2020 International Conference on Intelligent Engineering and Management (ICIEM)

Swarm Intelligence and its applications towards Various Computing: A Systematic Review

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Abstract— **Swarm intelligence is the discipline deals with artificial and natural systems that consists various individuals coordinated using self-organization and decentralized control. It consists of simple autonomous agents that come as emergent collective intelligence. The commands from global plan or leader are not followed by autonomous agent. This type of systems has been seen in various domains that makes swarm intelligence as a multidisciplinary character. Due to its popularity, various researchers have started working on it even in computing tasks but still they are unable to give a good survey on various swarm intelligence algorithms and use of it in computing work. Most of the people are unaware about the newly most effective invented swarm intelligence algorithms. In this paper we have given a comprehensive review on various swarm intelligence algorithms that prove to be efficient in multiple fields. The main focus is given to Bat algorithm, Firefly algorithm, Lion optimization algorithm, Chicken swarm optimization algorithm, Social Spider Algorithm and Spider Moneky optimization algorithm. Another thing covered in this paper is the comparative research on use of Swarm intelligence algorithm in Computing work. Cloud computing is the application that delivered as services through Internet and data centers software and hardware. We have covered the research work done by various researchers in cloud computing, Fog computing and Edge computing using swarm intelligence. The motive of this is to show the improvement in work comes after the introduction of Swarm intelligence in computing work.**

Keywords— ***Swarm Intelligence, Fat Algorithm, Spider Monkey optimization, Firefly Algorithm, Social Spider Algorithm, Computing***

I. INTRODUCTION

Swarm is a homogeneous simple agent in large number that interacts with themselves locally. It doesn't have any central control that allows to emerge a global interesting behavior. Nowadays a swarm based algorithms are emerged as a family of algorithms based on pollution and inspired by nature that re able to produce low, fast and cost effective solutions for some of the complex problems [1, 2]. SI is a new area of AI that model the collective behavior of social swarms in nature. Such as Bird flocks, ant colonies and honey bees. Although swarm or insects individuals like agents are relatively unsophisticated. They are limited with their own capabilities and interact together with certain behavioral pattern that helps in achieving the tasks that are necessary for their survival. Among swarm individuals, there can be either direct or indirect social interactions [3].

In this, one of the example is honey bees waggle dance like direct interaction done through audio or visual contact [4]. When there is change in environment then indirect interaction occurs and new environment is responded by other individuals like pheromone trails of ants that search for food sources deposited on their way. Stigmergy is the interaction of indirect type that means the communication through the environment [4].

As mentioned above the swarm intelligence is the discipline deals with artificial and natural systems that consist various individuals coordinated using self-organization and decentralized control [5]. It consists of simple autonomous agents that come as emergent collective intelligence. That's why the autonomous intelligent has become a system interacting with its environment that also consist of various other agents but they act independently from all other agents. The commands from global plan or leader are not followed by autonomous agent. This type of systems has been seen in various domains that makes swarm intelligence as a multidisciplinary character.

Cloud computing is the application that delivered as services through Internet and data centers software and hardware. There are some limitations of cloud computing that are compensated by the introduction of Fog and Edge computing. The improvement in computing is also done by the use of various swarm intelligence algorithms. That proves to be efficient in terms of performing various tasks of computing.

A. Novelty in the Paper

In most of the fields a better results has been achieved using swarm intelligence. Due to its popularity, various researchers have started working on it even in computing tasks but still they are unable to give a good survey on various swarm intelligence algorithms and use of it in computing work. Most of the people are unaware about the newly most effective invented swarm intelligence algorithms.

In this paper, we have focused on various existing swarm intelligence algorithms that aware people about those algorithms that can be prove to be good or efficient when they use it in their work. Other main motive of this paper is to give the survey or review on existing work done in computing: Cloud computing, Fog computing and Edge computing or these together using various swarm intelligence algorithms. Along with it the main motive is to show the improvement that comes after introducing the Swarm intelligence in their work.

