. In other words, plant species immediately disperse their seeds to place the propagules in safe sites where they can grow and survive

In some forests like tropical dry forests, all species are either clumped or randomly dispersed where the mode of dispersal affects the clumping of the trees. Different natural procedures distribute the seeds of all trees in the entire forest. These procedures are known as seed dispersal. Seed dispersal deals with the departure of diaspora, where diaspora is a unit of a plant like seed or fruit. Mostly joint procedure of dispersal and establishment is considered and not just movement of seeds to places where they cannot establish.

In the nature when the seeding process begins, some seeds fall just near the trees and begin to sprout. This procedure is named as local seed dispersal and we will refer to this process as ‘‘Local seeding’’. But most of the times, the interference of animals that feed on the seeds and also other natural processes such as the flow of the water and wind carry the seeds to faraway places. Also some trees give elegant wings and plumes to their seeds to be transported to far places. This way, the territory of various trees is expanded in the entire forest. This procedure is named as long-distance seed dispersal which we will name it as ‘‘Global seeding”.

II. INTRODUCTION TO FOREST OPTIMIZATION ALGORITHM

FOA is inspired by the growing and seeding procedure of the trees in the forest [7] [8]. This FOA involves three main stages namely 1.Local seeding of trees, 2. Population limiting, 3.Global seeding of trees. Like other evolutionary algorithm, FOA starts with the initial population of trees so that each tree represents a potential solution to the problem. Age is the numerical variable that is attached to each tree so that this variable defines the age of the particular tree and in the initial stage, age of the trees is set to 0. After the initialization of the trees, the local seeding operator will generate new trees from the tree with the age=0. The age of the trees is increased by 1 than other newly generated trees.

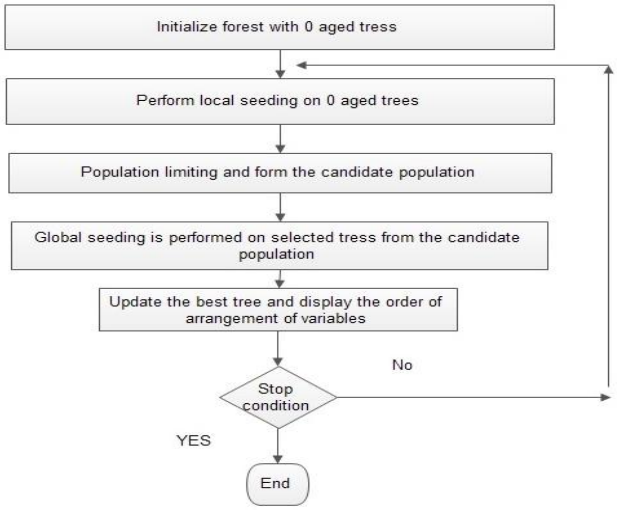

Fig.1 Flowchart for working of Forest optimization algorithm

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A. Initialize Tress

In FOA the potential solution of each problem has been considered as a tree. Each tree shows the values of variables. In addition to the variables, each tree has in a related to the *"Age"* of that tree. After each local seeding stage, the age of trees, except new generated trees in local seeding stage, increases by '1'.The process of increasing the age of trees is used by a controlling mechanism for limiting the trees in the forest. Figure 2 shows a solution representation of a N_{var} dimensional problem, where v_i are the values of the variables from the type of boxes and the *"Age"* part shows age of the related trees.

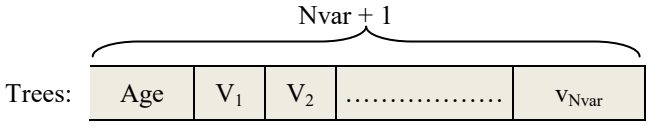

Figure 2. Solution representation of FOA.

A tree can also be considered as an array of length 1 x (N_{var}+ 1) where N_{var} is the dimension of the problem and "Age" represents the age of the related trees.

Tree = *[Age, v_1, $v_{2...}$ v_{Nvar}]*

The maximum age of a tree is a predefined parameter and is named as *"lifetime"*. The *"lifetime"* parameter should be determined at the start of the algorithm. When a tree's "Age" reaches to the "lifetime" parameter, that trees are omitted from the forest and is added to the candidate population. If we choose a big number for this parameter, for each iteration of the algorithm the age of trees is just increased and the forest will be full of old trees, which do not take part in the local seeding stage or if we choose a very small value for this parameter, the trees will get old very soon and they will be omitted at the beginning of the competition. Therefore, this parameter should provide a good chance of local search.

B. Local Seeding of the Trees

In nature when seeding procedure begins, some seeds fall just near the trees and after some time they turn into young trees. This local seeding of trees attempts to simulate this procedure of nature. This operator is performed on the trees with age 0 and adds neighbors of each tree to the forest. At this stage, after the local seeding executed on the trees at age 0, the age of all trees, except new generated trees is increased by 1.

Increasing the age of trees acts as a controlling mechanism on the number of trees of the forest. If a tree is promising, the procedure of the algorithm resets the age of that tree to '0' the result, will be possible to add neighbors of the good tree to the forest through performing local seeding stage, otherwise non-promising trees get old with each iteration of the algorithm and finally die after some iterations.

