An Overview of Mutation Strategies in Bat Algorithm

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***Abstract*—Bat algorithm (BA) is a population based stochastic search technique encouraged from the intrinsic manner of bee swarm seeking for their food source. BA has been mostly used to resolve diverse kind of optimization problems and one of major issue faced by BA is frequently captured in local optima meanwhile handling the complex real world problems. Many authors improved the standard BA with different mutation strategies but an exhausted comprehensive overview about mutation strategies is still lacking. This paper aims to furnish a concise and comprehensive study of problems and challenges that prevent the performance of BA. It has been tried to provide guidelines for the researchers who are active in the area of BA and its mutation strategies. The objective of this study is divided in two sections: primarily to display the improvement of BA with mutation strategies that may enhance the performance of standard BA up to great extent and secondly, to motivate the researchers and developers for using BA to solve the complex real world problems. This study presents a comprehensive survey of the various BA algorithms based on mutation strategies. It is anticipated that this survey would be helpful to study the BA algorithm in detail for the researcher.**

Keywords*—Bat algorithm; optimization; local optima; mutation strategies; premature convergence; swarm intelligence

I. Introduction

From last two decades, optimization [1] has been considered as the most active area of research. Advanced optimization algorithms are required as the real world's optimization problems shifting towards complexity. The major goal is to reach the optimal value of the fitness function. In real-life applications, optimization is mainly incorporated for nonlinear complex problems. It provides optimum solution by searching a vector in function. Available solutions are incorporated from possible values, however, optimum solution is the intense value [2]. The goals of optimization are to decrease cost, wastes and time, or increase performance [3], profits and benefits. This is the fact that established deterministic procedures or algorithms do not resolve a huge amount of data problems in real life.

Swarm Intelligence (SI) belongs to artificial intelligence domain, used to design multi-agent intelligent systems by embedding the qualities of social insects' behavior in the form of swarms such as bees, wasps and ants, and flocks of fishes and birds. SI first inaugurated by Beni [4] in cellular robotics system. Researchers are attracted with the behavior of flocks of social insects from many years. The individual member of these flocks can achieve hard tasks with the help of collaboration among others [5]; however, such colonies behave without any centralized control. SI is very famous in bio-inspired algorithms, computer science, and computational intelligence. In addition, this SI nature inspired Meta Heuristics algorithms [6] are commonly implemented for solving optimization problems as well as computational intelligence. As compared to traditional algorithms, particle swarm optimization, ant and bee algorithms, firefly and cuckoo search algorithms that based on SI are more beneficial.

A meta heuristic algorithm of SI family named Bat Algorithm (BA) introduced by Xin-She Yang, which works on the micro-bats' behavior of echolocation [2], with variation of pulse rate loudness and emission. The objective of BA is that they fly randomly with the variation in their velocity and frequency and find out their prey in search space [7]. Echolocation is the most essential feature of bat behavior, which means that bat produces a sound pulse and listen the echo that is bouncing back with collision of obstacle during flying [8]. BA is a novel approach based on the two important parameters: pulse rate and loudness [9], and both parameters are fixed while BA is executed.

For researchers, the most important issue is swarm convergence; they are still confused about the convergence of bat towards same curve. They are assumed to highlight the parameters, which causes swarm convergence. Bats' premature convergence [10] greatly affects the performance of BAT algorithm. Before global optimum solution is found, swarms stuck in local optima because of premature convergence. To resolve local optima issues, researchers have introduced many improve methods [11], where divergent mutations are executed on applicable parameters like frequency, pulse rate, velocity, swarm size and loudness [12].

Two most essential parts of meta-heuristic BA that needs to be balanced [7], are exploration and exploitation. Exploration

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is used to find out the global optimum solution while the exploitation is used to capture the local minimum solution. Without trapping into local optima, BA must have to achieve the global optimum solution. Although, the balance between both the components could cause the success of BA. A small amount of exploration [8] and a large amount of exploitation generates premature convergence, while a large amount of exploration and the small amount of exploitation have become the reason to create difficulties for algorithm towards the convergence in local optimum.

Premature convergence is the biggest issue of BA due to the exploration and exploitation [9]. However, researchers are still not sure about the convergence of bat and supposed [10] to point out all the parameters which cause the convergence. The researchers introduced various technique and BA variants to overcome the premature convergence in BA with changing the features like size, velocity, pulse emission rate, loudness, and frequency [6]. However, they succeeded to reduce the effect of premature convergence in BA with their enhanced BA version [11].

The rest of the paper is organized like this the standard BA is discussed in Section II. A comprehensive over view on BA mutation strategies is presented in Section III. Discussion is encompasses in Section IV and future direction for further enhancement is elaborated in Section V.

II. BAT ALGORITHM

The working of BA is quite similar to the natural behavior of bats. They use their echo to search the entire food; similarly, BA adopted the echolocation of micro bats in order to find the global best solution.BA follows the three basic rules: The first one is estimating the optimal distance to the food using the phenomena of echolocation. Secondly, population moves into the search space with distinct velocity and fixed frequency. However, the wavelength and bat loudness can vary according to their distance between food and the entire bat current position. The third rule followed by BA is linearly decreasing behavior of bat loudness factor.

BA includes a candidate solution which is revealed by the bat population, for $i = 1 \ldots N_p$ the candidate solution is expressed by the solution vector $x_{ik}^t = (x_1, \ldots . . x_{ik})$ along each dimension d within real value components x_{ij}^t, where the vector interval for each real value component is $x_{ij}^t \epsilon [x_l - x_u]$ and N_p representing the size of population. While, x_l and x_u defines the upper and lower limits of current vector solution [9]. The principal ingredients of BA are population initialization, mutation procedure, exploitation, exportation, and updating of the current best solution.

Step 1: In this phase of population initialization, the bats assigned an initial value considering as their current best vector position and velocity. Those initial values can be generated using uniform distribution at random locations.

Step 2: This phase includes the echolocation of bats, in which the mutation operator is carried out to simulate and designates the implicit individuals (bats) into the entire search space in order to find the temporary initial solution. The frequency of bats is represented by the following equation.

$$f_i = f_{min} + (f_{max} - f_{min}). R(0,1) \quad (1)$$

f_{max} and f_{min} are the maximum and minimum thresh hold of the bats frequency which is vary according to the nature of problem where $R(0,1)$ is a random number following the uniform distribution.

