Amended hybrid multi-verse optimizer with genetic algorithm for solving task scheduling problem in cloud computing

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Abstract: The central cloud facilities based on virtual machines ofer many benefts to reduce the scheduling costs and improve service availability and accessibility. The approach of cloud computing is practical due to the combination of security features and online services. In the tasks transfer, the source and target domains have difering feature spaces. This challenge becomes more complicated in network trafc, which leads to data transfer delay, and some critical tasks could not deliver at the right time. This paper proposes an efcient optimization method for task scheduling based on a hybrid multi-verse optimizer with a genetic algorithm called MVO-GA. The proposed MVO-GA is proposed to enhance the performance of tasks transfer via the cloud network based on cloud resources' workload. It is necessary to provide adequate transfer decisions to reschedule the transfer tasks based on the gathered tasks' efciency weight in the cloud. The proposed method (MVO-GA) works on multiple properties of cloud resources: speed, capacity, task size, number of tasks, number of virtual machines, and throughput. The proposed method successfully optimizes the task scheduling of a large number of tasks (i.e., 1000–2000). The proposed MVOGA got promising results in optimizing the large cloud tasks' transfer time, which refects its efectiveness. The proposed method is evaluated based on using the simulation environment of the cloud using MATLAB distrusted system. Keywords Cloud computing · Task scheduling · Multi-verse optimizer · Genetic algorithm · Hybrid method

Index Terms: Holography, image analysis.

1. Introduction

Cloud computing is defned as managing information and services of users and organizations using central technology such as storage, CPU, and network [1, 2]. Cloud computing aims to centralize the technology facilities to provide many benefts such as avoiding data redundancy, reducing physical costs, speeding up the services, and information fow. Technically, the cloud architecture is divided into three levels of services [3]; (1) the software as a service (SaaS), which represents the user services through system interfaces, (2) platform as a service (PaaS), which represents the operating system of the cloud, and (3) infrastructure as a service (IaaS), which contains the hardware facilities such as storages and network. The PaaS operates the data gathering between SaaS and IaaS through the network facilities [4]. The cloud takes one of three main deployment approaches; the frst approach is the private cloud applied in the local environment like organizations or cities [5, 6]. The second approach is the public cloud that allows cloud deployment as a global network (i.e., cross the countries). The hybrid deployment approach mixes between the private and public approaches. The public cloud connected with the private cloud before delivering the service to the users through the private cloud's SaaS. Despite the benefts of the hybrid cloud, one of the main challenges of this approach is scheduling tasks [7]. Task transfer scheduling is difcult due to the diferences in clouds' facilities specifcations, such as storage capacity, transfer rate, throughput, and processors speed [8]. These diferences may cause transfer workload, delivery time, and efciency of resource usability [9, 10]. The cloud environment ofers many benefts for businesses by centralizing technology facilities' operations (i.e., software and hardware). The facility's centralization could reduce the physical costs, speed up the services, avoid data redundancy, and improve the data's