Multi Objective Flexible Employee Scheduling Using PSBCSP Algorithm

[1]Mahalakshmi
School of Applied Sciences, REVA University, Bangalore, India,
[2] Murugesan R
School of Applied Sciences, REVA University, Bangalore, India,
[3] Ranjini K S
Department of Computer Applications, Dayanand Sagar college of Arts, Science and Commerce, Bangalore,, India.

ABSTRACT

In this paper an Artificial Immune System is used to study the employee scheduling problem in the manufacturing industries. Scheduling is done based on the aspects of both managements and employees. The management aspect is to reduce the total cost of the employee by minimizing the makes span. The employee aspects are preferred number of shifts, shift types, days off etc. In this scheduling an extra care is taken for not assigning Night Shift on the day before day off, because once night shift is assigned the employee almost present for the next morning. A mathematical model is formed based on flexible working of the employees. In this model 6 hour shifts are allotted to the employees, which reduces the total cost by 10.344% and the makes span by 4.545% compared to the other models.

Keywords – Positive Selection Based Clonal Selection Principle (PSBCSP), Employee Scheduling.

I. INTRODUCTION

In the present trend we often use computers and machineries to perform the jobs in a fraction of a second. These computers and machines should be operated by man power [1]. As of now there is no substitution for man intelligence power. So, man power is an important tool in software companies, hardware companies and industrial areas. Therefore, using their knowledge, intelligence, creativeness, personality character and adaption capacity to environment is very important [2]. Scheduling deals with arrangement, controlling and optimization of work and workloads in manufacturing system. Scheduling is the main key for all organization, which prepare calendar for any activity to functioning the organization. Employee scheduling is one of the important process in the manufacturing system. The days off assignment problem in the employee scheduling was provided by Burns and Carter [3]. They defined a set of lower bounds and in their result, an employee should work for six consecutive days of the week. Tour assignment problem is proposed by [4]. In their paper an employee is availing two consecutive days off in a week. The break assignment is proposed in [5]. Later [6] and [7] proposed a total model consisting of shift scheduling, days off assignment and break assignment. Doctor scheduling, nurse scheduling and employee scheduling using genetic algorithm are available respectively in [8], [9] and [10]. But there are very less literature available in shift scheduling using Positive Selection Based Clonal Selection Principle (PSBCSP). Therefore in this paper, we are applying PSBCSP for Employee scheduling. . Positive selection algorithm is developed by Seiden and Celeda in 1992 [11]. The main function positive selection algorithm [12] is to distinguish between the good and solutions in order to retain the good solution for future step and discard the bad solution permanently from the system. And the main objective of clonal selection principle [13, 14] is to select the best antibody for cloning and mutation in order to destroy the antigens. There two types of cells namely B-cells and T-cells for clonal selection principle. B-cell based clonal selection algorithm plays a vital role in solving various scheduling problems [15, 16, 17 and 18]. Both positive selection and clonal selection principle are combined to get a positive selection based clonal selection principle algorithm [19].

II. MATHEMATICAL FORMULATION

Every organization has its own fixed activities. In this research paper we are giving attention to one fixed organization. This organization prepares employees schedule. There are four 6hrs shift for an employee to work in a day. First is Morning Shift (MS) between 6am to12pm, second is Afternoon Shift (AS) between 12pm to 6pm, third is Evening Shift (ES) between 6pm to 12am and fourth is Night Shift (NS) between 12am to 6am. According to this totally 28 shifts per week are available. In this Paper

we are concentrating on both Organization objectives as well as employee's objectives. The Organization Objective is to minimize the Deflection or Modification in the required number of employees required for each shift. The Employee objective is to give preferences to the number of shifts, types of shifts, requested days off and consecutive days off working patterns in the employee schedules. As per the organization regulation an employee should adopt minimum 7 shifts and maximum 8 shifts per week. The preference of choosing shifts is given equally to all the employees. Final scheduling is done under the minimum requirement of employees for each shift. In this scheduling we are mainly concentrating on giving two consecutive days off for an employee by avoiding on−off−on and off−on−off pattern of working. And also, a night shift is not assigned for an employee who is going to take day off for the next day. This is programming model created for scheduling pattern as follows

