



Comprehensive Survey for Cloud Computing Based Nature-Inspired Algorithms Optimization Scheduling

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Authors' contributions

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ABSTRACT

Many applications in the real world include optimizing specific targets, such as cost minimization, energy conservation, climate, and maximizing production, efficiency, and sustainability. The optimization problem is strongly non-linear with multifunctional landscapes under several dynamic, non-linear constraints in some instances. It is challenging to address those issues. Also, with the increasing strength of modern computers, simplistic brute force methods are still inefficient and unwanted. Practical algorithms are also vital for these implementations whenever possible. Cloud computing has become an essential and popular emerging computing environment that supports on-demand services and provides internet-based services. Cloud computing allows a range of services and tools to be easily accessed from anywhere in the world. Since cloud computing has global access to its services, there will always be threats and challenges facing its servers and services, such as; task scheduling, security, energy efficiency, network load, and other challenges. In the research area, many algorithms have been addressed to solve these problems. This paper investigates relevant analysis and surveys on the above topics, threats, and outlooks. This paper offers an overview of nature-inspired algorithms, their applications, and valuation, emphasizing cloud computing problems. Many problems in science and engineering can be viewed

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as optimization problems with complex non-linear constraints. Highly nonlinear solutions typically need advanced optimization algorithms, and conventional algorithms can have difficulty addressing these issues. Because of its simplicity and usefulness, nature-inspired algorithms are currently being used. There are nevertheless some significant concerns with computing and swarming intelligence influenced by evolution.

Keywords: Cloud computing; nature-inspired algorithms; optimization scheduling.

1. INTRODUCTION

Cloud computing is a new system that helps people to pay accordingly and work highly. It also becomes more complex as it becomes successful. One of the problems of cloud computing is the assignment of resources. The aim is to assign tasks to appropriate resources, and cloud computing is a problem of NP-hard optimization. No algorithms have an optimum solution to NP-hard problems within polynomial time [1].

Like on-demand computing, Cloud computing is dominant technology today. Cloud computing is virtualized internet-based computing providing ICT resources to remote users [2]. It is a paradigm in which resources are available anytime, anywhere, and under the user's control while the remote clouds[3]. Data centers that contain many "virtualized" servers and high-bandwidth networks are the resources of "cloud computing" [4,5]. Besides, cloud computing considers as a cost-effective paradigm due to resource sharing [6].

Recently, cloud computing has become one of the most popular innovations that internet consumers and companies have used [7]. It has many advantages, including elasticity, rapid access to the infrastructure, reduced hardware and software, and faster coverage of the geographic area. For enterprise systems can intensify collaboration, scalability, nimbleness, and availability [8,9]. Besides, it sets a software update routine that minimizes user involvement. These advantages encouraged many companies to use cloud computing for their core business processes rather than their IT infrastructure [10].

Many global engineering problems have optimized using advanced technology and meta-heuristic algorithms using—these advanced techniques, methods, and algorithms [11]. New developments have also been developed in the computing cloud, such as unicorns, containers, orchestration (container is a virtualization system

at OS level to deploy and operate distributed apps without launching an entire VM in each application), container as well as service (CaaS) [12]. These recent advances have also brought new problems to be tackled in the safety sector. As technology changes, check and refresh security protocols and methods often keep hackers and assailants alive [13].

Nature-inspired algorithms are one of the most used methods for solving almost all problems globally. Cloud management is an analysis and configuration of the distribution of cloud services to optimize the efficiency of power applications, infrastructures, and workloads and reduce loss by over-supply [14]. The advent of DevOps led to a high-speed distribution and regular new code updates. These algorithms are inspired by nature and taking advantage of the natural methods for solving problems [15]. Among these problems is task scheduling in cloud computing systems that can be optimized based on these algorithms [16].

Task scheduling is one of the challenges in cloud systems, and there are many methods and techniques for solving its issues. In this paper, the optimization of scheduling in cloud computing has been reviewed based on nature-inspired algorithms.

The second section of this paper is a theoretical background of cloud computing and scheduling, then reviewing the nature-inspired algorithms. Section 3 is a literature review in optimizing scheduling in cloud computing using nature-inspired algorithms. Section 4 is a discussion and assessment of the literature that has been reviewed. Finally, concluding the overall work in this paper.

1.1 Cloud Computing Main Challenges

Multi-tenancy is an architecture that provides many clients and landlords with a single instance of a software program. All three models of operation IaaS, PaaS, and SaaS are multi-tenancy applicable. It has numerous benefits and problems as well [17]. The benefits are cost saves on the scaling of IT infrastructure and

licensing apps, etc. The critical challenges of multi-tenant are safety, power optimization and distribution of services, and high availability [18]. Since cloud computing has made the transfer of data from a server to a client, servers, and networks simpler, there will always be threats and challenges on their third-party servers in data centers or a privately-owned cloud [19]. These challenges are including; security, scheduling, energy efficiency, reliability, lack of resources, and others [20]. In this review article, the task scheduling issues in cloud computing will be reviewed.

In general, task scheduling is the process of arranging the user requests (tasks) in a particular order so that available resources will be used suitably. Scheduling is the technique of mapping a set of jobs to virtual machines or allocating virtual machines to run on the available resources to fulfill users' demands [21]. The available cloud-computing resource is scheduled at two levels; Virtual Machine (VM) level and Host-level. At the VM level, which is known as task scheduling, cloud tasks are assigned and mapped to execute the allocated VMs using a task/job scheduler. At the second level, host-level, known as the VM Scheduling, a VM scheduler can allocate the VMs into physical hardware [21, 22].

2. BACKGROUND THEORY

2.1 Cloud Computing

According to the National Institute of Standards and Technology (NIST), "Cloud computing is a paradigm for allowing ubiquitous, simple, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) quickly provisioned and released with minimal management effort or interference amongst service providers [23,24].

Cloud computing is a type of Web-based computing and data storage delivered online using distributed servers[25,26]. Cloud Computing provides computing, storage, and network services locally (like data centers, backhaul networks, and core networks) in the remote clouds [27,28]. Cloud computing's key features are; Cloud computing has several features, such as rapid elasticity, measured service, resource service, comprehensive self-service, on-demand network access, multi-tenancy, pooled infrastructure, broad access to networks, elasticity, self-service on-demand, and calculated service [29,30].

Cloud computing has two types: the first one is based on the location and has three sub-types; public, private, and hybrid clouds, as shown in Fig. 1 [31,32].