relationship schemes [11, 12]. The cloud deploys in wide applications to structure the data gathering between clouds. Organizations such as universities, banks, and hospitals may have their cloud that operated locally. However, these organizations book facilities of the public cloud to cut the operational costs of the cloud. It is hard to schedule the tasks to address the minimum makespan. A useful scheduler must apply benefcial strategies to handle the changing environment and the types of tasks. One of the primary essential issues of the tasks' transfer is task scheduling efciency [13]. The scheduling algorithm should distribute the tasks based on the available cloud resources to minimize makespan without violating precedence constraints. In the cloud, efcient task scheduling would utilize all available resources to improve the transfer system performance. This increases the scheduling decisions' complexity to assure the efciency of task transfer [12, 13]. Thus, the scheduling decision of task transfer is complicated due to the difculty of addressing transfer efciency. Hence, this paper proposes an optimization algorithm to improve task transfer performance based on the cloud environment. The task transfers' performance needs to cover the efciency properties to provide efective scheduler decisions in the tasks' queue under the dynamic changing of the active tasks in the cloud. 1 3 Amended hybrid multi-verse optimizer with genetic algorithm… Several kinds of research have been conducted to solve the transfer workload of heterogonous cloud tasks. The transfer efciency is the main issue of scheduling the tasks. The efciency focuses on transfer the tasks in response time based on the available cloud resources. Thus, faster tasks would transfer in frst under the condition of full or efective cloud deployment. There are many properties included in the computations of transfer efciency to schedule the transfer priority based on the delivery time. The nature-inspired algorithms, such as Dragonfy Algorithm (DA) [14], Gray Wolf Optimizer (GWO) [15], Marine Predators Optimizer (MPO) [16, 17], Salp Swarm Algorithm (SSA) [18], Grasshopper Optimization Algorithm (GOA) [19], Harmony Search (HS) [20], Sine Cosine Optimizer (SCO) [21], Particle Swarm Optimization (PSO), Firefy Algorithm (FA) [22], Krill herd Algorithm (KHA) [23, 24], Moth–fame Optimization (MOA) [25], Gradient-based Optimizer (GBO) [26], Group Search Optimizer (GSO) [27], Bat Algorithm (BA) [28], Aquila Optimizer [29], and Arithmetic Optimization Algorithm (AOA) [30], can be applied to solve the task schedule of heterogonous tasks transfer. This paper aims to improve the nature-inspired algorithm (multi-verse optimizer) by multi-objective properties to improve the efectiveness of the transfer scheduler of heterogonous cloud tasks. The proposed method hybridized the multi-verse optimizer with genetic algorithm (GA) to enhance its searchability and avoid the trap in the optimum local problem. The main motivations are in twofold: frstly, the heterogeneous tasks' transfer cost could be reduced through assign tasks for all available cloud resources. The efciency of the task transfer would be computed based on the transfer time of the tasks and depend on many properties such as throughput, the capacity of cloud machines, transfer rate, and processor speed. Secondly, the integration between the MVO and GA would provide efective processes to schedule cloud tasks transfer by optimizing the transfer time. The MVO-GA could schedule the transfer tasks based on the workload of the available cloud resources. On the other hand, the GA could improve the conventional MVO by applying the crossover and mutation processes to enhance the initiated tasks schedule by MVO.

