SCHEDULING OF AUTOMATED GUIDED VEHICLES IN A FMS ENVIRONMENT USING PARTICLE SWARM OPTIMIZATION

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE IN

Bachelor of Technology

In

Mechanical Engineering

By

Kaushik Mishra

Roll No. 107ME010

Department of Mechanical Engineering

National Institute of Technology

Rourkela

2011

NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA

CERTIFICATE

This is to certify that the thesis entitled, "Scheduling of Automated Guided Vehicles in FMS environment using Particle Swarm Optimization" submitted by Kaushik Mishra in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Mechanical Engineering at National Institute of Technology, Rourkela (Deemed University), is an authentic work carried out by him under my supervision. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any University/Institute for the award of any Degree or Diploma.

Date: 11 May,2011

Prof. S.S. Mahapatra

Department of Mechanical Engineering

National Institute of Technology

Rourkela-769008

ACKNOWLEDGEMENT

I avail this opportunity to extent my hearty indebtedness to my guide Prof. S.S. Mahapatra, Mechanical Engineering Department, for his valuable guidance, constant encouragement and kind help at different stages for the execution of this dissertation work.

I also express my sincere gratitude to Prof. R.K. Sahoo, Head of the Department, Mechanical Engineering, for providing valuable departmental facilities and Prof. S.K.Sahoo , Prof C.K. Biswas and Prof K.P.Maity, for constantly evaluating me and for providing useful suggestions.

Submitted By:

Kaushik Mishra

Roll No. 107ME010

Mechanical Engineering

National Institute of Technology,

Rourkela-769008

CONTENTS

Abstract:

Efficiency in management of the material handling system plays an important role in planning and operation of a flexible manufacturing system. Many researchers have addressed material handling and vehicle scheduling as two different problems. The following work focuses on scheduling of both machines and automated guided vehicles (AGVs) in a flexible manufacturing system (FMS). We have made an attempt to consider the scheduling of machines and vehicles in an integrated manner. Particle swarm optimization (PSO) is one of the efficient algorithms that aims to converge and give optimal solution in shorter time. Therefore we have considered PSO for such scheduling.

INTRODUCTION

Introduction

The current trend in manufacturing technology has its focus centered mainly on automated and integrated manufacturing environments. A carefully designed material handling system with proper efficiency is necessary for such integration. Present day material handling systems are agile and fail to provide a proper degree of flexibility. Flexible manufacturing systems (FMS) are an efficient production technique for a wide variety of part types. Automated guided vehicles (AGV) are efficient material transportation techniques that are increasingly finding their applications in FMS. There is a great deal of complexity involved in scheduling both Jobs and AGVs in an FMS environment.

The hard automation usually found in transfer lines has been replaced by computer control techniques in FMS based production processes. The main goal of computer controlled automation is to enable efficient material handling basing upon some computer fed logics. Various algorithms have been used to develop for the decision making and scheduling processes in FMS.In recent years, new algorithms such as non-sorting genetic algorithm–II (NSGA-II) and strength Pareto evolutionary algorithm–2 (SPEA-2) have been developed and are now widely used to address the decision making problems. In this work we have tried to reduce the make span of the manufacturing system using Particle Swarm Optimization(PSO).

Kennedy and Eberhart first developed Particle swarm optimization (PSO) in 1995. Originally it was developed for the purpose of simulation of human behavior but later it was used for optimization problems. Researches have shown that the PSO algorithm converges much faster than any other algorithm. Because of the rapid convergence of the PSO, it has been widely applied in many areas. It has turned out to be an efficient alternative for genetic algorithm and other efficient techniques.

PSO is a metaheuristic approach and makes few or no assumptions about the problem being optimized. Although the PSOs may not guarantee the discovery of an optimal solution, they search a larger space of candidate solutions which gives the algorithm an advantage over similar algorithms used for scheduling, such as Genetic Algorithm (GA). PSO does not require the problem to be differentiable and hence a large category of unstable and noisy problems can be solved using it.

The rest of the paper is organized as follows. Section 2 gives an insight to the literature review that was done, in section 3 we briefly discuss about the outlines of the PSO algorithm, in section 4 we discuss the proposed methodology. Results and analysis have been done in section 5 and a conclusion has been stated in section 6.

LITERATURE REVIEW

Literature Review:

Machine and vehicle have mostly been addressed as two different problems by many researchers. Very few researches have emphasized upon simultaneous scheduling of jobs and vehicles. A simultaneous scheduling problem has been stated in Ulsoyet. al.[1]. An integrated approach for the scheduling of jobs and machines has been done in this paper. The approach in the above problem involved the use of Genetic Algorithm. A deterministic offline scheduling problem has been stated by Raman et. al.[4] . The problem has been formulated as an integer programming problem and a solution procedure based on the concepts of project scheduling under resource constraints has been state by them. They assumed that the vehicles always returned to the load/unload station after transferring a load which reduces the flexibility of the AGV and influences the overall schedule length. Simultaneous scheduling of AGVs and machines using adaptive genetic algorithm was done by Jerald et.al.[2].

