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A Population based Metaheuristics for Optimum Design of Single Row Layout in Flexible Manufacturing System with Integrated Job shop Scheduling

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Abstract – Facility allocation and layout design plays a key role to achieve high revenue in current industrial sector. This paper conveys the design of single row layout in FMS in an optimum manner. The objective of single row layout problem is the allocation of the ordering of machines around the facility configuration, to reduce the total number of traversals for a part family. The clearance between the machines and material handling cost between the machines also considered in design of SR layouts. This work details the design, development and testing of Genetic Algorithm (GA), Partial Swarm Method(PSM) to solve the single row layout problems. The proposed methods validated and tested with randomly generated problem instances.

Keywords : Genetic Algorithm, Partical Swarm Method, FMS, SR

I. Introduction

Advancement of technology leads to increase in market for manufactured products globally. In this context, production of parts has become more competitive and industries have to hub their capital, capabilities on structuring a sustainable spirited advantage. Flexible Manufacturing System [i] combines collection of machines tools which are termed as numerical control machines that can arbitrarily process a cluster of jobs, taking automated material management and workstation control to balance resource exploitation over which the system can accept automatically to variation in jobs manufacture, amalgams and stages of yield. The objective of FMS is flexibility in production without compromising the quality of products. Flexibility can mean future cost avoidance.

The FMS layout involves allocating diverse reserve for attaining full competence. The arrangement has an influence on the make span and cost [iii] which should be determined in the inception of the FMS [iv]. In practice most commonly used type of FMS layouts[v] are

1) Line or single row layout.
2) Loop layout.
3) Stepladder layout.
4) U-shaped layout
5) Open field layout

Among the above layouts, this paper focus on single row layout design with integrated scheduling using GA and PSM

II. Literature review

Due to increased competitiveness, Flexible manufacturing systems were introduced to overcome the drawbacks of Dedicated Manufacturing Lines**[(2)** Indeed, FMS are able to carry out several parts in small and average series while adopting quickly production changes demand thanks to their flexibility. Several research work focus on design of Loop Layout. However, design of such systems ,in particular allocation of machines in their corresponding slots which form best order, is difficult due to increasing flexibility and complexity.

HamedSamarghandi, PouriaTaabayan.[v] consider the single row layout problem in which the size of facilities are assumed to be different and particle swarm optimization algorithm was applied to find near-optimal solutions of this problem. ApinanthanaUdomsakdigool,VoratasKhachitvichyanukul.[vi] presented the ant algorithm for solving the multi-objective JSP. The algorithm is tested on several benchmark problems and finally concluded that proposed algorithm is able to find the competitive solutions. B. V. Raghavendra and A. N. N. Murthy[vii] addresses the loading problem in flexible manufacturing systems using GA and GA based heuristic procedure for the loading problems in FMS in Identical parallel machine is presented. AyoubInsaCorréa, André Langevin, Louis-Martin Rousseau[viii] proposed a hybrid method designed to solve a problem of dispatching and conflict free routing of automated guided vehicles (AGVs) in a flexible manufacturing system by decomposition method to solve a difficult combinatorial integrated scheduling and conflict free routing problem.

II. Configuration of Single Row layout

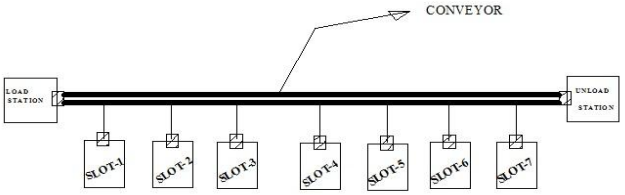

Fig 1. Single row ayout

II. Problem Formulation

1. The problem formulation procedure adopted by Hongbo Liu.et.al, (x).), has been used in this research work. The authors focus on design of ladder layout in flexible manufacturing system with [FJSP] flexible job scheduling problem as constraint with the following parameters.

2.

