IJARCCE ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 12, December 2021

DOI: 10.17148/IJARCCE.2021.101232

New Optimization Techniques used in Robotics

Gurjeet Singh[1], V. K. Banga[2]

Research Scholar I.KG Punjab Technical University, Punjab, India[1]

Professor & Principal, AGC, Amritsar, Punjab, India[2]

Abstract: It's very difficult to find the solution of Inverse Kinematics (IK) by using the conventional method. The main problem in solving the inverse kinematics by using older method is that it gives multiple solution. Many problems are continuous in the real world and finding the global solutions is difficult. Optimization is one of that solution. In this paper the different optimization techniques are discussed for trajectory planning and the obstacle avoidance for different DOF robot. With the help of different optimization techniques, the artificial robots are made. The capabilities of artificial intelligence techniques are explored in order to find the optimal solution without using much complex mathematics while using this technique. Here forward and inverse kinematics problems, position and joint displacement errors, velocity, acceleration and time are the main variables to be considered for optimization.

Keywords: kinematics, Robotics arm, robotics manipulator, optimization

[1]. INTRODUCTION

Optimization play an important role in robotics. The problem of kinematics has been solved by optimization. Kinematics play an essential role in robotics. In Robotics, if the joints variables are known then the position, and orientation of the end-effecter for the base to be computed, can be referred to as the Forward kinematics (FK) problem. Similarly, if position and direction have been given, calculate all possible sets of joint variables, called the Inverse kinematics (IK) problem. The solution of the kinematic Equations is nonlinear, so a unique elucidation cannot be obtained certainly. This gives rise to multiple solutions. An essential part of robot end effector is to reach the target position accurately. To obtain the above solution accurately, the knowledge of IK is required. The IK solution is an essential part of any industrial manipulator. Many researchers work on the getting an IK solution. A robotic manipulator consists of rigid links connected with revolute or prismatic joints to achieve the target.

[2]. OPTIMIZATION TECHNIQUES USED IN ROBOTICS

Different optimization techniques are used in robotics to find the solution of inverse kinematics.

A. Dragon Fly Optimization (DFO)

A novel swarm intelligence optimization technique is proposed called the dragonfly algorithm (DFO). The main inspiration of the dragonfly algorithm originates from static and dynamic swarming behaviors of dragonflies in nature [1]. Two essential phases of optimization, exploration, and exploitation, are designed by modeling the social interaction of dragonflies in navigating, searching for foods, and avoiding enemies when swarming dynamically or statistically. Dragonflies create sub swarms and fly over different areas in a static swarm, which is the main objective of the exploration phase [2]. However, in the static swarm, dragonflies fly in more enormous swarms and along one direction, which is favorable. [3].

B. Butterfly optimization algorithm (BOA)

It is a novel population-based metaheuristics algorithm that mimics butterflies' foraging behavior. BOA has been applied to many fields. It is inspired by the foraging and matting behavior of butterflies [4]. This is used to solve global optimization problems. In nature, there are approx. 18000 butterfly species. Butterflies used their sense of smell, hearing, and touching to find food, lay an egg, and escape from predators [5].

In this algorithm, butterflies act as a search agent, and they generate the fragrance that is our fitness value. This value is changing as butterflies move from one place to other. When it senses the scent from another butterfly, it moves toward it that is a global search, and when it is not able to see from the surrounding, it will move randomly, that is a local search. Each butterfly emits some fragrance that helps them to attract others. Depending upon the scent, butterflies move toward either each other or randomly [6].An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.

C. Ant colony Optimization (ACO)

Marco Dorgio developed it in 1992 to find the optimal solution. ACO is the swarm intelligence approach used to solve combinatorial optimization problems [7]. This technique is used to solve several problems. The idea of this technique came from the biological organism to communicate with each other. In this technique, the ant moves in a different direction to search the food, and once they find the food, they mark the path with a pheromone [8]. The quality of the pheromone depends upon the food quality. Other's ants follow the same pheromone to reach the food [9].