Offline model for simultaneous scheduling of AGVs and machines in an FMS environment for makespan minimization has been proposed by Ulsoy and Bilge [3]. They had adopted an approach involving Genetic Algorithms. In their approach the chromosome represents both the operation number and AGV assignment which requires development of special genetic operators.

Abdelmaguid et al. [5] has presented a new hybrid genetic algorithm for the simultaneous scheduling problem to minimize the makespan. The hybrid GAs composed of GA and a heuristic. The GA is used to address the first part of the problem that is theoretically similar to the job shop scheduling problem and the vehicle assignment is handled by a heuristic called vehicle assignment algorithm (VAA). Lacomme et al.[12] has addressed the simultaneous job input sequence and vehicle dispatching for a single AGV system. They solved the problem using the branch and bound technique coupled with a discrete event simulation model. [6],[8]and[9] give an idea of solving multi objective optimization problems. Jawaharet. al.[10] used genetic algorithm approach for scheduling of machines in an FMS environment.Nandiniet. al[11] gave an elaborate explanation of AGV scheduling for automated material handling system. Egbleu and Tanchoo[15] developed dispatching rules by characterization of automated guided vehicles. Zahoriket. al. [16] used network programming model for production scheduling in multi satge multi item capacitated system.

The simultaneous scheduling of material handling operations in a trip-based material handling system and machines in JIT environment was addressed by Anwar and Negi[13]. A beam search-based algorithm for the simultaneous scheduling of machines and AGVs was introduced by Karabtik and Sabuncuoglu [14]. They made the assumptions that vehicles always return to the load/unload station after transferring a load reduces the flexibility of the AGV and its influence on the schedule. The performances of machine and AGV scheduling rules against mean flow-time criterion was investigated by Sabuncuoglu andHommertzheim[7] using a simulation model. In this paper we have used Particle Swarm Optimization (PSO) for the scheduling of AGVs and Jobs. Blacewicz et al.[19] used a mathematical programming model for machine scheduling.Suribabu and Nilekantan[20] used Particle Swarm Optimization for urban water distribution networks. A similar approach can be used in machine scheduling too.Kotinis[21] used a swarm optimization approach for multi objective constraint problems. Das and Konar[22] used a swarm intelligence approach for two-dimensional IIR filters.

PSO (Particle Swarm Optimization) was adopted by Ulner to develop energy demand models to estimate energy demand based on economic indicators in Turkey. Previously Amjadiet.al. used PSO fore forecasting Iran’s electricity demand.

THE PROPOSED METHODOLOGY

The Proposed Methodology

Particle Swarm Optimization

PSOs are basically used for combinatorial optimization. Combinatorial optimization is a problem where the optimal solution is searched over a discrete search space. Problem such as job sequencing fit in as good examples of such problems where the search space candidate grows more exponentially as the size of the problem. Hence for such problems where the exhaustive search for an optimal solution becomes infeasible PSO is used.

Multiple candidate solutions coexist and collaborate simultaneously in a PSO environment. Each particle flies in the solution space looking to land at an optimal solution. With time the adjustments are done with respect to the particles history as well as the history of the neighboring particles.

Each particle represents a candidate solution. Every particle is a solution in a D-dimensional search space. Theparticle is represented as X_i=(x_{i1},x_{i2},………$x_{i\ dim-1}$). Where i= 1 to N. N is the swarm size and dim is the dimension number of each particle. Each particle adjusts its trajectory towards its own previous best solution, P-Best and the previous best solution of the entire swarm, G-Best. The following two equations govern the particles.

$$v_{id}= w * v_{id}+c_1*r_1(p_{id}-x_{id}) +c_2*r_2(p_{gd}-x_{id})$$

$$x_{id}= x_{id} +v_{id}$$

Here c1 and c2 are acceleration constants. The variables r1 and r2 represent random numbers in the interval of 0 to 1. The above equation helps the particle to look around the global best and the local best position.**w** represents the parameter that governs the dependency of the current velocity of the particles on their previous velocity. The product c_1 and r_1 represents the constant associated with the parameters that govern the dependency of the current velocity on the local best solution. Similarly the product of c_2 and r_2 represents the constant associated with the parameters that govern the dependency of the particle on the global best solution.

The first of the equation 3.1 shows the dependency of velocity on its previous velocity. The second part shows the dependency of the velocity on the local best solution and the third part represents its dependency on the global best solution. The last part of the equation always pulls the particles to the global best solution.

At each step the velocity of the particle is calculated according to equation 3.1 and then the position is updated according to the equation 3.2. A maximum velocity vector is generally defined to control v_i .When v_i exceeds the limit the value of v_i is set back to v_{max}. When the particle finds a better solution than the previous best solution it stores the solution in memory. The algorithm goes on iteratively until a predefined until a satisfactory solution is met or the maximum number of iteration is met.

