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Recent Developments in Bat Algorithm: A Mini Review

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Recent Developments in Bat Algorithm: A Mini Review

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Abstract: In present time, meta-heuristic algorithms have been widely adopted for solving diverse classes of optimization problems. These procedures/algorithms have advantage over classical algorithms due to strong exploration and exploitation capabilities. In recent time, a Bat algorithm is developed on the basis of echolocation characteristics of bat. This algorithm has applicability to solve number of constrained and unconstrained optimization problems. The bat algorithm gives state of art results as compared to same class of metaheuristics. The objective of this paper is to explore bat algorithm in terms of modifications, improvements, search strategies and nature of problems being solved. Hence, this paper presents the mini review on bat algorithm. Further, the applicability of bat algorithm in diverse filed has been discussed.
Keywords*:* Bat algorithm, Echolocation, Microbats and Solution Search Equation**.**

1. Introduction

In present time, large numbers of meta-heuristic algorithms are motivated from natural phenomena. Swarm intelligence, Physics law, Insect's behaviour, and Natural process of living beings etc. are inspiration from natural phenomena. Every meta-heuristic algorithm consists of unique characteristic to obtain the optimal solution. Further, the major benefit is elasticity of such algorithms. Elasticity helps algorithm to adjust according to the kind of problem. Different meta-heuristics have been developed so far such as ACO, Two-Step ABC, MCSS, ICSO, CCSS, PSO etc. [9-10, 19-22]. Recently, a new meta-heuristic algorithm inspired from bats behaviour has gained extensive popularity among researchers to solve diverse optimization tasks. This algorithm inspires through the echolocation feature of Microbats [41]. This feature helps microbats to detect prey and avoid obstacles. Microbat emits short pulses while searching prey. If a prey or obstacles is nearer to microbats, then emission pulse rate increases and loudness decreases. Further, the frequency of microbats can be tuned with loudness and pulse rate. In turn, it will change the wavelength of echolocation to detect objects. The frequency updating, velocity updating, and position update mechanism of bats are described using equations (1) to (3).

$$f_i = f_{min} + (f_{max} - f_{min})\beta \tag{1}$$

$$\boldsymbol{v_i^t} = \boldsymbol{v_i^{t-1}} + (\boldsymbol{x_i^t} - \boldsymbol{x_*})\boldsymbol{f_i} \tag{2}$$

$$\boldsymbol{x_i^t} = \boldsymbol{x_i^{t-1}} + \boldsymbol{v_i^t} \tag{3}$$

where f_i, v_i, x_i signify the frequency, velocity, and position of a bat respectively and $\beta \in [0,1]$ is a random vector sketched with uniform distribution. The primary aim of this work is to present state of art review on the Bat algorithm. Another aims to identify the thrust area of the Bat algorithm which can undergo for further improvements. Further, the applicability of the Bat algorithm in diverse fields is also one of objectives of this paper. Rest of paper presents the variants of bat algorithm in section 2, diverse application of bat algorithm in section 3 and finally conclusion in section 4.

2. Variants of bat algorithm

This section portrays the literature review on the bat algorithm. This section mainly focuses on incorporation of search mechanisms, improvements and modifications in bat algorithm. Fig. 1 illustrates the improvements in the bat algorithm using different aspects and also listed the different variant of bat algorithm. Fister et al. presented a hybrid bat algorithm (HBA) [12]. In this work, differential evolution strategies are used to boost the local search skill of original bat algorithm. The aim of the incorporation of these strategies into bat algorithm is to improve the candidate solution. Further, Fister et al. [13] introduced the concept of self-adaptation in bat algorithm, called hybrid self-adaptive bat algorithm (HSABA). In this work, control parameters of the candidate solutions are updated using self-adaptive learning rates. Further, a local search ability and domain specific knowledge methods are included in bat algorithm to make it more capable and stronger. Mirjalili et al. [26] introduced the binary version of bat algorithm. The solution search space is considered as hypercube in binary bat algorithm (BBA). The position of agents can be switched between "0" and "1" binary values. The transform function is employed to map velocity value to the probability value.