- Jobs $J=\{j_1,j_2,\ldots\ldots\ldots j_n\}$
- Batches $B=\{B_1,B_2,\ldots\ldots\ldots\ldots B_n\}$is a set of n jobs /n batches to be scheduled respectively. Each job J_i consists of a predetermined sequence of operations. $O_{i,j}$ is the operation j of J_i.
- Machines $M=\{M_1,M_2,\ldots\ldots\ldots\ldots M_m\}$ is a set of m machines,
- Slots $S=\{ S1,S2,S3\ldots\ldots\ldots S_m\}$ is a set of N fixed slots

I) *Objective Functions*

1) Minimize Make Span F (S_{maxi})

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$$Minimize, F(S_{max}) = S_{n,m}$$

(1)

Subjected To

a) conjunctive constraints

$S_{i,j,k} \leq S_{i,j+1,k} - T_{i,j+1}$, for j= 1, 2, 3…p

$S_{i,j,k} \geq 0$, for j = 1, 2, 3 …p

b) Resource constraints

$O_{i,j,k}$ = 1 if job i scheduled before job i' on machine k

= 0 otherwise for O € S (i,j,k)

for j = 1, 2,

i, i' = 1, 2, 3….. n ,

k, k' = 1, 2, 3 …m

c) Disjunctive constraints

$B_{i,k}$ = 1 if job i processed only once on machine k

= 0 otherwise

for B € S (i,j,k)

for i, i' = 1, 2, 3….. n,

k, k' = 1, 2, 3 …m

II) Minimize Total Transportation Cost (Z) =

$$\left[\sum_{m_i=1}^{M}\sum_{m_j=1}^{M}\left(MF_{m_im_2} * MH_{m_im_2} * RD_{m_in_2}\right) + LOC_{mi} + ULOC_{mj}\right] \quad \textbf{(2)}$$

Subjected to

$\sum_{mi=1}^{M} X_{mimj} = 1$ if machine m_i is at assigned to slot N

= 0 otherwise

$\sum_{mj=1}^{M} X_{mimj} = 1$ if machine m_j is at assigned to slot N

= 0 otherwise;

$X_{mimj} \in \{0,1\}$,

where mi, mj = 1,2,……..N

II. Proposed Methodology

The authors have considered two different method for analysing the optimum design of single row layout with job scheduling constrains where determining the optimum order of machine sequence is influenced by scheduling of parts which acts as a precedence constraints. The two different algorithm considered in this work are genetic algorithm and particle swarm method.

II.I Genetic Algorithm

Genetic algorithm is a population based stochastic search technique. It is one of the important method in Metaheuristics which search for most feasible solutions of a complex combinatorial problems. Genetic algorithm retains the natural selection which is very important mechanism by using artificial system softwares to comprise and elucidate the adaptive processes of natural systems.

In GA terminology, a candidate solution is represented by a sequence of numbers and/or characters known as a chromosome or string. Each element in the string is called a gene and represents a process variable. A selected number of strings is called a population and the population at a given time is a generation.

II.II Particle swarm optimization

Kennedy and Eberhart initiated the idea of function-optimization by means of a particle swarm[ix]. Suppose the global optimum of an *n*-dimensional function is to be located. The function may be mathematically represented as:

$f(x1, x2, x3, \ldots, xn) = f(\_X)$

where *x* is the search-variable vector, which actually represents the set of independent variables of the given function. PSO is a method for optimizing hard numerical functions on metaphor of fish. Suppose the following scenario, a flock of birds is randomly searching for food in an area, where there is only one piece of food available and none of them knows where it is, but they can estimate how for it would be at each iteration.

III. Results and Discussions

The simulation code is run for 10 independent trails for three randomly assumed problem instances KMN1 KMN2 and KMN3 and the obtained results are compared and tabulated in table 1 and table 2.

Table 1: Comparison of arithmetical results of the population based stochastic methods(for CBS with 100 generations)

Instan-M/c x J/B x Oper	GA				PSOM			
	MAKSP (min)		TTC Rs)		MAKSP (min)		TTC (Rs)	
	Best	Avg	Best	Avg	Best	Avg	Best	Avg
KMN 1-(7x7x7)	68	73.6	104	115	71	71.4	112	116.86
KMN 2-(7x6x6)	63	66.6	98	108	67	68.5	120	127.04
KMN 3-(7x7x6)	73	76.4	112	120	74	75.3	124	138.3

The table 1 shows the results of test problems for Batch size =1 from KMN1-KMN3 and is understand that, The test problems are solved [x] through the proposed algorithm and the results are compared and found that performance of GA and PSM for calculating total transportation cost (TTC) and makespan (MAKSP) is varying as per the problem size. By relative analysis, it is observed that, solutions are optimized for GA and found that GA affords best solution when compared with PSM to all problem instances.

