HEURISTICS APPROACHES FOR JOB SHOP SCHEDULING - AN OVERVIEW

Ramya. G[1], Chandrasekaran.M.[2]

[1]Research Scholar, Department of Melchanical Engineering, Sathyabama University, Chennai, India.
[2]Department of Mechanical Engineering,. Vels University, Chennai, India
Email: [1]ramyacadcam@gmail.com

Abstract

Challenging combinatorial optimization problems are encountered even in the job shop scheduling problems. Heuristics (Phylogenetic) algorithms are developed in scholastic search way in which natural big buoyancy is maintained. These are developed to bring optimized results in stipulated time with respect to optimum schedule. In this article, a brief overview has been presented to address the unique features, techniques and methods of recent development. Heuristics methodologies described in this paper contain many optional features that can determine their effectiveness in a given implementation. Because heuristic procedures do not reliably produce optimal schedules, it is logical to ask just how suboptimal they might be. In an experimental setting, a researcher might attempt to answer this question by solving several problems using a heuristic procedure and trying to estimate either the frequency with which optimal solutions are produced or the average deviation from optimality. Although no important design options arise in applying these techniques, an intriguing question is how to develop an efficient computer code for the algorithm. Researchers and Practitioners are implemented the various algorithms with necessary pseudo coding informative analysis for continuous and discrete optimization problems in terms of processing time, stipulated time, due date, convergence speed, tardiness, earliness and quality assurance. Comparative study analysis on the performance of Heuristics algorithms favors ideas or views on sophisticated model and helpful to all Practitioners and Researchers in solving optimization of job shop scheduling problems in an enhanced heuristics way.

Keywords: Job Shop Scheduling, Heuristics Approaches, Meta-Heuristics, Evolutionary Approaches, Hybrid Approaches

I. INTRODUCTION

A schedule is an allocation of tasks to the time intervals on the machines. It is considered to be a major task for productivity management. Scheduling theory is concerned primarily with mathematics models that relate to mthe scheduling function and the development of useful models and techniques. The quantitative approach translates the decision making goals into an explicit objective function and various deciosion making restrictions into consists of all costs in the system depending upon the type of scheduling. The performance of cost related measures such as machine idle time, job waiting time (lateness) and combination of these measures can be used for total system cost. There are two feasibility constraints found in scheduling problems (1). One is related to the amount of on the technological restrictions on the sequence in which tasks can be performed. The main aim of the scheduling is to find a schedule that minimizes the overall completion time, which is called the makespan. The objectives normally considered in scheduling are to determining the sequence, the start time and finish time of each task. In a manufacturing environment, kproduction schedule provides the basis for making customer delivery promises, utilizing plant capacity effectively and attaining firm's objectives.

The term, 'job shop' is used to describe a plant which is manufacturing a variety of items with different machinery requirements and routing using a process layout machine scheduling problems arises in diverse areas such as flexible manufacaturng system, production planning and logistics. The job shop scheduling problem (JSP) consists of a set 'm' machines $\{M_1, M_2 \ldots M_n\}$, and a collection of 'n' jobs $\{J_1, J_2 \ldots J_n\}$ are to be scheduled, where each job must pass through each machine only once. Each job has its own processing order and this may bear no relation to the processing order of the any other job. Often technological constraints tht each job should be processed through the machines in a particular order or as per precedence demand constraints. The constraints in Job shop scheduling are (i) Th number of machines (ii) Plant capacity (iii)Labour availability (iv) A job does not visit the same machine more than once (v) Operations cannot be interrupted (vi) Each machine can process only one job at a time (vii) Available machine time for processing (viii) Due date for the job.

Meeting due dates is often the most important targent in scheduling, but the due-date constraints are not frequently considered in job-shop scheduling problems. Due dates are treated as deadlines and require the job-shop scheduling to meet specific due dates in order to avoid delay penalties including customer's bad impression, cost of lost future sales and rush shipping cost. Garey show tht the job shop scheduling in an NP-hard problem (2). Because of the NP-hard characteristics of job-shop scheduling, it is usualy very hard to find its optimal solution and this solution in the mathematical sense is not always necessary in practice. Researchers and Practitioners turned to search its near optimal solutions with all kind of heuristic algorithms (3). Fortunately, near optimal solutions usually meet requirements of practical problems very well.

