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Staff Scheduling by a Genetic Algorithm

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Abstract. This paper describes a Genetic Algorithms approach to a manpower-scheduling problem arising at a Petrochemical Company. Although Genetic Algorithms have been successfully used for similar problems in the past, they always had to overcome the limitations of the classical Genetic Algorithms paradigm in handling the conflict between objectives and constraints. The approach taken here is to use an indirect coding based on permutations of the personnel's, and a heuristic decoder that builds schedules from these permutations. Computational experiments based on 52 weeks of live data are used to evaluate three different decoders with varying levels of intelligence, and four well-known crossover operators. The results reveal that the proposed algorithm is able to find high quality solutions and is both faster and more flexible than a recently published Taboo Search approach

Keywords: Genetic algorithm, classical genetic algorithms, staff scheduling, petrochemical company.

1. Introduction

Staff scheduling (shift working) is a comprehensive phenomenon. Social emergencies including medical care, fire department services, police and

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etc. require 24 hour services. Nowadays, Shift work in various part of industry, mine, service as well as their sub-categories such as refineries and petrochemicals is one of the stressful factors, having some negative effects on mental and physical health that can lead to outbreak of cardiovascular, digestive, and psychological diseases, accidents and finally falling efficiency (Jafari & Ghorbani, 2008). Shift can be related to each type of work done out of routine schedule (7a.m. to 6 p.m.), such as fixed night shifts, evening shifts or shifts before 6 a. m circular and changing shifts refer to work time changing from day to evening or day to night that might be weekly or monthly. Also, weekly intensive shifts in which every job is done out of daily job scheduling (conventionally 7: am to 6: pm) (Munch and Folklard, 2004). Governments and occupations whose constant activities are vital had to apply staff scheduling in a way that shift were divided in to 3 forms of morning, evening and night or two 12- hour shifts. In the US, schedule job refer to a job done out of 7-21 period and according to Koji, it is a job done before 6:00 a.m. or after 6:00 p.m. organizations with shift working need to be active during 24 hours (Heidari & Hossein pour, 2006: 342).

Human force scheduling has been highlighted by researchers during last decades (Ernest et al, 2004). Staff scheduling is a complicated issue due to numerous digital & even competitive limitations. Even without these complications, we face an exact problem with NP-Hard problem (Fukunaga et al, 2002). Accordingly, resource scheduling does not respond properly and logically through using linear planning and other classical optimizing methods. Therefore, using heuristic methods including genetic algorithm (which is heuristic in nature) is regarded essential to figure out these problems (Alves et al, 2006). Job shift is among stressful factures affecting labor force in the world. It can be found in industry and service providing organizations. Social emergencies such as medical care, fire department services, police and etc. have to work 24 hours (MotamedZade et al, 2004).

Genetic algorithm is considered to be a technique to find the optimum answer among conventional techniques in artificial intelligence. Due to this fact time staff scheduling by a designed system is more efficient than the one done by experts and can cause an increase in management

efficiency, staff's satisfaction, as well as a decrease in job problems with paper reports and the importance of staff's request along with caring the requirements of the company, the present study has been conducted to design a smart system regulating staff's shifts in utility units of a petrochemical plants through using genetic algorithm in order to provide better services and stand against problems caused by conventional scheduling. Other objectives also include homogenous distribution of force, appropriate distribution of ranks, importance of staff's request along with homogenous distribution of forces, caring justice in setting a program in case of lack of time or saving manager's time.

2. Literature Review

For those who work in shifts, tiredness in caused by their unusual timetable since they have to work against natural cycle of sleep- awake. In fact, they have to work at night and sleep during a day. There is no doubt that day sleeping is much more inappropriate than night sleeping generally. There are two reasons for this difference: first, by start of the day, most biological cycles of body (such as melatonin and internal temperature) start their ascending trend. Biological experiments clearly show that even after controlling disturbing factors, day sleeping is unable to compensate all tiredness. Second, time of person's rest parallels with start of daily activities and consequently, factors such as noise and light hamper an optimum sleep. The main problem goes when these staff suffers from a serious lack of sleep as the result of not compensating this lack and accumulating the fatigue. This serious lack of sleep results in a permanent drowsiness, falling awareness and efficiency, rising fatigue, failures and accidents for this group of staff rather than others not only endangering their health and peace, but also imposing spiritual, social & economic problems on families and the society (Sarema et al, 2006: 135-136). Due to economic and technical reasons in bigger settings including oil and petrochemical industries, job shift and 24 hour activities are more common. Therefore, negative sides are observed more in such places. Job shifts happen in various forms, and systems that each has its own Job shifts happen in various forms, and systems that each has its own fea-

tures, advantages and disadvantages. Petrochemical industry is among huge & sophisticated industries demanding 24 hour activities (Fischer, 2004).

