Forest Optimization Algorithm Implementation using Sphere Mathematical Function

Sathish Kumar Ravichandran, Archana Sasi, Shaik Hussain Shaik Ibrahim

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
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 Nvar 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.

| Trees: | Age | V_1 | V_2 | ……………….. | V_Nvar |
|--------|-----|-----|-----|-------------|---------|
| Nvar + 1 |

Figure 2. Solution representation of FOA.

A tree can also be considered as an array of length 1 x (Nvar+1) where Nvar is the dimension of the problem and “Age” represents the age of the related trees.

Tree = [Age, v_1, v_2, v_3…. 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 newly 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 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, v_1, v_2, v_3….., v_n) 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 dxi ∈ [-αx, αx] 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.
Step 1. Step by Step Implementation of Forest Optimization

Step 1.1: Initializing trees

Limit = 30, Forest Size = 30,

Step 2.1: Local Seeding

Input: (Total trees in the forest)

Output: (performing local seeding operation on trees with age 0.

Step 3. Update 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

Input:

Limit = 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 |
|-----|----|----|
| 0   | 2.93162379170604 | -0.8308280786907218 |
| 0.18156100835942 | 1.720202123044656 |
| 1.7163237771569401 | -0.662842502905250 |
| 2.5892375635511088 | -4.49730431972466 |
| 4.4104624601135155 | -2.824225761743885 |
| 1.9711922733280243 | 1.467038977706078 |
| 4.3215658086284695 | 3.54324639338072 |
| -0.209014708813942 | 1.2716273955205984 |
| 4.030557204726419 | 3.8071613221749164 |
| -2.8042052968800721 | -2.3482149818857 |
| 1.1326675835805585 | 4.6905544529599827 |
| -4.57556889641461 | -1.615505898472149 |
| -1.0430009947833105 | -0.838512800039089 |
| -2.5612115295929131 | -1.997642072769092 |
| -0.9408252069266236 | -2.5264258599999999 |
| 3.7906384906325555 | 0.7418534640651787 |
| 3.7657894642388135 | 3.54324639338072 |

| # | x1 | y1 | Age |
|----|----|----|-----|
| 9  | 2.93162379170604 | -0.8308280786907218 | 0  |
| 10 | 1.720202123044656 | 1.467038977706078 | 0  |
| 11 | -0.662842502905250 | 3.54324639338072 | 0  |
| 12 | -4.49730431972466 | 1.467038977706078 | 0  |
| 13 | -2.824225761743885 | 3.54324639338072 | 0  |
| 14 | 1.2716273955205984 | 3.8071613221749164 | 0  |
| 15 | -2.3482149818857 | 4.6905544529599827 | 0  |
| 16 | -1.615505898472149 | 0.7418534640651787 | 0  |
| 17 | -0.838512800039089 | 1.467038977706078 | 0  |
| 18 | -1.997642072769092 | 3.54324639338072 | 0  |
| 19 | -2.5264258599999999 | 1.467038977706078 | 0  |

| # | x1 | y1 | Age |
|----|----|----|-----|
| 20 | 0.7418534640651787 | 3.54324639338072 | 0  |
| 21 | 1.467038977706078 | 3.54324639338072 | 0  |
| 22 | -0.838512800039089 | 1.467038977706078 | 0  |
| 23 | -1.997642072769092 | 3.54324639338072 | 0  |
| 24 | -2.5264258599999999 | 1.467038977706078 | 0  |
| 25 | 0.7418534640651787 | 3.54324639338072 | 0  |
| 26 | 1.467038977706078 | 3.54324639338072 | 0  |
| 27 | -0.838512800039089 | 1.467038977706078 | 0  |
| 28 | -1.997642072769092 | 3.54324639338072 | 0  |
| 29 | -2.5264258599999999 | 1.467038977706078 | 0  |
Step 2.2: Population Limiting
Input: (Trees generated in local seeding)