A. **Indices**

n	number of employees working in organization
m	number of days in the scheduling period.
i	index of employees, i = 1,2,…….,n
j	index of days in the scheduling period, j = 1,2,……,m
s	shift types, s = 0,1,2,3,4.(s = 0 → day off, s = 1 → morning shift s = 2 → afternoon shift, s = 3 → evening shift and s = 4 → night shift)
p	scheduling periods, p=1,2,3and 4.(morning shift →6am to 12pm, afternoon shift → 12pm to 6 pm, evening shift →6pm to 12am and night shift → 12am to 6am).

B. **Parameters**

$$a_{ps} = \begin{cases} 1 & if\ the\ shift\ type\ s\ contains\ the\ period\ s \\ 0 & otherwise \end{cases}$$

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
pns_i	preferred number of shifts of an employee i.
pne_{jp}	preferred number of employees required for the period p on the day j
$\text{lb}_{jp}, \text{ub}_{jp}$	lower bound and upper bound on the demand of employees on the day j in the period p.
do_{ij}	days off of an employee i on the day j
max−score	maximum score of an employee if he allotted to his preferred shift

C. **Decision Variables:**

$$x_{ijs} = \begin{cases} 1 & if\ an\ employee\ i\ is\ assigned\ to\ shift\ s\ on\ the\ day\ j \\ 0 & otherwise \end{cases}$$

pde_{jp}	positive deflection from the preferred number of employees required for the day j in the period p
ds_i^+, ds_i^-	positive and negative deflection from the preferred number of shifts for each employee
rdo_i	negative deflection for the requested days off of an employee

$nspddo_i$	negative deflection of assigning night shift in the previous day of the day off
off−p_{ij}	the pattern of off-on-off in the scheduling period
on−p_{ij}	the pattern of on-off-on in the scheduling period
b_{ijs}	break for an employee i on the day j in the shift s

D. **Objective Functions:**

The objective of an organization management is to minimize the positive deflection from the preferred number of employees in the working period:

$$Minimize \sum_{j=1}^{m}\sum_{p=1}^{4} \text{pde}_{jp} \tag{1}$$

The objectives related to employees are given as follows.

Minimization of positive and negative deflections of each employee to preferred shift is taken as the first objective:

$$Minimize \sum_{i=1}^{n} (ds_i^+ + ds_i^-) \tag{2}$$

Minimization of negative deflection of the requested days off for an employee is considered as second objective:

$$Minimize \sum_{i=1}^{n} rdo_i \tag{3}$$

Minimization of off−on−off pattern is considered as third objective:

$$Minimize \sum_{i=1}^{n}\sum_{j=1}^{m} \text{off} - \text{p}_{ij} \tag{4}$$

Minimization of on−off−on pattern is considered as fourth objective:

$$Minimize \sum_{i=1}^{n}\sum_{j=1}^{m} \text{on} - \text{p}_{ij} \tag{5}$$

Minimization of negative deflection of assigning night shift in the previous day of the day off is the final objective:

$$Minimize \sum_{i=1}^{n} nspddo_i \tag{6}$$

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:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{s=0}^{4} x_{ijs} = 1 \tag{7}$$

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

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{s=1}^{4} \mathrm{dur}_s\, x_{ijs} \leq \max - \mathrm{shift} \tag{8}$$

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

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{s=1}^{4} \mathrm{dur}_s\, x_{ijs} \geq \min - \mathrm{shift} \tag{9}$$

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

$$\sum_{i=1}^{n}\sum_{j=1}^{m-2} x_{ij0} + \sum_{i=1}^{n}\sum_{j=1}^{m-2}\sum_{s=1}^{4} x_{i(j+1)s} + \sum_{i=1}^{n}\sum_{j=1}^{m-2} x_{i(j+2)0} - \sum_{i=1}^{n}\sum_{j=1}^{m-2} \mathrm{off} - \mathrm{p}_{ij} \leq 2 \tag{10}$$

