***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 the Job Shop Scheduling Problem and also the advancements in the development of methods to be used in solving the problem. It also classifies the Job Shop Scheduling Problems, based on 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.***

# 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 one of the most important issues in the planning and operation of any manufacturing system. It takes care of the allocation of resources to tasks over time, and its goal is to optimize one or more objectives. Depending on the problem being solved, tasks and resources can take many forms, and the 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, makespan, 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 methods work fine with conventional production set ups. The manufacturing scenario is rapidly changing towards adoption of automated machine tools as well as production methodologies. The current day manufacturing systems place tremendous emphasis on automated systems like CNC, FMS, CIM and manufacturing strategy from lean to lean-agile to improve productivity, flexibility and adaptability of the system [2,3]. In such situations, new scheduling methods must be adopted that are consistent with the modern manufacturing systems.

Section II of this research paper provides some essential facts and objective of scheduling, where as 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.

# Scheduling

## Scheduling: Essential Facts

Scheduling is essentially concerned with allocation of operations on machines that is used by many manufacturing and services industries. The main aim of scheduling is to optimize the allocation of resources for tasks in to given time period.

Schedules are divided into two classes, feasible schedule and infeasible schedules [4]. The unfeasible schedules are those schedules that violates some or all of the timing and technological constraints, whereas the feasible schedules are the ones which are compatible with all of the mentioned constraints.

In addition, if the set of jobs available for scheduling do not change over time, the system is called static, in contrast to cases in which new jobs appear over time, where the system is called dynamic [5].

Computational complexity of a problem is the maximum number of computational steps needed to obtain an optimal solution. For instance if there are n jobs and m available machines, the available number of schedule to be evaluated to get an optimal solution is (n!)m . Based on the complexity of the problem, all problems can be classified into two classes, called P and NP in the literature. Most of the Practical scheduling problems belong to the NP-hard class [6].

## 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 can be explained as a non decreasing function of job completion times. 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.

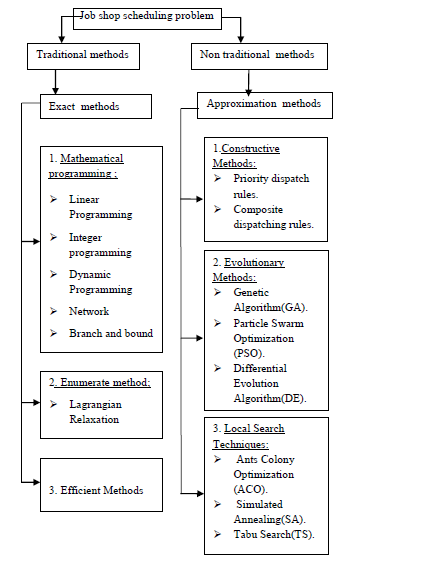
# job shop scheduling problem

Job shop scheduling problem (JSSP) was first proffered by Muth and Thompson in [7]. In the following more than forty years, JSSP has become a standard scheduling problem intimately related to industrial engineering, and the study of JSSP has been enriched by the contributions of various research disciplines, mainly Operations Research, Management Science, Computer Science, and Manufacture Science . Figure 1 classifies the traditional and non-traditional solution methodologies for JSSP.

The Shifting bottleneck (SB) proposed by Adams, et al. is a powerful heuristic for solving the JSSP [8]. An immune genetic algorithm was presented by C. Yongsheng and S. Shudong [9] for solving dynamic scheduling problems of job shop. R. Cheng and Li Yan [10] developed a framework to solve and optimize JSSP with uncertain processing times in which imprecise processing times are modeled as triangular fuzzy numbers (TFN). H. Zhou, et al. [11] developed a hybrid framework, which integrates A heuristic and A genetic algorithm (GA) for job-shop scheduling to minimize weighted detention. D.Y. Sha, et al. [12] developed a particle swarm optimization (PSO) for an elaborate multi-objective JSSP problem. J. Tang, et al. [13] proposed a new hybrid genetic algorithm to solve the job shop scheduling problem. W. Wisittipanich & V. Kachitvichyanukul [14] developed two new differential evolution algorithms (DE) for solving the job shop scheduling problem (JSSP) that minimizes two single objective functions: makespan and total weighted tardiness. The proposed algorithm aims to enhance the efficiency of the search by dynamically balancing exploration and exploitation ability in DE and by avoiding the problem of premature convergence.

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 so that it minimizes both maximum completion time and transportation cost, simultaneously. M. Ziaee [16] developed a heuristic method to minimize makespan for different jobs in a job shop scheduling. The proposed model is based 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 maturer and time performance. C.

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



[Turguner](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=p_Authors:.QT.Turguner,%20C..QT.&newsearch=true) [18] developed an Ant Colony Optimization (ACO) for the optimal solution by using some of the complex ACO story line. A. [Somani](http://ieeexplore.ieee.org/search/searchresult.jsp?searchWithin=p_Authors:.QT.Somani,%20A..QT.&newsearch=true) [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 based on traditional particle swarm optimization (PSO) algorithm and simulated annealing 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.

# Literature Survey on JSSP Scheduling

The brief literature review focuses on the research carried out in that 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 research in this field.