D. Ant Lion Optimizer

It is a novel nature-inspired algorithm. It employs the smart behaviour of antlions in hunting ants. Ant lions' life is divided into two phases: the larva stage and adulthood. The essential characteristic of the larva stage is hunting. The ant lion larvae dig a trap in the sand, which takes the form of a cone by going in a circular motion and throws sand outside the web, the area using its massive jaws. The size of the trap depends on two factors; the hunger level and the moon shape. After digging a trap, the larvae disappear beneath the bottom of the cone and wait for their preferable prey (ants) to be trapped in the hole. Once the ant lion understands that the target is in the trap, it attempts to catch it. However, insects usually try to escape from the cone and are not caught immediately. In this case, the ant lion throws sand intelligently toward the edge of the trap until the prey slides toward the bottom of the hole again. When the target slips to the bottom of the hole and is caught by the jaw, it is pulled under the soil and consumed. After consuming prey, ant lions throw food scraps out of the hole and adjust the gap to hunt other prey. Based on this description of the ant lion hunting process, a set of conditions can be formulated as in the following items

- Preys (ants) move randomly around the search space. These moves are affected by the traps of ant lions.
- The highest fitness ant lion builds an enormous pit.
- Catching an ant by an ant lion is proportional to the fitness of that ant lion.
- Each ant lion can catch an ant in each iteration.
- To simulate sliding ants toward ant lions, the range of random walks is decreased adaptively.
- If an ant becomes fitter than an ant lion, it is caught and pulled under the soil by the ant lion.
- An ant lion repositions itself to the latest caught prey and builds a pit to improve its chances of catching another prey after each hunt [10], [11].

E. Cuttlefish Algorithm

It is a meta-heuristic bio-inspired optimization algorithm. To solve numerical global optimization problems to find the optimal solution. The algorithm mimics the mechanism of color-changing behavior used by the cuttlefish [14].
The patterns and colours of the cuttlefish are produced by reflected light from three different layers of cells. The proposed algorithm considers mainly two processes: reflection and visibility. The reflection process simulates the light reflection mechanism used by these layers, while the visibility process simulates the visibility of matching patterns of the cuttlefish. In this algorithm, the population is divided into four groups. Two groups were used as a local search and the remaining two groups as global search, and each group shared the best result. Cephalopod is an example of a cuttlefish. Chromatophores, leucophores and iridophores are the three layers of the Cephalopods. Due to these three layers, it shows different colors, The colors seen by the cephalopods.
1. Chromatophores: Chromatophores are groups of cells that include an elastic saccule that holds a pigment, as well as 15-25 muscles attached to this saccule [16]. When the muscles contract, they stretch the saccule allowing the pigment to cover a larger surface area. When the muscles relax, the saccule shrinks and hides the pigment [16].
2. Iridophores: They are found in the next layer under the chromatophores. Iridophores work by reflecting light and can conceal organs, as is often the case with the silver coloration around the eyes and ink sacs. Additionally, they assist in concealment and communication.
3. Leucophores: These cells are responsible for the white spots occurring on some cuttlefish, squid, and octopus. Leucophores are flattened, branched cells that are thought to scatter and reflect incoming light. In this way, the color of the leucophores will reflect the predominant wavelength of light in the environment [17]. In white light, they will be white, whereas, in blue light, they will be blue.

F. Cuckoo Optimization Algorithm

Yang and Deb developed it in 2009 that was inspired by nature. It is based on the life of a bird called a cuckoo [19]. In this algorithm, a primary population, a group of cuckoos. The basis of this novel optimization algorithm is the Specific breeding and egg-laying of this bird. Adult cuckoos and eggs were used in this modeling. Adult cuckoos lay eggs in other birds' habitats. Those eggs grow and become mature cuckoos if they are not friends and not removed by host birds [20]. The immigration of cuckoos and environmental specifications hopefully leads them to converge and reach the best place for reproduction and breeding. The global maximum of objective functions is in this best palace. Each egg in the nest represents the solution. So, the number of eggs in the nest is the number of the resolution, and the cuckoo egg is the new solution. The best next with good quality of eggs will carry over to the next generation. High-quality eggs represent the best solution near-optimal value. The egg, which is more similar to the host egg, has the probability of getting a mature cuckoo. A new and better solution will replace the less fit solution. The number of hosts next represents the population, and the number of hosts that discover the cuckoo bird represents the worst solution, different from the optimal solution [22], [23].