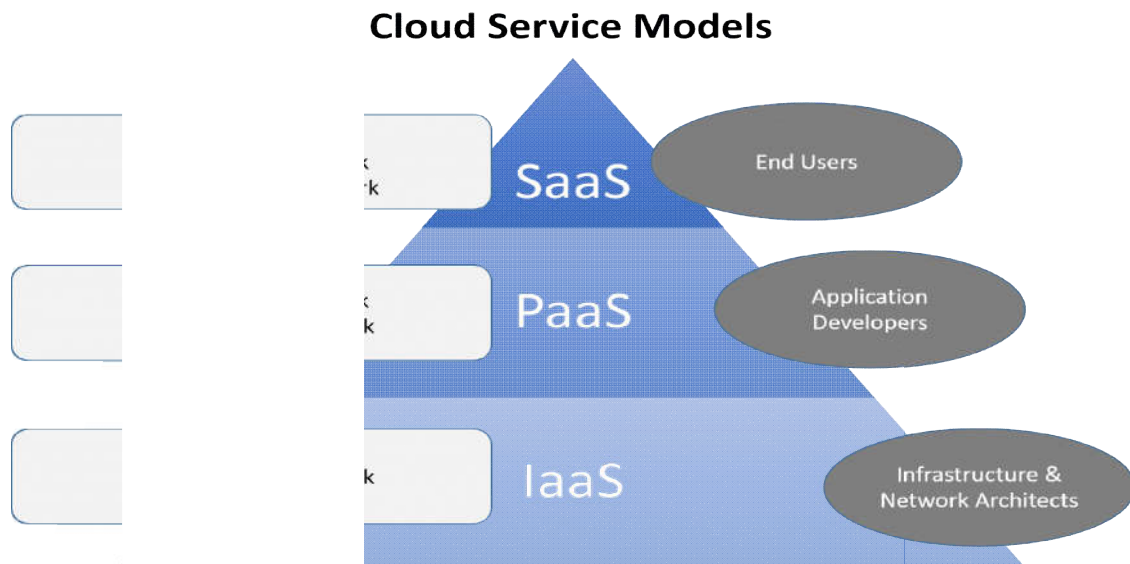


Fig. 1. Cloud service models [31,32]

- Public cloud: it is services on-demand, and it is available. It can be won by the government, academics, business, or organization [33].
- Private cloud: it is exclusive for use by an organization and available only for single architecture, and it can be managed and operated by the owner [34].
- Hybrid cloud combines both public and private clouds [35].

The second type, based on service provided, has three types:

- Infrastructure-as-a-service: The user can use provided software on cloud infrastructure via client interfaces, such as a web browser (e.g., web-based email) or a software interface that can be accessed from different client devices [36]. The cloud infrastructures are servers, networks, systems, and storage, and customers cannot control or monitor these components [37].
- Platform-as-a-service: The user can deploy consumer-developed or acquired apps built using the cloud infrastructure that providers many services to the customers [38]. The customer does not maintain and track the resources and only controls the installed software and future setups [39].
- Infrastructure as a Service (IaaS): is the ability to provide random software for users, including operating systems and programs, and other simple computational resources to install and execute this random software [40]. The customer cannot manage or track the Cloud Infrastructure but controls operating systems, storage, software, and insignificant control over selected network components [41].

The main advantage of cloud computing includes the cost-effective, fast request data provided even many users are using the resources simultaneously [42]. Because it is a service on-demand, users can access and use the data anytime and anywhere without extra software and hardware [43]. The only requirement is that the user needs a cloud service provider. Finally, the cloud servers have back-ups and disaster management technology, so the users' files are safe [31,44].

Considering many advantages that cloud computing has, its uses and application expanding, and it used in many areas such as:

a. File storage: Cloud storage is top-rated because users can store their information and data inside the cloud without using the local device, and users can access stored files through any device[44]. Many cloud storages types such as a file, object, and block storage meet users' needs of storing data and backing up files. These storage units provide secure access and scalability for increased storage or decreased storage based on the individual's budget [45].

b. Big Data Analytics: Nowadays, businesses for the performance of their customers, markets, and sales, are relay. The collected data can be used either to achieve better work performance [46]. Alternatively, to discover new opportunities for business growth or to find solutions to complex problems. The benefit of cloud computing is that the user will not pay for unused time; the only used resources will be paid [47].

c. Data backups and archiving: With the rapid development of technologies nowadays, cybercrimes became one of the most severe threats for users [48]. Users need to have a secure cyber environment, and the traditional data backups no longer are solutions to today's threats. Cloud computing provides a cloud-based backup with ease to use as a solution for these threats and challenges. Users can back up their data, including the sensitive data on cloud-based storage systems also; encrypting the data also possible in cloud computing [49].

d. Disaster recovery: It was a costly and time-consuming process to construct a disaster recovery site and test a disaster recovery plan in an isolated and managed area [50]. Cloud computing consists of disaster recovery procedures that are digitally stored in the cloud. In this model, users share data and settings so they can be replicated at multiple sites [51].

e. Communication: Cloud computing provides access to the use of online email and calendars [52]. A user's messages and files were stored in a cloud service rather than solely stored on the computer. That allows users to access the application from every part of the world via an individuated internet [53].

2.2 Optimization Algorithms

A practical method in the decision-making and analysis of physical processes is optimization. In mathematical terms, optimizing the solution from

among all possible solutions lies in finding the best solution [54]. Optimization is executed by evaluating different solutions iteratively before an optimal or satisfactory solution is found. A significant step in the optimization process is to classify the optimization model because algorithms are optimized to a specific problem category. Different forms of problems of optimization [55]:

- Continuous Optimization.
- Bound Constrained Optimization.
- Constrained Optimization.
- Derivative-Free Optimization.
- Discrete Optimization.
- Global Optimization.
- Linear Programming.
- Nondifferentiable Optimization.

Optimization algorithms are in many ways classified. The algorithms are classified into three groups depending on their nature: Deterministic algorithm, stochastic and hybrid algorithms. The algorithm takes the same direction and generates the same output with a specific input set in the deterministic algorithm [45]. The randomization of the stochastic algorithm is particular because a random number carries out the trial. It is further categorized into two types: heuristic and metaheuristic [57]. Heuristic algorithms are based on the principle of 'test and

error.' They produce "good enough solutions" reasonably to complex optimization problems but do not guarantee optimum solutions. These algorithms are built on expertise and practice in the search area [58].