Many literatures several benchmark problems are solved by the heuristics algorithms to produce optimum results. No comparable results ae available for the Tw-problem, however. As it turns out, NP-hard problems belong to two broad classes: NP-hard in the strong sense (or the strict sense) and NO-hard in the ordinary sense. For the latter category, optimal solutions can be obtained by algorithms tht are pseudo polynomial. As the term suggests, pseudo polynomial algorithms perform as efficiently as polynomial ones in practice, but fail to meet the strict formal definition of a polynomial algorithm. For example, a pseudo polynomial algorithm may be polynomial in the total processing time but not in the number of processing times, which is typically the relevant measure of problem size. If that total processing time is small enough, the pseudo polynomial algorithm will perform efficiently. The existence of a pseudo polynomial solution usually implies tht we can solve practical instances of the problem without prohibitive computational demands. This is the case for the T-problem, which has been shown to be pseudo polynomial by Lawler (1977). The

Tw-problem, in contrast, is known to be NP-hard in the strong sense. The ability to solve 30-job single-machine problems does not imply that we can solve optimally for 30 jobs in more complex problems. In multi machinie models, single-machine sub models may have to be solved repeatedly, perhaps as many as 2n times. When those demands are substantial, we may want to consider suboptimal methods, or heuristic procedures, which are capapble of obtaining good solutions with limited computational effort. In contrast to such methodologies as dynamic programming or branch and bound, these techniques do not guarantee that an optimum will be found, yet they are reatively simple and effective. In this paper illustrate how heuristic procedures can be evaluated.

II. JOB SHOP SCHEDULING

A. Scheduling Objectives

The scheduling is carried out to meet various objectives. These objectives are decided upon the situation, market demands and the customer's satisfaction. The objectives considered under the time and cost minimization are listed in the Table 1.

Table 1 Main Objectives of Scheduling

Sl. No.	Time Minimization	Cost Minimization
1	Minimize machine idele time	Minimize lthe costs due to not meeting the due dates
2	Minimize the mean flow time	Minimize the maximum lateness of any job
3	Minimize the mean tardiness	Minimize the total holding cost with no tardy jobs
4	Finish each job as soon as possible	Minimize the total holding cost with tardy jobs
5	Finish the last job as soon as possible	Minimize the number of late jobs

B. Job Shop Scheduling Problem

Typical scheduling problems involve minimizing the maximum $gj(t)$ value (the maximum costproblem) or minimizing the sum of gj(t) values (the total cost problem). Scheduling is defined as the art of assigning resources to tasks in order to insure the termination of these tasks in a reasonable amount of time (4). The term 'Scheduling' in manufacturing systems is used to the determination of the sequence in which parts are

to be processed over the production stages, followed by the determination of the start-time and finish-time of processing of parts, so as to meet an objective or a set of objectives. Also, the problem of scheduling is addressed after the orders are released into the shop floor, along with their process plans and machine routings (5). Scheduling plays a crucial role to increase the efficiency and productivity of the manufacturing system. The problem of scheduling is one of the operational issues to be addressed in the system on a daily or weekly basis. Job shop scheduling problems are Non-Polynomial (NP) hard [1] so it is difficult to find optimal solutions.

C. Review on Job shop Scheduling

Many researchers have been focusing on scheduling during the last few decades. Different approaches have been developed and implemented for solving various problems of job shop scheduling by considering various objectives. The literature review has been carried out based on the solution approaches employed for solving job shop scheduling problem and this is explained in the following sections.

In earlier research, the job-shop scheduling problem has been extensively studied with the objective of minimizing some functions of the completion times of jobs. Several techniques have been proposed and different heuristics have been designed and developed for solving the minimum makespan problem, the minimum total tardiness problem and so on. Simulated Annealing is used to solve job shop scheduling problem with the minimization of makespan (6). Ponnambalam et al had implemented Tabu Search for JSP with the minimization of makespan (7). Priority rules for job shops with weighted tardiness costs were proposed (8). Shifting Bottleneck Procedure with minimization of makespan was proposed by Adams et al (9). Carlier et al introduced an efficient algorithm for solving job shop problem (10). Two new dispatching rules for minimizing tardiness of the problem were developed by Anderson et al (11). Computational study is done for job shop scheduling with makespan criteria (12).

