CSF 407 – ARTIFICIAL INTELLIGENCE

Optimization of Job Scheduling in Open Shop

USING

Bat Algorithm

TEAM MEMBERS ID	NAMES
1 2020A7PS0274H	Kunchala Srivatsav Reddy
2 2020AAPS2108H	Rahul Reddy Sama
3 2020AAPS0391H	Kolli Shanmukh
4 2020A3PS0501H	Mithun Reddy D

GROUP ID - 14

1. INTRODUCTION

Metaheuristic Bat Algorithm

Metaheuristic algorithms are a type of optimization algorithm that can help solve complex problems that traditional methods cannot. They are inspired by natural processes and use probabilistic choices to improve solutions. Examples of such algorithms include GA, ant colony optimization, simulated annealing, PSO, and tabu search. They are used in many areas, including engineering, computer science, operations research, and economics.

Metaheuristic algorithms are useful when the solution space is too large and complex for traditional methods to be effective. They can handle multiple objectives and constraints, and find solutions that meet the requirements of the problem. They are also robust and can handle noisy or incomplete data.

The advantages of using metaheuristic algorithms include:

- They can answer a wide variety of problems with different objectives along with different constraints
- They can be used when analytical or exact solutions are not possible or too expensive to compute
- They can search for solutions in a parallel or distributed manner, which can speed up the optimization process
- They can handle problems with multiple solutions or Pareto-optimal solutions

However, metaheuristic algorithms also have some disadvantages, such as:

- They cannot guarantee finding the best solution
- They might be sensitive while choosing the algorithm parameters, such as population size or mutation rate
- They may require a huge number of function evaluations to find a good solution, which can take a long time
- It can be difficult to analyse and understand the algorithm's behaviour.

Despite their limitations, metaheuristic algorithms have confirmed to be successful in solving many real-life optimization problems and are a valuable tool for researchers and practitioners in various fields.

The Bat Algorithm is an optimization algorithm that is encouraged by the echolocation behaviour of bats. Developed in 2010 by Xin-She Yang, it is a metaheuristic method that uses the natural behaviour of bats to optimize a given objective function.

The algorithm is derived from the behaviour of the bats when they hunt for prey. Bats emit high-frequency sounds and use the echoes to locate their prey. By measuring the time difference between the emission and reception of the echo, bats can adjust their flight path to move closer to their target. The Bat Algorithm takes advantage of this behaviour to optimize a given problem.

In the Bat Algorithm, every bat can represent a probable result to the optimization problem. The bats' positions and velocities are renewed based on their previous positions, the best positions found so far, and the global finest positions found by all the bats. Randomness is introduced into the algorithm by adding a random velocity component to the bats' movements.

This algorithm is being successfully used to solve various optimization problems, including function optimization, feature selection, and parameter estimation. It is particularly useful when we are solving problems with many variables or non-linear, multimodal, and noisy objective functions. Additionally, the algorithm has been modified and adapted to work with different types of optimization problems, like multi-objective optimization and constrained optimization. Overall, the BA is a promising best cost reducing algorithm that has the potential to solve complex problems efficiently and effectively.

2. LITERATURE SURVEY

Xin-She Yang et.al (2010) introduced the BA, a new optimization method based on method of echolocation used to find food in dark by microbats, as compared to megabats which depend of the sense of smell to locate their food in the dark. This proposed algorithm combines the benefits of successful optimization algorithms, like GA and PSO, and is shown to be more accurate, reliable and efficient than the fore mentioned algorithms on various test functions. The paper presents a detailed description of the echolocation behaviour of microbats and how it can optimize objective functions. It also provides the basic concept and formulation of the MBA (Metaheuristic Bat Algorithm) and the pseudo code for its implementation. The algorithm uses virtual bats whose positions and velocities are updated depending on the current global best location and a fixed frequency. The rate at which the pulses are emitted and the loudness of the bats are also changed based on the iterations, with the goal of reducing the loudness and improving the pulse rate as the bats move closer to the optimal solution. The MBA is compared with a few other popular optimization algorithms, including GA and PSO, on various test functions. The results reflect the improved efficiency, reliability and accuracy of the Bat Algorithm compared to other algorithms used for testing. Overall, this paper provides a comprehensive overview of the Bat Algorithm and its implementation. The Bat Algorithm has potential applications in various fields, including engineering, finance, and computer science.

