An Evolutionary Sheep Flock Heredity Model Algorithm for minimizing Manufacturing cost in Job Shop Scheduling

G.Ramya, and M.Chandrasekaran

***Abstract*—**Increasing market competition has induced industries to search for easier way of manufacturing production processes. Production activities requiring for production facilities were group together and processed in sequence in order to reduce setup times, inventory cost and Manufacturing cost. Manufacturing industries are currently heading towards the development of highly automated manufacturing system, which generally lead to lower production costs and higher profit. In today's economic climate industries are realizing that responsibilities to customers' demands and adaptability to changing requirements, while delivering high quality products at low competitive prices and quick time. Today's Manufacturing System is enabled with excellent communication knowledge on production plan, proper scheduling of machinery process, human resource planning, Manufacturing cost and labor costs. Evolutionary algorithms are developed to bring optimized results in stipulated cost with respect to optimum schedule. This article deals with minimizing manufacturing costs based on machine work allocation and employee workload with Sheep flock heredity model algorithm (SFHMA). The Manufacturing cost minimization is to find a schedule that satisfies the organization's rules, machine allocation and Customers requirements. The Machine work allotment formulation is concerned with assigning machine load based on requirements, assigning number of employees into a given set of shifts over a fixed period of time and week task. Several local search methods and evolutionary heuristics algorithms has been proposed in many research on Job shop scheduling. The Results are compared with other evolutionary heuristics in terms of manufacturing costs. The corresponding evolutionary algorithm performs result oriented than other evolutionary Algorithm.

***Keywords*—**Job shop scheduling, Machine allocation, Manufacturing costs, Evolutionary Algorithm, Sheep Flock Heredity Model Algorithm.

I. INTRODUCTION

A SCHEDULE is an allocation of tasks to the time intervals on the machines. The aim is to find a schedule that minimizes the overall completion time, which is called the makespan. In the job shop scheduling problem n jobs have to be processed on m different machines. Each job consists of a sequence of tasks that have to be processed during an uninterrupted time period of a fixed length on a given machine. Due dates are treated as deadlines and require the job-shop scheduling to meet specific due dates in order to avoid delay penalties including customer's bad impression, cost of lost future sales and rush shipping cost [1].

Job shop scheduling problem has been described as NP which means Non deterministic Polynomial time. Lenstra et al [2] solved the 3 X 3 problem, the n X 2 instance with no more than 3 operations per job and the n X 3 problem with no more than 2 operations per job. Lenstra et al. proved that the n X 2 instance in which operations last for no more than 2 units of processing time and the n X 3 problem in which all operations are of unit processing time belongs to the set of NP instances [3]. Mattfeld et a proposed randomly generated solutions with precedence relations which are not uniformly distributed [4]. A 10 X 10 problem proposed by Fisher et al. was solved by Carlier et al. [5]. Shmoys et al.proposed several poly-logarithmic approximations for evaluating an optimal schedule with makespan minimization criteria [6]. French predicted that no efficient algorithms will ever be developed for the majority of scheduling problems [7]. As a result, the focus of optimisation research has turned to be enumerative approaches.

Efficient Methods are traditional approaches consider technological advances in both processes and equipment as the key to success and the right way to remain competitive. Many valid approaches and its advances are compared and shared between competitors in rapid form. Each and every approach have its own valid solution exclusively [8].

It has been recognized by many researchers that scheduling problems can be solved optimally using mathematical programming techniques and one of the most common forms of mathematical formulation for job shop scheduling problem was the Mixed Integer linear Programming (MIP) format of Manne . Blazewicz et al. Emphasized the difficulties of JSP and indicated that mathematical programming models have not been achieved enough breakthroughs for scheduling problems [9]. In earlier research, the job-shop scheduling problem has been extensively studied with the objective of minimizing some functions of the completion times of jobs. Typical scheduling problems involve minimizing the maximum gj(t) value (the maximum cost problem) or minimizing the sum of gj(t) values (the total cost problem). Scheduling is defined as the art of assigning resources to tasks in order to insure the termination of these tasks in a reasonable amount of time (10).

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Several techniques have been proposed and different heuristics have been designed and developed for solving the minimum makespan problem, the minimum total tardiness problem and so on. SFHM algorithm was used for minimizing mean tardiness and mean flow time multi objective criteria [11]. An effective SFLA was used for minimizing maximum completion time (i.e., makespan) [12]. The evolutionary approaches were also employed for various engineering application problems due to their robustness and convergence to global optima. Evolutionary Approaches are search and optimization algorithms inspired by the process of natural evolution and searching Techniques. EAs are employing a probabilistic search for locating a globally optimal solution. EAs have many advantages. EAs are providing a set of solutions near the optimal one on a wide range of problems. They can be easily modified with respect to the objective function and constraints [13]. Some other cases scheduling problem is addressed after the orders are released into the shop floor, along with their process plans and machine routings [14]. Scheduling plays a crucial role to increase the efficiency and productivity of the manufacturing system. The problem of scheduling is one of the operational issues to be addressed in the system on a daily or weekly basis. Job shop scheduling problems are Non-Polynomial (NP) hard] so it is difficult to find optimal solutions [15].