The number of seeds that fall on the land near the trees turning into trees as neighbors are considered as a parameter of this algorithm that is named as "Local Seeding Changes" or "LSC". At the first iteration of the algorithm, the trees with age 0 perform local seeding operation and new trees are added to the forest. At the next iteration, the number of added trees by local seeding operator decreases because there are trees with the age more than 0, which do not take part in local seeding stage. Now the new trees with age 0 will be added to the forest. Local seeding operator adds many trees to the forest, so there must be a limitation on the number of trees. This control is done in the next stage of the proposed algorithm;

C. Population Limiting

The number of trees in the forest must be limited to prevent infinite expansion of the forest. There are 2 parameters which limit the population of trees namely "Lifetime" and "area limit". In the first stage, the trees whose age exceed the "lifetime" parameter are removed from the forest and they are moved to the candidate population separately. In the second stage limitation parameter (i.e.) "area limit" is used. After ranking the trees according to their fitness values if the number of the trees is greater than the limitation of the forest, then the extra trees are removed from the forest and are added to the candidate population. So, after performing these two operations, the number of trees in the forest will be equal to the number of initial trees. After population limiting of the forest, global seeding stage is performed on some percentage of the candidate population. .

D. Global Seeding of the Trees

The seeds of the trees are dispersed in the entire forest and as a result, the habitat of the trees becomes wider. Also, other natural processes like wind and flow of water support to distribute the seeds in the entire forest. Global seeding stage attempts to simulate the distribution of the seeds of the trees in the forest. Global seeding operator is performed on a predefined percentage of the candidate population using "transfer rate" parameter.

E. Updating the Best Trees

After sorting out the trees according to their fitness values, the trees with the highest fitness value is selected as the best one and set age of the best tree to 0

III. PSEUDO CODE FOR FOREST OPTIMIZATION ALGORITHM

Input: lifetime, LSC, GSC transfer rate and area limit.
Output: Displayed the best tree in the forest
Step-1: Initialize the forest with random trees
1.1 Each tree is represented as a dimensional vector X, then X= (age, v1, v2, v3…., vn) for D Dimensional problem.
1.2 "Age" of each trees is initialized by "0".
Step-2 While stop condition is not satisfied do
2.1: Perform local seeding on trees with age 0

- For i=1 "LSC"
  - Randomly choose a variable from the selected tree.
  - Add a small amount dx-dx∈ [-ax, ax,]-to the randomly selected variable.
- Increase the age of all the trees by 1 except newly generated trees.

2.2 Population limiting

- Remove the trees with the age greater than "lifetime" parameter and add them to the candidate population.

- Sort out the trees according to their fitness value
- Remove extra trees that exceed "area limit" parameter from the end of the forest and add them to the candidate population.

2.3 Global Seeding

- Choose "transfer rate" percent of the candidate population
- For each selected tree
  - Choose "GSC" variable to the selected tree randomly
  - Change the value of each variable with another randomly generated variable and add a new tree to the forest with age=0.

2.4 Updation of the best trees so far
Sort trees according to their fitness value
Reset the age of the best to 0

3. Return the best trees as the result

IV. CASE STUDY

Step by Step Implementation of Forest Optimization algorithm using Sphere function

$$f(x) = \min\{x^2 + y^2 \mid x, y \in (-5, 5)\}$$

Input:

Lifetime = 2, LSC = 2, GSC = 1, Transfer Rate = 10, Area Limit = 30, Forest Size = 30,

Step 1.1: Initializing trees

Representation of initial forest

Age	x1	y1

Step 1.2: Age assigning

0	x1	y1

Initial of trees in the forest

#	x1	x2	Age
1	3.970638949632555	0.7418534660517873	0
2	-4.520393750831413	-1.0208286933604818	0
3	-0.1849012884370449	0.9410143189293771	0
4	-1.3221788538535129	1.834544549824698	0
5	0.8406731912742718	-2.208193759435547	0
6	4.983233605631799	2.883413750149658	0
7	-0.674172766660841	3.285181247697343	0
8	4.7593251449047695	-0.3821608078006511	0
9	-3.628719361230023	-2.9827128591700323	0
10	-0.293162379176084	-0.8308280786907218	0
11	1.0818565100835942	1.720202123044765	0
12	1.7163237771569415	-0.6628425302950252	0
13	2.582239735211088	4.49730431097246	0
14	4.4104628401135155	-2.824227561734858	0
15	1.9179122273328204	1.467038977760087	0
16	-4.3215635806824695	3.543426349338027	0
17	-0.20901147008813492	1.2712627935502594	0
18	-4.405357204726419	3.8076113521749164	0
19	-4.820452968800721	-2.348214984518975	0
20	1.1326367658080558	0.4695024559947827	0
21	-4.57556898641461	-1.6155605896472194	0
22	-1.0430029964783105	-0.835821800039084	0
23	-3.2561211259592913	-1.9979642207260992	0
24	-0.9408256209662316	-4.259285259999994	0
25	2.74961524476761	-4.848770540684755	0
26	-0.9196945148155784	0.3099701268291932	0
27	1.7393202531877208	2.180534643936751	0
28	4.306414330020193	3.0985194802013947	0
29	4.329062073095372	-0.11420850691043682	0
30	4.818539010638714	0.7076160317600113	0

Generation - 1

Step 2.1: Local Seeding

Input: (Total trees in the forest)

Output: (performing local seeding operation on trees with age 0 .fitness value for each tree is calculated and age 1 is increased for all new generated trees)