Bats used the following equation in order to update their current velocity v_{ik}^{t+1}:

$$v_{ik}^{t+1} = v_{ik}^t + (x_{ik}^t - p_i^t) f_i \quad (2)$$

At iteration, v_{ik}^t denotes to bats old velocity and p_i^t is current global optimum. x_{ik}^t is referred as the current bat position.

The updated bat positionx_{ik}^{t+1}can be calculated using the following equation:

$$x_{ik}^{t+1} = x_{ik}^t + v_{ik}^{t+1} \quad (3)$$

Step 3: In this phase of bat exploitation, a random walk is employed to adjust the current best solution.eq.4 is used to generate new solutions

$$x_{new}^t = p_i^t + \varepsilon A_{ik}^t \quad (4)$$

A_{ik}^t is bat loudness which is decrease linearly against each iteration t where ε is a scaling factor generated randomly of interval $[-1,1]$.

Step 4: The pulse rate r_{ik}^t of bats associated with the probability of the rate of omitting pulse in the particular iteration$t$. This probability highly depends on the loudness of batsA_{ik}^t. Basically, the pulse rate r_{ik}^t and the loudness A_{ik}^t of bats are two major controlled parameter employed to control the convergence rate of BA. Commonly, the loudness of bats A_{ik}^t tends to decreases and the pulse rate r_{ik}^t tends to increases when the bats nearly close to their best solution (Fig. 1 and 2). The loudness of bats raises and pulse rate declines when the bat gets its prey, so these both characteristics mimic the original bats.

Both control parameters are denoted by the following equations:

$$A_{ik}^{t+1} = \alpha A_{ik}^t \quad (5)$$

$$r_{ik}^t = r_{ik}^0 \, [1 - \exp(-\gamma^t)] \quad (6)$$

In the eq.5, α representing an constant usually fixed according to problem nature, this parameter is used to control the convergence of bats. Where eq.6 contains constant number as γ . Flow chart of Standard Bat Algorithm is given in Fig. 3. The pseudo code for standard BA is presented in Algorithm 1.

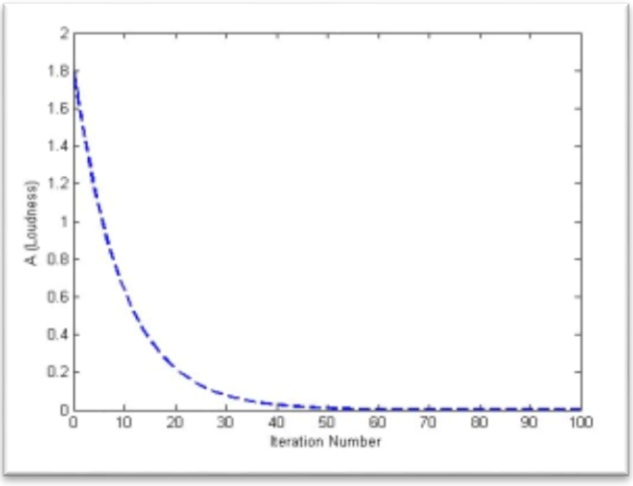

Fig. 1. Decreasing in loudness

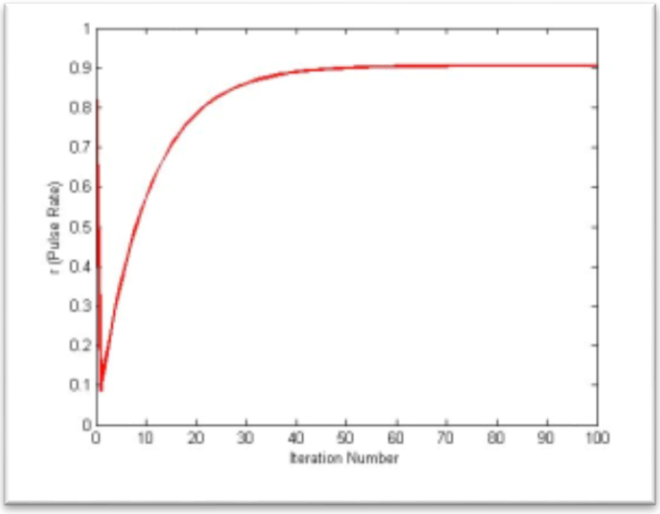

Fig. 2. Increasing in pulse rate

Algorithm 1: Standard Bat Algorithm

Input: $x_{ik}^{t} = (x_1, \ldots . x_{ik})$

Output: x_{ik}^{best} & $\min(f(x))$ →global optimum and minimal fitness function score

(1) x_{ik}^{t} ←Init(x_i); initialization at random location
(2) Intial_fitness(x_{ik}^{t}) ;
(3) $Calculate(x_{ik}^{best}\&)$;Ccurrent global optimum
(4) **While** ($t \leq t_{max}$) **do**
(5) **for** $i \leftarrow 1$ ... N_p **do**
(6) Update f_i by eq.1
(7) Update v_{ik}^{t+1} by eq.2
(8) Update $x_{ik}^{t+1}$by q.3
(9) **if** r(0,1) > r_{ik}^{t} **then**
(10) x_{new}^{t} ← update current solution by eq.4
(11) **end**
(12) f_{new} ← Compute $\boldsymbol{x_{new}^{t}}$
(13) eva ← eva +1;
(14) **if** $f_{new}^{min} < f_{old}^{min}$ **and** Ra(0,1) < A_{ik}^{t} **then**
(15) $x_{ik}^{t} \leftarrow \boldsymbol{x_{new}^{t}}$; $f_{old}^{min} \leftarrow f_{new}^{min}$;
(16) **end if**
(17) $f_{new}^{min} \leftarrow \min(f(x_{ik}^{best}))$;
(18) **end for**
(19) **end while**

