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An Effective Algorithm Using Moth Flame Optimization (MFO) for Numerical Expression Solutions

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ABSTRACT

The Moth Flame Optimization (MFO) algorithm is a member of the swarm intelligence family that is utilised to tackle complex optimization problems in various real-world domains. MFO, along with its different variations, offers simplicity in understanding and ease of operation. These algorithms have exhibited great success in solving optimization problems across diverse fields such as power and energy systems, engineering design, economic dispatch, image processing, and medical applications. This comprehensive review explores the different variants of MFO, encompassing the classic version, binary types, modified versions, hybrid versions, multi-objective versions, and the application aspect of the MFO algorithm in different sectors. Furthermore, the evaluation of the MFO algorithm is presented to assess its performance relative to other algorithms. The primary focus of this literature is to provide a survey and analysis of MFO and its applications. Additionally, the concluding remarks section delves into potential future research directions for the MFO algorithm and its variants.

KEYWORDS: Moth flame Optimization (MFO), Moth flame Optimization algorithm (MFOA), complex Optimization, Analysis of MFO,Applications.

1. sINTRODUCTION

Moth-flame optimization algorithm is a new metaheuristic optimization method, which was proposed by Seyedali Mirjalili in 2015 and based on the simulation of the behaviour of moths for their special navigation methods at night . They utilise a mechanism called transverse orientation for navigation. In this method, a moth flies by maintaining a fixed angle with respect to the moon, which is a very effective mechanism for travelling long distances in a straight path because the moon is far away from the moth. This mechanism guarantees that moths fly along a straight line at night. However, we usually observe that moths fly spirally around the lights. In fact, moths are tricked by artificial lights and show such behaviour . Since such light is extremely close to the moon, hence, maintaining a similar angle to the light source causes a spiral fly path of moths. In the MFO algorithm, Moths fly around flames in a Logarithmic spiral way and finally converge towards the flame . Spiral way expresses the exploration area and it guarantees to exploit the optimum solution. Optimization refers to the process of finding the best possible solution(s) for a particular problem. As the complexity of problems increases, over the last few decades, the need for new optimization techniques becomes evident more than before . Mathematical optimization techniques used to be the only tools for optimising problems before the proposal of heuristic optimization techniques. Mathematical optimization methods are mostly deterministic that suffer from one major problem: local optima entrapment. Some of them such as gradient-based algorithms require derivation of the search space as well. This makes them highly inefficient in solving real problems.

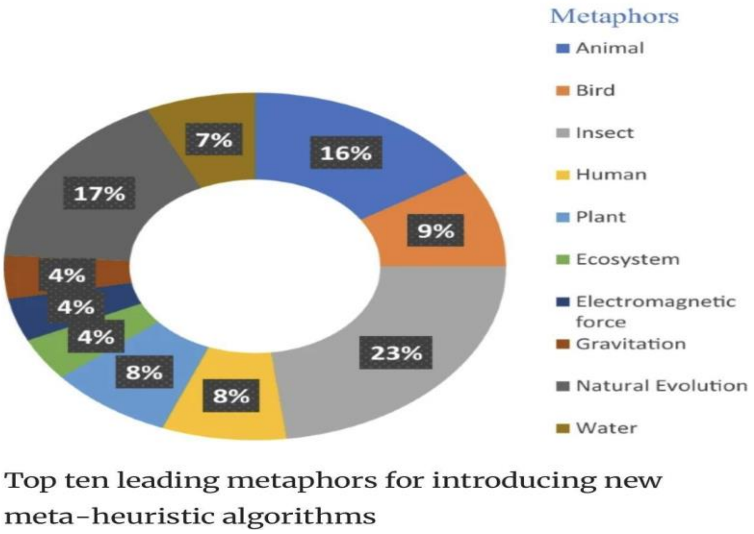

FIGURE 1.1 - META - HEURISTIC ALGORITHMS

1.2 INSPIRATION:

Moths belong to the class of insects called the phylum Arthropoda. They have two pairs of broad wings covered in tiny scales, are purely nocturnal, and like all insects, have a head, two antennae, a thorax, six legs, and an abdomen. The moths have unique navigation techniques that have caught metaheuristics researchers' interest. Typically, moths are night travellers using the moonlight for navigation. The navigation pattern of moths can be modelled using the transverse orientation mechanism. The flight pattern is such that a crosswise inclination is maintained by keeping a constant angle with the moon to maintain a straight path journey. The moths use the distance from the flame to achieve efficient navigation, meaning as the distance between them decreases, a helix path motion is activated to connect the moth with the flame.

