Iran J Public Health, Vol. 51, No.5, May 2022, pp.1125-1133

Original Article

Intelligent Model of Nursing Shift in Tehran University of Medical Sciences, Tehran, Iran

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(Received 10 Dec 2020; accepted 05 Feb 2021)

Abstract

Background: Nurses play a key role in increasing the efficiency of healthcare systems. Given the 24-hour performance of hospitals and the small number of nurses in the field of treatment, it is quintessential to re-shift them in the hospital. This study set out to achieve coherence in nursing shift planning and justice in the order of shifts in hospital.

Methods: This applied and a developmental study was performed from 2019 to 2020. We used genetic algorithm to provide operational solutions and define flexible shifts and plan nurses' working hours in Yas Hospital, Tehran University of Medical Sciences Hospital, Tehran, Iran.

Results: Based on the selection of each nurse and determining the approved shifts of each ward, the possibility of appropriate planning was provided to determine the required shifts per month and to estimate the needs of each department.

Conclusion: Using genetic algorithm and nursing shift in office automation console provides useful tools for managers at all organizational levels, according to which a good balance between the hospital's need for nurse and nurses' demands in different time periods.

Keywords: Shift; Nurses; Exploitation; Hospital; Genetic algorithm

Introduction

Hospitals are a special workforce that is known for providing indescribable services and has a large number of patients and special services for them (1). Among these forces are nurses, who are the most contented group among hospital groups and play an important role in increasing the efficiency of the hospitals (2, 3). Working in a rapidly changing environment in healthcare requires technical competencies. In addition, nurses make up the largest workforce in the health care system. They play a vital role in the treatment system (4). The human resources of each organization play a decisive role in exploitation, and nurses are considered

the most important human resources in hospitals (5). Nurses are the largest providers of health care in state hospitals as well (6-8).

Staff shifts are a complex balance between the needs of the organization and the legal obligations of employees. Work shifts have a significant impact on the health, lives of employees, and affect their exploitation. Nursing shift is an important factor that plays a key role in the hospital. Research has shown that working more than 12 hours increases errors at work (2).

The work process of nurses is such that in the face of various workloads, it can reduce their exploitation and lead to physical and mental fatigue. The results of a study have shown that reduced exploitation in relation to workload is sometimes associated with difficulty in activities (9). Furthermore, workload is one of the factors, which have a negative impact on the quality of working life (10). Shift work disrupts the connection between the internal clock of the body and the environment, which includes sleep disorders, increased accidents and injuries, and social isolation (11).

Night shifts are a risk factor for understanding nurses' health and it is the night shifts in which puts a lot of pressure on hospital nurses to take appropriate precautions to prevent burnout in nursing staff and prevent it (2, 12). Shift work is associated with impaired consciousness and sleep deprivation (13). Some errors in the hospital have been shown to be due to the effects of long work hours and shifts (14). In particular, night shifts have affected nurses' performance and patient satisfaction, and that nurses with night shifts and rotating shifts have been more likely to experience fatigue-related errors (6). The results of a study among nurses in South Africa showed that night shifts cause physical and mental stress in nurses, especially in cases of rapid rotating shifts. In addition, few nurses preferred night shifts, which was in turn due to social problems such as transportation (15).

Accordingly, by planning to change shifts through shift rotations, nurses' fatigue can be declined, which includes shifts in the morning, noon, and night. Furthermore, structured shifts can reduce problems such as absenteeism. Research shows that the power of nurses to choose certain shifts ameliorates their mood. The primary objective of nursing shifts is to minimize changes in the hospital's main work schedule, which is done at minimal cost. Reorganization of shifting is a cheap option due to the non-payment of additional wages (16). Research shows that a large proportion of nurses work 12-hour shifts. In the UK, research at Royal College of Nursing found that of the 76% of nurses responsible for nursing shifts, 45% of nurses worked 12-hour shifts, whereas in the United States, 70% of nurses worked 12 hours or more (17, 18).

