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](image1)

- Initialize forest with 0 aged trees
- Perform local seeding on 0 aged trees
- Population limiting and form the candidate population
- Global seeding is performed on selected trees from the candidate population
- Update the best tree and display the order of arrangement of variables

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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 $N_{\text{var}}$ 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 $1 \times (N_{\text{var}} + 1)$ where $N_{\text{var}}$ is the dimension of the problem and “Age” represents the age of the related trees.

Tree $= \langle \text{Age}, v_1, v_2, \ldots, v_{N_{\text{var}}}, \rangle$

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 tree is 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 $X= (\text{age}, v_1, v_2, v_3, \ldots, v_n)$ 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 $dx \cdot dx \in [-\Delta x, \Delta x]$ 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 2.1: Local Seeding

Input: (Total trees in the forest)

Output: perform local seeding operation on trees with age=0.

Fitness value for each tree in the forest

<table>
<thead>
<tr>
<th></th>
<th>x1</th>
<th>y1</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>f(x) min{x, y</td>
<td>x, y ∈ (-5,5)}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>x1</th>
<th>y1</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Step 1.2: Age assigning

<table>
<thead>
<tr>
<th>x1</th>
<th>y1</th>
<th>Age</th>
</tr>
</thead>
<tbody>
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Input: (Total trees in the forest)

Output: perform local seeding operation on trees with age=0.

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<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Step 2.2: Population Limiting

Input: (Trees generated in local seeding)

Output 1: Remove the trees, age bigger than lifetime

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

Input: (Trees in the candidate population)

Step 2.3: Global Seeding

Output 2: (Modification of elected candidates)

Step 2.4: Updating Best Tree

Output 2: (Selection of best trees)

Step 3: Global Seeding

Output 3: (Selection of best trees in candidate population)
### Step 3: Best Tree Finding

The best is updated to: [0.29316238 - 0.1330737] (0.103450215865981)

Restoring the age of the best. The best is: [0.29316238 - 0.1330737] (0.103450215865981)

**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)

### Step 3: Best Tree Finding

The best is updated to: [0.29316238 - 0.1330737] (0.103450215865981)

Restoring the age of the best. The best is: [0.29316238 - 0.1330737] (0.103450215865981)

**Generation - 2**

### Step 2.2: Population Limiting

**Input:** (Trees generated in local seeding)

**Output 1:** (Remove the trees, raise bigger than lifetime)

### Step 2.2: Population Limiting

**Input:** (Trees generated in local seeding)

**Output 1:** (Remove the trees, raise bigger than lifetime)

| 234.8867406637085 | 2.6892731962417428 | 0.10290996351451 | 22.43087935799770 | 0.10290996351451 |
| 24.3289407579439 | 0.016415924117442 | 0.577481398778858 | 0.016415924117442 | 0.577481398778858 |
| 2.7483108015726777 | 4.568924599978875 | 0.016415924117442 | 0.577481398778858 | 0.016415924117442 | 0.577481398778858 |
| 2.6982731962417428 | 0.10290996351451 | 0.10290996351451 | 22.43087935799770 | 0.10290996351451 |
| 108.07405710328852 | 5.0 | 0.10290996351451 | 22.43087935799770 | 0.10290996351451 |
| 0.38842641957307 | 0.016415924117442 | 0.577481398778858 | 0.016415924117442 | 0.577481398778858 |
| 2.43087935799770 | 0.10290996351451 | 0.10290996351451 | 22.43087935799770 | 0.10290996351451 |
| 0.12678969162478365 | 15.3643898497282 | 0.10290996351451 | 22.43087935799770 | 0.10290996351451 |
| 9.05887132831524 | 0.016415924117442 | 0.577481398778858 | 0.016415924117442 | 0.577481398778858 |
| 2.43087935799770 | 0.10290996351451 | 0.10290996351451 | 22.43087935799770 | 0.10290996351451 |
| 1.62778969162478365 | 15.3643898497282 | 0.10290996351451 | 22.43087935799770 | 0.10290996351451 |
### Step 3: Best Tree Finding

The best is updated to \( 0.0275052 - 1.04561065 \) \((1.09405815794243)\) Restoring the age of the best.

## V. CONVERGENCE OF FOREST OPTIMIZATION 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.
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


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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.

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