Xin-She Yang et.al (2012) talks about the application of BA for solving the complex problems of optimisation across several fields of engineering. The algorithm is based on the principle that microbats use echolocation for hunting and maneuvering inside the caves and has two essential components: position and velocity vectors of the bats, and variations in the rate of emission of pulses and the loudness. Bat Algorithm combines the major advantages of different existing algorithms, such as PSO and GA, and is shown to be a balanced combination of the standard PSO and the intensive local search controlled by the parameters of pulse emission rate and loudness. The proposed algorithm is validated with the help of eight different nonlinear optimisation problems in engineering. The problems are diverse, including mathematical problems, speed reducer design, parameter identification of structures, three-bar truss design, heater exchanger design, car side problem, and cantilever stepped beam. The results show that the performance of the bat algorithm is superior to many other existing algorithms, including GA, PSO, and harmony search

Xin-She Yang et.al (2012) proposed multi-objective bat algorithm (MOBA), a new algorithm for optimization based on the behaviour of microbats and their echolocation capabilities. MOBA solves complex multi-objective optimization problems with multiple design objectives and highly nonlinear constraints. The algorithm simulates the behaviour of microbats, including their ability to sense distance and identify prey using echolocation, using idealized rules. MOBA is tested using well-chosen test functions, including the ZDT1, ZDT2, ZDT3, and ZDT4 functions, with convex, non-convex, and discontinuous Pareto fronts. It is also applied when we want to design optimization benchmarks in structural engineering, such as bi-objective beam design. The results show that MOBA is a promising algorithm for solving nonlinear global optimization problems. Further research is needed to compare MOBA's performance with other popular methods for multi-objective optimization, such as GA, PCO, and differential evolution. Future work should focus on improving the diversity of solutions generated by MOBA to obtain more accurate approximations of the Pareto front. In summary, MOBA is a one of the best algorithms to solve complex multi-objective optimization problems. It has shown good performance and has the potential to be a major player in the field of global optimization.

Amir Hossein Gandomi et.al(2013) used BA to solve optimization problems with constraints, validating it against several benchmark problems in math and engineering design. The BA is a metaheuristic algorithm based on the echolocation behaviour of bats that shows promising results when we want to solve optimization problems that have structural design. Structural design optimization problems are often highly nonlinear and multimodal, making them difficult to solve with traditional methods. Metaheuristic algorithms, such as evolutionary and swarm intelligence algorithms, are becoming popular methods for solving these complex problems. Bats emit loud sound pulses and listen for the echoes that bounce back from the surrounding objects. Their echolocation behaviour can be analogous to an objective function to be optimized. Bats are unique mammals with wings and advanced echolocation abilities, ranging in size from the tiny bumblebee bat to the giant bat with a wingspan of 2 meters. There are more than thousands of different species of bats. Microbats use echolocation extensively to avoid obstacles, detect prey, and locate their roosting crevices in the dark.

Mridul Chawla et.al(2015) describes in more detail various variants of the BA, a metaheuristic optimization algorithm based on the echolocation behaviour of microbats. Hybrid BA with Harmony Search (HS/BA): This algorithm combines the upsides of both the BA and the HS algorithm. Differential Operator and Levy Flights BA (BA-DE/LF) is a variant which incorporates a differential operator to accelerate convergence and Levy flights to avoid local minima. The differential operator is same as to the mutation strategy "DE/best/2" in differential evolution. Hybrid BA with Fuzzy Logic: This variant used fuzzy logic to determine optimum capacitor locations and capacitor sizing for reducing the losses to the minimum possible level. It incorporated the advantages of both fuzzy logic and BA. A hybrid variant of BA called BA with Differential Evolution (HBA) uses differential evolution (DE) as a local search in BA. BA with Mutation (BAM): This variant mutated between bats while they were in the process of updating new solutions. It was applied to UCAV path planning to find safe paths connecting chosen nodes while avoiding threats and minimizing fuel cost.