G. CROW search algorithm

Crow search Algorithm is one of the metaheuristic optimization algorithm introduced by Askarzadeh. CSA is a population-based process. It is inspired by the intelligent behavior of the crow and their social interaction [24]. They are living in the flock. Crows are smart to store excess food at hiding places and retrieve the hidden foods even after a long

ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 12, December 2021

DOI: 10.17148/IJARCCE.2021.101232

time. Other crows see the hiding palace of the other crow and steal the food, so if one crow feels like this that other crow following it, they change the path from the food hiding palace to distract the following crow. CSA's earlier results show that it has the potential to solve various complex engineering-related optimization problems. In the Initialization stage, the group's crow represents the search agent(solution) in the population. The search space represents the environment. The population contain N solution

The position of each crow i at iteration t is represented by vector x_i^t

Where x_i^t = [x_{i1}^t, x_{i2}^t,x_{i3}^t,,,,,,,,,,x_{id}^t,]

And d is a problem dimension [287],[288].

H. Bird swarm algorithm

Bird swarm algorithm (BSA) is a new heuristic intelligent algorithm, which has been successfully applied in many fields. It was proposed by meng [27] in 2015. It is a new stochasticoptimization algorithm developed through the information-sharing mechanism and search strategy in the foraging process of birds. It has fewer adjusting parameters, faster convergence speed, and stronger robustness compared with other swarm intelligence algorithms. The birds swarm algorithm has been successfully applied to multi-objective optimization of microgrids [28], optimal operation of cascade reservoirs and flexible job-shop scheduling. Although the BSA and other traditional swarm intelligence algorithms have good precision and global optimization, there still exist some problems, such as it has poor initial population and is easy to fall into the local optimal [30].

I. Grey Wolf Optimizer (GWO)

It is a new metaheuristic algorithm developed by Mirjalili et al. in 2014 [31]. It is a population-based stochastic algorithm for finding the optimal result from the solution set (population).This algorithm was inspired by the social behavior and the hunting mechanism of grey wolves. This is used to find the optimal solution without getting trapped in premature convergence [32].GWO algorithm is inspired by grey wolves that belong to the Canidae family, which can work in the pack. They have the dominant pack leader. The average pack size is 5-12. There are mainly four different types of grey wolves, namely alpha(α), beta (β), delta (δ) and omega ω. Alpha wolf may be a male or female. It is a pack leader, and it is responsible for deciding hunting, sleeping place, time to wake up, and others. Beta wolf is at the second level. It helps the alfa wolf in making the decision and provides feedback to the alfa wolf. Delta wolves work for pack in case of any danger. They give food to the group. At the bottom, there is an omega wolf; it acts as a scapegoat.

Grey wolf optimization using the leadership and hunting mechanism of a grey wolf

The following are the main steps

- Searching for the grey Taking, chasing & approaching the prey
- Pursuing, Encircling, and harassing the prey until it stops moving
- Attacking the prey

In the GWO algorithm, the best, second and third best search agents have called α, β, and δ, respectively. Position of the prey compass to the optimal global solution of the optimization problem. The optimization process of the GWO algorithm is as follows. First, it creates several gray wolves randomly in a search space. During repetitions, α, β and δ calculate the prey's position, and other wolves update their positions based on positions of α, β, and δ. Following this, it encircles and approaches the prey, and ends the hunt by attacking the prey at the time that it stops moving. Various comparing definitions in the GWO algorithm have been described as follows [33]. To make similar the group hunting behaviour of grey wolves, α, β, and δ wolves has supposed to have better knowledge regarding the potential location of prey.

Initialize the grey wolf population $X_i (i = 1,2, \dots, n)$
Initialize d, A and C
Generate the Randomly Positions of Search Agent
Calculation the fitness of each search agent
X_α=the best search agent
X_β=the second-best search agent
X_δ=the third best search agent
While (t<max number of iterations)
  for each search agent
    Update the position of the current search agent by $\vec{X}(t+1) = \vec{X}_1 + \vec{X}_2 + \vec{X}_3/3$
  End for
  Update d, A and C
  Calculation the fitness of all search agents
  Update X_α, X_β *and* X_δ
End while
Return X_α

Figure 4.5. Pseudo code of GWO algorithm [296]

IJARCCE

ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 12, December 2021

DOI: 10.17148/IJARCCE.2021.101232

J. Grasshopper optimization algorithm (GOA)

It was a swarm intelligent algorithm developed by Mirjalili. It's a population-based method. GOA mimicking the behaviour of grasshopper swarms and their social interaction. It's inspired by foraging and swarming behaviour of grasshopper. Adult grasshopper plays an important role in this optimization.

