Particle Swarm Optimization: A Detailed Study in reference to Job Shop Scheduling and Flexible Job Shop Scheduling

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ABSTRACT-Particle Swarm Optimization (PSO) is a speculative technique for optimization. PSO originates from swarming or droving of birds and fish schooling and many more groups.
PSO became a choice for researchers since the past twenty years. PSO was first of all used by James Kennedy and Russell Eberhart. PSO has been used for an optimal solution in production industry for scheduling. These scheduling are Job Shop Scheduling (JSP) and Flexible Job Shop Scheduling (FJSP). The PSO variants mutation operator may apply to enhance optimized solution for FJSP. Mutation operator mutates global best particle (gbest) and local best particle (pbest) .It used to overcome local minima trap problem. As compared to other swarm optimization techniques, this technique is favored more as it works with fewer constraints, Before swarm intelligence optimization techniques, these problems were solved by mathematical methods. These traditional techniques are comparatively more complex. It delineates about various phases of PSO referred to in the past two decades and it explicates about the optimal solution for JSP, FJSP and Multi-objective FJSP (MFJSP).

KEYWORDS:-Particle Swarm Optimization, PSO variants, Flexible Job Shop Scheduling Problem, Optimization Algorithm.

I. INTRODUCTION

Particle Swarm Optimization-PSO is a [1] prosperous hypothetical technique for optimization. PSO is occupying on the basis of intelligence of swarms and action taken by swarms. There is a particle that creates a swarm, it moves in search space to search the most appropriate solution. In an N-dimensional space, each particle treated as a point.

Each [2] particle preserves its coordinates in the solution space. The best solution (fitness) is targeted by these coordinate values. The value of fitness is called personal best. Cited as *pbest*. Another global best value is the best value among all personal best values. This value is called *gbest*. In figure1 PSO initialize the particle variable like velocity and position vector. Evaluate fitness for personal best (pbest) and global best (gbest), and then update particle velocity and position.
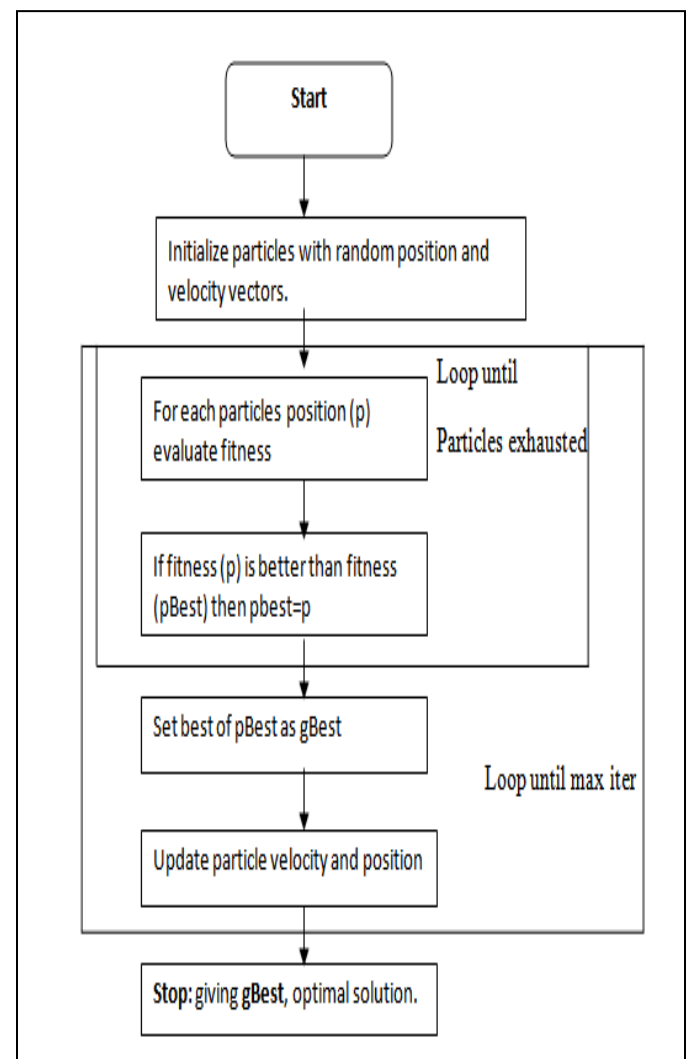