A study conducted in Australia compared the shifts of 8 and 12 hours among ICU nurses in two stages. In the first stage, the nursing shift pattern of 8 hours was evaluated in 2015 and in the second stage, 6 months after the 12-hour shifts in 2017 was re-evaluated. In the 12-hour shift, the number of nursing patients and the family absence decreased and job satisfaction and communication with colleagues, educational opportunities and quality of life among them increased; while patients were not at risk (19). The nursing shift transfer scheme has positive effects on effectiveness, including safe testing and knowledge of the patient's clinical condition next to his bed when shifts change (20).

A study conducted based on the ideal planning model running General Algebraic Modeling System (GAMS) software, showed the appropriate number of nurses per shift was allocated so that their efficiency increased (21). Given the problem facing hospital managers regarding the optimization of staff shifts and its impact on hospital performance and patient satisfaction, the issue of scheduling is important. In most industrialized countries, there is a shortage of nurses, which makes it difficult to provide health care. The shortage of nurses causes problems in hospital management, which include increased costs, increased workload and long waiting times. Among the problems of employee planning is the assignment of shifts, which, despite the multiple skills, the flexibility of onset and outset of shifts, and the evaluation of the quality of shift assignments

based on multiple criteria have become more complex.
Genetic algorithm has been effective in optimizing and solving the problem (18). Therefore, due to the 24-hour performance of the hospital and the small number of nurses in the field of treatment, it is important to re-shift them in the hospital.
We aimed to have coherence in nursing shift planning and justice in the order of shifts at university hospitals.

Materials & Methods

This applied and developmental study used genetic algorithm (GA) to design and determine flexible shifts and scheduled working hours in the hospital and provide operational solutions to the problem. The main pillar of this method was based on genetic algorithm and then, combining several applied meta-heuristic algorithms including guideline search, genetic operators, and weighted method, solution to optimize nurses' cataloging was presented. In addition, in this research, an attempt has been made to establish shift intelligence and its connection with the attendance system in the university's office automation. Research data was collected based on personal information of nurses in the university office automation and the terms, determined by matron of department for each shift as a system inputs.
Ethics Committee of Tehran University of Medical Sciences approved the study (Ethics code: IR.TUMS.MEDICINE.REC.1400.598).
The study population consisted of nurses of university hospitals. It was conducted between 2019 and 2020 and the shifts of nurses in the Yas Hospital of Tehran University of Medical Sciences were enrolled.

Results

Statement of the problem

Meta-heuristic algorithms include two important components of exploration and exploitation, both of which are generally designed independently of the content of each type of problem, only with mathematical principles and statistics; however, since feedback on personnel behavior can be obtained for the assignment of shifts, using machine learning rules, one can create the conditions for more intelligent solutions to be found over time in guideline and exploitation in a smarter way based on the organization's behavioral principles in less time.

Problem Solving Algorithm

Meta-heuristic algorithm is a combination based on a genetic algorithm, in which each chromosome is a data frame of a ward's shift, with each row for a staff and each column for the day, and the values of each gene for the set of shifts acceptable for each personnel that can generate new offspring and shifts using the genetic exploitation operation (Fig. 1).

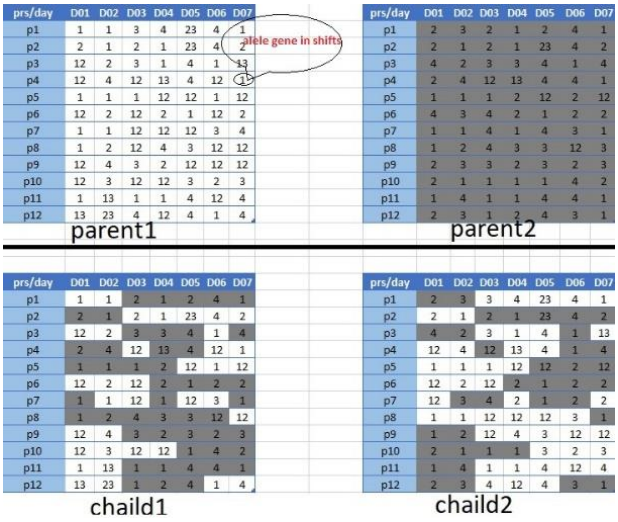

Fig. 1: Overview of genetic exploitation operations

Exploration

The first principle for implementing meta-heuristic optimization algorithms is to search and create a new method; so that high diversity could be acceptable in all sample spaces. Since this issue is constrained and divided into two categories, soft and hard, three general methods were used in this study:
Genetic operators: These operators are in turn divided into two main categories:

