Improving the Lion Optimization Algorithm: Proposal

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1 Introduction

The main feature of the Lion Optimization Algorithm is its degree of adaptability tightly coupled on the parameters used. Depending on the fitness function and parameters used, it could find a sweet spot in between to have better performance than other algorithms. An improvement is made to extend the functionality of the Optimization Algorithm. The improvement utilizes more information that is generated within the algorithm to further improve on its functionality.

The improvement is done across multiple sections of the algorithm to improve the overall performance of every run. Most of this improvements are also modeled heuristically after lions, their influence to another, their nature and broadly, evolution in general.

2 Group Direction in Prides

The best position in the pride influences where lions in a pride would roam. When doing roaming, female and male lions would have a bit of influence from the direction and distance to the best position in the pride.

This group influence is seen among lions as peers tend to swarm with each other and most lions that stray away from the pride will get attracted to where the most of his peers are located.

A new variable will be introduced, %I which will determine how much the direction of the lion will be influenced by the direction to the best position of the pride. The new modified roaming equation would be:

$$\text{Lion}' = \text{Lion} + 2D \cdot rand(0,1)(R1 \cdot (1 - \%I) + R3 \cdot \%I) + U(-1,1) \cdot \tan(\theta) \times D \times R2$$
$$\text{where } R1 \cdot R2 = 0, ||R2|| = 1$$

where Lion and Lion' is the previous and next position of the lion, respectively, and D is the distance between the lion's position and the selected point chosen by tournament selection in the pride's territory. The following figure shows the range of possible next positions of the lion.

A newly included variable $R3$ will represent the direction vector from the Lion's position to the best position in the pride. $R3$ can be represented by:

$$R3 = \frac{(\text{GBest} - \text{Lion})}{||\text{GBest} - \text{Lion}||}$$

where GBest is the best position in the pride.

3 Fitness Weighted Mating

Averaging between males in preparation for mating can be improved by weighing fitness values so that a better gene could be created to be used in mating with a female. The best male lion among suitors in mating will have more influence on the traits of the offsprings.

To produce better offsprings, nature has always arranged the better fit organisms to survive. In order to find better offsprings, female organisms would look for better fit organisms among the crowd to mate. To better model this trait in mating between multiple male lions to a female lion. The gene of the best male lion should better influence the gene of the offsprings.

To simulate this effect, an equation similar to inverse distance weighting [1] is created that instead uses fitness difference as basis to create a position that has a weighted average that relies more on better fit positions from multiple males.

$$\text{Lion Average} = \frac{\displaystyle\sum_{i=1}^{n} \left(\frac{\text{Lion}_i}{f_{\text{fem}} - f(\text{Lion}_i)} \right)}{\displaystyle\sum_{i=1}^{n} \left(\frac{1}{f_{\text{fem}} - f(\text{Lion}_i)} \right)}$$

where n is the number of male lions, Lion_i is the male lion's best position, f_{fem} is the mating female lion's current fitness and Lion Average is the weighted average of the positions between the male lions based on their fitness.

4 Simulated Annealing in Nomads

A simple mechanism would be added to not accept lions fit below a lower bound in nomad lions. The lower bound would be updated regularly such that lions that are bound to become nomad would be removed from the set of solutions if they do not meet the current lower bound of the nomads.

Nomad lions have to rely on themselves. They don't have territories, they are always moving and they need to adapt to changes to the environment otherwise they die from it. This is a defining process of evolution.

To simulate this trait in the algorithm, a lower bound defined by the current least fit nomad is made. In every iteration this lower bound is updated and lions that are to be added to nomads are checked if they're fitness is greater than the lower bound fitness (meaning they are less fit). If they are less fit, they are removed from the whole set of solutions. The procedure is as follows:

$$\begin{cases} \text{Remove Lion} & \text{if} f(\text{Lion}) > f_{LB} \\ \text{Add Lion to Nomads} & \text{otherwise} \end{cases}$$

where f_{LB} is the current lower bound fitness of the nomad group.