Shahla U. Umar (2021) comprehensively listed the main applications that have been solved using the Bat Algorithm, including scheduling problems, combinatorial optimization, engineering design, image processing, wireless sensor networks, feature selection, clustering, classification, regression and forecasting. It also reviews in depth multiple papers that evaluated the functioning of the BA compared to other metaheuristic algorithms like PSO, DE, GA, ABC and CS. The BA was shown to outperform these algorithms in things like solution quality, convergence speed and robustness. This paper also discusses in detail hybrid versions of the Bat Algorithm as well as modifications and improvements proposed in different studies to enhance its performance. These include the Enhanced Bat Algorithm, Modified Bat Algorithm, Uninhabited Combat Aerial Vehicle-Bat algorithm with Mutation, Bat Algorithm with Mutation, and Nonlinear Optimization Bat Algorithm. The paper concludes with a discussion of possible research directions in future, including combining the Bat Algorithm with other algorithms, applying the Bat Algorithm to more complex problems, developing an adaptive Bat Algorithm, and improving the convergence of the Bat Algorithm.

Iztok Fister et.al (2014) explores the use of the MBA algorithm that is used for planning sports training sessions. The algorithm was tested through a series of experiments and found to produce a wide range of effective solutions. The paper notes that the selection of training plans should take into account the current form of the athlete and the coach's strictness. In addition to detailing the results of the experiment, the paper also provides a comparative study of the MBA algorithm with other progressive swarm intelligence algorithms. The study found that the MBA algorithm performed well in comparison to other algorithms for several optimization problems. The paper includes convergence graphs that show the algorithm's performance over time. The graphs indicate that the algorithm's convergence rate is slower than some other optimization algorithms, but that it ultimately reaches a satisfactory solution. The paper concludes by discussing potential areas for future research. It suggests exploring the use of the MBA algorithm with different fitness functions or using it in combination with other optimization algorithms. Overall, this paper provides valuable insights into the use of MBA algorithm for sports training planning and highlights its potential for further research and development in this area.

Xin-She Yang et.al (2013) reviews Bat Algorithm, a popular optimization algorithm inspired by the echolocation behaviour of microbats. The algorithm uses automatic zooming, frequency tuning and parameter control to efficiently solve various optimization problems, including continuous and combinatorial problems, scheduling, image processing, and data mining. The paper explains the Standard Bat Algorithm, which is based on three rules: echolocation, random flight, and varying loudness and pulse rates. The algorithm balances exploration and exploitation to find promising solutions. The Bat Algorithm can be modified for different types of optimization problems. For example, Nakamura et al. (2012) developed the Binary Bat Algorithm (BBA) for feature selection. The algorithm has diverse applications, including in scheduling, image processing, and data mining. The paper suggests further research, including the development of hybrid algorithms and exploring the algorithm's performance in dynamic and multi-objective environments. Overall, this paper gives an outline of the Bat Algorithm and its potential applications.

S Raghavan et.al (2015) discusses workflow scheduling in cloud computing using bat algorithm in more detail. Workflow scheduling is an important aspect of cloud computing that involves mapping tasks to resources to optimize performance, cost, and service level agreements. Efficiently scheduling workflows is an NP-hard problem, so exhaustive approaches that try all possible solutions are not feasible. The paper proposes using a metaheuristic approach called bat algorithm to solve this complex problem in a non-exhaustive manner. The bat algorithm mimics the echolocation behaviour of bats to find near-optimal solutions. The paper first describes workflow scheduling and its importance in cloud computing. It then describes the bat algorithm in more detail and how it can be applied to map tasks to resources in a workflow to minimize cost while meeting service level agreements. The approach is evaluated by comparing it to other metaheuristic algorithms that have been applied to workflow scheduling, including PSO, ACO, and greedy randomized adaptive search procedure. Simulation results show that the bat algorithm can significantly reduce cost and make span, which is the total time to execute the workflow, compared to these other approaches for workflow scheduling in the cloud. The bat algorithm can optimize workflow scheduling by adjusting the mapping of tasks to resources in a probabilistic manner based on the performance of previous iterations. It converges on near-optimal solutions for this NP-hard problem in a relatively small number of iterations. It is shown in the results that the bat algorithm can reduce cost by up to 75% and make span by up to 68% compared to other approaches. Overall, the paper demonstrates that the bat algorithm is a promising approach for efficiently scheduling workflows in cloud computing environments.