1	3.970638949632555	0.7418534660517873	16.31632023343217	1
2	-4.520393750831413	-1.0208286933604818	21.476050883743763	1
3	-0.1849012884370449	0.9410143189293771	0.9196964348957988	1
4	-1.3221788538535129	1.834544549824698	5.113710626868892	1
5	0.8406731912742718	-2.208193759435547	5.5828510937373625	1
6	4.983233605631799	2.883413750149658	33.14669202285022	1
7	-0.674172766660841	3.285181247697343	11.246924749529406	1
8	4.7593251449047695	-0.3821608078006511	22.797222717941654	1
9	-3.628719361230023	-2.9827128591700323	22.0641802028239	1
10	-0.293162379176084	-0.8308280786907218	0.7762194769050984	1
11	1.0818565100835942	1.720202123044765	4.129508853253797	1
12	1.7163237771569415	-0.6628425302950252	3.3851275280021818	1
13	2.582239735211088	4.49730431097246	26.893708115594503	1
14	4.4104628401135155	-2.824227561734858	27.428443784484998	1
15	1.9179122273328204	1.467038977760087	5.8305906740224	1
16	-4.3215635806824695	3.543426349338027	31.231782075064103	1
17	-0.20901147008813492	1.2712627935502594	1.6597948848936128	1
18	-4.405357204726419	3.8076113521749164	33.90507631044626	1
19	-4.820452968800721	-2.348214984518975	28.750880437939134	1
20	1.1326367658080558	0.4695024559947827	1.5032985994452654	1
21	-4.57556898641461	-1.6155605896472194	23.545867568260494	1
22	-1.0430029964783105	-0.835821800039084	1.7864533320833091	1
23	-3.2561211259592913	-1.9979642207260992	14.594185814220051	1
24	-0.9408256209662316	-4.259285259999994	19.026663775119715	1
25	2.74961524476761	-4.848770540684755	31.070959750470774	1
26	-0.9196945148155784	0.3099701268291932	0.9419194801083683	1
27	1.7393202531877208	2.180534643936751	7.779966276557369	1
28	4.306414330020193	3.0985194802013947	28.146027350990785	1
29	4.329062073095372	-0.11420850691043682	18.753822015763507	1
30	4.818539010638714	0.7076160317600113	23.719038645450905	1
31	3.970638949632555	1.140531171915091	17.06678502244913	0
32	3.3397678585364527	0.7418534660517873	11.704395914006215	0
33	-4.4413536174464285	-1.0208286933604818	20.767713176392547	0
34	-3.8739794482236602	-1.0208286933604818	16.049807986447362	0
35	-0.04993215016313912	0.9410143189293771	0.8880011680500337	0
36	0.09425294832225473	0.9410143189293771	0.8943915666975571	0
37	-1.277991216935405	1.834544549824698	4.998815255855542	0
38	-1.3221788538535129	1.4923314348729566	3.9752100330873663	0
39	0.8406731912742718	-2.914351305040765	9.200174943720079	0
40	0.8406731912742718	-2.0690823419201334	4.987833152172972	0
41	4.983233605631799	2.979707945689193	33.71127660990142	0
42	4.983233605631799	2.7639024446078757	32.4717738916075	0
43	-0.674172766660841	2.716052220736909	7.831448585077029	0
44	-0.674172766660841	3.4011201321419167	12.022127072568318	0
45	4.796695369280667	-0.3821608078006511	23.154333348697442	0
46	4.7593251449047695	0.05298533355166746	22.653983280494387	0
47	-4.170604550758811	-2.9827128591700323	26.290518319068376	0
48	-3.86991309723507	-2.9827128591700323	23.872803380409803	0
49	-0.9517012651206165	-0.8308280786907218	1.5960105943730982	0
50	-0.293162379176084	-0.13231037496136144	0.10345021588659811	0
51	1.6187604036351078	1.720202123044765	5.579480588504614	0
52	1.3809397478944108	1.720202123044765	4.866089931442396	0
53	1.8829987972799336	-0.6628425302950252	3.9850446905255876	0
54	1.7163237771569415	-1.3074298434005347	4.655140103448617	0
55	2.245651687989737	4.49730431097246	25.268697569262628	0
56	2.582239735211088	4.4522980175098	26.49091968682472	0
57	4.408496887476889	-2.824227561734858	27.411106127356234	0
58	4.4104628401135155	-3.3661327057963444	30.783031857053995	0
59	1.9179122273328204	1.8666606062159021	7.162809130551059	0
60	1.9860885030584794	1.467038977760087	6.09675090425073	0
61	-4.3215635806824695	2.9657546877125416	27.47161264957	0
62	-4.805217645790761	3.543426349338027	35.64598691660192	0
63	-0.20901147008813492	1.8176317213822335	3.347470869203345	0
64	-0.20901147008813492	1.0846999294800923	1.2202597316425206	0
65	-4.1546934687466015	3.8076113521749164	31.75938202845696	0
66	-4.802825443247722	3.8076113521749164	37.56503644751898	0
67	-4.642283857711815	-2.348214984518975	27.06491302909114	0
68	-4.820452968800721	-2.023001348710212	27.329301281303024	0
69	1.1326367658080558	0.7750219883849532	1.8835251257402992	0
70	1.113532424427286	0.4695024559947827	1.4603870164360422	0
71	-4.332857702938913	-1.6155605896472194	21.383691892738348	0
72	-4.333305979317268	-1.6155605896472194	21.387576729208064	0
73	-1.0430029964783105	-1.2002752597966104	2.5285159499425554	0
74	-1.0430029964783105	-0.327641119998231	1.1952039541764297	0
75	-3.2561211259592913	-1.4407335327431487	12.678037899288956	0
76	-3.2561211259592913	-1.4066745139935124	12.581057975237286	0
77	-1.4910507515988212	-4.259285259999994	20.36474326989663	0

78	-0.5665456641354634	-4.259285259999994	18.462484915603913	0
79	3.2061672450529923	-4.848770540684755	33.79008415946302	0
80	3.3038877740835413	-4.848770540684755	34.426250179951026	0
81	-0.9196945148155784	0.44430227404837996	1.0432425113064239	0
82	-0.5239735443928268	0.3099701268291932	0.3706297547500878	0
83	2.178252118637497	2.180534643936751	9.499513625757116	0
84	1.8775648603362811	2.180534643936751	8.279981138177972	0
85	4.3258698079540405	3.0985194802013947	28.313972564555847	0
86	4.652813214539232	3.0985194802013947	31.24949377857842	0
87	4.6732880072473035	-0.11420850691043682	21.852664381732183	0
88	3.9732170548060792	-0.11420850691043682	15.799497347652606	0
89	4.818539010638714	0.37657332304030766	23.360125664672736	0
90	4.818539010638714	0.07478789297586919	23.223911425982887	0