As a practical study, this paper is descriptive-analytical which is in the format of software design whose data collection is through logs of stuff scheduling in one of petrochemical companies. Also, its validity has been approved by related experts after evaluating observations, time assessment, as well as service providing of human resources based on staff and heads' schedule by means of designing smart systems.

Shirazi et al. (2011) examined the relation between accidents, drowsiness, tiredness and job shift in one of projects of structuring dams and water power plants in westerns provinces of Iran. Moreover, Darvish et al. (2010) studied about increasing hospital efficiency by using smart networks. Also, Jafari & Ghorbani (2008) tried to evaluate the impacts of shifts on staff's physical & mental health in one of the companies of oil refinery. Kim et al. (2013) used efficient methods to figure out the problem of nurses' assignment by using genetic algorithm. Petrovic & Berghe (2006) employed Tabo algorithm to solve the problem of staff scheduling. Using genetic algorithm, Gomez et al. (2006) tried to examine and solve the problem of personal assignment through using genetic algorithm.

Also, Aickelin & Dowsland (2004) employed non-direct genetic algorithm to find the optimum answer for nursing personal assignment problem.

Moreover, Li & Aickelin (2003) used a Bayesian optimization algorithm to evaluate the staff Scheduling Problem.

3. Research Methodology

NP problem refers to a group of problems whose required time increases considerably by using each recognized algorithm (Solution) with increasing problem size. Problems such as backpack, vendor, scheduling, 1 & 0 scheduling and integrate scheduling are regarded as NP problems. The problem of shift distribution can be formulized by using integrate scheduling. To do so, we will have:

Staff i= 1, m
Shifts j=1, m
Day & night shifts (1 to 7 show day shift & 8 to 14 show night shift) k=1,...,14
Rand S=1, p
Decision making variable are

$$x_{ji} = \begin{cases} 1 & i\ the\ worker\ in\ j\ the\ shift \\ 0 & \end{cases} \quad (1)$$

Model parameters also include:
m → the number of shifts
n → the number of workers (staff)
p → the number of ranks

$$a_{jk} = \begin{cases} 1 & full\ status\ of\ shift \\ 0 & \end{cases} \quad (2)$$

$$q_{is} = \begin{cases} 1 & in\ the\ worker\ with\ ranks\ of\ s \\ 0 & \end{cases} \quad (3)$$

And also we have:
P_{ij} = the cost of employing i worker for working in shift j.
R_{ks} = Request for worker with rank of S in day & night shift of k
N_i = the number of night shifts of i the worker
D_i = the number of day shifts of i the worker during the week And also
B_i = the number of job shifts of i the worker in special circumstance of both night & day shifts.

In this equation f (i) equals with justified sum of the number of job shifts that i worker has to work in. Therefore for f (i) we have:

$$F(i) = \begin{cases} \sum_{k=1}^{7} {}^{a_{jk}} = D_j \ \ \forall j \ \ \in \ day\ shift \\ \sum_{k=8}^{14} {}^{a_{jk}} = N_j \ \ \forall j \ \ \in \ night\ shift \\ \sum_{k=1}^{14} {}^{a_{jk}} = B_j \ \ \forall j \ \ \in \ all\ shifts \end{cases} \quad (4)$$

The objective function of linear planning of integrates in found by minimizing total cost of all workers than can be viewed as:

$$\sum_{i=1}^{n} \sum_{jinF(i)}^{m} p_{ij} x_{ij} \rightarrow min! \tag{5}$$

In which limitations are as follow; The limitation of each worker is that he should work exactly in one shift:

$$\sum_{jinF(i)}^{m} x_{ij} = 1 \quad \forall i \tag{6}$$

The limitation of demand & request for a worker that needs to be satisfied for each shift (day/ night) with each rank

$$\sum_{i=1}^{n} \sum_{jinF(i)}^{m} q_{is} a_{jk} x_{ij} \geqslant R_{ks} \quad \forall k, s \tag{7}$$

In this schedule, equation 6 assures us that each worker works at least on shift & equation 7 shows that the request for workers with each different rank in each shift either day or night will be responded.

It is noted that using qis in this equation lets us replace workers with lower ranks instead of higher rank ones. To figure out the equation with 30 workers, 3 ranks & 400 shifts, we have formulation of integer including 12000 variables and 100 limitations. Even the most advanced software cannot find a solution for such an equation (Li & Aickelin, 2003). Such an equation is an NP-Hard problem (Osogami & Imai 2000) According to the modeled problem, the number of variables varies between 1000 to 2000 & also the number of limitation is more than 70 effective ones.

