Identification of a Heuristic Which Maximizes Percentage Utilization of Machines in a Job Shop Problem

P. D. D. Dominic

Abstract

This paper discusses a set of heuristic algorithms used to maximize the percentage utilization of machines in a Job shop scheduling (JSS) problem. Job shop scheduling environment consists of a set of machines and a collection of jobs to be scheduled. Each job consists of several operations with specified processing order. In this paper, Genetic Algorithm (GA), Simulated Annealing (SA) and Hybrid Simulated Annealing (HSA) algorithms are used for the objective measure of utilization of machines in Job Shop Model problem. These three algorithms are considered as different treatments of each problem and are compared. The conclusion is that percentage utilization of machine is maximum in most of the cases under Genetic Algorithm when compared with other two algorithms.

Keywords : *Job shop scheduling, Genetic Algorithm, Simulated Annealing, Hybrid Simulated Annealing and Percentage utilization of machines.*

Introduction

Manufacturing scheduling problems are classified into four categories: single machine scheduling problem, flow shop scheduling problem, job shop scheduling problem and open shop scheduling problem. The author considered the job shop-scheduling problem that is more challenging environment for his research in this paper. In today's global competition in the manufacturing sector, batch manufacturing has become popular in any organization. This is mainly due to shortened product life cycles and increased demand for product variety. According to French (1982) the general problem is to find a sequence, in which the jobs (e.g., a basic task) pass between the resources (e.g., machines), which is a feasible schedule and optimal with respect to some performance criterion. The machine scheduling problem is a rich and promising field of research. Traditionally, job shops are used for such task. The classical job shop scheduling problem is one of the best known machine scheduling problems (Kenneth 1984). The fundamental job shop scheduling problem is one of determining a job sequence schedule subject to restrictions on the order in which the jobs can be performed, which will minimize the objective of an organization. This method of solution is devised by Giffler and Thompson (1960).

The algorithm of Giffler and Thompson (GT) can be considered as a common basis of all Priority Dispatch Rule (PDR) (Haupt 1989) based heuristics. Oliver Holthaus (1997) proposed an efficient PDR, which probably the most frequently applied heuristic for solving job shop scheduling problem because of their ease of implementation and their low complexity.

A priority rule allows an idle machine to select its next operation from among those available. If there are two or more contenders for the same machine at any one time, a conflict will occur which is resolved by choosing only one of the contenders to be processed next on the machine, at no time. Conflicts among operations competing for the same machine are solved using set of PDR one by one, if all conflicts are resolved and active feasible schedule is generated.

The following seven time-independent priority dispatch rules like the Shortest Processing Time, The Longest Processing Time, The Fewest number of operations remaining, The Greatest number of operations remaining, The

Least Work Remaining, The Most Work Remaining, The Earliest Due-Date are taken as the gene number from one to seven are used whenever conflict operations occur.

Literature Review

Panneerselvam (2005) proposed a simple heuristic in a single machine-scheduling problem to minimize total tardiness. The accuracy is compared with the optimal solution of set of randomly generated problems using an ANOVA experiment and observed that the solution of the simple heuristic does not significantly form the optimal solution.

There are a number of approaches and procedures in the job shop scheduling literature. Singh and Bochynek (1997) compared several modern heuristic search methods like Genetic Algorithm, Simulated Annealing, Tabu Search and Hybrid Search with respect to standard cell placement on VLSI design, sequencing problem in terms of makespan criterion and computational time.

Dorndorf and Pesh (1993) proposed a Genetic Algorithm based on the idea of using a chain of priority dispatch rules, which fit the needs of a particular problem instantly. Within the GA each gene represents a priority rule from the set of priority rules.

Sridhar and Rajendran (1996) addressed a GA for part family grouping and scheduled the parts within the part families in a flow line based manufacturing cell. In their contribution, the objectives of makespan and total flow time have been considered independent and together. The proposed methodology is compared with the existing SA heuristic and indicated that GA fares better than SA in minimizing both makespan and total flow times.

Chen et al. (1995) proposed a GA based heuristic for flow shop problems with makespan as the criterion and compared the efficiency among the proposed GA heuristic with other algorithms. Their results reveal that the GA based heuristic is an effective method for flow shop problems and can be applied to any hard optimization problems.

Ponnabalam and Jawahar (1999) proposed to solve job shop scheduling problems with the makespan objective. Three perturbation schemes are used to study the effect on the problems considered. These are pairwise exchange, insertion and random insertions. The performance of the SA has been compared with the GA. The results are encouraging. The SA often gives better results. The CPU time is also very close to the time of Genetic Algorithm.