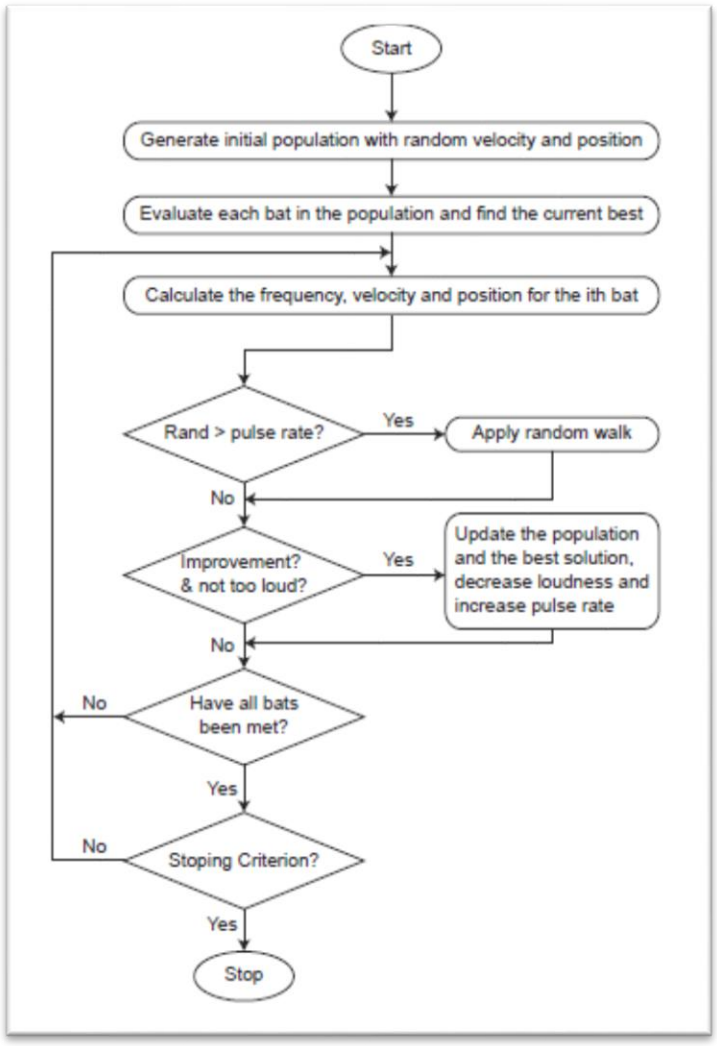

Fig. 3. Flow chart of Standard Bat Algorithm

III. Mutation Strategies

Swarm convergence has been prominent issue for the researchers till now researchers are confused to decide whether particles converge to the same curve or not. They are supposed to highlight [13] the parameter that plays major role in swarm convergence [14]. A mutated BA helps the particles to avoid premature convergence around local optima [15].

Table I shows the issued paper regarding mutation strategies in the highlighted time frame. It depicts the larger number of researchers shown the interest in this field. Multiple components impact this increment from 2011 to 2018 in publication. Moreover, it shows the awareness and significance of mutation strategies in different areas. Interestingly, Table I shows the maximum number of articles published in journals as opposed to the conference.

TABLE I. YEAR WISE STATISTICS WITH DETAILED OBSERVATION

Year	2011	2012	2013	2014	2015	2016	2017	2018	Total
Journal	2	3	4	11	7	7	2	2	38
Conference	-	-	2	3	8	8	4	-	25
Total	2	3	6	14	15	15	6	2	63

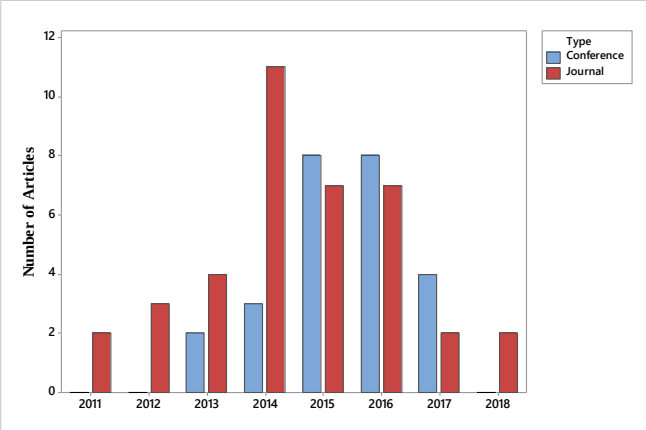

Fig. 4. Year wise representation of number articles

The objective of this paper is to give a review of related work, which is performed on Meta heuristic algorithms. The author in [16], introduced a new algorithm named as Generalized Evolutionary Walk Algorithm (GEWA). In last three years, various improvements and hybridizations on Meta heuristics are introduced. In this paper, the author examines the main elements of such algorithms and describes their work flow.

For the solution of engineering optimization issues in [17], a new BAT is introduced, where the validity of new BAT has been measured with consideration of seven benchmark problems of engineering design. The results illustrated that new BAT is significant as compared to others.

BAT is famous to resolve the problems of nonlinear global optimization, thus in [6] a solution of multi-objective optimization has been given, named Multi-objective Bat Algorithm (MOBA). Firstly, proposed approach validation is performed on standard sub-set of test function and after that against the design problems related to multi-objective like welded beam design. Exhaustive analysis shows the efficiency of proposed approach.

In order to solve binary problems, in [18], the author introduced a new approach Binary Bat Algorithm (BBA). A comparative study is performed on twenty-two standard functions along with Binary Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) to conclude the outcomes of new introduced approach. As well as, Wilcoxon's rank-sum nonparametric test is used to judge the BBA difference of results as compared to other algorithms. According to results, it is concluded that BBA gives outstanding results on most standard functions.

The author in [19], proposed a new modified technique Opposition-Based BAT algorithm (OBA).To improve the global optimal solution and convergence speed, opposition based methodology is integrated with standard BAT's foundation. According to the comparison results, conducted with other algorithms like real coded genetic algorithm (RGA), PSO and DE, effectiveness of proposed algorithm is proved in terms of efficiency.

Literature of last three year described in [20], the goal of this paper is to explain all working of BAT and its new versions as well as its applications. Moreover, the author of this paper precisely describes the case studies. In conclusion, future work related to BAT is also mentioned.

In [21], author proposed an Improved Bat Algorithm (IBA) for solving the insufficient performance of traditional BAT Algorithm. The author explored the exploitation and exploration strategies with three modifications.