On the other hand, metaheuristic algorithms are a series of high-quality techniques that improve the effectiveness of heuristic algorithms by effectively managing and changing their operations to produce high-quality performance [59]. The main benefit of these algorithms is that they do not need to be informed explicitly on optimization. The nature-inspired algorithm taxonomy is given in Fig. 2. These algorithms are categorized into bio-inspired algorithms, algorithms based on physics and chemistry, and others [56]:

First: Bio-Inspired algorithms (BI): they are algorithms inspired by natural organisms' biological phenomena. Living systems occur in nature and adopt a well-defined set of processes designed to meet their needs. These procedures inspired mathematicians to develop some algorithms, which eventually evolved into modern mathematical algorithms. There are four general classes of algorithms applied to the biological world: Swarm algorithms and non-war algorithms [56,60].

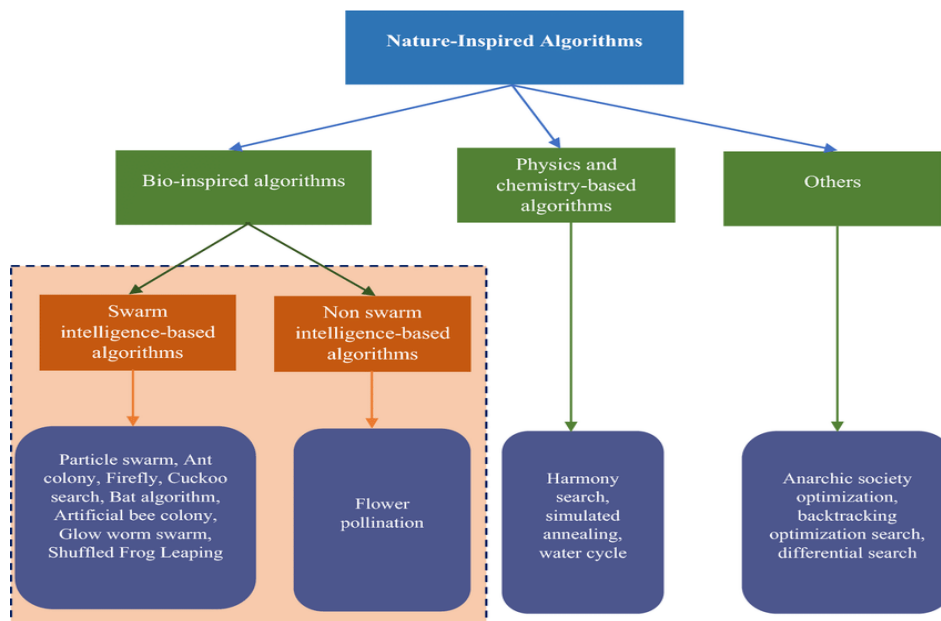


Fig. 2. Nature-inspired algorithms [56]

- Swarm-Intelligence-based algorithms are biological phenomena that inspire these algorithms. In general, these algorithms are based on Swarm Intelligence (SI), in which individual agents have no centralized control over their behavior. Interactions among these agents are the basis for intelligence [61]. The SI-based algorithms are the most common, and the reasons for their popularity are; the first reason is that these agents exchange information, causing self-organization, co-evolution, and learning during iterations [62]. The second reason is that these multiple agents can parallelize efficiently to get large-scale optimization.
- Non-Swarm Intelligence-based Algorithm is un-swarm bio-inspired algorithms such as Simulated annealing (SA) algorithms, Differential Evolution (DE) Algorithms, etc. [4]. Although classifying algorithms is not an uncomplicated process, mainly when they are not directly based on Bio-Inspired algorithms [63]. These algorithms' works are similar to genetic algorithms, and they are categorized as Bio-Inspired algorithms [64].

Second: Physics and Chemistry Based Algorithms: The nature-inspired algorithms that are not bio-inspired are considered physics and chemical systems' inspired algorithms. These algorithms include physical and chemical-related electrical charges, gravity, river systems, and other physical and chemical phenomena [65].

Third: Other Algorithm: this type of algorithm is nature-inspired but not inspired by biological, physical, or chemical source inspiration. It is inspired by other sources of inspiration, such as music, emotions, and social.

2.3 Nature-inspired Algorithms

The nature-inspired algorithm is a technique inspired by nature's processes and a meta-heuristic algorithm that helps solve complex computer science problems [4]. These algorithms are affected and based on biological, physical, or chemical functions. Ant Method, Ant Colony Optimization, Bee colony, Simulated Annealing, Water Cycle Algorithm, Black Hole Algorithm, and other algorithms are other examples of these algorithms.

Nature has helped develop many algorithms because it inspires mechanisms that effectively

solve problems, and these algorithms aid in calculating the optimal solution to a series of optimization problems. New technology has become a significant influence on our lives. While people actively spend time optimizing their learning styles [20]. Business people often adapt to business conditions and shifts [56].

3. LITERATURE REVIEW

Scheduling is recognized as one of the most crucial challenges in cloud computing, and many researchers work in this field and used many ways to optimize these issues. Nature-inspired computing and its algorithms played a significant role in optimizing cloud computing challenges, including scheduling. The literature about using nature-inspired algorithms for scheduling optimization in cloud computing will be reviewed in the following.

Abdullahi et al. [66] present the Discrete Symbiotic Organism Search (DSOS) algorithm for optimizing cloud task scheduling. The recently developed metaheuristic optimization method Symbiotic Organism Search (SOS) is used to overcome numerical optimization problems. Their algorithm is evaluated in the simulation environment using CloudSim, and the simulation results show that DSOS outperforms PSO and converges faster even when the search gets more prominent. This makes the algorithm suitable for large-scale scheduling problems.

Rjoub et al. [67] proposed a hybrid approach known as Multi-Label Classifier Chains Swarm Intelligence (MLCCSI) for improving efficiency by reducing the execution time. Their algorithm follows two main strategies; the swarm intelligence strategy based on ACO, ABC, PSO algorithms to find the optimum resource distribution in the dynamic cloud environment for each Task. The second strategy is applying the machine learning algorithm (Classifier Chains) that takes the result of the algorithms in the first strategy and generates a new hybrid model. The model was evaluated using CloudSim. The evaluation results show that the model minimized the make-span between 7% to 70% and utilized the resources effectively than the standard optimization algorithms.