In organizations, staff scheduling is done through 3 methods: personal, periodical and non-periodical. Personal scheduling which is set based on staff's requests includes a number of benefits such as decreasing absences, increasing organizational responsibility, imposing professional independence & saving manager's time. However, there are some inherent problems like superiority of staff's personal needs to organization's needs, lack of considering appropriate distribution of ranks for defining hours & shifts as well as unfair distribution of optimum shifts (Hosseini, 2009). In refineries & petrochemicals with fixed number of Labor force,

periodical scheduling is used. In fact, a stable schedule is defined for workers in a specific period of time. However, this technique is not fair enough.

In non-periodical scheduling, flexibility is really high and also staff's shifts & off days differs week to week. This technique highlights not only personal tendencies but also organizational requirements.

Genetic algorithm is one of the most innovational algorithms used to optimize various functions. In this algorithm, previous data is extracted based on genetically feature of algorithm, and used in search process (Harris, 2005).

Algorithm initiates from the first optimum point and proceeds step by step on each of its calculation either adapt or comparing with final optimum point. As a Mather of fact, genetic algorithm cover all optimum point & figures out their fitting based on a chromosomes' perspective and the direction including crucial character attributes.

Even when reaching some maximum points (relative), it considers all various optimum points & selects the final optimum one (Melanie, 1996). In genetic algorithm, the most crucial concept is:

1. Gene: forming elements of a chromosome the can be the figure, word or even directions of programming.

2. Chromosome: encoded response or a part of the response.

3. Venue: each gene has its own specific status which is called venue.

4. Population: a set of chromosomes.

In genetic algorithm, N represents the bigness of population, PC is the probability of intersection occurrence (crossover rate) & pm shows the probability of mutation occurrence (mutation rate) and all need to clear in each repetition. The general framework of on algorithm is as follow:

0. determine coding method

1. Generating N primary population

2. Calculating Fitness function of each chromosome in population

3. Making a new population (generation producing act): It is needed to do the following steps for N times;

3-1. Selecting 2 generator chromosome among current population using

3-2. Applying cross activator on parents with probability of PC occurrence & having a baby

3-3. Applying mutation on the child with probability of pm occurrence

3-4. adding a new baby to population

4. Selecting new population & replacing new population by current population using selection

5. Testing pausing circumstances and returning the best answer in case of any pause

6. Returning to step 2 (Seyed Hosseini et al, 1388: 79).

In this problem hagee Alvaneh and Bean's technique (1997), suggested for multiple planning of integrate, is used (Fuller, 1998; Holland, 1976; Fogel, 1998). Here, a chain including n elements as well as n workers in which i the element shows job shift given to i the worker for instance, if we have 5 workers, chain (3, 67, 56, 17, 1) shows the scheduling in which 1 and 17 are given to first & second workers.

Generating primary population: Staff's scheduling takes place for each day (Columns). For each day, for vector $v, v \in A^{staffnumber}$ is filled in a way that the number of needed people for each shift of the day is enough. This kind of planning continues to complete all shifts.

Fitness function: During producing the new population, answer evaluation (population members) is misleading since each set of answer is controlled by various limitations.

In order not to ignore any of limitations a set of penalty points is defined based on limitation amount & failure rate. Fitness of members is calculated through adding up the set of these points for all members. Therefore; appropriate fitness function is defined as sum of all penalties applied for limitations. Hence, appropriate fitness function of

problem:

$Fitness$

$\sum_{i=1}^{NW} P_1 \times \ distans\ (WB_i,\ Range\ of\ work)+$

$\sum_{i=1}^{ND} P_2 \times distans\ (DOB_i,\ leave\ Range)+\sum_{j=1}^{the\ number\ of\ shift} \sum_{i=1}^{NS_i} P_3 \times$

$distance(SB_{ij}\ leave\ range) + P_4 \times \ not\ allowed\ shift\ \ N_o$

Where NW & ND show the number of work blocks & blocks displaying the day, respectively. It is need to consider that NSj is the number of shift blocks from j shift. Also, WB_i & DOB_i show i working block & i non-working day block. SB_{ij} stands for i block shift from j shift. Moreover limitation fines will be $P2 = P1 = P3 = P4 = 1$. Distance function (X Block, distance) tends toward zero although X block length is between 2 numbers (range). Otherwise, returning distance of X block length is found out of range. For instance, if legal distance of working block is between 3X or 8 working blocks, fitness function tends toward 1.