Experiments are conducted using two task scheduling scenarios to validate the efectiveness of the proposed method. The results show that the proposed method got better results compared to other well-known methods. The contributions of this paper are summarized as follows. • A new adaptive task scheduling method in the cloud-computing environment to reach the minimum time of transfer the tasks on available resources. • Hybrid the multi-verse Optimizer with the genetic algorithm to improve its searchability. • Apply various evaluation criteria and several scenarios to evaluate the proposed scheduling method. The remaining section of this paper is organized as follows. Section 2 presents the previous work on the task scheduling area. Section 3 presents the proposed method hybrid multi-verse optimizer and genetic algorithm for solving the task scheduling problem. Section 4 discusses the experiments and results. Section 5 shows the L. Abualigah, M. Alkhrabsheh 1 3 conclusion and future works. Finally, Sect. 6 shows the Research Implications and

2. Related work

This section overviews the cloud computing defnition, services, approaches, importance, and limitations to give a good understanding of cloud computing technology [31]. The defnition of cloud computing is simplifed as the execution of working tasks all or many departments of an organization using a central virtual machine that contains all information, services, and hardware requirements rather than using a single IT system for each group of employees or department inside an organization [32]. There are three main services provided by cloud computing which are Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) [33, 34]. Figure 1 presents the architecture of cloud computing services. The descriptions of these services are given as follows. SaaS: this service represents users' and employees' interfaces that involve organizational activities of various domains like education and health [35]. These interfaces connected with working the application such as documentation of application, information-retrieving application, and reports application [36]. The users can insert, update, remove, and update their records to beneft from the business' services through user interfaces. Contrariwise, the employees and administrators can use SaaS to complete and manage their daily working tasks. Moreover, the managers and decision-makers can use SaaS to generate statistics, reports, and analytical data to support their decisions and control their business. SaaS can be deployed using only monitors without storage and CPU. PaaS: This service represents a cloud computing operating system which processes and manages the gathered information between SaaS (system users) and IaaS (systems storage and infrastructure). IaaS: this service represents the hardware components of cloud computing, such as CPUs, storage, and network facilities. Thus, IaaS processes send and store applications data supporting PaaS management using network facilities. Fig. 1 Services of Cloud computing 1 3 Amended hybrid multi-verse optimizer with genetic algorithm... Additionally, IaaS stores the applications deployed by PaaS and used by users' at the SaaS level. As mentioned in the previous section, the job scheduler of heterogeneous cloud tasks should be multi-objective. The transfer efciency and fairness need to be addressed. The job scheduler's multi-objective purpose increases the difculty of (1) map the transfer tasks based on the importance weights and (2) reduces the transfer costs. This section presents the related algorithms that could be applied to schedule the transfer of heterogeneous cloud tasks. Zeng in [37] mentioned that the MapReduce method is not investigated efectively in the applications of transferring the heterogeneous cloud tasks. The MapReduce works to reduce the tasks' transfer time though segment the large tasks as small blocks. The blocks can be delivered via diferent cloud paths. The MapReduce conducts based on two main processes: (1) map the transfer criteria through estimate the transfer time (input data of all tasks/blocks sizes), and (2) reduce the transfer time though allocate all available blocks in the cloud to transfer the data. The tasks that require fewer data will be transferred frst. They found that the MapReduce can save 25–50SLA agnostic. [38] proposed the multi-objective optimization to schedule the cloud tasks transfer based on many task properties. Although multi-objective optimization is adopting the genetic algorithm processes, the GA processes are managed in many stages based on nature's properties. Traditionally, the multi-objective optimization process starts with chromosome encoding for mapping and assignment of the task to the virtual machine. The next step is ftness calculation as per the objective of the functions. Genetic operators such as selection, crossover, and mutation are used during evolution. The evolution continues until the termination criteria are met. At this point, the Pareto front solutions from the evolution are retrieved and optimized to further process tasks. At each stage of multi-objective, a set of tasks, objectives, or properties will be evaluated. The multi-objective optimization is simulated based on two stages depending on two objectives which are the response time and resource consumption. The simulation results confrm that multi-objective optimization is useful for scheduling the task's transfer based on complex objectives or properties. The Directed Acyclic Graph (DAG) is suggested to schedule the transfer of efcient tasks based on the transfer time costs [39]. DAG works like a decision tree to compute the tasks' transfer time based on many priorities, such as available cloud resources, transfer paths, and