Xin-She Yang et.al (2012) delves into topology optimization, a challenging field in engineering and design. Topology optimization aims to find the best shape and material distribution in a given area to meet specific goals while using fewer materials. Traditional optimization methods struggle with nonlinear and complex problems, but new SIBA, such as the bat algorithm, offer promising solutions. The paper presents examples of using the bat algorithm to solve topology optimization problems, including designing a spring and optimizing heat transfer in a microdevice. The bat algorithm produced effective solutions, superior or comparable to traditional methods, with fewer evaluations. In summary, this paper provides valuable insights into the challenges and potential of topology optimization and swarm-intelligence-based algorithms, emphasizing the importance of proper problem formulation and the necessity for further research.

Omid Bozorg-Haddad et.al (2015) tested the algorithm on three standard functions, including the Rosenbrock, spherical, and Bukin-6 functions, and was found to perform better than the GA in view of correctness and reliability. The BA was also applied to two real-world problems: optimizing reservoir system operation and single-reservoir system operation. In the optimization of reservoir system operation, the Bat Algorithm was compared to other traditional optimization methods, such as LP, NLP, and DP, and was found to perform better in terms of merging to global optima and variance of results about global optima for reservoir optimization problems. The BA was also shown to perform better than the GA in the optimization of reservoir operation in a single-reservoir system.

A bat algorithm is suggested by G. Ravi Kumar et al. (2017) as a solution to the economic emission dispatch issue in power plants. The multi-objective problem formulation takes into account four significant and competing goals in power systems: fuel cost, nitric oxide emissions, carbon dioxide emissions, and sulphide oxide emissions. The weighting approach, which weighs the various objectives based on relevance, transforms the optimization issue into a scalar optimization problem. The IEEE 30-bus system tests the bat algorithm, which has six generating units and can handle load needs of 1800 MW, 2000 MW, and 2200 MW.. The algorithm is shown to produce non-subpar responses for the economic emission dispatch problem. dispatch problem for different loads. The case study outcomes demonstrate that the bat algorithm can successfully address the multi-objective economic and emission. In particular, the bat algorithm yields good solutions for this nonlinear mixed-integer optimization problem in a reasonable amount of time. The research concludes by presenting a unique strategy for solving the multi-objective economic emission dispatch problem with multiple loads based on the bat algorithm and weighting method. The case studies on a six-unit system show how practical and reliable the suggested approach for this crucial power system operational problem is. The proposed approach can help operators schedule generator outputs to minimize fuel costs and emissions while meeting load demands.

M Anandkumar et.al (2020) discussed an advanced optimization approach for energy-aware multicast routing in IoT applications. The aim of the approach is to select the most efficient nodes for routing, taking into account both energy and trust factors. To achieve this, a hybrid Bat and Genetic algorithm is used. The Genetic algorithm is an evolutionary algorithm that imitates natural selection, whereas the BA is a metaheuristic algorithm inspired by the echolocation behavior of bats. This combination results in a more robust and efficient algorithm. The evaluation of the approach was done using 50 and 100 nodes, and the results showed superior performance compared to conventional techniques. The approach not only resulted in minimal delay and maximal energy and throughput but also had a higher detection rate. The use of the hybrid Bat and Genetic algorithm was a major contributor to this success. To provide a clear and concise summary of the analysis, tables were included in the paper. These tables compare the performance measures with and without attacks. Overall, the suggested optimization method for IoT applications has shown tremendous potential in enhancing the effectiveness and dependability of routing.