In chaotic bat algorithm (CBA), Gandomi & Yang [15] measured the randomness using chaotic maps in each iterative search steps. Chaotic maps are used in four different ways for tuning the parameters of bat algorithm and enhancing the functioning of BA. The binary bat algorithm is further modified using chaos and incorporated elitist strategies by Zaho and He for increasing global search ability and effectiveness in search space named as chaotic binary bat algorithm (CBBA) [45]. The diversity of solutions is increased through chaotic maps and elitist strategies for exploring the global best solutions. Further, Yilmaz and Kucuksille [42] commended the concept of inertia weight factor in BA to develop exploitation process. The local search ability is also enhanced using adaptive frequency tuning. In another improved version of bat algorithm, local search pattern inspired form optimal forage strategy and global search pattern inspired from random disturbance strategy is reported by Cai et al. [8]. It is seen that optimal forage seeking strategy makes the bat algorithm more efficient and robust. In discrete bat algorithm (DBA) Hassan et al. [17] represented the solutions using locus-based adjacency scheme. To overcome from local optima, the η top bats are selected as per their fitness values instead of single global best selection. In improved discrete bat algorithm (IDBA), the random number and hamming distance are introduced by Osaba et al. [30] to calculate velocity.

The new solutions are generated using successor operator. The differential operator and population diversity mean based mechanism are adopted to perform global search in modified bat algorithm (MBA) by dos Santos & Askarzadeh [11]. In another variant, the original bat algorithm is modified using bacterial forage strategy by Goyal & Patterh [16]. The bat movement is decided as per their fitness function value. A robust optimization technique BAT-CLARA is introduced by Aboubi et al. [1]. This is the combination of k-medoids partitioning and bat algorithm. The search space is explored through the intelligent behaviour of bats. A Parallel Bat Algorithm with MapReduce is presented to manage huge data sets with different nodes [5]. The algorithm consists of three modules i.e., Bat movement module, fitness calculation module and reduce module. Iterative MapReduce method is applied to reduce computation time and memory requirement in hadoop based parallel binary bat algorithm (HPBBA) [28]. It consists of two parts, bat initialization and Iterative MapReduce. Meng et al. [25] integrated foraging habitations and doppler effect into bats, called NBA. The differential operator and Levy-flights are introduced in BA by Xie et al. [40] for self-adaptability and to handle premature convergence. Random walk property is employed by Neelima et al. [29] in hybrid, artificial bee colony bat (HABCBAT) in place of onlooker bee part of ABC algorithm [29]. This algorithm minimizes frequent item sets and decreases time, memory space requirement for frequent itemization. The firefly and bat algorithms (FFBAT) are combined to form an optimization approach named as FFBAT by Arunarani et al. [4].

Using variable neighborhood search strategy, the local search ability and diversity of original bat algorithm are enhanced by Wang et al. [39]. Two-stage bat algorithm (TSBA) is a novel frame work inspired from artificial bee colony algorithm [44]. The trade-off policy is used to equalize the association between exploration and exploitation. Standard Gaussian distribution is applied in bat algorithm by Cai et al. [7] to improve local search ability named as Bat algorithm with Gaussian walk (BAGW). Lamia & Habib [46] combined K-means with Bat algorithm (KMBA) to find the initial cluster centers. The optimal cluster numbers are generated after minimizing objective function and is validated using DB index. Cai et al. [47] proposed ensemble BA for large scale optimization problems. The probability selection mechanism is designed by adjusting six improved strategies from literature. To find the optimal solution by ensuring balance between exploration and exploitation, Rehman et al. [48] presented improved two-stage Genetic Bat Algorithm (GBa). Optimal solution is found using GA in first stage and then Bat algorithm is applied in second stage. To resolve data clustering issues, Zhu and Wang [49] proposed another variant of bat algorithm. The algorithm adopted foraging behaviour of bats and their unique flight mode. Two parameters- attenuation coefficient (α) and enhancement coefficient (γ) were tuned in order for improving convergence rate.