A new hybrid method introduced in [22], which combines BAT with the help of mutation operator of differential evolution and beta probability distribution (BADEBD). This method is proposed to solve the problems related to Jiles-Atherton (J-A) modeling. Test results produced significant outcomes as compared to simple BAT Algorithm.

To improve the performance, the author of [23] proposed a modification in hybridized BAT algorithm called a modified BAT-inspired differential algorithm. Modification is performed on mutation and crossover as well as for the stability of local and global search, a novel pulse rate function and loudness introduced. The analysis has performed on five standard test function, which concludes that proposed algorithm give outstanding results.

The author of [24] provided details of new technique BAT Algorithm with Gaussian Walk (BAGW), which is working to overcome the problems related to high dimensions in search spaces. In the paper, the operators: local search, velocity and frequency are helping to achieve BAGW for higher computational results. In the paper, analysis is performed on 4 benchmark functions, which provide the excellence of BAGW as compared to standard BAT.

The author in [25], proposed a new approach Chaotic Bat Algorithm, this approach is implemented by introducing chaos in BAT. The purpose of this introduced approach is to provide stable and strong global optimization by increasing the mobility of its global search. The comparative results of these variants shows that some chaotic variations outperform the benchmark BAT for standard functions.

A critical analysis of Swarm Intelligence (SI) algorithms explained [26], in which the behavior of evolutionary operators is examined. Furthermore, the working of crossover, mutation and selection operators is investigated to achieve exploitation and exploration. Beside this, algorithms are tested on self-organization, Markov chain framework and dynamic system. At last, future work is also discussed.

To overcome the limitation in population diversity, [27] presented a novel complex-valued bat algorithm. The introduced approach implemented the complex-valued encoding, so the imaginary and real parts will be individually updated. Beside this, introduced approach significantly expands the diversity towards the population as well as

dimensions are also expanding for indication. Comparison has been performed with PSO and fourteen test functions, which produced feasible results.

To figure out real world complex problems, an improved method of bat algorithm with chaos initiated. The method has been implemented for permutation of random number generation (RNG) with the use of chaotic sequences to initialize parameters [28]. Standard test functions used to investigate the validity of Chaotic Bat algorithm (CBA), which demonstrate efficiency of CBA than traditional BAT.

Towards the solution of binary space's optimization problem, S. Sabba et al. [29] inaugurated discrete binary bat algorithm (BinBA). The sigmoid function is embedded in proposed algorithm, which implemented by Kennedy in 1997 for binary PSO. The results are promising, when BinBA compared with multidimensional knapsack problems.

BAT is not good in explorative features, to sort out this problem a Novel Adaptive Bat Algorithm (NABA) introduced by Kabir et al. [30]. Two strategies embedded to enhance BAT exploration's degree: Gaussian probability distribution for production of step size in mutation and Rechenberg's 1/5 mutation rule. These strategies embedded to balance exploration and exploitation. Simulation results of NABA showed its compatibility, when conducted with test functions and comparison performed with traditional BATS.

In continuous domain, to resolve global numerical optimization, a self-adaptive bat algorithm (BA-SAM) is presented by Kabir et al. [31]where two enhanced search equations are introduced. Moreover, selection probability used to handle the frequency to apply the introduced equations that results in new BA-SAM. Experimental results showed that BA-Sam outperforms than traditional BAT and other algorithm, when tested on both uni-model and multi-model continuous test functions.

To remodel the echolocation model of BAT with proper utilization of cloud model, a new approach named Cloud Model Bat Algorithm (CBA) introduced in [14], to qualitatively represents the concept "Bats approach their prey". Moreover, for balancing of exploration and exploitation, population information communication and levy fight mode proposed. Experimental results are taken from function optimization, described that CBA is good in performance

For reduction of premature convergence in Bat swarm optimization (BSO), Chaotic based technique incorporated in BSO [32], to introduce Chaotic Bat Swarm Optimisation (CBSO). A best chaotic technique selected from available eleven chaotic map functions for CBSO. CBSO analysis performed on various test functions, which demonstrated that CBSO is good in quality than other algorithms. To represent the solution of weights and ANN architecture optimization, in [33], a novel modified bat algorithm proposed. For the improvement of BAT exploration and exploitation abilities, two modifications introduced. Throughout the training process, various versions of introduced BAT incorporated to figure out selection of architecture, weights and ANN's biases. The test was performed on six classifications and two datasets of standard time series, which showed satisfactory results.

To solve optimization problems related to discrete and continuous data by implementing BAT. Thus, experimental studies proved that the main problem is to set control parameters, and it consumes maximum time to provide its best combination of parameter. The paper is proposed a new advancement in BAT, which implemented without control parameters. Initially in [34], this version is tested on standard benchmark functions that shows the capability of this advanced version.

A Multi-Objective Binary Bat Algorithm (MBBA) proposed in [35], to handle binary search space problems associated with multi-objective optimization. The algorithm implemented an advanced BAT position upgrading method that performs effectively with binary search space. For enhancement in local search capabilities a mutation operator is initiated, to find heuristic Pareto Solution a Pareto dominance approach is used, and for BATs' flight a flight leader selection method. The MBBA is tested with non-dominated sorting genetic algorithm 2 (NSGA-2), and results proved MBBA performance is better.

To resolve the problem of global search, in [15], a Multi-Swarm Bat Algorithm (MBA) is introduced. With the help of parameter settings, information is transferred among various swarms through immigration operator. Although, this structure can produce good balance between local and global search. Furthermore, in swarm's elite, a best individual is passed by using selector operator. The BAT individual transferred towards next generation without using any operator, which ensures that throughout optimization process, these solutions cannot be damage. To evaluate the effectiveness of MBA, it is compared with actual BAT on sixteen standard functions, which conclude that MBA produce more significant values of functions than BAT.

For the solution of exploitation abilities in [36], authors introduced a new parameter called inertia weight that enhance the performance of exploitation ability. The parameter is used to control the effect of inertia of all BATs prior velocity. To test the outcomes, CEC2013 standard problems are verified through it, and experimental result shows the author's method validity.

