Flexible Employee Scheduling with Multi Skill Training Program using Genetic Algorithm

[1]Mahalakshmi, [2]Prof. Murugesan R

[1]Research Scholar, [2]Professor, [1,2]REVA University, Bangalore, Karnataka, India.

[1]*mahalakshmi4131@gmail.com*, [2]*contactmurugu@gmail.com*

Abstract - This paper is the study of flexible employee scheduling with the multi skill training program of the employees in the manufacturing process. The paper starts with mathematical modeling by giving flexibility in choosing the shift types and days off assignment to the employees. An extra care is taken for not assigning night shift on the day before the day off. A robust Genetic algorithm is used to solve the mathematical model constructed. A 6hour shift for morning as well as afternoon and 12hour shift for night is assigned to the employees, which reduces the total cost function of the employees by 10.33% compared to normal 8hour shifts. And also a multi skill training program to the employees are adapted, which again reduces the total cost function of the employees by 20% compared to untrained employees.

Keywords — Employee Scheduling, Multi skill training, Genetic Algorithm, Mathematical modeling, Crossover, Mutation.

I. INTRODUCTION

Balancing the work and workloads among the employees is an important task of the industrial management. We can overcome this issue if we use the manpower [1] in a flexible manner. This can be possible only if we frame the proper employee scheduling in the manufacturing process. Proper employee scheduling means choosing right shift duration (6hours or 8hours) and also giving flexibility in choosing the shift types and day off assignment to the employees. Two consecutive days off should be given to the employees to overcome the stress. The days off assignment is provided by Burns and Carter [2] by saying an employee should work more than six consecutive days of the week. A tour assignment problem is given in [3], which shows an employee can avail two consecutive days off in a week. Also a break assignment is introduced by [4], which says an employee should have proper breaks in between the working hours. In the later stage [5] and [6] proposed a complete model including shift scheduling and days off scheduling along with the break assignment problem. As we know that human resource is a key element for success of an organization [7, 8 and 9]. Now a days many organization putting an effort to train the employees for multi skill training [10 and 11]. These training programs will help in gaining the knowledge about other works related to manufacturing process, which also help in balancing the work pressure among the employees. So in this paper we are a making a flexible employee scheduling with multi skill training program of the employees. A mathematical model is formed based on some assumptions. We are implementing a Genetic Algorithm to study the model developed. Genetic algorithm is a tool for solving optimization problems which is developed based on the principal of natural selection. In 1970 John Holland introduced the genetic algorithm for the first time. And he introduced basic principles of genetic algorithm [12]. There after many more literatures are available in [13], [14] and [15] and few reports of the genetic algorithm are available in [16], [17], [18] and [19]. Genetic algorithm has wide range of application due its independent of error free surface. Non differentiable, multimodal, non-continuous, and also NP-Complete problems are solved using genetic algorithm [20]. The multimodal problems are solved with the relative ease using genetic algorithm in [21] and [22]. This is also used in solving nonlinear identification problems [23]. It is also used in the secure communication systems [24] and [25]. Genetic algorithms are also used in scheduling process of multiprocessor systems [26], Nurse scheduling [27] and Doctor Scheduling [28]. The above literature survey shows that there is no work on Employee scheduling using genetic algorithm. Therefore in this paper we are adapting genetic algorithm for employee scheduling with multi skill training program.

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II. MATHEMATICAL MODEL FORMULATION

The total concentration of the paper is flexible employee scheduling along with multi skill training program in order to minimize the cost function of the employees. In this paper we are framing 6 hour shift for morning and afternoon session and 2 continuous shift of 6hours for night session to the employees. There are three shift available for the employees namely Morning Shift (8am to 2pm), Afternoon Shift (2pm to 8pm) and Night Shift (8pm to 8am). Totally 21 shifts available for the employee in a week. An employee should do minimum of 2 night shift and 3 morning or afternoon shifts in a week and can do maximum of 2 night shifts and 4 morning or afternoon shift in a week. Also we are concentrating on giving two consecutive days off assignment, break assignment and not assigning night shift on the day before the day off.