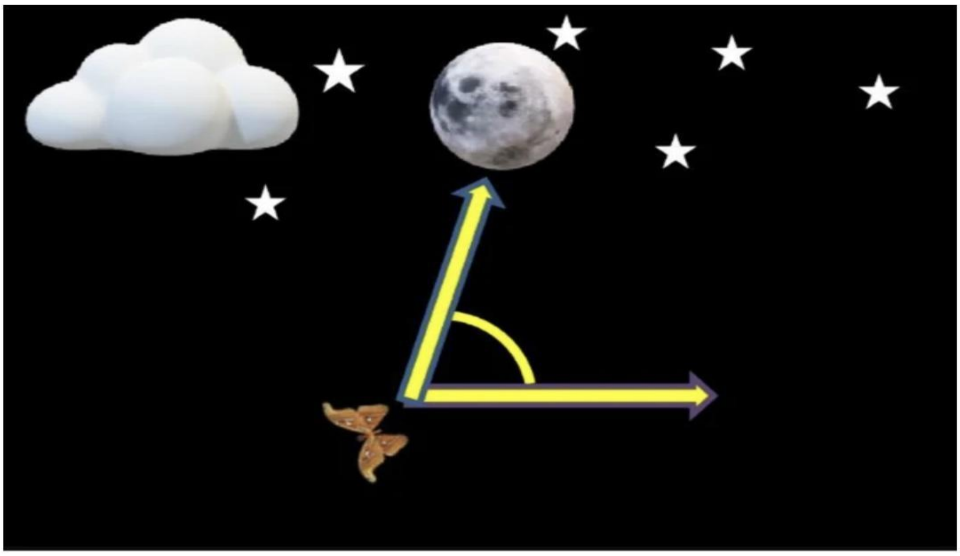

FIGURE 1.2 : NAVIGATION PATTERN OF MOON .

2. NSPIRATION OF MOTH FLAME OPTIMIZATION ALGORITHM:

In sufi literature one of the most loved metaphors is moth and flame. The moth's annihilation into the flame has been drawn again and again as an analogy for the seeker in the sufi path who seeks annihilation into Divine Essence. The sufistic term for the annihilation or passing away into Divine is Fana.

FIGURE 2.1 : INSPIRATION OF MFO

Like all insects, moths have a body with three main parts – head, thorax and abdomen. Moths have three pairs of jointed legs on the thorax . Moths are also characterised by their two pairs of large, scale-covered wings and by mouthparts that form a long proboscis for sipping nectar. Moths have compound eyes and two antennae .

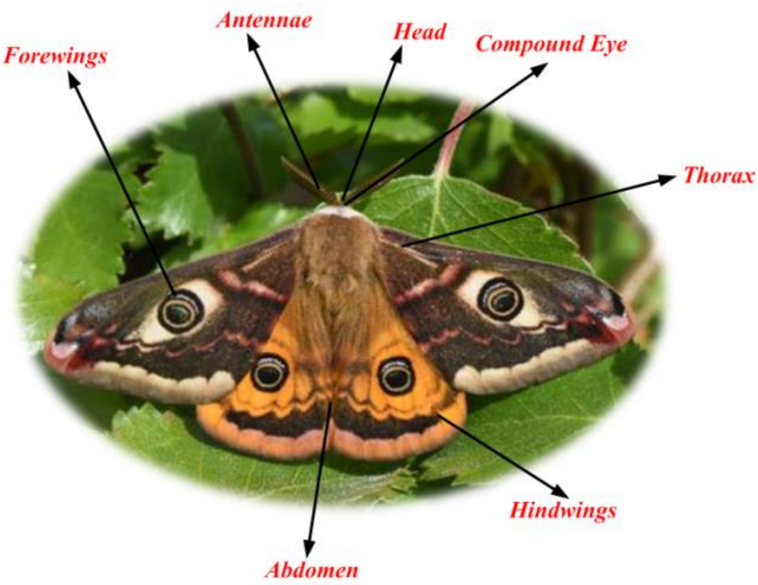

FIGURE 2.2 : MOTH STRUCTURE.

