Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X
Volume 3, Issue 10, 2025

PARAMETERS TUNING OF THE FIREWORKS INTELLIGENCE ALGORITHM FOR THE GLOBAL OPTIMIZATION

Mukhtar Ahmad[*1], Dr. Taj Rehman[2], Dr. Shafi Ullah Khan[3], Shah Fahad[4]

[*1,2,4]*Department of Computer Science, Qurtuba University of Science and Information Technology, Peshawar, Pakistan.*
[3]*Department of Electronics, Islamia College, Peshawar, Pakistan.*

[*1]mukhtar.ahmad@icp.edu.pk, [2]drtaj@qurtuba.edu.pk, [3]shafielectronics@icp.edu.pk, [4]shahfahadkhanmcs@gmail.com

DOI:https://doi.org/10.5281/zenodo.17511105

Keywords
Swarm Intelligence, Fireworks Algorithm, FWA, Global Optimization, Evolutionary Computation

Article History
Received: 12 September 2025
Accepted: 18 October 2025
Published: 31 October 2025

Corresponding Author: *
Mukhtar Ahmad

Abstract
The swarm intelligence algorithm, namely Fireworks, plays an imperative role in the solution of optimization problems in the field of engineering and sciences. The Fireworks Intelligence Algorithm (FWA) is a prominent swarm intelligence (SI) algorithm used for global optimization; however, its traditional form suffers from premature convergence and inefficient information sharing among individuals, limiting its performance on complex problems.
This research addresses the key limitations of conventional FWA, specifically its lack of population diversity, propensity to get trapped in local optima, and the absence of a dynamic mechanism to adapt to different problem landscapes.
In this paper, we highlighted the issues in its different versions that severely affect the efficiency of FWA, and we suggested different parameter modifications to enhance its efficiency by maintaining a proper balance between exploration and exploitation searches, and also keeping the diversity of the swarm of FWA for global optimization problems.

INTRODUCTION

The Swarm Intelligence (SI) algorithms were first introduced in 1980, and the researchers have shown keen interest in this field. SI algorithms have become a very popular area in many fields of Engineering, Computer Science, and Artificial Intelligence (AI). Subsequently, numerous stochastic population-based SI algorithms have been introduced in recent years, namely PSO [1], ACO [2], ABC [3], WOA [4], Dandelion Algorithm (DA) [5], and Collective Artificial System (CAS) [6-8]. Similarly, the Fireworks Algorithm (FWA) [9] was initially introduced in 2010 by Tan and Zhu as an SI algorithm that was motivated by the spontaneous display of fireworks explosions at night. Since then, it has been successfully used in a wide variety of real-world and inverse problems. For example, reconstructing the idealized image from the measured one. The FWA is applied on inverse problems including network reconfiguration, an anti-spam model measuring distance for orientation coding in identification [10], capacitated vehicle routing [11, 12], laser machining [13], multiple targets search [14, 15], a multilevel image thresholding problem [16, 17], multi-satellite control resource scheduling [18-20] and short-term power load forecasting [21].

Each firework in FWA is initially placed at random in the search space and then performs a local search by uniformly exploding a large number of sparks across a predetermined area. Then, among the current fireworks and sparks, the new fireworks are chosen. Fireworks continuously search for a new location by iterating the explosion and selection actions.

The FWA has issues in the explosion, mapping, mutation, and selection processes due to improper operators. Due to these improper operators, the FWA could not complete the iterative process, and the algorithm prematurely terminated. Moreover, no optimization technique or algorithm, according to the "no free lunch theorem," has the capacity to address every problem. In this regard, a modified FWA algorithm will be designed for the purpose to complete the iterative process by introducing proper explosion, mapping, mutation, and selection processes. The modified FWA will be able to find the global optimal solution of the inverse and real-world problem.

1. Related Work

The FWA has made significant advances recently due to its various applications. Some recent advancements introduced in FWA are discussed in the following paragraphs.

Enhanced Fireworks Algorithm (EFWA) was proposed in [22]. The EFWA introduced new operators for explosion, mapping, mutation, and the selection process. A dynamic FWA (dynFWA) has been suggested in [23] in which dynamic explosive search is used. Li et al. suggested the guided fireworks Algorithm (GFWA) in [24] that utilizes the explosion sparks' collective information to generate a Guiding Spark (GS) to help in the exploration and exploitation of both. To further improve information exchange among fireworks, a new idea was suggested that a loser-out tournament-based competition mechanism, leading to a Loser-out Tournament-based FWA. A firework has been deemed a loser and reinitialized if its fitness can't keep up with the best one at its present pace of advancement. GFWA and LoTFWA are the two most significant FWA variations [25]. Two distinct strategies to adaptively control the explosion amplitude were proposed and reported [26, 27], respectively. They highlighted that the lowest possible exploding intensity assessment criteria used by the EFWA is a specifically selected function that is rigid with regard to various goal factors and exploration phases. They separately claimed Adaptive FWA and Innovative Search FWA to overcome these problems. A more feasible solution was presented in [28], namely, a cooperative framework for the Fireworks algorithm (CoFFWA). This approach improved the exploitation using the crowd avoidance strategy.

