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Job Shop Scheduling Algorithms- A Shift from Traditional Techniques to Non-Traditional Techniques

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***Abstract*- The success of planning and operations phase essentially lies in efficient scheduling, and searching for the best scheduling algorithm in accordance with the problem in hand, is still a difficult task. Numerous job shop scheduling algorithms have been proposed and implemented, and each has its pros and cons. This review paper discusses the development of traditional and nontraditional Job Shop Scheduling Problem and also advancements in the development of methods to be used in solving the problem. It also classifies the JSSP, on the basis of the complexity of the solution. The survey provides an insight on the research carried out in this field.**

Keywords: Job Shop Scheduling Problem; Non-Traditional Techniques; Scheduling; Traditional Techniques.

I. INTRODUCTION

A procedural plan or layout, meant for achieving a goal/objective and which aids in measuring the work process, is termed as schedule, if the plan is associated with a list of proposed operations/events and their respective sequence. Scheduling is an elementary concern in the operation of any manufacturing systems and planning process. It is responsible for taking care of the assignment of resources for several tasks in given period of time, and its objective is to optimize other missions. Depending on the problem being solved, resources and different tasks may be molded in many forms, and objectives can also vary.

A job shop is an organization composed of a number of work stations capable of performing operations on objects. Job shop [1] accepts contracts to produce objects by putting them through a series of operations. Scheduling is generally bothered with allotment of operations on machines [2] so that some efficient achievement as flow time, make span, lateness, and tardiness may be met. Scheduling organizes and allows procedure development to be more realistic, thus finding fast solutions for applications in industries. Yet, these approaches produce excellent results with traditional

Production set ups. In modern era, there is a high demand for machine automation and innovative methodologies which yield most optimized results. Automated systems like FMS, CNC and CIM [3] are good examples of today's manufacturing industry's scenario. There is a demand for scalability, improvement in productivity, along with enhanced adaptability. Keeping up with such demands, there is a strong need for scheduling methods which encompass the specified demands in their design and which could be effectively implemented with the modern manufacturing systems.

Section II of this research paper provides some essential facts and objective of scheduling, whereas section III deals with Job Shop Scheduling Problem. Section IV is dedicated to literature survey and section V discusses the traditional and non-traditional techniques for solving the aforesaid problem.

II. SCHEDULING

A. Scheduling: Essential Facts

Allocation of operations on machines (commonly known as scheduling) by the automated system (in an optimized form and within a defined period) is highly required in several industries, especially the manufacturing units.

Schedules [4] are broadly classified into two branches, the feasible schedules and the unfeasible schedules. The feasible schedules are those which are compatible with all of the predefined constraints (based on time and technique used) and unfeasible schedules are those that disobey some or all deadlines and the mentioned constraints.

Other aspect of scheduling [5] is the static and dynamic state. If the no. of jobs in the scheduled set remains the same and do not change at run time, the scheduling is static, whereas the system is called dynamic if new jobs are introduced into the existing set during run time.

According to the complexity of the problem, the scheduling problems can be bifurcated into two forms: P and NP class. Computational complexity, i.e., the maximum no. of steps required for reaching optimality, for n jobs and m available machines in a scheduling problem, is calculated as $(n!)^m$. Most of the practically implemented scheduling problems fall into the category of the NP-hard problems.

B. Objective of Scheduling

Scheduling process is not quantifiable; it is complex and sometimes conflicting also. The main aim of scheduling is to reduce the performance estimate. The performance measure of

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scheduling is a non-shrinkable function of job completion time. It intends to carry out two major tasks:

(i) Minimize the makespan
1. Minimize the machine's unproductive time
2. Finish each job as it complete
3. Minimize the in process inventory costs

(ii) Cost reduction for performance measure based on due date.
1. Reduce the total detention
2. Reduce the cost which is not meeting the completion time.
3. Cut off the number of late jobs.
4. Prune the maximize prolongation of every task.
5. Minimize the detention.

III. JOB SHOP SCHEDULING PROBLEM

Job shop scheduling problem (JSSP) was first proffered by John F. Muth, and Gerald Luther Thompson [7]. Since past 4 decades, JSSP has become a classic scheduling problem. It is affiliated to industrial engineering mainly, though it is required in other branches also. The study of scheduling problem is carried out taking inputs from various streams like Computer Science, Operations Research, Management and Manufacturing. Figure 1 classifies the traditional and non-traditional solution methodologies for JSSP.