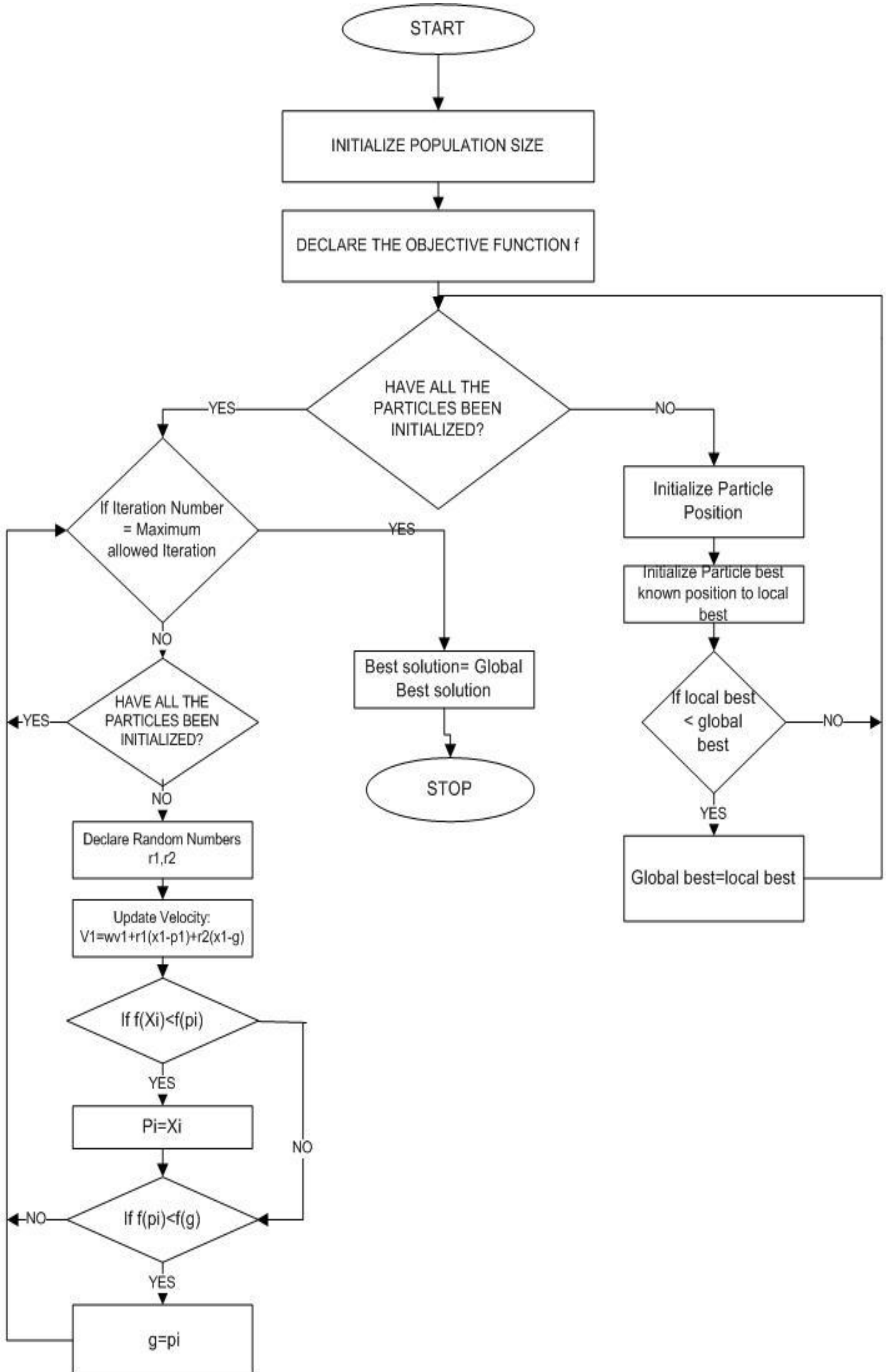

START
INITIALIZE POPULATION SIZE
DECLARE THE OBJECTIVE FUNCTION f
HAVE ALL THE PARTICLES BEEN INITIALIZED?
YES
NO
Initialize Particle Position
Initialize Particle best known position to local best
If local best < global best
NO
YES
Global best=local best
If Iteration Number = Maximum allowed Iteration
YES
Best solution= Global Best solution
STOP
NO
HAVE ALL THE PARTICLES BEEN INITIALIZED?
YES
NO
Declare Random Numbers r1,r2
Update Velocity: V1=wv1+r1(x1-p1)+r2(x1-g)
If f(Xi)<f(pi)
YES
NO
Pi=Xi
If f(pi)<f(g)
NO
YES
g=pi

Figure 1

FMS Environment

Machines are arranged in a typical layout in a given FMS environment. The automated guided vehicles and the set of jobs are scheduled as per an optimum sequence that contains information,both about the AGVs and the jobs and has the minimum makespan. An example from Ulsoy et al (1994) has been taken to explain the proposed methodology.