The different variant of PSO's methods and the enhanced version of the Firework algorithm performs well on various benchmark optimization problems, and even the published results demonstrate that both algorithms have the ability to solve complicated and complex engineering problems [29]. On the basis of the Enhanced Firework method, the author suggested two new operators, one for mutation and one for selection in Improved EFWA (IEFWA) [30]. IEFWA performs noticeably better than the EFWA. Later, they combined the FWA explosion operator with the BBO [31, 32]. The numerical analysis conclusion provides direction that the new Enhanced firework technique, having three novel models, performs well compared with the basic FWA and BBO [33].

In [34], four distinct types of mapping rules were proposed. Experimental results show that, compared to other mapping strategies, mapping to a small stochastic region performs better. The same issue of mapping was examined in large-scale optimization in [35]. On the majority of test functions, they discovered that Mirror mapping performs better than the others. In [36], an improved version of FWA (IFWA) is suggested. The suggested method uses the same dynamic exploding intensity, but the exploding amplitude will also be increased when all the fireworks are of the same fitness. A t-distribution is used in place of the Gaussian spectrum implemented in the EFWA's mutation operator. The IFWA outperforms FWA, EFWA, and dynFWA.

An Adaptive FWA (AFWA), in which an elitist-tournament selection process was suggested in [37]. The best candidate is chosen first in the elitism-tournament selection process of the Fireworks

Algorithm. The best applicant is then chosen to receive fireworks each time two candidates at random are chosen from the other candidates using Lévy distribution and the Gaussian scattering. An adaptive mutation which is combined into the Gaussian and Lévy distributions in the later search process reported in [38]. The testing of the methods on optimization problems demonstrates that the recommended approach performs much better than the EFWA, AFWA, and dynFWA.

The self-adaptive FWA (SF-FWA) method for the most effective large-scale optimization problem was introduced in [39]. The authors used the Expressive Fast Exploding strategy in order to achieve effective and efficient optimization. The results indicate that the proposed method performs better than published results regarding to large-scale optimization algorithms. Similarly, the performance of SF-FWA for the optimization of neural networks for solving reinforcement learning tasks shows that SF-FWA can be applied to a wider range of real-world problems.

A Lit Firework technique for optimization was described and explained in [40]. The basic firework algorithm has many parameters. During the selection process, many parameters are discarded, resulting in the loss of much location information are wasted. The LFWA uses a simple approach to reduce the variables. It uses the best possible information to balance the local search and global search abilities to construct an adaptive explosion radius. The adaptive explosion radius reduced the number of parameters without wasting the position information.

He et al. in [41] used FWA for Spam detection. The Local Concentration (LC) is used for feature extraction and SVM is used for classification. The experimental results demonstrated that FWA improved the efficiency and reduced the error in Spam Detection. For radio-isotopic identification, Alamaniotis et al. [42] used the FWA for the optimization of the coefficients of a linear combination of template signature pattern. Gonsalves [43] optimized the cost estimation of software using the FWA. The authors of [44] employed the FWA to maximize the feature subset for transmission line icing predictions. The EFWA was utilized by Tuba et al. [45] to optimize the SVM parameters, whose efficiency was shown using standard datasets. The multiclass SVM parameters were optimized by Zhang et al. [46] for the job of abnormal chart pattern recognition. Yang and Tan [47] utilized the FWA for initialization of k-means for document clustering. To initialize k-means for big data clustering, the authors of [48] devised a hybrid approach combining cuckoo search and the EFWA. A hybrid Ant Colony Optimization (ACO) with Firework method to solve the Capacitated Vehicle Routing Problem (CVRP) was recorded in [49]. The objective of CVRP is to find the optimal path to reduce vehicle travel. ACO is used with FWA to increase diversity and to avoid falling into local minima too early in the search process. The vehicle routing was modeled by Cai et al. [50], and they suggested a quantum evolutionary fireworks algorithm to solve it. The warehouse-scheduling problem was addressed by Ye et al. [51] by using local search and mutation processes in the FWA. The AFWA was utilized by Dou et al. [52] for concrete dams. Variants of the AFWA were proposed by Yin et al. [53] to optimize the control parameters for hypersonic vehicles. The authors of [54] suggested a hybrid FWA with a quantum computation technique to identify the best cooperative cognitive radio energy harvesting technology. The FWA was employed by Jam et al. [55], he et al. [56], and Ching et al. [57] for the edge values optimization in image splitting up, respectively. An explosive picture disruption strategy for maintaining privacy was put forth by Rahmani et al. [58]. In order to locate many cells in microscope pictures, Shi et al. [59] presented a modified FWA that uses distinct displacements on various dimensions. The FWA was employed by Beja et al. [60] and Taba et al. [61] for image registration. PSO, Kokoo search, and FWA were evaluated by Bejinariu et al. [62] for the task of image fusion.

2. Problem Statement

The basic version of FWA [9] has good global search ability, but its balance is not good with local search because of the static explosion amplitude and improper selection and mapping strategies, and thus, the technique could not complete the iterative process, and as a result, the process is premature. This premature convergence is one of the main problems in the basic version of FWA.