Hu Li et.al (2021) discusses multi-objective optimization algorithms and their application to control systems and engineering problems. It explores the complexities of controller tuning and highlights the limitations of traditional model analysis approaches. The Bat Algorithm and Particle Swarm Optimization are two examples of multi-objective metaheuristic algorithms that are discussed in the paper along with how they can be used to tune controllers. It suggests a brand-new competitive mechanism-based multi-objective bat algorithm (CMOBA) that, according to statistics, outperforms previous cutting-edge algorithms in at least 15 of 19 situations. The paper provides an excellent resource for researchers and practitioners seeking to understand how multi-objective metaheuristic algorithms can help solve issues with Pareto-objective optimization in real life. Additionally, the paper presents a new algorithm that has proven to be a top-performing solution to multi-objective optimizing issues.

Xioafeng Yeu et.al (2019) discuss the process of image segmentation, which extracts objects from an image. Multi-level thresholding is a popular method for this, but selecting optimal thresholds is challenging due to the computational intensity. To address this, the paper proposes a hybrid bat algorithm (IWBA) that combines the bat algorithm with invasive weed optimization (IWO) to select optimal thresholds. The algorithm can segment images more efficiently and accurately than other algorithms while maintaining versatility. To choose the IWBA algorithm's ideal parameters, the paper conducts an orthogonal test to study the influence of important parameters such as initial scale parameters, population size, threshold, loudness, and pulse rate. The findings demonstrate the robustness of the IWBA technique for parameter setting, and the parameters are ranked according to their significance. The IWBA algorithm outperforms other algorithms including the differential evolution algorithm, GSA algorithm, PSO-GSA algorithm, and BA algorithm, according to comparative trials. Overall, the IWBA algorithm is a significant contribution to image processing, providing a more efficient and accurate solution for multi-level image segmentation.

The Bat algorithm (BA), a contemporary metaheuristic optimization technique inspired by the echolocation behavior of microbats, is proposed in a paper by Aman Jantan et al. (2019). The standard BA algorithm effectively balances the search's exploration and exploitation process through the use of frequency tuning and automatic zooming. However, the quick shift to exploitation can lead BA to get stuck in local minima or maxima. To address this issue, the proposed Enhanced Bat (EBat) algorithm adds a mutation operator to increase diversity and avoid premature convergence. 24 benchmark functions are used to assess EBat's performance, and its results are compared to those of BA and other well-known metaheuristics. EBat shows very promising results and is able to outperform the original BA in many test cases. The article first provides background on numerical optimization and the standard BA. The proposed EBat algorithm is then further explained. The experimental setup and results are presented next, showing EBat's superior performance compared to BA and other metaheuristics. The article concludes that EBat is a promising enhancement of BA and can be a strong contender among metaheuristic algorithms for global optimization. In summary, the article proposes and evaluates a mutation-based enhancement to the Bat algorithm metaheuristic. The suggested EBat algorithm can avoid premature convergence and discover better answers than the original BA because it increases variety. EBat shows very good performance and can outperform other established metaheuristics, demonstrating its potential as an optimization algorithm.

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3. CONCLUSION

We learned about metaheuristic algorithms that solve complex optimization problems. These algorithms are inspired by natural processes and use probabilistic choices to improve solutions. These methods include, for instance, tabu search, ACO, SA, and PSO. They are particularly useful when the solution space is too large and complex for traditional methods to be effective. Additionally, they can handle multiple objectives and constraints and find solutions that meet the requirements of the problem.

