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Optimal Solution for a FMS Loop Layout Using Multi-Objective Genetic Algorithm

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Abstract:
The overall performance of Flexible Manufacturing Systems (FMS) can be improved considerably by optimal design and planning before its implementation. The design of the loop layout with an objective of finding an arrangement of machines around that loop, which minimizes the total travel distance of an Automated Guided Vehicle (AGV), plays an important role in achieving high performance in an FMS. The present paper studied about the minimization of the total distance travelled by AGV for different part types by considering the clearances between the machines. Multi objective Genetic Algorithm (GA) toolbox in MATLAB is used for the optimization of FMS loop layout. Both uni-directional loop layout and bi-directional loop layout were studied and results are compared. It is found that the MATLAB toolbox can be used effectively for solving multi-objective FMS loading problem.

Keywords: *FMS, Loop layout, Automated Guided Vehicle (AGV), Multi objective Genetic algorithm (GA) tool box, total distance travel.*

1. Introduction

Flexible manufacturing system is a manufacturing concept which operates with the lowest total cost and greatest agility. FMS is an arrangement of machines, interconnected by material transportation devices like automated guided vehicles, with all of its components being controlled by a central computer control system. FMS is called flexible as it is capable of processing a variety of different part styles simultaneously and production can be adjusted to market fluctuations. The efficiency of FMS can be improved by a good arrangement of machines in FMS layout. The appropriate type of layout for an FMS depends on part type, size and geometry, and also economics of compatibility with other FMS components. An optimum design of layout leads to a considerable reduction of the production time and manufacturing costs. The planning stage involves the study of route sheets for the various parts and based on the workflow structure and then appropriate layout of the machines should be selected.

Some commonly used FMS layouts are: 1) In-line layout 2) Loop layout 3) Ladder layout 4) Open field layout and 5) Robot-centered layout. The type of layout that suits well depends on a number of factors like the type of material handling system, space availability in the plant, number of operators working etc.,

Among all these layouts, loop layout is the widely used layout due to its high flexibility in material handling. The loop layout is generally suitable for mid volume and mid variety production. It consists of a conveyor loop with workstations/machines located around its periphery. This configuration allows a maximum flexibility in processing sequence, because any workstation is accessible from any other workstation.

The problem is related to the design of loop layout of FMS which involves determining the relative order of machines on the loop layout, so that the total distance of travel for the transportation gets minimized, thus leading to the improvement of the overall system output. The layout considered is used to process a group of parts on some specified machines. Each part has a unique routing sequence, which is assumed to be fixed and known.

Genetic algorithm is a stochastic method used for global search and optimization, which belongs to the group of evolutionary algorithms. These evolutionary algorithms use the main principles of the natural evolution like reproduction, selection and diversity of the species, cross over and mutation of genes.