The Enhanced FWA (EFWA) [22] focused only on the explosion and selection process. There was no consideration of mutation and the mapping process. Due to this improper mutation and improper mapping process, there is no balance exists in exploration and exploitation in EFWA. In the dynamic search Firework algorithm (dynFWA) [23], the authors used a dynamic explosion process instead of a static explosion. The dynFWA improved the local search, but there is no work done for the balancing the exploration and exploitation process or for the balancing local search and global search because the authors used only one or a single fittest (best objective) function in the search process instead of many objective functions. In the Adaptive Firework algorithm (AFWA) [26], the authors replaced the amplitude explosion process of EFWA with an adaptive explosion process. But updating only the amplitude explosion process could not handle the scattering due to improper mapping and improper selection process. Due to these limitations, AFWA was not capable of finding the optimal solution of the fittest function. Similarly, in Adaptive Mutation Dynamic Search Firework Algorithm (AMdynFWA) [38], the authors used a Gaussian mutation process to enhance the local search ability and Levy mutation to jump out from the local search without falling into local search according to the mutation probability. The authors used a mutation probability constant for all the test problems. Where the mutation probability is changing for different test functions. This is the limitation of Adaptive Mutation Dynamic Search FWA (AMdynFWA). All the updated versions have failed to find the optimal solution during the search process to solve the complex and real-world inverse problems.

3. **Firework Algorithm (FWA)**

The Firework Algorithm (FWA) was first introduced in 2010. The global optimization of complex problems is done using the fireworks algorithm. The natural phenomena of nighttime fireworks bursts served as the inspiration for the fireworks algorithm. If fireworks are made properly, they will produce a lot of sparks, which will concentrate the explosion's center. In this instance, the fireworks show is fantastic. The sparks created by a poor firework explosion, however, scatter in the area depicted in Figure 1. When set exploded in the ideal spot, fireworks generate the most sparkles. A good fireworks display will be near the ideal spot. A poor firework is placed outside of its ideal spot. The search field (explosion) radius is larger for poor fireworks than it is for excellent fireworks. The Fireworks Algorithm (FWA) is used to examine the ideal position for the fireworks and the number of sparks needed to achieve the best explosion inside a specific constrained space.

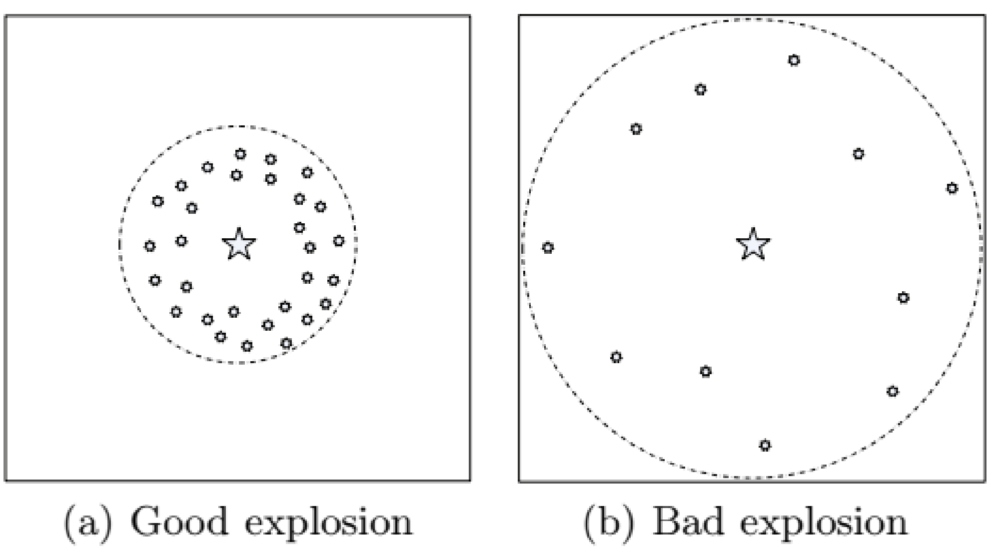

Figure 1: (a) Good Explosion (b) Bad Explosions [9].

4.1 Mathematical Model for FWA

Let FWA be designed to minimize *f(x)*, $x_{min} \le x \le x_{max}$, where $x = x_1, x_2, x_3, \ldots, .x_d$ shows locations in the search space, and *f(x)* is an objective function, and x_{min} and x_{max} show lower and upper bounds of the search space. The details of the different steps of FWA are given below.

4.1.1 Explosion Process

The explosion process can be mathematically represented as.

$$S_i = m.\frac{y_{max} - f(x_i) + \varepsilon}{\sum_{i=1}^{N}(y_{max} - f(x_i)) + \varepsilon}$$

(1)

Where S_i denotes the quantity of sparks produced by a single x_i firework, with i ranging from *1* to *N*, m set as a constant to regulate the quantity of sparks produced, y_{max} denotes the fitness function's worst value for the current generation, $f(x_i)$ denotes the fitness value of a single x_i and ε denotes the small value used to prevent the denominator from falling to zero.