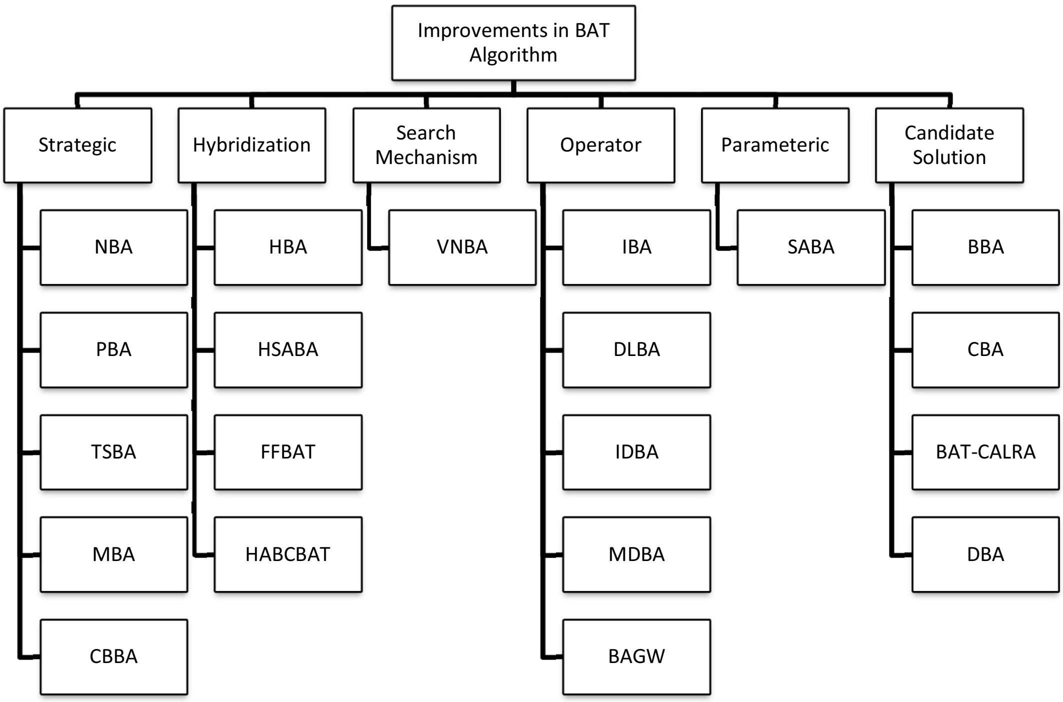

Figure 1. Bat algorithm and its variants.

For maintaining balance among exploration and exploitation tasks of BA, Li & Le [50] presented a hybrid metaheuristic named as improved Binary Bat Algorithm, called BBACE. The BBACE algorithm maintains the balance among search mechanisms using cross entropy method and can be applied for solving attribute selection problems. The algorithm adopted two operators Binary Bat algorithm (BBA) and Cross- Entropy (CE) for optimization. Zhu et al. [51] proposed an improved Bat algorithm for data clustering. The proposed algorithm applied Gaussian-like convergence and five other convergence factors for enhancing the global search capability. Further, local search was improved by adopting hunting strategy of whales of WOA and sine-position updating policy. Table 1 consists of the different improvements and techniques incorporated in bat algorithm to alleviate the shortcomings associated with this algorithm.

Table 1. List of improvements in Bat algorithm.