Abdullahi et al. [68] proposed a Chaotic Symbiotic Organisms Search (CSOS) algorithm to minimize make-span and cost with the main idea to prevent the premature convergence of SOS at the early stages of the optimization

process by implementing a chaotic map, which enlarges the search space and provides diversity. The proposed algorithm is evaluated using CloudSim and compared with SOS and PSO. The simulation results show that the proposed algorithm, compared to SOS and PSO, has better results and converges faster than SOS, and performs better than SOS.

Srichandan et al. [69] proposed MHBFA bacteria foraging optimization algorithm to solve task scheduling in cloud computing. Their algorithm simulated by using MATLAB simulator and compared with other algorithms such as PSO, GA, and BFA. The evaluation goes through two phases; the first phase presents the experimental results, and in the second phase, the statistical results. The experimental results that energy consumption is low in MHBFA comparing with GA, PSO, and BFA. Besides, GA, PSO, and BFA have higher energy consumption and make-span with the same data set as the algorithm. Simultaneously, the statistical results show that the MHBFA performs better in finding better Pareto-optimal solutions than the above algorithms.

Faraj et al. [70] proposed a two-stage model of a strategy named (MLCCAP). The first step is to program algorithms used in Advance Ant Colony Optimization (AACO) and Particle Swarm Optimization (PSO) algorithms, to decide the optimum resource allotment in the complex cloud structure for any mission. In the second step, the Classifier Chains machine-learning algorithm applied both algorithms' effects to create a new hybrid model considering the scale of tasks and the number of virtual machines. The suggested system is simulated with the CloudSim toolkit. The experimental findings show that the (MLCCAP) balances practically the full machine load and reduces the average margin between 12 and 76%. This approach is adaptable to current cloud computing networks to minimize make-up. The map control model could be generalized to incorporate a range of computer training methods, such as neural networks and decision-making bodies, with other related metrics such as processor power, RAM, and bandwidth considered.

Manasrah et al. [71] proposed a Hybrid GA-PSO algorithm to resolve workflow scheduling by integrating GA and PSO algorithms' strengths. To show its usefulness in solving workflow scheduling in the cloud world, the algorithm's performance is tested against other algorithms.

The GA-PSO algorithm was applied using Workflow-Sim to test the algorithm. By offering a higher tier of process control, Workflow-Sim expands the current CloudSim simulator by providing a valuable framework for implementing various scheduling algorithms. The findings show that, regardless of the number of workflow tasks, the algorithm often chooses the best solution for spreading the workflow tasks through the most available VMs.

Aloboud et al. [72] proposed A scheduling algorithm that imitates the cuckoo bird's parasitic behavior was suggested. Reproduce Cuckoos. The algorithm was evaluated and benchmarked against the current algorithm on a public cloud simulator. It was applied using Python and tested using a Haizea empirical assessment system in simulation mode, which triggered a shift in the Haizea scheduler. Compared to the non-fragmented low-priority job proposed in and already implemented in Haizea. The findings reveal that due to the Task's fragmentation, the cuckoo algorithm used the limited time to complete the Task, which decreases the waiting time for resources to become usable and increases their use time.

Sardaraz et al. [73] proposed a hybrid algorithm for scheduling cloud computing scientific workflow. In science workflows, the number of activities is immense, and these jobs have dependencies that make it impossible for the scheduler to plan tasks and use cloud services successfully. Workflow scheduling is known as NP-complete in the cloud world. Many variables affect scheduling algorithms' performance, such as QoS, user deadlines, monetary expense, execution time, data privacy and protection, etc. Workflow planning algorithms require substantial computational resources to make them ideal for cloud computing environments. The algorithm is based on the PSO methodology's preprocessing step to planning the PSO algorithm. Algorithms have been tested in terms of make-up (the total execution time of all workflow tasks), expense (cost of execution and data transmission of all workflow tasks), and load balancing (is the matrix that shows whether the system is well load-balanced). The suggested algorithm contrasted with regular PSO, GA, and advanced scheduler based on PSO methodology. To minimize execution time, cost and sustain a balanced load between nodes, the solution used parallelism.

Kumar et al. [74] proposed a CSA algorithm to offer an appropriate solution to the cloud task

scheduling problem tested in CloudSim. The algorithm's suggested findings indicate that the CSA produces a 5-15% increase in make-span value relative to ACO. The enhancement is between 12 and 20 percent as compared to CSA with Min-Min. The CSA generates make-span values closer to ACO in some cases, but still, it gives a lower make-span value. The CSA refines the schedule further after each iteration by seeking an alternate VM for the mission. So, the completion time of the assignment is reduced, which is directly expressed in the valuation of make-span.

Stromberg et al. [75] proposed the Whale Optimization Algorithm (WOA) to address the resource planning problem in cloud computing environments. Our ultimate conclusion in simulations with artificial data set is that the WOA-AEFS algorithm, on average, obtained the best results and proved to be a robust and successful optimization strategy for solving resource planning NP-hard problem. The study results were obtained from the MS and cost goals and the deadline breach rate. In all experimental cases, the WOA-AEFS surpassed the simple heuristics of WOA, PBACO, Min-Min, and FCFS. The second-best solution, the CPSO, just showed better efficiency indicators than our WOA-AEFS in certain situations.

Already et al. [76] proposed two standard algorithms LJFP-PSO and MTC-PSO, based on traditional Particle swarm optimization (PSO). Their algorithm uses heuristic scheduling algorithms to initialize the PSO search process and deal with the multimodal optimization problems in cloud systems. The algorithm has been evaluated in the MATLAB simulation environment and compared with swarm-based algorithms. The cloud was virtual, and 200 to 2000 tasks have been used; the size of the tasks was 1000-4000 and 40-300 VMs. The algorithm's simulation results show that the algorithm has an effective performance compared with other algorithms. Besides, comparison simulation findings showed that in convergence and load balancing, the algorithm exceeds recent task scheduling algorithms. It should be remembered that the PSO population's heuristic initialization produces initial particles that all begin the search process from a single starting place.

Sharma et al. [77] suggested that the Harmony-Inspired Genetic Algorithm (HIGA) reduces the amount of iteration waste in local or global regions to consider task preparation. The

algorithm was evaluated by using a well-known Cloud-SIM cloud environment emulator for simulation purposes. MATLAB 2013b is being used to incorporate the HIGA system. Changed Cloud-SIM uses the MATLAB Engine API to use the HIGA algorithm to perform solution searches. Their work experimentation is carried out (Intel Core-i7 8 Cores, 8 GB RAM, Windows 10 OS). With well-known standard algorithms such as Genetic Algorithm, Harmony Search, Particle Swarm Optimization, Heterogeneous Earliest Finish Time, Min-Min, and Max-Min, they compared the algorithm. The findings specify that the suggested HIGA algorithm uses less time in all situations to get to the optimum solution since it uses the number of iterations dynamically. This same functionality allows the algorithm a chance to minimize execution time by missing several iterations because of the algorithm's ability to detect and get out of the optimum local area. The outcome reveals that their HIGA algorithm reduces overhead execution by up to 21-39 percent.