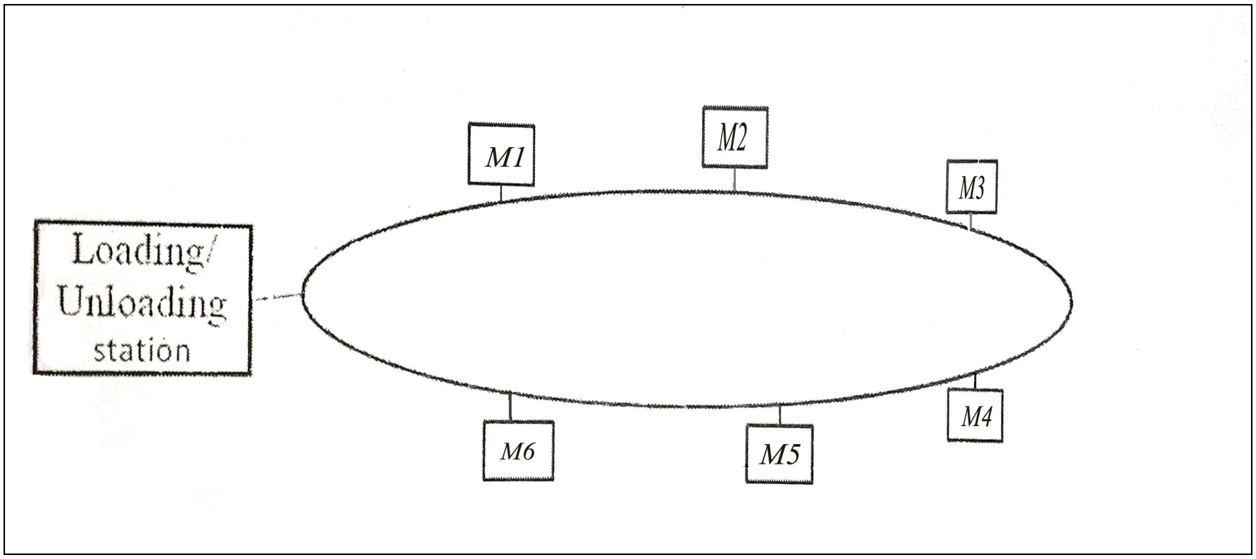

Figure 1: Loop layout configuration

2. Literature Review

In the earlier stages, FMS problems were formed as mathematical models; such as branch and bound method and dynamic programming, which can be applied to smaller problems only. Hera gu et. al [1] have carried out a survey of different methods like quadratic assignment, linear integer programming, mixed integer programming, graph theory that can be applied for facility layout problems. Koopmans et.al [2] defined different class of problems as a common industrial problem, in which the objective is to configure facilities, so as to minimize the cost of transporting materials between them. They modeled the problem of plant facility location with material flow between them as a quadratic assignment problem. In later stages the application of heuristic methods became a common tool for solving FMS layout design problems. These heuristic methods can be used to solve effectively small combinatorial optimization problems. They work effectively but there is a danger of trapping into a local optimum solution.

To overcome this difficulty, meta-heuristic techniques such as tabu search, Genetic Algorithm (GA), Simulated Annealing (SA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO) etc., are widely used.

K. Mallikarjuna et.al [5] studied on multi objective optimization related to FMS scheduling by various meta-heuristics like GA, SA. The authors made an attempt to consider machine arrangements in an optimum sequence with various constraints. Guanshsu A. Chang et.al [8] studied simulation models and investigated the effectiveness and efficiency of FMS with respect to manufacturing lead times, bottleneck analysis and the number of workstations. R.M. Satheesh Kumar et.al [7] considered the ordering of machines around a loop, to minimize the total number of travels for a family of parts. They used PSO technique to solve the problem, by considering the clearance between the machines. M. Sambathkumar et.al [9] tried to determine the ordering of machines around a bi-directional loop, and thus minimizing the AGV movement by using PSO technique, by considering the clearances between the machines. Mani Shivhare et.al [10] tried to optimize the FMS with an objective of minimization of distance travelled by an AGV. They found out the ordering of machines around a loop for optimum results with the help of PSO. Adel El-Baz M [11] considered the various material flow patterns of manufacturing environments of flow shop layout such as single line with multiple products, multi-line layout, semi-circular and loop layout. The effectiveness of the GA approach is evaluated and the cost performance is compared with other approaches. G.N. Purohith et.al [12] explored the potential power of genetic algorithm for optimization by using new MATLAB based implementation to a function.

After literature review, the main objective of this paper is defined as to minimize the total travel distance by all the parts in the layout. There are some basic assumptions to be assumed while implementing GA for layout optimization such as:

3. Assumptions

3.1. Model Assumptions

- Each machine performs a different operation.
- The distances between the machines are known and equal.
- There is a common loading and unloading point for the layout.
- No breakdowns in case of machines and material handling equipments.
- Each operation is executed on only one machine.

3.2. Data Assumptions

Data considered for the present problem:
Number of machines/workstations = 6
Number of work parts = 8

Number of AGV used = 1
Distance between the machines = 1m
The following typical problem (Table.1) represents the sequence of operations through which each part undergoes has been considered for applying GA:

Part	Operation1	Operation2	Operation3	Operation4
P1	M5	M1	M3	M2
P2	M2	M1	M5	M3
P3	M1	M3	M6	M5
P4	M2	M4	M3	M5
P5	M1	M3	M4	M5
P6	M3	M2	M5	M6
P7	M2	M5	M4	M3
P8	M1	M4	M3	M5

Table 1: Machine sequences for different work parts

4. Solving the Problem Using GA

4.1. General Formulation of Objective Function

The multi response objective function for the optimization of loop layout for 'n' machines are expressed as:
$F(c) = \sum w_k f_k$; k = 1, 2, …….. ,n
Where 'w_k' is the weighing factor for individual response function
'f_k' is the objective function for responses 'k'
'n' is the number of responses; as there are six machines in the layout, n equals to six. As equal priorities are given to all responses (machines) for simultaneous minimization, weighing factor can be taken as 1/6.
'f_k'for minimization in case with GA is taken as $1/(1+x_k)$
Each distance parameter has both upper and lower bounds, and the constraints formed by them are called bound constraints.

