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FMS scheduling using AGVs by soft computing techniques: A Review

R.S. Mishra[1] Gayathri Devi. K[2] . A.K Madan[3]

Department of Mechanical and Production Industrial and Automobiles Engineering, Delhi Technological University, Delhi, India
[1]Professor & Dean, [2] Research Scholar, [3] Professor

Abstract

Scheduling in flexible manufacturing Systems is one of the most sought out topic for researchers. There have been abundant research papers in this area over the past two decades. Various approaches have been adapted to schedule FMSs like simulation and analytical methods. In this paper, the literature dealing with the parts scheduling problem in flexible manufacturing systems (FMS) has been reviewed. Although the parts scheduling problem is only part of much larger decision-making process, it has fundamental implications on the overall performance of the system: internally by affecting the utilization of expensive resources (e.g. machine tools and fixtures), and externally by affecting its responsiveness to meet the changing customer demands. This paper mainly deals with various Non Traditional approaches like Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Simulated Annealing (SA) etc. used for scheduling of FMSs.

Keywords: Non Traditional, Techniques, FMS, AGV, Scheduling

1. Introduction

From 1960 to 1970 the market competition became intense which lead to emergence of new concepts in manufacturing. First the cost became a priority then quality and speed of delivery became the ultimatum.

These priorities led to flexibility of the manufacturing system and in turn various number of comprehensive manufacturing strategies are found. Computer Integrated Manufacturing, Just in Time (JIT) manufacturing, factory automation, lean manufacturing, and Flexible Manufacturing Systems are few to be named. There are various definitions of FMS throughout the literature. Simply it can be said

"FMS consist of a group of work stations mostly CNC interconnected by means of an automated material handling and storage systems and controlled by an integrated computer control system". A flexible manufacturing system (FMS) is a discrete-event system consisting a set of versatile machines, an automatic transportation system, a decision-making system, multiple concurrent flows of job processes that make different products, and often exploits shared resources to reduce the production cost [2]. The purpose of a FMS is to manufacture several kinds of parts, at low to medium volumes, efficiently. All activities in the system like metal cutting, monitoring tool wear, moving parts from one machine to another, setup, inspection, tool adjustment, material handling, scheduling and dispatching are under precise computer control. In general, an FMS can be characterized by various types of inherent flexibility such as process flexibility, routing flexibility, volume flexibility and machine flexibility [1]. The behavior of a FMS is extremely complicated and it has been difficult to analyze it theoretically. Thus, a FMS simulation system is often used to analyze the behavior of FMS on system design, performance and reliability evaluation, production planning, and so forth [3]. One of the major problems in simulating FMS is to describe stochastic behavior, such as failures of machine tools, repair time, and variations of processing time. In general, it is difficult to model the stochastic processes in which related complicated uncertain events are included [3].

1.1 Scheduling

The scheduling procedure of arriving tasks is achieved by running the FMS in real time; i.e., scheduling operations one at a time as each machine becomes available, according to the appropriate dispatching rules. This poses a unique and

Corresponding author: Prof. R.S. Mishra
Email Address: hod.mechanical.rsm@dtu.ac.in

challenging problem in several ways. For example: (i) after a part is loaded, which machines should it visit and at what time should it be processed on specific machines? (ii) if a machine fails, how should the schedule is adjusted for each part in the system? This discussion on the scope and significance of the FMS scheduling problem reveals that decision-making at this level is very difficult and complex [1]. The FMS scheduling problem may be characterized as follows: in a manufacturing system that comprises M machines (work stations) the jobs arrive continuously in time. Each job consists of a specified set of operations that have to be performed in a specified sequence (routing) on the machines. The goal of schedules for processing the jobs on each of the M machines is to find the best solution with respect to the given flow time or due date-based objectives. The decision for loading a job on a machine, when the machine becomes free, is normally performed by the help of a dispatching (scheduling) rule. Over the last years, many dispatching rules have been proposed and studied by many researchers [2].