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

$$\sum_{i=1}^{n}\sum_{j=1}^{m-2} x_{ij0} + \sum_{i=1}^{n}\sum_{j=1}^{m-2}\sum_{s=1}^{4} x_{i(j+1)s} + \sum_{i=1}^{n}\sum_{j=1}^{m-2} x_{i(j+2)0} - \sum_{i=1}^{n}\sum_{j=1}^{m-2} \mathrm{on} - \mathrm{p}_{ij} \leq 2 \tag{11}$$

For each day the minimum staff level should be maintained:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{s=1}^{4} a_{ps}\, x_{ijs} \geq \mathrm{lb}_{jp} \tag{12}$$

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

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{s=1}^{4} x_{ijs} + x_{i(j+1)s} + x_{i(j+2)s} + x_{i(j+3)s} + x_{i(j+4)s} + x_{i(j+5)s} \leq 5 \tag{13}$$

Care should be taken that the number of employees allotted for each shift should not exceed the preferred number of employees for each period of the working day:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{s=1}^{4} a_{ps}\, x_{ijs} - \sum_{j=1}^{m}\sum_{p=1}^{4} \mathrm{pde}_{jp} \leq \sum_{j=1}^{m}\sum_{p=1}^{4} \mathrm{pne}_{jp} \tag{14}$$

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

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{s=1}^{4}(x_{ijs} + x_{i(j+1)s} + x_{i(j+2)s} + x_{i(j+3)s} + x_{i(j+4)s}) - \sum_{s=1}^{3} x_{i(j+5)s} \leq 5 \tag{15}$$

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

$$\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{s=1}^{4} x_{ijs} - \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{s=1}^{4} b_{ijs} \leq 1 \tag{16}$$

Since an employee should not work more than five consecutive days and also giving two consecutive days off, we have to allot all the shifts in five days of the working period. As per the one of the organization regulation, an employee should do minimum 7 shifts per week. In that 7 shifts 5 shifts may be allotted for 5 consecutive days, the remaining 2 shifts must be inserted in any two working days in the scheduled period.

III. IMPLEMENTATION OF ARTIFICIAL IMMUNE SYSTEM (AIS)

The method is explained in two stages. In the first stage positive selection algorithm is used and in the second stage clonal selection principle is applied.

A. Positive Selection Algorithm

Upon the generation of the initial solution to the problem, the main function of positive selection principle algorithm is to distinguish between the good and bad solution in order to discard bad solution from the system. In the human body, good solutions represents the antibodies which recognizes and overcome the antigen. The following figure 1 represents the working rule of positive selection principle in the human body.

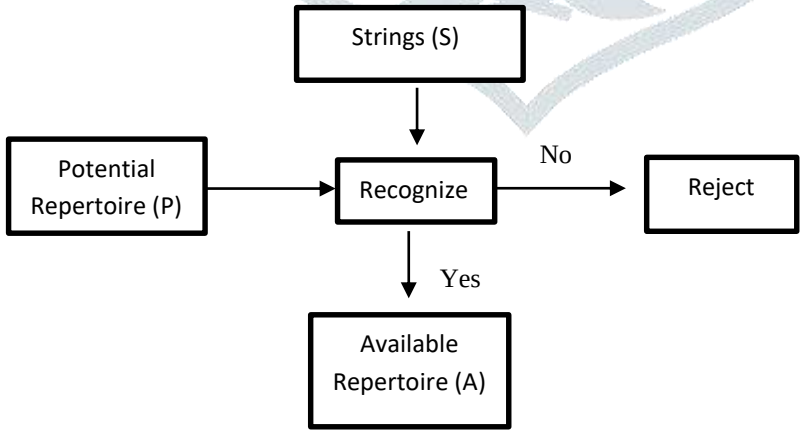

Figure1: Positive Selection Algorithm

Consider a case of infection (viral, bacterial) attacking the human body. The string S is the set of antigens attacking the human body which has to be destroyed. Potential Repertoire (P) represents the potentially T-cells in human immune system. To destroy the antigens, we need the cells which can overcome the antigen. Therefore all cells in the human body are tested to find whether they