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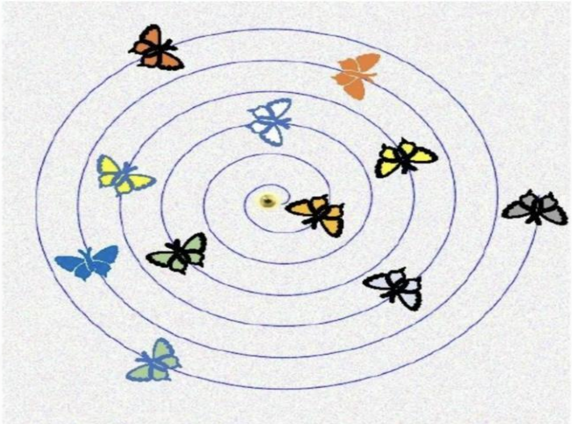

FIGURE 2.3 : SPIRAL MOVEMENT OF MOTH AROUND FLAME.

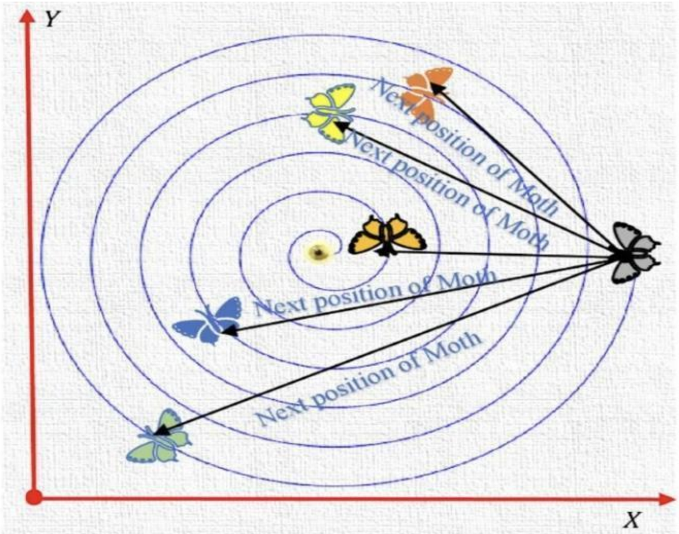

FIGURE 2.4 - POSITION OF MOTH .

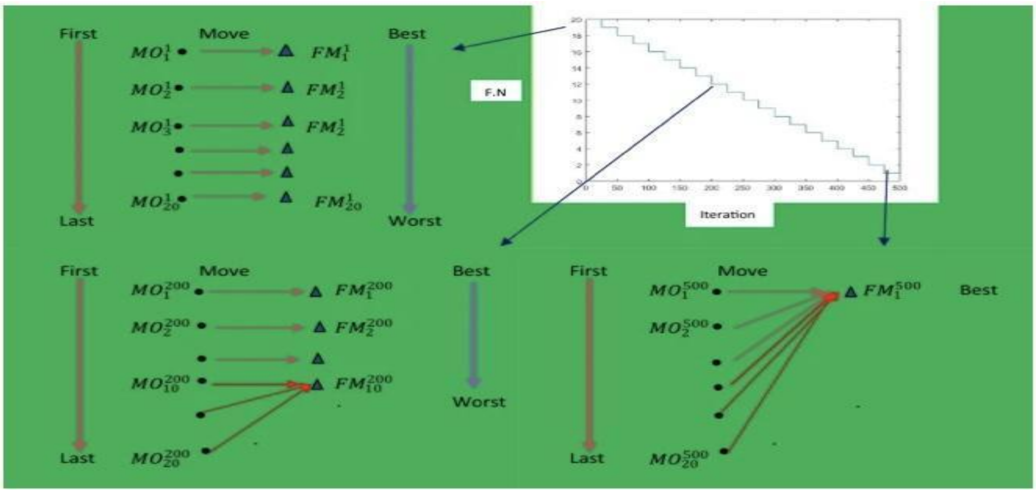

FIGURE 2.5 - VISUALIZATION OF THE MFO ALGORITHM OVER 500 ITERATIONS.