Raman et al introduced a decomposing approach for tardiness minimization work (13). AIS algorithm has been used for solving makespan minimization (14). Minimization of earliness criteria in scheduling was proposed by Asano et al (15). Mohammadreza Farahani, Saber Bayat Movahhed, Seyyed Farid Ghaderi, A hybrid meta heuristics optimization algorithm was tested on two test functions in different circumstances and the results were subsequently compared with those of the other evolutionary methods such as the SFLA. Success rate and search time were the parameters considered to check our method efficiency (4). Quan-Ke Pan & Ling Wang & Liang Gao & Junqing Li,an effective shuffled frog leaping algorithm (SFLA) for solving a lot-streaming flow shop scheduling problem with equal-size sub lots, where a criterion is to minimize maximum completion time (i.e., makespan) under both an idling and no-idling production cases[15]. M. Alinia Ahandani, N. Pourqorban Shirjoposht & R. Banimahd, Hybrid algorithms were generated by combining the shuffled frog leaping and a local search method. Also a new local search method by combining two other simple local searches was proposed (16). Emad Elbeltagia,, Tarek Hegazy, Donald Grierson compares the formulation and results of five recent evolutionary-based algorithms such as genetic algorithms, memetic algorithms, particle swarm, ant-colony systems, and shuffled frog leaping (17). M. Saravanan & A. Noorul Haq, approached a novel metaheuristic called Scatter Search (SS) for the JSS problem, an NP-hard sequencing problem to find a schedule to minimise the makespan (Cmax), that is, the time required to complete all jobs (18).

D. Scheduling Algorithms

Scheduling Algorithms were formulated in the mid fifties. Since then there has been a growing interest in scheduling. The complexity, dynamic characteristics, computation methods, applications and randomness can be considered from the classification of scheduling problem, therefore a lot of researches on Scheduling algorithms have been conducted in the past centuries (19). During the few years new and interesting scheduling problems have been formulated in connection with flexible manufacturing (20). Generally, Scheduling Algorithms have been investigated and classified with respect to their computation complexity, enumerative procedures and solution procedures.

Classifications of scheduling algorithms are shown in Figure 1. Further, Classification of Direct Approaches has shown in Figure 2. and Heuristics Approaches has shown in Figure 3.

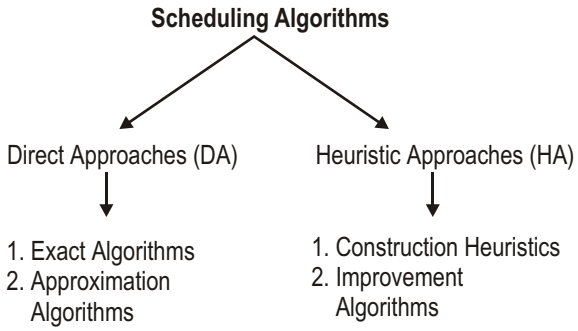

Fig. 1. Classification of Scheduling Algorithms

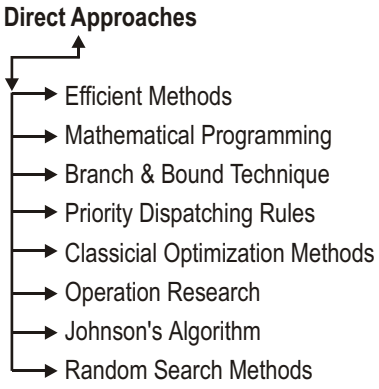

Fig. 2. Direct Approaches for JSS

E. Job shop scheduling using Direct Approaches

Direct Methods are traditional approaches consider technological advances in both processes and equipment as the keyto success and the right way to remain competitive. This is no longer a valid approach, since these advances are shared between competitors very rapidly and none of them can have them exclusively.

III. REVIEW ON JOB SHOP SCHEDULING USING HEURISTIC APPROACHES

The heuristic approaches were also employed for various engineering application problems due to their robustness and convergence to global optima. Heuristic method of learning involves discovery and problem solving using reasoning and past experience. An approach without formal guarantee of performance can be considered a “heuristic”. These heuristic approaches are used in practical situation when no better methods are available. The following section deals with the various heuristic approaches like Artificial Intelligence, Bottleneck based heuristics, Local search approaches, Meta Heuristics and Hybrid Approaches in earlier research work. Some of the heuristic algorithms are listed in Table 2.

