ENHANCED CUCKOO SEARCH ALGORITHM ON INDUSTRY APPLICATIONS

Dissertation submitted in fulfilment of the requirements for the Degree of

MASTER OF TECHNOLOGY

in

COMPUTER SCIENCE AND ENGINEERING

By
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ABSTRACT

This work proposes about job scheduling in industrial applications by using a new enhanced Hybrid algorithm that consists of Cuckoo Search (CS) and Particle Swarm Optimization (PSO) algorithm. The strategy is composed of smallest position value (SPV) rule. The solution having smallest position value will get resources first. Proposed Hybrid algorithm provides yet another solution for above problem and minimises completion time. This work also proposes basic cuckoo search and its latest developments in industrial applications along with comparative study with Ant Colony Optimization, Krill Herd algorithm and other existing algorithms.

Key words: Particle swarm optimization (PSO), Cuckoo Search (CS), Ant Colony Optimization (ACO), Krill Herd (KH), Job scheduling, SPV rule

DECLARATION STATEMENT

I hereby declare that the research work reported in the dissertation entitled "ENHANCED CUCKOO SEARCH ALGORITHM ON INDUSTRY APPLICATIONS" in partial fulfilment of the requirement for the award of Degree for Master of Technology in Computer Science and Engineering at Lovely Professional University, Phagwara, Punjab is an authentic work carried out under supervision of my research supervisor Mr. Sudhanshu Prakash Tiwari. I have not submitted this work elsewhere for any degree or diploma.

I understand that the work presented herewith is in direct compliance with Lovely Professional University's Policy on plagiarism, intellectual property rights, and highest standards of moral and ethical conduct. Therefore, to the best of my knowledge, the content of this dissertation represents authentic and honest research effort conducted, in its entirety, by me. I am fully responsible for the contents of my dissertation work.

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SUPERVISOR'S CERTIFICATE

This is to certify that the work reported in the M.Tech Dissertation entitled **ENHANCED CUCKOO SEARCH ALGORITHM ON INDUSTRY APPLICATIONS**, submitted by **Deepak Kumar Deepu** at **Lovely Professional University, Phagwara, India** is a bonafide record of his original work carried out under my supervision. This work has not been submitted elsewhere for any other degree.

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Signature of Candidate

Deepak Kumar Deepu

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INTRODUCTION

1.1 INTRODUCTION

Basically, any Optimization techniques is used for achieving the best or optimal solution to any problem that is under some circumstances. The area of interest in the field of optimization has been grow up day by day since last fifty years and theories have been proposed to provide a best or optimum solution. In real world scenario, optimization problems are very much tough, complex and challenging to solve and find out the exact optimum solution. For that reasons, Optimization tools is going to be used for solving the complex problems. Also, we can say that Optimization tools may or may not sufficient to provide the best optimum solution because the complexity of the problem. It is depending upon the degree of complexity or difficulty of the problem. As a result, various optimization techniques came into practice. Additionally, many new algorithms are proposed to solve these kinds of challenging optimization problems [28, 29].

There are so many decisions taken according to the constraints in the process of optimization problem. In optimization problem, the goal of the constraints is either maximize or minimize. The solution can be referred to as a function of certain design variables. The word optimum denotes the 'maximum' or 'minimum' value based on the given circumstances.

In the different field like Engineering, Mathematics and science etc., the optimization problems are always encountered. And also there is no such method or single method is available to solve all type of optimization problems. That's why the various amount of researches and theories have to come into existence. And also still under review and under process continuous development to provide best solutions for the difficult and complex problems based on some circumstances [27].

Metaheuristic algorithm have now become the best source to provide best or optimum solutions for the optimization problem. And also proven to be best efficient when it is compared with another metaheuristic algorithms and also heuristic algorithm based on linear and non-linear programming [26]. There are two phases in this type of algorithms:-

- Firstly, it find out the best individuals solution and current best solution.
- Secondly, considering all the constraints, the search space is explored thoroughly.

This process give guarantee that algorithm is become faster and also capable for solving bigger optimization problem or search space.

In many of the research areas, the nature has been one of the inspirations for all researchers. Hence, the nature inspired algorithms came into action of existences. All the existence algorithms are categorized into four major parts based on the source of inspiration.

1. Swarm intelligence
2. Biological inspired
3. Physics or Chemistry based
4. Others

Above all categorized algorithm are based upon the perspective and focus of the research and search scenario. So, categorization are done based upon the actual motivations and actual inspirations behind it. Now a days, there are almost 40 algorithms are used in different area of research [23].

Recently, the meta-heuristic optimization techniques is become more popular because there are some advantages of the metaheuristic algorithm compared to the deterministic algorithm approaches. The main advantages are to higher local optima avoidance capabilities, making meta-heuristic well-suited for real world problems with a large amount of local solutions. The other advantages of meta-heuristic are simplicity, flexibility and derivation free structure.

The nature motivated computation methods are described by the study of real world situation. Applicant explanation about the optimization problem show as the act of some special kind of function for population and fitness function that provides the actual kind of quality solutions for any problem [1]. The mostly used nature motivated innovative algorithms are PSO, GA, ACO, CS algorithms etc.

This work concentrates on the brief knowledge about Cuckoo Search algorithm and preparation to make new algorithm using CS and PSO and called as **"Enhanced Cuckoo Search"** algorithm (ECS) which are capable to decrease the cost and take less time to produce the result. It is also nature-motivated algorithm which is used in the area of optimization and computing intelligence. In almost every functions about any operational application in the field of industry area or engineering field, we all, mostly try some special effort to optimize the thing even if to the actual cost and time utilization, also to expand the benefit, evaluate outcomes of the solution, analyze the performance of the task and capability [3, 11, 12].

Nature inspired Searching type of mechanism or methods which is used for achieving the goal for problem of interest. So only for that reason, this work is totally dependent upon the actual function of CS and PSO with taking the help of SPV rules upon Job scheduling scenario.

1.1.1 CUCKOO SEARCH (CS)

CS is a swarm-intelligence-based optimization algorithm which was developed by Yang and Deb in 2009. And inspiration taken from natural behaviour of cuckoos. Also author provide the definition of CS algorithm by set three rules that is main ideal behaviour of any cuckoos in terms of becoming the appropriate for implementation as a computer algorithm.

Cuckoo search [2, 8, 9, 10, 12] and PSO has been used in different field of computing and engineering intelligence in terms of challenging scenario. E.g., in the field of Engineering and industries applications, CS [13, 14, 15, 16, 17] and PSO have very much remarkable performance over many other algorithms. That's why we are working upon this type of algorithm.

In fact, analysts recommend that PSO cannot prove that the convergence of global_search problem and for that reason there is no any mechanism in-built in PSO to find out globally. But it is very much clear that CS fulfill the condition of the global_search convergence needs and for that reason there has been guaranteed for global_search convergence properties [18, 21]. Moreover, Cuckoo Search algorithm (CS) has abilities to find sources either locally or globally.

a) Every Cuckoo secures only single egg at the same time and also Cuckoo stores their Child eggs in random selected nests.

b) The eggs which have highest quality will be the best optimal solution.

c) There are limited amount of host nests then host birds can find out an alien egg with probability (0, 1).

According to above mentioned rules, the CS works as follows:

- Each and every available eggs in a nest is a solution. In general, every nests can have more than one eggs represent a group of solutions. The main objective of CS is to provide the new and best optimal solutions that will come over worst solution in the current nest population.

- The best quality of solutions is calculated with objective function of problem. Generally, the objective function is needed to be maximized. Also there are many real world problems where we all take care about minimum values of the particular objective function.

- Furthermore, last rule is talking about host birds, Means the host nest is fixed or limited. So host birds may find or discover their eggs with probability 0 and 1. It means, probability that determine when the worst case is replaced with new one.

As Figure 1 and 2 shown, there are different types of cuckoo's eggs are available in the host nests or other members of cuckoos in different environments

Figure 1: Eggs of Cuckoos 1

Figure 2: Eggs of Cuckoos 2

Adaptation and Evolution

There are some female cuckoos having certain capabilities to specialize in mimicry in colours of another birds and also pattern of the egg of a few chosen egg host birds' species.

Consequence of CS

Some host bird can direct engage conflicts with the intruding cuckoos. For example, if a host birds discovers the egg are not their own , it will either throw these alien eggs away or simply abandon its nest and build a new nest anywhere else.

Representation of CS

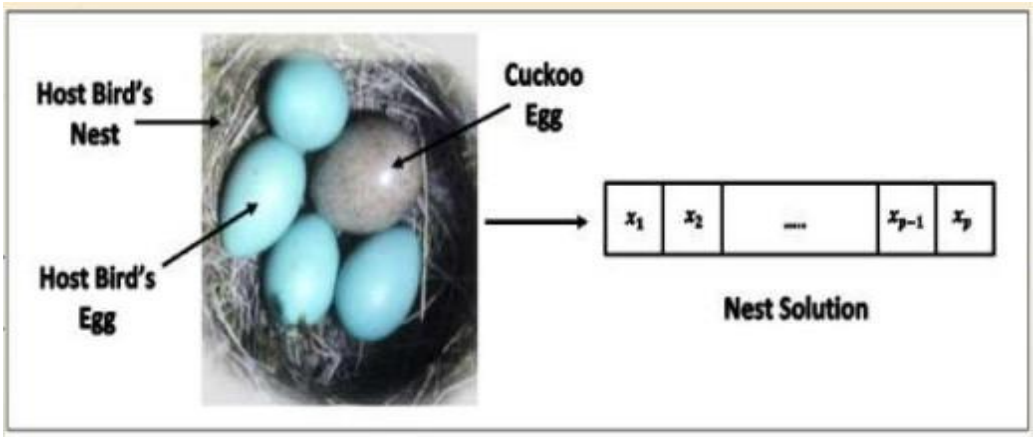

Figure 3: Representation of Cuckoo eggs [1]

- In a nest, each and every present or available egg provide the solution and cuckoo's egg provide a new solution.
- This technique is used to get better with worst solution that is presented in nests.
- In simple words, we can say that each and every nest has on egg. The algorithm become more complicated when each and every nest has more than one eggs represent the set of solutions.

Levy Flights

In a simple words, we can say that Levi flight [1] is a random selected path or walk that is used by cuckoos to find the resources.