For target matching, a novel approach introduced in [37], named as Chaotic Mutated Bat Algorithm (CMBA) Optimized Edge Potential Function (EPF). The proposed technique is suitable for the correctness and stability, used for target recognition and CMBA is used to optimize matching parameters. Real-world applications are experimented for the verification of introduced approach feasibility. The simulated results exhibited that introduced approach works effectively throughout the target matching.

In [38], author described a BAT Algorithm improvement by using fuzzy system that adapt its parameters, dynamically. The described method is compared with standard BAT and also with GA, which gives a more effective analysis related to BAT Algorithm. The exhaustive analysis proved that the proposed method produces outstanding results than original BAT Algorithm and Genetic Algorithm.

A new modified version of BAT Algorithm (BAT) introduced in [39], called as Enhanced BAT algorithm (EBA). Local and global searching features of BAT are modified to introduce a new version of BAT by using three different methods. EBA technique is tested on different standard functions that give excellent results as compared to BAT.

A new approach of BAT proposed called novel Bat algorithm (NBA) in [12] that deals with the behavior of BATs. For designing a novel local search technique, the author embedded environment selection of BATs and their self-adaptive remuneration in standard BAT for Doppler effect in echoes. Analysis is performed on four real life engineering problems and twenty standard functions, which demonstrate the superiority of NBA as compared to other algorithms.

To deal with constrained optimization a technique Novel Hybrid Bat Algorithm with Differential Evolution strategy (BADE) introduced in [40]. With the consolidation of DE with BAT, the intrusion of BATs can be significantly imitated by BADE. The impact of other BATs can be calculated by changing the velocity equation of BAT through the addition of mean velocity of swarm. The verification of introduced algorithm is done with nine standard functions and three problems related to engineering designs, which proved that the introduced algorithm is more effective.

In [3] a new variant of BA name Accelerated Bat Algorithm (ABATA) is proposed to improve the local search ability using the Nelder-Mead strategy. The proposed ABATA is tested on seven problems based on integer programming method. The results demonstrate that the proposed method performs better as compared to the classical methods.

The authors in [41], introduced a new variant of BAT algorithm with name Hybrid BAT. Additionally, some techniques of population initialization, decoding and encoding are also implemented to modify BAT for PP problems. Two techniques of local search are implemented in BAT to reduce local convergence. For the diversity of BATs' community, two novel operators for solution representation are also proposed. The experimental results of hybrid BAT impressively shows the efficiency.

In [42] a modified Bat Algorithm for the Quadratic Assignment Problem: Quadratic Assignment problem (QAP) is basically related to discrete search space. This paper is introduced an approach, which handled QAP with respect to Bat Algorithm (BA). As BA is suitable for continuous problems, it cannot be implemented directly to resolve QAP. Therefore, Smallest Position Value (SPV) rule is used to apply BA for QAP, which gives the solutions with appropriate findings concerned with sequencing problems. According to statistical results, the introduced approach provides outstanding results in all cases of PSO. However, the most crucial output result is when input size is small then BA meets optimal fitness whether problem size is huge.

To resolve the problem of global optimization, in [43] author proposed a novel methodology called Variable Neighborhood Bat Algorithm (VNBA), in which Variable Neighborhood Search (VNS) is implemented with simple BAT algorithm in terms of local search. An exhaustive analysis is performed on sixteen standard Test functions, which proved the outstanding performance of VNBA.

The author introduced a new methodology in [44] of BAT Algorithm, in which strategy adopts a dynamic behavior of BAT parameters. The author is used an Interval Type-2 Fuzzy Logic to implement the introduced strategy. The defined strategy is compared with Type-1 Fuzzy Logic, which shows the results in favor of Interval Type-2 Fuzzy Logic.

A new method Enhanced Shuffled BAT Algorithm (EShBAT) described in [45], which is an improved version of Shuffled BAT Algorithm (ShBAT). This method is implemented to increase the exploitation abilities of ShBAT where for the formation of super-memeplex, it collects best memeplex from many and form their groups. The super-memeplex forms independently, to further utilize best solutions. The EShBAT is verified on 30 standard functions. As compared to BAT and ShBAT, EShBAT gives superior results.

The authors of [46] introduced a new algorithm with name BAT-PSO to handle the image registration issues, to significantly utilize in health care and research. According to statistical results, BAT-PSO does better search for optimal parameters registration.

To resolve the issues related to divergence of BAT and convergence speed, a new advanced BAT introduced in [47] named as Local Enhanced Catfish Bat Algorithm (LECBA). To improve the exploitation capabilities, it keeps and uses the contradictions of first best and second best optimum search solutions. For the improvement of search precision, a dynamic adjustment is performed in evolution process on local scale element. If an algorithm produces similar global best for continuous iterations, then it is considered as local optimum. The results concluded with the comparison of various modifications in BAT shows the superiority of LECBA.

In [48] Multi-Objective Reactive Power Dispatch in Distribution Networks using Modified Bat Algorithm: the author produced a new variant of BAT algorithm with name Modified Bat Algorithm to support voltage in distributed architecture.

To support voltage in distributed architecture this paper is introduced a new Modified BATt Algorithm for Optimal Reactive Power Dispatch (OPRF). The major concern of objective functions of introduced approach is to reduce reactive power wastage as well as prevent voltage infringements. An introduced approach has been tested by using a test node feeder of IEEE 37. The tool for simulation of algorithm is python; similarly, PowerFactory is used for architecture. Test results explained that the introduced approach is able to reduce wastage whereas also supply voltage regulation.

In [49] Review of Recent Load Balancing Techniques in Cloud Computing and BAT Variants Is proposed. The purpose of this paper is to study all research algorithms of Load BATlancing, which is commonly used in current situation of Cloud Computing Environment. The most appropriate algorithms that are applicable in every emergent field, mainly inherited from nature. So, the paper is BATsed on one of the nature inspired technology called BATt Algorithm. The paper

is described a work, after comparing all recent BAT and Load BATlancing approaches.

In the paper, traditional BAT is hybridized with proposed method using tabu search, the selection procedure of new solution in traditional BAT is transformed. The target of proposed method is to increase the consistency of objective functions. The Hybrid BAT algorithm proved its superiority, when it is compared with other two standard algorithms in [50].