A. Indices

n Number of employees working in organization

m Number of days in the scheduling period.

i Index of employees, $i = 1, 2 \ldots n$

d Index of days in the scheduling period, $j = 1, 2 \ldots 7$

s Shift types, $s = 0, 1, 2, 3$. ($s = 0 \rightarrow$ day off, $s = 1 \rightarrow$ Morning shift, $s = 2 \rightarrow$ Afternoon shift, $s = 3 \rightarrow$ Night shift)

t Scheduling periods, p=1, 2 and 3 (morning shift →8am to 2pm, Afternoon shift → 2pm to 8 pm and night shift → 8pm to 8am)

w Set of skill W

g Set of service group G

W_g Skill set W including service group g.

B. Parameters

CF Cost function of the employees

dur_s Duration of shift s.

min−shift Minimum number of shifts allotted for an employee in the scheduling period

max−shift Maximum number of shifts allotted for an employee in the scheduling period

pne_{dp} Preferred number of employees required for the period on p the day d

$\mathrm{lb}_{dp}, \mathrm{ub}_{dp}$ Lower bound and upper bound on the demand of employees on the day d in the period p.

do_{id} Days off of an employee i on the day d

C. Decision Variables

x_{ws} Number of the employees trained for the set of skill w in the shift s

y_{wsd} Number of employees trained for set of skills w in the shift s on the day d

N_{wgdt} Number of employees trained for set of skill w of group g on the day d with time t

$nspddo_i$ Negative deflection of assigning night shift in the previous day of the day off

off−p_{id} off-on-off pattern of the scheduling period

on−p_{id} on-off-on pattern of the scheduling period

b_{ids} Break on the day d in the shift s of the employee i

D. Objective Functions

The objective function is to minimize the Cost function of the employees using multi skill training program.

$$\sum_{w}\sum_{s} CF.x_{ws} \tag{1}$$

The objectives related to employees are given as follows.

Minimization of off−on−off pattern

$$Minimize \sum_{i=1}^{n}\sum_{d=1}^{7} \mathrm{off} - \mathrm{p}_{id} \tag{2}$$

Minimization of on−off−on pattern

$$Minimize \sum_{i=1}^{n}\sum_{d=1}^{7} \mathrm{on} - \mathrm{p}_{id} \tag{3}$$

Minimization of negative deflection of assigning night shift in the previous day of the day off

$$Minimize \sum_{i=1}^{n} nspddo_i \tag{4}$$

E. Constraints

An employee should be assigned at least for any one of the shifts available for the day or should be taken day off:

$$\sum_{i=1}^{n}\sum_{d=1}^{7}\sum_{s=0}^{3} x_{ids} = 1 \tag{5}$$

The number of shifts assigned should not exceed the maximum number of shifts:

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$$\sum_{i=1}^{n}\sum_{d=1}^{7}\sum_{s=1}^{3} \text{dur}_s\, x_{ids} \leq \text{max} - \text{shift} \quad (6)$$

The number of shifts assigned should be greater than or equal to the minimum number of shifts:

$$\sum_{i=1}^{n}\sum_{d=1}^{7}\sum_{s=1}^{3} \text{dur}_s\, x_{ids} \geq \text{min} - \text{shift} \quad (7)$$

To avoid off−on−off pattern in the scheduled period we consider the following constraint:

$$\sum_{i=1}^{n}\sum_{d=1}^{d-2} x_{id0} + \sum_{i=1}^{n}\sum_{d=1}^{d-2}\sum_{s=1}^{3} x_{i(d+1)s} + \sum_{i=1}^{n}\sum_{d=1}^{d-2} x_{i(d+2)0} - \sum_{i=1}^{n}\sum_{d=1}^{d-2} \text{off} - \text{p}_{id} \leq 2 \quad (8)$$

To avoid on−off−on pattern in the scheduled period we consider the following constraint:

$$\sum_{i=1}^{n}\sum_{d=1}^{d-2} x_{id0} + \sum_{i=1}^{n}\sum_{d=1}^{d-2}\sum_{s=1}^{3} x_{i(d+1)s} + \sum_{i=1}^{n}\sum_{d=1}^{d-2} x_{i(d+2)0} - \sum_{i=1}^{n}\sum_{d=1}^{d-2} \text{on} - \text{p}_{id} \leq 2 \quad (9)$$