4.1.2 Amplitude of Explosion

The amplitude of explosion can be calculated as.

$$A_i = k.\frac{f(x_i) - y_{min} + \varepsilon}{\sum_{i=1}^{N}(f(x_i) - y_{min}) + \varepsilon}$$

(2)

Equation (2) A_i shows the amplitude of fireworks x_i to generate the explosion sparks, k is set constant to control the amplitude, and $y_{min} = \min(f(x_i)$ where $i = 1, 2, 3 \ldots . n$ is the minimum value (best fitness value) among n fireworks. If the fireworks x_i is near to boundary, then the spark may produce out from the feasible space. Therefore, mapping is needed to keep the spark within the feasible space.

4.1.3 Mapping Process

If the fireworks x_i is near to boundary, then the spark produced may out from the potential space/ search space. Therefore, mapping is needed to keep the spark within potential space. If $x_i \prec x_{min}$ or $x_i \succ x_{max}$ then mapped x_i to potential space/ search space using equation.

$$x_i = x_{min} + |x_i| \% (x_{max} - x_{min})$$

(3)

4.1.4 Mutation Process

In FWA mutation sparks are generated using Gaussian distribution as

$$.x_k^j = x_k^j . g$$

(4)

Where x_k^j shows the position of current individuals in the current explosion and g shows a Gaussian random number with both mean value and standard deviation value equal to *1* shown in the equation below.

$$g = Guassian(1, 1)$$

(5)

After a normal explosion and Gaussian spark generation, the next step is the selection of individuals for the next generation.

After a normal explosion and Gaussian spark generation, the next step is the selection of individuals for the next generation.

4.1.5 Selection Process

In the subsequent generation's method of selection, the best person is always kept first. The subsequent *(N-1)* persons are then picked according to how far they are from other people. Distance from other people is taken into account throughout the choosing procedure. The person who is farther away from other people has a greater probability of being chosen than those who are closer to other people. One may compute the distance between two individuals using the formula.

$$D(xi) = \sum_{j \in k} d(x_i, x_j) = \sum_{j \in k} \|x_i - x_j\| \tag{6}$$

Where x_i and x_j (i ≠ j) are any locations and the set of all current locations are shown with k.

4.2 Suggested Modified and Hybrid version of FWA

To increase the efficiency of FWA for global optimization, the following modification can be made.

1. To introduce new models for selection and mapping operators of the FWA for the purpose of maintaining the diversity of the sparks during the search process.
2. To introduce new models for selection and mapping operators of the FWA for the purpose of maintaining the diversity of the sparks during the search process.
3. To integrate modified FWA with other swarm intelligence algorithms to design a hybrid FWA algorithm to optimize the real-world inverse problems.

The flow chart of the suggested modified and hybrid Fireworks algorithm is shown in Figure 2.

4. Conclusion

In this paper, we analyzed the Fireworks Intelligence Algorithm (FWA), which is one of the prominent swarm intelligence (SI) algorithms frequently used for different inverse and real-world optimization problems in the field of engineering and sciences. We highlighted the issues of basic FWA and its different versions, which limit its efficiency for global and real-world inverse optimization problems. We figure out the parameter that needs tuning to enhance its efficiency. We also suggested the idea of integration of tuned FWA with other swarm intelligence algorithms to introduce a modified and hybrid FWA algorithm, which can enhance the efficiency of FWA for the global and inverse real-world optimization problems.

