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A Trajectory Based Methods for Parallel Scheduling of Machines and AGV'S in an FMS Environment

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Abstract: *Now a days latest manufacturing sectors facing difficulty with two different categories of processing of parts like semi-finished jobs and finished jobs. In literature it is assumed that, for machine scheduling models, either there is infinite number of handling or carrier systems for the job to reach desired location or jobs are distributed on the spot from one workstation to other without travel time involved. Further it is observed that simultaneous scheduling of machines and AGVs in the FMS environments involves certain exceptional difficulties as they are treated as NP hard problems. Those difficulties are assigning AGV in sequence of task along with operation sequence of machines and operation order of machines based on precedence constraints. Trajectory based methods are powerful metaheuristic for solving combinatorial optimization problems like NP hard problems such as scheduling. In this paper, author addressed about parallel scheduling of machines and AGV's for determining minimum makespan, mean makespan and tardiness using simulated annealing algorithm and tested over 20 standard benchmark problems collected from literature. Finally, the proposed method is compared with literature results and conclusions are depicted.*

Keywords: *Flexible manufacturing system, NP hard problems, Parallel scheduling, Makespan, Tardiness Simulated annealing algorithm*

I. Introduction

Flexible manufacturing systems (fms) are intended to merge the effectiveness of a mass-production and the flexibility of a job shop for the batch production of a part variety and mix of products. fmss enlarge the flexibility and productivity of distinct part manufacturing. it is observed that fms is not only fetching complexity to control, but also caters a number of decision problems. the nature of a fms is entirely different from a conventional job shop. due to new circumstances of fms over job shop, it caters new capabilities which give new constraints to the scheduling problem. the flexibility in manufacturing can be observed by free movement of parts with in shop floor without any delay from one station to other based on hardware and layout design in fms. further, setup time of machine is assumed to be zero. so, machines can be switch over to part to part with zero down time.

During former epoch, there was a considerable research has been made to scheduling of machines and agv's separately in fms environment, despite the two problems are closely interconnected. literature survey shows that only few researchers addressed the scheduling of agv's and machines as one stream. this area of research have many difficulties such as precedence constraints of travel times dead heading trips between successive loaded trips of agvs. hence, this paper aims at np hard problems by introducing heuristic algorithm which involves both agv and machine scheduling constraints with an objective of makespan minimization and determination of mean makespan and tardiness.

II. Literature Survey

Now a days, owing to huge capital investment and also having high potential FMS act as tactical aggressive tool which makes an attractive subject for researchers (1). Based on this, researchers have one more attractive area in FMS is parallel scheduling of machines and AGV's which was addressed by few researchers in (2) various ways for formulation of online priority dispatche rules. It is observed that FMS scheduling has been widely used over last three decades which sequentially gains the interest of both industrial and academic sectors. (3) focused on Bi-objective scheduling problem in flexible manufacturing cell in order to determine maximum completion time (makespan) and maximum tardiness.They proposed a new hybrid genetic algorithm (HGA) combined with four priority dispatching rules. (4) addressed the logistic scheduling refers to problems inwhich decisions on job scheduling and transportation are integrated into a single framework.A logistics scheduling model for two processing centers that are located in different cities is presented. Author have considered two different transshipment modes:

(i) item transshipment;
(ii) batch transshipment

Under item transshipment, once a job in *Bik* is completed in center *Mk*, it is immediately transported to center *Mi*. In batch transshipment, all jobs in *Bik* have to be transported together as a batch from*Mk* to*Mi* when the last jobin ¯*Bik* is completed on *Mk.(*5) proposed a multiagent based scheduling approach for AGVs and machines within a manufacturing system where the AGV breakdowns are considered. Authors focused on AGV breakdown situation modeling under a multi-agent based system approach. The proposed method is designed by using the Prometheus methodology that defines a detailed process for specifying, designing, implementing, and testing/debugging agent oriented software systems. (6) addresses the simultaneous job input sequencing and vehicle dispatching problems in flexible manufacturing systems (FMS) using a single device Automated Guided Vehicle System (AGVS).They proposed a new lower bound and tested the benchmarks stating that this lower bound Outper forms the lower bound previously published.