recognize the antigen or not. The cells which possess capacity of recognition of the antigens are called Available Repertoire (A), which will be retained for further usage of destroying the antigens. The remaining cells which fails in the recognition of antigens are discarded from the system. The positive selection algorithm is applied for filtering purposes. Those solutions satisfying certain criteria is retained, other solutions are completely discarded from the system. To check the satisfaction level of the solution, we are fixing a threshold value. A solution is retained if the optimal value of the solution is less than the threshold, otherwise it is completely discarded from the system

B. Clonal Selection Algorithm

The clonal selection algorithm is based on the working principle of human immune system. B-cells along with the T-cells will destroy the various viruses and bacteria which attacks the human body. But it has been observed that B-cells has unique tendency to clone those cells which are capable of destroying antigens attacking the human body. Upon the attack of antigen a particular string formation of B-cells are done to overcome the infection. The cell will clone for a large amount to produce high capacity antibodies to overcome the antigen. Usually B-cells themselves under goes process of cloning and mutation repeatedly to recognize the right solution to destroy the antigens.

IV. COMPUTATIONS AND RESULTS

We are making a scheduling pattern for one week of the working period. In this problem we are concern with a small unit of a manufacturing industry with 30 employees. There are four shifts available in each day of the working period namely Morning Shift (6am to 12pm), Afternoon Shift (12pm to 6pm), Evening Shift (6pm to 12am) and Night Shift (12am to 6am). As one of the regulation of management each employee should do minimum of 7 shifts and maximum of 8 shifts per week. The minimum number of employees required (lb_{jp}) for the week days (i.e., Monday to Friday) and weekend days (i.e., Saturday and Sunday) is given as follows. In the week days each 8 employees are needed for morning, afternoon, evening shifts and 7 employees are needed for night shifts. In the Weekend days each 8 employees are needed for morning, afternoon, evening shifts and 8 employees are needed for night shifts. The maximum number of employees (ub_{jp}) is determined as (lb_{jp}+3). The preferred number of employees (pne_{jp}) is determined as (lb_{jp}+1). Since in the scheduling pattern has two consecutive days off, the employee has to choose any one of the Son & Mon, Mon & Tue, Tue & Wed, Wed & Thu, Thu & Fri, Fri & Sat and Sat & Sun pattern. The preferred number of shifts, shift types and days off for each employee is given in Table 1 and the number of employees required for each shift is given in the Table 2.

Table 1: Preferred number of shifts, shift types and day off of the employees.

Employees	Preferences of the employees		
	Number of shifts	Shift types	Day's off
1	7	MS/AS	Son & Mon
2	7	MS/AS	Son & Mon
3	7	MS/AS	Son & Mon
4	7	MS/AS	Son & Mon
5	7	MS/AS	Mon & Tue
6	7	MS/AS	Mon & Tue
7	8	MS/AS	Mon & Tue
8	7	MS/AS	Mon & Tue
9	8	MS/AS	Tue & Wed
10	7	MS/AS	Tue & Wed
11	7	AS/ES	Tue & Wed
12	7	AS/ES	Tue & Wed
13	7	AS/ES	Wed & Thu
14	7	AS/ES	Wed & Thu
15	7	AS/ES	Wed & Thu