Step 2.2: Population Limiting

Input :(Trees generated in local seeding)

Output 1: Remove the trees, age bigger than lifetime)

1	1.9860885030584794	1.46703897776087	0
2	1.9179122273328204	1.8666606062159021	0
3	1.7393202531877208	2.180534643936751	1
4	-0.674172766660841	2.716052220736909	0
5	1.8775648603362811	2.180534643936751	0
6	0.8406731912742718	-2.914351305040765	0
7	2.178252118637497	2.180534643936751	0
8	-0.674172766660841	3.285181247697343	1
9	3.3397678585364527	0.7418534660517873	0
10	-0.674172766660841	3.4011201321419167	0
11	-3.2561211259592913	-1.4066745139935124	0
12	-3.2561211259592913	-1.4407335327431487	0
13	-3.2561211259592913	-1.9979642207260992	1
14	3.9732170548060792	-0.11420850691043682	0
15	-3.8739794482236602	-1.0208286933604818	0
16	3.970638949632555	0.7418534660517873	1
17	3.970638949632555	1.140531171915091	0
18	-0.5665456641354634	-4.259285259999994	0
19	4.329062073095372	-0.11420850691043682	1
20	-0.9408256209662316	-4.259285259999994	1
21	-1.4910507515988212	-4.259285259999994	0
22	-4.4413536174464285	-1.0208286933604818	0
23	-4.332857702938913	-1.6155605896472194	0
24	-4.333305979317268	-1.6155605896472194	0
25	-4.520393750831413	-1.0208286933604818	1
26	4.6732880072473035	-0.11420850691043682	0
27	-3.628719361230023	-2.9827128591700323	1
28	4.7593251449047695	0.05298533355166746	0
29	4.7593251449047695	-0.3821608078006511	1
30	4.796695369280667	-0.3821608078006511	0
31	4.818539010638714	0.07478789297586919	0
32	4.818539010638714	0.37657332304030766	0
33	-4.57556898641461	-1.6155605896472194	1
34	4.818539010638714	0.7076160317600113	1
35	-3.86991309723507	-2.9827128591700323	0
36	2.245651687989737	4.49730431097246	0
37	-4.170604550758811	-2.9827128591700323	0
38	2.582239735211088	4.4522980175098	0
39	2.582239735211088	4.49730431097246	1
40	-4.642283857711815	-2.348214984518975	0
41	-4.820452968800721	-2.023001348710212	0
42	4.408496887476889	-2.824227561734858	0
43	4.4104628401135155	-2.824227561734858	1
44	-4.3215635806824695	2.9657546877125416	0
45	4.306414330020193	3.0985194802013947	1
46	4.3258698079540405	3.0985194802013947	0
47	-4.820452968800721	-2.348214984518975	1
48	4.4104628401135155	-3.3661327057963444	0
49	2.74961524476761	-4.848770540684755	1
50	-4.3215635806824695	3.543426349338027	1
51	4.652813214539232	3.0985194802013947	0
52	-4.1546934687466015	3.8076113521749164	0
53	4.983233605631799	2.7639024446078757	0
54	4.983233605631799	2.883413750149658	1
55	4.983233605631799	2.979707945689193	0
56	3.2061672450529923	-4.848770540684755	0
57	-4.405357204726419	3.8076113521749164	1
58	3.3038877740835413	-4.848770540684755	0
59	-4.805217645790761	3.543426349338027	0
60	-4.802825443247722	3.8076113521749164	0

Output 2: (Remove extra trees according to area limit and add them to candidate population)

1	-0.293162379176084	-0.13231037496136144	0.10345021588659811	0
2	-0.5239735443928268	0.3099701268291932	0.3706297547500878	0
3	-0.293162379176084	-0.8308280786907218	0.7762194769050984	1
4	-0.04993215016313912	0.9410143189293771	0.8880011680500337	0
5	0.09425294832225473	0.9410143189293771	0.8943915666975571	0
6	-0.1849012884370449	0.9410143189293771	0.9196964348957988	1
7	-0.9196945148155784	0.3099701268291932	0.9419194801083683	1
8	-0.9196945148155784	0.44430227404837996	1.0432425113064239	0
9	-1.0430029964783105	-0.327641119998231	1.1952039541764297	0
10	-0.20901147008813492	1.0846999294800923	1.2202597316425206	0
11	1.1135324244427286	0.4695024559947827	1.4603870164360422	0
12	1.1326367658080558	0.4695024559947827	1.5032985994452654	1
13	-0.9517012651206165	-0.8308280786907218	1.5960105943730982	0
14	-0.20901147008813492	1.2712627935502594	1.6597948848936128	1
15	-1.0430029964783105	-0.835821800039084	1.7864533320833091	1
16	1.1326367658080558	0.7750219883849532	1.8835251257402992	0
17	-1.0430029964783105	-1.2002752597966104	2.5285159499425554	0
18	-0.20901147008813492	1.8176317213822335	3.347470869203345	0
19	1.7163237771569415	-0.6628425302950252	3.3851275280021818	1
20	-1.3221788538535129	1.4923314348729566	3.9752100330873663	0
21	1.8829987972799336	-0.6628425302950252	3.9850446905255876	0
22	1.0818565100835942	1.720202123044765	4.12950885253797	1
23	1.7163237771569415	-1.3074298434005347	4.655140103448617	0
24	1.3809397478944108	1.720202123044765	4.866089931442396	0
25	0.8406731912742718	-2.0690823419201334	4.987833152172972	0
26	-1.277991216935405	1.834544549824698	4.998815255855542	0
27	-1.3221788538535129	1.834544549824698	5.113710626868892	1
28	1.6187604036351078	1.720202123044765	5.579480588504614	0
29	0.8406731912742718	-2.208193759435547	5.5828510937373625	1
30	1.9179122273328204	1.46703897776087	5.8305906740224	1