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3. MOTH FLAME OPTIMIZATION ALGORITHM (MFO) : -

Moths are fancy insects, which are highly similar to the family of butterflies. Basically, there are over 160,000 various species of this insect in nature. They have two main milestones in their lifetime: larvae and adult. The larva is converted to moth by cocoons. The most interesting fact about moths is their special navigation methods at night . They have been evolved to fly at night using moonlight. They utilised a mechanism called transverse orientation for navigation. In this method, a moth flies by maintaining a fixed angle with respect to the moon, a very effective mechanism for travelling long distances in a straight path. Since the moon is far away from the moth, this mechanism guarantees flying in straight line. The same navigation method can be done by humans. Suppose that the moon is in the south side of the sky and a human wants to go to the east. If he keeps the moon on his left side when walking, he would be able to move toward the east in a straight line . Despite the effectiveness of transverse orientation, we usually observe that moths fly spirally around the lights. In fact, moths are tricked by artificial lights and show such behaviours. This is due to the inefficiency of the transverse orientation, in which it is only helpful for moving in a straight line when the light source is very far .

When moths see a human-made artificial light, they try to maintain a similar angle with the light to fly in a straight line. Since such a light is extremely close compared to the moon, however, maintaining a similar angle to the light source causes a useless or deadly spiral fly path for moths.

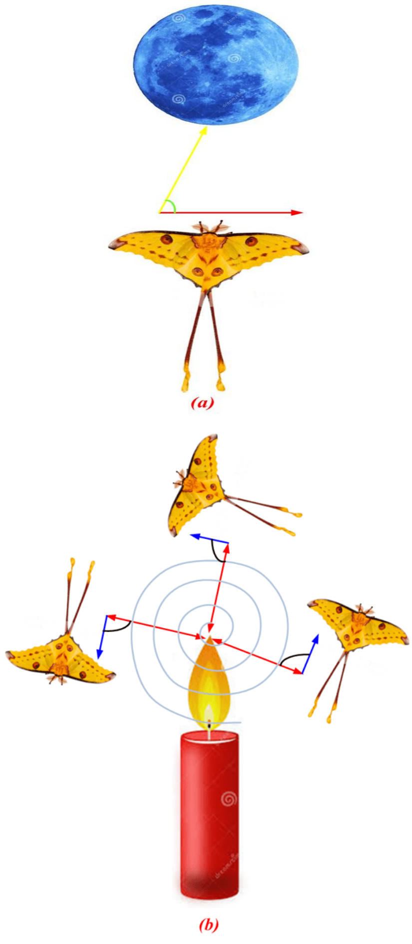

FIGURE 3 : - MOTH FLAME OPTIMIZATION ALGORITHM.

3.1 - STEPS FOR MOTH FLAME OPTIMIZATION :-

- Parameter Setting
- Population Initialization

- Fitness function
- Iteration process
- Optimal selection

3.1.1 - PARAMETER SETTING :

A parameter is a limit. In mathematics a parameter is a constant in an equation, but parameter isn't just for math anymore: now any system can have parameters that define its operation. You can set parameters for your class debate .

3.1.2 - POPULATION INITIALIZATION :

The MFO is one of the recent meta-heuristic optimization techniques. MFO algorithm imitates the navigation method of moths in the night. In this algorithm, the moths are the candidate solutions and the moths' positions are the problem's parameters. In this way, moths can fly in I-D, 2-D, 3-D, or hyper dimension space by exchanging their position vectors.

3.1.3 - FITNESS FUNCTION:

For the fitness function was a measure to determine the goodness or quality of a single solution in a population. At the end of each iteration, fitness value is calculated for each agent for evaluating quality search.

3.1.4 -ITERATION PROCESS :

An iterative process, or on-going process, is systematic repetition of sequences or formulas that aims to achieve a given result. It is a process where different data is tested until the desired result is obtained.

3.1.5 - OPTIMAL SELECTION :

For each iteration, update the position and fitness of moths and flames according to. Moths update their positions in hyper spheres around the best solutions obtained so far. The sequence of flames is changed based on the best solutions in each iteration, and the moths are required to update their positions with respect to the updated flames. When the iteration criterion is satisfied, the best moth is returned as the best obtained approximation of the optimum.