Flexible manufacturing system (FMS) is one of the most researched areas in the field of production engineering. Many Production houses aim to implement such set ups for production related because of their higher efficiency and flexibility.For a lay man we can simply say that flexible manufacturing system is a setup where all the parts of a product are manufactured from different in machines, i.e., different machines machine different parts of the same product. Hence because of this increased flexibility different variety of products can be manufactured. A layout of the FMS is shown in Figure 1.

Automated Guided Vehicle(AGV)

AGVs are robotic carriers that are used for material handling and transportation. Initially the AGVs transport the from the loading and unloading points to the machines where the initial operations are scheduled. The AGV performs two types of trips the loaded trips and the dead-heading trips. The loaded trips are when the AGVs are when the AGVs move the load from the loading and unloading point or from one machine to another machine or to the loading and unloading point. Dead heading trips are the ones that have the AGVs moving without any load carried to the loading and unloading point or to the machine to receive a job. Deadheading trip can start immediately after the delivery and vehicle demand at different workstations are considered and the subsequent assignments are made.

Scheduling of AGVs

In the following example we have considered a system having two automated guided vehicles with identical speeds. The two AGVs are scheduled as per the sequence of the PSO algorithm.If no vehicle is available we compute the earliest available times of the AGVs and then assign the task. If the vehicle is idle and no job is ready, identify the operation that is going to be completed early and move the vehicle to pickup that job. This type of vehicle scheduling methodology helps in reducing the waiting times and thus helps in improving the resource utilization and the throughput. The algorithm describing the vehicle allotment procedure has been shown in figure2. A lay out of the example considered with the automated guided vehicles has been shown in figure1.

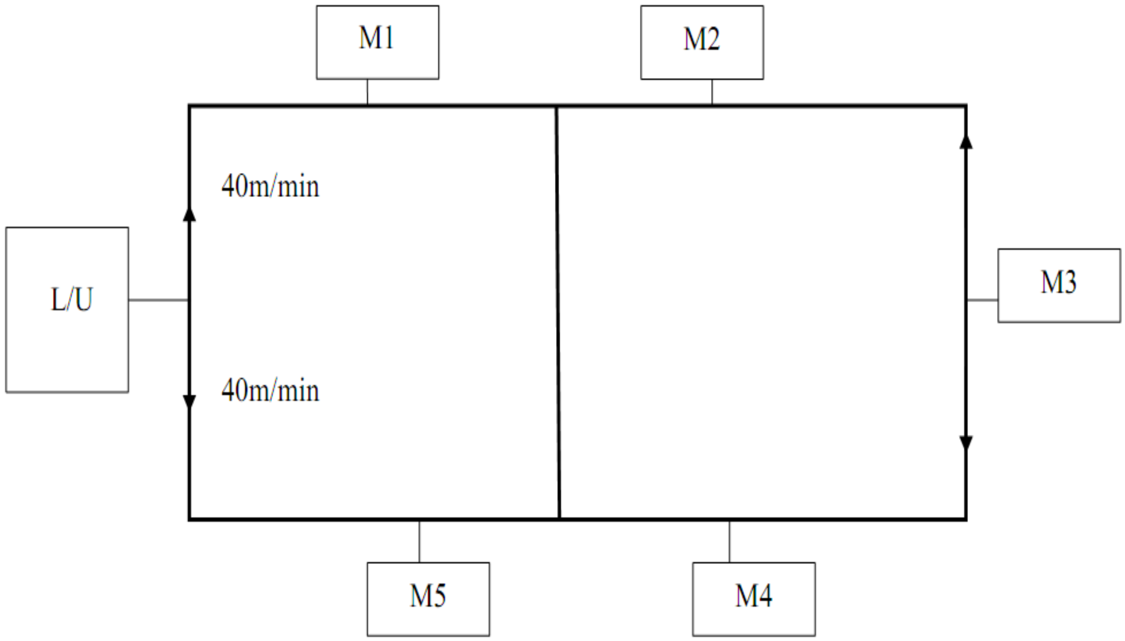


Figure 2

1. ***Start***

2. ***Input Sequence***

3. ***Operations are scheduled as per sequence***

4. ***The AGV scheduled as per sequence is called***

5. ***AGV is moved from the current position to the request point***

6. ***If the job is not ready the AGV waits for the job***

7. ***The job is moved to the next Machine***

8. ***If the machine is not free the job is loaded in the machine buffer***

9. ***If all operations are completed calculate the Makespan else move to the next operation***

10. ***Stop***

Figure 3

Scheduling of AGVs

The sequence are represented in a double allelic form as used in Bile and Ulsoy(1994) . The sequences are represented as fixed length strings that contain both the dimensions of the search space, i.e., the machine sequences as well as the vehicle sequences.