Cross over: These operators are considered as local search operators, and since each row of genes that are the shifts of one staff is linked to its own row in another shift, there will be no problem in terms of accepting admitting shifts for personnel. The cross overs are performed in three forms: single, double, uniform, and of course, an alternative method is performed between the two genes in the chromosome itself.

Mutation: A shift for a staff is replaced by another shift from a set of acceptable shifts.

Tabu Search: Since the successive use of a local genetic operator, given that each row belongs to a staff, is likely to return to the previous state, and this creates many repetitive loops in creating new populations and thus in high repetitions and causes severe slowness, an attempt has been made to use the tabu search method. This keeps the last operator on each chromosome and genome, and in a new search, the probability of selecting that method becomes zero. However, for each chromosome, the number of operators used during its life cycle is recorded, and the probability of selecting a new operator is proportional to the inverse of this value for parent chromosomes.

Guideline Search: To prevent non-compliance with strict restrictions such as shifts on the day off, guideline searches are used so that the new gene is acceptable if the condition is met. Otherwise, the gene will return to its previous state. Regarding the selection of search methods, an attempt has been made to store each value in the database in a relatively optimal ratio with one rank, and in each new iteration for each ward, it is possible to use either the previous optimal shifts or a new random shift.

Exploitation

In order for a meta-heuristic method to be closer to a convergence in terms of optimal response after a lot of searching, it also made sure that the probability of getting stuck in the optimal local locations was minimized. Therefore, the following methods were used: Weighted sum, Simulated Annealing, and Goal Attainments.

Definition of constraints

Horizontal constraints: These constraints are considered independent for each staff and in each period, according to the score obtained from exploitation, it is predicted how long they should be present, which is usually more than the amount of overtime and less than the deductible. This means that it has been tried to get closer to this value for each staff (neither less nor more).

Exploitation is calculated based on annual work, hard work, shift work, and if there is a veteran, the percentage of casualties or disabilities, and in each case the allowable working hours of the personnel are determined based on the above scores. Therefore, it can be concluded that each staff member who has a higher annual score, they will have more payments.

Another point that can be considered in this constraint is the imbalance of the number of personnel or resources in relation to the needs of each ward. Holidays and non-holidays, as well as any shifts (morning, evening and night) will be in accordance with the sample in the table below. In other words, the needs of human resources in each ward are known in each case and the available resources are known. Therefore, it is clear at the outset that on average to what extent each professional and non-professional staff should have overtime more than their exploitation, and that the algorithm should try to arrange the shift in such a way that it is fairly distributed among all forces.

It can be concluded that the penalty function resulting from the horizontal constraint can be defined as follows:

$$x_{ij}^{k}: \begin{cases} 1 & if\ Personnel\ i\ in\ day\ j\ Assign\ to\ shift\ k \\ 0 & esle \end{cases}$$

t^k: The amount of working hours of each shift k

ω_i: The amount of the required work based on the score of the system

θ_i: Overtime required by the department for personnel i proportional to being either professional or non-professional

$$P_w = \sum_{i=p_1}^{p} \sum_{j=1}^{d} \sum_{k=1}^{s} \left| \frac{\omega_i + \theta_i - (x_{ij}^{k} t^k)}{\omega_i} \right|$$

$$\theta_i =$$

Vertical constraints: These constraints are defined independently for the day and include:
- The daily requirement of the ward, which should be based on level, and let's assume that if we divide by k level, we will have the following penalty function (Table 1):