Table 1

***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. |
| 2 | 1988 | J. Adams, E. Balas, and D. Zawack | The Shifting Bottleneck Procedure for Job Shop Scheduling | Introduced the Shifting Bottleneck (SB) which is a powerful heuristic for solving the Job Shop Scheduling Problem. Used to find a bottleneck machine ( a machine having the longest makespan). |
| 3 | 1990 | Biegel and Davern | Genetic algorithms and job shop scheduling. | Applied genetic algorithm optimization concepts to job shop scheduling problems to minimize tardiness. |
| 4 | 1995 | Colin R. Reeves | A Genetic algorithm Flowshop sequencing. | Finding the minimum makespan of the n jobs, m machine permutation flowshop 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 | Introduced an immune genetic algorithm to solve scheduling problems of job shop. |
| 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 | J. Yang ,et al. | Clonal Selection Based Memetic Algorithm for Job Shop Scheduling Problems | Designed to enhance exploration and exploitation. In the clonal selection mechanism, clonal selection, hypermutation and receptor edit theories are presented to construct an evolutionary searching mechanism which is used for exploration. |
| 9 | 2010 | D.Y.Sha | A multi-objective PSO for job-shop scheduling problems | A particle swarm optimization (PSO) was used for an elaborate multi-objective job-shop scheduling problem. PSO was used to solve various benchmark problems. Test results demonstrated that the PSO performed better in search quality and efficiency than traditional evolutionary heuristics. |
| 10 | 2011 | W. Wisittipanich & V. Kachitvichyanukul | Two enhanced differential evolution algorithms for job shop scheduling problems | Two new differential evolution algorithms (DE) for solving the job shop scheduling problem (JSSP) that minimises two single objective functions: makespan and total weighted tardiness. The proposed algorithms aim to enhance the efficiency of the search by dynamically balancing exploration and exploitation ability in DE and avoiding the problem of premature convergence. |
| 11 | 2013 | M. Ziaee | Job shop scheduling with makespan objective: A heuristic approach | Developed a heuristic method to minimize makespan for different jobs in a job shop scheduling. The proposed model is based on a constructive procedure to obtain good quality schedules very quickly. |
| 12 | 2014 | D. Tuan , et al. | Dual Hybrid Algorithm for JSSP Problem | A genetic algorithm (GA) combined with the dual hybrid approach to obtain a new genetic algorithm GTD-GA. The algorithm proposed new hybrid approach called dual hybrid. |
| 13 | 2014 | P. Chuan Ma,et al. | A hybrid particle swarm optimization and simulated annealing algorithm for job-shop scheduling | A new hybrid algorithm based on traditional particle swarm optimization (PSO) algorithm for addressing a JSSP is proposed. Firstly, a particle encoding is designed to reduce the range of solution space. Secondly, a simulated annealing operator combined with local search operator is immersed into the algorithm to extricate itself from local optimal solution. |

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| --- | --- | --- | --- | --- |
| 14 | 2014 | A. Somani | Parallel Genetic Algorithm for solving Job-Shop Scheduling Problem Using Topological sort | Parallel Genetic Algorithm (PGA) by using Topological Sorting, which is able to improve the solution of JSSP. The proposed algorithm minimizes the execution time for makespan calculation by using PGA. Proposed PGA applies parallel topological sort on initial populations to generate linear sequences. After that whatever acyclic schedules come, it applies crossover mutation on that and finally calculates the minimum makespan parallel for each linear sequence in optimal time. |

# 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.

## Traditional Techniques

Conventional techniques are also known as optimization techniques. These techniques are apathetic and ensure guarantee 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 elasticity due to 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 alikeness methods. These methods are very vigorus 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)).

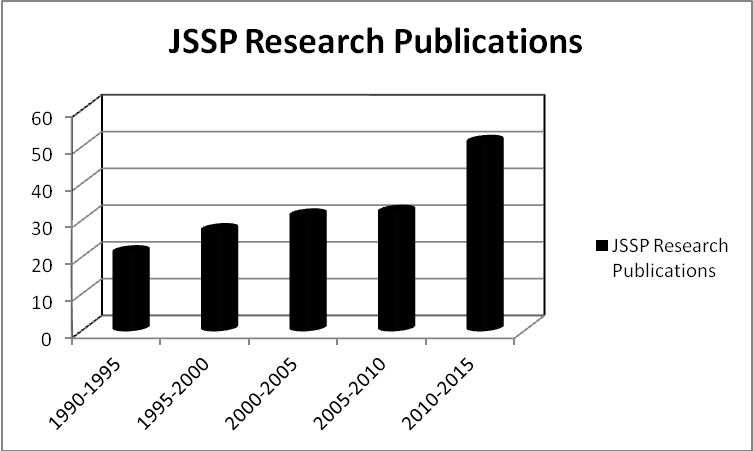
*Benefits of Non-Traditional Techniques*

1. Non traditional methods provide global optimal solutions for scheduling.
2. Search area for optimal solution is quite large.
3. 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. Efficiency of a Non-Traditional algorithm depends on two goals such as exploration and exploitation.

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



# conclusion

Since job shop scheduling problems fall into the class of NP-complete problems, they are among the most difficult to formulate and solve. Some optimization problems (including various combinatorial optimization problems) are sufficiently complex that it may not be possible to solve for an optimal solution with the kinds of 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 structure and strategy guidelines for designing a specific heuristic method to fit a particular problem. A key feature of these metaheuristics procedures is their ability to escape from local optima and perform a robust search of a feasible region. This paper introduces the most prominent types of non-conventional type algorithms or meteheuristics.

Job shop scheduling problems are the most important because it impacts the ability of manufacturers to meet customer demands and make a profit. It also impacts the ability of autonomous systems to optimize their operations, the deployment of intelligent systems, and the optimizations of communications systems. For this reason, operations research analysts and engineers will continue this pursuit well into the next coming centuries.

VII. FUTURE SCOPE

The present day manufacturing systems place tremendous emphasis on automated systems like CNC, FMS, CIM and manufacturing strategy from lean to lean-agile to improve productivity, flexibility and adaptability of the system. In such situation, new scheduling methods have been adopted in consistent with the manufacturing systems such as JSSP. This Review paper shows different Non-Traditional method 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 extension of JSSP by using these Non-Traditional methods.

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