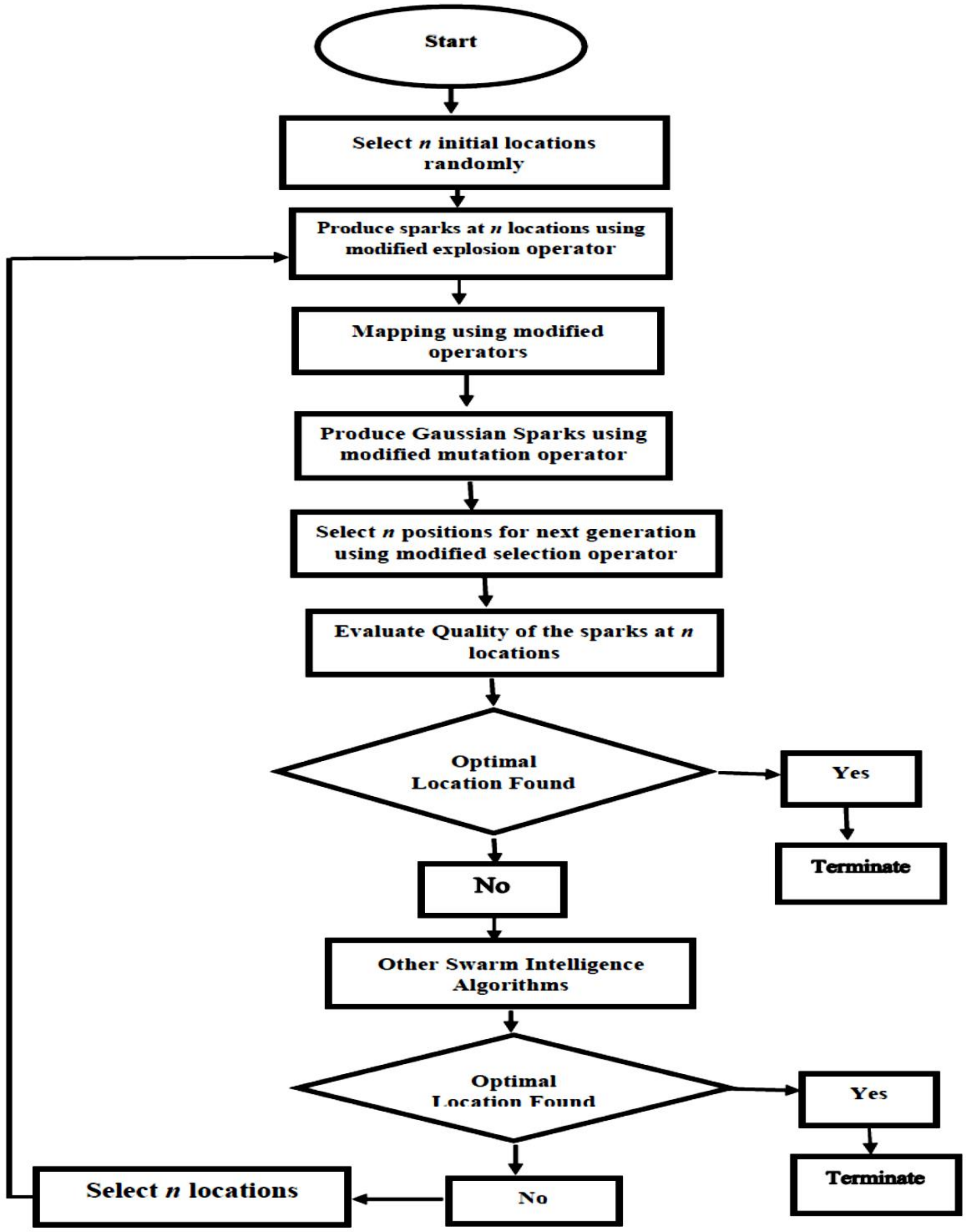

Figure 2: Flow Chart of the Proposed Algorithm

REFERENCES

[1] J. Kennedy and R. Eberhart, "Particle swarm optimization," in *Proceedings of ICNN'95 - International Conference on Neural Networks*, vol. 4, pp. 1942–1948, 1995. doi: 10.1109/ICNN.1995.488968.

[2] M. Dorigo, M. Birattari and T. Stutzle, "Ant colony optimization," in IEEE *Computational Intelligence Magazine*, vol. 1, no. 4, pp. 28-39, Nov. 2006. doi: 10.1109/MCI.2006.329691.

[3] D. Karaboga and B. Basturk, “A powerful and efficient algorithm for numerical function optimization: Artificial bee colony (ABC) algorithm,” *Journal of Global Optimization.* vol. 39, no. 3, pp. 459–471, 2007.doi: 10.1007/s10898-007-9149-x.

[4] S. Mirjalili and A. Lewis, “The Whale Optimization Algorithm,” *Advances in Engineering Software,* vol. 95, pp. 51–67, 2016. doi: 10.1016/j.advengsoft.2016.01.008.

[5] X. Li, S. Han, L. Zhao, C. Gong, and X. Liu, “New Dandelion Algorithm Optimizes Extreme Learning Machine for Biomedical Classification Problems,” *Computational Intelligence and Neuroscience*. vol.. 2017, 2017. doi: 10.1155/2017/4523754.

[6] H. Mori and H. Ikegami, “An advanced fireworks algorithm for distribution network reconfigurations,” *IEEE Power and Energy Society General Meeting*, vol. 2018-Janua, pp. 1–5, 2018. doi: 10.1109/PESGM.2017.8274092.

[7] H. Ikegami and H. Mori, “Development of discrete CoFFWA for distribution network reconfigurations,” *Electrical Engineering in Japan (English Transl. Denki Gakkai Ronbunshi)*, vol. 205, no. 3, pp. 55–62, 2018. doi: 10.1002/eej.23151.

[8] W He, G Mi, and Y Tan, "Parameter optimization of local-concentration model for spam detection by using fireworks algorithm."*Advances in Swarm Intelligence: 4th International Conference, ICSI 2013, Harbin, China, June 12-15, 2013, Proceedings, Part I* 4pp. 439-450. Springer Berlin Heidelberg, 2013.

[9] Y. Tan and Y. Zhu, "Fireworks algorithm for optimization."*Advances in Swarm Intelligence: First International Conference, ICSI 2010, Beijing, China, June 12-15, 2010, Proceedings, Part I 1*. Springer Berlin Heidelberg, 2010.

[10]S. Zheng, and Y. Tan,"A unified distance measure scheme for orientation coding in identification." In 2013, *IEEE Third International Conference on Information Science and Technology (ICIST)*, pp. 979-985. IEEE, 2013.