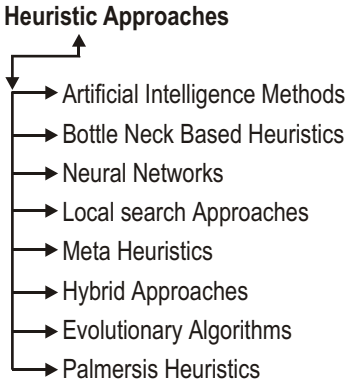

Fig. 3. Heuristics Approaches for JSS

A. Meta Heuristics

Meta-heuristic approaches are the most recent developments in neighborhood search methods for solving complex optimization problems (21). Meta-heuristic approaches based on neighborhood strategies were employed by Grabowski et al. (22), There are many meta heuristics meta-solvers such as Genetic Algorithms, Tabu Search and Simulated Annealing in scheduling. Grabot et al. (23) used Fuzzy Logic principles to combine dispatching rules for multi-criteria job shop problems and stressed the imprecision of straight-forward methods using mathematical approaches such as fuzzy constraint relaxation, which is integrated with a knowledge-based scheduling system.

a. Simulated Annealing Techniques

Simulated Annealing is a combinatorial optimization technique based on random evaluations of the objective function in such a way that transitions out of a local minimum are possible. SA is based on the analogy to the physical process of cooling and recrystalization of metals. Mohanasundaram et al. (24) proposed Pareto archived simulated annealing for JSP with multiple objectives such as mean flow time and makespan. Ponnambalam et al. used SA for solving JSP with the objective of minimization of makespan (25).

Table 2. Heuristics Algorithms

Artificial Intelligence Methods	Optimization Methods	Constraint Programming, Artificial Neural Network, etc.
Hybrid Approaches		Hybridoptimization, Adaptive neural network, Hybrid heuristic genetic algorithm, Hybrid particle swarm optimization, Hybrid Shuffled Leaf Frog Algorithm, etc. Simulated Annealing,
Meta heuristics		Critical Block Simulated Annealing, Taboo search, Fuzzy Logic, Greedy Randomisedadaptive search, Bee Colony Optimization, etc. Geneticalgorithm, Ant colony Optimization
Evolutionary Approaches		OptimalSwarm optimization, Particle Swarm optimization, Scatter Search Algorithm, Shuffled Frog Leaping Algorithm, Sheep Flock Heredity Model Algorithm, Selective BreedingAlgorithm. Memetic Algorithm, etc. Combinatorial Optimization, Multi Level Local Search, Local Minimum, Threshold
Local Search Approaches		Acceptance, Tabu Search, etc. Shifting Bottle Neck procedure
Bottle neck based Heuristics		

b. Bee Colony Optimization

Bee colony optimization is usually used to measures performance that are related to job shop scheduling include machine utilization, cycle time, throughput rate and inventory level. Of these measures, utilization of manufacturing resources is of vital importance to any manufacturing enterprise (26). Typically the bee colony working method is base onthe nectar searching.

B. Local Search approaches

The results of Approximation algorithms are guaranteed within a fixed percentage of actual optimum. Local search techniques though not optimal but guaranteed to produce feasible solution.

Methods of solving combinatorial optimization problems are discrete analog of “hill climbing” local search method which is used to solve discrete optimization problems. Aarts et al. proposed a local search technique for combinatorial optimization with makespan minimization criteria (27).

a. Tabu Search

Tabu Search (TS) stems from general tenets of intelligent problem solving and derived from the works of Glover (28). In essence TS is a simple deterministic oriented search procedure that constrains searching and seeks to transcend local optimality by storing the search history in its memory. Laguna et al. presented some of the earliest TS approaches in scheduling (29). Ponnambalam et al. Implemented Tabu Search for JSP with minimization of makespan and also used to solve JSP in different ways (7).

C. Evolutionary Approaches

Evolutionary Approaches are search and optimization algorithms inspired by the process of natural evolution and searching Techniques. EAs are employing a probabilistic search for locating a globally optimal solution. EAs have many advantages. EAs are providing a set of solutions near the optimal one on a wide range of problems. They can be easily modified with respect to the objective function and constraints (30). The following topic deals with the various Evolutionary approaches.

a. Genetic Algorithms

Genetic Algorithms (GA) are based on an abstract model of natural evolution, such that the quality of individuals builds to the highest level compatible with the environment by Gen, M et al. (31). Cheng et al. presented an analysis which indexes nine categories of representation schemes (32). Bierwirth developed a generalized-permutation genetic algorithm to solve JSP and analyzed three crossover operators, which preserve the relative, position and absolute permutation order of operations (33). Shi applied a crossover technique which produces offspring by dividing arbitrarily chosen mate randomly (34).

