International Journal of Electrical and Computer Engineering (IJECE)
Vol. 12, No. 3, June 2022, pp. 2876~2884
ISSN: 2088-8708, DOI: 10.11591/ijece.v12i3.pp2876-2884

Establishing a cyclic schedule for nurse in the health unit

Isra Natheer Alkallak[1], Ruqaya Zedan Shaban[2]
[1]Department Basic Sciences, College of Nursing, University of Mosul, Mosul, Iraq
[2]Computer Unit, College of Medicine, University of Mosul, Mosul, Iraq

Article Info

Article history:

Received May 2, 2021
Revised Oct 2, 2021
Accepted Nov 5, 2021

Keywords:

8-puzzle
Heuristic
Nursing rostering
Sudoku grid

ABSTRACT

This research presents the interleaving two approaches. These are intelligence's ideas as well as heuristic technique as 8-puzzle and sudoku grid to solve the nurse rostering. The research proposed algorithm to assign shifts cyclically. It is considered by three shifts in one day to 9 nurses, each nurse has 8 days work with a holiday in the cyclically scheduling. The task appeared the allocation of nursing staff in health unit management theoretically. There are three shifts which cover 24 hours. The shifts are early, late, and night. This algorithm simulated the shifts through the directions of blank's move in 8-puzzle with the methodology of sudoku grid with hard constraints should be met at all times. In our solution do on two goals first, we create a schedule that meets all the tough constraints and guarantees fairness. The second objective is to try to verify as many of the soft constraints as possible, by shifting and rotating while maintaining the soft constraints. The approach was implemented as a simulation, and a satisfactory result was demonstrated. experimental effects are extremely convenient and versatile to find appropriate nursing rostering schedule, rather than using manual techniques. The code developed to simulate it in MATLAB.

Corresponding Author:

Isra Natheer Alkallak
Department Basic Sciences, College of Nursing, University of Mosul
Mosul, Iraq
Email: alkalak.isra@uomosul.edu.iq

1. INTRODUCTION

The nursing rostering problem is a combinatorial problem [1]. Nurse rostering problem was an active area of study and interest within artificial intelligence. A roster is described as a collection of nurse assignments for day-to-day shifts over a given period of time [2]–[4]. The number of hours worked per nurse per week or satisfying duration. In nurse schedules, their cyclical attributes may be classified accordingly. A group of nurses operates a set schedule for service in cyclical scheduling, and this schedule will be repeated as many times as possible into the future. Cyclic scheduling is effective because the coverage is balanced over the schedule's days and shifts. The day is split into three shifts as an early day shift, a late day shift, and a night shift [5]–[7]. The task is to create cyclic schedules for a group of nurses by assigning each nurse one of several possible shift patterns [8]–[10]. These schedules have to execute job contracts and satisfy demand specifications for a given number of nurses in each shift. These schedules must fulfill working contracts and meet the demand in every shift for a specified number of nurses. There are many solutions to the nursing rostering problems in earlier literature and although the problem of allocating work shifts to nurses is very difficult. This research focused on nurse rostering by using methods of artificial intelligence. The dilemma with nurses being assigned to service rosters exists in wards of health units around the world. Nurse rostering is a schedule consisting of shift assignments and nurses working in a health unit to rest days [11]–[13]. Heuristic strategies are aimed at finding good solutions but optimal solutions of this nature are not guaranteed [14], [15].

This study is the first of its kind by integrating the concepts of artificial intelligence and its algorithms in solving the problem of rostering nurses and in a proposed algorithm that includes emphasizing the application of hard constraints and not violating them, as well as applying the soft constraints to the problem to be solved as much as possible. The aim of research to heuristically create cyclically nursing rostering through artificial intelligence problems as 8-puzzle and sudoku grid. The research is organized according to the following. Firstly, we described the nursing rostering problem. Later, we present the heuristic approach and cyclic rosters and it showed the behaviors of 8-Puzzle and Sudoku grid approaches in section two. Additionally, the attributes for proposed constraints were defined in section two following the hard constraints and the soft constraints. Section three are described in detail the cyclic schedule design with the proposed algorithm for building of cyclic schedule. Section four discusses the results are examined. Finally, section five concludes this research.

2. HEURISTIC APPROACH AND CYCLIC ROSTERS

A roster is described as a collection of nurse assignments to day-to-day shifts over a given period [16]. For combinatorial problems, a heuristic approach may generate efficient results for hard combinatorial problems such as nurse rostering in obtaining optimal/near-optimal results [17]–[19]. Heuristics have been used to fix employee staffing concerns. In cyclical rosters, all workers of the same class perform precisely the same line of work. For acyclic rosters, the lines of jobs for individual workers are fully independent. In acyclic rosters, the lines of work are completely independent for individual employees [20]. Also, it is referred to as fixed scheduling [21]. The accurate specifics of the issue, however, vary from hospital to hospital. A selection of nurses for cyclical scheduling. In cyclical scheduling, a set of nurses work a fixed duty roster, and this roster is repeated as many times as required into the future [14], [21], [22].