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Table 2: Comparison of arithmetical results of the population based stochastic methods(for Batch size =1 with 100 generations)

Instance (M/c x J/B x O)	GA			PSOM		
	BWT (min)	MASEQ	MWT (min)	BWT (min)	MASEQ	MWT (min)
KMN 1 (7x7x7)	B1:7 **B2: 38** B3: 25 B4: 31 B5: 22 B6: 31 B7: 34	4 1 7 5 2 3 6	M1: 28 M2: 23 M3: 28 **M4: 31** M5: 21 M6: 29 M7: 28	B1: 10 **B2: 41** B3: 28 B4: 34 B5: 25 B6: 34 B7: 37	4 1 2 5 7 3 6	M1: 31 M2: 26 M3: 31 **M4: 34** M5: 24 M6: 32 M7: 31
KMN 2 (7x6x6)	B1: 18 B2: 8 B3: 27 **B4: 28** B5: 12 B6: 27	2 6 3 1 5 7 4	M1: 15 **M2: 39** M3: 35 M4: 34 M5: 17 M6: 18 M7: 25	B1: 22 B2: 12 B3: 31 **B4: 32** B5: 16 B6: 31	4 7 6 2 3 1 5	M1: 19 **M2: 43** M3: 39 M4: 38 M5: 21 M6: 22 M7: 29
KMN 3 (7x7x6)	B1: 17 B2: 28 B3: 31 B4: 45 B5: 6 **B6: 49** B7: 15	7 3 4 2 1 6 5	M1: 36 **M2: 41** M3: 14 M4: 24 M5: 34 M6: 29 M7: 13	B1: 18 B2: 29 B3: 32 B4: 46 B5: 7 **B6: 50** B7: 16	6 4 7 3 9 8 2 1 5	M1: 37 **M2: 42** M3: 15 M4: 25 M5: 35 M6: 30 M7: 14

The table 2 shows the results of test problems for variable batch size (VBS) from KMN1-KMN3 and is comprehend that the test problems are solved through the proposed algorithm and the results are compared and found that performance of GA and PSM for calculating Batch waiting time(BWT) and Machine waiting time(MWT) obtained for corresponding [x] problem instances is varying as per the problem size and based on make span(MAKSP) value (if make span is same for both algorithm ,then waiting times will also be the same and viceversa) . By relative analysis, it is observed that, GA shows minimum waiting times when compared with SA to all test problems. Further, the required machine sequences (MASEQ) are depicted in the same table.

Comparison of Make span & total transportation cost for batch size =1by the proposed evolutionary algorithms for instance KMN1, KMN2&KMN3 is depicted in Fig.2&Fig.3. The plot shown in Fig .2&Fig.3is styled for 7M-7B-7O, 7M-6B-6O as well as for 7M-7B-6O.It is observed that, there are moderate variations in results of MAKSP and TTC against different problem instances shown in the plot for GA and PSM for instance 01 ,02& 03 i.e. MAKSP and TTC is superior for GA than PSM .Finally, from plots it is concluded that GA afford the best makespan and Total transportation cost when compared with PSO to all test problems.

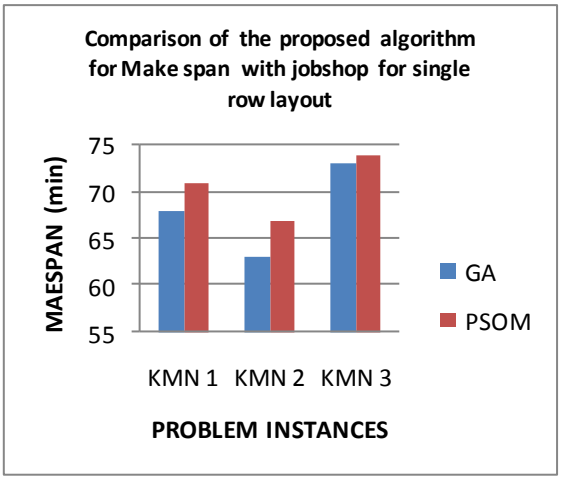

Fig. 2 Comparison of Makespan for Batch size=1by proposed algorithms (Instance 01 , 02 & 03)