Sanaj et al. [78] proposed a chaotic squirrel search algorithm (CSSA) to optimize multi-task scheduling in the cloud atmosphere. With this algorithm, jobs are generated continuously, which makes the current approaches more cost-effective. The algorithm is evaluated in a cloud simulator toolkit (CloudSim), and the outcome is compared with scheduling algorithms to achieve ideal outcomes with several goals. The results indicate that the model can identify the most attractive compromise solution.

Attiya et al. [79] Proposed an integrated version of the HHO algorithm with simulated annealing (HHOSA) to improve the rate of convergence and local search of HHO with the motivation of the uniqueness of their investigation method. To evaluate the method, a CloudSim simulator is used for performance evaluation and compared with other scheduling algorithms. The developed method results show that it can achieve near-optimal performance and performs better than other scheduling algorithms, especially in minimizing the makespan while maximizing the utilization of resources.

Semenkina et al. [80] proposed two methods for addressing the hierarchical planning problem in cloud computing. The first approach suggested is to find an optimal order of projects and then solve resource-constrained project planning for each of them. The second one suggests that if there is a disagreement in deciding the next

Task, they prioritized all tasks and include them in the plan-building process. They compared numerous algorithms, such as intelligent waterfall, the optimization of the genetic algorithm and ant colony, and a self-configuring variant of the latter two. Using the outcomes of solving test problems, the algorithm efficiency and multiple solution representation methods are

compared. The results indicate that it is essential that all bionic algorithms move to adaptive methods that allow tuning algorithm parameters during their work. This property is essential when solving scheduling challenges incorporate production planning when a solution must be found very rapidly, based on the production chain's current state.

Table 1. Critical analysis of existing studies

References year	Algorithm	Parameters	Simulation environment	Accuracy	Pros and cons
[66],	DSOS	Parasites	CloudSim	99%	Comparing the DSOS and SAPSO, the simulation results show that the DSOS performs better than the second algorithm with the Increased search space. It means that DSOS outperforms SAPSO with large search spaces.
[67],	MLCCSI	Data center, VM and Task	CloudSim	75%	The proposed method is suitable to be implemented on existing cloud computing systems that will decrease makespan and reduce utilization. However, it has not been tested on other challenges in cloud systems such as migration and quality of service constraints.
[68],	CSOS	Different parameters	CloudSim	Not clear	The CSOS performs better than the SOS and can cover near-optimal solutions because it converges faster with fewer iterations due to the replacement of random sequence components.
[69],	HBFA	Different parameters	MATLAB	70%	The strategy has better results than other multi-objective algorithms. However, it cannot speed up the convergence rate, and the performance needs to be more examined for improvement.
[70],	MLCCAP	Cloud center, VM and Task	Cloud-Sim	76%	The algorithm balanced the load of the system

References year	Algorithm	Parameters	Simulation environment	Accuracy	Pros and cons
[71],	Hybrid GA-PSO	Make-span, Cost, and LB	clouds	100%	and reducing the average make-span. The algorithm gives optimal solutions, but it has been tested in homogenous environments and needs further testing in heterogeneous environments.
[72],	Cuckoo Scheduling Algorithm	tight_fit_capacity + slot_duration	Public cloud simulator	90%	Execution time was reduced by employing the cuckoo algorithm to choose the lowest-fragment work.
[73],	Hybrid scheduling algorithm	Make-span, Cost, and LB	CloudSim		Although the proposed algorithm achieved improvement over (PSO, GA, GA-PSO, and PSO-DS) algorithms with limited target parameters, and it needs to include more parameters for best improvement.
[74],	CSA	Heterogenous parameters	CloudSim		The CSA algorithm reduced the make-span value better than the compared algorithms (ACO and Min-Min) when using fixed flight length values.
[75],	WOA-AEFS	Control	CloudSim	60%	To address the original WOA's limitations, the hybrid algorithm was devised, and the ability to fix scheduling problems in cloud computing has also been developed.
[76],	LJFP-PSO and MCT-PSO	Performance	MATLAB	80%	the demonstrated efficiency of the LJFP and MCT-PSO algorithms. Also, comparison simulation findings showed that the suggested heuristic converges faster than recent work scheduling algorithms.
[77],	HIGA	network topology and bandwidth, memory space,	CloudSim	90%	The proposed algorithm reduced the number of iterations; besides, the algorithm

References year	Algorithm	Parameters	Simulation environment	Accuracy	Pros and cons
[78],	CSSA	degree of heterogeneity Data center	CloudSim	92%	uses a cooling method, leading to less energy consumption. The algorithm uses the "escape" and "death" procedures during winter and summer, which enhanced the convergence velocity.
[79],	HHOSA	Data center, VM and Task	CloudSim	95%	The algorithm has a high performance and can be applied to other optimization problems such as IoT, feature selection, and fog computing.
[80],	self-configuring method	Not identified	Not identified		The suggested approach is advantageous because it does not require the user to pick algorithm parameters but offers competitive results. Furthermore, to solve complex challenges, using various configurations at different quests is a practical approach.
[81],	CEFA	Data center	CloudSim	87.5% for hard deadline and 100% for a soft deadline.	Reducing the execution time and costs by taking advantage of expanded slack time
[6],	New scheme with firefly algorithm	Data center	CloudSim	90%	The suggested scheme eliminates the degree of imbalance, and the makespan is reduced. Moreover, at peak loads, the system is more reliable and better performing than traditional systems.

Abualigah et al. [81] new algorithm with elite-based differential evolution has been implemented to address multi-objective work scheduling issues in cloud computing environments. The multi-objective nature of the issue derives from the need to remove make-pan while simultaneously maximizing capital use of the suggested solution, referred to as MALO. Other well-known strategies such as PSO, SOS, MSA, ACA, GA-PSO, and others are evaluated

and contrasted with the effectiveness (performance) and scalability of the MALO task scheduling method. The results showed that for solving task scheduling, MALO performed better than the other algorithms. MALO converged faster than the other approaches for more vast search spaces, making it suitable for significant scheduling problems. Finally, the observations were examined using statistical t-tests, which

showed that MALO collected the fundamental effects.