transfer throughput. DAG is efective in calculating the transfer time of complex tasks (i.e., a large set of tasks of heterogeneous resources). The time costs of all tasks are calculated to estimate the average transfer cost. The minimum and maximum costs can be determined based on specifc formulas. Thus, the task scheduler will arrange the transfer priority based on the transfer time (the minimum costs are transferred frstly). The simulation result shows that DAG is useful to schedule the large set of tasks of heterogeneous resources based on the transfer cost (i.e., time). [40] proposed a genetic algorithm (GA) to schedule the transfer of heterogeneous tasks based on the priority vectors of the tasks (transfer fairness). The users compute the transfer tasks' ftness function based on many properties, such as the trust of tasks and transfer repetition. The candidate tasks are considered as the initial L. Abualigah, M. Alkhrabsheh 1 3 chromosomes. The higher priority task is selected based on the ftness of the task's properties, which is analyzed through crossover and mutation processes. This means the task priority is computed dynamically based on the property's appearance of current active tasks. The simulation results show the efectiveness of GA in optimizing the task priority based on the ftness function of the task properties detected in the population. They argued that task transfer based on the priority is the best compared with other scenarios, such as transfer the shortest tasks frst. [41] presented a cost-efcient task scheduling algorithm using two heuristic strategies. The frst strategy dynamically maps tasks to the most cost-efcient VMs based on the concept of Pareto dominance. The second strategy, a complement to the frst strategy, reduces the monetary costs of non-critical tasks. The simulation results showed that the algorithm could substantially reduce monetary costs while producing the makespan as good as the best known task scheduling algorithm can provide. However, this algorithm is inapplicable to multiple types of VMs with different pricing models. [42] proposed a Cloud scheduler based on Ant Colony Optimization (ACO). The scheduler's goal is to minimize the weighted fow time of a set of PSE jobs while minimizing makespan. Simulated experiments performed with real PSE job data and other Cloud scheduling policies indicate that this proposal allows for a more agile job handling while reducing PSE completion time. Besides, the evaluation results showed that ACO performs better than random and best efort algorithms. [43] proposed a trust dynamic level-scheduling algorithm named CloudDLS by integrating the existing DLS algorithm. This study's main contribution is extending the traditional formulation of the scheduling problem so that both execution time and reliability of applications are simultaneously accounted for. Theoretical analysis and simulations proved that the Cloud-DLS algorithm could efciently meet the requirement of Cloud computing workloads in trust, sacrifcing fewer time costs and assuring the execution of tasks securely. [44] proposed a new priority-based job-scheduling algorithm in cloud computing based on multiple criteria decision-making model. This scheduling algorithm consists of three levels of priorities, including scheduling level (objective level), resource level (attribute level), and job level (alternative level). The algorithm calculates the priority vector of scheduling jobs (PVS), then chooses a job with a maximum priority value based on PVS and allocates appropriate resources. The result of this paper indicated that the proposed algorithm has reasonable complexity. All of the above-related works focused on the efciency of the tasks scheduler by transferring the heterogeneous tasks in response time based on the available cloud resources. Therefore, this paper's main challenge is to optimize the transfer of the heterogeneous task depending on the efciency factors. The proposed optimization algorithm should work on multi properties of cloud resources such as speed, capacity, task size, number of tasks, number of virtual machines, and throughput. One of the most suitable reviewed algorithms for this paper is the multi-verse optimizer (MVO). MVO is a recently proposed evolutionary algorithm that works to optimize the solutions based on universe theory [45]. All universe objects (i.e., cloud tasks) belong to the initial hole called a white hole. Based on specifc conditions, many objects could move to an inverse hole called a black hole. The black hole may receive other objects from the universe called a wormhole. The white hole's object characteristics are difering from the 1 3 Amended hybrid multi-verse optimizer with genetic algorithm... characteristics of the objects in the worm universe. The black hole responsible for the schedule all received objects based on the various characteristics. Keep in mind that not all universes objects are allowed to move to a black hole (i.e., the movement is under control conditions). Based on the reviewed works of heterogeneous task scheduling, the transfer scheduler should address the transfer efciency through transfer the queued tasks as fast as possible. The conducted works have lacked an efective optimization algorithm to schedule the transfer of the task based on multi-objective problems (efciency properties). This paper tries to fll the research gap by applying the MVO algorithm to schedule heterogeneous tasks transfer via the hybrid cloud. MVO algorithm expected to handle the efciency properties to schedule the transfer tasks regarding its size based on the available cloud resources. On the other hand, the GA will be applied to optimize the scheduled tasks' transfer time. The integration between MVO and GA could help

