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Meta heuristic optimization algorithms used in flexible manufacturing techniques: A review

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Abstract

Analysis and modeling of flexible manufacturing system (FMS) consists of scheduling of the system and optimization of FMS objectives. Flexible manufacturing system (FMS) scheduling problems become extremely complex when it comes to accommodate frequent variations in the part designs of incoming jobs.
In this paper different evolutionary algorithms are used in literature to estimate possible performance parameters like maximum production rate, make span time and overall utilization. Through this study, an effort is also made to present the improved design for existing flexible manufacturing system employed. Various design and performance parameters are then evaluated and compared for the existing and improved FMS.

Keywords: Meta heuristic optimization. , Flexible Manufacturing Techniques

1. Introduction

Scheduling is one of the most significant fields in production engineering. It is the decision-making process in which resources are allocated over a span of time to perform a collection of tasks. The goal of scheduling is to make it optimal by selecting such as best resource for each operation, the process sequence for each resource and the beginning time.
FMS has gradually grown as a solution to methodical mid-volume production of a heterogeneous part types with less setup time, low inventory, short lead time, low work-in-process, high quality and high machine utilization. (Veeranna.V, 2002). Job-shop scheduling problem is one of the hardest combinatorial optimization problems (Jain and Meeran, 1999) in the scheduling. The classical Job-shop scheduling consists of scheduling a set of jobs on a set of machines with the objective to minimize any criterion. It is well known fact that this problem is NP-hard (Garey et al., 1976).The flexible job shop scheduling problem (FJSP) is the simplification of the classical job shop problem, where operations are allowed to be processed on any machine from a given set along dissimilar routes. Flexible job shop scheduling problem possess many applications in viable environment. Evolutionary Algorithms (EAs) has engrossed notable consideration with respect to intricate scheduling problems, which also called evolutionary scheduling. Though, EAs differ in the nature of the particular scheduling problem and practical executions. In order to have an effective execution of EAs for production scheduling, this paper focus on making a literature survey of researches based on hybrid EAs.

2. Classification of scheduling problem

The classification of the literature based on the application of evolutionary Algorithms to scheduling problems is presented. There are six criteria: (A) type of FMS; (B) type of resources and capacity constraints; (C) job characteristics; (D) scheduling problem approached; (E) measure of performance; (F) utilized approach.

2.1 Types of FMS

The FMS environment divided into five subtypes proposed by Mac carthy and Liu (1993a).

2.1.1 SFM (single flexible machine)

A CNC with tool-changing capabilities and a material handling and storage system.

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2.1.2 FMC (flexible manufacturing cell)

It is composed of a group of single flexible machine with a single material handling system.

2.2.3 MMFMS (multi-machine flexible manufacturing system)

It had few single flexible machine connected by an automatic material handling system made up of two or more material handling sub-systems, making it possible to serve two or more machines simultaneously.

2.2.4 MCFMS (multi-cell flexible manufacturing system)

An FMS composed of several flexible manufacturing cells and possibly single flexible machines, all connected by an automatic material handling system.

2.3 Resources and constraints on the system

It is based on the research of McCarthy and Liu (1996), which state resource types using the following details: machines (M), storage buffers (SB), material handling devices (HD), tool-changing devices (TD), fixtures (FX) and pallets (PL). Constraint on the system capacity depends on the number of each kind of resources. If the capacity of a specific resource is unlimited, then it does not represent a constraint on the studied scheduling problem (McCarthy and Liu (1996))
The third criterion supported the work of MacCarthy and Liu (1996) and classifies the jobs according to intricacy. The measure of intricacy is predicted on the number of operations in each job. Two choices are possible.

- JC1 (job complexity = 1): every job contains one operation;
- JC+ (job complexity>1): some or all jobs contain two or more operations;

The third criterion also classifies the jobs according to routing flexibility, which may assume two values:

- RF1: there is just one machine enabled to perform a one operation;
- RF 2: there are more than two machines allowed to perform one or more operations.