In [51] Modified Bat Algorithm for Localization of Wireless Sensor Network is introduced. The paper is proposed a technique for wireless sensor networks, which is used to estimate the node localization issues. In the meantime, with the use of bacterial foraging optimization algorithm's technique called bacterial foraging, the modification in traditional BA is performed. The simulation results of proposed method describe that its robustness is increased as well as it provides appropriate success in increment of localization ratio and a good convergence speed.

For community detection, four novel variants of BAT proposed in [52] by combining modularity metric and Hamiltonian function with enhanced discrete BAT and Novel BAT algorithm. Comparison of new variants had been performed with previous approaches like fast greedy modularity optimization, Grivan and Newman, Reichardt and Bornholdt, Ronhovde and Nussinoy and specral clustering, which illustrated promising results of new variants.

The author in [53] described about the emergent field of nature-inspired meta heuristic BAT algorithm and its application, which showed the effectiveness and efficiency of BAT.

To figure out higher dimensional problems in search space and reduce the step size along with the use of BAT, N. M. Nawi et al. [10] proposed an approach named Improve Bat Algorithm with Gaussian distribution random walk (BAGD). The objective of proposed BAGD is to take short step during the period of search. Comparative analysis was performed with six metaheuristic algorithm based on ten standard test functions, which indicates BAGD performance is better than others.

A new algorithm named Bat Flower Pollination (BFP) introduced, to handle the synthesis of diversely separated linear antenna array (LAA) in [54]. The introduced approach works with both BAT and flower pollination algorithm (FPA). To avoid local minima, both algorithms collaborate with each other as well as also suitable for synthesis of diversely separated LAA. A validity of introduced BFP was confirmed through ten standard test functions along with other famous techniques. The results of test concluded that proposed BFP gives superior results than others.

BAT performance is not good for multi-model numerical problems as described in [55], so the author proposed optimal forage strategy. The strategy implemented to direct each bat for search direction. Moreover, random disturbance strategy also used to increase the pattern of global search. CEC2013 test suite was considered for verification of modified algorithm along with four evolutionary algorithms. The results explained the effectiveness of modified approach.

To find global optimal solution with proper consistency and increase the exploration ability of BAT, D. Singh et al. [56] proposed modified bat algorithm (MBA). Experimental analysis showed MBA is better than others, when it was tested against standard benchmark problems as well as with state0of0art algorithms.

To solve the BAT Algorithm, local search problem, a new method Velocity Adaptive Shuffled Frog Leaping BAT Algorithm (VASFLBA) is proposed by the authors in [57]. By the usage of meme transfer process with respect to Shuffled Frog Leaping Algorithm (SFLA), a local search capability is extended. Beside this, for improvement of global search capability, random population competition is proposed. A differential mutation process is implemented to advance the global search optimum, so the algorithm can stand out in local optimal, when an algorithm is trapped in local optimal. The validity of VASFLBA is tested with standard functions. Because of these experimental results, this algorithm is implemented for industrial control system (ICS), to optimize its parameters that belong to support vector machine (SVM). The experimental results show that VASFLBA is better in performance as compared to BAT, SFLA and other algorithms.

The authors introduced a new variant of BAT algorithm in [58] with name Improved Binary Bat Algorithm (IBBA). An IBBA is used to enhance the global search of BAT with the help of crossover, mutation and selection operators belong to Differential Evolution (DE). The experiment conducted with respect to PSO and GA, showed that IBBA is better in correctness and stability.

A novel hybrid algorithm (MDBAT) with hybridization of traditional BAT and multi-directional search algorithm (MDS) introduced by the authors in [59]. It is used to handle the problem belongs to global optimization. The author's goal is to reduce the slow convergence that is the reason, MDS is used for hybridization. MDS speed up the working of introduced algorithm rather than continues the iterations of BAT for a long time without any satisfactory results. The introduced algorithm is tested against sixteen global optimization issues as well as with eight standard algorithms. In conclusion, MDBAT outperforms than other algorithms.

A novel resolution method belongs to directional bat algorithm (dBA) is introduced, to handle reliability based design optimization (RBDO) by A. Chakri et al. in [60]. In the meantime, ε-contrained technique was also embedded into dBA, to resolve constrained optimization problem in effective manner. Various engineering problems were used for testing and results concluded that proposed method can solve RBDO problems.

An improved version of BA called I-BAT is proposed [61] to enhance the exploitation capabilities of BA. The authors used Torus distribution to initialize the bats in I-BAT and the controlled factor equal 0.1 is carried out for managing the search manner into the local area. Experimental Results proved I-BAT as superior Algorithm.

IV. DISCUSSION

From the comprehensive review of mutation strategies of BA, it can be seen that by improving and enhancing the BA following benefits can be achieved.

a) higher convergence ratio

b) better accuracy

c) maximum robustness

From Table II, the results acquired from the literature show that by enhancing the BA with mutation techniques advances the features of standard BA for higher convergence ratio, better accuracy, and maximum robustness

V. CONCLUSION

BA has been widely used in various areas as an approach to solve real world nonlinear complex optimization problems. BA yet needed extreme inspection to enhance the performance of BA and researcher have suggested various BA variants for it. Table II elaborates the research participation presented.

The paper gave the detail on mutation strategies for different BA approaches utilized to resolve the local minima problem of premature convergence problem to attain the best results. We tried to give a survey on different mutation strategies and analyzed each mutation technique separately. With proper rate of growth in the research area, it is expected that more work possible in coming few years. We anticipated that this survey will provoke addition attention for these problems and major research will excite the elementary insight of how BA mutation strategies enhance the performance of standard BA. We are confident that kind of understanding may encourage the BA researchers for better awareness about a particular BA, to enhance it or to devise a new one.