In manufacturing systems, the decisions related to machine scheduling is based on jobs on the machines are often made in a sequential operational processes. The objective of job scheduling is to find the optimum schedule to minimize the costs and completion time whereas the objective of maximize the overall production profit. In many manufacturing industries machine allocation is first prepared and then the scheduling of jobs must take based on the resources availability or first the scheduling of jobs is done and the machine allocation established based on the machine availability.

Manufacturing industries are currently heading towards the development of highly automated manufacturing system, which generally lead to lower production costs and higher profit. Today's Manufacturing System is enabled with excellent communication knowledge on production plan, proper scheduling of machinery process, human resource planning, Manufacturing cost and labor costs. This article deals with minimizing manufacturing costs based on machine work allocation and employee workload with Sheep flock heredity model algorithm (SFHMA). Evolutionary algorithms are developed to bring optimized results in stipulated cost with respect to optimum schedule. The Manufacturing cost minimization is to find a schedule that satisfies the organization's rules, machine allocation and Customers requirements. The Machine work allotment formulation is concerned with assigning machine load based on requirements, assigning number of employees into a given set of shifts over a fixed period of time and week task. The hierarchical approach, which was first proposed by Brandimarte was implemented for formulation of objective function and solving the scheduling problems with objective of minimizing manufacturing cost [16]. In order to decrease the complexity, this method considering assigning machine allocation as sub problem and sequencing the order as another sub problem separately.

II. Job Shop Scheduling

A. Job Shop Scheduling Problems

In the job shop scheduling problem n jobs have to be processed on m different machines. Each job consists of a sequence of tasks that have to be processed during an uninterrupted time period of a fixed length on a given machine. So the maximum of completion time needed for processing all jobs is subjected to the constraints that each job has a specified processing order through the machines and that each machine can process at most one job at a time. The term 'Scheduling' in manufacturing systems is used to the determination of the sequence of operations in which parts are to be processed over the production stages.

B. Machine Allocation

All Machine Allocation has been found to be an effective way explicitly to consider relationships between the end items of various processes and machines. Machine allocation systems determine the quantity of each machine that will be used in the production of a prescribed volume of final work, and the times at which each of them must be utilized to meet prescribed due dates for the final products. These systems are highly detailed and an excellent means for assigning loads and tracking resource requirements. It does not encompass short term scheduling decisions like machine loading and operations sequencing. Once work load has set due dates for each stage, it becomes the responsibility of the shop floor scheduling system to meet such deadlines. This is a critical activity because the load on work centers changes over time. There can be such unexpected events as machine breakdowns, raw material shortage, scrap and rework, all causing the actual lead time to differ from the planned one. The Machine work allotment formulation is concerned with assigning machine load based on requirements, assigning number of employees into a given set of shifts over a fixed period of time and week task.

C. Manufacturing Cost

Normally, manufacturing system consists of active period starts from the first day of production on the machine with certain set of actions and operations. In general Meeting the due dates is the most important goal of scheduling to avoid the delay penalties including customer's bad impression, lost future sales. Due-date oriented functions, whereas the main aim of optimizing the makespan is to minimizing the manufacturing costs and maximizing the output.

D. Evolutionary Algorithms

The evolutionary approaches were also employed for various engineering application problems due to their robustness and convergence to global optima. Evolutionary Approaches are search and optimization algorithms inspired by the process of natural evolution and searching Techniques. EAs are employing a probabilistic search for locating a globally optimal solution. EAs have many advantages. EAs are providing a set of solutions near the optimal one on a wide range of problems [13]. They can be easily modified with respect to the objective function and constraints.