Fitness Function:

Every sequence when generated is first evaluated by calculating its objective value. These objective values are a measure of the efficiency of the sequence generated, hence otherwise known as fitness function. In the present work we are considering makespan as the objective value.

Operation Completion Time $O_{ij} = T_{ij} + P_{ij}$

T_{ij}= Travel time

P_{ij}= Processing Time

j=operation number

i= job number

C_i= Summation of O_{ij} for i= 1 to n

Makespan= max(C_i) where i= 1 to n

ILLUSTRATIVE

EXAMPLE

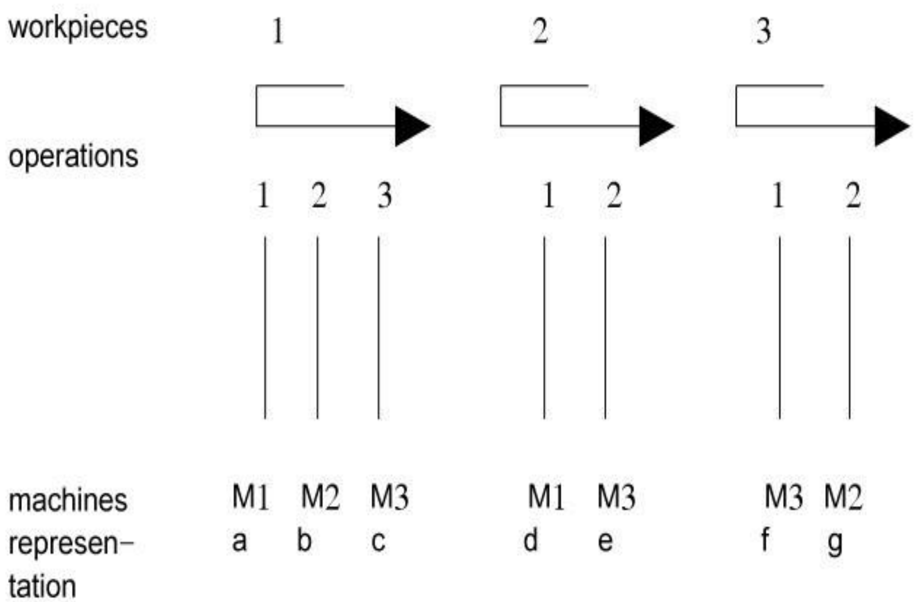
Illustrative Example

Figure 4 shows the representation of the jobs taken from Ulsoyet.al(1994). There are three jobs and three machines. Job 1 has three operations to be done as shown in figure. Similarly job 2 has two and job 3 has two operations. Overall there are seven operations. These operations are numbered as a,b,c,d,e,f,g starting from the first operation of number 1. For example first operation of job3 is the sixth operation so it is named as f. Now there are two AGVs to be sequenced too. The AGVs are numbered as 1 and 2. The representation of the AGVs is integrated in the sequence for the machines. The sequence is a double allelic representation as shown in figure 3.

[f2, d1,a1,e2,b2,g1,c2]

Figure 4

From the above figure it is inferred that the first operation is operation f, i.e., the first operation for job number 3. This job3 is to be transported by AGV no.2. The second operation in the sequence is operation d, the first operation for Job2 and the transporting vehicle will be AGV no.1. Similarly for other operations in the sequences we can proceed. The AGV travel time matrix and also the job processing times are represented in figure4.



	L/U	M1	M2	M3
L/U	0	4	8	10
M1	18	0	4	6
M2	20	14	0	8
M3	12	8	6	0

TRAVEL TIME MATRIX

P1			P2			P3		
op	P	m	op	P	m	op	P	M
a	12	M1	d	14	M1	f	10	M3
b	8	M3	e	18	M3	g	15	M2
c	15	M2						

PROCESS TIMES

Figure 5

RESULTS & DISCUSSIONS

Results And Discussions

The authors have done an extensive study and tested the proposed algorithm for single objective makespan minimization problem with some of the problems stated in Ulsoy et. al (1994). The results reported in the literature are compared with the best results for a population size of 30, number of iterations 10 . Figure 5 shows the variation of makespan based on the value of **w** for the example shown in figure 4. The optimum value of for **w** is 0.75 for the cited problem. Figure 6 shows the convergence curve for EX23. The makespan for EX23 came to be 80 and the value of **w** taken for EX23 is 0.70. Table 1 shows a comparison of the results obtained for some bench mark problems taken from Ulsoy et.al. (1994) using PSO . PSO algorithm seems to be giving better results at a quicker time than other cited algorithms. A total of 18 such benchmark problems have been considered where the PSO algorithm seems to be at par or has outperformed other algorithms.

Figure 10 represents thevarious laouts that have been used to perform the simulations and figure 9 gives the coreesponding travel time matrices.