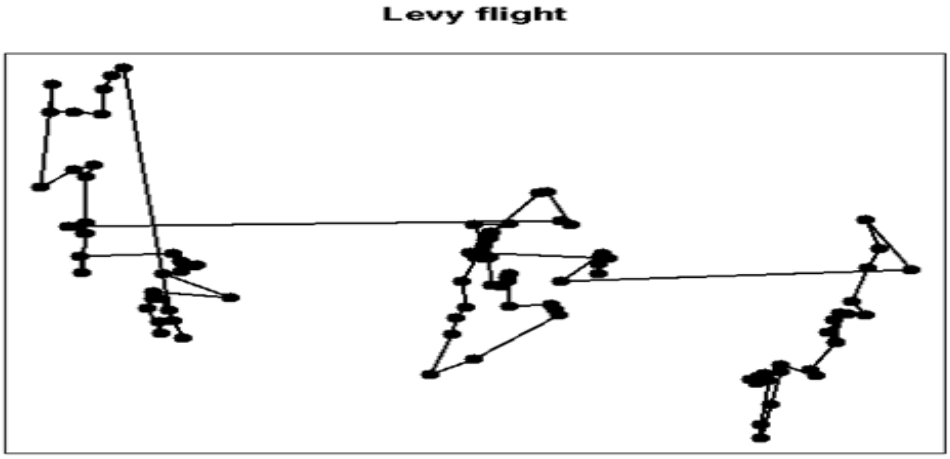

Figure 4: Representation of Levi flight

The Basic Pseudo code for CS given below:-

```
Start
        Objective function f(x), x = (x1,....., xd) T
        Generate initial population of n host
        Nests xi (i = 1, 2……n)
While (t < Max_Generation) or (stop criteria)
        Get a cuckoo randomly by Levy flights
        evaluate its quality/fitness Fi
        Choose a nest among n (say, j) randomly
If (Fj < Fi)),
        Change j by the new possible solution;;
End
        A fraction (pa) of worse nests
        are abandoned and new ones are built;
        Keep the best solutions
        (or nests with quality solutions);
find the current best by using Rank the solutions
End While
        Results Postprocess
Activity End
```

Basic work process is also shown in Figure 5.

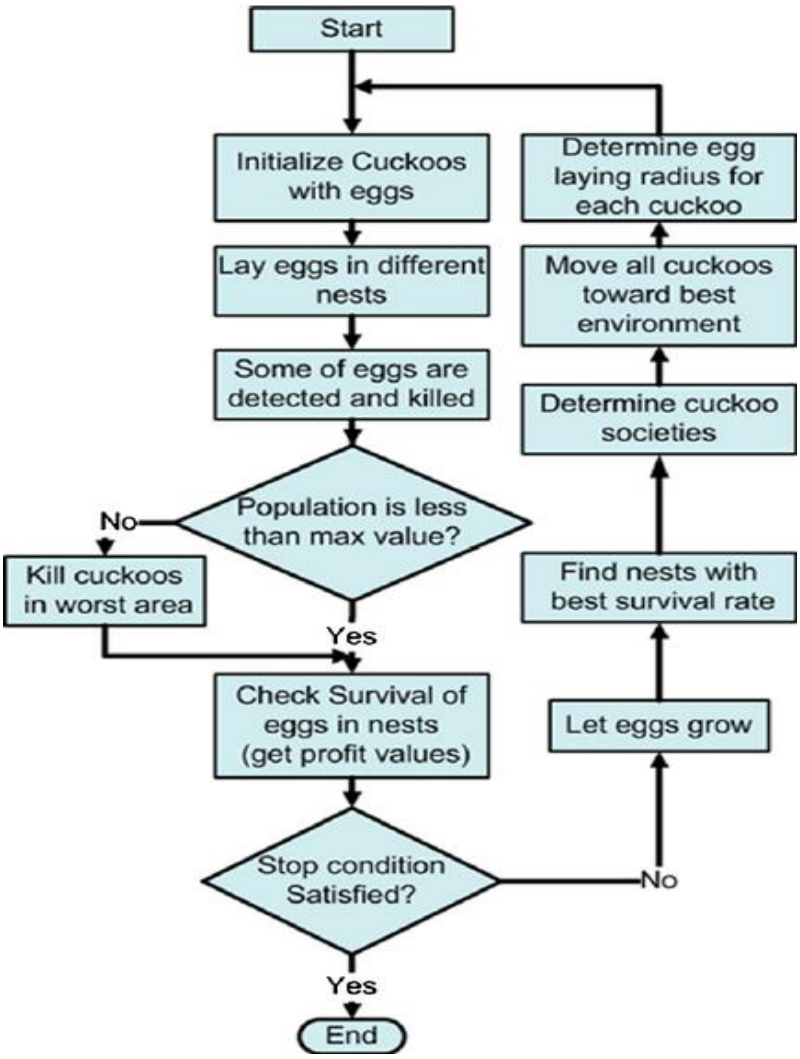

Figure 5: Flow Chart of Cuckoo Search

1.1.2 PARTICLE SWARM OPTIMIZATION (PSO)

PSO is a kind of heuristic local search optimization technique. It was introduced in 1995 by Eberhart and Kennedy. The idea was taken from intelligence mechanism of swarm and it was completely based upon innovative ideas of collective behavior of birds and fish [31].

According to the real world situation, when the birds are responsible for finding the food, they are either in different direction or at the same direction before they are identifying the place of food is present. Although the birds are finding the food from different places

like one place to another, one bird among the group can smell the place of food and having the better food resource information. This information is transmitting to all other birds and based on the quality of the information all other birds will update their direction and velocity towards the bird which is having better food resource information. Before Particle Swam Optimization (PSO) algorithm is concerned, all the possible solutions are considered as birds which searching for a food and good information is almost equal to the optimum solution.

PSO is heuristic optimization that is based upon local search optimization algorithm with the help of initialized population of random selection solutions called 'particle'. Each solution or each single solution in a search space like a bird is called 'particle'. Each and every particle having fitness value that are evaluated by the fitness function to be optimized. And also having velocities that are guide to the particles. Every particles fly or random walk through the problem space followed by particles with the optimal or best solutions. PSO is initialized with the help of random particles or solutions and after that searches for optimal solutions by update each and every generations [30].

Each and every particles knows about their own natural behaviours. Means everyone responsible to know about himself and it is called the best value (*pbest*) and best position of particular particle. Also everyone knows about the good optimal value in a group and t is called (*gbest*). This knowledge is very much helpful in the terms of the performance of the particles. Also each and every particles update their positions according to the need of the problem:

1) The actual distance between current to pbest position.
2) The actual distance between current to pbest position.

Actually, PSO formulae represent each and every particle as optimal solution of a problem in N-dimensional search space. Basically, the actual position of particle i is represented as Xi= ($X_{i1,}$ X_{i2}……X_{iN}). Each and every particle also take care of a memory of its previous best position represented as Pi= (P_{i1}, p_{i2}……P_{iN}). Moreover, the particle in a swarm is moving around. Thus the velocity of this is represented as Vi= (V_{i1}, V_{i2}……V_{iN}).

Hence, Velocity is updated by equation (1) for particles.

$Vid = w \times V_{id} + c1 \times rand() \times (P_{id} - X_{id}) + c2 \times rand() \times (P_{gd} - X_{id})$ ---------- (1)

Where i = Index of particles, i∈ {1…….N)

n = Size of population

d = Size of dimension, d∈ {1…….N)

rand () = Random selection variable between 0 and 1

V_{id} = Velocity

X_{id} = Current position

c1 =Cognitive component

c2 = Social component

P_{id} = *pbest* of particle *i*

P_{gd} = *gbest* of the group

w = inertia weight.

The weight of inertia *w* has some functionality to improve the working process. Basically, *w* is responsible for decrease linearly from about 0.9 to 0.4 within an iteration or run. Actual selection of the inertia weight provides a common balance between global and local search space of exploration and exploitation.

The constant c_1 and c_2 is used for learning rate for factors. Actually, they are represented as the weight of the stochastic acceleration terms which is responsible for each particle towards the pbest and gbest position. There are two value categorized in this terms- low value and high value.

Low value is responsible for allowing for travelling as long as possible from sources to destination regions before going to return to source. Where high value is responsible for unexpected movements towards the target regions. The cognitive parameters the behaviors of particular to the past behaviors of duplicate that proved successfully where as social parameters denotes the behaviors to others success. Normally, c1 and c2 are fixed with 2.0 that will make the all surrounding regions as a search space in terms of *pbest* and *gbest*. Also, if any possibility is to learning rate is equal then scenario of same equality.

Actual place is for search space is pointing to the solution space for the same problem updated by the equation 2.

$$X_{id} = X_{id} + V_{id} \quad (2)$$

Each and every particles of swarm is responsible for finding the better solutions for better positions. That's why the best positions or optimal solutions is recommended as effort by all population. PSO is very much simple, efficient, and easy to understand. The actual working process of PSO is below:

- Initialization the particle's populations with random positions
- For every particles, calculate fitness function
- Compare fitness evaluation with pbest and gbest of particles
- Identification of the swarm particles with optimal success and allotted.
- Then, updation of position and velocity of particles

For every particle 'i' at time't' has the below mentioned points to consider:-

- Vi, Xi, t are the velocity vectors and the position
- Pi, t is the memory where store the position
- Gi, t is the best global position

At each and every time t of the procedure, the velocity of the function is changed and update the particle in the new position from a previous position. New position is evaluated as the total sum of new updated velocity and previous position of the particle in equation 3.

$$\mathbf{Xi_{t+1} = Xi_t + Vi,t+1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)}$$

Updated velocity is consider in equation 2.

$$\mathbf{Vit_{+1} = \omega.Vit - c_1.r_2.(Pi,t - Xi,t) + c_2.r_3.(Gi,t - Xi,t) \ldots\ldots\ldots (4)}$$

In the third equation ω is weight of inertia that handles the effect of earlier to balancing of exploration and exploitation characteristic of this technique. Linear Decreasing Inertia Weight is considered and it is evaluated by the following equation 5.

$$W_k = W_{max} - (W_{max} - W_{min}) / (iter_{max}) * k \ldots\ldots\ldots\ldots (5).$$

The Linearly Decreasing strategy improves the work performance of PSO. The parameter c1 and c2 denoted as the weights of acceleration effect and if c1 is zero there no cognitive element and if c2 is zero there no social element in the algorithm.

As Figure 6 and 7 shown, how to swarm of particles involved in searching the food source from their destination in huge amount group.