2. Different Methodologies

Scheduling in an FMS environment is more complex and difficult than in a conventional manufacturing environment (French, S. 1982), Scheduling of FMS is NP- hard scheduling problems. Therefore, determining an optimal schedule and controlling an FMS is considered as a difficult task.
FMS operations in literature could be classified in the following ways:

- Mathematical programming approach
- Multi-criteria decision making approach
- Heuristics oriented approach
- Control theoretic approach
- Simulation based approach.
- Artificial intelligence (AI) based approach

Recently, Several heuristic procedures such as dispatching rules (Durgesh Sharma-2012, Veeranna.V -2006), local search and meta-heuristics involving Genetic Algorithm (GA), Simulated Annealing (SA), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO) and Tabu Search (TS) have been developed for scheduling problems [Brucker, P. (1995]. No methods guarantee to find an optimal schedule, but have the ability to find near optimal solutions in a short time. Metaheuristic optimization algorithms are inspired by biological phenomena or natural phenomena. Some of the newly introduced algorithms include Bacterial Foraging optimization algorithm (BFOA), Biogeography-based optimization (BBO), Firefly optimization algorithm, Cuckoo search optimization galaxy-based search algorithm, and Spiral dynamics inspired optimization (SDA). All these algorithms have gained attention due to their simplicity to program, fast computing time, easy to implement, and possibility to apply to various applications. [5]
Following is the table of different literature in the scheduling problems for the past Eighteen years (2000-2018) and the methodologies that have been used has been clearly discussed.

S.No	Author	Methodology	Objective Function	Findings
1	Zhao, Chunwei Wu, Zhiming [2001]	Genetic Algorithm	To reduce tardiness	In this a genetic algorithm with the concepts of virtual and real operations are introduced. Chromosome coding and genetic operators of GAs are defined during the problem solving. A minimum weighted tardiness objective function is used to define code fitness, which is used for selecting species and producing a new generation of codes. Finally, they have given several experimental results.
2	Kumar, R Tiwari, M K Shankar, R [2003]	Ant colony optimization		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. 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
3	Noorul Haq, A. Karthikeyan, T. Dinesh, M. [2003]	Simulated annealing and modified GA	Minimize make span. Minimize the distance travelled and the number of backtracking movements in MHS scheduling.	The integrated scheduling of FMS, namely, the production scheduling conforming to the MHS scheduling, is addressed. An enumerative heuristic is used, namely Giffler and Thompson, which is an evolutionary combining a Genetic Algorithm (GA) and a stochastic neighborhood searchtechnique using a Simulated Annealing (SA) algorithm is employed.