$$
\begin{aligned}
Z = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 & \\
+a+b & \quad (1) \\
+a+b & \quad (2) \\
+a+b & \quad (3) \\
+a+b & \quad (4)
\end{aligned}
$$

In order to address the above technological challenges, we need to develop flexible spine humanoid robots as experimental platforms. Recently, a few researchers have developed several spinal robots based on the anatomy of the human skeleton, Mizuuchi built a tendon-driven robot called "Kenta" [**?**], [**?**]. Although the robot has a spine, there has been no data to show that it can move in a flexible way. Also, the robot cannot stand up without external support because the upper body is too heavy [**?**]. Mizuuchi later improved his prototype. However, it is also unable to stand up without external support [**?**], [**?**].

At the German Space Agency (DLR), Hirzinger and his group developed a spine robot called "Justin". The robot has a 3-DOF movable upper-torso, two arms and dexterous hands. Unlike the tendon-based robots developed by Mizuuchi and his colleagues, each controllable spinal joint of Justin is directly actuated by a DC Motor via a Harmonic Drive Gear. In order to prevent the robot from falling, the designers fixed the robot to a large platform [**?**]. In November, 2007, researchers from Sugano Lab of Waseda University announced a new humanoid robot for household work and home care. The robot is called "Twendy-One". It has a 4-DOF spine but it is fixed on a wheeled mobile platform. Thus, balancing is not an issue for this robot. It has a 4-DOF spine but it is fixed on a wheeled mobile platform. Thus, balancing is not an issue for this robot.

Inspired by the flexibility of belly dancers, Or conducted the first scientific study on belly dancing [**?**]. He developed a database of belly dancing movements using computer animations. Later, Or recorded the movements of a professional belly dancer using a 12-camera VICON [**?**] motion capture system. By analyzing the movements of the dancer, he developed a spinal mechanism which allows a full-body humanoid robot to exhibit all the human spine motions in 3D although with less degree of freedom [**?**]. Moreover, the robot is able to stand up while performing dynamic

TABLE I
MATH SPACINGS USED BY LATEX

Size	Width	Cmd.	Used for	Example
small	1/6 em	\,	symbols	$a\,b$
medium	2/9 em	\:	binary operators	$a\:+\:b$
large	5/18 em	\;	relational operators	$a\;=\;b$
negative small	−1/6 em	\!	misc. uses	$a\!b$

torso motions without external support. In terms of controlling the mechanical spine, Or used a model of the lamprey central pattern generator. Experimental results showed that by using such neural networks, only three control parameters are needed to generate all human spinal motions. In order to conduct research on human-robot interactions, Or developed a new, full-body flexible spine humanoid robot [**?**], [**?**]. Experimental results showed that it is possible for humans to perceive emotions expressed by a flexible spine humanoid robot. Later, Or developed the world's first humanoid robot that can walk more naturally, like a human, with flexible spinal motions.

The aluminum foil contours over the semicircular aperture to produce a variable height surface with the desirable characteristics for this test in Table I. The 100 nm aluminum foil has a transmission of approximately 35% at $\alpha = 46.9$ nm considering the layer of native oxide 19 and effectively cuts the lower photon energy plasma emission from the Ar discharge in the laser source. The sample was immersed in a solution of MIBK-methyl isobutyl ketone (4-Methyl-2- Pentanone) with IPA (isopropyl alcohol) 1:3 for 30 seconds, rinsed with IPA for 30 seconds, and was finally dried using compressed nitrogen $x = \sum_{1=0}^{z} 2^1 Q$.

3. The proposed hybrid multi-verse optimizer with genetic algorithm (MVO-GA)

This section presents the research methodology including the research design, proposed properties and algorithm, simulation environment, and evaluation processes. The research methodology is constructed based on the related works in the domain of transfer heterogeneous cloud tasks to assure useful achievement of the research objectives. The research methodology is the set of related processes and settings that should be accomplished to address the research objectives. Based on the research objective, questions, and objectives, the methodology was planned straightforwardly to develop the research

3.1. Methodology design

This paper focuses on scheduling heterogeneous based on the cloud environment. The main research challenge is identifed as to schedule the transfer of the task-based efciency properties. Several previous works and studies have been reviewed to determine competency characteristics that can be applied to scheduling the priority of transferring heterogeneous tasks. The most important properties are the network transfer rate, transfer throughput, path distance, storage capacity, and processor speed. Based on the efciency properties, the tasks should be scheduled based on the available cloud resources to produce an efcient workload of heterogeneous tasks transfer. For this purpose, this paper proposes a multi-verse optimization algorithm with a genetic algorithm, called