[11] W. Yang and L. Ke, “An improved fireworks algorithm for the capacitated vehicle routing problem,” *Frontiers of Computer Science*, vol. 13, no. 3, pp. 552–564, 2019. doi: 10.1007/s11704-017-6418-9.

[12] Y. Cai, Y. Qi, H. Chen, H. Cai, and O. Hejlesen, "Quantum Fireworks Evolutionary Algorithm for Vehicle Routing Problem in Supply Chain with Multiple Time Windows,"*2018 2nd IEEE Advanced Information Management, Communications, Electronic and Automation Control Conference (IMCEC)*, pp. 383-388, Xi'an, China, 2018. doi: 10.1109/IMCEC.2018.8469677.

[13] D. Goswami and S. Chakraborty, “A Study on the Optimization Performance of Fireworks and Cuckoo Search Algorithms in Laser Machining Processes,” *Journal of the Institution of Engineers. Ser.* C, vol. 96, no. 3, pp. 215–229, 2015. doi: 10.1007/s40032-014-0160-y.

[14] H. Chen, X., Deng, L. Yan, and Z. Ye, "Multilevel thresholding selection based on the fireworks algorithm for image segmentation,"*2017 International Conference on Security, Pattern Analysis, and Cybernetics (SPAC)*, pp. 175-180, Shenzhen, China, 2017. doi: 10.1109/SPAC.2017.8304271.

[15] Y. Chen, W., Yang, M. Li, Z., Hao, P., Zhou, and H. Sun, “Research on Pest Image Processing Method Based on Android Thermal Infrared Lens,” *IFAC-PapersOnLine*, vol. 51, no. 17, pp. 173–178, 2018. doi: 10.1016/j.ifacol.2018.08.083.

[16] W. Liu, H. Shi, X. He, S. Pan, Z. Ye, and Y. Wang, “An application of optimized otsu multi-threshold segmentation based on fireworks algorithm in cement sem image,” *Journal of Algorithms and Computational Technology*, vol. 13, pp. 1–12, 2019. doi: 10.1177/1748301818797025.

[17] M. Tuba, N. Bacanin and A. Alihodzic, "Multilevel image thresholding by fireworks algorithm,"*2015 25th International Conference Radioelektronika (RADIOELEKTRONIKA)*, pp. 326-330, Pardubice, Czech Republic, 2015. doi: 10.1109/RADIOELEK.2015.7129057.

[18] Z. Liu, Z. Feng and L. Ke, "Fireworks algorithm for the multi-satellite control resource scheduling problem,"*2015 IEEE Congress on Evolutionary Computation (CEC)*, Sendai, pp. 1280-1286, Japan, 2015.doi: 10.1109/CEC.2015.7257036.

[19] Z. Liu, Z. Feng,and L. Ke, "A modified fireworks algorithm for the multi-resource range scheduling problem." In*Advances in Swarm Intelligence: 7th International Conference, ICSI 2016, Bali, Indonesia, June 25-30, 2016, Proceedings, Part I7*, pp. 535-543, Springer International Publishing, 2016.

[20] T. Zhang, L. Ke, J. Li, J. Li, Z. Li and J. Huang, "Fireworks algorithm for the satellite link scheduling problem in the navigation constellation,"*2016 IEEE Congress on Evolutionary Computation (CEC)*, pp. 4029-4037, Vancouver, BC, Canada, 2016. doi: 10.1109/CEC.2016.7744301.

[21] C. Lei, B. Fang, H. Gao, W. Jia and W. Pan, "Short-term power load forecasting based on Least Squares Support Vector Machine optimized by Bare Bones Fireworks algorithm,"*2018 IEEE 3rd Advanced Information Technology, Electronic and Automation Control Conference (IAEAC)*, pp. 2231-2235, Chongqing, China, 2018. doi: 10.1109/IAEAC.2018.8577212.

[22] S. Zheng, A. Janecek and Y. Tan, "Enhanced Fireworks Algorithm,"*2013 IEEE Congress on Evolutionary Computation*, pp. 2069-2077, Cancun, Mexico, 2013. doi: 10.1109/CEC.2013.6557813.

[23] S. Zheng, A. Janecek, J. Li and Y. Tan, "Dynamic search in fireworks algorithm,"*2014 IEEE Congress on Evolutionary Computation (CEC)*, pp. 3222-3229, Beijing, China, 2014. doi: 10.1109/CEC.2014.6900485.

[24] J. Li, S. Zheng and Y. Tan, "The Effect of Information Utilization: Introducing a Novel Guiding Spark in the Fireworks Algorithm," in IEEE *Transactions on Evolutionary Computation*, vol. 21, no. 1, pp. 153-166, 2017. doi: 10.1109/TEVC.2016.2589821.

[25] J. Li and Y. Tan, "Loser-Out Tournament-Based Fireworks Algorithm for Multimodal Function Optimization," in IEEE *Transactions on Evolutionary Computation*, vol. 22, no. 5, pp. 679-691, 2018. doi: 10.1109/TEVC.2017.2787042.