Figure 6: Particle of Swarms type 1 [39]

Figure 7: Particle of Swarms type 2 [40]

The Basic Pseudo code in step by step of the PSO given below:-

Initialize swarm size and PSO parameters

Initialize velocities and position of particle

Initialize individual best solution

Consider Best swarm particle

Loop start

    Update the velocities

    Update the positions

    Determine the personal best position

    Determine Best particle of the swarm

    Local search (optional)

End loop

stop

There are basic work process of PSO is also shown in Figure 5. Where we explain about how PSO responsible for find out the target source from their current position in different environment.

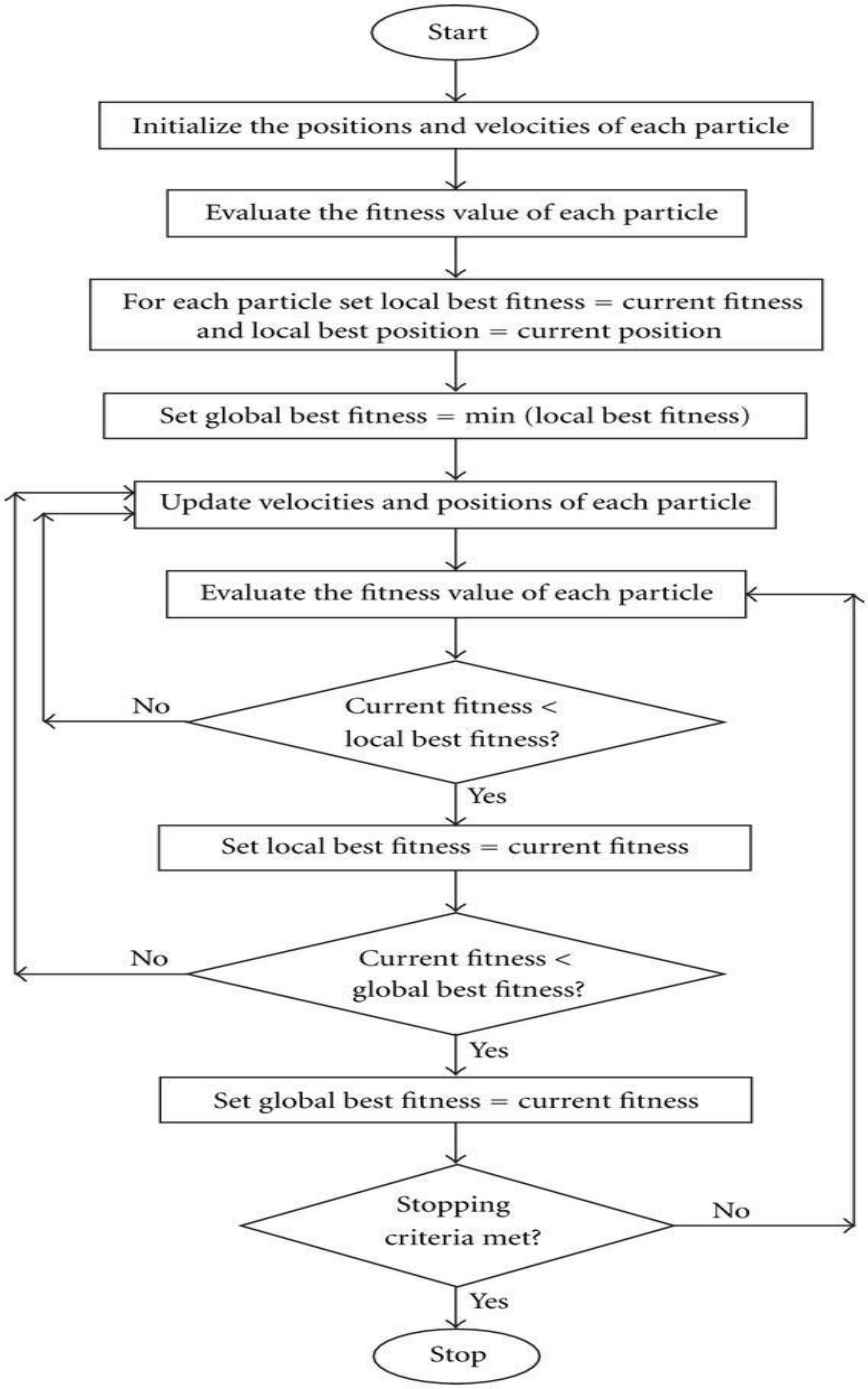

Figure 8: Flow Chart of PSO

1.1.3 ANT COLONY OPTIMIZATION (ACO)

Swarm intelligence is a commonly creative and innovative approach to solve the optimization problem. It takes inspirations from the natural social behaviours of animals, birds and other insects. In general, ants are inspired by a huge amount of techniques and methods which is best studied and very much successful in terms of general approach optimization techniques called as ACO. Ant Colony Optimization is taking working inspiration from the foraging natural behaviours of others ants. The main behaviours of any ants is to find out some shortest path with the help of some marking process and that should be helpful of their others member of ants [24].

ACO defines the some similar techniques to resolve the problems of optimization. From beginning of 1990's, whenever the first ACO was proposed, Ant Colony Optimization very much familiar with attention of growing up the number of researches and many more successful applications are now present today. Hence ACO gives us many more solutions for different-different optimization problem [25].

ACO mechanisms is one of modern mechanism to resolve optimization problem and also find out optimal solution or optimization. The movement of source of Ant Colony Optimization algorithm is real ant colonies [26]. As we all know that natural ants are capable to find the food by own and mark visual signs for their others member of ants. Because ants are blind and then intellect the path with the help of their antennas and pheromone trail leave back behind the ants [19].

- The working process of ants to find their food with the help of shortest path is very interesting.
- Each and every ants having their own capabilities to remember their path.
- These mechanisms evaporate with time

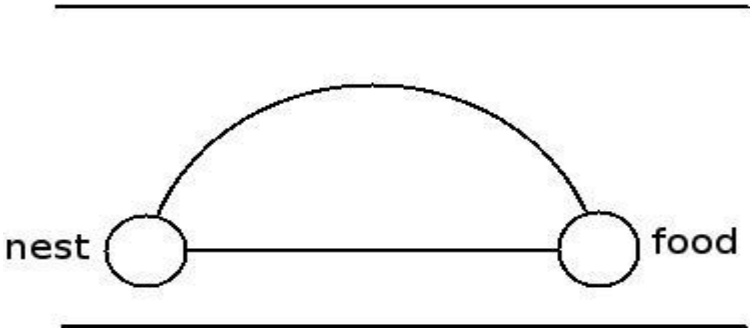

Figure 9: Basic Scenario of find food from source

- There is a techniques when an ant finds food then that ants marks its returning journey with the help of pheromones.
- The marks of the ants is helpful in case of find the shortest path.
- The shortest path is going to be considered as the way to find food for remain all other ants
- All ants will going through the shortest path that is found by their friends.
- Finally, Ants reach their food destination with the help of shortest path.

Natural behaviour of Ants

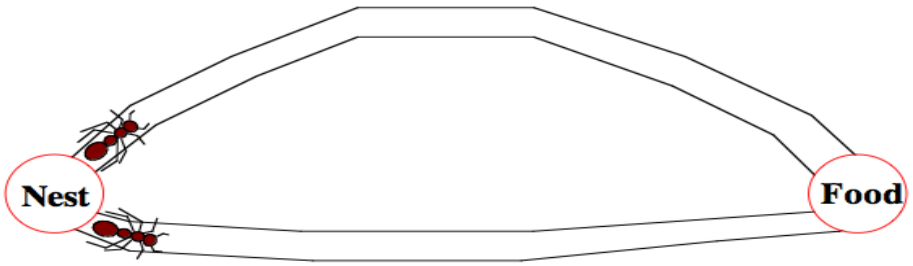

Figure 10: 2 ants start with equal probability of going on either path.

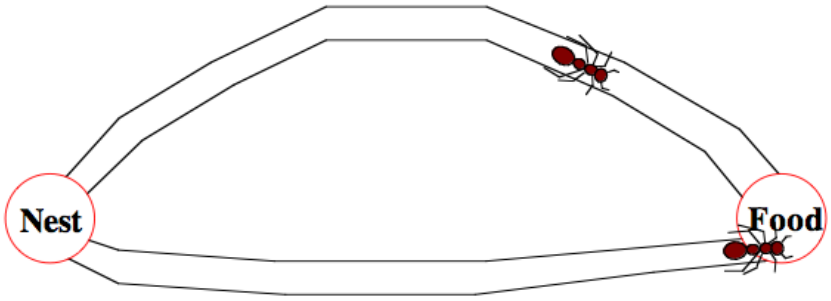

Figure 61: The ant on shorter path has reach first from its nest to the food.

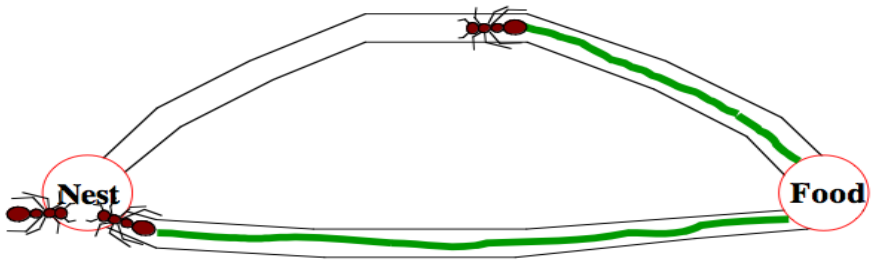

Figure 12: The density of pheromone on the shorter path is higher

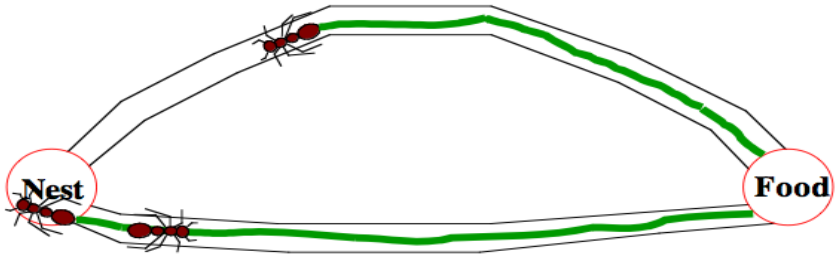

Figure 13: The next ant takes the shorter route.