2.1. Behaviors of 8-puzzle and sudoku grid approaches

The 8-puzzle is a square tray, where 8 square tiles are placed. The remaining square of ninth is uncovered. Each tile has a number on it. In that space, a tile that is adjacent to the blank space can slide. A game consists of a starting position and a goal position that is assigned. The sliding tile puzzle, which features n tiles numbered from 1 to n and one blank tile in a square grid, is also called the n-puzzle [23]. Sudoku grid is a popular problem of combinatorial optimization and is known as Np-complete. Sudoku puzzle is composed of 81 cells, contained in a 9×9 grid. Each cell includes a single integer between one and nine. Divide the grid into nine sub-grids 3×3. The constraints of the Sudoku problem are met with each row, column, and sub-grid 3×3 of cells to contain the integers one through to nine exactly once [24], [25].

2.2. Attributes for proposed constraints

Preliminary, the research addressed the issue of rostering. Nurse rostering is a sort of resource-sharing question that allows nurses to be allocated the workload regularly. The job is to locate change allocations, for a group of nurses as 9 nurses, over a fixed period of time as 8 days with the holiday. Each **s**hift time equals 8 hours. The day is divided into three shifts an early, late, and night. This problem had constraints as hard and soft. In this research, we focused on the directions for blank's move in 8-puzzle and generate nine submatrices, each sub-matrix was 3×3 and it contained one blank; thus, we generated the matrix 9×9. This matrix is the Aggregation of the nine submatrices, each of which represents 8-puzzle, also this matrix contained one blank in a row, column, and diagonal. This stems from the hypothesis of interleaving between 8-puzzle concepts and the sudoku grid.

2.3. The hard constraints

In this research, the schedule is invalid when hard constraints fail. The hard constraints are enforced and should always be met. The hard constraints are: i) the nurse is assigned one shift. The nurse will not be assigned to either the early shift, late shift, or night shift on the same day, ii) no early shift after night shift, and iii) during a holiday, a nurse may not work shifts.

2.4. The soft constraints

In this analysis, the soft constraints include: i) a maximum number of shifts operated as three shifts during the scheduling period, ii) the average number of the working hour are 8 hours, iii) the total number of consecutive working days are 8, with one holiday, iv) for each nurse, no shifts over the holiday day, and v) Each day, three kinds of shifts are distributed with the holiday to all nurses.

3. CYCLIC SCHEDULE DESIGN

Proposed steps produce cyclical scheduling to consulting a nurse roster solution, by assigning the number of three type's shifts. Within a scheduling period of 9 days as 8 days with holiday to 9 nurses.

Step 1: Initialize 8-puzzle square and we highlighted the blank position. The character x denoted to the blank in 8-puzzle in Figure 1.

Step 2: Generate 9 samples of 8-puzzle by moving the blank's position to each position in 8-puzzle. Illustrated graphically in Figure 2.

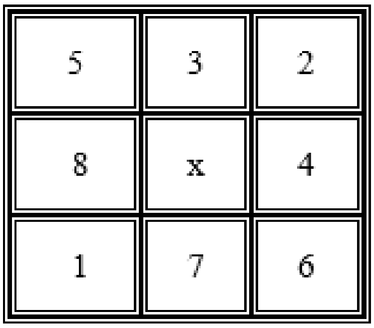

Figure 1. 8-puzzle square

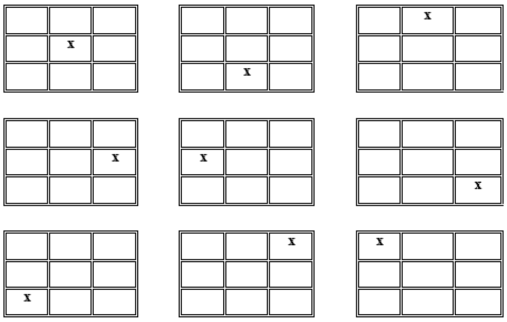

Figure 2. Cases of 8-puzzle's blank with different directions

Step 3: Generate matrix as 9×9. Divide the matrix into 9 sub-matrixes of 3×3. This matrix is the structural sudoku grid. Illustrated graphically in Figure 3.

Step 4: In Figure 4 noticed the characters E, L and N mean early, late, and night shifts respectively. Assign first column, second column, and third column by characters E, L, N, in first, fourth and seventh submatrices. Assign first column, second column, and third column by characters L, N, E, in second, fifth, and eighth submatrices by rotating the column E to right in the previous original assignment. Assign first column, second column, and third column by characters N, E, L, in third, sixth, and ninth submatrices by rotating the column N to left in the previous original assignment. Illustrated graphically in Figure 4.