4	Jerald, J. Asokan, P. Prabaharan, G. Saravanan, R. [2005]	Genetic algorithm (GA), simulated annealing (SA) algorithm, memetic algorithm (MA)	Minimizing the idle time of the machine, and minimizing the total penalty cost for not meeting the deadline concurrently	The authors have written the software in C language. Results are obtained for three types of problems: 10 jobs 8 machines, 20 jobs 15 machines and 43 jobs 16 machines. Results obtained by the different approaches are compared and the performances are analysed. Particle swarm algorithm is found to be superior and gives the minimum combined objective function.
5	Jerald, J. Asokan, P. Saravanan, R. Rani, A. Delphin Carolina [2006]	Adaptive GA	Minimizing penalty cost and minimizing machine idle time	The designed scheduling procedure with adaptive genetic algorithm software was developed in C programming language to conduct experiments. This nearest to optimal schedule for the FMS obtained by the AGA procedure was compared to the sequence obtained by GA. For the experimental problem, the sequence obtained by the AGA gives a minimum total penalty cost as well as a comparatively lower minimum machine idleness (i.e. maximum system utilization), and thus a minimum COF,
6	Srinoi, P. Shayan, E. Ghotb, F. [2006]	Fuzzy Logic Approach	Average machine utilization, meeting due dates, setup times, work in process and mean flow times	The job priority relationships for assigning operations to machines and relationships for a set of due dates and setup times of jobs have been developed mathematically and exemplified. Several experiments were conducted to investigate the feasibility and effectiveness of the proposed method. These examples demonstrate positive improvement and promising results. The performance of the new approach is superior to that of existing methods when using the same data.
7	Izakian, Hesam Ladani, [2009]	Discreet Particle Swarm Optimization	Minimizing make span and flow time	The performance of the proposed method was compared with the fuzzy PSO through carrying out exhaustive simulation tests and different settings. Experimental results show that the proposed method outperforms fuzzy PSO.
8	Gnanavel Babu, a. Jerald, [2009]	Differential Evolution	Scheduling of machines and scheduling of AGVs. Minimize make span	The purpose of this work is to make AGV scheduling an integral part of the scheduling activity, actively participating in the specification of the off-line schedule. The computational results have indicated that the differential evolution algorithm is very effective in generating optimal solutions for FMS.
9	Fatos Xhafa, Javier Carretero [2009]	Taboo search	Minimization of the makespan and flowtime	The computational results show that the TS scheduler outperforms Ritchie's implementations for most of the considered instances at far inferior executions times. Additionally, TS has also been tested in more realistic frameworks (larger static and dynamic instances), outperforming also previous approaches.
10	Udhayakumar, P. Kumanan, S. [2010]	Ant colony optimization, Genetic algorithm	to find the nearoptimum schedule for two AGVs based on the balanced workload and the minimum traveling time for maximum utilization	A scheduling procedure is developed for the task scheduling of AGV with the multiple objective of balancing the AGVs and minimizing the task times of AGVs in an FMS. The near-optimum schedules for the combined objective function are obtained by using GA and ACO algorithm and the results are compared. The result obtained by the ACO algorithm is promising and encouraging
11	Li-Ning Xing, Ying-Wu Chen, Peng Wang, Qing-Song Zhao, [2009]	Knowledge based ACO	Flexible Job shop scheduling	The performance of KBACO was largely improved by integrating the ACO model with knowledge model. In KBACO, some available knowledge was learned from the optimization of ACO by the knowledge model, at the same time, the existing knowledge was applied to guide the current heuristic searching of ACO.

12	Muhammad Hafidz Fazli bin Md Fauadi and Tomohiro Murata [2010]	Binary Particle Swarm Optimization		It exploits a population of particles to search for promising regions of the search space (swarm). While each particle randomly moves within the search space with a specified velocity. It stores data of the best position it ever encountered. This is known as personal best (pbest) position. Upon finishing each iteration, the pbest position obtained by all individuals of the swarm is communicated to all of the particles in the population. The best value of pbest will be selected as the global best position (Gbest) to represent the best position within the population.
13	Wu, Chin Chia Hsu, Peng Hsiang Lai, Kunjung [2011]	Simulated Annealing	To find a schedule to minimize the total completion times	A branch-and- bound algorithm with a dominance property and two lower bounds was developed to derive the optimal solution.The computational results showed that the branch-and-bound algorithm could solve instances up to 24 jobs, and with the help of the proposed heuristic initial solution, the branch-and-bound algorithm performed well in terms of the number of nodes and the execution time. Moreover, the computational experiments also showed that the proposed simulated-annealing algorithm per- formed effectively with the average error percentage less than 0.1482%. Future
14	Sriramka, Irshant [2012]	Genetic algorithm	Minimum total penalty cost as well as a higher utilization of machines (i.e. Minimum machine idleness).	The designed scheduling procedure with genetic algorithm was coded in C++. From the last generation of trial schedule with minimum COF, an optimal schedule was selected.as a result a minimum COF is obtained. COF was compared to other scheduling results.
15	A.V.S.Sreedhar Kumar, V.Veeranna, B.Durgaprasad and B.Dattatraya Sarma[2013]	Bacterial Foraging Optimization Algorithm (BFOA) Genetic Algorithm (GA) and Differential Evolution (DE).	Combination of minimizing the machine ideal time and minimizing the total penalty cost.	Results are obtained for 43 jobs- 16 machines. Results obtained by the different approaches are compared and the performances are analyzed for the combined objective function. BFOA algorithm is found to be superior and gives the minimum combined objective function. We 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 convergence of the evolutionary algorithms in finding the optimum schedule.
16	Andreas Fink J Homberger [2013]	Ant colony optimization	Resource-constrained project scheduling Decentralized coordination	For the considered 36 problem instances 19 new dominating decentralized solutions were obtained. This motivates the use of the presented ant colony optimization approach, which is based on the idea to update pheromones based on voting, for other coordination problems as well. With
17	Kechadi, M-Tahar Low, [2013]	Neural networks	Minimize the cycle time of a schedule	Some algorithms to deal with special situations. The authors have also extended this RNN technique by coupling it with the Lagrangian Relaxation method. The resulting approach is called Lagrangian Relaxation Recurrent Neural Network (LRRNN) Experimental results show that both approaches (RNN and LRRNN) are efficient and return very good solutions for cyclic job shop scheduling problems. The authors found out that RNN does not scale well with the size of the problem. It does reasonably well for the problems of size up to about 100 operations. In other words, RNN is much more efficient on smaller problems, while LRRNN can deal much better with larger problems. In