II. MODEL OF VARIOUS SWARM INTELLIGENCE

Swarm intelligence (SI) comes an adaptive strategy that takes the collective intelligence as a behaviour that don't have any centralized control stricture on behaviour of

978-1-7281-4097-1/20/$31.00 ©2020 IEEE

individuals. SI rules are not very complex, it is simple, self-organizing that's why it is widely used in searching methods, computing improvement, optimizing, Cognitive network, Natural Language Processing, etc [6]. There are various paradigm of SI such as cuckoo search, fish schooling, bird flocking and animal herding, etc. In this section we have covered some of the new SI algorithms such as Bat algorithm, Firefly algorithm, Lion optimization algorithm, Chicken swarm optimization algorithm, Social spider algorithm and Spider monkey optimization algorithm, There are some other SI based algorithms but we have covered only these because researchers are not aware about it.

A. *Bat Algorithm (BA):* Bat Algorithm: The BA is based on echolocation of microbats that is used by bats for finding the food and it was proposed by Xin-She Yang [7]. It use frequency tuning that is one of the first algorithm in optimization and computational intelligence. It is effective to use BA in nonlinear and multi-objective problems. And they found their obstacles, prey using their special high level capability of bio-sonar that is also known as echolocation. Its efficiecny depends on Automatic zooming that is the capability performed on automatic switch to insensitive exploitation from explorative direction and other is Frequency tuning that is frequency variation done on the echolocation.

In this every bat is encoded with some velocity and location at iteration t that is denoted as vti and xti respectively. It is done in a d-dimensional search or solution space [8]. To particular problem a location can be consider as solution vector. During iterative search process a current best solution x can be found among n bats in the population. In standard bat algorithm, the mathematical equtions for updating the new location xi (t) and velocity vi(t) are:

$$xi(t+1) = xi(t) + vi(t+1) \quad \ldots\ldots(1)$$

$$vi(t+1) = vi(t) + (xi(t) - pi(t)) - fi \quad \ldots\ldots(2)$$

$$fi = f_{min} + (f_{max} - f_{min}) - b \quad \ldots\ldots(3)$$

In the above equation b is the random vector with uniform distribution under [0, 1], p(t) is the current global solution and the value of f_{max} and f_{min} are 1 and 0 respectively.

Application of BA: It is used in scheduling, classification, fuzzy logic, Inverse problem, combinational optimization, parameter estimation, continuous optimization, image processing, data mining and many more [8].

B. *Firefly Algorithm (FA):* The

Fireflies are insects that produces a light and blink at night. Yang have formulated the firefly metaheuristic algorithm inspired by firefly flashing behaviour. The bioluminescent phenomenon of communication is formulated with some assumptions such as:

- Fireflies are unisex that's why they attract to each other regardless of their sex
- The brightness and attractiveness between various fireflies are directly proportional to each other [9]. In this, the less bright fireflies are attracted by brighter one that is inversely proportional to the distance between multiple fireflies.

There is random movement between the fireflies in case of same brightness of both fireflies.

The adjacent fireflies light intensity is directly proportional to the attractiveness of firefly. The variation of attractiveness is denoted by β and distance between flies is r.
The firefly attract each other

$$\beta = \beta_0 e^{-\gamma r^2} \quad \ldots\ldots(4)$$

In above equation β_0 is the attractiveness when distance r=0.

The movement between two fireflies I and j, where I is attracted towards the j more attracted firefly is determined by equation given below:

$$x_i^{t+1} = x_i^t + \beta_0 e^{-\gamma r^2}(x_j^t - x_i^t) + \alpha_t \epsilon_i^t \ldots\ldots\ldots\ldots(5)$$

In above equation $\beta_0 e^{-\gamma r^2}(x_j^t - x_i^t)$ is due to attractiveness of the firefly x_j and $\alpha\epsilon_i$ a randomization parameter. It becomes a simple random movement in case of zero β_0.

In FA the new firefly position attractiveness is compared with old one and if higher attractiveness value is produced by new position then firefly will move towards it otherwise it will remain in the current position [10].

Application of FA: It is used in digital image compression, feature selection, engineering design problems, highly nonliniear, multimodal design problens, antenna design optimization and scheduling problems.