[26] J. Li, S. Zheng and Y. Tan, "Adaptive Fireworks Algorithm,"*2014 IEEE Congress on Evolutionary Computation (CEC)*, pp. 3214-3221, Beijing, China, 2014. doi: 10.1109/CEC.2014.6900418.

[27] S. Zheng, A. Janecek, J. Li and Y. Tan, "Dynamic search in fireworks algorithm,"*2014 IEEE Congress on Evolutionary Computation (CEC)*, pp. 3222-3229,Beijing, China, 2014. doi: 10.1109/CEC.2014.6900485.

[28] S. Zheng, J. Li, A. Janecek and Y. Tan, "A Cooperative Framework for Fireworks Algorithm," in IEEE/ACM *Transactions on Computational Biology and Bioinformatics*, vol. 14, no. 1, pp. 27-41, 1 Jan.-Feb. 2017. doi: 10.1109/TCBB.2015.2497227.

[29] J. J. Liang, B. Y. Qu, P. N. Suganthan, and A. G. Hernández-Díaz, "CEC2013 Benchmark Functions," *KanGAL*, no. January, pp. 251–256, 2013.

[30] B. Zhang, M. Zhang, and Y.J.Zheng,"Improving enhanced fireworks algorithm with new gaussian explosion and population selection strategies." In Advances *in Swarm Intelligence: 5th International Conference, ICSI 2014, Hefei, China, October 17-20, 2014, Proceedings, Part I 5*, pp. 53-63. Springer International Publishing, 2014.

[31] B. Zhang, Y. J. Zheng, M. X. Zhang, and S. Y. Chen, "Fireworks Algorithm with Enhanced Fireworks Interaction," in IEEE/ACM *Transactions on Computational Biology and Bioinformatics*, vol. 14, no. 1, pp. 42-55, 1 Jan.-Feb. 2017. doi: 10.1109/TCBB.2015.2446487.

[32] D. Simon, "Biogeography-Based Optimization," in IEEE *Transactions on Evolutionary Computation*, vol. 12, no. 6, pp. 702-713, Dec. 2008. doi: 10.1109/TEVC.2008.919004.

[33] J. J. Liang, B. Y. Qu, P. N. Suganthan, and Q. Chen, "Problem Definitions and Evaluation Criteria for the CEC 2015 Competition on Learning-based Real-Parameter Single Objective Optimization," *Tech. Report201411A, Comput. Intell. Lab. Zhengzhou Univ. Singapore*, no. November 2014.

[34] S. Cheng, Q. Qin, J. Chen, Y. Shi, and Q. Zhang, "Analytics on fireworks algorithm solving problems with shifts in the decision space and objective space."*International Journal of Swarm Intelligence Research (IJSIR)*6, no. 2 pp. 52-86, 2015.

[35] X. Ye, J. Li, B. Xu, and Y. Tan, "Which Mapping Rule in the Fireworks Algorithm is Better for Large Scale Optimization,"*2018 IEEE Congress on Evolutionary Computation (CEC)*, pp. 1-8, Brazil, 2018. doi: 10.1109/CEC.2018.8477645.

[36] X. Li, S. Han, and C. Gong, "Analysis and improvement of fireworks algorithm"*Algorithms*,*10*(1), p.26. 2017. doi: 10.3390/a10010026.

[37] X. Li,S. Han,L. Zhao, and C. Gong, "Adaptive fireworks algorithm based on two-master sub-population and new selection strategy." In Neural *Information Processing: 24th International Conference, ICONIP 2017, Guangzhou, China, November 14–18, 2017 Proceedings, Part IV 24*, pp. 70-79. Springer International Publishing, 2017.

[38] X. G. Li, S. F. Han, L. Zhao, C. Q., Gong, and X. J. Liu, "Adaptive mutation dynamic search fireworks algorithm."*Algorithms*10, no. 2, p.48, 2017.

[39] M. Chen, Y. Tan, "SF-FWA: A Self-Adaptive Fast Fireworks Algorithm for effective large-scale optimization."*Swarm and Evolutionary Computation*80, 101314, 2023.

[40] H. Mo, and M. Zeng, "A Lite Fireworks Algorithm for Optimization."*arXiv preprint arXiv:2301.02795*, 2023.

[41] W. He, G. Mi, and Y. Tan, "Parameter optimization of local-concentration model for spam detection by using fireworks algorithm." In Advances *in Swarm Intelligence: 4th International Conference, ICSI 2013, Harbin, China, June 12-15, 2013, Proceedings, Part I 4*, pp. 439-450. Springer Berlin Heidelberg, 2013.

[42] M. Alamaniotis, C. Choi, and L. Tsoukalas, "Application of fireworks algorithm in gamma-ray spectrum fitting for radioisotope identification."*International Journal of Swarm Intelligence Research (IJSIR)*6, no. 2, 102-125, 2015.

[43] T. Gonsalves. "Feature subset optimization through the fireworks algorithm."*Int. J. Electr. Comput. Sci. Eng*4, no. 3, 211-218, 2015.

[44] T. Ma, and D. Niu, "Icing forecasting of high voltage transmission line using weighted least square support vector machine with fireworks algorithm for feature selection."*Applied Sciences*6, no. 12, 438, 2016.