Dominic and Kannabiran (2003) proposed to solve job shop scheduling problems with the Mean tardiness objective. Four Meta heuristics are compared on the measure of mean tardiness. Their results reveal that GA based heuristics outperformed when compared with other algorithms like SA, HSA and Iterative methods. These four methods are considered as different solutions for each problem. Douglas (1991) two-way analysis of variance (ANOVA) and Duncan's Multiple Range test are applied to test its significance and proposed that they are significant.

Genetic Algorithm (Type 1)

Biegel and Davern (1990) showed the method of applying genetic concepts to scheduling problems. Randomly generated priority dispatching rules are taken. While solving job shop problem conflict may occur in some stages. For the first conflict, the first gene in the chromosome is taken as PDR to resolve the conflict, second gene is chosen to resolve the second conflict and so on. If conflict number exceeds the chromosome size, the researcher chose the size of seven PDR again the first gene is selected to resolve the eight conflicts. The process is repeated until the entire operation is scheduled. This PDR chromosome set undergoes GA process for a given number of generations. The better value of objective measures and corresponding chromosome is selected as a chromosome set.

Simulated Annealing (Type 2)

In this method, randomly generated chromosome is the initial seed and it represents a schedule as a sequence of operations, and each gene stands for one operation. For a 'n' job with 'm' machine problem, a chromosome contains n * m genes. Each job appears in the chromosome exactly m times, and each repeating (each gene) does not indicate a concrete operation of a job but refers to an operation which is context dependent.

Consider the three job three machine problem, a chromosome is given as [3 2 2 1 1 2 3 1 3] where 1 stands for job J1, 2 for job J2, and 3 for job J3. Because each has three operations, it occurs exactly three times in the chromosome. For example, there are three 2's in the chromosome, which stands for the three operations of job J2. The first 2 corresponds to the first operation of job J2 which will be processed on machine 1, the second 2 corresponds to the second operation of job J2 which will be processed on machine 3, and the third 2 corresponds to the third operations for job J2 which will be processed on machine 2. We can see that all operations for job J2 are named with the same symbol 2 and then interpreted according to their orders of occurrence in the sequence of this chromosome. According to these relations, corresponding machine list is obtained.

Hybrid Simulated Annealing (Type 3)

In this method the better operation sequence obtained from Genetic Algorithm is given as an initial seed chromosome. According to the chromosome, sequence operations of the job are scheduled. The objective function like percentage utilization of machines is obtained.

Numerical illustration

In this section, all three algorithms of scheduling job shop namely, Genetic Algorithm, Simulated Annealing and Hybrid Simulated Annealing methods are compared using the performance measures namely Percentage Utilization of machines. The performance measures are generated using simulation. The consolidated results are given in the form of tables and comparative graphs.

Percentage Utilization Of Machines - A Comparison

All the algorithms are compared based on the objective measure Percentage Utilization of Machines. For this comparison a sample of twenty problems was taken. The consolidated results are given in the form of tables and comparative graphs. The values are tabulated in Table 1.

From **Table 1,** it can be inferred that the Percentage Utilization of Machines is maximum in most of the cases under Genetic Algorithm. Out of 20 problems, 17 times it got the maximum percentage utilization of machines, when compared with the other two algorithms. For the Second and Third positions there is a tough competition between the algorithms of Hybrid Simulated Annealing and Simulated Annealing method respectively.

From **Figure 1,** it is evident that Genetic Algorithm performs better than Simulated Annealing and Hybrid Simulated Annealing Methods for the objective function namely Percentage Utilization of Machines. Out of 20 problems, 17 times it got the maximum percentage utilization of machines, when compared with the other two algorithms

From **Figure 2,** it is proved that the performance of Genetic Algorithm is better than Simulated Annealing for the objective function namely Percentage Utilization of Machines. Out of 20 problems, 19 times it got the maximum percentage utilization of machines, when compared with Simulated Annealing algorithm.

From **Figure 3,** it is clear that Hybrid Simulated Annealing Methods is better than Simulated Annealing for the objective function namely Percentage Utilization of machines. Out of 20 problems, 17 times it got the maximum percentage utilization of machines, when compared with Simulated Annealing algorithm.