3.2 - FLOW CHART OF MFO :

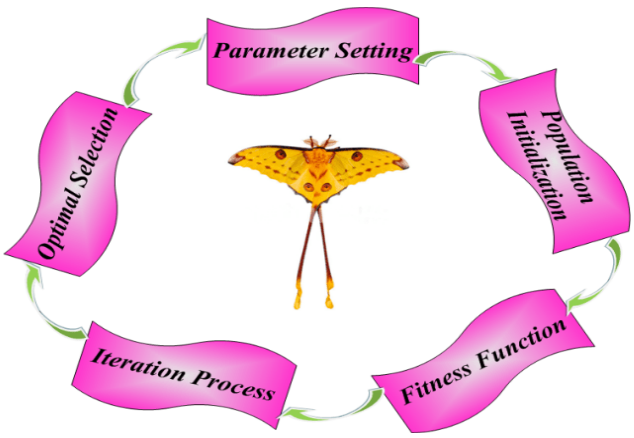

FIGURE 3.2 - FLOW CHART OF MFO .

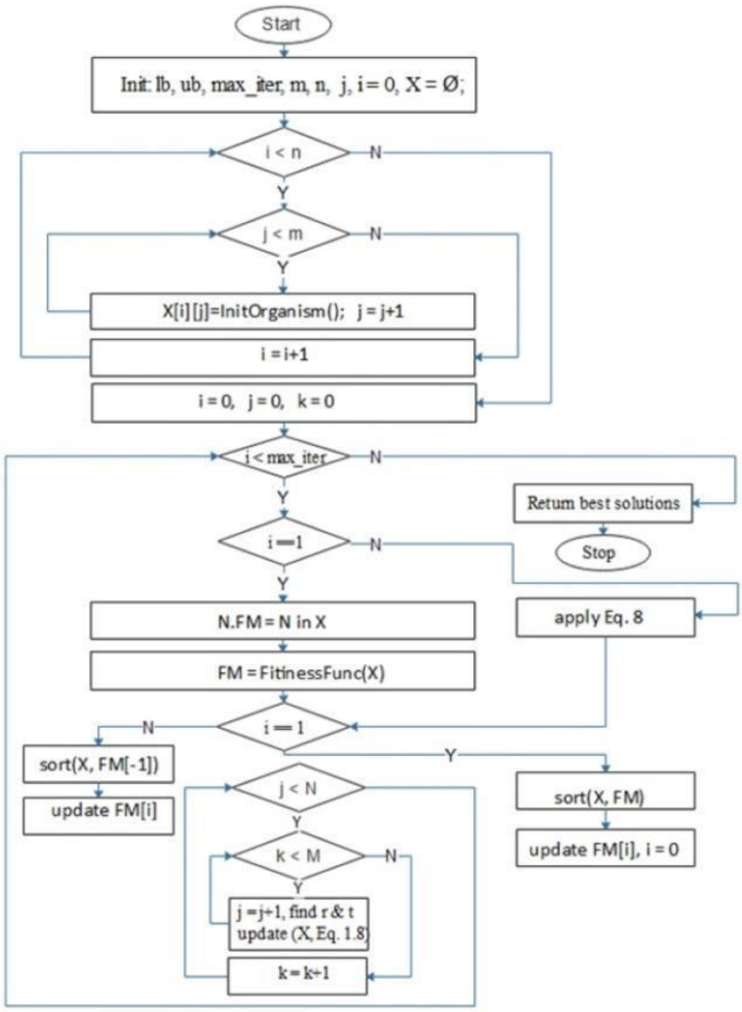

FIGURE 3.3 : FLOW CHART OF THE MFO ALGORITHM.

