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Staffs Scheduling Problem Based on the Genetic Algorithm - A Case Study of a Vietnamese Company

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***Abstract*— *The scheduling problem plays an important role in all activities of humans. Scheduling is the process of arranging, planning, and managing to optimize work effectively. Scheduling is used to allocate plant and machinery resources, plan human resources, plan production processes. For that reason, the purpose of this paper is to solve the human resource scheduling problem by applying the Genetic Algorithm (GA) - a metaheuristic method is applied to minimize the total cost and enhance the scheduling ability to meet the demand. First of all, this study introduces a mathematical model based on the Nurse Scheduling Problem (NSP) and then applying the Genetic Algorithm to address the staff scheduling problem in a case study of a Vietnamese Company. To sum up, the final result of this study must have a significant improvement in the current staff scheduling problem of the company and also make sure that the application of this algorithm is more efficient than the use of manpower.*

***Keywords*— *Genetic algorithm, nurse schelduling problem, optimization, staff scheduling, particle swam optimization*.

I. Introduction

Most of the company or any organization also have a special interest in the division of labor because the costs of the personnel are one of the important elements. Therefore, to increase profits, most of the companies usually find a way to minimize the cost of personnel but still meet the required demand or set a logical scheduling plan. For many industrial organizations, the staff scheduling problem depends on many factors such as working hours, overtime, shift rotation... or have to work on the night-shift. Moreover, the efficient scheduling of daily working time for the employees must be developed based on their wishes and plans which helps them get higher motivation at work. This also improves the quality of the company output. Furthermore, one of the factors is labor law, all the staff scheduling problems and must follow labor laws. Thus, to make a staff schedule efficiently, we have to obey these basic standards.

This paper focuses on is workforce scheduling optimizing the timetable of a team of employees who are assigned to work at a warehouse for six months. In general, given the practice elements, many workers show a strong preference for working night shifts since they receive better pay, therefore the company is more likely to face the over-staffing during periods of lower demand. Besides, others desire to work on several constant timeframes based on their individual circumstances. For the aforementioned reasons, a working schedule is always made with the expectation that guarantees the job satisfaction of employees and the objectives include minimizing the cost, operating effectively employees in every working stage, saving time, and compliant with the Labor's Law on the working time.

This research will concentrate on staff scheduling for a six-month period. The Genetic Algorithm is used to solve the problem.

II. Literature Review

The nurse scheduling problem (NSP) has been researched since the end of the 19th century. In 1976, Miller et al. [1] was introduced a method for solving the NSP, in particular, developing a two-phase theoretical model for balancing the stability among employee reporting and internal nursing priorities in order to minimize an objective function that balances the trade-off between staffing coverage and schedule preferences of individual nurses, subject to some constraints on the nurse schedules.

In fact, scheduling is an important role in the field of manufacturing, hospitals, services, transportation, etc. Hence, the staff scheduling problem can be modeled based on the nurse scheduling problem (NSP).

There are many studies [2-4] which apply metaheuristics algorithms for solving scheduling problems. Among those algorithms, Genetic Algorithm (GA) [2], Particle swarm optimization (PSO) [3], Grey Wolf Optimizer (GWO) [4] are most frequently applied.

The Grey Wolf Optimizer (GWO) algorithm was developed by Mirjalili et al. in 2014 [5]. This algorithm is inspired by the living and hunting behavior of wolves. In comparison with other metaheuristics, GWO is proven to be capable of giving competitive results in optimization. However, this algorithm is proposed for continuous search spaces, some adjustments should be made in order to apply the GWO to discrete search space. For example, in the scheduling problem, there are many discrete characteristics that the original GWO algorithm cannot solve radically. Therefore, in 2018, Jiang & Zhang introduced a method [6] to solve this problem by using the Genetic Algorithm (GA) to implement crossover search operator and mutation to process the discrete characteristics of the scheduling solutions. It is noticeable that the GWO algorithm cannot find the best fitness solution in discrete space. To overcome this one, GWO must be combined with GA, which leads to taking more computational time.

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In 1995, optimize various continuous nonlinear functions and tackle the big datasets problem, Eberhart and Kennedy (1995) first suggested the particle swarm optimization method (PSO) [7]. This model is developed to simulate the behavior of birds. This algorithm is developed to simulate the behavior of birds. This is also a metaheuristic approach based on the population, which optimizes a given objective function by iteratively trying to improve a population of particle solutions. In search space, similar to the swarm of birds, the particle moves with a velocity that is continuously changed according to the particle's own experience, the experience of its neighbors, or the experience of the whole swarm until it detects a suitable position. The PSO algorithm has been effectively applied to a wide variety of applications.

The Genetic Algorithm (GA) was first introduced in the early 1970s by John Holland, this algorithm became popular through the work of John particularly his book Adaptation in Natural and Artificial Systems (1975) [8] The operation of the algorithm is that randomly generates an initial population including individuals and then implements the mutation between a random couple of individuals to create new individuals. A fitness function is used to select individuals with better performance. Finally, the algorithm selects half the individuals with better performance and adds them to the new population. If the new population satisfies the necessary condition, the algorithm ends; otherwise, the algorithm enters the next generation. As can be seen, the Genetic Algorithm (GA) is a very potential algorithm and as expected. Nowadays, there is a lot of application of this algorithm in the optimization problem, which indicates the GA is an effective method for scheduling compared to other algorithms.