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

| 1 | 198608880305084794 | 1.4670837977687809 |
| 2 | 9197122287330524 | 1.866666666062615902 |
| 3 | 1.739230215375770820 | 2.180354439369761751 |
| 4 | -0.6741726676666677 | -2.1760522270639906 |
| 5 | 1.8775684030630256 | 1.3400000040563084 |
| 6 | 0.840679191724721748 | -2.9143530150407667 |
| 7 | 1.0828507247303055 | 0.2681971969874074 |
| 8 | 4.6523014355256604 | 2.3709391997750887 |
| 9 | 5.3349768853564527 | 0.7418356605734580 |
| 10 | 0.8135069613809379 | 0.1284535146398144 |
| 11 | -0.6741726676666677 | -2.1760522270639906 |
| 12 | 1.53540061728204096 | 1.7289220233741506 |
| 13 | 1.279702169350407636 | 0.8482538930244078 |
| 14 | 0.9197122287330524 | 0.3477048417803345 |
| 15 | 1.7163237751766945 | -0.6012253902550023 |
| 16 | -1.3221788533515219 | 1.492334348720966 |
| 17 | 0.9197122287330524 | 0.3477048417803345 |
| 18 | 1.7163237751766945 | -0.6012253902550023 |
| 19 | 0.9197122287330524 | 0.3477048417803345 |
| 20 | 1.7163237751766945 | -0.6012253902550023 |
| 21 | 0.9197122287330524 | 0.3477048417803345 |

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

Output 1:

| 1 | 4.652831214529320 | 3.0985194802031947 |
| 2 | 1.9179122273328204 | 1.866666666062615902 |
| 3 | 4.7592514494074695 | -0.5032186078006561 |
| 4 | 0.3397064993525113 | -0.237107548070679972 |
| 5 | 4.2546516878997377 | 4.4973041097192648 |
| 6 | 0.4410462840131155 | -0.2822425765173485 |

Step 2.3: Global Seeding
Input: (Trees in the candidate population)

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

Output 2:

| 1 | 4.652831214529320 | 3.0985194802031947 |
| 2 | 1.9179122273328204 | 1.866666666062615902 |
| 3 | 4.7592514494074695 | -0.5032186078006561 |
| 4 | 0.3397064993525113 | -0.237107548070679972 |
| 5 | 4.2546516878997377 | 4.4973041097192648 |
| 6 | 0.4410462840131155 | -0.2822425765173485 |

Step 2.4: Updating Best Tree
Input: (Total trees in the forest and trees in candidate population) + 30 more trees

Output:

| 1 | -0.293623279167084 | 0.1321034719636144 |
| 2 | 0.2593735449028629 | 0.3990710282931972 |
| 3 | -0.293623279167084 | 0.1321034719636144 |
| 4 | 0.2593735449028629 | 0.3990710282931972 |
| 5 | -0.009645148581758 | -0.101431592997371 |
| 6 | 0.108565108359429 | 0.1209096294990823 |

Step 2.5: Updating Best Tree
Input: (Total trees in the forest and trees in candidate population) + 30 more trees

Output:

| 1 | -0.293623279167084 | 0.1321034719636144 |
| 2 | 0.2593735449028629 | 0.3990710282931972 |
| 3 | -0.293623279167084 | 0.1321034719636144 |
| 4 | 0.2593735449028629 | 0.3990710282931972 |
| 5 | -0.009645148581758 | -0.101431592997371 |
| 6 | 0.108565108359429 | 0.1209096294990823 |

Step 2.6: Updating Best Tree
Input: (Total trees in the forest and trees in candidate population) + 30 more trees

Output:

| 1 | -0.293623279167084 | 0.1321034719636144 |
| 2 | 0.2593735449028629 | 0.3990710282931972 |
| 3 | -0.293623279167084 | 0.1321034719636144 |
| 4 | 0.2593735449028629 | 0.3990710282931972 |
| 5 | -0.009645148581758 | -0.101431592997371 |
| 6 | 0.108565108359429 | 0.1209096294990823 |

Step 2.7: Updating Best Tree
Input: (Total trees in the forest and trees in candidate population) + 30 more trees

Output:...
Step 3: Best Tree Finding
The best is updated to [−0.29316283−0.133073]
(0.1034502158869581)

Restoring the age of the best. The best is [−0.29316283
−0.133073] (0.1034502158869581)

Generation - 2

Step 2.2: Population Limiting

Input (trees generated in local seeding)

Output 1: Remove the trees, age bigger than lifetime

| 11.28403410477848 | -1.42956218458761 | 0 |
| 3.973270666649595 | 2.80722787917337 | 0 |
| 2.3218647684162571 | 2.10299699388251 | 0 |
| 3.0554442539180739 | 3.644820832889517 | 0 |
| 2.7448867821536384 | 2.698273219642147 | 0 |
| 1.6790654402418624 | 0.947849672888501 | 0 |
| 2.4562304274367275 | 2.154688967732937 | 0 |
| 1.6634959026669537 | 0.663071394462817 | 0 |
| 1.5987908366510525 | 0.662108988200172 | 0 |
| 0.8171613844443821 | 0.662231966242173 | 0 |
| 1.013142855868970 | 0.662108988200172 | 0 |
Step 3: Best Tree Finding
The best is updated to [0.027505, 1.04561065] (1.094058157942432) Restoring the age of the best.