b. Particle Swarm Optimization

Particle Swarm Optimization is an evolutionary computation technique proposed by Kennedy and Eberhart (17,35). PSO combines local search by self-experience and global search by neighborhood experience, and possesses high search efficiency. Particle swarm optimization requires only primitive and simple mathematical operators, and is computationally inexpensive in terms of both memory requirements and time. The particle swarm concept was based on the premise of social behavior of bird (30). The original intent was to graphically simulate the graceful but unpredictable choreography of a bird flock. A PSO algorithm mimics the behavior of flying birds and their means of information exchange to solve optimization problems. PSO has been introduced as an optimization technique in real-number spaces. The PSO algorithm is also problem-independent, which means little specific knowledge relevant to a given problem is required. This makes PSO more robust than many other search algorithms.

c. Ant Colony Optimization

Ant Colony Optimization (ACO) method is a stochastic optimization technique used for solving job shop problem with single objective criteria was proposed by Colorni et al. (36). It models the behavior of ants in finding the shortest path to their food source (30). The ant is a simple co-operating agent whose search performance becomes very effective when working collectively with many other simple agents, allowing poor local minima to be transcended.

d. Scatter Search Algorithm

M. Saravanan & A. Noorul Haq applied a novel Meta heuristic approach called Scatter Search Algorithm (SSA) for solving Job shop scheduling to find a schedule to minimize the makespan (Cmax) (18). Scatter Search (SS) is a heuristic study on integer linear programming problems which also provides a number of formative ideas of Tabu Ant Colony Optimization Search and also Scatter Search provides a systematic and unified framework to embody local search in an evolutionary strategy, exploring selected regions extensively with the objective of finding effective solution combinations (37). The SS algorithm can be divided into 2 phases, an initial phase and an evolutionary phase. As in the evolutionary methods, the highest evaluated solutions found by the local search phase are used to update the set of solutions, called Reference Stage (RS). The next stage process is repeated using the new solutions in the next iteration until the RS does not converge, called evolutionary stage. SSA provides unifying principles for joining solutions based on generalized path constructions and by utilizing strategic designs where other approaches resort to randomization which is not based solely on randomization as the main mechanism for searching. The goal of these procedures is to enable a solution procedure based on the combined elements to yield better solutions than the one based on the original elements.

e. Shuffled Frog Leaping Algorithm

Eusuff et al. proposed a new meta-heuristic algorithm called Shuffled Frog Leaping Algorithm for solving scheduling problems with discrete decision variables (35). SFLA is a population-based cooperative search metaphor combining the benefits of the genetic-based memetic algorithm and the social behavior based particle swarm optimization Inspired by natural memetics (5), Muzaffar Eusuff and Lansey described the algorithm through observing, imitating, and modeling the behavior of frogs searching for food placed on separate stones haphazardly positioned in a pond (38). SFLA has been tested on a large number of combinatorial problems and found to be efficient in finding global solutions (39). The SFLA is a population-based cooperative search metaphor inspired by natural memetics and consists of a frog leaping rule for local search and a memetic shuffling rule for global information exchange.

The SFLA comprises a set of interacting virtual population of frogs partitioned into different groups (memeplexes), referred to as memeplexes, searching

for food (5). The algorithm functions simultaneously as an independent local search in each memeplex (39). Furthermore, the SFLA compares favorably with the Genetic Algorithm, the Ant Colony Optimization, and the Particle Swarm Optimization in terms of time processing (17).

D. Hybrid Approaches

Wang et al. described a hybrid optimization strategy for job-shop scheduling with makespan minimization criteria (40). Hong Zhou et al. Presented a hybrid heuristic genetic algorithm for Job shop scheduling problems with minimization of makespan (41). Hybrid Algorithm describes combining the social and natural behavior of any different search algorithms by reasonably. This concept used to develop a general, fast and easily implemented hybrid optimization algorithm. The effectiveness and efficiency of the hybrid algorithm are demonstrated by applying it to some benchmark job-shop scheduling problems. Moreover, such Hybrid Algorithm can be applied to many combinatorial optimization problems by simple modification.

a. Hybrid Particle swarm optimization

Wei-jun Xia • Zhi-ming Wu developed a Hybrid Particle Swarm Optimization (HSPO) for finding the minimum makespan for solving Job shop scheduling (39). HSPO algorithm combines social behavior of PSO and SA. However, PSO is a stochastic search algorithm with inadequate global search-ability at the end of a run. Simulated annealing (SA) employs certain probability to avoid becoming trapped in a local optimum and the search process can be controlled by the cooling schedule.