The employee should not work more than five consecutive days in the scheduled period:

$$\sum_{i=1}^{n}\sum_{d=1}^{7}\sum_{s=1}^{3} x_{ids} + x_{i(d+1)s} + x_{i(d+2)s} + x_{i(d+3)s} + x_{i(d+4)s} + x_{i(d+5)s} \leq 5 \quad (10)$$

Night shift should not be allotted to an employee i on the previous day of the day off:

$$\sum_{i=1}^{n}\sum_{d=1}^{7}\sum_{s=1}^{3} (x_{ids} + x_{i(d+1)s} + x_{i(d+2)s} + x_{i(d+3)s} + x_{i(d+4)s}) - \sum_{s=1}^{3} x_{i(d+5)s} \leq 5 \quad (11)$$

An half an hour break is given for an employee in each shift:

$$\sum_{i=1}^{n}\sum_{d=1}^{7}\sum_{s=1}^{3} x_{ids} - \sum_{i=1}^{n}\sum_{d=1}^{7}\sum_{s=1}^{3} b_{ids} \leq 1 \quad (12)$$

III. Implementation of Genetic Algorithm

A. Creating initial population

We randomly create the initial population of the employee chromosomes. Then we check whether primary goal is achieved or not trough minimum working requirements.

B. Crossover

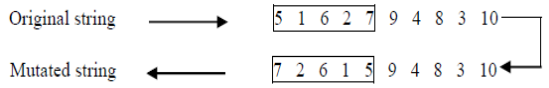
Main intention of crossover is to combine the good properties of both the parents to yield a new better chromosome [29, 30]. Simple crossover operator is consists of randomly selected crossover point and there after recombines the pair of chromosome in order to form new chromosome.

C. Mutation

The next stage of the crossover is the mutation process which acts on the pair of chromosomes. Mutation is the important force for revolution although it is infrequent in nature. There are two important mutation process namely inverse mutation and pairwise mutation.

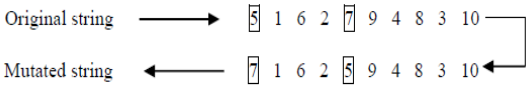
i. Inverse Mutation:

We generate some random positions between (1, n), where n is the number of employees. Let us select two position randomly for mutation, let it be 1 and 5. Then inverse mutation is obtained by reversing the order of the sequence between the positions 1 and 5 as given below



ii. Pair wise Mutation:

We generate some random positions between (1, n), where n is the number of employees. Let us select two position randomly for mutation, let it be 1 and 5. Then pairwise mutation is obtained by interchanging the positions 1 and 5 as given below



D. Evaluation of Fitness value

The fitness value is calculated using two criteria depending on the solution type.

Criteria 1: If the chromosome is under the feasible solution, then the fitness value is the objective function value.

Criteria 2: If the chromosome is under the non-feasible solution then the fitness value is equal to 1000 iterations.

E. Chromosome Selection

Chromosomes are selected using Roulette.

F. Preserving Strategy

The chromosome with high fitness values are replaced by the new chromosomes with the low fitness value and used as initial population for next generation.

G. Termination Criteria

Once we met the specified number of iterations, we stop the process immediately.

The general flow chart of genetic algorithm is given in the figure 1.

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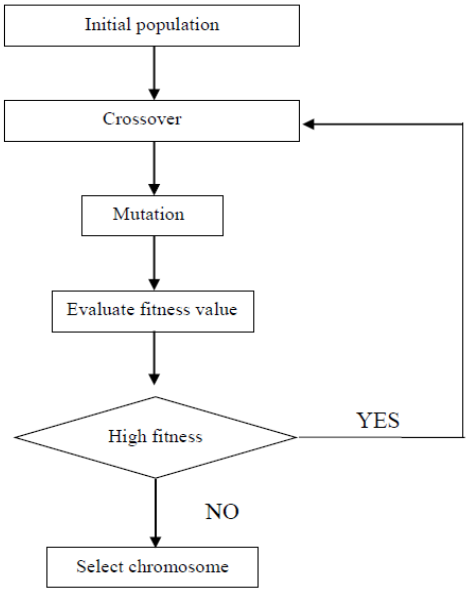