Step 2.3: Global Seeding

Input: (Trees in the candidate population)

Trees in the candidate population is 60, so we select 6 elements (10% of the total candidate population)

Output 1:

| 1 | 4.652813214539232 | 3.0985194802013947
| 2 | 1.9179122273328204 | 1.8666606062159021
| 3 | 4.7593251449047695 | -0.3821608078006511
| 4 | 3.9732170548060792 | -0.11420850691043682
| 5 | 2.245651687989737 | 4.49730431097246
| 6 | 4.4104628401135155 | -2.824227561734858

Output 2: (Modification of elected candidates)

[4.65281321 3.09851948] => 4.652813214539232
[1.91791223 1.86666061] => 1.9179122273328204
[4.75932514 -0.38216081] => 4.7593251449047695
[3.97321705 -0.11420851] => 3.9732170548060792
[2.24565169 4.49730431] => 2.245651687989737
[4.41046284 -2.82422756] => 4.4104628401135155

Step 2.4: Updating Best Tree

Input: (Total Trees in the forest and tress in candidate population= 30 +6=36 trees)
Output :

| 1 | -0.293162379176084 | -0.13231037496136144 | 0.10345021588659811
| 2 | -0.5239735443928268 | 0.3099701268291932 | 0.3706297547500878
| 3 | -0.293162379176084 | -0.8308280786907218 | 0.7762194769050984
| 4 | -0.04993215016313912 | 0.9410143189293771 | 0.8880011680500337
| 5 | 0.09425294832225473 | 0.9410143189293771 | 0.8943915666975571
| 6 | -0.1849012884370449 | 0.9410143189293771 | 0.9196964348957988
| 7 | -0.9196945148155784 | 0.3099701268291932 | 0.9419194801083683
| 8 | -0.9196945148155784 | 0.44430227404837996 | 1.0432425113064239
| 9 | -1.0430029964783105 | -0.327641119998231 | 1.1952039541764297
| 10 | -0.20901147008813492 | 1.0846999294800923 | 1.2202597316425206
| 11 | 1.1135324244427286 | 0.4695024559947827 | 1.4603870164360422
| 12 | 1.1326367658080558 | 0.4695024559947827 | 1.5032985994452654
| 13 | -0.9517012651206165 | -0.8308280786907218 | 1.5960105943730982
| 14 | -0.20901147008813492 | 1.2712627935502594 | 1.6597948848936128
| 15 | -1.0430029964783105 | -0.835821800039084 | 1.7864533320833091
| 16 | 1.1326367658080558 | 0.7750219883849532 | 1.8835251257402992
| 17 | -1.0430029964783105 | -1.2002752597966104 | 2.5285159499425554
| 18 | -0.20901147008813492 | 1.8176317213822335 | 3.347470869203345
| 19 | 1.7163237771569415 | -0.6628425302950252 | 3.3851275280021818
| 20 | -1.3221788538535129 | 1.4923314348729566 | 3.9752100330873663
| 21 | 1.8829987972799336 | -0.6628425302950252 | 3.9850446905255876
| 22 | 1.0818565100835942 | 1.720202123044765 | 4.12950885253797
| 23 | 1.7163237771569415 | -1.3074298434005347 | 4.655140103448617
| 24 | 1.3809397478944108 | 1.720202123044765 | 4.866089931442396
| 25 | 0.8406731912742718 | -2.0690823419201334 | 4.987833152172972

| 26 | -1.277991216935405 | 1.834544549824698 | 4.998815255855542
| 27 | -1.3221788538535129 | 1.834544549824698 | 5.113710626868892
| 28 | 1.6187604036351078 | 1.720202123044765 | 5.579480588504614
| 29 | 0.8406731912742718 | -2.208193759435547 | 5.5828510937373625
| 30 | 1.9179122273328204 | 1.46703897776087 | 5.8305906740224
|31| 1.9179122273328204 |1.86666061| | 7.162809145
|32| 3.9732170548060792 |-0.11420851| | 7.959477694
|33| 4.7593251449047695 |-0.38216081| | 23.41649745
|34| | 4.4104628401135155 |-2.82422756| | 27.42844371
|35| |4.6528132145392 32 | 3.09851948| | 31.24949378
|36| |3.9732170548060792 |4.49730431| | 36.01219982

Step 3: Best Tree Finding

The best is updated to [-0.29316238 -0.13231037] (0.10345021588659811)
Restarting the age of the best. The best is [-0.29316238 -0.13231037] (0.10345021588659811)

Generation - 2

Step 2.1: Local Seeding

Input: (Total trees in the forest)
Output: (performing local seeding operation on trees with age 0 .fitness value for each tree is calculated and age 1 is increased for all new generated trees)