In 2000, X. Cai, K, N. Li [9] applied GA for scheduling staff of mixed skills under multi-criteria to minimize the total cost for assigning staff to satisfy the manpower demands over time, and also seek a solution with the maximum surplus of staff. At the same time, this method makes sure to reduce the variation of staff over different scheduling periods. Hence, the outcome results are reported, which show the effectiveness of the proposed approach in finding desirable solutions.

In 2009, Chang-Chun Tsai and Sherman H. A. Li [10] have developed two-stage mathematical modeling for nurse scheduling wherein hospital management requirements, government regulations, and nurse shift preferences are incorporated. They proposed a meta-heuristic – Genetic Algorithm to arrange nurse roster scheduling. An empirical case study results that GA can be an efficient algorithm for solving the nurse scheduling problem. In addition, it can also be easily modified to suit different cases encountered in hospitals.

In 2015, C. Chen, T. Liu, C. Tasi, and H. Wang [11] studied an evolutionary approach based on a greedy genetic algorithm (GA) to serve as an efficient solver for real-world teacher volunteer transferring problems (TVTPs). To identify the effectiveness of GA, several real-world transferring cases are research, and the results show the benefits while adopting the proposed approach in the practical application which can greatly increase the successful transferring numbers compared to the official TVTP results.

III. Model Development

Based on the company policies, there are many strict requirements to create a model. There a fixed number of assigned to the tasks. The demand for each task must not exceed the available human resource, else it must be extended the period of time of progress. The first day of the week started on Monday. The task types can be scheduled in advance. The amount of each task can be quantified to ensure enough employee for different tasks on different days. There will be more tasks at the end of the month. Each employee will have at least one day off in a week.

$$\min Z = \sum_{i=1}^{I} U_i C_i + \sum_{j=1}^{J} U_j W_j \quad (1)$$

Where:

i: index of employee $i = 1 \dots I$

j: index of supervisor $j = 1 \dots J$

Z: is the total cost.

Ui: is the cost for employee i per shift.

: is the cost for supervisor j per shift.

- The cost for employee i per shift, Shift 1: \$24/shift, Shift 2: \$21/shift, Shift 3: \$45/shift

- The cost for supervisor j per shift, Shift 1: \$40/shift, Shift 2: \$35/shift, Shift 3: \$75/shift

The following constraints need to satisfied:

- If the employee i is assigned to a shift k then $Y_i = 1$,

$$\sum_{d=1,k=1}^{D,K} X_{idk} \le C_i, \forall i$$

Where:

X_{idk}: binary variable, $X_{idk} = 1$ if the employee i is assigned to shift k on d day, otherwise $X_{idk} = 0$.

C_i: if the employee i is assigned to any shift then $C_i = 1$, otherwise $C_i = 0$.

- If the supervisor j is assigned to a shift k then $W_j = 1$,

$$\sum_{d=1,k=1}^{D,K} Y_{jdk} \le W_j, \forall j \quad (2)$$

Where:

Y_{jdk}: binary variable, $Y_{jdk} = 1$ if the supervisor j is assigned to shift k on d day, otherwise $Y_{jdk} = 0$.

W_j: if the supervisor j is assigned to any shift then $W_j = 1$, otherwise $W_\text{j} = 0$

The employee i and supervisor j cannot work on two consecutive shifts:

$$X_{id3} + X_{i(d+1)1} \le 1 \quad (3)$$

$$X_{id2} + X_{id3} \le 1 \quad (4)$$

$$X_{id1} + X_{id2} \le 1 \quad (5)$$

$$X_{id1} + X_{id3} \le \quad (6)$$

$$Y_{jd3} + Y_{j(d+1)1} \le 1 \quad (7)$$

$$Y_{jd2} + Y_{jd3} \le 1 \quad (8)$$

$$Y_{jd1} + Y_{jd2} \le 1 \quad (9)$$

$$Y_{jd1} + Y_{jd3} \le 1 \quad (10)$$

Each employee/supervisor cannot work six consecutive days:

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$$\sum_{t=0}^{t=6} XR_{i(d+t)} \geq 1, \forall\, i, d = 1 \dots D-6 \quad (11)$$

$$\sum_{t=0}^{t=6} YR_{j(d+t)} \geq 1, \forall\, j, d = 1 \dots D-6 \quad (12)$$

Where:

X_{Rid}: binary variable, $XRid = 1$ if employee I off on d day.

Y_{Rjd}: binary variable, $YRjd = 1$ if supervisor J off on d day.

The number of employees/supervisors per shift type k must meet the demand:

$$\sum_{d=1}^{D} X_{idk} \geq M_{dk}, \forall\, k \quad (13)$$

$$\sum_{d=1}^{D} Y_{jdk} \geq 1, \forall\, k \quad (14)$$

Where:

Mdk: number of employees required for shift t on d day.

Rid: maximum number of days that each employee can take off.