The Shifting bottleneck (SB) invented by Adam Baharum, et al. is a vigorous heuristic for solving the JSSP [8]. An immune genetic algorithm has been produced by County Yong-sheng and Wang Shudong [9] to solve dynamic scheduling problems of JSSP. R. Holland Cheng and LiYan [10] developed a framework to find out solution for unpredictable processing times in which approximate processing times are defined as triangular fuzzy numbers (TFN) to optimize JSSP. H. Zhou, et al. [11] Developed a hybrid structure, which integrates a heuristic and a genetic algorithm (GA) for JSSP for minimizing weighted incarceration. D.Y. Sha, et al. [12] developed a particle swarm optimization (PSO) for complicated multi-objective JSSP problem. Jie Tang, et al. [13] suggested a new hybrid genetic algorithm to solve the JSSP. W. Wisittipanich & V. Kachitvichyanukul [14] developed two new differential evolution algorithms (DE) to solve the job shop scheduling problem (JSSP) which decreases makespan and total weighted tardiness. They discovered solution to increase the efficiency of the search. They balanced exploration and exploitation ability in DE.

M. Dastpak, et al. [15] developed a new approach with job shop scheduling problem (JSSP) and quadratic assignment problem (QAP) simultaneously. Objective of this research is to specify the location of machines and the scheduling of jobs. It reduce maximum completion time and transportation cost. M. Ziaee [16] developed a heuristic method to minimize makespan for different jobs. The proposed model is found on a constructive procedure to obtain good quality schedules, very quickly. H. Tao [17] developed a GA parallel sampling algorithm to optimize the control of SA binding guidelines to control the convergence of the algorithm to avoid pre mature and time performance. C.

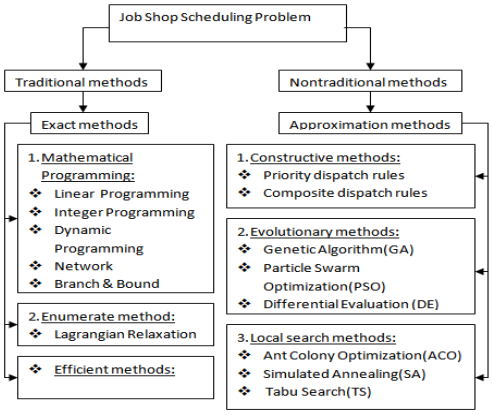

Fig. 1. Classification of various solutions for Job Shop Scheduling Problem

Turguner [18] developed an Ant Colony Optimization (ACO) for the optimal solution by using some of the complex ACO story line. A. Somani [19] developed a parallel genetic algorithm (PGA) by using topological sorting to minimize the execution time for makespan. A. Ouaarab, et al. [20] developed a Discrete Cuckoo Search (DCS) algorithm for balancing the search between local and global hit or miss walk. P. Chuan, et al. [21] suggested an algorithm of the combination of a new hybrid algorithm found on traditional particle swarm optimization (PSO) algorithm and simulated annealing (SA) algorithm. It is used to extricate itself from local optimal solution. A. Boozed, et al. [22] developed a cat swarm optimization algorithm (CSO) that finds the best sequence of operations with optimal execution time called makespan.

IV. LITERATURE SURVEY ON JSSP SCHEDULING

The brief literature review focuses on the research carried out in the last several decades on scheduling problems. Critical analysis of literature facilitates to classify the literature into different categories i.e., based on solution procedure, and on the complexity of the problems as provided in Table 1. Graph provided in Figure 2 shows a steady rise in the research in this field.

TABLE I. LITERATURE SURVEY OF JOB SHOP SCHEDULING PROBLEM AND RELATED ALGORITHMS

SI. No.	Year of Publication	Author	Title	Findings
1	1963	Muth and Thompson	Industrial Scheduling	Job shop scheduling problem (JSSP) was first proposed.