III. Problem Description and Mathematical Formulation

We consider the following job shop scheduling problem with single level J jobs on M Machines. Let U denote set of machines. Consider a non-pre-emptive job shop with m machines ($M_i = i, \ldots. m$) & n jobs ($N_i = i, \ldots n$). When j_i is the set of job to be processed on machine M_i . The execution of the ith operation of job Jj requires a resource or machine selected from a set of available machines. The operation sequence of the job j is denoted by O_{ij} (Where i^{th} operation on j^{th} machines $M_{j)}$. Objective functions depend on due date which are associated with the jobs. The organization has to process a set of n jobs J = {1, n} during the time horizon (T). Each job j has a release date rj and a due date dj .We assume that there is a Manufacturing cost Mc if job j starts at time t. Activities representing machine inactivity (breakdown, maintenance, idle etc.) gathered in set P.

$$\min (f) = \sum_t Mc \quad (1)$$

Where, U denotes total manufacturing cost, which is the total cost (Mc) required to manufacture the jobs in k number of machines. Eq.(1) represents exactly once the each job has to be started, All the started jobs finished within its time zone, each job can be processed by a machine at each time period with satisfaction of precedence constraint, all machines are available at t = 0 and each job Jj can be started at t = 0, at a given time, a machine can only execute one operation. High speed machines are sophisticated compared to low speed machines and high speed machines require less processing time to manufacture a job compared to low speed machines. Hence, the high speed machines incur more manufacturing cost than low speed machines. In order to resemble this relationship the following exponential function is used to calculate the unit manufacturing cost shown in Eq.(2).

Manufacturing cost of a machine per unit time

$$M_c = \frac{A \, x \, e^{-k \, x \, \sum Pt}}{\Sigma Pt} \quad (2)$$

Where, A is the constant coefficient represents fixed costs as 1000. The term e is exponential function. The term k determines the cost of producing a single job to the required dimension and includes the charge rate of the machine. is total processing time of all jobs on a machine [17].

IV. Proposed Methodologies

A. Sheep Flock Heredity Model Algorithm (SFHMA)

Evolutionary algorithms are quite interesting and effective in solving scheduling problems [18]. The several separated flocks of sheep in a field as shown in Figure 1.

Fig. 1 Flocks of sheep in the field

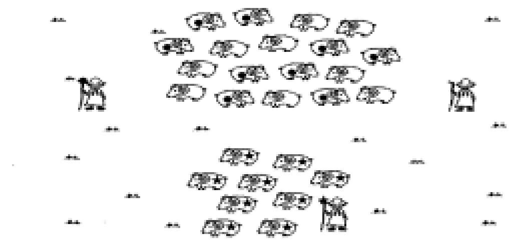

Fig. 2 Mix of two flocks of sheep

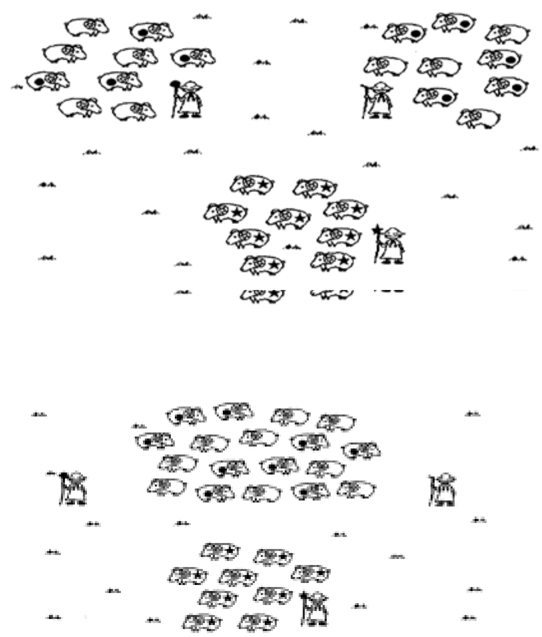

Fig. 3 New Flocks of sheep in the field

Normally, sheep in an each flock are living within their own flock under the control of shepherds. So, the genetic inheritance only occurs within the flock in other words, some special characteristics in one flock develop only within the flock by heredity, and the sheep with high fitness characteristics to their environment breed in the flock. Assume that two sheep flocks were occasionally mixed in a moment when shepherds looked aside as shown in Figure 2. Then, shepherd of the corresponding flocks run into the mixed flock, and separate the sheep as before. However, shepherds cannot distinguish their sheep originally they owned because the appearance of any sheep is the same. Therefore, several sheep of one flock are inevitably mixed with the other flocks as shown in Figure 3. Namely, the characteristics of the sheep in the neighbouring flocks can be inherent to the sheep in other flocks in this occasion. Then, in the field, the flock of the sheep, which has better fitness characteristics to the field environment, breeds most.