Authors	Algorithms	Techniques	Modifications
Fister Jr et al. [12]	- Hybrid Bat Algorithm (HBA)	- Differential Evolution Strategies	The concept of mutation, crossover and differential selection is incorporated to improve the performance and convergence rate. - Mutation $u_i^t = w_{r0}^t + F(w_{r1}^t - w_{r2}^t)$ (4) for $i = 1$ to NP - Crossover $z_{i,j} = \begin{cases} u_{i,j}^{(t)} & rand_j(0,1) \leq CR \vee j = j_{rand,} \\ w_{i,j}^{(t)} & otherwise \end{cases}$ (5) - Differential Selection $w_i^{(t+1)} = \begin{cases} z_i^{(t)} if & f(Z^{(t)}) \leq f(Y_i^{(t)}), \\ w_i^{(t)} & otherwise \end{cases}$ (6)
Fister et al. [13]	- Self- Adaptive Bat Algorithm (SABA)	- Self- adaptive mechanism for control parameters	- Candidate solution $x_i^t = \left(x_{i0}^{(t)} \dots \dots x_{iD}^{(t)}, A^{(t)}, r^{(t)}\right)^T$ (7) for $i = 1$ to N The control parameters modification equation $A_{i,j} = \begin{cases} A_{l,b}^{(t)} + rand_0(A_{u,b}^{(t)} - A_{l,b}^{(t)}) \text{ if } rand_1 < \tau_1, \\ A^{(t)} \end{cases}$ (8) $r^{(t+1)} = \begin{cases} r_{l,b}^{(t)} + rand_2(r_{u,b}^{(t)} - r_{l,b}^{(t)}) \text{ if } rand_3 < \tau_2, \\ r^{(t)} \end{cases}$ (9) τ_1, τ_2 denotes the learning rates and $rand_i$ designates the randomly generated values.
	- Hybrid Self-Adaptive BA algorithm (HSABA)	- Differential evolution strategy and crossover control parameter CR	- The DE strategy is selected as per probability value of crossover control parameter. $DE\ y_n = \begin{cases} \text{DE strategy} & \text{if } rand(0,1) \leq CR \vee n = D, \\ x_{in}^{(t)} & otherwise \end{cases}$ (10)
Mirjalili et al. [16]	- Binary Bat Algorithm (BBA)	- Transform Function	- V- Shaped transform function is adopted that can be described in equation 11. $V\left(v_i^k(t)\right) = \left\lvert \frac{2}{\pi} \arctan\left(\frac{\pi}{2} v_i^k(t)\right) \right\rvert$ (11) - The positions of bats are updated using new equation (12)

			$x_i^k(t+1) = \begin{cases} (x_i^{(k)}(t))^{-1} & if\ rand < V\left(v_i^k(t+1)\right) \\ x_i^{(k)}(t) & rand \geq V\left(v_i^k(t+1)\right) \end{cases}$ (12) where, the v_i^k(t) and $x_i^{(k)}(t)$ velocity and position of i[th] particles and $(x_i^{(k)}(t))^{-1}$is the complement of $x_i^{(k)}(t)$
Gandomi and Yan [15]	- Chaotic Bat Algorithm(CBA)	- Chaotic Maps	- Chaotic maps-based strategies are introduced in bat algorithm such as CBA-I $f_i = f_{min} + (f_{max} - f_{min})CM_i$ (13) - In original BA, β is a random number, while in CBA, chaotic number is used. - CBA-II: Parameter of position updated mechanism (λ_i) is modified through chaotic maps $v_i^t = v_i^{t-1} + (x_i^t - x^*)CM_i f_i$ (14) - CBA-III & CBA-IV: Loudness and emission pulse rate are also replaced with chaotic maps.
Yilmaz and Kucuksille [42]	- Improved Bat Algorithm (IBA)	- Inertia Weight Factor and Adaptive Frequency Modulation	- Inertia Weight Factor is calculated using equation (15) $w_{iter} = \frac{iter_{max} - iter}{iter_{max}}(w_{max} - w_{min}) + w_{win}$ (15) $iter_{max}$ is maximum iteration number. - Adaptive Frequency Modulation In IBA each dimension is assigned a frequency f_{min} and f_{max} , which is calculated as $f_i = f_{min} + \frac{\sqrt{(min(diff) - dif\ (j))^2}}{range} * (f_{max} - f_{min})$ (16) where $diff_j = \sqrt{(x_{ij} - x_j^*)^2}$is distance between i and global best solution and range = max(diff) − min(diff) is variation in frequency as per distance.
Cai et al. [8]	- Improved bat algorithm with optimal forage and random disturbance strategy	- Optimal Forage and Random Distribution	- Introduced random distribution strategy and modified velocity equation $v_{ik}^{t+1} = (x_{mk}^t - x_{nk}^t) \cdot rand$ (17) where m, n denotes the randomly selected bats from population.
Meng et al. [25]	- Novel Bat Algorithm (NBA)	- Doppler Effect and Foraging Habitats	- New solution is generated using $x_{i,j}^{t+1} = \begin{cases} g_j^t + \theta * \lvert maen_j^t - x_{i,j}^t \rvert * \ln\left(\frac{1}{u_{i,j}}\right) & if\ rand_j(0,1) < 0.5 \\ g_j^t - \theta * \lvert maen_j^t - x_{i,j}^t \rvert * \ln\left(\frac{1}{u_{ij}}\right), & otherwise, \end{cases}$ (18) $f_{i,j} = f_{min} + (f_{max} - f_{min}) * rand(0,1)$ (19) $f_{i,j} = \frac{(c + v_{i,j}^t)}{c + v_{g,j}^t} * f_{i,j} * \left(1 + C_i * \frac{(g_j^t - x_{i,j}^t)}{\lvert g_j^t - x_{i,j}^t \rvert + \varepsilon}\right)$ (20) $v_{i,j}^{t+1} = w * v_{i,j}^t + (g_j^t - x_{i,j}^t) * f_{i,j}$ (21) $x_{i,j}^{t+1} = x_{i,j}^t + v_{i,j}^t,$ (22) where $w \epsilon [0,1]$ and C is positive no.