Fig.1 Concept of general PSO Algorithm

PSO counts on stimulating of each particle's pbest and the gbest locations. V_k is the initial particle's velocity and S_k is the starting searching space,[3] as per each iteration the value of velocity(V_k) and Searching space(S_k) has updated and value of pbest and gbest also updated accordingly as shown in Fig.2.
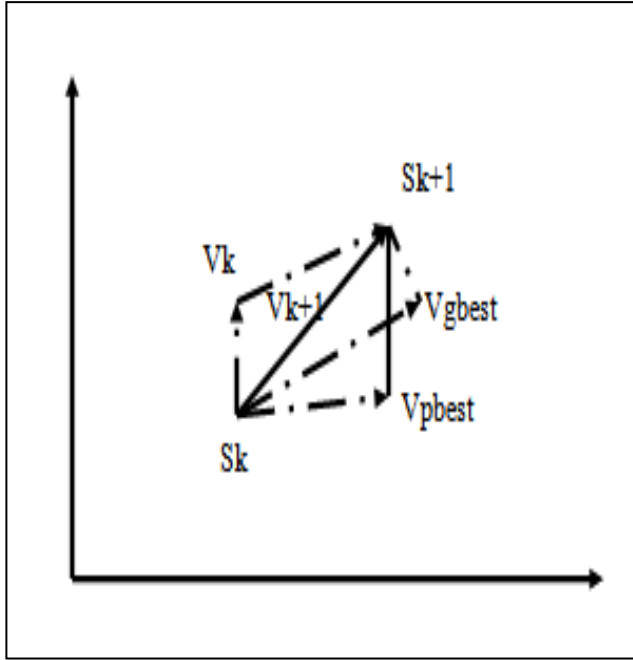

Fig.2. Searching point by PSO

v_{pbest} : velocity based on pbest.

v_{gbest} : velocity based on gbest

s^k :current searching point

v^k :current velocity

s^{k+1}: modified searching point.

v^{k+1} :modifiedvelocity.

II. VARIANTS OF PSO

In 1995, Kennedy proposed PSO [4]. PSO has diverse variants with various specifications follows as a coefficient factor, Inertia weight etc. PSO variants are given below. Table 1 shows various PSO variants with their methodology.

Table 1: Study of various variants of PSO

S.No.	Variants Of PSO	Methodology
1	Initialization[5]	Initialization of particle should be proper. If initialization is not proper, garbage search space may occur due to this optimal solution is not achieved.
2	Construction Factor[6]	Balancing of Exploration and Exploitation by updating velocity $vij(t+1) = \chi[vij(t+1) + \varphi1(vij(t) - xij(t)) + \varphi2(yij(t) - xij(t))])$ Where $\chi = 2 \div \|4 - \varphi - \sqrt{\varphi2 - 4\varphi}\|$ $\varphi = c1 + c2, \varphi1 = c1\gamma1, \varphi2 = c2\gamma2$
3	Inertia weight(w)[7]	w Controls exploitation and exploration, if w is greater exploration is upgraded. w is low exploitation is updated. $w = (wini - wend - d1)exp\left(\dfrac{1}{1 + \frac{d2t}{tmax}}\right)$
4	Mutation operator[8]	Mutate global best particle or local best particle to enhance optimized solution. It compares original particle fitness with gbest, then best fitness has been selected. Mutation of particle done by the following equation. $gbesti(i) = gbesti(i) + W(i) * N(Xmin, Xmax)$
5	Hybridization	Several optimization techniques can be combined with other optimization techniques. Example combines PSO with biogeography-based optimization
6	Alleviate Premature	Optimization of stagnation achieved by mitigating premature convergence.

S.No.	Variants Of PSO	Methodology
7	Simplifications	PSO should be simplified without affecting its performance
8	Multi-objective optimization	The Pareto dominance is used when PSO particles are moved.
9	Binary, Discrete, and Combinatorial PSO[9]	A particle's velocity will be continuous and position of it will remain discrete. Positions of particle updated by following rule xt+1ij= {10if r<sig (vt+1ij).
10	Bare-bones PSO[10]	Momentum and position of particles have updated using parametric probability density function. Updated rule for particle's position in jth component is xt+1ij=N(µtij,σtij), where N is a normal distribution with µtijσtij==btij+ltij2,|btij−ltij|.
11	Fully informed PSO	Particle uses its neighbor's information, and according to this information, updates velocity of particles. The velocity-update rule is v→t+1i=wv→ti+φ|Ni|∑pj∈ NiW(b→tj)U→tj(b→tj−x→ti),Where W:Θ→[0,1] is a function.

Utilization of PSO and Latest Aspects:-

The neural network was the first area for PSO. Other areas of PSO are telecommunications, data mining, arrangement, domination, combinative optimization, signal processing and much more. PSO algorithm provides the solution for single-objective optimization and multi-objective optimization with dynamic problems. Various researches are directed in the following fields:

- Analytical aspects
- Algorithms for Matching problems
- Developed a solution for single, more or the different class of problems.
- Cogent selection
- Analogy of PSO variants with other algorithms

III. JOB SHOP SCHEDULING PROBLEM

Job shop scheduling problem (JSSP) was proffered by Muth and Thompson. JSSP has evolved [11] a definitive scheduling problem. This is related to industrial engineering. Study of JSSP has been embellished due to a keen interest in various research disciplines; various creations have developed to solve uni and multimodal problem. James Kennedy and Russell Eberhart [12] brought a new edition of PSO.They reviewed that how many iterations is required to check criterion of an error if we do change in pattern.
There is a concession between the global and local search for dissimilar problems. The local search and global search intelligence should be treated separately. Considering this, Y. Shi and R. Eberhart in 1998 [7] introduced inertia weight w which shown in the equation.
w is a positive constant factor for balancing global and local search variable.

$$Vi(v+1)= w * Vi(v) + c1* rand( ) * (\pi(v) - Xi(v)) + c2* rand( ) * (g(v) - Xi(v))$$
$$Xi(v+1) = Xi(v) + Vi(v+1)$$

Traditional particle swarm optimization (PSO) algorithm [13] now improved as a new hybrid algorithm for JSSP. In this algorithm, the area of solution space has been reduced for particles. To improve the performance of individual search, simulated annealing operator is combined with local search operator.