III. Mathematical Formulation

Given an FMS environment with workstations, AGVs and set of jobs, determine the starting and completion times of operations for each job and the trips between workstations together with the vehicle assignment. The objective is to minimize the makespan (Cmax) which implies that the cost of a schedule depends on the duration for which the whole system is allocated to process a set of jobs.

3.1 Objective Function

1 Minimize (Makespan)= Max(C1, C2, C3….Cn)

Job Completion Time = $\mathbf{C_i} = \sum_{i=1}^{n} O_{ij}$

Operation completion time= $O_{ij}=T_{ij}+P_{ij}$

2. Tardiness = $T_i = C_i - D_i$

3. Mean Tardiness $= (1/n) \sum_{i=1}^{n} T_i$

IV. Configuration And Operating Environment of FMS

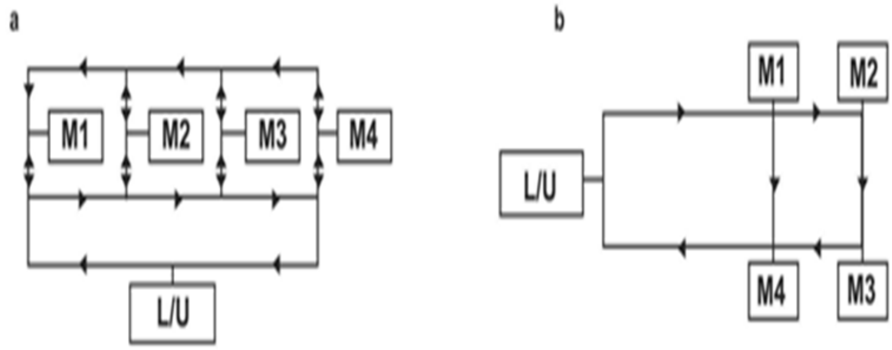

Figure1: a) FMS layout-1 **b)** FMS layout2

V. FMS Description

Today Flexible Manufacturing System (FMS) seem to be a very promising technology as they provide a variety of flexibility that is essential for design of planning for simultaneous scheduling of machines and automated guided vehicles (AGVs) to stay competitive in the highly dynamic and changing design environment. In the literature reported that, the subject of design of planning for simultaneous scheduling of machines and automated guided vehicles (AGVs) using non optimization technique system has generally been set out either as a comparison of various vehicle dispatching rules in relation to a prespecified schedule and on a particular layout [7, 8] or in relation with the design jobset [9, 10].

5.1 Proposed Methodology:

In this study, a flexible manufacturing system (FMS) in which material transfer between machines is performed by a number of identical automated guided vehicles (AGVs) is considered, and the problem of design of planning for simultaneous scheduling of machines and AGVs using nontraditional optimization technique is addressed. Authors have considered 4 different layouts and 5 job sets consisting of 1- 10 different job sets and operations on machines to be performed. The problem objective is makespan minimization, mean makespan, mean tardiness and CPU time. The formulation consists of constraint sets of a machine scheduling sub problem and a vehicle scheduling sub problem which interact through a set of Tabu search and simulated algorithm constraints for the material handling trip starting times. An iterative procedure is developed where, at each iteration, a new machine schedule is generated by a Tabu search and simulated algorithm procedure.

5.2 Tabu Search:

Tabu search is a higher level search technique which directs the natural search procedure to survey the solution space beyond local optimality. Here, the key components of Tabu search is its concern with adapting memory,that enables the procedure search behavior with more flexibility.TS is depends on the vicinity of problem, incorporate adaptive memory and receptive exploration. Being more concerned in adapting memory features, TS gives provision for applying the procedures that are able to search the solution space economically and effectively. It is known that local selections are directed by information gathered during the search, TS shows difference with memory less designs which greatly depends up on semi random processes that employ a form of sampling.

5.3 Simulated Annealing:

Simulated Annealing is a trajectory based probabilistic method introduced by Kirkpatric, Gelett and Vecchi (1983) and cerny (1985) for identifying the global[20] minimum of a objective function which have several local minima. It works on the principle of emulating the physical annealing process in which solid is slowly cooled so that finally its structure is "frozen" this will happens at a minimum energy system. Annealing is a physical process for obtaining a low energy state of a solid in two steps:

1. Attaining recrystalization point while heating metal.
2. Reducing temperature of the metal slowly by cooling, allowing it to attain thermal balance at each temperature.