EAMPLE	STW Slide Time Window Heutristic[1]	UGA Ulsoy's Genetic Algorithm[2]	AGA Adaptiv Genetic Algorithm[2]	PSO Particle Swarm Optimization
EX 220	143	143	143	141
EX 230	146	146	146	147
EX 102	139	137	136	133
EX 103	143	143	141	138
EX 21	105	104	102	98
EX 22	80	76	76	70
EX 23	86	86	86	80
EX 31	105	105	99	98
EX 32	88	85	85	68
EX 33	86	86	86	76
EX 62	100	98	98	93
EX 63	104	104	104	99
EX 73	91	88	86	85
EX 81	161	152	161	136
EX 82	151	142	151	114
EX 83	153	143	153	116
EX 84	163	163	163	158
EX 92	104	102	104	102

Table 1

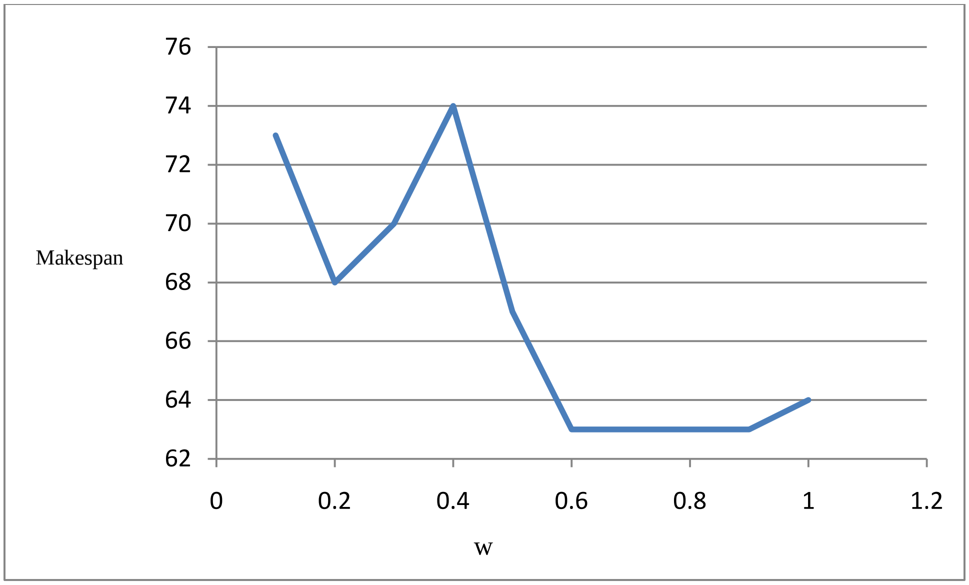


Figure 6

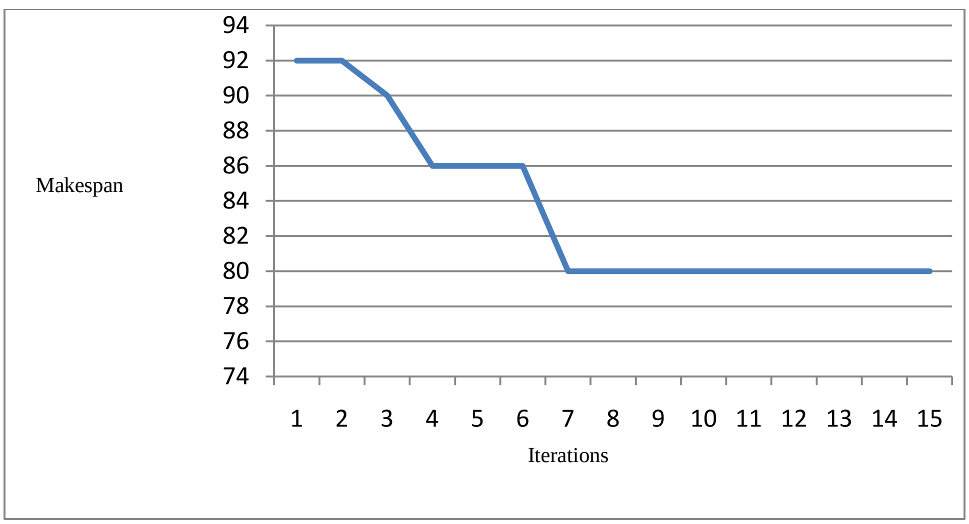


Figure 7

LAYOUT 3

	L/.U	M1	M2	M3	M4
L/U	0	2	4	10	12
M1	12	0	2	8	10
M2	10	12	0	6	8
M3	4	6	8	0	2
M4	2	4	6	12	0

LAYOUT 4

	L/.U	M1	M2	M3	M4
L/U	0	4	8	10	14
M1	18	0	4	6	10
M2	20	14	0	8	6
M3	12	8	6	0	6
M4	14	14	12	6	0

LAYOUT 1

	L/.U	M1	M2	M3	M4
L/U	0	6	8	10	12
M1	12	0	6	8	10
M2	10	6	0	6	8
M3	8	8	6	0	6
M4	6	10	8	6	0

LAYOUT 2

	L/.U	M1	M2	M3	M4