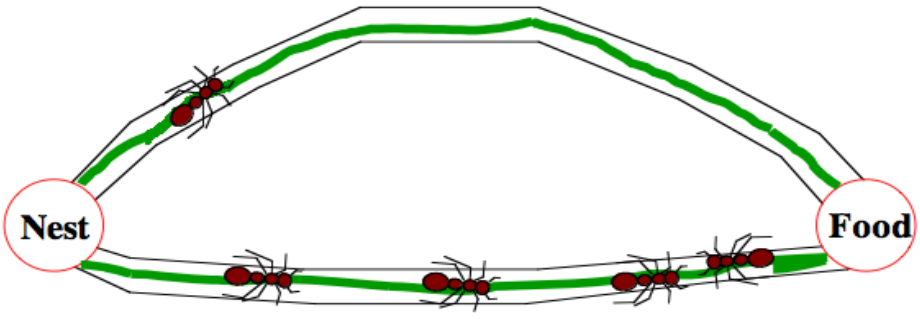

Figure 14: More ants begin using the path with higher pheromone

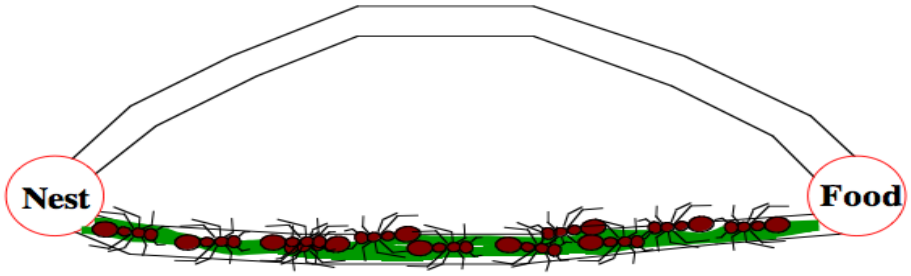

Figure 15: After some time, the shorter path is almost exclusively used

1.1.4 KRILL HERD OPTIMIZATION (KH)

The KH algorithm is a newest algorithm that was first introduced by Gandomi and Alavi in 2012. Main behavior of the Krill is to herd some food or to reach out to the destination is simplified and idealized. Actually, the KH optimization is inspired by Biological behaviours optimization algorithm. The motive of this algorithm is to solve complex problem of engineering field. This algorithm is inspired by herding behaviour of Krill swarms. This algorithm is evaluated with the help of different type of benchmark function for testing its efficiency [33, 34].

The Krill herd algorithm is a very newest optimization techniques and it is inspired by the natural behaviour of the swarms of krill. According to the working process of the krill for herding behaviour of krill swarm, the investigators or researchers who are responsible for investigating the movements of the krill swarms has two main goals:-

- To increase the Krill density
- To reach out to the destination or food source

Hence, these two behaviours is going to consider as a constrained optimization process [35]. The exact place or location of a Krill herd optimization is affected by following three factors:-

- The movements of Kill is going to be convinced by other herding behaviours of Krills
- Activity of hunting
- Irregular selection of decision.

Basically, Krill species is found in the southern ocean. According to the some gathered knowledge, the length of an adult body is approx. 6 cm and the weight is almost close to 2 grams. The main characteristic of Krill is that they herd large object even the individuals are not much as length as object.

ALGORITHM OF KRILL HERD

Initialize parameters (*Dmax*, *Nmax*, etc.)

for *i* = 1 to *M* **do**

Generate Solution (*xi* (*k*))

Evaluate and update best solutions

K (*xi* (0)) Evaluate quality (*xi* (0))

end for

x ← Save best individual *x*

//Main loop

repeat

sort population of krills

for *i* = 1 to *M* **do**

Perform motion calculation and genetic operators:

Ni Motion induced by other individuals

Fi Foraging activity

Di Random diffusion

Crossover

Mutation

update krill position *g*

Update Solution (*xm* (*k*))

evaluate and update best solutions *g*

$K(xi(k))$ Evaluate quality($xi(k)$)

end for

$x \leftarrow$Save best individual x

stop condition Check stop condition ()

until stop condition = **false**

return $K(x)$

1.1.5 JOB SCHEDULING

Job scheduling problem [4, 5, 6] is a combinatorial optimization problem. Job Scheduling can be used in scientific computing and high power computing for solving all the combinatorial optimizations problems. The major problem in job scheduling is that many scheduling do not fit into a common description model. Therefore, for scheduling problems it is difficult to define a common frame work [7].

In this work, we have proposed a Hybrid algorithm which combines the advantage of PSO and Cuckoo Search for solve the job scheduling problems. Our approach is based on metaheuristic principles which have the advantage of minimizing the setup time, completion time and process time [22].

Some assumptions for the Job Scheduling problem are:-

1) Jobs should be finite set.
2) Each and every job contains a series of operations that needs to be performed.
3) Machines should be finite set.
4) All the machines are capable of handling only one operation at a time.

Some of the constraints are:-

1) No job should visit the same machines twice.
2) No condition among operation of various jobs.
3) Preemption type of operation is not allowed.
4) A single machine is capable of handling individual job at a time.

5) No machines fail during its operation

Process time

Process time can be defined as the time taken to create the task of job and save the disk information. Thus job manager saves the task information in its database, for the other types of schedulers, saves the task information in files on the file system.

$$P_t = C_t + T_t \quad \text{……………………………………} (1)$$

Setup time

Setup time is the time taken to display the result to the client. In general for the job manager this includes the time taken to obtain the results from the database. For the other types of schedulers is the time taken to read from the file system.

$$S_t = P_t + F_t \quad \text{………………………………} (2)$$

Completion time

Total time is the time taken to perform the Process time and Setup time.

$$C_t = P_t + S_t \quad \text{……………………………………} (3)$$

1.1.6 SPV RULE

- The SPV rule is used to find permutation according to the continuous position. It contain n number of tasks and m number of resources [30].
- Each and every position vector have a continuous set of values.
- According to the SPV rule, the continuous position vector is transform with discrete value of permutation for task set [32].
- The resources of the task is to be allotted with the help of operation vector.

CHAPTER 2

REVIEW OF LITERATURE

X.S. Yang et al. [1] proposed a heuristic algorithm, Cuckoo Search (CS) for solving the problem of optimization. Actually this technique is totally dependent on the behavior of obligate brood parasitic of Cuckoos and that is the mixture of Levy flight management of some birds and fruit flies. They offer a new optimization techniques against evaluate its functions and then after compare its results with PSO and Genetic algorithm.

X. S. Yang et al. [2] proposed the basic concept of Cuckoo Search and the latest innovations of Cuckoo Search and their applications in the industries field. They figured out the study of CS algorithm and find out some proper strategy related to the Cuckoo Search. And also they suggested why Cuckoo Search is so efficient. They also considered the advantages of the CS algorithm and limitations of CS algorithm.

R.G. Babukartik et al. [3**]** proposed hybrid algorithm based on ACO and Cuckoo search. They have compared the Hybrid algorithm with CS and ACO. The results show that Hybrid algorithm produces more accurate and better results than CS and ACO.

P. Ravichandran, 2016 et al. [4] proposed parallel line Job Shop scheduling with the help of PSO, Cuckoo Search algorithm (CS) and Hybrid CS-PSO. A comparison is made between CS, PSO and Hybrid PSO-CS in solving the scheduling problems. The results show that hybrid PSO-CS algorithm provides a better solution than CS and PSO for parallel line job shop scheduling.

H. Wang, 2016 et.al [5] proposed a local search technique with the help of Cuckoo Search (CS) which is used for solving the problem of Flow Shop scheduling problem. In this paper, SPV rule is also applied to handle the discrete variable and also to transform regular basis problem into discrete Job permutation. The NEH heuristic is used to give high quality initial solutions, for population initialization. Local search strategy is considered by Cuckoo Search algorithm because of the improvement of exploitation ability.

Ali Al-maamari et al. [6] proposed a Dynamic Adaptive Particle Swarm optimization (DAPSO) to solve the problem of PSO weakness in inertia weight where great inertia weight facilitates a global find while a little inertia weight

facilitates a local search. Also, a new task scheduling algorithm has been produced to increase the Makespan and maximize the utilization ratio of application work-flows on the Cloud computing. With the help of new described algorithm, the local search problem is improved.

K. Thanushkodi et al. [7] introduced a new technique, improved Particle Swarm Optimization (IM-PSO) algorithm. This algorithm is used for the multiprocessor architecture in Job scheduling. It is used to reduce or minimize the setup time, waiting time and total time of the process. They described IM-PSO strategy in detailed manner and shown the results upon different number of processors.

Maryam Rabiee et al. [8] applied Cuckoo Optimization Algorithm (COA) to solve problem of job scheduling in grid computing design, implement and produce the result. The methodology of results shown that introduced algorithm provides very much efficient result compare then Genetic and PSO.

V. Selvi et al. [9] proposed hybrid of PSO and cuckoo search algorithm. The job scheduling (JS) mostly considered operational research in IT fields. A hybrid approach of Particle Swarm Optimization (PSO) and Cuckoo Search (CS) is obtained and experimental results demonstrate that the Improved Cuckoo Search method (ICS) is a better method compared with the other simplex evolutionary algorithm.

Satyendra Singh et al. [10] proposed Hybrid algorithm for job scheduling with the help of Genetic and Cuckoo search algorithm. Proposed algorithm combine the merits of Cuckoo search algorithm and Genetic algorithm. Using this algorithms, they minimize the makespan time.

Sumandeep Aujla et al. [11] proposed the Hybrid Cuckoo algorithm for the optimization solution for task scheduling. The propose algorithm is the combination of the Genetic algorithm (GS) and Cuckoo search algorithm (CS).

M. Prakash et al. [12] introduced a strategy to map the resources optimally using Cuckoo Search. Cuckoo Search algorithm techniques are the type of techniques for optimization which selects the best resources that are present in the datasets. Also this mechanism is responsible for allocating the best suited job by secured timeline that is needed for users and also take less execution time to produce the better results with the help of CS algorithm.

Manian Dhivya et al. [13] proposed Cuckoo Search algorithm (CS) which is used for finding the energy efficient cluster head selection and arrangement of clusters with the sensors nodes. Also they have described new optimization techniques

that are based on collection of datasets pattern which incorporates CS and Generalized Particle Model Algorithm (GPMA). Nodes are expanded un-sequentially and managed as linear cluster with the help of CS. The information is stored when the clusters heads are collected with the help of GPMA. The GPMA is also responsible for converting the energy network utilization problem into dynamic numerous particles in a force-field.