Hybrid optimization algorithm HPSO may fail to find the required optima in cases when the problem to be solved is too complicated and complex. SA employs certain probability to avoid becoming trapped in a local optimum, and the search process can be controlled by the cooling schedule. By designing the neighborhood structure and cooling schedule of SA, Hybrid Shuffled Leaping Frog Algorithm we can control the search process and avoid individuals being trapped in local optimum more efficiently. Thus, a hybrid algorithm of PSO and SA, named HPSO, is developed. It can be seen that PSO provides initial solution for SA during the hybrid search process. Such a hybrid algorithm can be converted to general PSO by omitting the SA unit, and it can be converted to traditional SA by setting swarm size to one particle. HPSO implements easily and reserves the generality of PSO and SA.

b. Hybrid Shuffled Leaping Frog Algorithm

Mohammadreza Farahani et al. identified a new hybrid algorithm called Hybrid Shuffled Leaping Frog Algorithm based on the identification of the weaknesses of the basic SFLA (4). At First, the SFLA is initially applied to different functions and to identify the fundamental weaknesses of this method as per the elimination of the effective frogs from memeplexes by solving procedure in consequence order. Some memeplexes are being wasted in the local minima. One way to reduce the probability of this occurrence s this method is to improve the guiding particle in each memeplex. This method is similar to the SFLA, partitions particles into different groups called memeplexes and identified the best particle in each memeplex thereafter determines its movement through the search space in each iteration of the algorithm toward the global best particle and the worst particle in each memeplex keeps track of its coordinates in the solution space by moving toward the local best particle in the same memeplex.

Chen Fang et al. proposed encode concept for the virtual frog as the extended activity list and decode it by the SFLA-specific serial schedule generation scheme (42). The initial population is generated by the regret-based sampling method and the priority rule. Then, virtual frogs are partitioned into several memeplexes, and each memeplex evolves by adopting the effective resource-based crossover. Combining the permutation-based local search and forward-backward improvement is to enhance the improved exploitation ability. To maintain the diversity of each memeplex, virtual frogs are periodically shuffled and reorganized into new memeplexes. HSLFA also has a distinct advantage over the SFLA in that it reduces the probability of the particles being trapped in the local minima by directing the best local particle toward the global best particle.

IV. COMPARISON AMONG HEURISTICS ALGORITHMS FOR SOLVING JOB SHOP SCHEDULING PROBLEMS

A detailed investigation on enhancing the many studies have been reported to increase the results of

the optimum schedule and computational stability of the Heuristic Approaches for Job Shop

Scheduling with meeting requirements in diverse industrial applications. This paper outlines an understanding of history, operation and engineering application of Heuristics Algorithms in order to solve the optimization of Job Shop Scheduling

A. Heuristics Search Solutions

Due to the combinatorial nature of job shop scheduling the existing Approaches have extreme difficult in effectively searching the solutions. According to the literature results, it is an interesting fact that the Simulated Annealing technique was superior and working faster than the other local search techniques. For theoretical problems the local search techniques were better than the Genetic

Algorithms. Due to the advantage of GA the usage of a special neighborhood structure could not be applied for practical scheduling problems. But Genetic Algorithms can be applied for practical scheduling problems at any moment according to the complexity of the problem. The ability of the GA seem to be only average and to get easily adapted new problem types. Some papers have focused on quality-oriented functions, whereas optimizing the makespan aims to maximizing the output and minimizing costs. Such work focuses on the effectiveness rather than the efficiency of the job shop in meeting customer's satisfaction.

For smaller size problems Scatter Search and Genetic Algorithm methods are gives the optimum results veryquickly, where as for big size problems the scatter search method ives optimum result very quickly as well as the best value among the other methods. In the encoding scheme, only position coordinates are used in the practical computational process. Position coordinates represents jobs order on all machines. In this wayk, we convert a continuous optimization problem to a discrete optimization problem.

B. Comparative Review Statement

The comparative review analysis of the Heuristics algorithms from the various aspects of nature, representation, computation and applications are listed in Table 3 for Hybrid algorithms, Table 6 for Meta Heuristics, Table 5 for local search methods and Table 6 for Evolutionary Algorithms.