Figure 1: Flow Chart of the Artificial Immune System

IV. COMPUTATIONS AND RESULTS

We are considering a small part of the manufacturing process with 25 employees in it. There will be three shifts available per day namely morning shift (8am to 2pm), afternoon shift (2pm to 8pm) and night shift (8pm to 8am). Each employee must do minimum of 2 night shifts and 3 morning or afternoon shift per week. An employee can take two consecutive days off in a week. And also we are concentrating on not assigning night shift on the day before the day off of the employee because once the night shift is assigned , the employee is almost present for the next morning of the day off. Also we are training the employees with the multi skill training program in order to equalize the work pressure of the employees. This intern reduces the make span and total cost function of the manufacturing process. The minimum number of employees required for each shift of each day of the week are given in the table 1.

Table 1: Maximum number Employees required for each shift

Days	Number of Employees required		
	Morning Shift(M)	Afternoon Shift(A)	Night Shift(N)
Mon	6	6	7
Tue	6	6	7
Wed	6	6	7
Thu	6	6	7
Fri	6	6	7
Sat	7	7	8
Sun	7	7	8

The algorithm is coded in the MATLAB R2012a (7.14.0.739), 64-bit (win64). The tests were executed in an Intel core i3 processor under a Microsoft Windows 7 (64-bit) operating system. The obtained shift scheduling pattern of the employees is given in the table 2.

The proposed model is consisting of 6hour shift rather than normal 8hour shift. Because in 6hour shift only one break of half an hour is enough for lunch but in 8hour shift an employee is availing one hour lunch break. This increases the total make span and the total employee cost of the manufacturing process. A comparison analysis of proposed 6hour shift and regular 8hour shift for completing
Project of different durations are given in the table 3 and shown in figure 2.

The proposed model also contains a multi skill training program to the employees which is essential for equalizing the work pressure among the employees. A simple example of use of multi skill program to the employees is given as follows. Consider two employees, Employee 1 with a small project of 4 hours and an Employee 2 a small project of 8hours. In the proposed 6hour shift, Employee1 requires only one shift of 6hour and he will finish his project in 4hours and will be free for remaining 2hours. But Employee 2 requires one complete shifts 6hour and an extra 2hour of next shift to compete the project. If the employees are trained for multi skills, we can give extra work of Employee 2 to Employee 1 to equalize the work pressure and also we can complete both the project in one shift only. This reduces the total make span and cost of the employee. A comparison table of trained employees with non-trained employees is given in the table 4 and shown in figure 3.

Table 2: Obtained employee scheduling pattern

Employees	Working days						
	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1	N	M	M	N	A		
2	N	M	M	N	A		
3	N	M	M	N	A		
4	M	N	N	A			M
5	M	N	N	A			M
6	M	N	N	A			M
7	N	N	A			M	M
8	M	N	A			M	N
9	A	N	A			M	N
10	N	A			M	M	N
11	N	A			M	M	N
12	N	A			M	M	N
13	A			M	M	N	N
14	A			M	M	N	N
15	A			M	M	N	N
16			N	M	A	N	M
17			N	M	A	N	A
18			N	M	A	N	A
19		N	A	A	N	A	

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20		M	N	N	M	A	
21		A	A	N	N	A	
22			A	A	N	N	A
23			M	A	N	N	A
24			M	N	N	A	A
25			M	N	N	A	A

Table 3: Comparison table of 6hour shift with 8hour shift

Duration of the project in hours	Number of employees required to complete the project in 8 hour shift	Number of employees required to complete the project in 6 hour shift (Proposed)
500	15	13
1000	29	26
1500	44	39
2000	58	52
2500	73	65
3000	87	78
3500	102	91
4000	116	104
4500	131	117
5000	145	130