Xie et al [40]	- Differential Operator;along with Lévy-flights trajectory Algorithm (DLBA) -	- Differential Operator and Lévy-flights trajectory	- In DLBA, the position x of each bat individual are updated using equation (23) $x_i^{t+1} = x_{best}^t + f_{1i}^t(x_{r1}^t - x_{r2}^t) + f_{2i}^t(x_{r3}^t - x_{r4}^t)$ (23) where x_{best}^t is current global best location and x_i^t is individual bat in swarm. - Lévy flights $x_i^t = \hat{x}_i^{t-1} + \mu \mathrm{sign}[\mathrm{rand} - 0.5] \oplus \mathrm{Levy}$ (24) $\mathrm{Levy} \sim u = t^{-\lambda}, (1 < \lambda \leq 3)$ (25)
Aboubi et al. [1]	- BAT-CLARA: BAT-inspired algorithm for Clustering LARge Applications	- k-medoids	- The search space divided as: - Artificial world - Neighbourhood search. - Bats position. - Fitness function. - Distance among neighbours.
Ashish et al. [5]	- Parallel Bat Algorithm-Based Clustering Using MapReduce	- Parallel processing and MapReduce	- Bat Movement: - The position of the bat is updated using map reduce function. Re-initialization is done, if boundary constraints exploit. - Fitness Calculation: - Fitness of all the bats is computed in this step. - Reduce Phase: - Current best- position is updated using output gathered from all the mappers.
Neelima et al. [29]	- Hybrid ABCBAT	- Random walk	- Initialize population. - Compute fitness value of the population. - Produce new solution for each employee bees. - Choose best solutions. - Rank bats to find current best solution by updating the solution by random walk.
Arunaran iet al. [4]	- Firefly and bat algorithms (FFBAT) -	- Multi-objective functions	- Firefly algorithm $y_i^{k+1} = y_i^{k+1} y_i^k - \beta_0^{ak} e^{-\gamma D_{ij}^2}(y_j^k - y_i^k) + \sigma_k \mu_i^k$ (26) - where y_i^{k+1} is the new updated solution, y_j^k and y_i^k are $j^{th}$and i^{th}solutions, $\sigma_k$is arbitrary parameter, $\mu_i^k$is random number, $\beta_0^{ak}$and γ are constants. BAT algorithm $Y_i^{k+1}=Y_i^k + V_i^{k+1}$ (27) $V_i^{k+1}=V_i^k + (Y_i^k - Y_i^c) * F_i$ (28) $F_i = F_{min} + (F_{max} - F_{min}) * \beta$ (29)
Hassan et al. [17]	- Discrete Bat Algorithm (DBA)	- Locus based encoding scheme	- The difference operator between bat position is calculated using equation (30) $d_n = (x_i - x_i^*) = \begin{cases} 1 & \text{if } g(x_i) \neq g(x_i^*) \\ -1 & \text{if } g(x_i) = g(x_i^*) \end{cases}$ (30) - New position is updated using $d_i^{new} = \begin{cases} x_i^* & \text{if } v_i \geq 1 \\ x_i & \text{otherwise} \end{cases}$ (31) - where x_i is position and $g(x_i)$ is the group - assignment of node i. In global best solution, the η $(10\%\ of\ popolation\ size)$ top bats as per fitness value to be selected.
Osaba et al. [30]	- Improved Discrete Bat	- Random number and Hamming distance	- Velocity v_i^t= Random [1, HammingDistance (x_i^t, x_*)] (32)