Chakravarthi et al. [82] presented a Cost-Effective Infrastructure as a Service (CEI/CES) workflow scheduler. The CEFA follows an innovative approach for problem encoding, population initialization, and efficiency estimation to find a cost-effective and time-sensitive workflow. Furthermore, it compared with ICP, PSO, RCT, and RTC (RWO) algorithms. Simulating in a virtual environment using CloudSim and the results indicate that the algorithm performs better than the other algorithms with a maximum success rate.

Tapale et al. [6] proposed a modern workflow design that incorporates negotiating algorithms and redistributes resources to cloud VMs to use dependable ones. The suggested simulation is run using the tool and tested against actual work. The study has found that the scheme does better than the current work.

4. SURVEY DISCUSSION AND ANALYSIS

Scheduling is considered one of the challengeable issues in cloud computing, and much literature works about it. Researchers are used many tools, methods, models, and algorithms to optimize the cloud's scheduling tasks. One of the most potent methods is using nature-inspired computing and its algorithms for optimizing cloud computing issues in general and cloud computing in specific. As illustrated in table1, sixteen articles have been reviewed using nature-inspired algorithms for scheduling optimization. They test the algorithms in a virtual environment except one that tested the real public cloud [25]. 75% of the articles are using the CloudSim for simulation (12 papers), and the rest are using MATLAB for simulation. The algorithms are varying. All of the algorithms are bio-inspired algorithms, and most of them are PSO-based algorithms. The parameters are different, and the most used Cloud center, VM, and Task as parameters. Another critical point is that these algorithms are simulated and tested after comparing them with other algorithms to see their performance and how they affect the scheduling problems. The addressed algorithms in the literature review section referred that the nature-inspired algorithms in general and bio-inspired algorithms in specific have a significant role in optimizing cloud scheduling issues in cloud computing.

5. CONCLUSION

A lot of new difficulties are growing as cloud computing shifts day by day. The job scheduling for a cloud computing situation is one of them. In this paper, the numerous existing algorithms have been studied for resource allocation and job scheduling that can fundamentally improve resource use's effectiveness in the cloud environment according to specific circumstances and tabulate their parameters, such as efficiency, nature of tasks, and environment. The scheduling's primary purpose is to increase the utilization of resources and minimize the availability of resources. Several algorithms are proposed for achieving efficient scheduling. However, because task scheduling is a heuristic problem, more research can be done in this field, and more optimized solutions can be achieved.

Although the diverse implementation range is relatively narrow and intermediate, usually under several hundred parameters, for nature-related algorithms and evolutionary algorithms, if parallel computation, high-performance computing, or cloud computing techniques will scale these algorithms is not clear.

One challenge facing algorithms motivated by default is how to better the algorithms that perform effectively to solve real-world problems on a wide scale? There are other open-ended issues with natural algorithms, such as optimizing the equilibrium between manipulation and discovery, how to cope efficiently with non-linear limitations, and how to use those algorithms in machinery and profound learning. Calculation influenced by nature is an active research area. It is hoped that the five open issues we outlined earlier will shortly stimulate more research into this field.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. GA, EN, Said A. Nature inspired algorithms in cloud computing: A survey. International Journal of Intelligent Information Systems. 2016;5:60-64.
2. Shukur H, Zeebaree S, Zebari R, Zeebaree D, Ahmed O, Salih A. Cloud computing virtualization of resources allocation for distributed systems. Journal

- of Applied Science and Technology Trends. 2020;1:98-105.
3. Asim M, Wang Y, Wang K, Huang PQ. A review on computational intelligence techniques in cloud and edge computing. *IEEE Transactions on Emerging Topics in Computational Intelligence*. 2020;4:742-763.
 4. Abd El-Nasser G, Said A Nature inspired algorithms in cloud computing: A survey. *International Journal of Intelligent Information Systems*. 2016;5:60.
 5. Salih AA, Abdulrazaq MB. "Combining best features selection using three classifiers in intrusion detection system," in 2019 International Conference on Advanced Science and Engineering (ICOASE). 2019;94-99.
 6. Tapale MT, Goudar RH, Birje MN, Patil RS. Utility based load balancing using firefly algorithm in cloud. *Journal of Data, Information and Management*. 2020;2:215-224.
 7. Abdulrazaq M, Salih A. Combination of multi classification algorithms for intrusion detection system. *Int. J. Sci. Eng. Res*. 2015;6:1364-1371.
 8. Salih AA, Zeebaree SR, Abdurraheem AS, Zebari RR, Sadeeq MA, Ahmed OM. Evolution of mobile wireless communication to 5G revolution. *Technology Reports of Kansai University*. 2020;62:2139-2151.
 9. Ibrahim IM. Task scheduling algorithms in cloud computing: A review. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*. 2021;12:1041-1053.
 10. Kumar PR, Raj PH, Jelciana P. Exploring security issues and solutions in cloud computing services – A survey. *Cybernetics and Information Technologies*. 2017;17:3-31.
 11. Sadeeq M, Abdulla AI, Abdurraheem AS, Ageed ZS. Impact of electronic commerce on enterprise business. *Technol. Rep. Kansai Univ*. 2020;62:2365-2378.
 12. Alzakholi O, Shukur H, Zebari R, Abas S, Sadeeq M. Comparison among cloud technologies and cloud performance. *Journal of Applied Science and Technology Trends*. 2020;1:40-47.
 13. Abdulla AI, Abdurraheem AS, Salih AA, Sadeeq MA, Ahmed AJ, Ferzor BM. et al. Internet of things and smart home security. *Technol. Rep. Kansai Univ*. 2020;62:2465-2476.
 14. Abdurraheem AS, Salih AA, Abdulla AI, Sadeeq MA, Salim NO, Abdullah H, et al. Home automation system based on IoT; 2020.
 15. Dino HI, Zeebaree SR, Salih AA, Zebari RR, Ageed ZS, Shukur HM, et al. Impact of process execution and physical memory-spaces on os performance; 2020.
 16. Salih AA, Abdulazeez AM. Evaluation of classification algorithms for intrusion detection system: A review. *Optimization (PSO)*. 2018;42:43.
 17. Sallow AB, Zeebaree SR, Zebari RR, Mahmood MR, Abdulrazaq MB, Sadeeq MA. Vaccine tracker/SMS reminder system: Design and implementation.
 18. Ageed Z, Mahmood MR, Sadeeq M, Abdulrazaq MB, Dino H. Cloud computing resources impacts on heavy-load parallel processing approaches. *IOSR Journal of Computer Engineering (IOSR-JCE)*. 2020;22:30-41.
 19. Kashikolaei SMG, Hosseinabadi AAR, Saemi B, Shareh MB, Sangaiah AK, Bian GB. An enhancement of task scheduling in cloud computing based on imperialist competitive algorithm and firefly algorithm. *The Journal of Supercomputing*. 2019;76:6302-6329.
 20. Meraihi Y, Gabis AB, Ramdane-Cherif A, Acheli D. A comprehensive survey of Crow search algorithm and its applications. *Artificial Intelligence Review*. 2020;54:2669-2716.
 21. Hafez NAaA. Review on scheduling in cloud computing. *IJCSNS International Journal of Computer Science and Network Security*. 2018;18:4.
 22. Cui H, Liu X, Yu T, Zhang H, Fang Y, Xia Z. Cloud service scheduling algorithm research and optimization. *Security and Communication Networks*. 2017;1-7.
 23. Al-Issa Y, Ottom MA, Tamrawi A. eHealth cloud security challenges: A survey. *J Healthc Eng*. 2019;7516035.
 24. Kak SF, Mustafa FM, Valente P. A review of person recognition based on face model. *Eurasian Journal of Science and Engineering*. 2018;4:157-168.
 25. Chaudhary D, Kumar B. Cost optimized hybrid genetic-gravitational search algorithm for load scheduling in cloud computing. *Applied Soft Computing*. 2019;83:105627.
 26. Du Y, Wang JL, Lei L. Multi-objective scheduling of cloud manufacturing resources through the integration of Cat