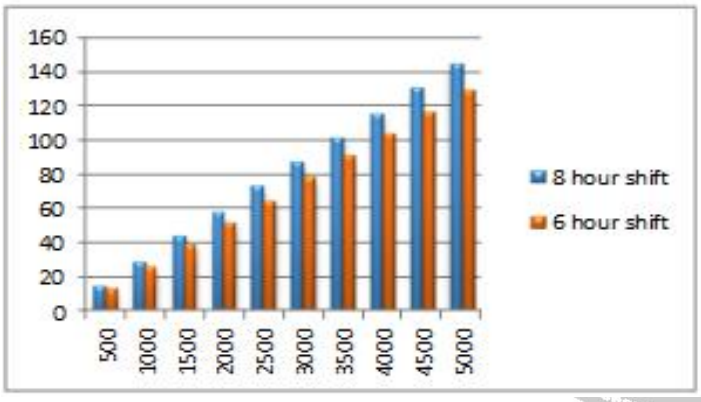

Figure 2: Comparison chart of 6hour shift with 8hour shift

Table 4: Comparison table of trained employees with untrained employees

Duration of the project in hours	Number of untrained employees required to complete the project	Number of trained employees required to complete the project (Proposed)
500	13	10
1000	26	20
1500	39	31
2000	52	41
2500	65	52
3000	78	62
3500	91	72
4000	104	83
4500	117	93
5000	130	104

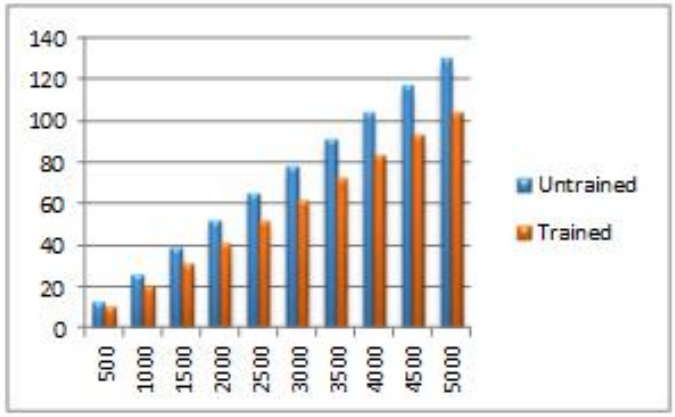

Figure 3: Comparison chart of trained employees with untrained employees

V. CONCLUSION

As one of the essential driver to the manufacturing process is to balance the workload among the employees. To overcome this issue we prepared a mathematical model consisting of flexible employee scheduling along with the multi skill training program. Which not only balances the workload, also reduces the total cost function of the employees in the manufacturing process. We can observe that proposed shift type reduces the total cost function of the employees by 10.34% compare to 8hour shift. The multi skill training program reduces the total cost function by 20%compared to untrained employee cost. Finally we conclude that the proposed yielded a better result compared to others.

REFERENCES

[1] Hoong Chuin Lau. *On the complexity of man power shift scheduling*, Computers & Operations Research 1996, Volume 23, pages 93-102

[2] Burns RN, Carter MW. *Work force size and single shift schedules with variable demands*. Management Science 1985; 31(5):599–607.

[3] Alfares HK. *An efficient two-phase algorithm for cyclic days-off scheduling*. Computers & Operations Research 1997; 25:913–23.

[4] Bechtold SE, Jacobs LW. *Implicit modeling of flexible break assignments in optimal shift scheduling*. Manag Sci 1990; 36(11):1339–51

[5] Jarrah AIZ, Bard JF, DE Silva AH. *Solving large-scale tour scheduling problems*. Manag Sci 1994; 40(9):1124–45.

[6] Bard JF, Binici C, deSilva AH. *Staff scheduling at the United States postal service*. Comput Oper Res 2003; 30(1):745–71.

 DOI : 10.18231/2454-9150.2017.0059

[7] Dessler, G. (2008), *Human Resources Management*, 11th ed., Prentice- Hall, Englewood Cliffs, NJ.

[8] Cascio, W.F. (2009), *Managing Human Resources: Productivity*, Quality of Work Life, Profit, 8th ed., Irwin: McGraw-Hill, New York, NY.

[9] Draft, R.L. (2008), *New Era of Management*, 2nd ed., Thomson South-Western, Mason, OH.

[10] Blickstein, S. (1996). *Does training pay off*?. Across the Board, 33(6), 16-20.