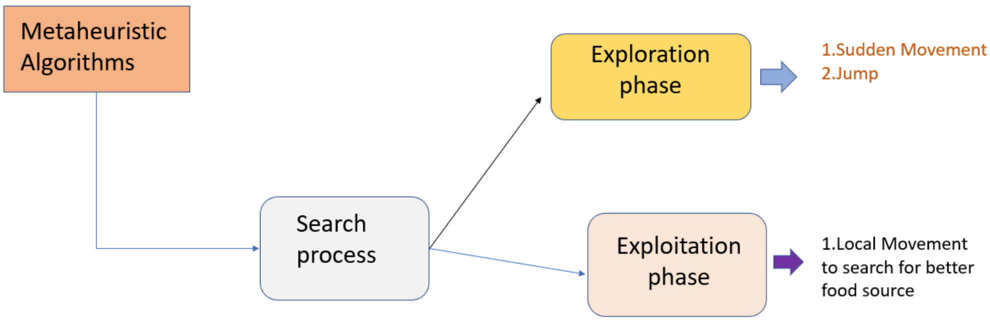

Figure 4.6. GOA algorithm [299]

GOA is basically inspired by long range and movement of adult grasshopper in a group the mathematical model of the grasshopper behaviour is represented by [36].

$x_i = S_i + G_i + A_i$

i^{th} is the position of the grasshopper (i= 1,2,3…..n)

S_i= represent the social interaction in the group

G_i = Force of gravity

A_i = Wind direction

It is the only creature in the earth that form the largest swarm and the millions of grasshoppers jump and move. Food source foraging is the important behaviour of grasshopper swarm

For grasshopper random behaviour use random value [0,1]

$x_i = r_1 S_i + r_2 G_i + r_3 A_i$

Where r_1

, r_2, r_3 are random number

The pseudo code for GHO

1) Parameter Initialization.
2) Population Initialization Phase.
3) Compute Fitness Value for each grasshopper.
4) Select the Best solution among all.
5) Check While (current iteration (t) < maximum iteration (maxT))
6) Normalize distance between grasshopper in the range [1,4].
7) Update the position of current grasshopper.
8) Being current grasshopper back if it goes outside boundaries.
9) Update current best solution if their any new best solution.
10) Current Iteration = current Iteration +1;
11) Return Best solution.

K. Seagull Optimization Algorithm (SOA)

Dhiman and Kumar proposed it in 2019. The inspiration of this algorithm is the migration and attacking behaviors of a seagull in nature. These behaviors are mathematically modeled and implemented to emphasize exploration and exploitation in a given search space [40].

Seagulls, scientifically named Laridae, are sea birds that can be found all over the planet. There is a wide range of seagulls species with different masses and lengths. Seagulls are omnivorous and eat insects, fish, reptiles, amphibians, earthworms, and so on. The body of most seagulls is covered with white plumage. Seagulls are brilliant birds. They use bread crumbs to attract fish and produce rain-like sounds with their feet to attract earthworms hidden under the ground. Seagulls can drink both fresh and saltwater. Most animals are unable to do this. However, seagulls have a particular pair of glands right above their eyes, specifically designed to flush the salt from their systems through openings in the bill.

IJARCCE

ISSN (O) 2278-1021, ISSN (P) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering

Vol. 10, Issue 12, December 2021

DOI: 10.17148/IJARCCE.2021.101232

Generally, seagulls live in colonies. They use their intelligence to find and attack the prey. The most important thing about the seagulls is their migrating and attacking behaviors.

Migration is defined as the seasonal movement of seagulls from one place to another to find the most prosperous and most abundant food sources that will provide adequate energy [41]. This behavior is described as follows:

- During migration, they travel in a group. The initial positions of seagulls are different to avoid collisions between each other.
- In a group, seagulls can travel towards the best survival fittest seagull, i.e., a seagull whose fitness value1 is low compared to others.
- Based on the fittest seagull, other seagulls can update their initial positions.

Seagulls frequently attack migrating birds over the sea [42] when they migrate from one place to another. They can make their spiral natural shape movement during shooting. These behaviors can be formulated so that they can be associated with the objective function to be optimized. This makes it possible to develop a new optimization algorithm [305].