Koffka Khan et al. [14] proposed to collect the datasets for the Health and Safety (HS) risk of employees on their place of work then analysed the collected datasets and apply some techniques for methodology. The evaluation of a Health and Safety (HS) risk is to be done with the help of Cuckoo Search algorithm with neural-swarm techniques and call it Neural-Swarm Cuckoo Search algorithm (NSCS). Health and Safety are actually depend upon four level of risks: - Low risk, High risk, medium risk and Extreme High risks.

Moe Zaw et al. [15] proposed Cuckoo Search algorithm which is used to optimize in the area of web document for clustering and that is to discover the best centroids of cluster. Also CS is responsible to find the best global solution for the clustering algorithm.

Sean P. Walton et al. [16] described Modified Cuckoo Search (MCS). This algorithm is much faster than other normal Cuckoo Search algorithm. It means that the calculation of the number of objective function needs to achieve the target output. It has also a capacity to determine the function which has many dimensions, multi-model and non-smooth. This method is responsible for produce the very good results and also reduce the time complexity of CPU.

Ala'a Abu-Srhahn et al. [17] proposed an algorithm which used the merits of Cuckoo search algorithm and define the new algorithm technique and call it Cuckoo search optimizer (CSO). Also used the merit of GA in terms of avoid the local minima problem. This technique minimizes the problem of makespan and used the scheduling in computing. The final results has been compare with the merits of ACO for present the importance of introduce algorithm.

Christian Blum et al. [18] proposed a demonstration that can be deal with actual scenario of ant's behaviors. Also they provide some techniques to know about how to deal with general terms of discrete optimization. After the summarization they demonstrate to how ant colony optimization techniques is applied in terms of continuous optimization problems. And also they provide some good examples of recently research related to the ant colony optimization.

Saad Ghaleb Yaseen et al. [19] proposed a techniques to know about ACO as a distributed optimization algorithm which is used to find out the complex behaviours of groups and Travelling Salesman Problem (TSP). Also they give some solutions to find out best optimal solution in terms of good propagation.

Nima Jafari Navimipour et al. [20] proposed a new evolutionary optimization algorithm and give the name CSA which is used to schedule the task in cloud computing. They give the basic idea about cuckoo search which is basically inspired by obligate brood parasitic behavior of some cuckoo species in terms of levy flights techniques. The experimental results shows that the value of pa is low and the speed of algorithm is very high.

Iztok Fister Jr. et al. [21] proposed a timely review of all the development of the state of art in last five years. It help us to find out the basic advantages and disadvantages in terms of cuckoo search algorithm and give some solution for future scope in case of powerful research.

Hedieh Sajedi et al. [22] proposed a new algorithm with the combination of cuckoo search and genetic algorithm and name as Cuckoo-Genetic (CUGA) algorithm. The main purpose of this paper is to minimize the completion time of machines. And also it is very effective to avoid trapping in local minimum. The results clearly shows that proposed algorithm is very much efficient compare than GA, COA and PSO. And also provide high range of performance.

Ala'a Abu-Srhahn et al. [23] proposed a combinatorial algorithm which takes the advantages of cuckoo search optimizer and genetic algorithm for minimizing the local minima problem. It also help us to improve the results compare than previous one. Also it help us to minimize the makespan and result have been compared with ACO and GA to show the importance of the proposed algorithm.

Kirti Pandey et al. [24] proposed an algorithmic techniques to determine certain aspects like time number of iteration and nature of algorithm to solve the optimization problem. Routing is the major issues in today's scenario where time efficient is going faster onto it. Also they proposed new concept that is based upon GA and give the best optimal solution in terms of routing with efficient time without repeating the each and every nodes.

Kanika Malik et al. [25] proposed the different type of meta-heuristic algorithm for travelling salesman problem and evaluate their performance on the basis of their working process. Performance in the terms of their total time taken by the machines to evaluate the same problem.

Valentín Osuna-Enciso et al. [26] proposed the mixture of different type of Gaussian function to evaluate the 1-D histogram of a gray level images. And it is using with the help of three nature inspired algorithm that is PSO, ABC, DE (Differential evolution). And experimental results are shown the main advantages of the each algorithm in different multi-thresholding problem.

Deepthi S et al. [27] proposed the mechanism to compare four types of optimization algorithm that is ACO, Firefly, BA and CS algorithm and evaluates its performance results on the basis of its their own behaviors. Each and every algorithms having its own inspiration of behaviors to perform.

Ahmed Ahmed El-Sawy et al. [28] proposed a new novel hybrid algorithm and name of that hybrid algorithm is ACO-FA. This hybrid algorithm is combination of the merits of ACO and Firefly algorithm for solving unconstrained optimization problem. Hence finally, the proposed algorithm ACO-FA is evaluated on different types of benchmark problems and proven that hybrid algorithm is better than other meta-heuristic algorithms.

Iztok Fister et al. [29] proposed the techniques for hybridization and adaptation functionality with respect to different types of nature inspired optimization algorithm techniques. The main aim of hybridization and adaptation are to evaluate the machines performance on the basis of some same amount of work for each algorithm.

Vaibhav Bhardwaj et al. [30] proposed a new PSO algorithm and named enhanced PSO. They proposed strategy contain the basics process of SPV rule because the smallest position value taken first. Also the new proposed algorithm provides new and innovative optimal solution with respect to the graph planer coloring problem

Guiyan Ding et al. [31] proposed a new novel operator called “Disruption operator”. Disruption operator having ability between exploitation and exploration. That is used to evaluate nonlinear benchmark functions and also compare with improve PSO.

Sandeep Kumar et al. [32] proposed a new “PSO” to resolve the JS (Job Scheduling) problems. The algorithm that was proposed consists the basics concept of SPV rule that based upon label based and arithmetic crossover in terms of genetic algorithm. The new PSO is very much helpful in case of job scheduling problem and performance is improved more accurately efficiently.

Gai-Ge Wang et al. [33] proposed Discrete Krill Herd method that is to evaluate the optimal solution or optimal sequence of scheduling within the domain. Moreover, this strategy is also integrated with DKH because this strategy is very much capable to guide the Krill Swarm to move towards the better optimal solution in all the times.

Devi Madamanchi et al. [34] proposed the algorithm with help of five different type of benchmark functions. And experimental results proves that Krill Herd algorithm is very much accurate and efficient to produce the solution of optimization problem.

Gobind Preet Singh et al. [35] proposed the algorithm which is used to find out optimal solution for optimization problem with the help of fifteen unimodal and multimodal benchmark function. It all benchmark function are commonly used in the area of engineering optimization. And on the basis of these functions they evaluated the result and monitor the performances in terms of efficiency, convergences and completion time.

CHAPTER 3

PRESENT WORK

3.1 PROBLEM FORMULATION

Job Scheduling can be used in scientific computing and high power computing for solving all the combinatorial optimizations problems. The major problem in job scheduling is that many scheduling do not fit into a common description model. Therefore, for scheduling problems it is difficult to define a common frame work.

In this work, we have proposed a Hybrid algorithm which combines the advantage of PSO and Cuckoo Search to solve the job scheduling problems. Our approach is based on metaheuristic principles which have the advantage of minimizing the setup time, completion time and process time. Also there are lots of problem in terms of existing algorithm as well.

Brood parasite birds- The birds who does not make their own nests and laying their nests in some other bird's nests. For example- Cuckoo.

Combinatorial Problem- The problem where an optimal ordering and selection of options is desired.

Cost - Time and space taken by algorithm for execution.

Hybrid- Merging of two algorithms or combination of two algorithms.

Local Search- Local search is a metaheuristic method to solve NP complete problems. It moves from one solution to another in the search space till the time an optimum solution is not found or time is not over.

Metaheuristic algorithms - These algorithms are nature inspired algorithm. These kinds of algorithms are problem independent algorithms that can be applied a broad range of problems.

3.2 OBJECTIVE OF STUDY

The main objective of this paper is:-

- This paper proposes about job scheduling in industrial applications by using proposed Hybrid algorithm that consists of two algorithms which are Cuckoo search (CS) and PSO algorithm [11].
- The strategy composed of smallest position value (SPV) rule [30].
- The comparison of the work done between hybrid algorithm and CS, PSO, ACO and KH algorithm with the help of SPV rule for Job Scheduling [4].
- Proposed Hybrid algorithm provides yet another solution for above problem and minimises total completion time.
- This algorithm also proposes ECS and PSO with its latest developments in industrial applications along with comparative study with other existing algorithms like ACO and KH.

3.3 RESEARCH METHODOLOGY

The global update pheromone method is used by the CS, ACO and PSO to find the best path. The pheromone updating is partly postponed by the global pheromone update method of ACO. So in that case, the ant colony optimization algorithm does not able to provide an optimal solution. In the process of searching, the ant colony always moves towards the path of the highest pheromone density exists. And same in the case of CS and PSO. The main drawback of ACO and PSO is that it cannot make local search faster. So ACO and PSO is entangled in local optimum and better solution cannot be found. We are going to propose a fast and efficient algorithm which will remove the drawback of this algorithms like ACO, KH and CS. So to overcome the problem, we have designed a hybrid algorithm in which we have used Cuckoo search algorithm with PSO algorithm to make local search and global search faster for traversing the node [25, 26, 27].

3.3.1 Existing System

ACO, CS and PSO is a good metaheuristic algorithm to solve optimization problem. This existing algorithm uses the behaviour of real swarming system in real world. The main motive is to resolve the total completion time of the system. And also find out to search the shortest path between nests and food source. While walking, particles or ants leaves a chemical material on its path. Based upon the density of pheromone, ant moves. Higher the pheromone density, higher will be probability to choose the path by rest of the ants. So probability of high amount of pheromone on shorter path has higher probability. By this way ants always choose shortest path.

3.3.2 Problem Faced by existing algorithm

There are some problems faced by existing algorithm which are given as follows:

- In ACO ants always walks through that path where pheromone density is high, so till the time pheromone density will not be high ants will not walk through that path, this makes whole process slow.
- PSO is good for local search but not for global search
- CS traps in local minima also.
- It has search space large.
- It provides slow global best solution.

3.3.3 Proposed System

In our research we proposed a new fast solution for Job Scheduling Problem by using PSO with CS algorithm. To solve this problem first we have formulated it as an optimization problem. In this case first we have formulated the Job scheduling problem according to proposed hybrid PSO and CS algorithm. Our proposed algorithm combines the advantages of PSO and CS. The major drawback in the PSO is that while trying to solve the combinatorial optimization problems the search has to perform much faster, but only for local search not for globally. In order to overcome this drawback, Cuckoo search is used with PSO to create new hybrid algorithm and named as Enhanced Cuckoo Search (ECS).