C. *Lion Optimization Algorithm (LOA):* It is lion's social system inspired pupulation based algorithm along with its collaboration characteristics that are describe as pride [11]. In the world, Lion is considered as a strongest mammal because of its unique social behaviour and its algorithm was modelled on the basis of lion two unique behaviours that are:

- Territorial defence
- Territorial takeover

On the basis of these two unique behaviours of lion a three steps generates a solutions of LO [12]. These three steps are:

- Each cub solution differentiation is either original or a derived solution.
- The existing and new solutions are compared and evaluated by territorial defence.
- Further the territorial will take over and keep the existing solution for further improvement. In this case the existing solution is better than the new solution.

In working of LOA various steps are:

- Initialization: In this randomly population is generation

$$Lion = [x_1, x_2, x_3, \ldots\ldots, x_n]$$

After than fitness or cost value of each lion is computed using cost function:

$$Fitness\ value = f(x_1, x_2, x_3, \ldots\ldots, x_n)$$

- Hunting: In order to provide food for female pride they search for a prey in a group. To catch and encircle the prey a specific strategies are used by hunters.
- Moving toward safe place: In this each pride territory consist of personal best positions of each member that assist LOA in saving the best solution obtained so far after some iteration that is used as a valuable information for improving the solutions in LOA.
- Roaming: In order to emulate the behavior of resident males and randomly select the percentage of pride territory and visited by that lion. In this the roaming is the string local search that assist LOA in searching around for a solution to improve it

Application of LOA: It is prove to be effective in solving the single or multi-variable and continuous optimization problems.

D. Chicken swarm optimization (CSO) Algorithm: Chicken are sociable birds who lives in a groups and CSO algorithm [13]. Every cheicken has its own motion laws and they are identified as hens, roosters and chicks according to the fitness values of the chickens. In group of chickens a viatl role is played by hierarchal order that is used to model CSO algorithm. This is a new inteligent bionic algorithm based on hens, cocks and chicks food searching behaviour. In this, a hen, chicken and cock particle swarm are sorted out according to its particle fitness values that comes after mapping the individual specific particle in searching space by chicken swarm. And a different searching mode is used by each subswarm.

It will work by selecting best fitness swarm particles as cock particle swarm that is given by equation:

$$x_{ij}^{t+1} = x_{ij}^{t}\ randn(0, \sigma^2), x_{ij}^{t} \quad \ldots\ldots\ldots\ldots(1)$$

Where x_{ij}^{t+1} and x_{ij}^{t} are the position of jth dimension of particle i in t+1 and t iterations respectively. Random number of Gaussian distribution is represented as $randn(0, \sigma^2)$ in which σ^2 is a variance. That can be calculated using equation given below:

$$\sigma^2 = \begin{Bmatrix} 1, & fit_i < fit_k \\ exp\left(\frac{(fit_k - fit_i)}{|fit_i| + \xi}\right), & fit_i \geq fit_k \end{Bmatrix}, \quad (2)$$

In above equation i, k represents the number of cock swarms. Fitness values of cock particle I and k is denoted by fit_i and fit_k. ξ represent a very small number.

Application of COA: It is used in flexible job shop scheduling, communication optimization, disaster and environment assessment, microgrid optimization operation, reservoir optimization scheduling, social network construction and detection, image recognition processing, etc [14].

E. Social Spider Algorithm (SSA): SSA are organism living in groups that have aggressive characters among their own species [15]. The SSA is made by their foraging behaviours and they cooperate to perform daily tasks. On the basis of female and male spiders, SSA is divided into two different evolutionary operators that divide their tasks for web design, prediction and mating. This optimization method was comes in existence in 2013 that has attracted the attention of themetaheuristic community.

The search space is assume as spider and communal spider web of each candidate solution in the population. According to solution fitness value, each spider receives a weight that it symbolizes [16]. In designing the SSA, main motive is solving a nonlinear global optimization problem with box constraint in the form:

Minimize: $f(x)\ \ x = (x^1, x^2, x^3, \ldots\ldots x^d) \epsilon\ \mathbb{R}^d,$

The above equation is subjected to $x\ \epsilon\ X$, a $\mathbb{R}^d$ approaches to R is a nonlinear function.