4.2. Solving the Objective Function Using Genetic Algorithm

A genetic algorithm starts with an initial random population of individuals (chromosomes), representing different possible solutions to a problem. The fitness of each individual is evaluated in each generation with the help of a fitness function and then selected for next generation based upon its fitness. New generation, known as offspring are produced by genetic operations like crossover and mutation. The size of the population of next generation is maintained constant by considering only the fittest of the population from the previous generations. This process is terminated when some termination criteria like maximum number of generations, maximum time limit, maximum fitness limit is reached. The formulated problem is solved using GA toolbox by feeding the input data (Fig.2) and the results are given in Tables 2 and 3.
The aim of applying multi-objective GA optimization for loop layout is to minimize the total distance travelled by the AGV and thus improving the productivity. From the results, it can be decided whether unidirectional loop or bidirectional loop is best suited for our layout. An objective function is used to evaluate the performance of the algorithm in the problem domain. In the case of multi objective problems, the objective function values are in vectorial form. Based on the objective function values optimum sequence has been selected.

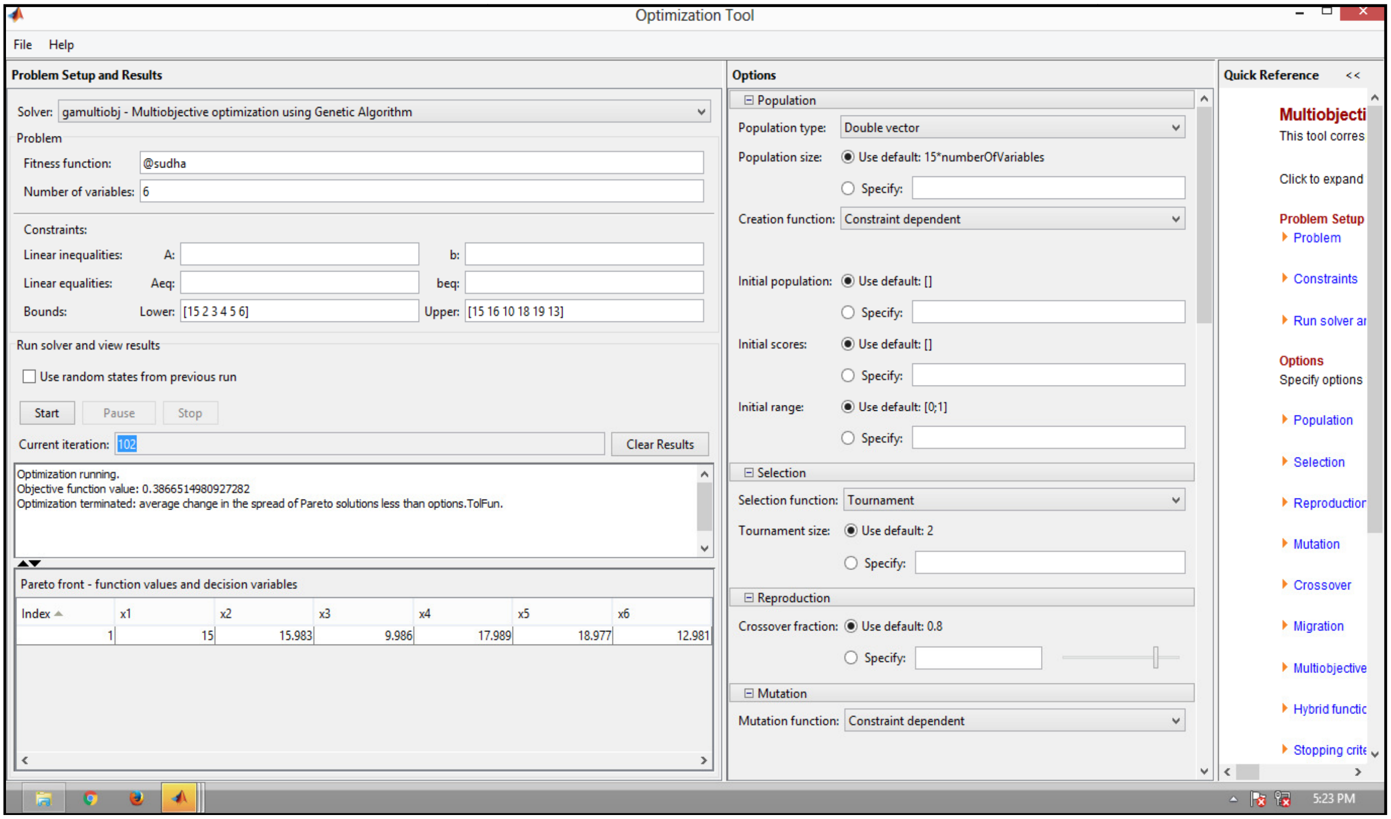

Figure 2: Screenshot of multi-objective toolbox using GA in MATLAB

5. Results of Optimized Loop Layout