[45] E. Tuba, M., Tuba, and M. Beko, "Support vector machine parameters optimization by enhanced fireworks algorithm." In International *Conference in Swarm Intelligence*, pp. 526-534. Cham: Springer International Publishing, 2016.

[46] M. Zhang, Y. Yuan, R. Wang, and W. Cheng. "Recognition of mixture control chart patterns based on fusion feature reduction and fireworks algorithm-optimized MSVM."*Pattern Analysis and Applications*23, 15-26, 2020.

[47] X. Yang, and Y. Tan, "Sample index-based encoding for clustering using evolutionary computation." In Advances *in Swarm Intelligence: 5th International Conference, ICSI 2014, Hefei, China, October 17-20, 2014, Proceedings, Part I 5*, pp. 489-498. Springer International Publishing, 2014.

[48] J. Karimov, and M. Ozbayoglu, "High quality clustering of big data and solving empty-clustering problem with an evolutionary hybrid algorithm." In 2015 *IEEE International Conference on Big Data (Big Data)*, pp. 1473-1478. IEEE, 2015.

[49] Y. Gao, H. Wu, and W. Wang, "A hybrid ant colony optimization with fireworks algorithm to solve capacitated vehicle routing problem," *Appl. Intell.*, vol. 53, no. 6, pp. 7326–7342, 2023. doi: 10.1007/s10489-022-03912-7

[50] Y. Cai, Y. Qi, H. Chen, H. Cai, and O. Hejlesen, "Quantum fireworks evolutionary algorithm for vehicle routing problem in supply chain with multiple time windows." In 2018, *2nd IEEE Advanced Information Management, Communications, Electronic and Automation Control Conference (IMCEC)*, pp. 383-388. IEEE, 2018.

[51] F. Liu, B. Xiao, H. Li, and L. Cai, "Discrete fireworks algorithm for clustering in wireless sensor networks." In Advances *in Swarm Intelligence: 9th International Conference, ICSI 2018, Shanghai, China, June 17-22, 2018, Proceedings, Part I 9*, pp. 273-282. Springer International Publishing, 2018.

[52] S. Dou, J. Li, and F. Kang, "Parameter identification of concrete dams using swarm intelligence algorithm."*Engineering Computations*34, no. 7, 2358-2378, 2017.

[53] X. Wei, L. Liu, Y. Wang, and Y. Yang, "Reentry trajectory optimization for a hypersonic vehicle based on an improved adaptive fireworks algorithm."*International Journal of Aerospace Engineering*2018.

[54] G. Hongyuan, D. Yanan, and L. Chenwan. "Quantum fireworks algorithm for optimal cooperation mechanism of energy harvesting cognitive radio."*Journal of Systems Engineering and Electronics*29, no. 1, 18-30, 2018.

[55] H. Chen, X. Deng, L., Yan, and Z. Ye, "Multilevel thresholding selection based on the fireworks algorithm for image segmentation." In 2017 *International Conference on Security, Pattern Analysis, and Cybernetics (SPAC)*, pp. 175-180. IEEE, 2017.

[56] M. Tuba, N. Bacanin, and A. Alihodzic. "Multilevel image thresholding by fireworks algorithm." In 2015, the *25th International Conference Radioelektronika (RADIOELEKTRONIKA)*, pp. 326-330. IEEE, 2015.

[57] Y. Chen, W., Yang, M., Li, Z., Hao, P., Zhou, and H. Sun, "Research on pest image processing method based on Android thermal infrared lens."*IFAC-PapersOnLine*51, no. 17, 173-178, 2018.

[58] A. Rahmani, A. Amine, R. Hamou, M. Rahmani, and H. Bouarara. "Privacy preserving through fireworks algorithm-based model for image perturbation in big data."*International Journal of Swarm Intelligence Research (IJSIR)*6.3, 41-58, 2015.

[59] J. Shi, B. Xu, P. Zhu, and M. Lu, "Multi-task firework algorithm for cell tracking and contour estimation." In 2016 *International Conference on Control, Automation and Information Sciences (ICCAIS)*, pp. 27-31. IEEE, 2016.

[60] S. Bejinariu, H. Costin, F. Rotaru, R. Luca, C. Niţă, and C. Lazăr, "Fireworks algorithm based image registration." In*Soft Computing Applications: Proceedings of the 7th International Workshop Soft Computing Applications (SOFA 2016), Volume 1 7*, pp. 509-523. Springer International Publishing, 2018.

[61] E. Tuba, I. Strumberger, D. Zivkovic, N. Bacanin, and M. Tuba, "Rigid image registration by bare bones fireworks algorithm." In 2018, the *6th International Conference on Multimedia Computing and Systems (ICMCS)*, pp. 1-6. IEEE, 2018.

[62] S. Bejinariu, R. Luca, and H. Costin, "Nature-inspired algorithms based multispectral image fusion." In the 2016 *International Conference and Exposition on Electrical and Power Engineering (EPE)*, pp. 010-015. IEEE, 2016.