C. Trends of Heuristic approaches for Job shop Scheduling

The heuristic approaches have more benefits compared with the direct approaches. The heuristic approaches produce optimal solution for various size problems. Objective functions have given more importance than derivatives. Many Heuristic approaches use a population of points during search. Initial populations are generated randomly which enable to explore the search space is large. These approaches efficiently explore the new combinations with available knowledge to find a new generation. Though an extreme work has been on solving JSS optimization using Meta heuristics and local search techniques are still the major potential area yet to be explored by the researchers using Efficient Heuristics Algorithms.

V. CONCLUSION

A great deal of research has been focused by many researchers for solving job shop scheduling problem. Many scheduling problems are naturally formulated with multiple objectives. Recently, new search techniques based on natural phenomena has received attention to solve a wide range of combinatorial optimization problem. Meeting due dates is the most important goal of scheduling to avoid the delay penalties including customer's bad impression, lost future sales. Some papers have focused on due-date oriented functions, whereas the main aim of optimizing the makespan is to minimizing costs and maximizing the output. Many researches Heuristics Algorithms are competent and prove to be a good problem-solving technique for job shop scheduling.

Table 3. Comparative Analysis of Hybrid Heuristics Algorithms

Heuristic Approaches	Hybrid Algorithms		
Algorithm Names	Hybrid Particle Swarm optimization	Hybrid Shuffled Frog Leaping Algorithm	Hybrid Ant Colony Optimization
Reference	Wei-jun Xia et al.[39]	Mohammadreza Farahani et al. [4]	Heinonen,J et al [43]
Objective	To find the minimum makespan	To reduce the particle probability	To improve resulting schedule to find the minimum makespan
Nature of the Algorithm	It combines social teration of the algorithm behavior of PSO and the global best particle andthe worst particle in each memeplex		Post Processing algorithm & Individual operations allowed to calculate makespan.
Description	By designing the Initially applied neighborhood structure and to different functions and cooling schedule of SA	we to identify the can control the searchfundamental process and avoidweaknesses of this individuals being trapped in method as per the local optimum moreelimination of the efficiently effective frogs from memeplexes	It consists two parts, ACO part where ants crawl over the search space trying to construct a feasible tour
Solution Methodologies	Hybrid search process by setting swarm size particle	By solving procedure to one in consequence order	Global Pheromone update & Iteration Procedure
Computation	Implements easily and reserves the generality of PSO and SA.	Guiding particle in each memeplex & movement through the search space	Post processing part springs with complete schedule to operate.
Application	Problem to be too complicated and complex & JSS	JSSP, FSS, Various types of scheduling Problem & Lot Streaming,	JSS & Scientific problems
Remarks	HPSO may fail to find the required optima in cases when the problem to be solved is too complicated and complex	To maintain the diversity of each memeplex, virtual frogs are periodically shuffled and reorganized into new memeplexes.,	Good harnessing, mimicking and utilizing processes occurring in nature

Table 4. Comparative Analysis of Meta Heuristics Algorithms

Heuristic Approaches	Meta Heuristics		
Algorithm Names	Simulated Annealing Algorithm	Tabu search	Bee colony Optimization
Reference	Mohanasundaram et al. [24] & Ponnambalam et al. [25]	Glover [28], Laguna et al. [29] & Ponnambalam et al. [7],	Chin Soon Chong [26]
Objective	Mean Flow Time, minimization of makespan & to solve nonlinear programming problems to find optimum solution,	To find makespan time & near To measures optimal solutions of performance combinatorial optimization problems	To measures
Nature of the Algorithm	Random Optimization & Probabilistic search algorithm	Generates neighborhoods & Adjacent pair wise interchange method used.	Working behavior based on bee colony nectar searching
Description	Combined with other methods & very sensitive performance initial values and parameters	It consists several elements like move, neighborhood, initial solution, search strategy, memory, aspiration function & stopping rules	Related to job shop scheduling include machine utilization, cycle time, throughput rate and inventory level.
Solution Methodologies	Random Search Technique & Parallelism Concept	Based on iterative improvements	Working method is base on the nectar searching
Computation	Convergence is slow & execution time is long	Initial solution construction & Neighborhood solution	Quickly get an optimal solution
Application	Solving complex nonlinear scheduling problems	Permutation Flow Shop scheduling & JSSP	JSS
Remarks	Algorithm is simple, universal & robust	Neighborhood structure that generates feasible solutions by reversing the order procedures	Utilization of manufacturing resources is of vital importance to any manufacturing enterprise

Table 5. Comparative Analysis of Local Search Techniques and Bottleneck based Heuristics