A ten number of both combinations of machine sequences which have lower objective function values in both uni-directional loop layout and bi-directional loop layout have been shown in Table 2 and Table 3.

From Table 2 and 3 of machine sequences that are obtained from GA, it is found out that machine sequence 246315 is having lowest objective function value among all the sequences of both uni-directional and bi-directional loop layouts. The optimized machine sequence is shown in Fig.3

S.No	Sequence	Objective Function Value
1	246315	0.335061
2	364152	0.338841
3	346152	0.33886
4	642315	0.339525
5	341652	0.343533
6	361452	0.343586
7	461523	0.345365
8	314652	0.349293
9	316452	0.349644
10	625431	0.351075

Table 2: Machine sequences in uni-directional loop layout

S.No	Sequence	Objective Function Value
1	146253	0.359487
2	164352	0.442171
3	241563	0.511921
4	421536	0.521373
5	261543	0.528942
6	426135	0.529811
7	641523	0.530937
8	142365	0.540026
9	531642	0.540625
10	614253	0.542014

Table 3: Machine sequences in bi-directional loop layout

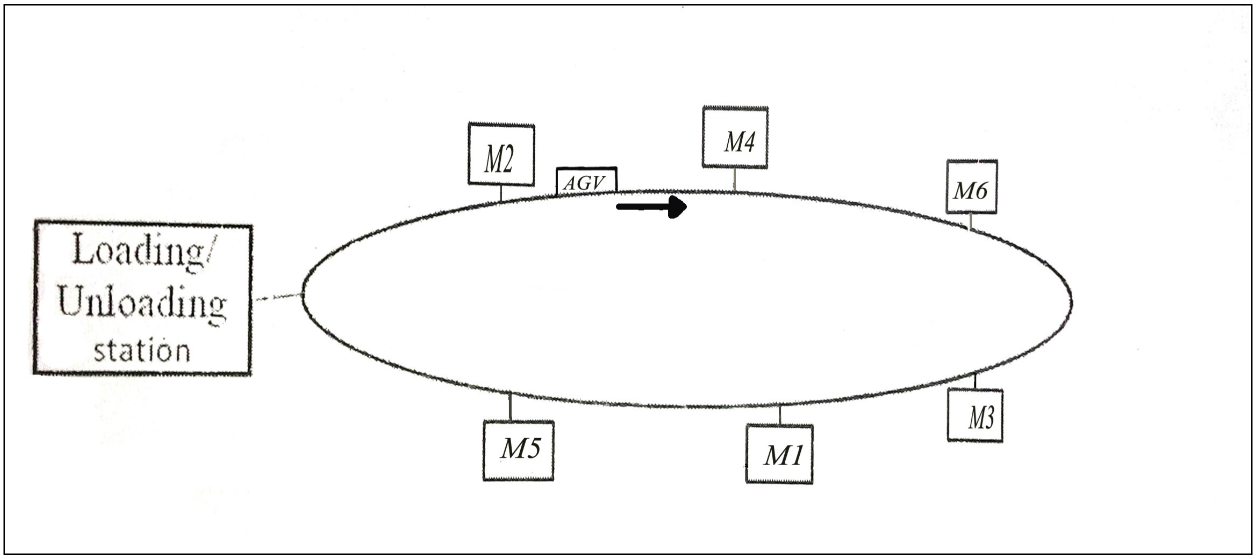

Figure 3: Optimized machine sequence

6. Conclusion

The performance analysis of FMS loop layout with various machine sequences is carried out. A multi-objective Genetic Algorithm is used for optimizing loop layout of FMS to minimize the total distance travel for AGV by considering different machine sequences. The results of uni-directional and bi-directional loop layouts are compared. This approach can be extended for other types of layouts also.

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