18	Mousavi, S. Meysam Tavakkoli-Moghaddam, Reza [2013]	Hybrid simulated Annealing (HSA)	To concurrently design a cross-docking center location and a vehicle routing scheduling model, known as NP-hard problems.	A two-stage mixed-integer programming (MIP) model has been proposed for the location of cross-docking centers and vehicle routing scheduling problems with multiple cross-docking centers for the distribution networks in the supply chain. To solve the presented two-stage MIP model, in this paper a new two-stage hybrid simulated annealing (HSA) algorithm with tabu list has been introduced. In the algorithm by the combination of simulated annealing (SA) and tabu search (TS), not only the number of solution revisits but also computational time to obtain a near-optimal solution has been remarkably decreased. The presented algorithm characterizes a special solution representation for the location and routing scheduling in the cross-docking distribution systems.
19	Thanapal P Dr. Gunasekaran [2013]	Particle Swarm Optimisation	Minimizing make span and flow time	Best-effort scheduling algorithms target on community Grids in which resource providers provide free access. The comparison of these algorithms in terms of computing time, applications and resources scenarios has also been examined in detail. Since the service provisioning model of the community Grids is based on best effort, quality of service and service availability cannot be guaranteed. Therefore, we have also discussed several techniques on how to employ the scheduling algorithms in dynamic Grid environments. QoS
20	NIthish Mathew, R.Saravanan [2013]	Non-dominated sorting Genetic Algorithm NSGA-II	minimizing machine idle time and minimizing total penalty cost	A Comparison between the proposed NSGA II and other algorithms namely SPT, PSO, CS (found in literature) and NSGA II after 40 generations has been presented. The results obtained by the proposed NSGA – II and it performs better in terms of objective functions and computational effort, i.e.50% less than CS. Software has been written in .net Language. FMS schedule is obtained for 40 jobs and 32 machines.
21	Paslar, Shahla Ariffin, M.K.a. Tamjidy, Mehran Hong, Tang Sai [2014]	Biogeography-based optimization	Integrating the assignment of appropriate machine-tool combination to each part-operation and sequencing and timing of those part-operations with constraints	The proposed algorithm is capable to obtain optimal/suboptimal solutions for the small- and medium-sized problems in limited time. Constraints such as limitation on set-up and machining cost, number of tool copy and part’s due date are imposed on the system.
22	Yin, Yunqiang Wu, Wen Hung Cheng, T. C E Wu, Chin Chia Wu, Wen Hsiang[2015]	A honey-bees optimization algorithm	To minimize the weighted sum of the completion times of the jobs of one agent with the restriction that the maximum lateness of the jobs of the other agent cannot exceed a given limit.	The authors considered a two-agent singe-machine scheduling problem with arbitrary job release dates. A branch-and-bound solution scheme and a marriage of honey-bees optimization algorithm is to solve the problem optimally and approximately. Computational results show that the BAB algorithm can solve problem instances with up to 24 jobs. The results also show that the MBO algorithm performs quite well in terms of both accuracy and stability.
23	Hamesh babu Nanvala Gajanan. K. Awari[2015]	Ant colony optimization and particle swarm optimization	Minimizing machine idle time and minimizing total penalty cost	The comparison of these algorithms in terms of computing time, applications and resources scenarios has also been examined in detail. Since the service provisioning model of the community Grids is based on best effort, quality of service and service availability cannot be guaranteed.