[11] Pollitt, D. (2001). *A flexible workforce for the modern economy: the role of education and training*. Education+ Training, 43(7), 345- 376.

[12] J. H. Holland, *Adaption in Natural and Artificial Systems*. Cambridge, MA: MIT Press, 1975.

[13] L. Davis, *Handbook of Genetic Algorithms*. New York: Van Nostrand Reinhold, 1991.

[14] D. E. Goldberg, *Genetic Algorithms in Search, Optimization, and Machine Learning*, Reading, MA: Addison-Wesley, 1989.

[15] Z. Michalewicz, *Genetic Algorithms + Data Structures = Evolution Program*, 2nd Ed. Berlin: Springer-Verlag, 1994.

[16] D. Beasley, D. R. Bull, and R. R. Martin, "*An overview of genetic algorithms: Part I-Fundamentals*," Univ. Comput., vol. 15, no. 2, pp. 58-69, 1993.

[17] D. Beasley, D. R. Bull, and R. R. Martin, "*An overview of genetic algorithms: Part 2-Research topics*," Univ. Comput., vol. 15, no. 4, pp. 170-181, 1993.

[18] M. Srinivas and L. M. Patnaik, "*Genetic algorithms: A survey*," Computer, pp. 17-26, June 1994.

[19] D. Whitley, "*A genetic algorithm tutorial*," Dept. Comput. Sci, Colorado State Univ., Tech. Rep. CS-93-103, Nov. 1993.

[20] M. R. Garey and D. S. Johnson, Computers and *Intractability: A Guide to the Theory of NP-Completeness*. San Francisco, CA: Freeman 1979.

[21] R. Nambiar and P. Mars, "*Adaptive IIR filtering using natural algorithms*," in Workshop on Natural Algorithms in Signal Processing, Chelmsford, Essex, Nov. 1993, pp. 20/1-20/10.

[22] P. B. Wilson and M. D. Macleod, "*Low implementation cost IIR digital filter design using genetic algorithms*," in Workshop on Natural Algorithms in Signal Processing, Chelmsford, Essex, Nov. 1993, pp. 4/1-4/8.

[23] R. C. Caponetto, L. Fortuna, G. Manganaro, and M. G. Xibilia, "*Chaotic system identification via genetic algorithm*," in 1st IEENEEEE Int. Con$ GAIs in Engineering Systems: Innovations and Amlications, Sheffield, 1. U.K., 1995: pp. 178-174.

[24] L. 0. Chua, K. Eckert, Lj. Kocarev, and M. Itoh, "*Experimental chaos synchronization in Chua's circuit*," Int. J. Bifurcation, Chaos, vol. 2, no. 3, pp. 705-708, 1993.

[25] Lj. Kocarev, K. S. Halle, K. Eckert, U. Parlitz, and L. 0. Chua, "*Experimental demonstration of secure communications via chaos synchronization*," Int. J. Bifurcation, Chaos, vol. 2, no. 3, pp, 709-713, 1992.

[26] H. Heidari and A. Chalechale, "*Scheduling in Multiprocessor System Using Genetic Algorithm*", IJAST, vol 43, (2012), pp.81-94.

[27] U. Aickelin and K. A. Dowsland, "*An indirect Genetic Algorithm for a Nurse-Scheduling Computers & Operations* Research, vol. 31, no. 5, (2004) April, pp. 761-778.

[28] Abir Alharbi and Kholood AlQahtani, "*A Genetic Algorithm Solution for the Doctor Scheduling Problem*", ADVCOMP 2016: The Tenth International Conference on Advanced Engineering Computing and Applications in Sciences.

[29] Z. Wang, J.-L. Liu, and X. Yu, "*Self-fertilization based genetic algorithm for university timetabling problem*," in Proceedings of the 1st ACM/SIGEVO Summit on Genetic and Evolutionary Computation (GEC '09), pp. 1001–1004, ACM, Shanghai, China, June 2009.

[30] J. Wang and K. Chu, "*An application of genetic algorithms for the flexible job-shop scheduling problem*," International Journal of Advancements in Computing Technology, vol. 4, no. 3, pp. 271–278, 2012.

 DOI : 10.18231/2454-9150.2017.0059