From **Figure 4,** it is clear that Genetic Algorithm is better than Hybrid Simulated Annealing for the objective function namely Percentage Utilization of Machines. Out of 20 problems, 16 times it got the maximum percentage utilization of machines, when compared with Hybrid Simulated Annealing algorithm.

The performances of the algorithms are tested using simulation models. The factors and the levels of experimentation are obtained. Five replications in each problem type are taken into consideration with the different factors. All three Meta heuristics like Genetic Algorithm, Simulated Annealing and Hybrid Simulated Annealing methods of scheduling job shop. The numbers of machines are 10, 6 and 5 are taken as the second parameter. Those are compared using ANOVA and DUNCON'S multiple range tests for the performance measure namely Percentage Utilization of Machines with 5% level of significance. The result shows that there will be a significant effect on the performance measure namely Percentage Utilization of Machines. The GA performs better than all other two algorithms in terms of the performance measurement.

CONCLUSION

It is well known that the determination of a sequence, which has the maximum percentage utilization of machines on the job shop environment, is a combinatorial problem. Hence, researchers have developed several heuristics for this type of problem. In this paper an attempt has been made to develop a comparison between the meta heuristics like operation based and priority dispatch rule based Genetic Algorithm (GA), Simulated Annealing (SA) algorithm and Hybrid Simulated Annealing are applied to schedule a job model and its programming was implemented using Turbo C. These three are considered as different types of treatments of each problem and are compared with the objectives of Percentage Utilization of Machines in a job shop environment. Genetic Algorithm performs better than other two algorithms namely Simulated Annealing and Hybrid Simulated Annealing. In industries, practitioners can quickly implement this Genetic algorithm that gives very good results, whereas they will find it difficult to compare with all Meta heuristics.

Table 1
Comparison of algorithms with the objective of Percentage Utilization of Machines

Sl.No	GA	SA	HSA
1	0.77	0.64	0.63
2	0.68	0.57	0.65
3	0.65	0.54	0.60
4	0.69	0.60	0.63
5	0.71	0.62	0.60
6	0.65	0.55	0.63
7	0.68	0.57	0.61
8	0.62	0.53	0.59
9	0.70	0.55	0.59
10	0.71	0.56	0.62
11	0.64	0.60	0.64
12	0.66	0.50	0.59
13	0.59	0.54	0.58
14	0.67	0.51	0.55
15	0.86	0.83	0.88
16	0.89	0.74	0.85
17	0.97	0.86	0.82
18	0.86	0.74	0.86
19	0.77	0.85	0.87
20	0.68	0.61	0.63

Figure 1
Comparative graph GA, HSA and SA for Percentage Utilization of Machines

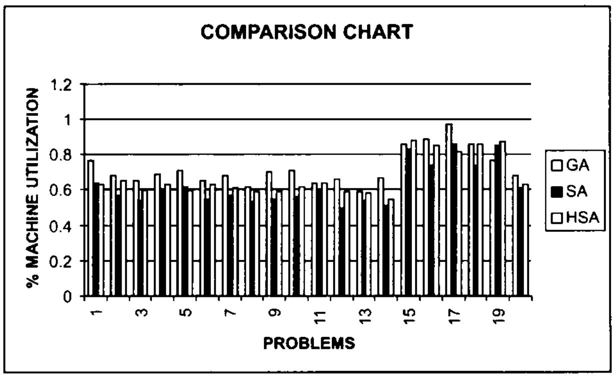


Figure 2
Comparative graph GA and SA for Percentage Utilization of Machines.

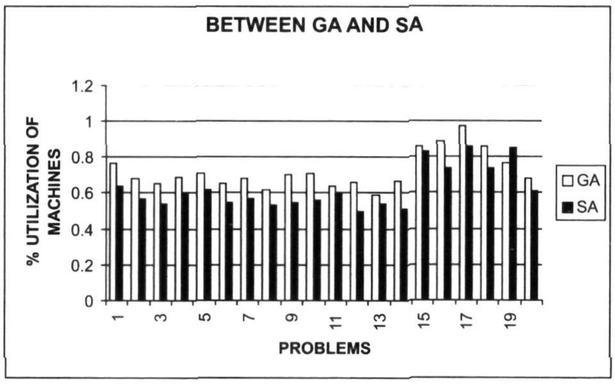


Figure 3
Comparative graph HSA and SA for Percentage Utilization of Machines.