Complete algorithm is shown as below:

Algorithm to solve JSP

1. Initialization.
2. Insert no. of nodes in the graph to traverse.
3. Traverse each node using hybrid algorithm (PSO and CS).
4. Traverse each node exactly once and return back to starting node.
5. If all nodes traversed then terminate else repeat step 2 to 5.

Ant Colony Optimization algorithm

1. Initialize (pheromone trails, ant solution construction).
2. Assign each ant to different nodes to traverse the path.
3. Perform local search using cuckoo search algorithm and then update the path.
4. For each ant calculate fitness function and update the value of pheromone.
5. If total iteration < maximum iteration then go to step 2 else terminate.

Cuckoo Search algorithm

1. Initialize nests and random initial solution
2. Get the current best nests.
3. While (F_{min} > max generation)

   Get the cuckoo by random walk, if not replace it by Mantegna search
4. Evaluate the quality fitness, randomly choose nests among n (call as j)
5. If ($F_i < F_j$) then replace j value by new solution.
6. Retain the best solution and nest.

End while else go to step 2

Particle Swarm Optimization

1. Initialize swarm size and PSO parameters
2. Initialize velocities and position of particle
3. Initialize individual best solution
4. Consider Best swarm particle
5. Loop start
6. Update the velocities
7. Update the positions
8. Determine the personal best position
9. Determine Best particle of the swarm
10. Local search (optional)
11. End loop
12. stop

Krill Herd algorithm

1. Initialize parameters (Dmax, Nmax, etc.)
2. Evaluate and update best solutions
3. Sort population of krills
4. Perform motion calculation and genetic operators:
5. Crossover
6. Mutation
7. Update krill position
8. Update Solution
9. Evaluate and update best solutions

10. Evaluate quality end for
11. Return K(x)

Hybrid Algorithm to solve JSP

1. Initialization.
2. Insert no. of nodes in the graph to traverse.
3. Traverse each node using hybrid algorithm (ACO and CS).
4. Assign each ant to different node
5. Perform local search using cuckoo search
6. Initialize nest
7. Get the current best nest
8. **While** (F_{min} > max generation)
9. Get the cuckoo by random walk
10. **End while**
11. Evaluate the quality fitness, randomly choose nests among n (call as j)
12. If ($F_i < F_j$) then replace j value by new solution.
    Else retain the best solution and nest.
13. Choose next city according to fitness value of cuckoo search
14. For each ant update the value of pheromone and calculate fitness function.
15. If total iteration < maximum iteration then go to step 2
    Else terminate
16. Traverse each node exactly once and return back to starting node.
17. If all nodes traversed then terminate
    Else repeat step 3 to 17.
18. Stop

3.3.4 Hybrid PSO-CS Algorithm:

Need for Hybrid Mechanism in PSO

- According to the above mentioned theories and introduction, PSO is faster to find out the quality solutions. Moreover, if we compare with other

optimization techniques then we observe some difficulties in terms of obtaining optimal quality solutions. Also we observe that it faces problem like premature convergences and also find some difficulty like poor fine-tuning capabilities of desired solutions

- The main disadvantages of PSO is prematurely converge. Main reason behind this is that, particles move towards or converge to a single point for global best search in terms of between current best position and global best position. There is no guaranteed for a local optimum solution.

- One more reason behind this is to fast rate of acquire the knowledge information flow between particles is a cause of loss in diversity that is responsible for the possibility of trapped in local minima.

- However, further disadvantages is that PSO approaches is problem-dependent performance. Problem-dependency is generally used for the different parameters in each and every algorithm. Different setting of different parameters are responsible for high quality of performance in terms of variances. The weight of inertia (w) is increased and it is totally depend upon the increasing speed of particles. And it help us to find destination in terms of global search (exploration) and local search (exploitation). Also, if we reduce the weight of inertia then it is going to be decrease the speed of all swarm's particles in terms of global search and local search.

- So in simple words, we can say that finding the best optimal solution is difficult. Hence it takes some difference from one problem to other problem. That's why we can say on above parts that PSO is problem-dependent on the basis of performance.

- The Hybrid mechanism is responsible for addressed the problem-dependency. It is going to the combine different type of approaches that is very much useful from different advantages of each approaches.

Hybrid Algorithm is formed by mixture of both Cuckoo Search and PSO techniques.

Enhanced Cuckoo Search (ECS) algorithm is very much efficient and motivated by the working criteria of Cuckoos. So this paper work is all about basic ideas and description of ECS and their applications. AS we all know, CS algorithm included in the different domain areas like Industries, Engineering field, Medical field, artificial intelligence and networking areas also. This paper will analyse that ECS algorithm performance in term of computational intelligence will produce much improved result than CS and PSO.

Intelligence based algorithms like CS and PSO are very much powerful to solve a large range of nonlinear or non-sequence optimization problem. That's why we have large number of applications in the field of industries and Engineering areas.

Following is the pseudo code for ECS technique.

Input: D= number of dimension, m= number of subcomponent and other parameter of CS and PSO.

Output: the best solution gbest

Begin

1. Initialization step

    1.1 **Initialize** two D-dimensional solutions sets pop1 and pop2 with search space [Xjmin,Xjmax]

    1.2 **Decompose** the D-dimensional solutions sets pop1 into m-dimensional subpop

Repeat

2. Dimensional cooperation with CS framework:

    2.1 **For each** j to m **do**

        Evolve the $subpop_i$ using CS algorithm

3. Exchange information in component cooperation:

4. Optimization by the PSO with inertia weight algorithm:

5. Exchange information in component cooperation:

    Until stopping condition is true

End

Basic steps of hybrid algorithm is shown in Figure 16. Here we explain about working process of hybrid algorithm

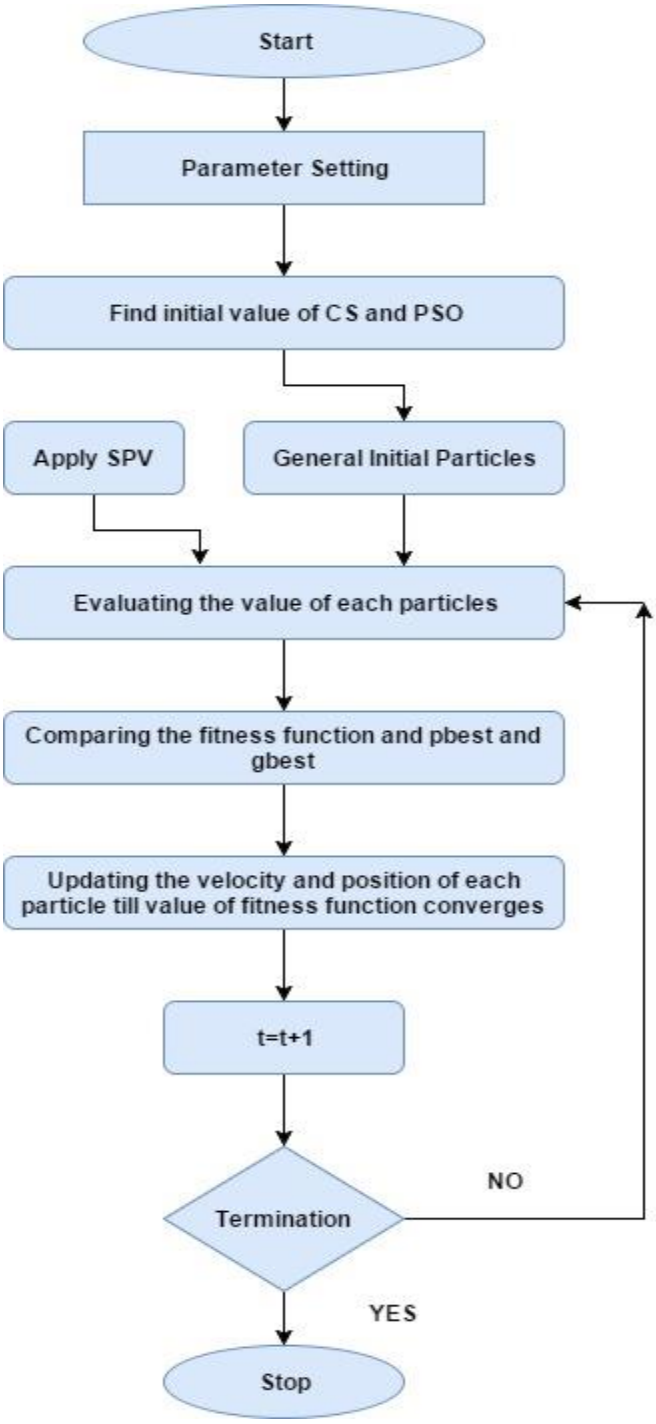

Figure 7: Flow Chart of Hybrid algorithm

CHAPTER 4

EXPERIMENTAL RESULTS

4.1 Experimental Setups

We have analysed the result obtained by our proposed hybrid algorithm and compared with existing algorithm. To test the efficiency of our algorithm results of our hybrid PSO and CS is compared with other existing algorithms like CS, PSO, ACO and KH results. In a JSP we already have the information about the number of cities. We have to find out fitness function which is total travelling distance and sequence of path which will provide us the optimal results. We have conducted the experiment by changing the number of cities and then compared our results with others algorithm.

According to this paper, the expected outcomes are achieved by the two different approaches CS and PSO algorithm. Result will be based on combination of CS and PSO and we call it enhanced Cuckoo Search (ECS). The experimental results will be evaluated with respect to the comparison between PSO, CS and Enhanced Cuckoo Search (ECS). And also will show that ECS algorithm will produce better results than CS and PSO algorithm.

There is some consideration about the outcomes of the work:-

- The strategy will composed of smallest position value (SPV) rule.
- The performance comparison of the Cuckoo Search algorithm and Hybrid-PSO with respect to Job Scheduling.
- Proposed Hybrid algorithm will provide yet another solution for above problem and will minimise completion, process and setup time.

All the algorithms stated above were simulated in MATLAB. The main objective of this work is to compute total completion time to complete the iterations is used to compare the results. The time is taken form the MATLAB profile which can give execution time of the code.

Performance of the hybrid algorithm is scrutinized by experimental results. All experiments are supervised with the Matlab R2014a and executed on Intel® Core(TM) i3-3217u @ 1.80GHz with 2-GB memory capacity. The vital criterion for hybrid algorithm is settled as follows. Let the maximum number of iterations be 200 and the supreme swarm size is 64. In this section we analyse the result for our proposed algorithms. To test the effectiveness of our algorithm results of existing approach is

compared with Hybrid algorithm. We have information about the number of resources and number of tasks or nodes that completes the appropriate activity. We just need to find the sequence which provides us the optimal results. In specific manner, we have taken four experiments to show the comparative analysis for different iterations.