Heuristic Approaches	Local Search Techniques		
Algorithm Names	Artificial Intelligence Methods	Neural Networks	Shifting Bottleneck Procedure Algorithm
Reference	Zhang et al. [44]	Zhang, H.C et al. [45]	Adams et al.[9] & Carlier [46]
Objective	To find optimum solutions	Computes an output that is propagated to the output nodes	To find minimum makespan
Nature of the Algorithm	Biological understanding and uses principles in nature to find solutions	Based on the brain structure of simple living entities	The actual strategy involves relaxing the job shop problem into m one machine problems and iteratively solving each sub problem
Description	It concerned with integrating biological and computer intelligence	Massively parallel network of interconnected simple processors (Neurons) in which each neuron accepts a set of inputs from other neurons	More sophisticated approaches which can bridge the gap between PDRs and time consuming combinatorial exploding exact methods
Solution Constraint Methodologies satisfaction approaches		Neural network methods.& BEP application	Exact scheme to deal with Delayed Precedence Constraints
Computation	Algorithm complexity is large	Network parameters & Energy Functions	Combinatorial exploding exact methods & time is larger
Application	To solve the all type of scheduling problem	JSS & SMS	Almost all JSS
Remarks	Simplified model of human brain	Receives variable data such as job orders, capacity availability and set-up times, while outputting machine orders	Solution quality and computing time were affected significantly by routing structure

Table 6. Comparative Analysis of Evolutionary Algorithms

Heuristic Approaches	Evolutionary Algorithms					
Algorithm Names	Genetic Algorithm	Ant Colony Optimization	Shuffled Frog Leaping Algorithm	Scatter Search	Particle swarm Optimization	Memetic Algorithm
Reference	Gen .m et al.[31], Cheng et al.[32]	Colorni et al. [36]	Eusuff et al. [35]	M. Saravanan & A. Noorul Haq [18]	Kennedy et al. [17, 35]	Yarong Chen et al. [19]
Objective	To optimize and solve JSP with makespan	To finding the shortest path sequence	To finding global solutions	To find a schedule to minimize the makespan (C_{max})	Possesses high search efficiency	To reach near optimum solutions to Large scale optimization problems
Nature of the Algorithm	Model of Natural Evolution. Based on iterative improvements.	It models the behavior of ants in finding the shortest path to their food source	Population-based cooperative search metaphor.	Providing a wide exploration search through intensifications & diversifications	Evolutionary computation technique & premise of social behavior of bird	Combination of GA and Local Search methods to reach Global Optimization Fitness Function
Description of Chromoisome	Solutions nexpression	stochastic optimization technique used for solving job shop problem with single objective criteria	benefit sadaptive of the genetic-based memory memetic algorithm principle to and the social avoid behavior based generating or particle swarm in corporating optimization duplicate Inspired by natural solutions at memetics various stages		It combines local search by self-experience and global search by neighborhood experience	Consideration Survival of the genetically fittest & most experienced
Solution Methodologies	Crossover operators,, Relative position & Absolute permutation on order of operators	Stochastic Optimization Technique with single objective criteria	Frog leaping rule for local search and a memetic shuffling rule for global information exchange.	Principles for joining solutions based on generalized path constraints & strategic design	Primitive and simple mathematical operators	Element that form a Chromosome called memes. Chromoso me & offspring allowed to gain some experience through LSM.

Heuristic Approaches	**Evolutionary Algorithms**					
Computation Offspring by dividing arbitrarily chosen Mate randomly	Produces	Completion time is long	Imitating, and modeling the behavior of frogs searching for food placed on separate stones haphazardly positioned in a pond	Permutation problem consists an adaptation and main mechanism for searching	Problem independent & robus than many other search algorithms	Crossover rate, Number of generations & Population size Single Machine
Application	Vasrious types of Scheduling problems,, SMS, Parallel Machine Scheduling,, FSS & JSSP etc..	Discrete Optimization Problem & JSSP	Solving scheduling problems with discrete decision variables	To solve Optimization most difficult Problems & NP-hard JSS combinational Optimization Problem		Scheduling and Parallel Scheduling
Remarks	Fitness function affects the result of solution and Need not define the search rules	The ant is a Population-based simple cooperative search co-operating metaphor agent; serch performance becomes very effective and allowing poor local minima to be transcended.		To enable a solution procedure based on the combined elements and Achieves better results for all JSSPs.	Computationaly inexpensive memory requirements and time	Convergence rate is fast & computation efficiency is high

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