- swarm optimization and Firefly algorithm. *Advances in Production Engineering and Management*. 2019;14:333-342.
27. Yazdeen AA, Zeebaree SR, Sadeeq MM, Kak SF, Ahmed OM, Zebari RR. FPGA implementations for data encryption and decryption via concurrent and parallel computation: A review. *Qubahan Academic Journal*. 2021;1:8-16.
 28. Sadeeq MA, Zeebaree SR, Qashi R, Ahmed SH, Jacksi K. "Internet of things security: A survey," in 2018 International Conference on Advanced Science and Engineering (ICOASE). 2018;162-166.
 29. Ageed ZS, Zeebaree SR, Sadeeq MM, Kak SF, Yahia HS, Mahmood MR, et al. Comprehensive Survey of Big Data Mining Approaches in Cloud Systems. *Qubahan Academic Journal*. 2021;1:29-38.
 30. Abdulrahman LM, Zeebaree SR, Kak SF, Sadeeq MA, Adel AZ, Salim BW, et al. A state of art for smart gateways issues and modification. *Asian Journal of Research in Computer Science*. 2021;1-13.
 31. Jujare VA. Cloud computing: Approach, structure and security. *The Second International Conference on Computing Methodologies and Communication (ICCMC 2018) IEEE Conference*; 2018.
 32. Sridhar SDSS. A survey on cloud security issues and challenges with possible measures. *International Conference on Inventive Research in Engineering and Technology (ICIRST 2016)*; 2016.
 33. Sadeeq MM, Abdulkareem NM, Zeebaree SR, Ahmed DM, Sami AS, Zebari RR. IoT and cloud computing issues, challenges and opportunities: A review. *Qubahan Academic Journal*. 2021;1:1-7.
 34. Shukur H, Zeebaree SR, Ahmed AJ, Zebari RR, Ahmed O, Tahir BSA, et al. A state of art survey for concurrent computation and clustering of parallel computing for distributed systems. *Journal of Applied Science and Technology Trends*. 2020;1:148-154.
 35. Maulud DH, Zeebaree SR, Jacksi K, Sadeeq MAM, Sharif KH. State of art for semantic analysis of natural language processing. *Qubahan Academic Journal*. 2021;1:21-28.
 36. Kareem FQ, Zeebaree SR, Dino HI, Sadeeq MA, Rashid ZN, Hasan DA, et al. A survey of optical fiber communications: Challenges and processing time influences. *Asian Journal of Research in Computer Science*. 2021;48-58.
 37. Sadeeq MA, Zeebaree S. Energy management for internet of things via distributed systems. *Journal of Applied Science and Technology Trends*. 2021;2:59-71.
 38. Abdullah SMSA, Ameen SYA, Sadeeq MA, Zeebaree S. Multimodal emotion recognition using deep learning. *Journal of Applied Science and Technology Trends*. 2021;2:52-58.
 39. Ageed ZS, Ibrahim RK, Sadeeq MA. Unified ontology implementation of cloud computing for distributed systems. *Current Journal of Applied Science and Technology*. 2020;82-97.
 40. Zeebaree S, Ameen S, Sadeeq M. Social media networks security threats, risks and recommendation: A case study in the kurdistan region. *International Journal of Innovation, Creativity and Change*. 2020;13:349-365.
 41. Sallow AB, Sadeeq M, Zebari RR, Abdulrazzaq MB, Mahmood MR, Shukur HM, et al. An investigation for mobile malware behavioral and detection techniques based on android platform. *IOSR Journal of Computer Engineering (IOSR-JCE)*. 2020;22:14-20.
 42. Abdulazeez AM, Zeebaree SR, Sadeeq MA. Design and Implementation of Electronic Student Affairs System. *Academic Journal of Nawroz University*. 2018;7:66-73.
 43. Mohammed SM, Jacksi K, Zeebaree SR. A state-of-the-art survey on semantic similarity for document clustering using GloVe and density-based algorithms. *Indonesian Journal of Electrical Engineering and Computer Science*. 2021;22:552-562.
 44. Abdalla PA, Varol A. Advantages to disadvantages of cloud computing for small-sized business. 2019;1-6.
 45. Samann FEF, Zeebaree SR, Askar S. IoT provisioning QoS based on cloud and fog computing. *Journal of Applied Science and Technology Trends*. 2021;2:29-40.
 46. Younis ZA, Abdulazeez AM, Zeebaree SR, Zebari RR, Zeebaree DQ. Mobile Ad Hoc network in disaster area network scenario: A review on routing protocols. *International Journal of Online and Biomedical Engineering*. 2021;17.
 47. Abdulrazzaq MB, Mahmood MR, Zeebaree SR, Abdulwahab MH, Zebari RR, Sallow AB. An analytical appraisal for supervised classifiers' performance on facial