B. SFHMA for Job Shop Scheduling

Begin
Initialize the population,
Stage 1:
Select the parent
Sub chromosome level crossover
Set sub chromosome level crossover probability
If population probability is less than or equal to sub chromosome level probability
Perform sub chromosome level crossover
Else retain the old sequences
Sub chromosome level mutation
Set sub chromosome mutation probability
If population probability is less than or equal to sub chromosome mutation probability
Perform sub chromosome level mutation
Else retain the same sequences
Stage 2:
Select two sequences from population
Chromosome level crossover
Set crossover probability
If population probability is less than or equal to crossover probability
Perform chromosome level crossover
Else retain the same sequences
Chromosome level mutation
Set mutation probability
If population probability is less than or equal to mutation probability
Perform chromosome level mutation
Else retain the same sequences
End if terminal condition satisfied

V. RESULTS AND DISCUSSIONS

A. Benchmark Problem

The proposed Sheep Flock Heredity Model Algorithm designed for minimizing manufacturing cost is coded in "C" Language on an Intel Core 2 Processor and tested with benchmark problems found in Kacem et al shown in Table.1. [19]. Pareto optimal solutions are obtained for instances, i.e., 4 jobs × 5 machines problem. Table 2 shows the best solutions obtained for the instances 4x5. It can be found that the proposed algorithm is more efficient than hybridization of evolutionary algorithms and fuzzy logic (HEAFL) proposed by Kacem et al. [19] for solving the four Kacem instances. Each instance characterized by number of jobs (J), number of machines (M) and each operation Oi,j of job i.

TABLE I
PROBLEM 4X5 INSTANCES WITH 12 OPERATIONS

Job	$O_{i,j}$	M_1	M_2	M_3	M_4	M_5
J_1	$O_{1,1}$	2	5	4	1	2
	$O_{1,2}$	5	4	5	7	5
	$O_{1,3}$	4	5	5	4	5
J_2	$O_{2,1}$	2	5	4	7	8
	$O_{2,2}$	5	6	9	8	5
	$O_{2,3}$	4	5	4	5	5
J_3	$O_{3,1}$	9	8	6	7	9
	$O_{3,2}$	6	1	2	5	4
	$O_{3,3}$	2	5	4	2	4
	$O_{3,4}$	4	5	2	1	5
J_4	$O_{4,1}$	1	5	2	4	12
	$O_{4,2}$	5	1	2	1	2

Step 1: Initial Sequence Generation

The initial sequence generated randomly and the corresponding makespan for the sequence is given Table 4. With a crossover probability a second and a third sub chromosomes (sub string) are chosen randomly and crossover is performed.

Step 2: Process of Sub Chromosome Level Inverse Mutation

Probability for this chromosome is less than process mutation probability. Second and Third sub strings are selected to perform this process. Each sub string 4 and 9 positions are chosen randomly to perform inverse mutation

Step 3: Global Level Crossover Process

Crossover probability this sting is less than the process crossover probability. Sequences 1 and 6 are selected for crossover. At the position of 6^{th}sub string is chosen as the crossover position..

Step 4: Global Level Inverse Mutation Process

Probability for this string is less than process mutation probability. The 2^{nd} and 6^{th} sub string positions are randomly selected to perform inverse mutation..

Step 5: labor Cost and due date calculation

Manufacturing cost for each job was given below.

$M^1_1 = M^1_2 = 4$, $M^1_{\ i} = 2$ (i = 3, 4,…, 8), $M^1_9 = M^1_{\ 10} = 1$, $M^l_{\ i} = M^1_{\ i}$ M i (i= 1,….., 10, l = 2,….., 20).

The following parameters are obtained on trail and error basis.

Population Size (n) =10,
Fitness function = fit(X)=(1/Z1)xK, where K=10,
Crossover = Single point crossover, Crossover Probability (Pc)=0.8, Mutation = Inverse mutation, Mutation Probability(Pm) =0.05,Termination Criteria =Number of iterations (100)

TABLE II
RESULTS OBTAINED IN SFHMA [MC]

Problem	Jobs	Machines	HEAFT	GA	SFHMA
KA01	4	5	406.88	392.76	392.45
KA02	8	8	634.35	632.45	633.47

Apparently, the SFHM algorithm minimizes the manufacturing cost of each job. The computational results in our approach are quite superior compared to other approach are shown in Table 2.. The results obtained from the computational study have shown that the proposed algorithm is a viable and effective approach than other evolutionary for problems on a large scale.

VI. CONCLUSIONS

In this paper, SFHM approach has been used for solving job shop scheduling problems with minimization of manufacturing cost. The algorithm uses Multi Stage Genetic Operation. The SFHM approach has been tested in a single-objective cost context to evaluate its effectiveness. Afterwards this algorithm has been tested on Kacem 4x5 instances problem. The results were compared with other evolutionary heuristics that tested the same problems. SFHM algorithm gives better results than other algorithms. The proposed SFHM algorithm is competent and proves to be a good problem-solving technique for job shop scheduling.

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