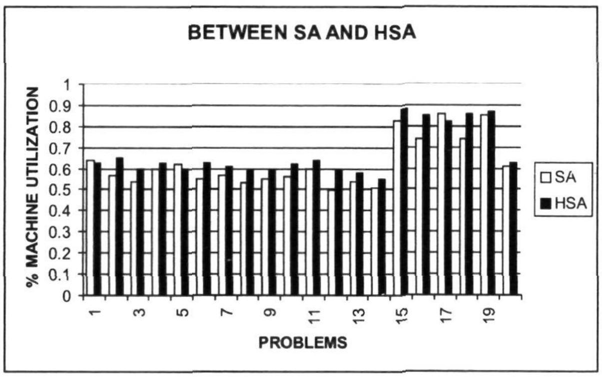
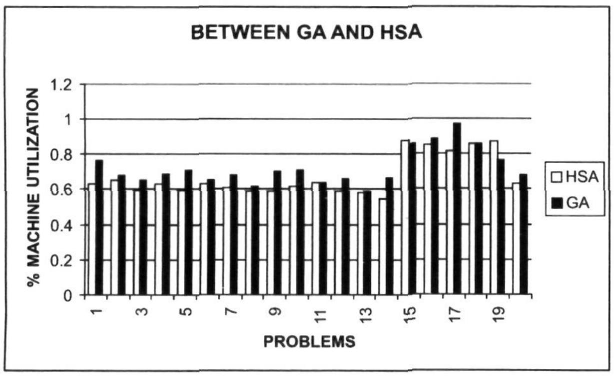


Figure 4
Comparative graph HSA and GA for Percentage Utilization of Machines.



References

Biegel, J.E., James J. Davern., (1990), Genetic Algorithms and job shop scheduling. *Computers Industrial Engineering,* Vol.19 Nos.1-4: pp 81-90.

Chen, C.L., Vempati, V.S., Aljaber, N. (1995) Theory and methodology: An application of Genetic Algorithms for Flow Shop Problems, *European Journal of Operational Research,* 80 pp. 389-396.

Dominic, PDD., and Kannabiran, G., (2003), The Objective Measure of Mean Tardiness Compared with different Meta Heuristics in a Job Shop, *Udyog Pragati - The Journal for practicing managers,* Vol. 27, No.4, pp: 1-6.

Dornorf, U., Pesch, E. (1993), Combining Genetic and Local Search for solving the *job shop scheduling problem,* APMOD93 Proceedings, Budabest: pp.142-149.

Douglas C. Montgomery, (1991), Design and analysis of experiments, *John Wiley & sons,* inc., second edition.

French S., (1982), Sequencing and Scheduling, New York , Halsted Press.

Giffler B., Thompson, G.L.,(1960), Algorithms for Solving Production Scheduling Problems. *International Journal of Operations Research,* No. 8: pp 487-503

Haupt, R.,(1989), A survey of priority rule based scheduling, *Operations Research Spektrum,* No. 11: pp 3-16.

Holthaus, O., Ziegler, H.,(1997), Improving Job Shop Performance by Coordinating Dispatching Rules, *International Journal of Production Research,* Vol. 35, No. 2: pp. 539-549.

Kenneth, R. Baker., (1984), Sequencing Rules And Due-date Assignments in a Job Shop, Management Science, Vol. 30, No. 9, pp: 1093-1103.

Oliver Holthaus., Chandrasekharan Rajendran., (1997), Efficient Dispatching Rules for Scheduling in a Job Shop, *International Journal of Production Economics,* No.48, pp:87-105.

Panneerselvam, R. (2005), Simple heuristic to minimize total tardiness in a single machine scheduling problem. *International Journal of Advanced Manufacturing Technology,* Springer- Verlag London Limited 2005.

Ponnambalam, S.G., Jawahar, N., Aravindan, P. (1999), A Simulated Annealing Algorithm for job Shop Scheduling. *Production Planning and Control,* No.10,: pp. 767-777.

Singh, K., Bochynek, R. (1997), Comparison of Heuristic search methods for Sequencing problems a Computational study, *Proceedings of the first international conference on operations and quantitative management,* Jan. 5-8, jaipur (India) : pp. 451-458.

Sridhar, J., Rajendran, C. (1996), A Genetic Algorithm for family and Job Scheduling in a Flow line based manufacturing cell, *Proceedings of 16th International Conference on Computers and Industrial Engineering,* March 7-9,: pp. 337-340.

About the Author :
P.D.D.Dominic is a Senior Lecturer at the Department of Management Studies, National Institute of Technology, Tiruchirappalli.
He can be reached at dominic@nitt.edu (or) pdddominic@yahoo.com