4.2 Experimental Results

In the first experiment we have taken 5 cities. The distance between each pair of cities is given following by a symmetric matrix of 5*5:

1. First we create 5*5 matrix to find the results between hybrid and others existing algorithms for 50 iterations.

D= [0 18 3 12 10
18 0 10 5 17
3 10 0 9 10
12 5 9 0 12
10 17 10 12 0]

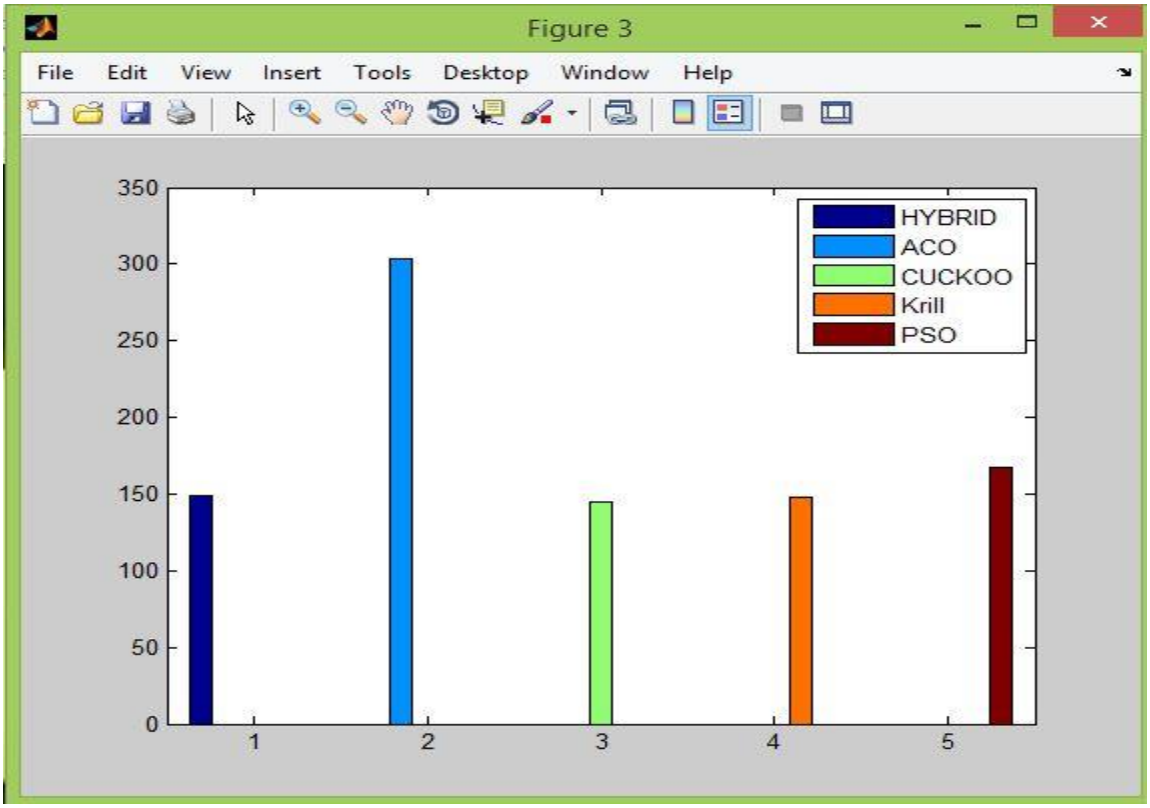

Figure 8: Bar chart of Comparison results of 50 iterations

In Figure 17, the comparison between hybrid and other existing algorithm have done with 5*5 matrices and 50 iterations. The hybrid algorithm is providing better results compare than others. And numerical value of results is shown in table 1.

HYBRID	ACO	CUCKOO	KRILL	PSO
148.1254	313.1456	151.2564	159.5689	173.2578

Table 1: Time taken by each algorithms with 50 iterations

2. Second, we create 10*10 matrix to find the results between hybrid and others existing algorithms for 100 iterations.

D=[0 18 3 12 10 7 10 8 9 10
18 0 10 5 17 12 7 12 13 19
3 10 0 9 10 9 14 16 12 6
12 5 9 0 12 10 13 9 5 11
10 17 10 12 0 15 7 13 10 4
7 12 9 10 15 0 7 14 10 7
10 7 14 13 7 7 0 8 9 9
8 12 16 9 13 14 8 0 9 6
9 13 12 5 10 10 9 9 0 9
10 19 6 11 4 7 9 6 9 0]

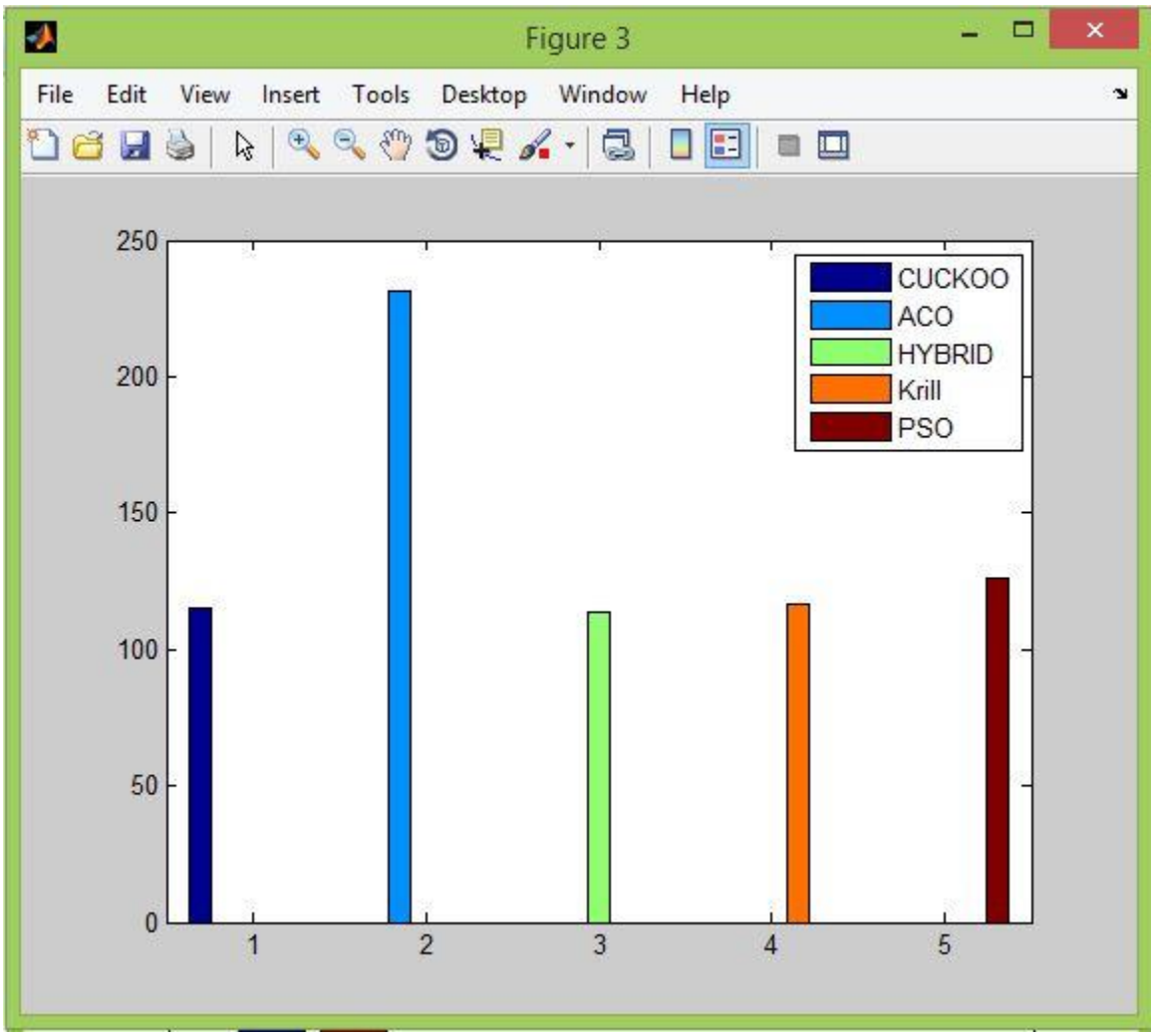

Figure 9: Bar charts of Comparison results of 100 Iterations

In Figure 18, the comparison between hybrid and other existing algorithm have done with 10*10 matrices and 100 iterations. The hybrid algorithm is providing better results compare than others. Numerical value of results is shown in table 2.

HYBRID	ACO	CUCKOO	KRILL	PSO
123.1487	239.1245	124.7414	127.8541	133.1487

Table 2: Time taken by each algorithms with 100 iterations

3. Then, we create 15*15 matrix to find the results between hybrid and others existing algorithms for 150 iterations.

```
D=[ 0 18  3 12 10  7 10  8  9 10 10 12 16 16 10
   18  0 10  5 17 12  7 12 13 19  9 18  5 11  7
    3 10  0  9 10  9 14 16 12  6 10 11 10  7  7
   12  5  9  0 12 10 13  9  5 11 11 12 10 12  5
   10 17 10 12  0 15  7 13 10  4  2  3  8 11 19
    7 12  9 10 15  0  7 14 10  7  8  6 12  6  3
   10  7 14 13  7  7  0  8  9  9 14 14  7 15 11
    8 12 16  9 13 14  8  0  9  6 10 10  6 12 13
    9 13 12  5 10 10  9  9  0  9 11 10  8 14  5
   10 19  6 11  4  7  9  6  9  0 11  8 14 12  8
   10  9 10 11  2  8 14 10 11 11  0 11  1  5  6
   12 18 11 12  3  6 14 10 10  8 11  0 15  6 11
   16  5 10 10  8 12  7  6  8 14  1 15  0  9 12
   16 11  7 12 11  6 15 12 14 12  5  6  9  0 3
   10  7  7  5 19  3 11 13  5  8  6 11 12  3  0];
```