L. Tree-seed algorithm

The natural phenomenon in TSA is the relationship between trees and their seeds. In nature, trees spread to the surface through their seeds. These seeds grow over time, and new trees come from these seeds. Suppose we assume that the surface of these trees is a search space for the optimization problem. The location of trees and seeds can be considered as a possible solution for the optimization problem. Obtaining a location of a seed that will be produced from a tree is essential for the optimization problem because this process constitutes the core of the search. We propose two search equations for this process. The first equation (Eq. 2.1) considers the tree location that the seed will be produced for this tree and the best location of the tree population. This search equation also improves the local search or intensification capability of the proposed algorithm. The second update rule (Eq. 2.2) uses two different tree locations for producing a new seed for the tree [306].

$$S_{i,j} = T_{i,j} + \alpha_{i,j} * (B_j - T_{r,j}) \quad \textbf{Equation 2.1}$$

$$S_{i,j} = T_{i,j} + \alpha_{i,j} * (T_{i,j} - T_{r,j}) \quad \textbf{Equation 2.2}$$

where, $S_{i,j}$ is jth dimension of ith seed that will be produced ith tree, $T_{i,j}$ is the jth dimension of ith tree, B_j is the jth dimension of best tree location obtained so far, $T_{r,j}$ is the jth dimension of rth tree randomly selected from the population, α is the scaling factor randomly produced in range of [1, 1] and i and r are different indices. The most important point is which equation will be selected to produce a new seed location. This selection is controlled by a control parameter of the method named as search tendency (ST) in range of [0, 1]. The higher value of ST provides a powerful local search and speed convergence, the lower value of ST causes slow convergence but powerful global search. In other words, the exploration and exploitation capabilities of the TSA are controlled by ST parameter

In the beginning of search with TSA, the initial tree locations which are possible solutions for the optimization problem are produced by using Eq. (2.3).

$$T_{i,j} = L_{j,min} + r_{i,j} (H_{j,max} - L_{j,min}) \quad \textbf{Equation 2.3}$$

where, $L_{j,min}$ is the lower bound of the search space, $H_{j,max}$ is the higher bound of the search space and $r_{i,j}$ is a random number produced for each dimension and location, in range of [0, 1]. For minimization, the best solution is selected from the population using Eq. (2.4).

$$B = \min\{f(T_i)\} \; I = 1,2,3,,,,N \quad \textbf{Equation 2.4}$$

where, N is the number of trees in the population. While the new seed locations are generated for a tree, the number of seeds can be more than one and this number depends on the population size. In the analysis of effects of control parameters to the performance of TSA, 10% of population size is the minimum number of seeds produced for a tree and 25% of the population size is the maximum number of seeds produced from a tree. The number of seed production is completely random in TSA. In the algorithm, it is seen how to use the control parameter ST in TSA. If randomly produced number in range of [0, 1] is less than ST, Eq. (2.4) is used for updating the dimension, otherwise Eq. (2.4) is used.

This hybrid approach combines the exploration stage of TSA and the exploitation stage of SOA [43]. TSA mimics the jet impulsion and the swarm behaviour of tunicates for the period of foraging and navigation procedure. SOA procedure motivates the attacking and the migration behaviour of a seagull in the environment. The hybrid algorithm can be defined in the next part as follow.

[3]. CONCLUSION

In this paper, we have discussed various methods for the optimization such as DFO (dragonfly optimization), BOA (butterfly optimization), CSA (crow search algorithm), BSA (bird swarm algorithm), SHO (selfish herd optimization), ALO (antlion optimization), ACO (ant colony optimization), GWO (Grey wolf optimization), GOA (grasshopper optimization), COA (cuckoo optimization algorithm), CFA (cuttlefish algorithm), SOA (seagull optimization algorithm), are utilized for both forward and inverse kinematic analysis and the trajectory planning problem. A hybrid algorithm has

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 10, Issue 12, December 2021
DOI: 10.17148/IJARCCE.2021.101232

also been proposed. Different parameters of the optimization algorithms have also been studied. Various steps of optimization algorithms have been discussed.