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TABLE II. YEAR WISE RELATED WORK WITH DETAILED OBSERVATION

Review						
S.No	***Authors***	***Year***	***Paper Title***	***Modification Techniques***	***OBSERVATION***	***Results Validation***
1	Xin-She Yang	2011	Review of Metaheuristics and Generalized Evolutionary Walk Algorithm	Generalized Evolutionary walk algorithm (GEWA)	Initial version of BA	-
2	Jiann-Horng Li	2011	A Chaotic Levy Flight Bat Algorithm for Parameter Estimation in Nonlinear Dynamic Biological Systems	Chaotic Levy Fight Bat Algorithm	Standard Bat Algorithm	Effective
3	Jiawei Zhang	2012	Image Matching using a Bat Algorithm with Mutation	Bat Algorithm with Mutation (BAM)	Simple BAT and other optimization algorithms	superior
4	Xin-She Yang	2012	Bat algorithm: a novel approach for global engineering optimization	new BA	Seven benchmark engineering problems	significant results
5	Xin-She Yang	2012	Bat Algorithm for Multi-objective Optimisation	Multiobjective Bat Algorithm (MOBA)	sub-set of test functions and multiobjective design problems	Efficient
6	Galge Wang	2013	A Novel Hybrid Bat Algorithm with Harmony Search for Global Numerical Optimization	novel robust hybrid metaheuristic optimization method (HS/BA)	Fourteen test functions	Outperforms
7	Iztok Fister Jr	2013	A Hybrid Bat Algorithm	Hybrid Bat Algorithm (HBA)	Standard Benchmark Test Functions	Improved
8	Seyedali Mirjalili	2013	Binary Bat Algorithm	Binary Bat Algorithm (BBA)	Twenty two standard functions, Binary GA and PSO	Outstanding Results
9	Suman Kumar Saha	2013	A new design method using opposition-based BAT algorithm for IIR system identification problem	Opposition-Based Bat Algorithm (OBA)	Standard Bat Algorithm	Effective
10	Xin-She Yang	2013	Bat Algorithm: Literature Review and Applications	Review	Standard Algorithms	significant results
11	Selim Yilmaz	2013	Improved Bat Algorithm (IBA) on Continuous Optimization Problems	Three modifications in standard BAT	Ten standard functions	Better in quality
12	S.Yılmaz	2014	Modified Bat Algorithm	Modified Bat Algorithm (MBA)	fifteen standard Test functions	Quality solution
13	Leandro dos Santos Coelho	2014	Bat-Inspired Optimization Approach Applied to Jiles-Atherton Hysteresis Parameters Tuning	Hybrid BA with a mutation style operator from differential evolution and beta probability distribution (BADEBD)	Standard Bat Algorithm	Better in performance
14	Adis Alihodzic	2014	Improved Hybridized Bat Algorithm for Global Numerical Optimization	Modified Bat-inspired differential evolution	Five standard functions	Outperforms
15	Iztok Fister Jr	2014	A Novel Hybrid Self-Adaptive Bat Algorithm	Hybrid Self-Adaptive Bat Algorithm (HSABA)	Standard Algorithms	HSABA works adequately
16	Osama Abdel-Raouf	2014	An Improved Chaotic Bat Algorithm for Solving Integer Programming Problem	Improved Chaotic Bat Algorithm (IBACH)	Traditional BA, PSO and Other Search Algorithms	Works with less computational time
17	XingjuanCai	2014	Bat algorithm with Gaussian walk	BAT Algorithm with Gaussian Walk (BAGW)	Four benchmark functions	Excellent
18	Amir H. Gandomi	2014	Chaotic Bat Algorithm	BAT algorithm with chaos	Standard functions	Outperforms
19	Xin-She Yang	2014	Swarm Intelligence Based Algorithms: A Critical Analysis	Critical analysis on SI	Self-organization, Markov chain framework and dynamic system	
20	Liangliang Li	2014	A novel complex-valued bat algorithm	Complex-Valued Bat Algorithm	PSO and fourteen test functions	Feasible results
21	Homayun Afrabandpey	2014	A Novel Bat Algorithm Based on Chaos for Optimization Tasks	Chaotic Bat Algorithm (CBA)	Standard Test functions and traditional BAT	Efficient
22	Sara Sabba	2014	A discrete binary version of bat algorithm for multidimensional knapsack problem	Discrete Binary Bat Algorithm (BinBA)	Multidimensional Knapsack problem	Promising results
23	Md. Wasi Ul Kabir	2014	A Novel Adaptive Bat Algorithm to Control Explorations and Exploitations for Continuous Optimization Problems	Novel Adaptive Bat Algorithm (NABA)	Test functions nad Traditional BAT	Compatible
24	Md. Wasi Ul	2014	Bat Algorithm with Self-adaptive	Self-Adaptive Bat	Uni-model and multi-	Outperforms