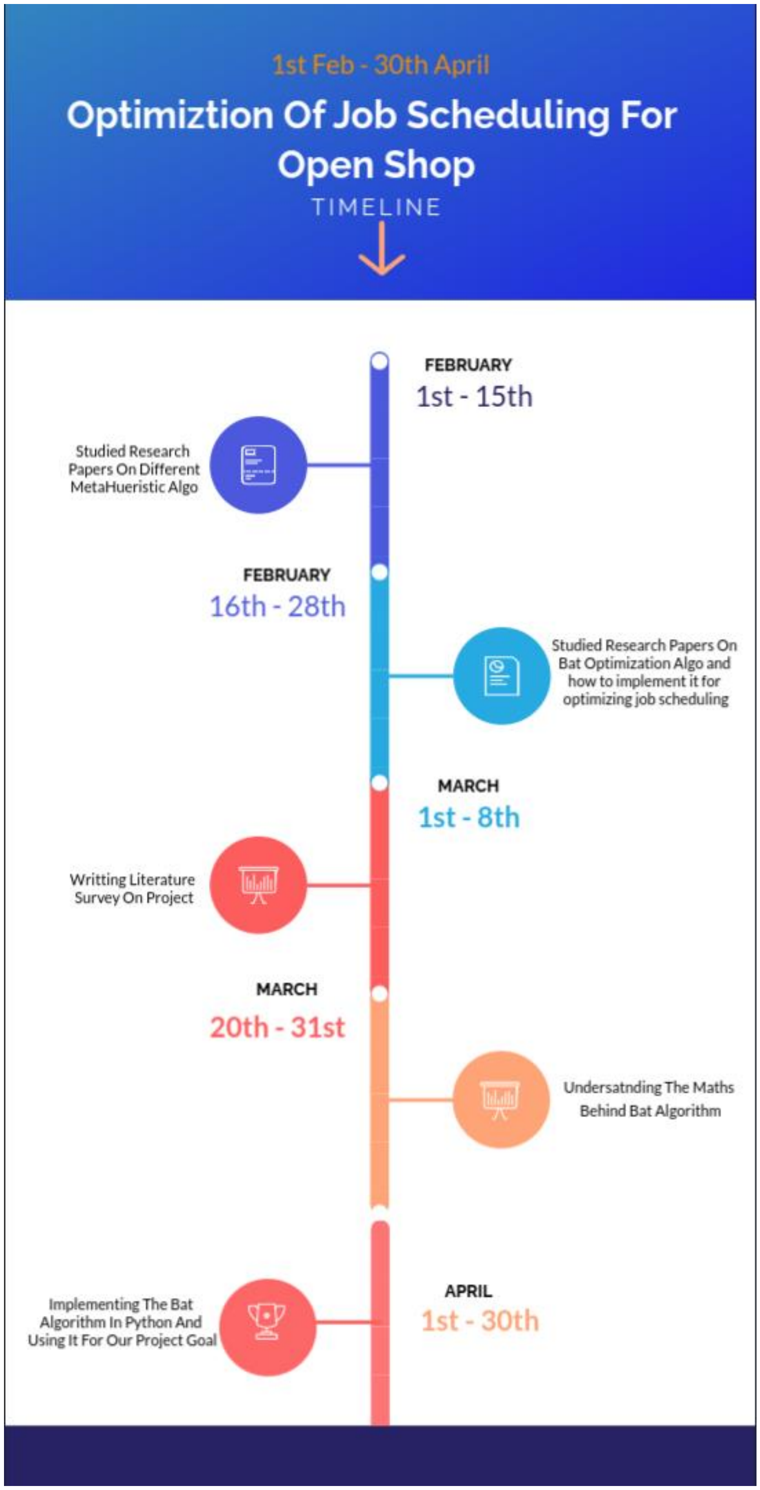
The study also highlights the advantages and disadvantages of using metaheuristic algorithms. For example, they can deal with a variety of issues with different objectives and constraints, but cannot guarantee to find the optimal solution.

We learned about the Bat Algorithm, a metaheuristic technique that was influenced by bats' use of echolocation. Several optimization issues have been successfully solved using the Bat Algorithm, including function optimization, feature selection, and parameter estimation. Additionally, the algorithm has been modified and adapted to work addressing several optimization challenges, including multi-objective optimization and constrained optimization.

We looked at a number of articles that assessed the effectiveness of the Bat Algorithm and its modifications in a variety of contexts, including energy-aware multicast routing, workflow scheduling, economic emission dispatch in power systems, and sports training planning. The outcomes demonstrate how effective the Bat Algorithm is as an optimization technique.

We plan on using bat algorithm for solving the optimal sequence scheduling problem (OSSP), which aims to minimize the make span of production systems. The algorithm has shown to be effective and efficient in solving standard benchmarks of small, medium, and large-scale problems.

GRAPHICAL TIMELINE



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