REFERENCES

[1] N. Nachammai and R. Kayalvizhi, “Dragonfly Algorithm Based Fuzzy Logic Controller for Power Electronic Converter,” vol. 7, no. 1, p. 5.“DFO.pdf.” , 2017

[2] Y. Meraihi, A. Ramdane-Cherif, D. Acheli, and M. Mahseur, “Dragonfly algorithm: a comprehensive review and applications,” Neural Comput & Applic, vol. 32, no. 21, pp. 16625–16646, , doi: 10.1007/s00521-020-04866-y, Nov. 2020.

[3] S. Mirjalili, “Dragonfly algorithm: a new meta-heuristic optimization technique for solving single-objective, discrete, and multi-objective problems,” Neural Comput & Applic, vol. 27, no. 4, pp. 1053–1073, , doi: 10.1007/s00521-015-1920-1, May 2016.

[4] S. Arora and S. Singh, “Butterfly optimization algorithm: a novel approach for global optimization,” Soft Comput, vol. 23, no. 3, pp. 715–734, , doi: 10.1007/s00500-018-3102-4, Feb. 2019.

[5] M. Tubishat, M. Alswaitti, S. Mirjalili, M. A. Al-Garadi, M. T. Alrashdan, and T. A. Rana, “Dynamic Butterfly Optimization Algorithm for Feature Selection,” IEEE Access, vol. 8, pp. 194303–194314, doi: 10.1109/ACCESS.2020.3033757, 2020.

[6] M. R. C. Qazani, S. M. J. Jalali, H. Asadi, and S. Nahavandi, “Optimising Control and Prediction Horizons of a Model Predictive Control-Based Motion Cueing Algorithm Using Butterfly Optimization Algorithm,” in 2020 IEEE Congress on Evolutionary Computation (CEC), Glasgow, United Kingdom, Jul. 2020, pp. 1–8. doi: 10.1109/CEC48606.2020.9185842, 2020.

[7] Mirjalili, Seyedali. "Ant colony optimisation." In Evolutionary Algorithms and Neural Networks, pp. 33-42. Springer, Cham, 2019.

[8] X. Deng, W. Yu, and L. Zhang, “A new ant colony optimization with global exploring capability and rapid convergence,” in Proceedings of the 10th World Congress on Intelligent Control and Automation, Beijing, China, Jul. 2012, pp. 579– 583. doi: 10.1109/WCICA.2012.6357946 2012.

[9] X. Deng, W. Yu, and L. Zhang, “A new ant colony optimization with global exploring capability and rapid convergence,” in Proceedings of the 10th World Congress on Intelligent Control and Automation, Beijing, China, Jul. 2012, pp. 579– 583. doi: 10.1109/WCICA.2012.6357946, 2012.

[10] Xiang-yang Deng1, Wen-long Yu1, Li-min Zhang2 “Analysis and comparison among Ant System; Ant Colony System and Max-Min Ant System with different parameters setting” 3rd International Conference on Computational Intelligence & Communication Technology (CICT), Ghaziabad, India, 9-10 Feb. 2017

[11] S. Kumar and A. Kumar, “A brief review on antlion optimization algorithm,” International Conference on Advances in Computing, Communication Control and Networking (ICACCCN), Greater Noida (UP), India, Oct. 2018, pp. 236–240. doi: 10.1109/ICACCCN.2018.8748862, 2018.

[12] T. Tian, C. Liu, Q. Guo, Y. Yuan, W. Li, and Q. Yan, “An Improved Ant Lion Optimization Algorithm and Its Application in Hydraulic Turbine Governing System Parameter Identification,” Energies, vol. 11, no. 1, pp 95, doi: 10.3390/en11010095, Jan. 2018.

[13] M. M. Mafarja and S. Mirjalili, “Hybrid binary ant lion optimizer with rough set and approximate entropy reducts for feature selection,” Soft Comput, vol. 23, no. 15, pp. 6249–6265, , doi: 10.1007/s00500-018-3282-y, Aug. 2019 .

[14] Eesa, Adel Sabry, Adnan Mohsin Abdulazeez Brifcani, and Zeynep Orman. "Cuttlefish algorithm-a novel bio-inspired optimization algorithm." International Journal of Scientific & Engineering Research 4, no. 9: 1978-1986, 2013.

[15] M. S. A. Daweri, S. Abdullah, and K. A. Z. Ariffin, “A Migration-Based Cuttlefish Algorithm With Short-Term Memory for Optimization Problems,” IEEE Access, vol. 8, pp. 70270–70292, doi: 10.1109/ACCESS.2020.2986509, 2020.