Mutation operator: mutation

Crossover: There are 3 cross operator:

Random cross

1. Selecting a random number x in range $x \in (1, w)$

2. Selecting related time to number x from related column

3. Changing columns between crossed blocks related to people (staff)

   3-1. Column X is selected randomly

   3-2. Selecting $y(y \in (1, w - x))$ for a block from columns

   3-3. replacing selected blocks among people

Separating crossed columns:

1. Selecting random number x $(x \in (1, 3))$

2. Selecting time X of a random column which is not in vicinity of selected column

3. Replacing selected column among population number

4. Practical Example

In this section, a real numerical example is used to elaborate the issue. In this example, there is a working station including 9 staff that regularly changes their shift. Our assumptions are as follow:
Staff number=9, shifts:

1) day; shift
2) evening & shift
3) night. Also, considered rules for designing a shift include the followings:

a. A fixed and stable job shift is avoided as much as possible
b. the number of long and constant shift as well as extra working hours is minimized
c. In scheduling, one or two free days are defined.
d. Working of two shifts during 24 hours is avoided
e. After finishing each shift, at least 24 hour rest is included.
f. It was tried to have an exact and predictable schedule that all staff are informed of and set their life schedule based on.
g. schedule is set to be regularly circular and clockwise (morning, evening, night)
h. It has been tried to have at least two people working simultaneously.

Accordingly, Setting primary staff's schedule and working shifts are as follow:

$$R_{3,7} = \begin{pmatrix} 2 & 2 & 2\,2 & 2 & 2\,2 \\ 2 & 2 & 2\,3 & 3 & 3\,2 \\ 2 & 2 & 2\,2 & 2 & 2\,2 \end{pmatrix}$$

Limitations: working period is between 4 to 7 days. Only those working in shifts (3) & (2); or before weekends can have 1 shift off. Constantly, at least two shifts need to be identical (i.e. two following evenings). We cannot plan for two more durations during 7 days that cannot follow

each other. No one should work more than 5 shifts. Moreover, we cannot change shift, i.e. (night, day), (night, evening), (evening, day). The maximum length of holidays needs to be between 2 to 4 days.

$$MaxS_3 = (7, 6, 4)$$

In order to find the answer of this problem through genetic algorithm, we need 4850 repetition (485070) evaluation). The answer for the problem expressed in repetition 25 (5250 evaluation) is optimized & presented in Table 1.

Table 1. The answer of genetic algorithm for the problem

Labor /day	**Saturday**	**Sunday**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
1	day	day	Evening	Evening	Night	Night	Rest
2	Rest	day	day	Evening	Evening	Evening	rest
3	Rest	Rest	day	Day	Evening	Evening	Evening
4	Rest	Rest	Evening	Evening	Evening	Night	Night
5	Night	Rest	Evening	Day	Day	Day	Day
6	Evening	Evening	Evening	Rest	Day	Day	Day
7	Day	Night	Night	Night	Rest	Rest	Night
8	Night	Night	Night	Evening	Rest	Evening	Evening
9	Evening	Evening	Evening	night	night	rest	rest

5. Conclusion

One of the main objectives of the present planning is to distributes working force in working shift equally that can lead to remove any injustice shift distribution & finally to increase job satisfaction & organizational justice & fairness. Although working shift is a vital issue there day, it can bring about some downsides for those working in shifts. Most of them suffer from various ailments since unusual working hours affect their physical & mental aspects. Furthermore, the lack of enough sleep

may cause some accidents; hence, some modifying & preventive suggestions are presented to minimize these complaints & problems and also to increase managers, staff and their family's awareness.

Studies show that shift working has some disadvantages on health workers, such as 3 factors of workers' circadian rhythm sleeping and personal life. Negative impacts of shift in rhythm of circadian are: bad temper, difficulty in sleeping and digestion. Two first factors can cause digestive problems such as dyspepsia. These problems make the absence to the person and consequently falling efficiency therefore, staff's schedule needs to be adjusted while considering the least damage to the worker. Here, using health experts, nutritionists & physician's ideas matter.

Night working can violate sleep-awake cycle causing some physical & mental outcomes. When compatibility system of body dysfunctions, daily cycle stops working properly, many significant changes are imposed on body, and sleeping is disturbed and all those who work during night complain about these factors. They cannot sleep well during day because of light & daily activities & suffer from digestive, cardiovascular ailments family and mood problems. On the other hand, occupational commitments & family ones will be in conflicts. Therefore, one of the most crucial problems that need to be considered is making a balance between job & personal life.

Moreover Due to this fact that, according to a lot of studies, ladies who work in shift or unusual work hours, it is possible to state that their lives are affected by the negative outcomes that even can lead to lack of coordination among their social & personal activities, and increase their interpersonal paradoxes & endanger their mental health.

It is worth noting that objective function & stating the present article for this specific company are taken into consideration. Limitations are also highlighted. Hence, in order to use the findings of this paper in other studies, real factor omitted need to be added to the real context.

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