1	-0.8577391980790328	-1.2711690903968709	2.3515873883016702	1
2	-4.629807623753078	-1.6214111127688815	24.064092629572546	1
3	-2.2365117281651257	4.338318812899264	23.822994832575834	1
4	2.2384038793597707	4.198766890293449	22.640095326157386	1
5	-4.918760138741302	2.102909963531454	28.616431617190212	1
6	0.5545444239158037	4.899674349008521	24.314328244428182	1
7	2.369745338120458	-1.5669570934727628	8.071047500328252	1
8	1.128405341077884	-3.747977518460864	15.320634092661152	1
9	-3.3972037656489595	2.80227687913733	19.393749132687127	1
10	0.6853851976972329	-3.806820052184301	14.96163177893496	1
11	2.6777438128093785	-2.8961793935624747	15.558167006734811	1
12	4.513518553968916	2.830294955283539	28.38241927092511	1
13	4.248697688663507	2.6987233196241247	25.334539605537678	1
14	4.20954727088551	-3.748399910440927	31.7707901144132	1
15	-4.462444359647684	-4.787620286091116	42.834717666742606	1
16	2.5936523121135426	-4.441546062876302	26.454363744783905	1
17	1.9783379027195567	-1.56882803146837	6.375042249657735	1
18	0.09356588965311374	1.2734525228536855	1.6304359036689948	1
19	-4.879952067189559	3.1455581915929614	33.70846851476523	1
20	3.5536809988370557	-4.831386035322201	35.9709396638019 14	1
21	0.1120680880125624	-1.045610645490913	1.1058608783147155	1
22	-4.502480566873244	-2.9544761583378323	29.001260625257878	1
23	2.348239840747553	4.569692465003953	26.396319574388002	1
24	3.078800857595356	-2.7324874125831347	16.945502180655172	1
25	2.3218476684170835	-3.454600356254267	17.325240216765955	1
26	4.255425323283514	2.787934378808324	25.881222782583958	1
27	3.070847027569476	3.3410694141117947	20.592846296645618	1
28	-2.7014297933666045	3.634681952887858	20.50863582713743	1
29	-3.571314992965544	3.628092883395917	25.917348749528585	1
30	4.5465237019664	-3.620490324760114	33.77882796422386	1
31	-1.232072458471697	-1.2711690903968709	3.1338733993048997	0
32	-1.0475909140819457	-1.2711690903968709	2.7133175796474545	0
33	-4.629807623753078	-2.1546681786623902	26.077713593102423	0
34	-4.718985157652433	-1.6214111127688815	24.897794914754385	0
35	-2.2365117281651257	4.101353726433083	21.823087099546694	0
36	-2.171236156366834	4.338318812899264	23.535276569070298	0
37	2.2384038793597707	4.006114592549756	21.059406055772968	0
38	1.503903197588092	4.198766890293449	19.891368226740205	0
39	-5.0	2.102909963531454	29.422230314719 86	0
40	-4.375760471496188	2.102909963531454	23.569510018628407	0
41	1.1796954304142488	4.899674349008521	25.39849003487233	0
42	0.5545444239158037	5.0	25.307519518096 11	0
43	1.7089992221037045	-1.5669570934727628	5.376032873935676	0
44	1.8801753576629723	-1.5669570934727628	5.990413908347694	0
45	0.9778270949691861	-3.747977518460864	15.003481306543934	0
46	1.128405341077884	-4.129562114858716	18.32658187424949	0
47	-3.895412671496819	2.80227687913733	23.026995588605637	0
48	-3.491155432436 7042	2.80227687913733	20.040921960779965	0
49	0.6853851976972329	-4.192450341934224	18.04639273880687	0
50	1.1507469921899274	-3.806820052184301	15.81609754974665	0
51	2.4954843124534762	-2.8961793935624747	14.615297033397303	0
52	2.8551058268656693	-2.8961793935624747	16.5394843622982	0
53	4.513518553968916	3.27220208627904	31.07915623047056	0
54	4.513518553968916	2.255732992402409	25.460181070034388	0
55	4.51626775325967	2.6987233196241247	27.6797819750162	0
56	4.811167231844031	2.6987233196241247	30.430437688652816	0
57	4.20954727088551	-3.542870156950861	30.272217174832665	0
58	4.078190688908187	-3.748399910440927	30.68214118369098	0
59	-5.0	-4.787620286091116	47.921308003791175	0
60	-4.107054840610523	-4.787620286091116	39.789207467573505	0
61	2.5936523121135426	-4.5165827892235955	27.12655240804272	0
62	2.434065513808859	-4.441546062876302	25.652006354165565	0
63	1.9783379027195567	-1.2862955598420225	5.5683771246061164	0
64	1.3936207408068626	-1.56882803146837	4.40340016152799	0
65	0.09356588965311374	1.6231678612529974	2.6434284815112083	0
66	0.43759329919098344	1.2734525228536855	1.8131692234592658	0
67	-4.161857340410629	3.1455581915929614	27.215592858627414	0
68	-4.446681925765809	3.1455581915929614	29.667516485629903	0
69	3.5536809988370557	-4.952696894203116	37.15785516734473	0
70	2.906081529502361	-4.831386035322201	31.787600878421163	0
71	0.02750519911759974 3	-1.045610645490913	1.094058157942423	0
72	0.1120680880125624	-1.0728329908561767	1.1635298826202007	0
73	-4.906304478451562	-2.9544761583378323	32.800753005460535	0
74	-4.337751748399009	-2.9544761583378323	27.545019600925336	0
75	3.0470624994129167	4.569692465003953	30.16667910000424	0
76	2.7483108015072673	4.569692465003953	28.435301486395424	0
77	3.078800857595356	-2.1610863812001098	14.149309067738486	0
78	3.037161537830285	-2.7324874125831347	16.690837666800896	0
79	2.3267581122371315	-3.454600356254267	17.34806693429341	0
80	2.3218476684170835	-3.784976914956835	19.717026842090007	0
81	4.255425323283514	2.4951305218134827	24.334321002927823	0
82	4.23274909702457	2.787934378808324	25.68874301890367	0
83	2.394138245356954	3.3410694141117947	16.894642767794206	0
84	2.587100184369492	3.3410694141117947	17.855832193877 99	0
85	-3.434248179334121	3.634681952887858	25.00497345590842	0
86	-2.7014297933666045	4.234409335478387	25.22794534887525	0
87	-3.274457199064606	3.628092883395917	23.885127919054124	0
88	-3.571314992965544	4.359257750080097	31.757418910613872	0
89	4.5465237019664	-4.138552458322235	37.79849422282727	0
90	4.5465237019664	-3.8204555947802024	35.26675872422961	0