4. NUMERICAL EXPRESSION OF MFO :

Moth flame algorithm Numerical expressions are given,

1. The mathematical model of this problem is as follows.
Min $f(x) = 0.6224X_1X_3X_4 + 1.7781X_2X_3^2 + 3.1661X_1^2X_4 + 19.84X_1^2X_3$
$0 \le X_1 \le 99$
$0 \le X_2 \le 99$
$10 \le X_3 \le 200$
$10 \le X_4 \le 200$
$f(x) = 0.6224 * 90 * 150 + 1.778 * 40(90)^2 + 3.1661(20)^2 * 150 + 19.84(20)^2 * 90$
$= 8402.4 + 576072 + 189966 + 714240$
$= 1488680.4$
The mathematical model of this problem is as follows.
2. Min $f(x) = 1.10471\ X_1^2X_2 + 0.04811\ X_3X_4(X_2 + 14)$
$0.1 \le X_1 \le 2$
$0.1 \le X_2 \le 10$
$0.1 \le X_3 \le 10$
$0.1 \le X_4 \le 2$
$f(x) = 1.10471(0.5)^2 * 5 + 0.04811 * 7 * 0.6\ (5 + 14)$
$= 1.38 + 3.839$
$= 5.219$
3. The mathematical model of this problem is as follows.
$f(x) = (X_3 + 2)\ X_2X_1^2$
$0.05 \le X_1 \le 2.00$
$0.25 \le X_2 \le 1.30$
$2.00 \le X_3 \le 15.0$
$f(x) = (10 + 2)\ 0.75 * (1)^2$
$= 12 * 0.75 * 1$
$= 9$

FIGURE 4. : NUMERICAL EXPRESSION OF MFO.

5. APPLICATION OF MFO :

- Training multi-layer preceptors
- Optimal Power Flow
- Tomato diseases detection
- Terrorism detection
- Annual power load forecasting
- Feature selection
- Multi area power system
- Automatic Test Generation

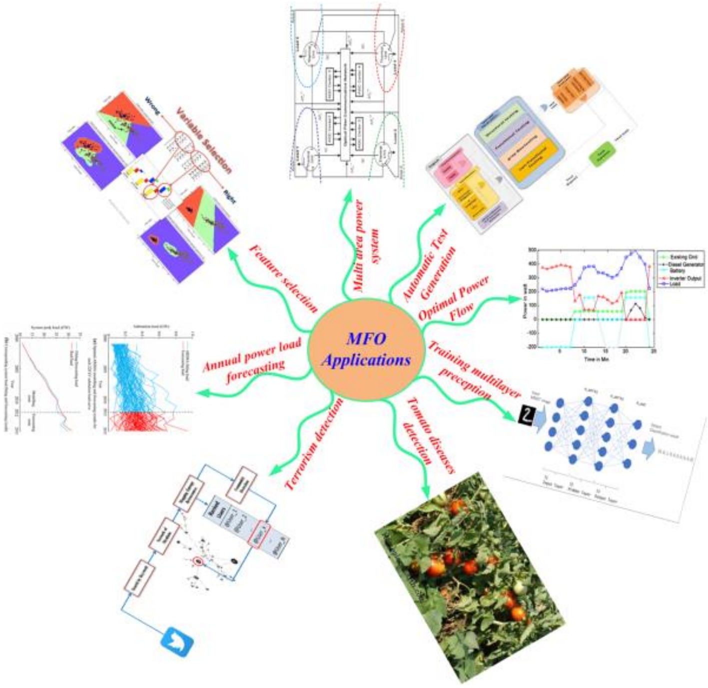

FIGURE 5.1: APPLICATIONS OF MFO.

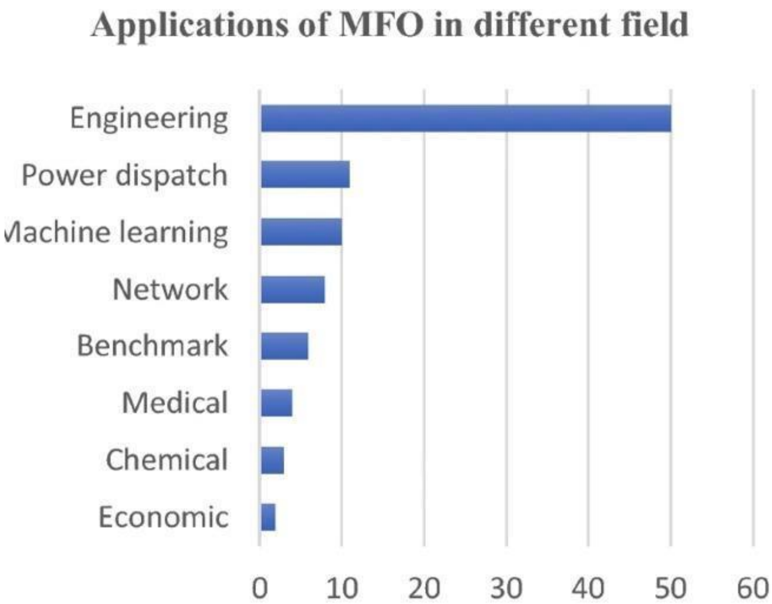

FIGURE 5.2 : DISTRIBUTION OF MFO IN VARIOUS FIELDS.