L/U	0	4	6	8	6
M1	6	0	2	4	2
M2	8	12	0	2	4
M3	6	10	12	0	2
M4	4	8	10	12	0

Figure 8

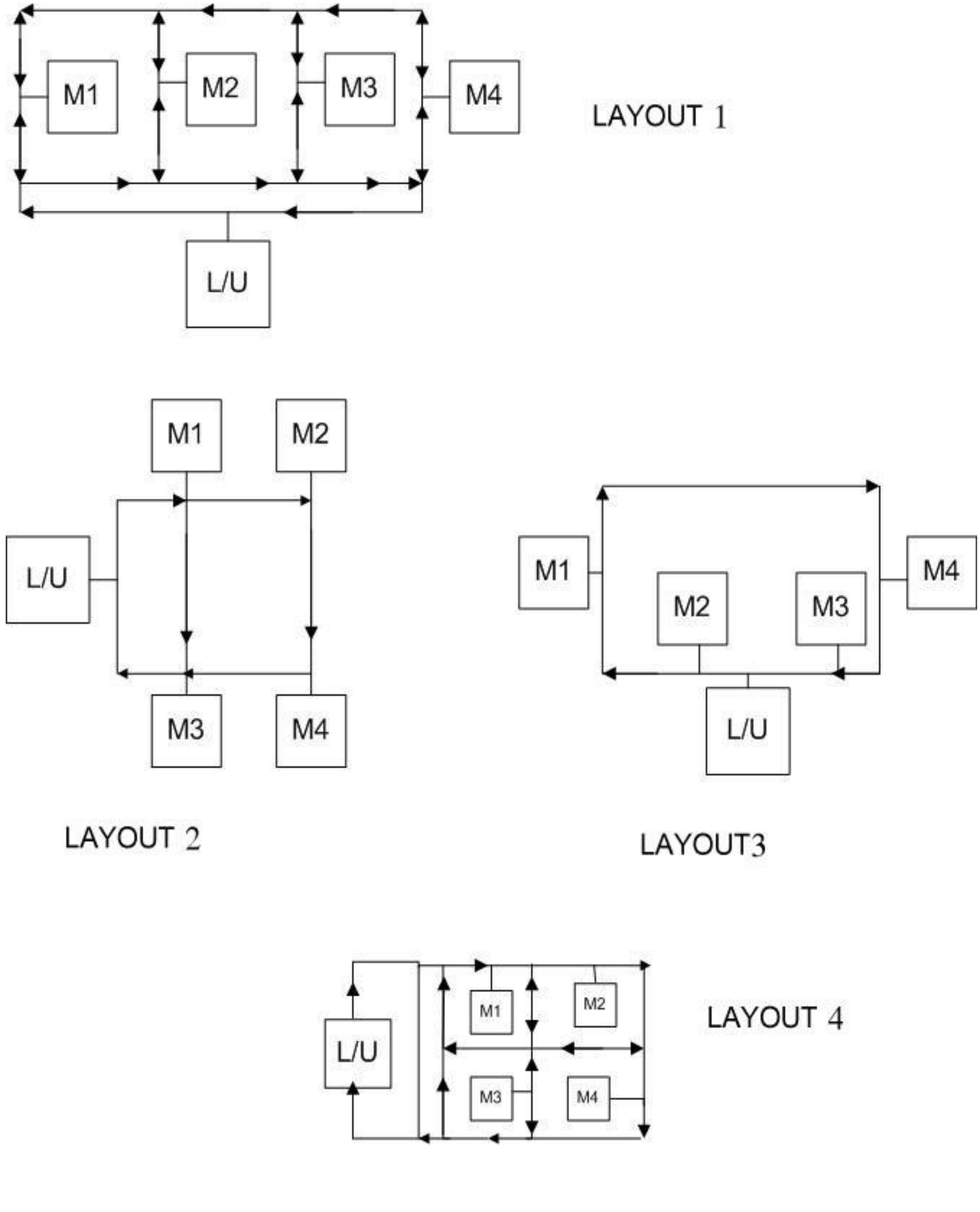

M1
M2
M3
M4
L/U
LAYOUT 1
M1
M2
L/U
M3
M4
LAYOUT 2
M1
M2
M3
M4
L/U
LAYOUT3
L/U
M1
M2
M3
M4
LAYOUT 4

Figure 9

CONCLUSION

Conclusion

The present work is focused on scheduling of jobs and AGVs simultaneously in an FMS environment using particle swarm optimization. The scheduling of jobs and AGVs using PSO aims at minimizing the makespan time. A comparison based on this makespan time has been carried out. The algorithm has been encoded in Visual C++ 2007 edition. The algorithm has proved to be efficient in many of the bench mark problems addressed in Ulsoy et.al.(1994) . In most of the cases the algorithm converged within 15 iterations for a population size of 25. The computational time has been reasonable and the solutions obtained are near to optimal. The PSO based approach has considerable potential approach to manufacturing.