24	C.S.P Rao, M.V.Satish kumar, G.Rangajanardhan [2015]	Hybrid Differential Evolution		In this by the application of differential evolution, the simultaneous scheduling of machines and AGV‟s has been done. In this, operation based coding system is employed to represent the solution vector, which is further modified to suit the DE application
25	Xu Zhhang Wang Lili yi Hong Xue Sonsong Yang [2016]	Integrated ant colony optimization algorithm	Minimizing the make span of processing plans	Different sizes of processing plans are randomly generated, through which max–min ant colony optimization algorithm is proved effectively to tackle early stagnation and local convergence and thus obtains better solution than ant colony optimization algorithm and bidirectional convergence ant colony optimization algorithm.
26	Fatima El Khoukhi a,⇑, Jaouad Boukachour b, Ahmed El Hilali Alaoui c[2017]	Bi-level disjunctive/conjunctive graph. Dual Ants colony algorithm	Minimize make span	This paper investigates the Flexible Job Shop Scheduling Problem (FJSSP) with machine unavailability constraints due to Preventive Maintenance (PM) activities, under the objective of minimizing the makespan.They proposed two new formulations: the first one in the form of a Mixed Integer Nonlinear Program (MINLP) and the second corresponding to a bi-level disjunctive/conjunctive graph
27	Win-Chin Lina, Yunqiang Yinb, Shuenn-Ren Chengc, T.C.E. Chengd, Chia-Han Wua, Chin-Chia Wu [2017]	Particle swarm optimization algorithm (PSO), an opposite-based particle swarm optimization (OPSO) algorithm.	To minimize the total completion time of the orders of one agent, with the restriction that the total completion time of the orders of the other agent cannot exceed a given limit	Developed a branch-and-bound algorithm incorpo-rating several dominance rules and a lower bound to solve this intractable problem. They conducted extensive computational experiments to evaluate the efficiency of the branch-and-bound algorithm and accuracy of the proposed PSO, O-PSO, and W-PSO1 algorithms. it was very efficient in quickly obtaining solutions that are very close to the optimal solutions. Future studies may consider using other PSO algorithms such as EDAPSO, CLPSO, CPSO, SAPSO, YSPSO etc to solve the problem
28	Maziar Yazdani, Aldeida Aleti,Seyed Mohammad Khalili, Fariborz Jolai [2017]	Imperialist competitive algorithm hybridized with an efficient neighborhood search.	The sum of the maximum earliness and tardiness criteria	To extend the proposed imperialist competitive algorithm to other scheduling problems and introduce new neighborhood search operators for the job shop scheduling problem. It would also be a valuable extension to work on relaxing some of the constraints and extend the work done here to other scheduling environment
29	N. Sivarami reddy,Ramamurthy, D. V., K. Prahlada RAO[2017]	Symbiotic organisms search algorithm	Minimize make span	They tested the proposed SOS algorithm on 22 job tests and compared the results with existing methods. The results showed that the proposed method outperformed. The same SOS was used for simultaneous scheduling of AGVs and tools.
30	Veeraiah,Pratapa Reddy.Y, VS Mohan Kumar. P, W D S Milton. P [2017]	NEH, EDD, NEHEDD, SPT& WEDD algorithms.	minimizing of weighted sum of total weighted squared tardiness, make span, total weighted squared earliness and number of tardy jobs	An attempt is made to analyse the task of using multi objective minimizing of weighted sum of total weighted squared tardiness, makespan, total weighted squared earliness and number of tardy jobs.
31	Behzad Karimi, S.T.A. Niaki,Hassan Haleh,Bahman Naderi[2018]	Non-dominated sorting cuckoo search and multi-objective teaching–learning-based optimization	To maximize shop reliability as well as to minimize production time, simultaneously.	A bi-objective nonlinear optimization model is developed for the problem under investigation to maximize shop reliability as well as to minimize production time, simultaneously. In order to assess the efficiency of the proposed model, some random instances are generated, based on which two meta-heuristic algorithms called non-dominated sorting cuckoo search and multi-objective teaching–learning-based optimization