Step 2.2: Population Limiting

Input :(Trees generated in local seeding)
Output 1: (Remove the trees, age bigger than lifetime)

1	1.128405341077884	-4.129562114858716	0
2	-3.3972037656489595	2.80227687913733	1
3	2.3218476684170835	-3.784976914956835	0
4	1.503903197588092	4.198766890293449	0
5	-3.4911554324367042	2.80227687913733	0
6	-2.7014297933666045	3.634681952887858	1
7	3.070847027569476	3.3410694141117947	1
8	2.2384038793597707	4.006114592549756	0
9	-2.2365117281651257	4.101353726433083	0
10	2.2384038793597707	4.198766890293449	1
11	-3.895412671496819	2.80227687913733	0
12	-2.171236156366834	4.338318812899264	0
13	-4.375760471496188	2.102909963531454	0
14	-2.2365117281651257	4.338318812899264	1
15	-3.274457199064606	3.628092883395917	0
16	-4.629807623753078	-1.6214111127688815	1
17	0.5545444239158037	4.899674349008521	1
18	4.255425323283514	2.4951305218134827	0
19	-4.718985157652433	-1.6214111127688815	0
20	-3.434248179334121	3.634681952887858	0
21	-2.7014297933666045	4.234409335478387	0
22	0.5545444239158037	5.0	0
23	4.248697688663507	2.6987233196241247	1
24	1.1796954304142488	4.899674349008521	0
25	4.513518553968916	2.255732992402409	0
26	2.434065513808859	-4.441546062876302	0
27	4.23274909702457	2.787934378808324	0
28	4.255425323283514	2.787934378808324	1
29	-3.571314992965544	3.628092883395917	1
30	-4.629807623753078	-2.1546681786623902	0
31	2.348239840747553	4.569692465003953	1
32	2.5936523121135426	-4.441546062876302	1
33	2.5936523121135426	-4.5165827892235955	0
34	-4.161857340410629	3.1455581915929614	0
35	-4.337751748399009	-2.9544761583378323	0
36	4.51626775325967	2.6987233196241247	0
37	4.513518553968916	2.830294955283539	1
38	2.7483108015072673	4.569692465003953	0
39	-4.918760138741302	2.102909963531454	1
40	-4.502480566873244	-2.9544761583378323	1
41	-5.0	2.102909963531454	0
42	-4.446681925765809	3.1455581915929614	0
43	3.0470624994129167	4.569692465003953	0
44	4.20954727088551	-3.542870156950861	0
45	4.811167231844031	2.6987233196241247	0
46	4.078190688908187	-3.748399910440927	0
47	4.513518553968916	3.27220208627904	0

48	-3.571314992965544	4.359257750080097	0
49	4.20954727088551	-3.748399910440927	1
50	2.906081529502361	-4.831386035322201	0
51	-4.906304478451562	-2.954476158337823	0
52	-4.879952067189559	3.1455581915929614	1
53	4.5465237019664	-3.620490324760114	1
54	4.5465237019664	-3.8204555947802024	0
55	3.5536809988370557	-4.831386035322201	1
56	3.5536809988370557	-4.952696894203116	0
57	4.5465237019664	-4.138552458322235	0
58	-4.107054840610523	-4.787620286091116	0
59	-4.462444359647684	-4.787620286091116	1
60	-5.0	-4.787620286091116	0

Output 2: (Remove extra trees according to area limit and add them to candidate population)

1	0.027505199117599743	-1.045610645490913	1.094058157942423	0
2	0.1120680880125624	-1.045610645490913	1.1058608783147155	1
3	0.1120680880125624	-1.0728329908561767	1.1635298826202007	0
4	0.09356588965311374	1.2734525228536855	1.6304359036689948	1
5	0.43759329919098344	1.2734525228536855	1.8131692234592658	0
6	-0.8577391980790328	-1.2711690903968709	2.3515873883016702	1
7	0.09356588965311374	1.6231678612529974	2.6434284815112083	0
8	-1.0475909140819457	-1.2711690903968709	2.7133175796474545	0
9	-1.232072458471697	-1.2711690903968709	3.1338733993048997	0
10	1.3936207408068626	-1.56882803146837	4.40340016152799	0
11	1.7089992221037045	-1.5669570934727628	5.376032873935676	0
12	1.9783379027195567	-1.2862955598420225	5.5683771246061164	0
13	1.8801753576629723	-1.5669570934727628	5.990413908347694	0
14	1.9783379027195567	-1.56882803146837	6.375042249657735	1
15	2.369745338120458	-1.5669570934727628	8.071047500328252	1
16	3.078800857595356	-2.1610863812001098	14.149309067738486	0
17	2.4954843124534762	-2.8961793935624747	14.615297033397303	0
18	0.6853851976972329	-3.806820052184301	14.96163177893496	1
19	0.9778270949691861	-3.747977518460864	15.003481306543934	0
20	1.128405341077884	-3.747977518460864	15.320634092661152	1
21	2.6777438128093785	-2.8961793935624747	15.558167006734811	1
22	1.1507469921899274	-3.806820052184301	15.81609754974665	0
23	2.8551058268656693	-2.8961793935624747	16.5394843622982	0
24	3.037161537830285	-2.7324874125831347	16.690837666800896	0
25	2.394138245356954	3.3410694141117947	16.894642767794206	0
26	3.078800857595356	-2.7324874125831347	16.945502180655172	1
27	2.3218476684170835	-3.454600356254267	17.325240216765955	1
28	2.3267581122371315	-3.454600356254267	17.34806693429341	0
29	2.587100184369492	3.3410694141117947	17.85583219387799	0
30	0.6853851976972329	-4.192450341934224	18.04639273880687	0