3.2. Task scheduling problem

The cloud task scheduling problem is defned as scheduling and allocating various tasks to numerous virtual machines accomplished in a short execution period. Consider the cloud system (CS) consists of Npm physical machines (PM), and each physical machine consists of Nvm virtual machines (VMs) [7]. where PMi (i=1,. . . ., Npm) denotes the PMs presented in the cloud, and it can be represented as in Eq. (2): where VMk, k=1,2 ,. . . , Nvm represents the kth virtual machine. Nvm is the number of virtual machines and VMk denotes the kth virtual machine resource in the cloud environment. The feature of VMk is defned as: where SIDVk is the serial number of virtual machines and MIPSk is the information processing speed of virtual machines (unit: millions-of-instructions-per-second, mips). where Ntsk is the number of tasks submitted by the users. Taskl represents the lth task in the task sequence. The feature of Taskl is defned as: where SIDT l is the serial number of tasks and task length l is the instruction length of the task (unit: million instructions). Time ECT l refers to the expected completion time for the Task l; Pl l refers to the task priority the number of tasks for Ntsk, the number of virtual machines for Nvm. The Expect Complete Time (ECT) matrix of size Ntsk×Nvm denotes the execution time required to run the task on each computing resource (virtual machine) that can be calculated by the following matrix: The main objective function is to reduce the makespan by locating the best set of tasks to be executed on VMs. where ECTlk refers to the required execution time of lth task on kth VM where Nvm is the number of VMs and Ntsk is the number of tasks. TLi is the task–length i. The ftness value is defned as: CS = (1) [PM1, PM2, ..., PMi , ..., PMNpm] PMi = (2) [VM1, VM2, ..., VMk, ..., VMNvm] VMk = (3) [SIDVk, MIPSk] T = (4) [Task1, Task2, ..., Taskl, ..., TaskNtsk] Task1 = (5) [SIDl, tasklengthl, ECTl, Pll] ECT = ECT1, 1 ECT1,2 ETC1,3 ETC1, Nvm ECT2, 1 ECT2,2 ETC 2,3 ETC2, Nvm ECT3, 1 ECT3,2 ETC 3,3 ETC3, Nvm ECTNtsk,1 ECTNtsk,2 ECTNtsk,3 ECTNtsk,Nvm ....(6) ETC = (7) TLi MIPSk , k = 1, 2, 3, ..., Nvm, i = 1, 2, 3, ..., Ntsk 1 3 Amended hybrid multi-verse optimizer with genetic algorithm fit = max (8) ECTlk , l [1, Ntsk] mapped to kth V

3.3. Multi-verse optimizer

MVO applied for a structured section of the population that will involve the computation of the ftness solution of efcient task scheduling. For example, suppose V1, V2, V3, V4 is the cloud virtual machines, and suppose T1, T2, T3, and T4 are the active transfer tasks (as shown in Table 1). The population of MVO (White hole) is all active tasks in array [i][j], where i the number of tasks and j the number of virtual machines. Then, the ftness solution of each column in the array is computed. Hence, the optimal virtual machine for each task based on the transfer speed will be estimated. For example, T1/V2, T2/V3, T3/V4, and T4/V2 are the optimal solutions for each task in the array (i.e., black hole). Based on the black hole population, the GA will be applied to optimize the task scheduling based on the available cloud resources according to the intersection between the transfer tasks. The solutions of the MVO are updated using Eq. (9): where xji indicates the jth parameter of ith universe, Ui shows the ith universe, NI(Ui) is normalized infation rate of the ith universe (the ftness values), r1 is a random number in [0, 1], and xjk indicates the jth parameter of kth universe selected by a fit = max (8) ECTlk , l [1, Ntsk] mapped to kth V M, k = 1, 2, 3, ..., Nvm x j kr1 ¡ Ni(Ui) Xj i r1 Ni(Ui) (10) x j i = if(r2 ¡ WEP) if (r3 ¡ 0.5)Xj + TDR × ((ubj lbj) × r4 + lbj) if (r3 ¡ 0.5)X j + TDR × ((ubj lbj) × r4 + lbj if(r2 WEP) x j i TDR = 1 (11) l1p L1p WEP = min + l (12) (max min L) Table 1 Example of VMs and tasks population T1 T2 T3 T4 V1 T1/V1 T2/V1 T3/V1 T4/V1 V2 T1/V2 T2/V2 T3/V2 T4/V2 V3 T1/V3 T2/V3 T3/V3 T4/V3 V4 T1/V4 T2/V4 T3/V4 T4/V