16	8	AS/ES	Wed & Thu
17	7	AS/ES	Thu & Fri
18	7	AS/ES	Thu & Fri
19	7	AS/ES	Thu & Fri
20	7	AS/ES	Thu & Fri
21	7	ES/NS	Fri & Sat
22	8	ES/NS	Fri & Sat
23	7	ES/NS	Fri & Sat
24	7	ES/NS	Fri & Sat
25	7	ES/NS	Sat & Sun
26	7	ES/NS	Sat & Sun
27	7	ES/NS	Sat & Sun
28	7	ES/NS	Sat & Sun
29	7	ES/NS	Sat & Sun
30	7	ES/NS	Sat & Sun

Table 2: Number Employees required for each shift

Days	# of Employees required			
	Morning Shift	Afternoon Shift	Evening Shift	Night Shift
Mon	8	8	8	7
Tue	7	8	8	6
Wed	8	8	8	8
Thu	7	7	8	8
Fri	8	8	7	6
Sat	7	7	8	6
Sun	8	8	8	8

The proposed algorithm is coded in the MATLAB R2014b (7.14.0.739), 64-bit (win64). All tests were executed on an Intel core i5 processor under a Microsoft Windows 7 (64-bit) operating system. The resulting employee schedule is given in the Table 3 and the employee score for the obtained scheduling pattern is given in the Table 4.

Table 3: Obtained employee scheduling pattern

Employees	Working Days						
	Mon	Tue	Wed	Thu	Fri	Sat	Sun
1		MS&AS	MS&AS	MS	NS	ES	
2		MS	MS&AS	MS&AS	NS	ES	
3		MS	MS	MS&AS	MS&AS	ES	
4		MS	MS	AS	MS&AS	MS&AS	
5			MS&AS	ES&NS	AS	MS	MS&AS
6			MS	AS	MS&AS	MS	MS&AS
7			AS	MS	MS&AS	MS&AS	MS
8			MS	AS	MS	MS&AS	MS&AS
9				MS&AS	MS	MS	MS&AS
10	MS&AS			MS	MS	MS&AS	MS
11	AS&ES			NS	NS	AS&ES	MS
12	AS&ES			NS	NS	ES	AS&ES
13	MS	AS&ES			NS	NS	NS
14	MS	AS&ES			AS&ES	NS	ES

15	MS	MS			AS&ES	AS&ES	AS
16	MS&AS	MS			NS	AS&ES	NS
17	AS&ES	AS	AS			NS	AS&ES
18	AS&ES	AS	AS			NS	NS
19	MS	AS&ES	AS&ES			MS	MS
20	AS&ES	MS	AS&ES			ES	AS&ES
21	ES&NS	ES	MS	MS			ES&NS
22	MS	AS&ES	ES&NS	ES			ES&NS
23	AS	AS	ES&NS	ES&NS			ES&NS
24	AS	ES	ES&NS	ES			ES&NS
25	NS	ES&NS	ES	NS	ES		
26	ES&NS	ES&NS	NS	AS	AS		
27	ES&NS	NS	NS	ES&NS	ES		
28	NS	ES&NS	NS	ES	ES		
29	NS	NS	ES&NS	ES&NS	ES		
30	NS	NS	ES&NS	ES&NS	ES		

Table 4: Preference score of the employees

Employees	Preferences scores of the employees			
	Number of shifts	Shift types	Day's off	Not assigning night shift in previous day of the day off
1	10	7.8	10	10
2	10	7.4	10	10
3	10	8.5	10	10
4	10	10	10	10
5	10	8.3	10	10
6	10	10	10	10
7	8.7	10	10	10
8	10	10	10	10
9	8.7	10	10	10
10	8.7	10	10	10
11	10	7.8	10	10
12	10	8.9	10	10
13	10	7.4	10	10
14	10	7.3	10	10
15	10	7.3	10	10
16	7.8	7.4	10	10
17	10	7.5	10	10
18	10	6.5	10	10
19	10	6.8	10	10
20	10	7.4	10	10
21	10	7.3	10	10
22	8.7	7.4	10	10
23	10	7.5	10	10
24	10	8.6	10	10
25	10	10	10	10
26	10	7.2	10	10
27	10	10	10	10
28	10	10	10	10
29	10	10	10	10
30	10	10	10	10

V. CONCLUSION

In this scheduling an extra care is taken for not to assign Night Shift (12am to 6am) on the day before the day off because once night shift assigned, the employee almost present for the next morning. Also, we consider the following example to validate our model consisting of 6 hour shifts.