	Algorithm (IDBA)		- This shows that v_i of a bat i at time step t, is a random number and hamming distance. New solutions are generated using successor operators 2-opt and 3-opt.
Natesan et al. [28]	- Hadoop Based Parallel BBA (HPBBA)	- Iterative Map Reduce	- Hadoop Based PBBA works in two parts - Part1: The first part is responsible for bats initialization. - Part2: Iterative MapReduce is responsible to discover the best optimal solution.
Wang et al. [39]	- Variable Neighbourhood Bat Algorithm (VNBA)	- Variable Neighbourhood search	- The position of bat i is updated using equation 33. $u_i(j) = X_{iN}(j)$ (33) - Population diversity is improved using equation $u_i(j) = X_{iN}(j)$ if rand < 0.5 (34) - New generated position can be calculated using $u_i(j) = \begin{cases} X_{iN}(j) & \text{if rand} \geq 0.5 \\ X_{iN}(k) & \text{if rand} < 0.5 \end{cases}$ (35) where, X_{iN} is neighbour of i bat and rand isa number.
dos Santos Coelho and Askarzadeh [11]	- Modified DBA	- Differential operator and diversity mean.	- Differential operator $x_{i,new}^{t} = x_{i1,old}^{t-1} + s(x_{i2,old}^{t-1} - x_{i3,old}^{t-1})$ (36) where, s (scale factor) is a random vector and i1, i2 and i3 are mutually different integers. - Average Diversity based updation mechanism $A_i^t = 1 - DM. r_i^t = DM$ (37) where, DM is average diversity of current normalized population.
Zhang et al. [44]	- Two-stage bat algorithm (TSBA)	- Trade off strategy	- Frequency is calculated using equation (38) $f_i^j = f_{min} + (f_{max} - f_{min}) \propto$ (38) - Velocity is calculated using equation (39) $v_i^j = \mu v_i^j + (x_{i,food}^j - x_{best}^j) f_i^j$ (39) - Position is calculated using equation (40) $x_{i,new}^j = \omega x_i^j + v_i^j$ (40) where i is i^{th} food source and j is j^{th} components of solution space. Two inertial parameters: μ and ω. $\omega = \omega_{min} + (\omega_{max} - \omega_{min}) \left\| \frac{\sin(\varphi t)}{\varphi t} \right\|$ (41) $\mu = 1 - e^{-\kappa \sqrt{\sum_{j=1}^{D} (x_{i,food}^j - x_{best}^j)^2}}$ (42) - New solution generation $x_{i,new} = x_{i,old} + \rho A^t$ (43) $\rho = \frac{1}{1+e^{at-b}} \varepsilon$ (44) Where, φ, κa, and b are constants.
Goyal and Patterh	- Modified Bat Algorithm(MBA) with bacterial	- Bacterial foraging strategies	- Bat position movement is calculated using equation (45)