3.4. Genetic algorithm

The genetic algorithm is used to achieve an accurate schedule to process tasks in the Cloud. GA would be applied to the black hole prepared by MVO (MVO works to reduce the population boundaries). Hence, GA could fnd optimal solutions due to the reduced number of tasks population. The main operators of the genetic algorithm are the following: • Selection method: this method is used to select pair random solutions to apply the crossover and mutation operator based on its probability [46]. • Crossover: this operator collects a pair of chromosomes to generate the chromosomes of the next generation using two-point method. Some characteristics of the frst parent are transmitted to the new chromosome, but the rest of the characteristics come from the rest of the parents [47]. The crossover probability used in this paper is 0.8. • Mutation: mutation

TABLE II
POSSIBLE Ω FUNCTIONS

Range	$\Omega(m)$
$x < 0$	$\Omega(m) = \sum_{i=0}^{m} K^{-i}$
$x \geq 0$	$\Omega(m) = \sqrt{m}$

TABLE III
NETWORK DELAY AS A FUNCTION OF LOAD

β	Average Delay	
	λ_{min}	λ_{max}
1	0.057	0.172
10	0.124	0.536
100	0.830	0.905*

*limited usability

operator in a genetic algorithm is used to maintain the diversity of the population by changing the chromosome with a small probability from the interval [0, 1], which is known as the probability of mutation (Pm), fxed is 0.2. Besides, two mutation points Mp1 and Mp2 should be defned to perform mutation operation. The mutation points are a random number between 0–1. • Termination condition: this condition will apply if there are no further improvements to the Fitness value and the termination criteria best chromosome in the population is reached. More details for the used GA are given in [48, 49]

3.5. Hybrid multi-verse optimizer with genetic algorithm (MVO-GA)

On the other hand, the genetic algorithm (GA) is a search heuristic inspired by Charles Darwin's natural evolution theory. This algorithm refects the process of natural selection where the fttest individuals are selected for reproduction to produce ofspring of the next generation. The GA includes many processes and computations to fnd the ftness solution based on the study environment. Figure 2 illustrates the methodology design of this paper. MVO and GA could be collaborative to support this paper through two main stages. The MVO would reduce the task's boundaries, TB=(V, E), where V is the set of tasks to be executed. E is the transfer paths of the tasks via the cloud virtual machines (VM). On the other hand, the GA will be applied to each task set in black holes to optimize the task scheduling based on efciency properties as given in Fig. 3. The next section explains the details of the research methods. Multi-verse optimizer (MVO) is a proposed evolutionary algorithm that works to optimize the solutions based on universe theory [45]. All universe objects (i.e., cloud tasks) belong to the initial hole called a white hole. Based on specifc conditions, many objects could move to a smaller hole called a black hole. The black 1 3 Amended hybrid multi-verse optimizer with genetic algorithm... hole may receive other objects from another universe called a wormhole. The white hole's object characteristics are difering from the characteristics of the objects in the worm universe. The black hole responsible for scheduling all received objects based on the various characteristics. Keep in mind that not all universes objects are allowed to move to a black hole (i.e., the movement is under control conditions)

Two holograms digitized in this manner are displayed in Fig. **??**. The digital reconstruction of the hologram digitized by the AFM is based on a numerical Fresnel propagator in Table II and III. To obtain the amplitude and the phase distribution of the field in the image plane, the field emerging from the hologram illuminated by a plane wave is back propagated with the Fresnel-Kirchhoff integral. The integral was evaluated by the product of the spatial frequency representation of the hologram obtained through a two dimensional fast Fourier transformation and the quadratic phase free space Fresnel propagator in the spatial frequency domain.

Holograms recorded in such a fashion can not be reconstructed in the conventional way with an optical reconstruction beam. In order to numerically reconstruct the holograms, the surface modulation was digitized with a Novascan atomic force microscope operated in tapping mode.

Holograms recorded in such a fashion can not be reconstructed in the conventional way with an optical reconstruction beam. In order to numerically reconstruct the holograms.