A**. Minimizing the Makes Span**

Assuming that we got an order, which will take approximately 1000 hours to complete. In the normal 8 hour shifts an employee will be availing 1 hour break (Including two short breaks and one lunch break) and therefore he will be working only for 7 hours per shift. So to complete the order it will take approximately 143 shifts of 8 hours i.e. 143×8=1144 hours. But if we allot 6 hour shift it will be containing only one half an hour break and an employee will be working for 5½ hours per shift. To complete the same order, it will need nearly 182 shifts of 6 hours i.e. 182×6=1092 hours. It will reduce 52 hours of the total completion time compared to 8 hours shift.

B**. Minimization of Cost**

Suppose the same order should be delivered within week then we must assign proper number of employees required to complete and deliver the order. In 8 hour shift each employee will be working only for 7 hours (remaining one hour is the break). Since each employee will be working only 5 shifts per week then total working hour of each employee becomes 5×7=35 hours per week. Therefore, we need minimum of 29 employees to deliver the order in a week. But in the case of 6 hour shift each employee will be working 5½ hours (remaining half an hour is the break). Since each employee will be working minimum 7 shifts per week then the total working hour of each employee becomes 7×5½ = 38½ per week. Therefore, we need minimum of 26 employees to deliver the order in a week. This will reduce 3 employees salary in the total cost comparing with 8 hour shift. The proposed model reduces the total cost by 10.344% and the makes span by 4.545% compared to the other models (8 hour shifts). Comparison between proposed model of 6 hour shifts and the existing 8 hour shifts is given in the figure 2.

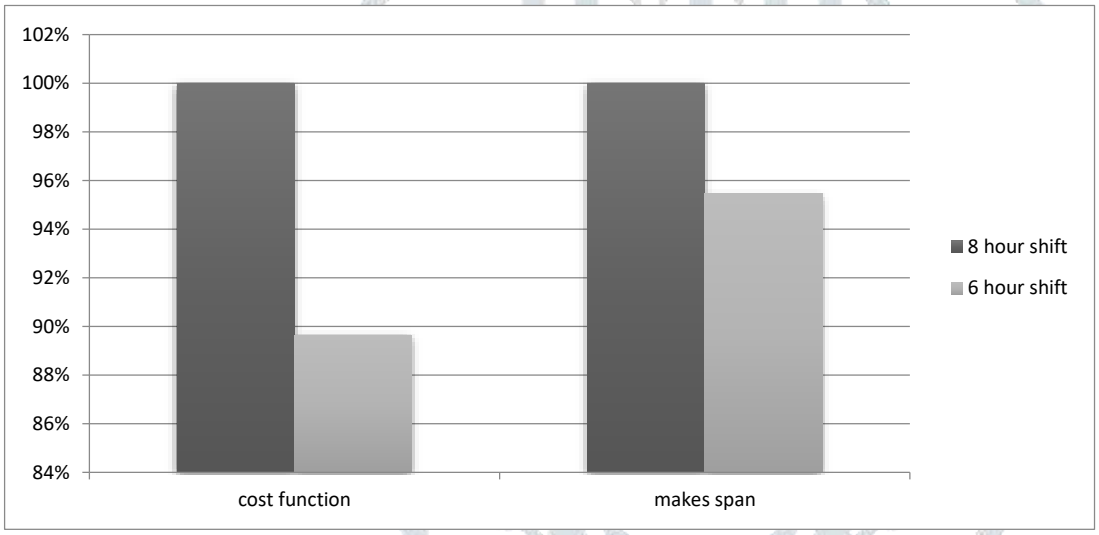

Figure 2: Comparison of proposed 6 hour shift with 8 hour shift

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