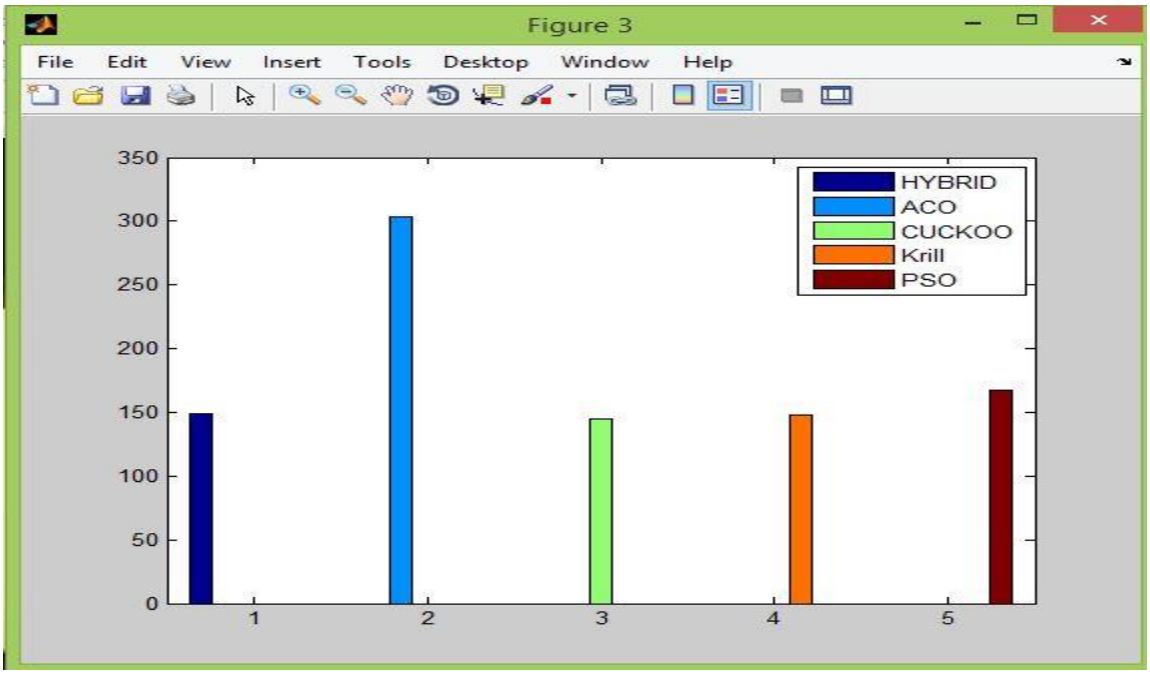

Figure 10: Bar charts Comparison results with 150 iterations

In Figure 19, the comparison between hybrid and other existing algorithm have done with 15*15 matrices and 150 iterations. The hybrid algorithm is providing better results compare than others. Numerical value of results is shown in table 3.

HYBRID	ACO	CUCKOO	KRILL	PSO
148.1254	313.1456	151.2564	159.5689	173.2578

Table 3: Time taken by each algorithms with 150 iterations

3. Then, we create 20*20 matrix to find the results between hybrid and others existing algorithms for 200 iterations.

D= [0 18 3 12 10 7 10 8 9 10 10 12 16 16 10 9 5 3 13 12
18 0 10 5 17 12 7 12 13 19 9 18 5 11 7 11 11 15 9 11
3 10 0 9 10 9 14 16 12 6 10 11 10 7 7 18 13 13 12 14
12 5 9 0 12 10 13 9 5 11 11 12 10 12 5 11 10 17 8 14
10 17 10 12 0 15 7 13 10 4 2 3 8 11 19 7 3 17 7 10
7 12 9 10 15 0 7 14 10 7 8 6 12 6 3 6 6 11 16 9
10 7 14 13 7 7 0 8 9 9 14 14 7 15 11 4 12 12 9 14
8 12 16 9 13 14 8 0 9 6 10 10 6 12 13 7 12 6 10 13
9 13 12 5 10 10 9 9 0 9 11 10 8 14 5 10 6 10 7 8
10 19 6 11 4 7 9 6 9 0 11 8 14 12 8 8 6 6 11 5
10 9 10 11 2 8 14 10 11 11 0 11 1 5 6 8 5 4 11 14
12 18 11 12 3 6 14 10 10 8 11 0 15 6 11 9 3 10 10 8
16 5 10 10 8 12 7 6 8 14 1 15 0 9 12 9 9 8 17 12
16 11 7 12 11 6 15 12 14 12 5 6 9 0 3 13 13 11 5 6
10 7 7 5 19 3 11 13 5 8 6 11 12 3 0 6 6 7 12 6
9 11 18 11 7 6 4 7 10 8 8 9 9 13 6 0 14 8 7 8
5 11 13 10 3 6 12 12 6 6 5 3 9 13 6 14 0 12 8 10
3 15 13 17 17 11 12 6 10 6 4 10 8 11 7 8 12 0 2 12
13 9 12 8 7 16 9 10 7 11 11 10 17 5 12 7 8 2 0 19
12 11 14 14 10 9 14 13 8 5 14 8 12 6 6 8 10 12 19 0]

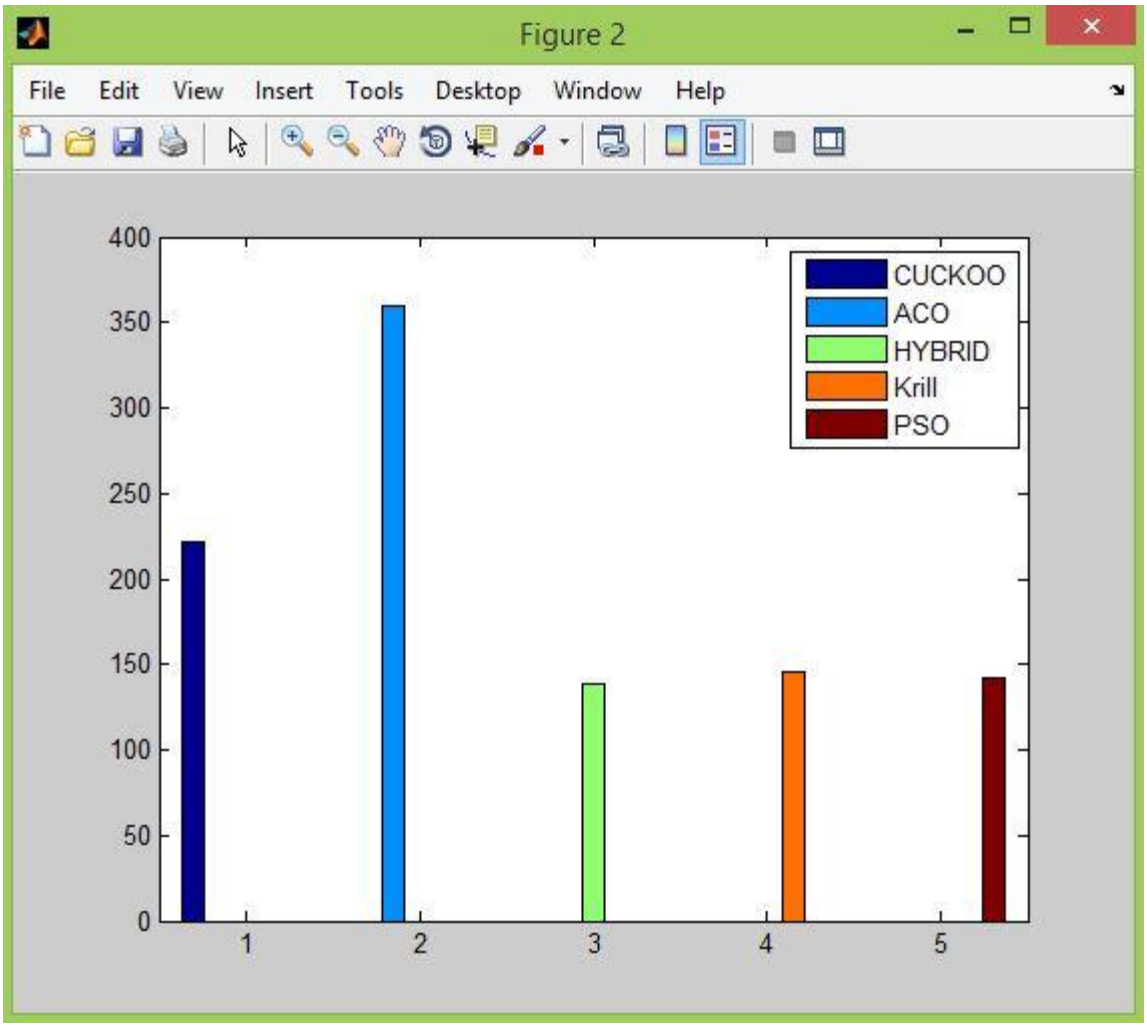

Figure 11: Bar charts Comparison results with 150 iterations

In Figure 20, the comparison between hybrid and other existing algorithm have done with 20*20 matrices and 200 iterations. The hybrid algorithm is providing better results compare than others. Numerical value of results is shown in table 4.

HYBRID	ACO	CUCKOO	KRILL	PSO
146.1254	373.1245	224.4987	152.1487	148.5846

Table 4: Time taken by each algorithms with 200 iterations

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

Enhanced Cuckoo Search (ECS) algorithm is very much efficient and motivated by the working criteria of Cuckoos. So this paper work is all about basic ideas and description of ECS and their applications. AS we all know, CS algorithm included in the different domain areas like Industries, Engineering field, Medical field, artificial intelligence and networking areas also. This paper analyses that ECS algorithm performance in term of computational intelligence produces much improved result than CS and PSO.

Intelligence based algorithms like CS and PSO are very much powerful to solve a large range of nonlinear or non-sequence optimization problem. That's why we have large number of applications in the field of industries and Engineering areas.

Some algorithm like PSO that is very much efficient for local search strategy but is not good for global search strategy. For resolving the problem of global search strategy we have to use algorithm like CS. Anyhow, there are still lots of challenges issues that is required to be reduce in future study.

5.2 FUTURE WORK

In future, this hybrid algorithm can be applied for variations of multi-objective job scheduling, process planning and load balancing problems to make a comparative study with existing algorithms.

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APPENDIX

ABBREVIATIONS:

- **CS** – Cuckoo Search
- **PSO** – Particle Swarm Optimization
- **ACO** – Ant Colony Optimization
- **KH** – Krill Herd
- **ECS** – Enhanced Cuckoo Search
- **JSP** – Job Scheduling problem
- **SPV** – Smallest Position Value
- **GA** – Genetic Algorithm

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