- expression recognition based on relief-feature selection. in *Journal of Physics: Conference Series*. 2021;012055.
48. Sadeeq MJ, Zeebaree SR. Semantic search engine optimisation (SSEO) for dynamic websites: A review. *International Journal of Science and Business*. 2021;5:148-158.
 49. Qadir GA, Zebaree SR. Evaluation of QoS in distributed systems: A review. *International Journal of Science and Business*. 2021;5:89-101.
 50. Khalid ZM, Zebaree SR. Big data analysis for data visualization: A review. *International Journal of Science and Business*. 2021;5:64-75.
 51. Hama Ali KW, Zeebaree SR. Resources allocation for distributed systems: A review. *International Journal of Science and Business*. 2021;5:76-88.
 52. Hamad ZJ, Zeebaree SR. Recourses utilization in a distributed system: A review. *International Journal of Science and Business*. 2021;5:42-53.
 53. Husain BH, Zeebaree SR. Improvised distributions framework of hadoop: A review. *International Journal of Science and Business*. 2021;5:31-41.
 54. Saeed J, Zeebaree S. Skin lesion classification based on deep convolutional neural networks architectures. *Journal of Applied Science and Technology Trends*. 2021;2:41-51.
 55. guide N. Types of optimization problems; 2020.
 56. Yadav A, Vishwakarma DK. A comparative study on bio-inspired algorithms for sentiment analysis. *Cluster Computing*. 2020;23:2969-2989.
 57. Ahmed KD, Zeebaree SR. Resource allocation in fog computing: A review. *International Journal of Science and Business*. 2021;5:54-63.
 58. Mohammed CM, Zebaree SR. Sufficient comparison among cloud computing services: IaaS, PaaS, and SaaS: A review. *International Journal of Science and Business*. 2021;5:17-30.
 59. Zeebaree SR. "Remote controlling distributed parallel computing system over the cloud (RCDPCSC)," in 2020 3rd International Conference on Engineering Technology and its Applications (IICETA). 2020:258-258.
 60. Ahsan MM, Gupta KD, Nag AK, Poudyal S, Kouzani AZ, Mahmud MAP. Applications and evaluations of bio-inspired approaches in cloud security: A review. *IEEE Access*. 2020;8:180799-180814.
 61. Carrion G, Huerta M, Barzallo B. Monitoring and irrigation of an urban garden using IoT," presented at the 2018 IEEE Colombian Conference on Communications and Computing (COLCOM), Medellin, Colombia; 2018.
 62. Ahmed Saleh I, Ibrahim Alsaif O, Abduttalib Muhamed S, Ibrahim Essa E. Task scheduling for cloud computing based on firefly algorithm. *Journal of Physics: Conference Series*. 2019;1294:042004.
 63. AL-Zebari A, Zeebaree S, Jacksi K, Selamat A. ELMS-DPU ontology visualization with protégé VOWL and web VOWL. *Journal of Advanced Research in Dynamic and Control Systems*. 2019;11:478-85.
 64. Sulaiman MA, Sadeeq M, Abdurraheem AS, Abdulla AI. Analyzation study for gamification examination fields. *Technol. Rep. Kansai Univ*. 2020;62:2319-2328.
 65. Hasan DA, Hussan BK, Zeebaree SR, Ahmed DM, Kareem OS, Sadeeq MA. The impact of test case generation methods on the software performance: A review. *International Journal of Science and Business*. 2021;5:33-44.
 66. Abdullahi M, Ngadi MA, Abdulhamid SiM. Symbiotic organism search optimization based task scheduling in cloud computing environment. *Future Generation Computer Systems*. 2016;56:640-650.
 67. Rjoub G, Bentahar J. Cloud task scheduling based on swarm intelligence and machine learning. 2017;272-279.
 68. Abdullahi M, Ngadi MA, Dishing SI. Chaotic symbiotic organisms search for task scheduling optimization on cloud computing environment. 2017;1-4.
 69. Srichandan S, Ashok Kumar T, Bibhudatta S. Task scheduling for cloud computing using multi-objective hybrid bacteria foraging algorithm. *Future Computing and Informatics Journal*. 2018;3:210-230.
 70. Task scheduling based on advance ant colony optimization and particle swarm optimization with machine learning in the cloud environment; 2018.
 71. Manasrah AM, Ba Ali H. Workflow scheduling using hybrid GA-PSO algorithm in cloud computing. *Wireless Communications and Mobile Computing*. 2018;1-16.

72. Cuckoo-inspired job scheduling algorithm for cloud computing; 2019.
73. Sardaraz M, Tahir M. A hybrid algorithm for scheduling scientific workflows in cloud computing. IEEE Access. 2019;7:186137-186146.
74. Prasanna Kumar KR, Kousalya K. Amelioration of task scheduling in cloud computing using crow search algorithm. Neural Computing and Applications. 2019;32:5901-5907.
75. Strumberger I, Bacanin N, Tuba M, Tuba E. Resource scheduling in cloud computing based on a hybridized whale optimization algorithm. Applied Sciences. 2019;9:4893.
76. Alsaidy SA, Abbood AD, Sahib MA. Heuristic initialization of PSO task scheduling algorithm in cloud computing. Journal of King Saud University - Computer and Information Sciences; 2020.
77. Sharma M, Garg R. HIGA: Harmony-inspired genetic algorithm for rack-aware energy-efficient task scheduling in cloud data centers. Engineering Science and Technology, an International Journal. 2020;23:211-224.
78. Sanaj MS, Joe Prathap PM. Nature inspired chaotic squirrel search algorithm (CSSA) for multi objective task scheduling in an IAAS cloud computing atmosphere. Engineering Science and Technology, an International Journal. 2020;23:891-902.
79. Attiya I, Abd Elaziz M, Xiong S. Job scheduling in cloud computing using a modified harris hawks optimization and simulated annealing algorithm. Comput Intell Neurosci. 2020;3504642.
80. Semenkina OE, Popov EA. Nature-inspired algorithms for a scheduling problem in operational planning. IOP Conference Series: Materials Science and Engineering. 2020;734:012107.
81. Abualigah L, Diabat A. A novel hybrid antlion optimization algorithm for multi-objective task scheduling problems in cloud computing environments. Cluster Computing. 2020;24:205-223.
82. Chakravarthi KK, Shyamala L, Vaidehi V. Cost-effective workflow scheduling approach on cloud under deadline constraint using firefly algorithm. Applied Intelligence. 2020;51:1629-1644.

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