3. Literature review

J. Jerald et.al[1] devised different scheduling mechanisms to generate optimum scheduling; these include evolutionary approaches such as genetic algorithm (GA), memetic algorithm (MA) , simulated annealing (SA) algorithm and particle swarm algorithm (PSA) considering multiple objectives, i.e. minimizing the idle time and the total penalty cost for not meeting the due date. The results of the different optimization algorithms (memetic algorithm, genetic algorithm, simulated annealing, and particle swarm algorithm) are compared and conclusions is made that PSO algorithm is found to be of better-quality and gives the minimum of combined objective function. Hence it is evident that the procedures developed in this work can be suitably modified to any kind of FMS with a large number of components and machines subject to multi objective functions.
Anshuman Mishra et.al. [2], made an effort to consider simultaneously the machine and vehicle scheduling aspects in FMS and tackle the problem of make span minimization using particle swarm optimization (PSO).For the same objective function PSO gives better optimization than GA The no of iteration required in case of PSO is very less in comparison to GA. As the number of variables are increased the optimal properties of the PSO change in a much more expected manner than those of GA.
Ajay Singholi et.al. [3], enhanced the performance of manufacturing system in Indian industry. The evaluation of parameters in this case study are from a universally accepted mathematical model given by Solbergiv, (1981). The performance parameters of the manufacturing firm's present conventional manufacturing system were calculated analytically. A new FMS model is anticipated by reducing the number of servers to an optimum number. The new FMS model shows an improved machine utilization and reduced workload per machine. There is a significant increase from 11 to 30% to 80 to 100% in the proposed model. Ajay Singholiet.al [4], made an effort to present the improved design for existing flexible manufacturing system employed in the company. Various parameters are evaluated and compared for the existing and improved FMS. Main reason was to analyze the existing system and to improve the performance of system.
Quantitative modeling, simulation modeling have been used to achieve the objectives. At first various operational and performance parameters were calculated then the new FMS has been proposed with the optimum number of servers. The overall system utilization increased 88.53% to deliver 99.99%.. The management have better approach and rules for various decisions relating to process and operations improvement and investment in new facility. Future aspects are to conduct various simulation experiments so that system would be tough enough to handle all situation and vibrant market conditions.
Amir Musa Abazari et.al [5] proposed a linear mathematical programming model with both continuous and zero-one variables for job selection and operation allocation problems in an FMS to maximize profitability and utilization of system. The proposed model assigns operations to different machines considering capacity of machines, batch-sizes, processing time of operations, machine costs, tool requirements, and capacity of tool magazine. A genetic algorithm (GA) is then proposed to solve the formulated problem. Performance of the proposed GA is evaluated based on some bench mark problems adopted from the literature. A statistical test is conducted which implies that the proposed algorithm is robust in finding near-optimal solutions. Comparison of the results with those published in the literature indicates supremacy of the solutions obtained by the proposed algorithm for attempted model. This paper presents a mathematical programming model for solving machine loading

problem in flexible manufacturing systems. The proposed model takes into account many practical parameters including capacity of machines, capacity of tool magazine, tool requirement of different operations, and over-utilization and under-utilization costs of machines. An effective solution approach based on genetic algorithm is presented to solve the formulated model. Some benchmark problems adopted from the literature are solved by the proposed GA. Computational results indicate that the proposed model provides very promising solutions compared with those available in the literature. It is worth noting that application of the proposed model is limited to certain cases where there are sufficient number of jigs, fixtures, pallets and material handling devices in the shop floor. The work may be extended further by imposing constraints on the availability of these resources. Solution of the attempted problem identifies assignment of machines to different operations of the selected jobs. This solution should then be used to determine the sequence of jobs on different machines. This problem is addressed as the scheduling in the literature. This issue can be attempted in future researches to yield more efficient utilization of resources.

A.V.S.Sreedhar et .al.[6], used state of art techniques to establish Optimization methods like GA, D.E. and BFOA algorithms .optimization process is automated by using a MATLAB based GUI that is user friendly. 43 jobs- 16 machines are used for obtaining result. Results obtained by the different approaches are compared and the performances are analyzed for the combined objective function of minimizing total penalty cost and minimizing total machine idleness. BFOA algorithm gave better results and gives the minimum combined objective function. They have also evaluated the effectiveness of combined objective function in which the penalty value is moderated by the inclusion of reward. The inclusion of reward has improved the merging of the evolutionary algorithms in finding the optimum schedule.

R. Tavakkoli-Moghaddam et.al. [7], used a class of FMS known as flexible manufacturing cell. A new HGA-based approach is proposed to schedule jobs and AGV for minimizing make span and maximum tardiness, simultaneously. It used Visual C++ and run for problems of different sizes. One of the best advantages is the required time to solve medium to large size problems that is essential issue in industries. It will be a new opening for future research, this work can be further continued by applying other heuristic methods separately or in addition with HGA algorithm.