In SS algorithm each spider let j then according to solution fitness their weight is wei and its weight is calculated the equation:

$$we_j = \frac{fit_j - worst}{best - worst}$$

In above equation the fit_j is the position of jth spider and best is the best fitness value of whole population and worst is worst fitness value of whole population.

Application of SSA: It is used in multispectral image segmentation, clustering for high dimensional dataset, image processing, control, computer vision, filter designing, and renewable energy.

F. Spider Monkey (SM) optimization algorithm: It is a spider monekys intelligence inspired populaton based optimization algorithm that search the most suitable source of food [17]. The fitness of a solution is the excellency of food source and its major characteristics and strategies are similar to artificial bee colony algorithm. The SM algorithm search for large space with the exploration and exploitation function that help in generation of the greatest feasible solutions.

SM is a collaborative iterative process based on error and trail that contain 6 phases name as global, local, local and global leader, local and global decision leader learning phase [18].

First step in SMO implementation is initialization of the population:

$$SM_{ij} = SM_{minj} + U(0,1) \times (SM_{maxj} - SM_{minj})$$

- The current position of each SM is modified in local leader phase that is done on the basis of experience of local leader experience information and local group members experience.
- The local group members and global leader experience used by each SM experience to update their position in global leader phrase. There is almost same position update equation is used for both global and local leader phase.
- The local leader position is updated by applying greedy selection in local leader learning phase and the selection of local leader updated position is done on the basis of SM that have best fitness.
- After that the best fitness value is obtained by taking place of local leader learning, local leader decision and global leader decision phase [19].

Application of SM optimization algorithm: It is used in solving numerical optimization problems, Image segmentation, etc.

III. USE OF VARIOUS SWARM INTELLIGENCE IN COMPUTING

In this section we have given the review on computing field in which various types of Swarm Intelligence algorithms are used. In this we have covered the work done in Cloud computing, Fog computing and Edge computing using Ant colony optimization (ACO), Firefly algorithm (FA), Flower Pollination algorithm, Artificial Bee Colony (ABC), Bat optimization, Lion optimization, etc., Swarm intelligence are used.

Table. 1: Comparison of different application area of machine learning

Author	**Swarm Intelligence algorithm**	**Computing approach**	**Purpose to use it**	**Outcomes**
V. Vinothina, (2012), [20]	Improved Workflow Scheduling using ACO (IWSACO)	Cloud Computing	Scheduling Scientific Workflow task	As compared to results obtained by other existing algorithms a proposed approach is able to work well in terms of resource cost and scheduling time.
Ms. Nithya.G, et.al., (2014), [21]	Jumper Firefly algorithm	Cloud computing	Job Scheduling	As compared to standard firefly algorithm and other swarm intelligence algorithms an improved results are achieved using Jumper firefly.
Elaheh Hallaj, et.al, (2015), [22]	Artificial Bee Colony (ABC)	Cloud Computing	ABC algorithm reach to an optimal assignment of tasks to resources.	The use of ABC algorithm for scheduling in distributed computing area gives better results.
Xiao-Ke Li, et. al., (2015), [23]	Discrete Firefly algorithm	Cloud Computing	To work on resource wastage and energy consumption	The Open stack c10ud platform is used for experiment purpose that shows a less energy consumption and resource wastage is achieved using proposed algorithm.
R. SundarRajan, et.al., (2016), [24]	Firefly algorithm	Cloud computing	In reasoning processing an effective fill is controlled by it	It help in reducing the overall completion time or makespan by evenly distributing the load.
Jaspinder Kaur, et.al., (2017), [25]	Flower Pollination Algorithm	Cloud Computing	For task scheduling or evenly allocating the resources to task	As compared to Genetic algorithm, Round robin and First come first serve algorithms an improved results are achieved in terms of makespan.
Gaith Rjoub, et.al, (2017), [26]	Artificial Bee Colony, Artificial Bee Honey algorithm, Particle swarm optimization and multilabel classifier chain Machine learning Algorithm (MLSCCI)	Cloud Computing	Minimize the makesapn of the given task set.	The entire system load effectively balanced by MLSCCI that results in reduction of average makespan by 7 to 75%.
Bin Bin	GA,	Fog	Feature	Fog