θ_i : Number of personnel present in the shift with k level per day i

l_0^k : Number of personnel required with k level per day

$$P_l = \sum_{j=1}^{k} \sum_{i=d_1}^{d} \max\{\left(1 - \frac{l_i^k}{l_0^k}\right), 0\}$$

Table 1: Daily requirement of wards in case Hospital

Maximum(standard) nonprofessional layout			*At least(currently) nonprofessional layout*			*Maximum(standard) professional layout*			*At least(currently) professional layout*			*Active Beds*	*Award*	*Hospital*
Night	Evening	Morning	Night	Evening	Morning	Night	Evening	Morning	Night	Evening	Morning			
1	1	2	0	1	1	2	3	4	2	2	4	27	Surgery	1
3	3	3	0	0	0	6	6	4	4	4	4	18	CCU	
1	1	1	0	0	0	2	2	4	2	2	4	9	Post cat.	

Combined constraints: These constraints include those related to days and other personnel in a ward that can include:
- Unusual shifts of continuous days
- Restriction of a staff for special shifts (for example, pregnant nurses or nurses with children will not have night shifts, etc.)
- Constraint on the number of days per week
- Constraint on the amount of hours per week

Data set

• ***Personnel***: Includes basic personnel information such as name, personnel number, and level of work, and there is also a mandatory attendance for each course of work and a score from the calculation of projected exploitation.

• ***Need of the day***: The needs of each ward in each day (vertical constraint), where we assume that for each day at least the required number of personnel is defined according to their three types of expertise (Table 2).

• ***Shift***: For each shift, we defined mandatory hours (Table 3).

Shift output: For each ward, the system suggests the same output for each part of the shift for the personnel. Of course, for each proposed output, it identifies the three points that this arrangement has: horizontal constraint score, vertical constraint score, combined constraint score, and total score (Table 4).

Table 2: The needs of each ward based on date

ID	*Work Section ID*	*Year*	*Month*	*Personal Type Req. ID*	*Shift Type ID*	*Req Min Count*	*Req Max Count*	*Day_diff_type*	*Personnel Type Req Count*
1	1	2019	6	0	1	4	4	Null	Null
2	1	2019	6	0	1	2	3	Null	Null
3	1	2019	6	0	1	2	2	Null	Null
4	1	2019	6	0	2	1	2	Null	Null
5	1	2019	6	0	2	1	1	Null	Null
6	1	2019	6	0	2	0	1	Null	Null

Table 3: The amount of mandatory time required for each shift

ID	*Code*	*Title*	*length*	*Start Time*	*End Time*	*Type*
1	1	M	540	360	900	1
2	2	A	460	900	1360	2
3	3	N	440	1360	360	3
4	4	Off	0	0	0	0
12	12	MA	1000	360	1360	12
13	13	MN	980	360	360	13
23	23	AN	900	1360	360	23

Table 4: Output of each shift for each proposed ward

ID	*Personnel Base ID*	*Day*	*Shift ID*	*Rank*	*Cost*	*End Time*	*Used Parent Count*	*Work Section ID*
1	2315	1	2	9	0.0605476	2019-11-10 18:14:00	3	1
2	2315	2	2	9	0.0605476	2019-11-10 18:14:00	3	1
3	2315	3	1	9	0.0605476	2019-11-10 18:14:00	3	1
4	2315	4	12	9	0.0605476	2019-11-10 18:14:00	3	1
5	2315	5	3	9	0.0605476	2019-11-10 18:14:00	3	1
6	2315	6	1	9	0.0605476	2019-11-10 18:14:00	3	1
7	2315	7	13	9	0.0605476	2019-11-10 18:14:00	3	1
8	2315	8	1	9	0.0605476	2019-11-10 18:14:00	3	1
9	2315	9	3	9	0.0605476	2019-11-10 18:14:00	3	1
10	2315	10	1	9	0.0605476	2019-11-10 18:14:00	3	1
11	2315	11	3	9	0.0605476	2019-11-10 18:14:00	3	1
12	2315	12	1	9	0.0605476	2019-11-10 18:14:00	3	1
13	2315	13	2	9	0.0605476	2019-11-10 18:14:00	3	1
14	2315	14	1	9	0.0605476	2019-11-10 18:14:00	3	1

This section includes an API server for accessing the user interface to machine-trained models such as optimizer models and organizational behavior neural network models, which use net core technology here as well as React.js for the user interface.