SI. No.	Year of Publication	Author	Title	Findings
2	1988	Egon Balasand Adams	The Shifting Bottleneck Procedure for Job Shop Scheduling	Developed a methodology (Shifting Bottleneck) which is a greatest technique to solve job shop scheduling.
3	1990	John e.biegel andJames j. Davern	Genetic algorithms and job shop scheduling.	Applied genetic algorithm optimization concepts to job shop scheduling problems to diminished tardiness.
4	1995	Colin R. Reeves	A Genetic algorithm Flowshop sequencing.	Developed a solution for diminishing makespan of the n jobs, m machine for flow shop sequencing.
5	2002	Jose Fernando Gonçalves	A Hybrid Genetic Algo for Job Shop Scheduling Problem	Generates parameterized active schedules, and a local search procedure.
6	2005	C. Yongsheng and S. Shudong	Job shop dynamic scheduling problem based on immune genetic algorithm	To solve scheduling problems of job shop scheduling problem developed an immune genetic algorithm
7	2007	R. Cheng, Li Yan	Research on job-shop scheduling in fuzzy environment	Developed a framework to solve and optimize JSSP with uncertain processing times. To deal with uncertain environment, a fuzzy framework is used with genetic algorithm (GA).
8	2008	Jin hui Yang ,et al.	Clonal Selection Based Memetic Algorithm for Job Shop Scheduling Problems	Developed a solution to increase inspection and exploitation to compose evolutionary searching techniques for JSSP.
9	2010	Dy Sha	A multi-objective PSO for job-shop scheduling problems	Developed an algorithm for multiobjective job shop scheduling to enhance search quality and efficiency of searching to optimal scheduling.
10	2011	W. Wisittipanich & V. Kachitvichyanukul	Two enhanced differential evolution algorithms for job shop scheduling problems	Developed an algorithm to minimized makespan and tardiness by doing balance of exploration and exploitation ability in DE.
11	2013	M. Ziaee	Job shop scheduling with makespan objective: A heuristic approach	Developed a heuristic method for minimizing makespan of jobs for JSSP and discovered a solution for well schedules frequently.
12	2014	D. Tuan , et al.	Dual Hybrid Algorithm for JSSP Problem	Developed an algorithm Genetic algorithm with dual hybrid access.
13	2014	P. Chuan Ma,et al.	A hybrid particle swarm optimization and simulated annealing algorithm for job-shop scheduling	Developed a hybrid algorithm for improving space of searching by using PSO and SA has been used for local search optimal solution.
14	2014	A. Somani	Parallel Genetic Algorithm for solving Job-Shop Scheduling Problem Using Topological sort	Found solution for JSSP by using topological sorting to minimized makespan and crossover mutation has applied to optimized local search.