Each employee and each supervisor must not work exceed five shifts per week:

$$\sum_{t=0}^{t=6} X_{i(d+t)k} \leq 5, \forall\, i, k, d = 1,8,15,22, .. \quad (15)$$

$$\sum_{t=0}^{t=6} Y_{j(d+t)k} \leq 5, \forall\, j, k, d = 1,8,15,22, .. \quad (16)$$

Where:

d: index of day $d = 1 \dots D$

k: set of the kth shift in the planning horizon ($k = 1,2,3$)

Following the natural selection theory, the algorithm starts with the selection of the best fitness individuals among a population and then creates the next generations that are produced from the fittest individuals of the previous generation. The new generation inherits all the best of the characteristics of chosen parents. Therefore, through this process, the achieved outcome is all feasible solutions. After that repeating this process until reaching the limit of iterations (or the satisfaction solution). The flowchart below is the specific explanation about the mechanism of the genetic algorithm.

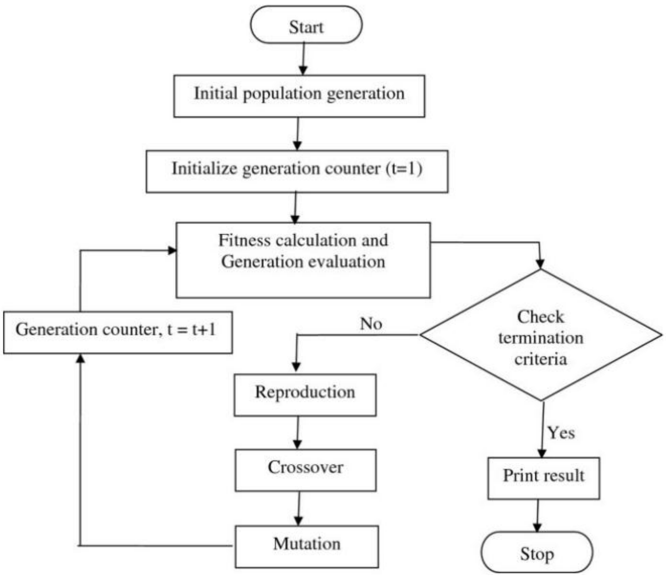

Fig. 1. Genetic Algorithm flow chart

IV. ANALYSIS

After finding the feasible solutions, the next step is to calculate the gap between the result obtained using the Genetic Algorithm and the result obtained using IBM CPlex. And the comparison was demonstrated in the table I and II:

TABLE I. Comparison of results obtained with the cases of low demand

S. No.	Month	Demand	Supervisor	Day	Cost (GA)	Cost (CPlex)	Gap	Percentage (%)
1	March	(1,1,1)	10	31	6560	4650	1910	41.08
2	April	(1,1,1)	10	30	6265	4500	1765	39.22
3	May	(1,1,1)	10	31	6860	4650	2210	47.53
4	June	(1,1,1)	10	30	6545	4500	2045	45.44
5	July	(1,1,1)	10	31	6915	4650	2265	48.71
6	August	(1,1,1)	10	31	6975	4650	2325	50.00
	Average				6687	4600	2087	45.33

TABLE II. Comparison of results obtained with the cases of high demand

S. No.	Month	Demand	Staff	Day	Cost (GA)	Cost (CPlex)	Gap	Percentage (%)
1	March	(6,6,6)	44	31	14400	16740	-2340	13.98%
2	April	(8,7,8)	44	30	16056	20970	-4914	23.43%
3	May	(6,9,8)	44	31	16344	21483	-5139	23.92%
4	June	(9,9,6)	44	30	15840	20250	-4410	21.78%
5	July	(6,9,7)	44	31	15432	20088	-4656	23.18%
6	August	(7,8,7)	44	31	15416	20181	-4765	23.61%
	Average				15581.3	19952	-4370.7	21.65%

As seen from table I, results obtained by CPlex are better than those obtained using the Genetic Algorithm (average gap of 45.33%). However, when demands are high as shown in Table II, the Genetic Algorithm consistently provides better results with an average gap of 21.65%. The results are understandable since when demands are low, the available

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search space is small and it is more accurate to use an exact method like CPlex. However, when demands are high, the available search space is significantly larger and due to the combinatorial nature of scheduling problems, the exact method cannot evaluate the whole search space. Meanwhile, the GA provides slowly changed and improved results.

V. CONCLUSION

This paper applied the Genetic Algorithm for solving the staff scheduling problem of a Vietnamese company. This application shows the outcome satisfied the expected demand. The benefits of the Genetic Algorithm are first improving search space to provide a general-purpose solution to the scheduling problem and eliminate undesirable schedules based on the criterion of the human scheduler. Besides, the setting of the demand (the number of staff, the number of days) is also simple, and the computation time for scheduling makes sure that it can help to reduce the manpower. Therefore, this algorithm is able to apply to solve the scheduling problems for all organizations. On the other hand, the role of genetic algorithms such as crossover, mutation, and selection in alleviating the premature convergence is studied extensively, and it is also applicable to solve the job-shop scheduling, image processing, inventory control, forecasting & network design, and gaming.

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