	Kabir		Mutation: A Comparative Study on Numerical Optimization Problems	Algorithm (BA-SAM)	model optimization test problems	
25	Yongquan Zhou	2014	Cloud Model Bat Algorithm	Cloud Model Bat Algorithm (CBA)	Function optimization	Good performance
26	A. Rezaee Jordahi	2015	Chaotic Bat Swarm Optimisation (CBSO)	Chaotic Bat Swarm Optimisation (CBSO)	Various test functions	Good in quality
27	Najmeh Sadat Jaddi	2015	Optimization of neural network model using modified bat-inspired algorithm	Modified Bat Algorithm	Six classifications and two standard time series datasets	Satisfactory results
28	Iztok Fister Jr	2015	Towards the Development of a Parameter-free Bat Algorithm	Advanced BAT	Standard functions	Showed good capability
29	Laamari Mohamed Amine	2015	A Multi-objective Binary Bat Algorithm	Multi-Objective Binary Bat Algorithm (MBBA)	non-dominated sorting genetic algorithm 2 (NSGA-2)	Better in performance
30	Gai-Ge Wang	2015	A Multi-Swarm Bat Algorithm for Global optimization	Multi-Swarm Bat Algorithm (MBA)	Satndard BAT and sixteen standard functions	Significant in performance
31	Zihuha Cui	2015	Bat Algorithm with Inertia Weight	New parameter with inertia weight	CEC2013 standard problems	Validate
32	Yimin Deng	2015	Chaotic Mutated Bat Algorithm Optimized Edge Potential Function For Target Matching	Chaotic Mutated Bat Algorithm (CMBA) Optimized Edge Potential Function (EPF)	Real world applications	works efficiently
33	Jonathan Pérez	2015	Proposed Augmentation of the Bat Algorithm using fuzzy logic for dynamic parameter adaptation	Bat Algorithm improvement by using fuzzy logic for dynamic parameter	Satndard BAT and GA	Outstanding Results
34		2015	A new modification approach on Bat Algorithm for solving optimization problem	Enhanced Bat Algorithm (EBA)	Standard Functions	Excellent Results
35	Xian-Bing Meng	2015	A novel bat algorithm with habitat selection and Doppler effect in echoes for optimization	Noval Bat Algorithm (NBA)	Twenty Standard functions and four real life engineering applications	Superior
36	Xianbing Meng	2015	A Novel Hybrid Bat Algorithm with Differential Evolution Strategy for Constrained Optimization	Hybrid Bat Algorithm with Differential Evolution Strategy (BADE)	Nine standard functions and three real life engineering design problems	Effective Results
37	Ahmed Fouad Ali	2015	Accelerated Bat Algorithm for Solving Integer Programming Problem	Accelrated Bat Algorithm (ABATA)	four standard algorithms and seven integer programming problems	works in less computational time
38	Jinfeng Wang	2015	A Hybrid Bat Algorithm for Process Planning Problem	Hybrid BAT	Two standard algorithm	Satisfactory Solution
39	Padmavathi Kora	2015	Improved Bat algorithm for the detection of myocardial infarction	Improved Bat	Four benchmark functions	Better in performance
40	Apurv Shukla	2015	A modified Bat Algorithm for the Quadratic Assignment Problem	Modified Bat	Traditional BA, PSO and Other Search Algorithms	works efficiently
41	Gai-Ge Wang	2016	An Improved Bat Algorithm with Variable Neighborhood Search for Global Optimization	Variable Neighbourhood Bat Algorithm (VNBA)	Sixteen Standard Test Functions	Outperforms
42	Jonathan Perez	2016	Bat Algorithm with Parameter Adaptation using Interval Type-2 Fuzzy Logic for Benchmark Mathematical Functions	a new methodology of Dynamic behavior of BAT parameters	Type-1 fuzzy Logic	Best results
43	Hema Banati	2016	Enhanced Shuffled Bat Algorithm (EShBAT)	Enhanced Shuffled Bat Algorithm (EShBAT)	Thirty Test Functions	Superior results
44	Sumitha Manoj	2016	Hybrid BAT-PSO Optimization Techniques for Image Registration	BAT-PSO	Ten standard functions	Better in performance
45	Liu Yi	2016	Local Enhanced Catfish Bat Algorithm	Local Enhanced Catfish Bat Algorithm (LECBA)	Modified BAT	Excellent Results
46	Aadil Latif	2016	Multi-Objective Reactive Power Dispatch in Distribution Networks using Modified Bat Algorithm	Modified BA	Standard bench mark functions	Outperforms
47	Shabnam Sharma	2016	Research & Analysis of Advancement in BAT Algorithm	Reviewof relate work	Un-constrained problems	Best results
48	Sinha Sheikh Abdullah	2016	Review of Recent load Balancing Techniques in Cloud Computing and BAT Variants	V-BAT	Standard functions	works efficiently
49	Messaoudi	2016	Hybrid Bat algorithm for overlapping	Hybrid Bat Algorithm	Two standard	Superior

	Imane		community detection		algorithm	
50	Sonia Goyal	2016	Modified Bat Algorithm for Localization of Wireless Sensor Network	Modified BA	Ten standard functions	Better
51	Jigyasha Sharma	2016	Community Detection Using Meta-heuristic Approach: Bat Algorithm Variants	Four new variants of BAT	fast greedy modularity optimization, Grivan and Newman, Reichardt and Bornholdt, Ronhovde and Nussinoy and specral clustering	Promising results
52	N. Mohan	2016	A Comprehensive Review of BAT Algorithm and its Applications to various Optimization Problems	Survey on BAT applications	Constrained problems	works efficiently
53	Nazir Mohd Nawi	2016	A Modified Bat Algorithm Based on Gaussian Distribution for Solving Optimization Problem	Improved Bat Algorithm with Guassian distribution random walk (BAGD)	Ten standard test functions along with six meta heuristic algorithms	Better in performance
54	Rohit Salgotra	2016	A novel bat flower pollination algorithm for synthesis of linear antenna arrays	Bat Flower Pollination (BFP)	Ten test functions and other famous techniques	Superior results
55	Xingjuan Cai	2016	Improved bat algorithm with optimal forage strategy and random disturbance strategy	Optimal Forage Stategy	CEC2013 test suite along with four evolutionary algorithms	Effective
56	Deepika Singh	2017	A Novel Modified Bat Algorithm for Global Optimization	Modified Bat Algorithm (MBA)	Standard benchmark problems and state-of-art algorithms	Better
57	Jinle Li	2017	Application of Velocity Adaptive Shuffled Frog Leaping Bat Algorithm in ICS Intrusion Detection	Velocity Adaptive Shuffled Frog Leaping BAT Algorithm (VASFLBA)	Standard Functions	Better performance
58	Siquing Sheng	2017	Capacity configuration optimisation for stand-alone micro-grid based on an improved binary bat algorithm	Improved Binary Bat Algorithm (IBBA)	PSO and GA	Better in stability
59	Fábio A. P. Paiva	2017	Modified Bat Algorithm With Cauchy Mutation and Elite Opposition-Based Learning	Modified Bat having Cauchy mutation and elite opposition Based learning	Four benchmark functions	Excellent
60	Mohamed A. Tawhid	2017	Multi-directional bat algorithm for solving unconstrained optimization problems	Multi-Directional Bat Algorithm (MDBAT)	Eight standard algorithm and sixteen global optimization problems	Outperforms
61	Asma CHAKRI	2017	New directional bat algorithm for continuous optimization problems	Directional BAT Algorithm (dBA)	BAT variations, ten standard algorithm and functions from CEC'2005 standard suite	Better
62	Asma CHAKRI	2018	Reliability based-design optimization using the directional bat algorithm	Novel resolution method belongs to Directional Bat algorithm	Various engineering problems	Solve RDBO problems
63	Waqas Haider Bangyal	2018	An Improved Bat Algorithm based on Novel Initialization Technique for Global Optimization Problem	Improved Standard BA (I-BAT)	Standard Functions	Superior results