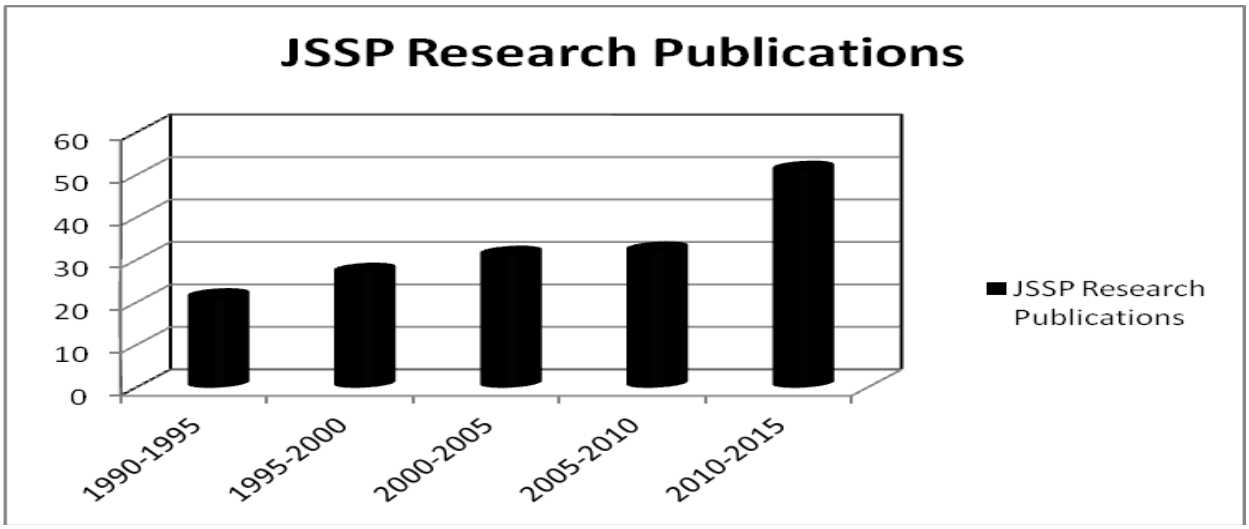

Fig. 2. Frequency of Research Publications in last 25 years

V. JSSP: SOLUTION TECHNIQUES

For scheduling of JSSP problem, there are different approaches of approximation and accretion techniques. Scheduling Techniques can be divided into two sections, Traditional techniques and Non-Traditional techniques.

A. Traditional Techniques

Conventional techniques are also known as optimization techniques. These approaches are apathetic and ensure assurance of global confluence as long as problems are miniature. Some of the traditional techniques which have been used for scheduling are as follows- Dynamic Programming, enumerate Procedure Decomposition, Goal Programming and Efficient methods.

Traditional techniques absorb Mathematical programming, Transportation, Network, Linear Programming Cutting Plane / Column Generation Method, Integer programming, Branch-and-Bound, Mixed Integer Linear programming, and Surrogate Duality.

Benefits of Traditional Techniques

1. Single process or scheduling can easily manage in traditional techniques.
2. Machines can be expanded with full of flexibility.
3. It gives high production volume flexibility by small increments to productive capacity.
4. Low annihilation.

Drawbacks of Traditional Techniques

1. Using traditional techniques need immoderate computation time.
2. Traditional techniques are unable to handle multiple objectives.
3. Majority of the scheduling problem solutions are based on NP - hard, so it diminish the performance of traditional methods, as designing of these methods is a difficult task.
4. For solving branch and bound problems, it requires extensive computing.

Due to these limitations, researchers have directed towards implementation of non-traditional techniques for solving JSSP scheduling.

B. Non-Traditional Techniques

Non- traditional techniques are commonly known as a likeness methods. These methods are very vigorous and do not assure for most favorable but promise optimized solutions. Frequently used techniques are Local Search Techniques(Ants Colony Optimization, Iterative Methods, Genetic Algorithm, Expert Systems, Tabu Search, Simulated Annealing, Insertion Algorithms (Bottleneck based heuristics, Shifting Bottleneck Procedure(SBP)), Particle Swarm Optimization, problem Space Methods like Problem & Heuristic Space and GRASP and Artificial Neural Network(ANN)).

Benefits of Non-Traditional Techniques

a) Nontraditional methods provide global optimal solutions for scheduling.
b) Search area for optimal solution is quite large.
c) These techniques traverse all new possible combinations with available information to find new generations.

Drawbacks of Non-Traditional Techniques

1. Solutions by Non-Traditional is approximate not exact.
2. Analysis of any Non-Traditional method depends on collection of Data Set.
3. Non-Traditional algorithms adaptability depends on two approaches, i.e., exploration and exploitation.

VI. CONCLUSION

Job shop scheduling problem comes into the category of NP-complete problems, which are hardest to define and solve. Some optimization problems such as combinatorial optimization problems are sufficiently complex. It is difficult to find an optimal solution by using exact algorithms. In such cases, heuristic methods are commonly used to search for a good (but not necessarily optimal) feasible solution. Several metaheuristics are available that provide a general formation and strategy ground rule to design a particular heuristic method to solve a exact problem. A key feature of these metaheuristics procedures is their ability to escape from local optima and perform a vigorous search for feasible region. This paper introduces the most prominent types of non-conventional type algorithms or meteheuristics.

JSSPs are the critical because it impacts the capability of producers to accommodate to customer demands and earn profits too. It also impacts the ability of autonomous systems to optimize their operations and the optimizations of communications systems. This is the reason for research analysts and engineers to continue this quest in the coming centuries.

VII. FUTURE SCOPE

The current age of manufacturing systems emphasizes on improving productivity and elasticity of the systems. So, new scheduling methods such as JSSP have been accepted in the industry. This review paper reviews different Non-Traditional methods (with findings) for solving Job Shop Scheduling Problem.

The future work can be extended for solving Flexible Job Shop Scheduling Problem (FJSSP), which is the higher expansion of JSSP by using these Non-Traditional methods.

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