REFERENCES

References

1. B. S. P. Reddy . C. S. P. Rao(2006) “A hybrid multi-objective GA for simultaneous scheduling of machines and AGVs in FMS”, International Journal Adv Manufacturing Technology,31

2. Asokan , R. Saravanan, A. Delphin Carolina Rani(2006) “Simultaneous scheduling of parts and automated guided vehicles in an FMS environment using adaptive genetic algorithm”, J. Jerald , P. International Journal Adv Manufacturing Technology, 29

3. Bilge U, Ulusoy G (1995) “A time window approach to simultaneous scheduling of machines and material handling system in an FMS”. Operations Research 43:1058−1070

4. Raman N, Talbot FB, Rachamadgu RV (1986)” Simultaneous scheduling of machines and material handling devices in automated manufacturing.” In: Proc Second ORSA/TIMS Conf. on Flexible Manufacturing Systems .

5. Abdelmaguid TF, Nassef AO, Kamal BA, Hassan MF (2004) “A hybrid GA/heuristic approach to the simultaneous scheduling of machines and automated guided vehicles”. Int J Prod Res 42: 267−281

6. Schaffer JD (1985)“Multiple objective optimization with vector evaluated genetic algorithms.” Proc First International Conference on Genetic Algorithms, pp 93–100

7. Sabuncuoglu I, Hommertzheim DL (1992)”Dynamic dispatching algorithm for scheduling machines and automated guided vehicles in a flexible manufacturing system.”Int J Prod Res 30:1059–1079

8. Hajela P, Lin CY (1992) “Genetic search strategies in multi-criterion optimal design”. StructOptimiz 4:99–107

9. Srinivas N, Deb K (1994) “Multiobjective optimization using non-dominated sorting in genetic algorithms”. EvolComput 2 (3):221–248

10.Jawahar N, ArindamP ,Ponnabalam S (1998)”A Genetic Algorithm for Scheduling Flexible Manufacturing System”. Int J AdvManuf Technol14: 588–607

11.Namita Singh, P.V. Sarngadharan, Prabir K. Pal (2009), “AGV scheduling for Automated material distribution: a study case‖, Springer Science+Business Media “, LLC 2009.

12. P. Lacomme; A. Moukrim, N. Tchernev,(2005)”Simultaneous job input sequencing and vehicle dispatching in a single-vehicle automated guided vehicle system: a heuristic branch-and-bound approach coupled with a discrete events simulation model”, International Journal of Production Research Volume 43, Issue 9, Pages 1911 - 1942

13.Pundit, R., and Palekar, U.S., (1990),” Job-Shop Scheduling with Explicit Material Handling Considerations.” Working Paper, Dept. of M and IE, Univ. of Illinois at Urbana-Champaign, Urbana, IL61801.

14.Carvalho, D., Protti, F., Gregorio, M. D., & Franca, M. G. (2005),”A novel distributed scheduling algorithm for resource sharing under nearheavy load.” In: Principles of distributed systems,(pp. 431–442). Springer.

15.Egbelu, J. P., &Tanchoco, J. M. A. (1984),” Characterization of automatic guided vehicle dispatching rules”, International Journal of Production Research, 22, 359–374.

16.Zahorik, A., Thomas, L.J., and Trigeiro, W.W., (1984), “Network Programming Models for Production Scheduling in Multi-StageMulti-Item Capacitated System.” Management Science, 30 (3), 308-325

17. Kim, C.W., and Tanchoco, J.M.A., 1991,” Conflict Free Shortest Time Bi-Directional AGV Routing”. International Journal of Production Research, 29 (12), 2377-2391.

18.Huang, J., Palekar, U.S., and Kapoor, S.G., 1993, “A Labeling Algorithm for the Navigation of AutomatedGuidedVehicles.” ASME Transactions, Journal for Engineering for Industry, 115, 315-321.

19. Blazewicz, J., Dror, M., andWeglarz, J.,(1991)"Mathematical Programming Formulations for Machine Scheduling: A Survey." European Journal of Operational Research, 51 (3), 283-300.

20. C. R. Suribabu, T. R. Neelakantan (2006)"Design of water distribution networks using particle swarm optimization."Urban Water Journal Volume 3, Issue 2, Pages 111 - 120

.

21. MiltiadisKotinis(2010)" A particle swarm optimizer for constrained multi-objective engineering design problems Engineering Optimization"Volume 42, Issue 10, First published 2010, Pages 907 – 926.

22. Swagatam Das, AmitKonar(2007)" A swarm intelligence approach to the synthesis of two-dimensional IIR filters", Engineering Applications of Artificial Intelligence Volume 20, Issue 8, Pages 1086-1096.

40 | P a g e