V. CONVERGENCE OF FOREST OPTIMIZATION ALGORITHM

The Proposed FOA algorithm is made run for 30 generations and the convergence 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.

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: (population candidate 10 %)

Output 2: (Modification of elected candidates)

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.

REFERENCES

1. Chaiyaratana, N., Zalzala, A.M.S., Recent Developments in Evolutionary and Genetic Algorithms: Theory and Applications, in: Second IEEE International Conference on Genetic Algorithms in Engineering Systems: Innovations and Applications, Glasgow,UK 1997, pp.270-277. Wu ziniu, The basic elements of computing hydromechanics. Beijing: the Science Press. 2001. 1-8.

2. Marra, M.A., Waltcott, B.L., Stability and optimality in genetic algorithm controllers, in: IEEE International Symposium on Intelligent Control Dearborn, MI USA 1996, pp. 492 - 496. C.W. Hirt, B.D. Nichols. Volume of fluid (VOF) method for the dynamics of free boundaries. Journal of Computational Physics, 1981, 39:201-225.

3. Marco Dorigo, Mauro Birattari, and Thomas Stützle, Ant Colony Optimization, IEEE Computational Inte. Maga.1 (2006) 28-29.

4. Christian Blum ALBCOM research group, Ant Colony Optimization: Introduction and Hybridizations, in: 7th IEEE International Conference on Hybrid Intelligent Systems, Kaiserlautern, 2007, pp.24-29.

5. Enhai Liu, Yongfeng Dong, Jie Song, Xiangdan Hou, Nana Li, A Modified Particle Swarm Optimization Algorithm, IEEE Education Technology and Training, 2008. and 2008 International Workshop on Geoscience and Remote Sensing, ET and GRS 2008. 2 (2008) 666-669.

6. Bo Li Ren, Yue Xiao, The Particle Swarm Optimization Algorithm: How to Select the Number of Iteration, 3rd IEEE International Conference on intelligent Information Hiding and Multimedia Signal Processing, Kaohsiung, Taiwan.2 (2007) 191-196.

7. Sathish Kumar Ravichandran, Archana Sasi, Optimal Arrangement of Ration Items in to Container Using Modified Forest Optimization Algorithm, Indian Journal of Computer Science and Engineering (Scopus Journal) Vol. 11, no.4, 2020.

8. Sathish Kumar Ravichandran and Archana Sasi “Effective Storage of Goods in a Warehouse using Farm Optimization Algorithm” International Journal of Cloud Computing (Scopus Journal) Vol.09, No.2/3, 2020.

AUTHORS PROFILE

Sathish Kumar Ravichandran, received his B.Tech, M.E, and Ph.D in Information Technology, Computer Science Engineering and Information and Communication Engineering from Anna University Coimbatore and Anna University Chennai, Anna University Chennai in 2011, 2013, and 2019 respectively. He is currently working as Assistant Professor in Computer Science and Engineering department at Christ University Bangalore in Karnataka. He received the best paper award in IEEE sponsored International Conference on Advanced Computing & Communication System, India. He serves as an Editorial review member for many UGC journals. He published many research papers in SCI, Scopus indexed Journals. His research area includes Supply Chain Management, Big Data Analytics, IoT, and Bio-Inspired Optimization algorithms.

Archana Sasi, received her B.Tech and M.Tech in Computer Science and Engineering and Computer and Information Science from the College of Engineering Cherthala in 2012 and 2014. She is currently working as Assistant Professor and doing her Ph.D. under the Department of Computer Science Engineering in School of Engineering at Presidency University, Bangalore, Karnataka, India. She has published many articles in CSI India Magazine, Scopus indexed Journals. Her research area includes Supply Chain Management, Internet of things and Machine Learning.

Shaik Hussain Shaik Ibrahim, is currently working as an Assistant Professor in the School of Computer Science and Engineering, Reva University, Bangalore, Karnataka, India. He received his Bachelor’s degree in Information Technology from Anna University Coimbatore, TamilNadu, India in 2011, Master’s degree in Computer Science and Engineering from Anna University, Chennai, TamilNadu, India in 2015 and Ph.D degree in Computer Science and Engineering from Anna University, Chennai, TamilNadu, India in 2020. His research area includes Data Mining, Machine Learning and Optimization Algorithm.