Coello, Lechga and Plido developed pursuit for PSO. In which Pareto dominance [14] is combined with PSO. This algorithm uses an alternate warehouse to mentor particle flight.

Liang, Zho, Guo, and Ge developed a [15] original PSO-based algorithm for JSSP. This algorithm productively achieves the effectiveness of parallel and distributed computing systems. Lei

[16] Supervised a PSO to minimize makespan and total job tardiness for JSSP. JSSP can convert the discrete problem into continuous optimization problem using the priority-based method. He altered portrayal of a particle in favor of the position, displacement, and velocity.
A hybrid particle swarm optimization (HPSO) [17] for the job shop scheduling problem (JSSP) has been introduced by Sha. Earlier search solutions space for particle was discrete. They altered, position, displacement and velocity of the particle. Particle position changed conferment to the predilection list-based representation. In this, the velocity of the particle depends on tabu search and displacement of particle based on swap operator. Location of particle has been decoded using Giffler and Thompson's heuristic method.

D.Y. Sha has [18] developed a particle swarm optimization (PSO) for an intricate multi-objective job-shop scheduling problem. It workout for continuous optimization problems. He modified the position, movement, and velocity of the particle by introducing distinct solution space.

IV. FLEXIBLE JOB SHOP SCHEDULING PROBLEM

Flexible job shop scheduling is an expansion of job shop scheduling problem. FJSP means that machine can act upon any task from existing set of machines. FJSP is a little bit complex as compared to JSP because given a set of machines required to determine the assignment of an operation. Essentially, it is used in flexible manufacturing system (FMS).It becomes effortful to get the optimal schedule in a given period of time as increasing number of jobs.
The FJSP problem divided into two sub-problems, they are:
1. Assignment Problem- Assignment problem assigns a machine from a set of available machines.
2. Sequence Problem. Sequence problem means to identify an array of all operations on each machine.

Brandimarte [19] was the initiator for using Breakdown Avenue for FJSP. He used dispatching rules to solve the modular problem of routing.

Wu and Xia [20] developed an effortlessly accoutered solution to solve multi-objective flexible JSSP. It is the amalgamation of PSO and SA. PSO is used to accredit operations to the specific machine and simulated annealing provides a range of operation on the machine. PSO provides an elucidation when the search process is hybrid for SA.
Carlo, Prospero Naval and Raquel [21] purposed an idea to optimize multi-objective problem by enhancing the PSO algorithm by using crowding distance computation method.

Shao and Zhang [22] invented a particle swarm optimization (PSO) algorithm. Multi-objective FJSSP can be solved by combining Tabu search (TS) algorithm with incommensurable objectives. They used various objective decision-making methods with global criterion approach. There are three measures for performance, makespan, and tardiness and progression time.

Zhigang Lian has developed [23] a multi-objective exemplary when completion time is different on various parallel machines. He focused on performance measures, makespan, tardiness and process time of every job.

Sha, Lin [24] initiated evolutionary PSO algorithm to give solution for FJSSP with multiple objectives. They used a variety of strategies to modify delineation of position, movement, and velocity of the particle.

T.koli and M.ddamn [25] introduced the new variation of multi-objective Pareto archive PSO algorithm. To find Pareto optimal solution, combined genetic operators as changeable neighborhood search (VNS) with Character of scatter search (SS) with PSO.

Li [26] proposed hybrid algorithm. Using fuzzy processing time it solves FJSSP by grouping with tabu search (TS). For exploration in global search used PSO and TS used for exploitation in local search. The global best particle provides optimal search space for other particles.

S.V. Kamble and S.U. Mane projected a fusion algorithm which is the combo of PSO and Simulated annealing (SA) [27] to solve FJJSP. They proposed the solution to minimize five objectives: tardiness, makespan, entire workload, maximal machine workload, and machine inactive time. If machine collapse, rearrangement approach is used to jumble up the workload. To recognize Pareto front for FJSSP, PSO got mixed with SA algorithm.

V. CONCLUSION

Particle swarm optimization is a heuristic worldwide optimization technique for unraveling scheduling problems like (Job Shop Scheduling Problem and Flexible Job Shop Scheduling Problem).This review paper shows the different solutions of these problems by implementing PSO using various variants to optimize solutions. Here we have presented the concept of PSO and work carried out on PSO by different researchers.
From above study, after proposing of PSO, many researchers are dedicating to enhance the performance of it. In standard PSO, inertia weight had not included, now inertia weight has been using to improve the performance of PSO. Researchers are also working on the global best particle to help it from being locally trapped by introducing the different mutation operators.

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