Mani Shivhare and Sunita Bansal [8] used Particle Swarm Optimization (PSO) technique for optimizing the bidirectional loop layout of flexible manufacturing system. The main aim of the research was to minimize the number of backtracking and the distance travelled by AGV in loop layout only. It is an efficient algorithm for solving these problems. A generalized approach of plant layout was proposed which was better than other optimization techniques like Genetic Algorithm and Simulated Annealing used in other research papers.

Nidhish Mathew et.al. [9], used Multi-objective Non-Dominated genetic algorithm (NSGA-II) for optimization. FMS schedule is obtained for 40 jobs and 32 machines. Two objectives i.e. minimizing total penalty cost and minimizing total machine idle time are achieved using NSGA-II. For the given set of objectives, the results obtained by the NSGA-II-based algorithm were compared with a number of existing algorithms including CS, SPT, and PSO (found in literature), and the results of NSGA-II-based algorithm is found to be superior than modified to any kind of FMS with a large number of components and machines. Future work will include or as good as the best results obtained by the aforementioned methods. After 3000 generation the best solution is obtained. The problem of computational effort of FMS scheduling increases in proportion to the number of components. In the case of 40 components 159152832478977343 4561126959612e+47combinations are possible. Due to the very high computational effort exhaustive search is not possible. Similarly random search also requires a lot of computational effort. By implementing genetic algorithm for 3000 generations, only 1.5 lakh computations are needed for getting the optimal solution. The research work leads to the conclusion that NSGA II is superior in terms of computational effort and pare to optimal front. The procedure developed in this work can be suitably the availability and handling time of load unloading stations, robots and AGV's. Gaurav Kumar and Dr. Trilok Singh Bisoniya, [10] used a simulation modeling and optimization of FMS objectives for evaluating the effect of factors such as demand arrival time,. System utilization and throughput both are affected by these factors. It is observed that from comparing the result maximum percentage of utilization is 10% against of throughput parameters. System utilization and throughput is more affected by demand arrival time comparatively other three factors like no. of AGVs, velocity of AGVs, and distance preference between two work stations used in system. Distance preference also affects throughput and system utilization. For both system utilization and throughput distance preference should be smallest and as the demand arrival time increases both system utilization and throughput of system decreases. Based on the limitation of the floor and material handling path different layout patterns may be considered for FMSs. In the cases that there is not enough space for straight line layout (single row),

Sadegh Niroomand et.al. [11], addressed a new meta-heuristic algorithm to solve a closed loop layout problem. The proposed algorithm applies a modified version of the recently invented migrating birds optimization method. The computational experiments show that in most of the benchmark problems the results obtained from the proposed migrating birds optimization method is better than those obtained by other methods which are published in the literature. Open-field and closed loop layouts may be useful. The closed loop layout pattern is even more useful where Automated Guided Vehicles (AGVs) are used to move the material. An exact MILP model of closed loop layout from the literature was tackled in this study. The NP-hardness of the model is the main limitation of previous study (Niroomand & Vizvári, 2013) and this study which make the model difficult to give a good feasible solution especially for the case of large size problems. A recently introduced meta-heuristic algorithm (MBO) was modified (MMBO) in this paper to solve the closed loop layout model. The proposed MMBO algorithm uses some natural and logical rules to solve the model. The algorithm mixes the logics of geometry and human thinking to arrange the cells

around a rectangular closed loop without any overlap by use of logical functions in computer programming. On the other hand, the natural behavior of birds when migrating, is applied in a computer program to construct the proposed algorithm. To test the performance of the proposed MMBO algorithm, the standard form of the MBO and SA algorithms were also simulated.

Ranbir Singh, Rajender Singh and B.K. Khan [12], discussed various Mathematical, heuristics, hierarchical approaches, global optimization techniques and network modelling. Which have been widely used for solving the formulated problems. Because of less computational requirements, easy and fast convergence, better ease of apply, less time requirements are some of the factors attracting the researchers to use global optimization techniques for solving the mathematical or other model of the loading problems and other problems and FMS's. The authors after spending a lot of time on analyzing and studying the research papers, books, Ph.D. thesis and other relevant materials suggests integer programming for modelling the loading problems and PSO for solution of the model. To analyses the system performance and to provide insight of how the system behaves, and how system component behaves, and to identify the key factors and parameters affecting the system, modelling and simulation of the physical system is the only best solution. Various types of results, graphs, plots etc can be generated for useful analysis of the system. The key to be remembered is that the validity and accuracy of the result will depend on the model developed, and the information induced in the model (value of parameters and key variables). It is the human who developed the model and it is him only to validate and validate the results. The software or model will give the results in the type the user wants. Validation, accuracy and acceptance of the results depend on the user. The modelling simulation and analysis can be expensive and time consuming to develop and run for desired accurate and acceptable results and outputs. An ideal model should be least expensive which should require least computational time. A research work is required to compare the various modelling techniques on basis of certain parameters, which will help the industry and academicians in selection of the type of modelling techniques under certain parameters and constraints.