[16]	foraging strategy		$x_i^t = x_i^{t-1} + v_i^t \frac{\Delta_i}{\sqrt{\Delta_i^T \times \Delta_i}}$ (45) where, v_i^t defines velocity and Δ_i represents random number
Zhao and He [45]	- Chaotic binary bat algorithm(CBBA)	- Chaos and elitist strategy	- The original bat algorithm's Frequency parameter β is modified by chaotic maps $f_i = f_{min} + (f_{max} - f_{min})c_i$ (46) - Elitist strategy is used to find global best solution with better fitness value.
Cai et al. [7]	- BA with Gaussian walk (BAGW)	- Standard Gaussian distribution	- Frequency is calculated using equation (47) $f_{i,j} = f_{min} + (f_{max} - f_{min}).\beta$ (47) where, $f_{i,j}$ is $\vec{f} = (f_{i1}, f_{i2}, f_{i3}, \ldots. f_{iD})$ - Velocity is calculated using equation (48) $v_{ik}(t+1) = (x_{ik}(t) - p_k(t)).f_i$ (48) - Position is calculated using equation (49) $\overrightarrow{x_j}(t+1) = \vec{p}(t) + \eta\mu$ (49)
Lamia & Habib [46]	- k means combined with Bat Algorithm (KMBA)	- Discrete PSO based and K-means	- Two important tasks were employed in the improvement: - First task is searching best cluster numbers by using discrete PSO approach. - Second task uses the K-Means algorithm to find best set of cluster centers as per assigned number of clusters.
Cai et al. [47]	- Ensembled BA	- Concept of integration of six improved strategies	- Six improved strategies were considered from the literature. - Selection mechanism was chosen for adjusting the probability of each strategy, based on constant and dynamic probability.
Rehman et al. [48]	- Improved Genetic Ba	- Genetic Algorithm and Bat algorithm	- GA was used to initialize the chromosomes and Bat algorithm was used for initializing bat population in the search space. - Firstly GA was executed to obtain best fitness value in the search space. - Then, Bat algorithm was applied using the best value given by GA to obtain global best fitness value.
Zhu and Wang [49]	- Bat algorithm for data clustering	- Foraging behavior and flight mode of bats	- Proposed algorithms considered both foraging behaviour and flight mode of bats. - Used for solving data clustering problems. - Number of simulations reported that parameter setting for attenuation coefficient (α) to be initialized in [0.3, 0.4] and enhancement coefficient (γ) in [0.5, 10] for addressing data clustering problems.

Li & Le [50]	- Improved Binary Bat Algorithm with Cross-Entropy method (BBACE)	- Cross- Entropy method	- Employed CE method in BA - CE enhanced the global search of BBA - Employed K-nearest neighbour for classification accuracy
Zhu et al.[51]	- Improved Bat algorithm	- Convergence factor, WOA, sine position update	- Six Convergence factors were applied for global search - One was employed as Gaussian-like convergence by adding non-linear mutation operator D in velocity update equation of bats for enhancing global search as equation (50) : $v_i^{t+1} = v_i^t + (x_i^t - x_t)f_iD$ (50) $D = 2ca - c$ (51) $c = 2exp\left(-\frac{(1.5t)^2}{Maxiter^2}\right)$ (52) where, t is current number of iteration and Maxiter is maximum iterations. - Similarly five other convergence factors were employed using cosine form, sine form, tangent form, power function, exponential function form. - For local search, hunting mechanism from WOA was employed along with sine position update strategy using equation (53) $x_{new} = \begin{cases} x_{old} + r_1 sin(r_2)\lvert r_3 x_* - x_{old}\rvert, \lvert A\rvert \geq 1 \\ x_* - A.D, \lvert A\rvert < 1 \end{cases}$ (53) - If $\lvert A\rvert < 1$, new position(X,Y) is updated using best position in the current record. - If $\lvert A\rvert \geq 1$, adopts sine position update strategy.

3. Diverse application of bat algorithm

There are numeral real-world fields, where bat algorithm finds optimal solutions. The details of these diverse filed are listed in Figure 2 and description of these fields among with bat algorithm is mentioned below.

3.1 Clustering:

Clustering methodology-based bat algorithm is used to solve problem of crop classification [36]. The partitional clustering is used to extract information. BAT-CLARA is introduced for clustering [1]. Parallel Bat Algorithm with MapReduce clustering algorithm is developed to handle huge amount of data [5].