32	Tadeu K. Zubaran, Marcus Ritt [2018]	Iterated tabu search algorithm	Minimizing make span	Proposed an algorithm which is able to find solutions for the partial shop scheduling problem. In computational experiments we find that the proposed single heuristic can compete with the state-of-the-art heuristics for the partial shop, group shop, mixed shop, and open shop, and in many cases, improves the state of the art.
33	Guohui Zhang,· Lingjie Zhang, Xiaohui Song,Yongcheng Wang,Chi Zhou[2018]	Variable neighborhood search (VNS) based on genetic algorithm i	To minimize the maximum completion times of operations or makespan is considered.	IN FJSP they tried to minimize the maximum completion times of operations or make span is considered. To solve such an NP-hard problem, variable neighborhood search (VNS) based on genetic algorithm was proposed to enhance the search ability and to balance the intensification and diversification. The computational results and comparisons illustrate that the proposed algorithm is efficiency and effectiveness
34	Edilson Reis Rodrigues Kato,Gabriel Diego de Aguiar Aranha, Roberto Hideaki Tsunaki[2018]	Particle swarm optimization (PSO)Random Restart Hill Climbing (RRHC)	To minimize critical machine workload (Cm), the machine with the biggest workload (Wm), total workload time of all machines (Wt),	Authors used a hierarchical approach that divides the problem into two sub-problems, being the Particle Swarm Optimization (PSO), responsible for resolving the routing sub-problem, and Random Restart Hill Climbing (RRHC) for the resolution of scheduling sub-problem. Experimental results using technical benchmarks problems are conducted, and proved the effectiveness of the hybridization, and the advantage of PSO+RRHC algorithm compared to others local search algorithms in the resolution of the scheduling problem
35	V.K. Chawlaa, A. K. Chanda and Surjit Angra[2018]	Grey wolf optimization algorithm (GWO)	To balance the workload of AGVs and to minimize the travel time of AGVs	Investigations are carried out for the multi-objective scheduling of AGVs to simultaneously balance the workload of AGVs and to minimize the travel time of AGVs in the FMS. The multi-objective scheduling is carried out by the application of nature-inspired grey wolf optimization algorithm (GWO) to yield a balanced work-load for AGVs and also to minimize the travel time of AGVs simultaneously in the FMS.

3. Conclusions

Following conclusions were drawn from present investigation.

- Nontraditional optimization algorithms have to be integrated for both scheduling of AGV'S and Machines simultaneously.
- Nature inspiring optimization techniques have been continuously proving to get near optimal results with more complex problems.
- Integrated multi-objective scheduling of multi-load AGVs for different sizes of FMS configurations has to be considered.
- The factor of the reliability for multi-load AGVs, production centers, and part mix ratio have to be considered.
- Multi objective scheduling of FMS has to explore as real world scenarios demand it.
- A simulation model can be made use of to create a model in flexible manufacturing system.
- The number of AGV'S can be increased. Robots and automated storage retrieval system (AS/RS) can be incorporated to the problem.
- Problems can be implemented as real time scheduling problem and with necessary additions; traffic control and safety can be incorporated for automated guided vehicle

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