Accordingly, Tehran University of Medical Sciences in collaboration with Chargoon Company, in order to achieve the goals of e-government, including speeding things up, closer to justice in paying employee benefits, reducing human involvement in calculating working hours and consequently reducing human errors, has set up a shift system for staff attendance in office automation. One of the features of this system is the ability to perform calculations related to the exploitation law for nursing staff. According to this system, it

is necessary to use the attendance system, which can be done in 3 stages of preparation (adding shift calendar), preparation (defining individual work conditions), and preparation (changing the leave group). The necessary actions in each section are shown in Fig. 2.

preparation	Adding shift calendar	Selecting the user and identification code based on the desired date and defining the operational unit of the individual
	Defining individual work conditions	Selecting an effective date for the project in the unit, type of work shift, number of personnel card, shift calendar, and group of features
	Changing the leave group	Changing the leave group based on the time of the project
	Defining the shift by the relevant authority	Selecting the desired individual and determining the proper shift

Fig. 2: Shift in office automation

Discussion

The results of this study displayed that based on the selection of each nurse and determining the approved shifts of each ward, the possibility of appropriate planning was provided to determine the required shifts per month and to estimate the needs of each department. Furthermore, creating a console in the office automation of Tehran University of Medical Sciences for different layers, including nurses, supervisors, nursing managers and hospital managers, has created different applications and advantages. The console allows nurses to see the demand for each shift.

It also helps supervisors review the overall status of each shift and instantly shows them which nurses are on the shift. In addition, it gives them an estimate of the shifts for the next period of time. In addition, it provides hospital nursing managers with resource planning for all nurses per month, setting normal, special shifts, and shutting down the active workforce throughout the shift, delays and advances, overwork, and estimating the need for more staff in the ward. In this way, hospital managers can check the demand in each shift and plan the necessary work for the human resources in the hospital, including nurses and doctors, based on compliance with hospital conditions and providing resources and coverage of services.

Hospitals can reduce the planning problem through smart modeling, simulation and intelligent scheduling, and by developing applications of these tools while intelligently managing the time and cost of the necessary conditions to increase efficiency and provide solutions based on artificial intelligence for complex problems of health care systems.

A study in South Korean hospitals among nurses showed that the high workload affects the quality of services to patients (22). Moreover, reduced productivity in teaching hospitals has been linked to nurses' workload (9). The effective scheduling of nursing shifts is a vital issue that lack of proper scheduling causes fatigue and problems at work. As research has shown, shifts of more than 12 hours and working more than 40 hours per week increase the error in nurses' performance (12). Due to the variability of workload, staff shifts are complex. Various methods have been used for staff scheduling and planning in various studies, including operations research methods, machine learning, data analysis, simulation and modeling in order to determine the shift scheduling framework for proper distribution of staff in the hospital (23). The office automation system allows the exchange

of letters daily, staff control, sending messages and attendance system (24).

Conclusion

In this study, applying the model of genetic algorithm and nurses 'shift in office automation console, a useful tool for nurses, head nurses and managers at all organizational levels has been provided. It balances between hospital needs for nursing staff and nurses' demand in different time periods. The presented method in this research can be used as a model in other hospitals.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

Acknowledgements

This study was a part of research project funded and supported by Tehran University of Medical Sciences, Tehran, Iran (Number: 1400-2-451-54352). The authors would like to thank Tehran University of Medical Sciences, Tehran, Iran and Yas Hospital.

Conflict of interest

The authors declare that there is no conflict of interest.

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