VI. Results And Comparison

Trajectory based algorithm procedure has been used for generating necessary code in C++ language and simulation is done using IDE tool for various test problems. As per the AGV assignment heuristics for different trajectory based algorithms, the simulation code is developed. Here population size is considered as 1 due to trajectory based nature of algorithms which means having only one population in each generation.

The authors have considered SET of problem instances. The SET of problems is designed as Problem instances 1 – 2, here 1 indicates layout 1 problems and 2 indicates layout 2 problems. Under the problem instances 1 – 2 the designations are indicated as INST XY. Where X stands for layout number and y stands for job set number. Table 1 shows that the results of make span for t/p ratio > 0.25 and these results are executed for 100 generation on IDE Simulation software in each trail for which 10 trail runs are conducted for proposed trajectory based algorithms. The bench mark problems are solve through the propose algorithms and the results are assimilated and observed that for all problem instances the makespan value is higher at initial trail and reach to minimum value at final trail and gets fluctuate in intermediate trails.

Table 1 :- Comparison of MEAN MAKESPAN results of the trajectory based method for t/p >0.25 (Problem instances 1-2) with 100 generations for 10 trials

PROB	SA										TS									
INST	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
INST11	68	66	59	59	57	64	68	68	62	52	67	77	68	62	69	62	64	62	71	62
INST12	65	62	65	63	58	65	66	68	65	62	65	68	66	61	67	67	67	64	61	58
INST13	73	68	65	75	75	72	76	73	71	61	71	77	70	69	67	76	68	71	69	63
INST14	70	64	68	63	66	69	70	63	65	63	66	72	67	70	70	74	68	69	64	64
INST15	60	51	47	47	48	49	60	53	55	44	48	58	55	52	60	49	52	52	48	46
INST16	70	74	70	71	71	71	75	67	71	61	69	74	73	71	67	73	71	73	67	66
INST17	54	54	59	54	56	58	59	55	60	49	56	58	55	54	54	54	53	59	56	51
INST18	79	81	86	74	82	86	86	84	86	80	86	90	81	82	81	81	79	86	82	77
INST19	68	65	65	65	65	70	72	64	64	63	64	66	65	65	64	65	63	65	66	63
INST110	75	80	76	79	76	76	80	76	74	72	79	79	78	71	74	77	77	76	72	67
INST21	50	60	60	60	50	56	60	58	52	48	56	60	60	60	55	50	42	54	57	44
INST22	62	64	66	62	64	64	67	62	61	56	63	67	63	60	61	57	61	61	63	52
INST23	65	65	67	66	66	66	70	66	67	57	58	70	65	69	69	65	63	61	59	57
INST24	60	56	58	58	52	60	60	55	56	55	60	60	57	56	60	56	59	50	55	55
INST25	42	42	42	50	46	42	46	45	45	42	45	48	45	42	42	48	41	46	48	37
INST26	75	72	73	76	75	75	76	73	73	68	73	80	72	74	68	72	73	72	76	67
INST27	59	52	56	56	57	52	61	60	58	46	56	59	56	59	57	57	54	57	57	52
INST28	79	78	76	74	78	77	82	77	76	76	77	81	81	79	79	81	77	81	79	74
INST29	63	63	53	65	65	63	64	62	63	62	63	65	63	63	63	63	63	62	63	58
INST210	72	68	71	73	74	73	75	71	73	66	73	78	75	73	73	71	73	73	69	65