[16] A. S. Eesa, A. M. A. Brifcani, and Z. Orman, “A New Tool for Global Optimization Problems- Cuttlefish Algorithm,” vol. 8, no. 9, p. 6, 2014.

[17] Bustamam, V. Y. Nurazmi, and D. Lestari, “Applications of Cuckoo search optimization algorithm for analyzing protein-protein interaction through Markov clustering on HIV,” Bali, Indonesia, 2018, p. 020232. doi: 10.1063/1.5064229.

[18] R. Rajabioun, “Cuckoo Optimization Algorithm,” Applied Soft Computing, vol. 11, no. 8, pp. 5508–5518, doi: 10.1016/j.asoc.2011.05.008, Dec 2011.

[19] A. Iglesias et al., “Cuckoo Search Algorithm with Lévy Flights for Global-Support Parametric Surface Approximation in Reverse Engineering,” Symmetry, vol. 10, no. 3, p. 58, doi: 10.3390/sym10030058, Mar. 2018.

[20] X.-S. Yang and Suash Deb, “Cuckoo Search via Lévy flights,” in 2009 World Congress on Nature & Biologically Inspired Computing (NaBIC), Coimbatore, India, pp. 210–214. doi: 10.1109/NABIC.2009.5393690, 2009.

[21] E. Shadkam and M. Bijari, “Evaluation the Efficiency of Cuckoo Optimization Algorithm,” IJCSA, vol. 4, no. 2, pp. 39–47, doi10.5121/ijcsa.2014.4205, Apr. 2014.

[22] Mohamed Arezki Mellal, Smail Adjerid, and Edward J. Williams, “Optimal selection of obsolete tools in manufacturing systems using cuckoo optimization algorithm,” Chemical Engineering Transactions, vol. 33, pp. 355–360, doi: 10.3303/CET1333060, Jul. 2013.

[23] Z.-X. Wu, K.-W. Huang, and A. S. Girsang, “A Whole Crow Search Algorithm for Solving Data Clustering,” in 2018 Conference on Technologies and Applications of Artificial Intelligence (TAAI), Taichung, pp. 152–155. doi: 10.1109/TAAI.2018.00040, Nov. 2018.

[24] 1C. Qu and Y. Fu, “Crow Search Algorithm Based on Neighborhood Search of Non Inferior Solution Set,” IEEE Access, vol. 7, pp. 52871–52895, doi: 10.1109/ACCESS.2019.2911629, 2019.

[25] S. Shirke and R. Udayakumar, “Evaluation of Crow Search Algorithm (CSA) for Optimization in Discrete Applications,” in 2019 3rd International Conference on Trends in Electronics and Informatics (ICOEI), Tirunelveli, India, pp. 584–589. doi: 10.1109/ICOEI.2019.8862669, Apr 2019.

[26] K. Mishra and S. K. Majhi, “A binary Bird Swarm Optimization based load balancing algorithm for cloud computing environment,” Open Computer Science, vol. 11, no. 1, pp. 146–160, doi: 10.1515/comp-2020-0215, Jan. 2021.

[27] X.-B. Meng, X. Z. Gao, L. Lu, Y. Liu, and H. Zhang, “A new bio-inspired optimisation algorithm: Bird Swarm Algorithm,” Journal of Experimental & Theoretical Artificial Intelligence, vol. 28, no. 4, pp. 673–687, doi: 10.1080/0952813X.2015.1042530, Jul. 2016.

[28] C. Zhou, L. Mei, R. Chellali, and Y. Zhao, “An Improved Bird Swarm Algorithm with Adaptive Characteristics,” presented at the 2018 International Symposium on Communication Engineering & Computer Science (CECS 2018), Hohhot, China,. doi: 10.2991/cecs-18.2018.40, 2018.

[29] 1C. Zhou, L. Mei, R. Chellali, and Y. Zhao, “An Improved Bird Swarm Algorithm with Adaptive Characteristics,” presented at the 2018 International Symposium on Communication Engineering & Computer Science (CECS 2018), Hohhot, China, . doi: 10.2991/cecs-18.2018.40, 2018.