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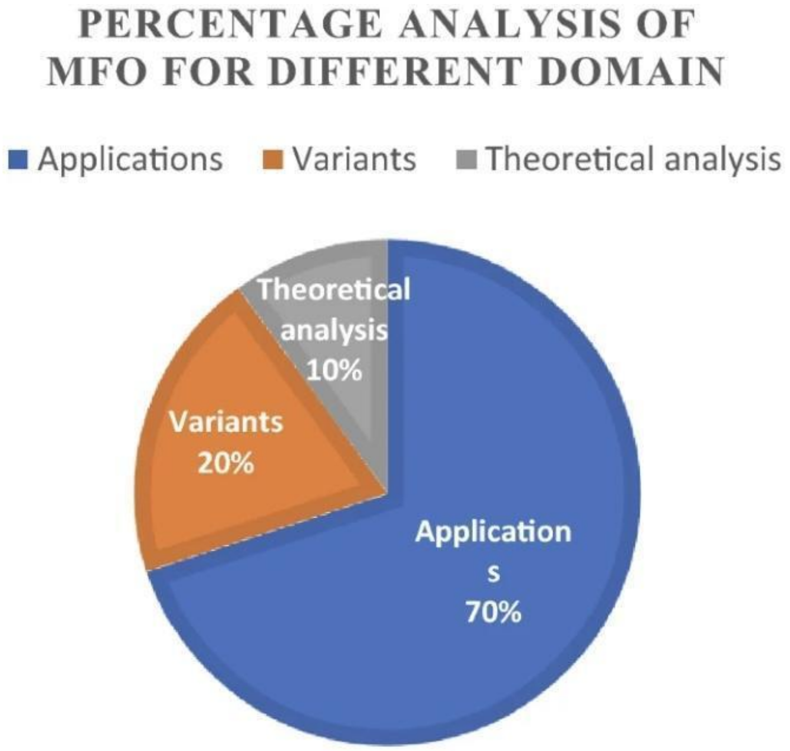

FIGURE 5.3 : MODIFICATION OF MFO IN PERCENTAGE.

5.1 - IMPROVEMENTS OF MFO ALGORITHM:

A new version of the MFO algorithm, EMFO, based on the mutualism phase of symbiotic organism search, has been proposed. The authors added the mutualism phase of SOS after the position update phase of the basic MFO algorithm to get better quality solutions. The suggested EMFO was evaluated against a wide range of other state-of-the-art metaheuristic algorithms and MFO versions. The EMFO has also been used to tackle seven engineering design problems. The obtained results proved that the suggested EMFO outperforms among other competitive algorithms in terms of solution quality and convergence rate.Sahoo et al. (2022) proposed a novel improved MFO algorithm named m-DFMO by using modified dynamic opposition learning (DOL) strategy to accelerate the convergence rate and helps in removing local optima stagnation. In the beginning, the authors modified the basic DOL strategy with the help of simple quadratic interpolation and embedded it after the position update phase of the MFO algorithm. To measure the efficiency of the newly m-DMFO algorithm, it was tested on a wide range of benchmark functions and a few engineering design problems. Furthermore, the diversity of the m-DMFO algorithm was analysed. From the overall experimental evaluations and diversity analysis, it can be seen that the suggested algorithm outperforms among other algorithms and achieves a good trade-off between diversification and intensification.

6. ADVANTAGES OF MFO :

- Population-based algorithms have high ability to avoid local optima since a set of solutions are involved during optimization.
- ILS is an improved hill climbing algorithm to decrease the probability of trapping in local optima .
- Hill climbing is also another local search and individual-based technique that starts optimization by a single solution.

- Although different improvements of individual-based algorithms promote local optima avoidance, the literature shows that population-based algorithms are better in handling this issue.
- A right balance between these two milestones can guarantee a very accurate approximation of the global optimum using population-based algorithms.

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