5 Improved Ranked Selection Randomization

In selecting lions in a group sorted by fitness, with the best fit at the least index, the random selection of lions listed in a ranked order can be improved. By raising the random function that selects a number between 0 to 1 (inclusive) to a power k there will be higher chances for lower indexes in the list which represents better fit lions to be selected.

The new algorithm should adopt a new random selection function that allows to selects more higher fit lions than other lesser lions. The new $rand(0,1)$ function will be modified for a new function

$$rand(0,1,K) = U(0,1)^K$$

where $U(0,1)$ is a random number between 0 to 1 with uniform distribution.

A new variable K will be introduced to the algorithm. This will represent the degree to which the random selection curve will tend to lean. When $K > 1$, the random selection function will produce more lower indices that has better fit lions. When $K = 1$, the function will be back to its normal setting. When $K < 1$, the function will produce more higher indices.

6 Center Based Per Axis Randomization

Generating new points can be improved by randomizing based on a central point in the search space. Points far from the center point should be generated at lesser quantities and points near the center should be generated at greater quantities. **This section focuses on a new center based randomization method that improves finding more points that are either near or far a "hotspot" or a central point.**

In the algorithm, nomads either stay in their positions doing nothing or reset to a new position in every iteration. This can be improved by introducing a new randomization method that can randomize a new position based on the previous position. In this improvement, Nomad lions either roam around a place to "stay" or find a new place.

The nomad lion roaming can be improved by changing the nomad lion roaming equation to

$$\text{Lion'}_{ij} = \begin{cases} \text{RANDC}(\text{Lion}_{ij}) & \text{if } \text{rand}(0,1) > pr_i \\ \text{RAND}_j & \text{otherwise} \end{cases}$$

such that RANDC is a new function to be added to the algorithm such that:

$$\begin{aligned} \text{RANDC}(\text{Lion}_i j) = \text{Lion}_{ij} &- (\text{Lion}_{ij} - \text{LB}) \cdot |\min(0, U_{\text{-1 to 1}})|^{\text{deg}} \\ &+ (\text{UB} - \text{Lion}_{ij}) \cdot \max(0, U_{\text{-1 to 1}})^{\text{deg}} \end{aligned}$$

where LB is the lower bound or the "minimum" of the search space, UB is the upper bound or the "maximum" of the search space, deg is the degree of nearness of the generated points to the center and $U_{\text{-1 to 1}}$ is a random number between -1 to 1 with uniform random distribution.

The points that are near to the axis of the center point are more likely to be generated than those that are far from the center point when the 'deg' is greater than 1. When 'deg' is less than 1, points far from the center point are generated more while when 'deg' is 1, it is generating a uniform random number only.

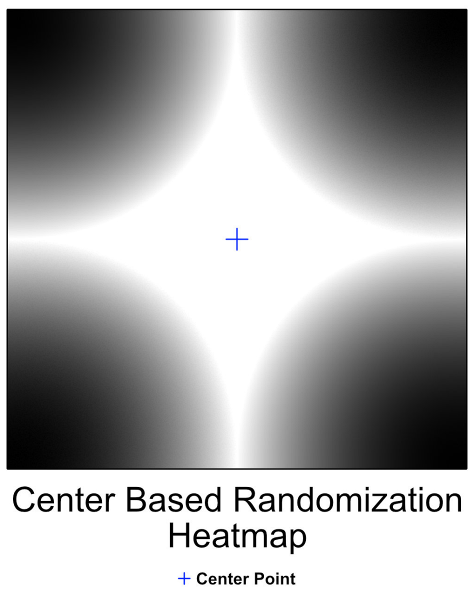

Figure 1: Heat map of a 2D area of points that are more likely to less likely to be generated from light to dark based on a center point

References

[1] NSF National Center for Geographic Information and Analysis interpolation: Inverse distance weighting. http://www.ncgia.ucsb.edu/pubs/spherekit/inverse.html. Accessed: 2019-02-05.