Step 2.3: Global Seeding

Input: (Trees in the candidate population)

Trees in the candidate population is 60, so we select 6 elements (10% of the total candidate population)

Output 1: (candidate population 10 %)

| 1 | 2.7483108015072673 | 4.569692465003953
| 2 | -3.571314992965544 | 3.628092883395917
| 3 | 4.248697688663507 | 2.6987233196241247
| 4 | 1.128405341077884 | -4.129562114858716
| 5 | -4.502480566873244 | -2.9544761583378323
| 6 | 4.255425323283514 | 2.4951305218134827

Output 2: (Modification of elected candidates)

[2.7483108 4.56969247] => 2.7483108015072673
[-3.57131499 3.62809288] => 3.628092883395917
[4.24869769 2.69872332] => 2.6987233196241247
[1.12840534 -4.12956211] => -4.129562114858716
[-4.50248057 -2.95447616] => -2.9544761583378323
[4.25542532 2.49513052] => 2.4951305218134827

Step 2.4: updating Best Tree

Input: (Total Trees in the forest and tress in candidate population= 30 +6=36 trees)

Output:

1	0.027505199117599743	-1.045610645490913	1.094058157942423
2	0.1120680880125624	-1.045610645490913	1.1058608783147155
3	0.1120680880125624	-1.0728329908561767	1.1635298826202007
4	0.09356588965311374	1.2734525228536855	1.6304359036689948
5	0.43759329919098344	1.2734525228536855	1.8131692234592658
6	-0.8577391980790328	-1.2711690903968709	2.3515873883016702
7	0.09356588965311374	1.6231678612529974	2.6434284815112083
8	-1.0475909140819457	-1.2711690903968709	2.7133175796474545
9	-1.232072458471697	-1.2711690903968709	3.1338733993048997
10	1.3936207408068626	-1.56882803146837	4.40340016152799
11	1.7089992221037045	-1.5669570934727628	5.376032873935676
12	1.9783379027195567	-1.2862955598420225	5.5683771246061164
13	1.8801753576629723	-1.5669570934727628	5.990413908347694
14	1.9783379027195567	-1.56882803146837	6.375042249657735
15	2.369745338120458	-1.5669570934727628	8.071047500328252
16	3.078800857595356	-2.1610863812001098	14.149309067738486
17	2.4954843124534762	-2.8961793935624747	14.615297033397303
18	0.6853851976972329	-3.806820052184301	14.96163177893496
19	0.9778270949691861	-3.747977518460864	15.003481306543934
20	1.128405341077884	-3.747977518460864	15.320634092661152
21	2.6777438128093785	-2.8961793935624747	15.558167006734811
22	1.1507469921899274	-3.806820052184301	15.81609754974665
23	2.8551058268656693	-2.8961793935624747	16.5394843622982
24	3.037161537830285	-2.7324874125831347	16.690837666800896
25	2.394138245356954	3.3410694141117947	16.894642767794206
26	3.078800857595356	-2.7324874125831347	16.945502180655172
27	2.3218476684170835	-3.454600356254267	17.325240216765955
28	2.3267581122371315	-3.454600356254267	17.34806693429341
29	2.587100184369492	3.3410694141117947	17.85583219387799
30	0.6853851976972329	-4.192450341934224	18.04639273880687
31	1.12840534	-4.129562114858716	18.32658187
32	4.25542532	2.4951305218134827	24.33432097
33	4.24869769	2.6987233196241247	25.33453962
34	-3.57131499	3.628092883395917	25.91734873
35	2.7483108015072673	4.56969247	28.43530153
36	-4.50248057	-2.9544761583378323	29.00126065

Step 3: Best Tree Finding

The best is updated to [0.0275052 -1.04561065] (1.094058157942423) Restarting the age of the best.

V. CONVERGENCE OF FOREST OPTIMIZING ALGORITHM

The Proposed FOA algorithm is made run for 30 generations and the convergences of the algorithm is captured and displayed using figure 3. In X axis Generation of the algorithm and in Y axis fitness value of the iterations are considered.

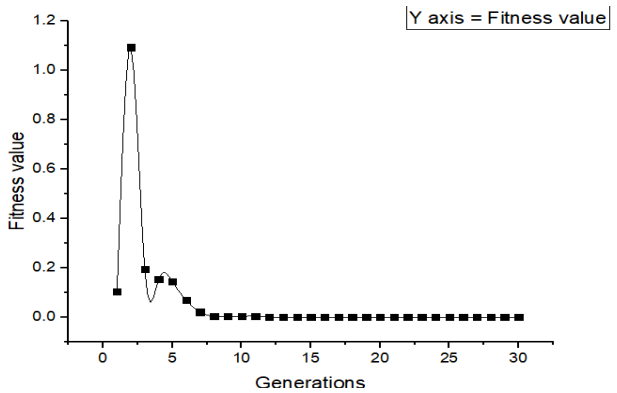

Fig 3. Convergence of Forest Optimization Algorithm

VI. CONCLUSION

FOA is an optimization algorithm that is inspired by the growth of trees in a forest and performs global optimization by three mechanisms:

growth, proliferation, and death. The global optimization efficiency of the FOA is evaluated using the sphere function. The results of the tests demonstrate that the FOA has incredible global optimization capabilities.

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