[30]Mirjalili, Seyedali, Seyed Mohammad Mirjalili, and Andrew Lewis. "Grey wolf optimizer." Advances in engineering software 69 (2014): 46-61.

[31] J.-S. Wang and S.-X. Li, “An Improved Grey Wolf Optimizer Based on Differential Evolution and Elimination Mechanism,” Sci Rep, vol. 9,

Vol. 10, Issue 12, December 2021
DOI: 10.17148/IJARCCE.2021.101232

no. 1, p. 7181, Dec. 2019, doi: 10.1038/s41598-019-43546-3.
[32] H. Joshi and S. Arora, "Enhanced Grey Wolf Optimization Algorithm for Global Optimization," FI, vol. 153, no. 3, pp. 235–264, doi: 10.3233/FI-2017- 1539, Jun. 2017.

[33]K. Teeparthi and D. M. Vinod Kumar, "Grey wolf optimization algorithm based dynamic security constrained optimal power flow," in 2016 National Power Systems Conference (NPSC), Bhubaneswar, , pp. 1–6. doi: 10.1109/NPSC. 197, Dec. 2016.
[34]P. Niu, S. Niu, N. liu, and L. Chang, "The defect of the Grey Wolf optimization algorithm and its verification method," Knowledge-Based Systems, vol. 171, pp. 37 43, , doi: 10.1016/j.knosys.2019.01.018, May 2019.
[35] M. Steczek, W. Jefimowski, and A. Szeląg, "Application of Grasshopper Optimization Algorithm for Selective Harmonics Elimination in Low-Frequency Voltage Source Inverter," Energies, vol. 13, no. 23, p. 6426, , doi: 10.3390/en13236426, Dec. 2020.
[36]S. Saremi, S. Mirjalili, and A. Lewis, "Grasshopper Optimisation Algorithm: Theory and application," Advances in Engineering Software, vol. 105, pp. 30–47, , doi: 10.1016/j.advengsoft.2017.01.004, Mar. 2017.
[37] Y. Meraihi, A. B. Gabis, S. Mirjalili, and A. Ramdane-Cherif, "Grasshopper Optimization Algorithm: Theory, Variants, and Applications," IEEE Access, vol. 9, pp. 50001–50024, doi: 10.1109/ACCESS.2021.3067597, 2021.
[38] M. Sulaiman, "Implementation of Improved Grasshopper Optimization Algorithm to Solve Economic Load Dispatch Problems," Hacettepe Journal of Mathematics and Statistics, pp. 1–21, , doi: 10.15672/hujms.507579, Dec. 2019.
[39] Jia, Z. Xing, and W. Song, "A New Hybrid Seagull Optimization Algorithm for Feature Selection," IEEE Access, vol. 7, pp. 49614–49631, doi: 10.1109/ACCESS.2019.2909945, 2019.
[40] V. Kumar, D. Kumar, M. Kaur, D. Singh, S. A. Idris, and H. Alshazly, "A Novel Binary Seagull Optimizer and its Application to Feature Selection Problem," IEEE Access, vol. 9, pp. 103481–103496, doi: 10.1109/ACCESS.2021.3098642, 2021.
[41] L. Xu, Y. Mo, Y. Lu, and J. Li, "Improved Seagull Optimization Algorithm Combined with an Unequal Division Method to Solve Dynamic Optimization Problems," Processes, vol. 9, no. 6, p. 1037, doi: 10.3390/pr9061037, Jun. 2021.
[42]G. Dhiman and V. Kumar, "Seagull optimization algorithm: Theory and its applications for large-scale industrial engineering problems," Knowledge-Based Systems, vol. 165, pp. 169–196, doi: 10.1016/j.knosys.2018.11.024, Feb. 2019.
[43] P. Bujok, "Enhanced Tree-Seed Algorithm Solving Real-World Problems," in 2020 7th International Conference on Soft Computing & Machine Intelligence (ISCMI), Stockholm, Sweden, pp. 12–16. doi: 10.1109/ISCMI51676.2020.9311593, Nov. 2020.
[44] V. Muneeswaran and M. P. Rajasekaran, "Performance evaluation of radial basis function networks based on tree seed algorithm," in 2016 International Conference on Circuit, Power and Computing Technologies (ICCPCT), Nagercoil, India, pp. 1–4. doi: 10.1109/ICCPCT.2016.7530267, Mar. 2016.