M. NageswaraRao, K. Narayana Rao b and G. Ranaga Janardhana[13], examined the importance of simultaneous scheduling of machines and two identical automated guided vehicles (AGVs) in a flexible manufacturing system (FMS).Optimum AGVs operation plays a crucial role in improving the performance of FMS. A hybrid meta heuristic algorithm is proposed and developed the code in JAVA to provide optimum. Sequence with relative makespan value and AGVs schedule for ten job sets and four lay outs. The code will enhance the productivity, minimize the delivery cost and optimally utilize the entire fleet simultaneous scheduling of machines and AGVs adopting minimization of relative makespan function, provide better performance when compared with other algorithms.

Yedem Muni Ratnam, K Mohan Krishna, P.Giribabu [14] presented a Genetic Algorithm based scheduling of Flexible manufacturing system. This work considered multiple objectives, i.e., minimizing the idle time of the machine and minimizing the total penalty cost for not meeting the deadline concurrently. Software is developed for getting optimum sequence of operation. FMS considered in this work has 16 CNC Machine tools for processing 43 varieties of products. Various meta-heuristic methods are used for solving same scheduling problems taken from the literature. The results available for the various existing meta-heuristic methods are compared with results obtained by GA. After 1700 generations of GA the global optimum schedule is obtained. R Kumar et.al, used the ant colony optimization (ACO) technique for scheduling in FMS. Since the operation of a job in FMSs can be performed on more than one machine, the scheduling of the FMS is considered as a computationally hard problem. The proposed solution procedure applies a graph-based representation technique with nodes and arcs representing operation and transfer from one stage of processing to the other. Individual ants move from the initial node to the final node through all nodes desired to be visited. The solution of the algorithm is a collective outcome of the solution found by all the ants. The pheromone trail is updated after all the ants have found out their respective solutions. Various features like stagnation avoidance and prevention from quick convergence have been incorporated in the proposed algorithm so that the near-optimal solution is obtained for the FMS scheduling problem, which is considered as a non-polynomial (NP)-hard problem. The algorithm stabilizes to the solution in considerably lesser computational effort. Extensive computational experiments have been carried out to study the influence of various parameters on the system performance. S. Karthikeyan et.al. [15], emphasized that Firefly Algorithm (FA) a nature-inspired optimization algorithm can be successfully applied to continuous optimization problems. A hybrid discrete firefly algorithm (HDFA) is proposed to solve the multi-objective flexible job shop scheduling problem (FJSP). FJSP is an extension of the classical job shop scheduling problem that allows an operation to be processed by any machine from a given set along different routes. Three minimization objectives - the maximum completion time, the workload of the critical machine and the total workload of all machines are considered simultaneously. It also proposes firefly algorithm's discretization which consists of constructing a suitable conversion of the continuous functions as attractiveness, distance and movement, into new discrete functions. In the proposed algorithm discrete firefly algorithm (DFA) is combined with local search (LS) method to enhance the searching accuracy and information sharing among fireflies. The experimental results on the well-known benchmark instances and comparison with other recently published algorithms shows that the proposed algorithm is feasible and an effective approach for the multi-objective flexible job shop scheduling problems.

4. Conclusion

In this paper, a survey of researches based on using evolutionary techniques used for production scheduling problems. The interdependence of the jobs/operations sequence and machine assignment make scheduling a formidable combinatorial problem. EAs got the wide attention of researchers because of its

intelligent, parallelism, robustness and good adaptability and the capability of global search.

However, EAs differ in the implementation details and the nature of the particular problem applied; EAs guided new individuals by semi random operators, through mutation and/or recombination, suffers from low efficiency. In this paper, firstly, for the scheduling optimization, it is usually necessary to examine whether we can build an effective genetic search with the encoding in EAs. Paper has summary of the advantages (and disadvantages) of various representations for scheduling problems. The hybrid algorithms design with priority dispatching-based heuristics, critical path-based local search and parameter adaptation. During the search process, the EAs can store ample data about the search information, population information and problem features. As a future research evolutionary algorithms with machine learnings is an interesting field that is able to give us more insights regarding the evolutionary behavior and potential advantages by applying to manufacturing scheduling problems.

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