Ma, et.al., (2018), [27]	Firefly, PSO, Elephant, CS4.5 decision tree, etc.	computing	Selection	computing using HT coupled with FSHarmony could have a good accuracy, low latency and reasonable data scalability.
Baichuan Liu, et.al., (2018), [28]	Markov Approximation based algorithm	UAV-Edge-Cloud computing	For UAV swams it is used to solve routing optimization problem.	The use of proposed algorithm able to achieve the high efficiency.
Chengfeng Jian, et.al., (2018), [29]	chaotic bat swarm algorithm	Edge computing	For improving the speed of update and dynamic parameter mechanism.	It improve the learning model that results in achieving the quick predicting scheduling results and also able to find the better solution with fewer iterations.
Nadeem Javaid, et.al, (2019), [30]	Cuckoo search with Levy Walk distribution (CLW) and Flower Pollination (FP)	Cloud and Fog computing	Enhancing the fog performance that reduces the issues related to latency and delay.	The results shows that the proposed FP and CLW algorithm have minimum response time and processing time as compared to other algorithms.
Mainak Adhikari, et.al, (2019), [31]	accelerated particle swarm optimization (APSO)	fog-cloud Computing	Consideration of trade-off between cost and latency to find a suitable computing device for each real time task	The experimental results indicate that the proposed strategy outperforms the existing schemes in terms of average delay by 18%, computation time by 21%, resource utilization by 27% and average cost 23%.
Vinita Yadav, et.al, (2019), [32]	Genetic Algorithm and Particle Swarm Optimization (GA-PSO) technique	Fog computing	For optimal allocation of services in less makespan and energy consumption in fog computing environment.	The proposed algorithm gives better results than individual GA and PSO in terms of energy consumption and makespan time.
Tanissia Djemai, et.al, (2019),	Discrete Particles Swarm Optimization algorithm (DPSO)	Cloud, Fog and IoT	Evaluation of total system energy consumption	The proposed algorithm prefers the middle layers devices then it chooses between cloud and IoT device according to the application.
Hina Rafique, et.al, (2019), [33]	Hybrid of modified particle swarm optimization (MPSO) and modified cat swarm optimization (MCSO). Or NBIHA	Fog Computing	The resources of fog device level are managed by resources.	The proposed approach gives better results in terms of average response time, execution time and energy consumption as compared to state of the art scheduling techniques.
Kaushik Sekaran, et. al., (2019) [34]	Dominant Firefly algorithm	Cloud computing	Improving the response time of cloud computing and M-Learning and solve load imbalance in cloud servers	The results demonstrated an improvement in energy consumption among Cloud servers.

IV. CONCLUSION

Swarm is a homogeneous simple agent in large number that interacts with themselves locally. It doesn't have any central control that allows to emerge a global interesting behavior. Nowadays a swarm based algorithms are emerged as a family of algorithms based on pollution and inspired by nature that re able to produce low, fast and cost effective solutions for some of the complex problems.SI is a new area of AI that model the collective behavior of social swarms in nature. Such as Bird flocks, ant colonies and honey bees. In this paper, we have focused on various existing swarm intelligence algorithms that aware people about those

algorithms that can be prove to be good or efficient when they use it in their work. We have covered some of the existing swarm intelligence algorithms such as Bat algorithm, Firefly algorithm, Lion optimization algorithm, Chicken swarm optimization algorithm, Social Spider Algorithm and Spider Moneky optimization algorithm. Other main motive of this paper is to give the survey or review on existing work done in computing: Cloud computing, Fog computing and Edge computing or these together using various swarm intelligence algorithms. Along with it the main motive is to show the improvement that comes after introducing the Swarm intelligence in their work.

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