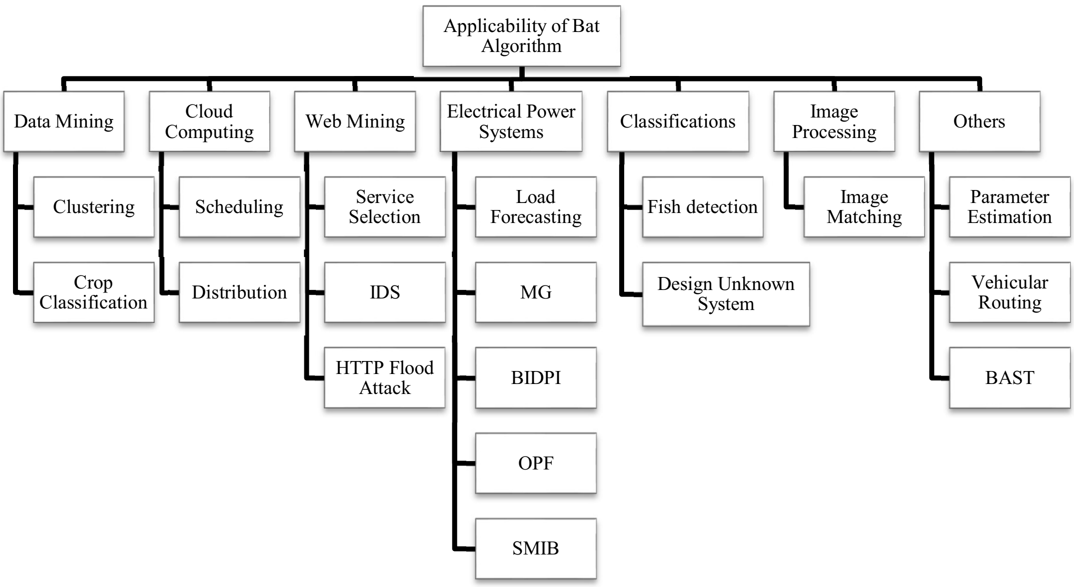

Figure 2. Application of bat algorithm in different fields.

3.2 Power Systems:
Bat algorithm is used in micro grid for energy management and renewable power sources with minimized cost [6]. For achieving best system configuration in electrical distribution system, modified bat algorithm is proposed for power loss reduction with a short loss rate [3]. In a power system, Bat algorithm-based OPF is used to minimize real power losses [33]. A bat inspired PID is developed for SMIB using power system [35]. For short-term load forecasting, Bat algorithm-based back propagation approaches are used in which weather factors such as temperature and humidity; are considered [34].

3.3 Cloud Computing:
The bat algorithm (IBA) is adopted to balance the load in cloud environment [32]. The population is generated using Min-Min; Max-Min and Alpha-Beta pruning algorithm. The bat algorithm is used to keep minimum sequence of executing tasks. Mapping and selection of optimal resources reduces the overall workflow cost. Further, θ-modified bat algorithm is used for distribution feeder-reconfiguration problem [18].

3.4 Classification and Identification:
To lower the fish classification interval throughout the fish detection process, the BA is adopted [14]. Bat algorithm is utilized to design adaptive infinite-impulse response to approximate the unknown system [22].

3.5 Web Mining:
For improvement of quality in web service selection, bat algorithm is applied [31]. Further, BA is also used in intrusion detection system due to its very quick convergence [2]. In application layer, BA also applied for detection of HTTP flood attack [37].

3.6 Image Processing:
A bat inspired algorithm, called BAM is developed for solving image-matching task [43].

3.7 Scheduling Problems:
The Bat Algorithm-based Scheduling-Tool (BAST) is used to solve multi-stage, multi-machine and multi-product scheduling problems [43].

3.8 Parameter Estimation:
Chaotic sequence and levy-flight are incorporated for estimating the parameter of non-linear systems [24].

3.9 Vehicular Routing:
The DBA is used for handling the vehicle-routing problem through time windows [38].

4. Conclusion
This paper focuses on the recent development in bat algorithm. It is observed that large numbers of improvements are incorporated in to bat algorithm to make it more robust, efficient and effective. Further, it is noticed that many researchers proposed diverse solutions to manage the local optima problem of bat algorithm. It is also observed that different local search methods are also integrated into bat algorithm to generate diverse population and improve local and global solutions. The solution search equations have deep impact to obtain optimal solution. It is seen from table 1 that many researchers have highlighted the aforementioned issue and proposed new solution search equations for bat algorithm. The control parameters help to balance exploration and exploitation processes. Some work is also focused on the control parameters of bat algorithm and developed new mechanism for the same as self-adaptive mechanism etc. The concept of parallelism is also added into the bat algorithm to make it suitable for parallel applications and problems.

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