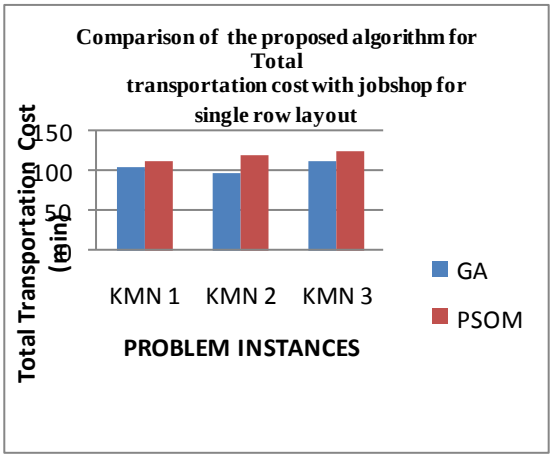

Fig.3 Comparison of Total Transportation cost(Rs) for Batch size=1by proposed algorithms(Instance 01 , 02 & 03)

Comparison of Batch waiting time (BWT) and Machine waiting time (MWT) for batch size = 1 by the proposed evolutionary algorithms is depicted in Fig.4 and Fig.5. The plot

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shown in Fig.4 and Fig.5 is styled, for instance, which has 7 batches/jobs. It is observed that BWT and MWT for variable batch size are less for GA when compared with PSO.

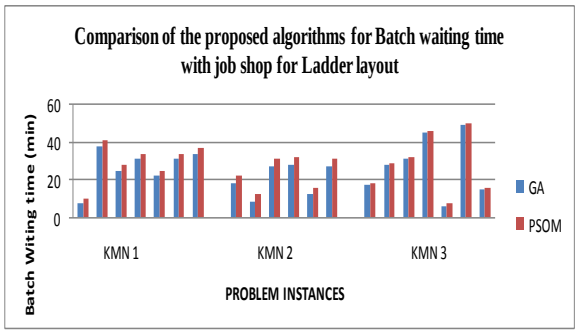

Fig.4 Comparison of Batch waiting time for Batch size=1by proposed algorithms(Instance 01 , 02 & 03)

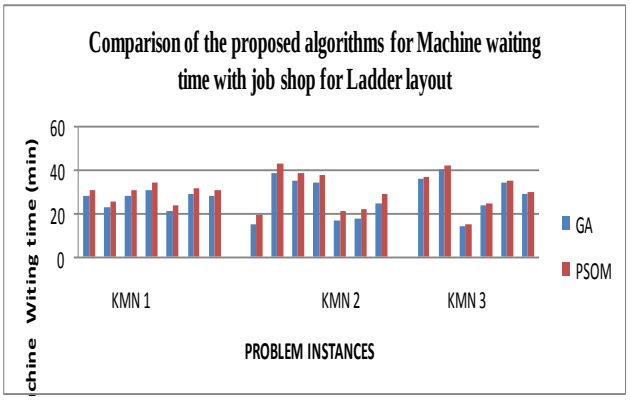

Fig.5 Comparison of Machine waiting time for Batch size=1by proposed algorithms(Instance 01 , 02 & 03)

IV. Conclusion

The issue confronted in designing facility layout is ordering of machines with job processing constraints which arise from scheduling of these jobs on machine which is to be processed on corresponding machines. The main objective of this work is allocating the machines on available slots in an optimum manner by satisfying the job shop scheduling constraints. To resolve the issue authors have used to population base metaheuristic methods such as genetic algorithm and particle swarm method. So, from the results and discussion it is observed that the performance of the genetic algorithm in yielding the minimum makespan and transportation cost is better than particle swarm method. Finally it is concluded that GA is marginally superior than particle swarm method.

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