4. Experimental results

This section provides the experimental settings of the proposed algorithms for scheduling the cloud task transfer. Based on the experiments, the system results are discussed using various datasets of transfer tasks. Besides, this section present the products' conclusion compared with other studies related to cloud task transfer scheduling. As explained in Sect. 3, this paper applies the multi-verse objective (MVO) and genetic algorithm (GA), called MVO-GA, to optimize the cloud tasks. The proposed MVO-GA algorithm's main aim is to schedule the cloud transfer tasks in terms of transfer time. Thus, the cloud tasks need to be designed on the available virtual machines to reduce the currently active tasks' transfer time. The MVO-GA is proposed to distribute the transfer tasks based on the workload of the available virtual machines. Thus, the transfer tasks dataset is allocated based on the transfer properties of virtual machines such as machine storage, throughput, CPU, and transfer speed. After rescheduling the transfer tasks according to machine workload, the GA is applied to enhance task scheduling based on crossover and mutation processes. The output of the MVO-GA is considered as the initial population of the GA. Hence, the crossover and mutation processes work to optimize the task scheduling by looking for better possibilities to transfer some tasks through other virtual machines. In summary, MVO works to assure the virtual machines' workload, and the GA works to enhance the workload of these machines

4.1. Simulation environment

The experiments are conducted through a simulation of a hybrid cloud environment and heterogeneous task transfer. The proposed method is evaluated using two experiments attributes to understand the accuracy of the proposed methods in this paper. Table 2 summarizes the simulation attributes in this paper. For efective simulation, a MATLAB toolbox called a distributed system would be utilized. This toolbox is useful to simulate a distributed network such as a hybrid cloud environment. Fig. 3 Flowchart of the proposed hybrid MVO and GA method 1 3 Amended hybrid multi-verse optimizer with genetic algorithm... All experiments will be executed for ten diferent runs, and each run includes 500 iterations.

4.2. Experimental settings

This paper uses three modes of cloud task transfer scheduling; schedule 600 tasks, 1000 tasks, and 2000 tasks. The variety of dataset sizes could support the complex testing of the task transfer scheduling. The scheduling challenge is increased as the dataset size is increased. The datasets are imported for the simulation environment using MATLAB 2017a software. Each task in the dataset is represented by four main parts: the task ID, the task size, the expected time to transfer the task (ECT), and the priority of the task transfer. This paper uses the task ID as a unique transfer identifer. On the other hand, the task size is used for the computational transfer time. Furthermore, the expected ECT is used to compare the real and expected transfer time in the context of MVO and GA processes. The transfer priority is not used in the scheduling process due to focusing on transfer time rather than transfer priority. In a cloud transfer environment, the dataset placement would be managed using two main strategies: (1) transmit the dataset directly using the virtual machines, (2) transmit the dataset across data centers. The transfer across the data center is essential in a large number of datasets due to its efectiveness in managing the scheduling queue in a short time. Thus, this paper uses two data centers to schedule the dataset queue for MVO processes. The experimental settings are adopted from related works to the scheduling of cloud transfer tasks. The experiments are conducted based on two virtual machines under the specifcations mentioned in Table 4. The CloudSim version 3.0.3 is utilized in the experiments to conduct task transfer scheduling on MATLAB 2017a Table 2 Simulation attributes Entity Parameter Values of settings Cloudlets Number of cloudlets 100–2000 Length 1000–2000 Virtual machine RAM 512 MB MIPS 100–1000 Size 10,000 Bandwidth 1 Gb/s Policy type Time shared Operating system Windows No of CPU 1 Hosts No of hosts 2 RAM 2048 MB Storage 100 GB Bandwidth 1 Gb/s Policy Type Time share Data center No of data center 2

software in a distributed environment. The CloudSim is implemented to handle the prototyping of MVO and GA. The settings of CloudSim apply to two virtual machines of 512 RAM and 100–1000 MIPS. On the other hand, the number of cloudlets is 100–2000 of length 1000–2000. The settings include two data centers, and each data center holding two hosts. The hosting capacity is there 1 TB, and the RAM capacity is 2048 MB. The simulation is conducted on Windows 2010 platform using a time-shared policy to simulate the reality of transfer time. The used machine has one CPU of dual-core properties for the hosted virtual machines

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