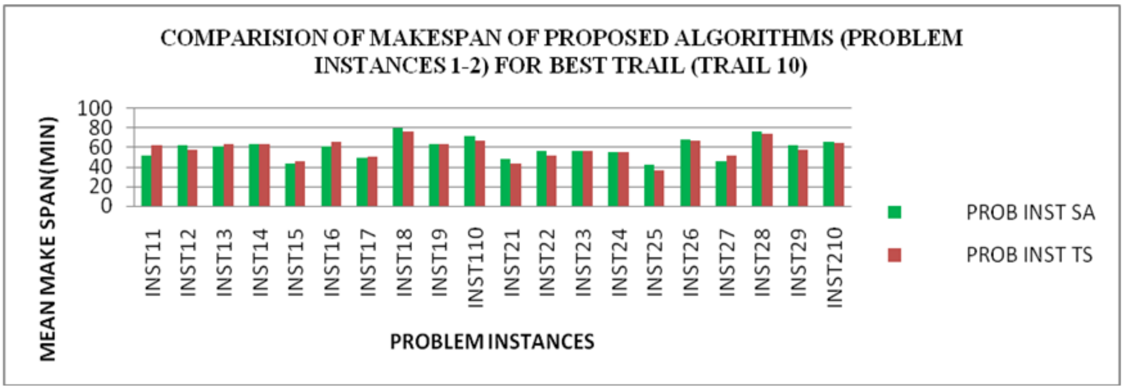

Fig 2: Comparision of Makespan of Proposed Algorithms (Problem Instances 1-2) For Best Trail (Trail 10)

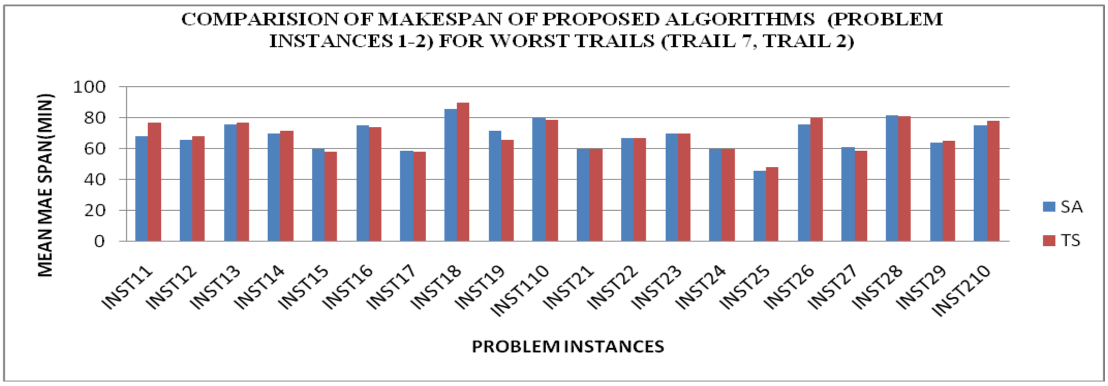

Fig 3: Comparision Of Makespan Of Proposed Algorithms (Problem Instances 1-2) For Worst Trails (Trail 7, Trail 2)

The graphs shown in Figs. 2 and 3 are styled for problem instances1-2. It is observed that there are moderate variations in results of Mean makespan against problem instances shown in the plot for SA and TS. It is found that Mean makespan is low at problem instance INST25 and generates high Mean makespan value for INST18 whereas at remaining problems. Mean makespan varies moderately because it depends on size of the problem. Furthermore, SA provides marginally better values than TS curve, since Simulated Annealing is probabilistic metaheuristic which can search for more feasible solutions by cooling probability where as Tabu search does not have such parameters.

VII. Conclusions

In this paper, it is observed that the proposed trajectory based algorithm needs two stages of calculation. During the inception of algorithms as first stage, it is compulsory to recognize the nature of algorithms and their probabilities in finding the optimum solution. While in the second stage, order of machines are altered and accordingly machine representations act as data flow into the trajectory based algorithm by accepting and rejecting based on precedence constraints in yielding optimum solutions. The performance of the proposed algorithm is tested over a number of problems selected from the literature and is compared to many other algorithms existing in the literature. Hence from the results and discussion it is understand that for best trail, out of proposed trajectory based method, Tabu search performance is marginally better than simulated annealing for layout 2 and 4 where as for layout 1both methods are performing same manner in yielding mean makespan. On other side for worst trail, Tabu search provides marginally better mean makespan results than simulated annealing for layout 2 where as for layout 1 both methods are equally works in getting the results.

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