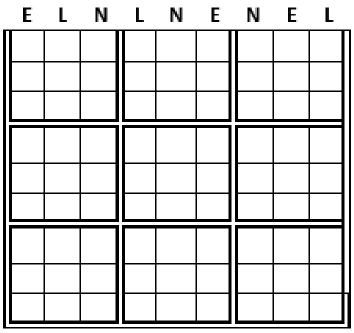

Figure 3. Original matrix

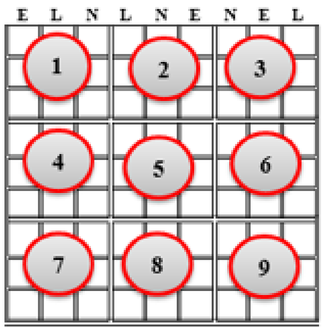

Figure 4. Shifts assignment

Step 5: We can obtain several matrixes 9×9 by assigning all cases (nine) of 8-Puzzle with different arrangements. Here, the arrangement for cases of 8- Puzzle's blank with different directions are arbitrary on the condition that there is a single blank in the row, column, or diagonal to satisfy the constraints of the Sudoku grid as follows in Figure 5. Figure 5 is the source or foundation in the generation of the rest of the forms through shifting and rotating operations. In Figure 5, we noticed the distribution of blanks in the first row, second row, and third row in the first, second and third submatrices respectively. The blanks are shifted to the right by once column to generate the fourth, fifth and sixth submatrices respectively. Also, the blanks are shifted to the right by twice columns to generate the seventh, eighth, and ninth submatrices respectively.

Step 6: When we rotate to down the first, second, and third submatrices in Figure 5, thus generate the Figure 6 case 2, also, the rest of the submatrices get rotated.

Step 7: When we rotate to up the seventh, eighth, and ninth submatrices in Figure 5, thus generate the Figure 7 case 3, also, the rest of the submatrices get rotated.

Step 8: When we shift to the right first, fourth, and seventh submatrices in Figure 5, thus generate the Figure 8 case 4, also the rest of the submatrices get shifted.

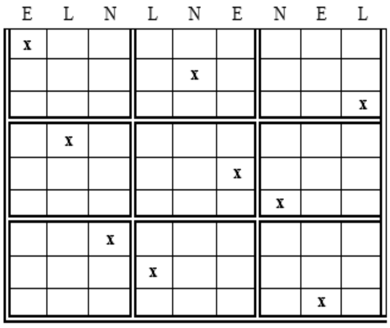

Figure 5. Case 1 (source case)

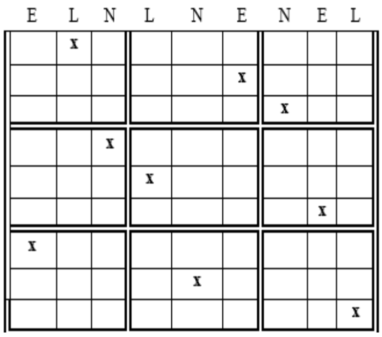

Figure 6. Case 2 (Step 6)

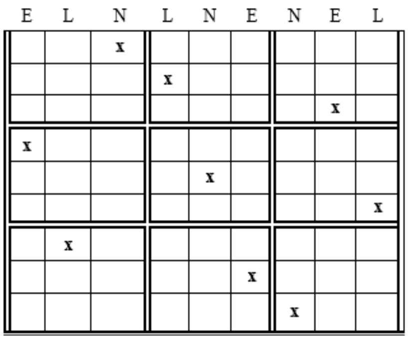

Figure 7. Case 3 (Step 7)

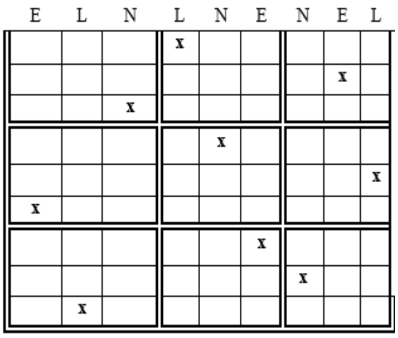

Figure 8. Case 4 (Step 8)

Step 9: When the shift to the left the second, fifth, and eighth submatrices in Figure 5, thus generate the Figure 9 case 5, also the rest of the submatrices get shifted.

Step 10: To assign the holiday day through Figure 5 Case 1 Source case for each nurse, for each blank in Figure 5 represented the position of holiday in the final matrix as Figure 10. To assign all shifts in the final solution through.

Figures 5 to 9 with duplicate some figures. Each row of the above-mentioned forms refers to each nurse. Figure 10 illustrated the schedule is a complete of shifts generated.

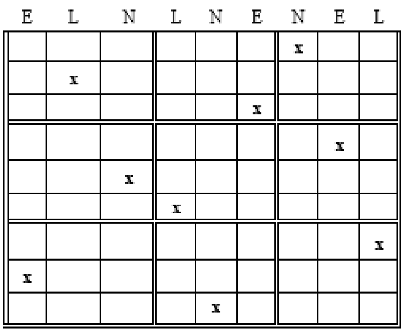

Figure 9. Case 5 (Step 9)

	Day1	Day2	Day3	Day4	Day5	Day6	Day7	Day8	Day9
Nurse1	Holiday Case1	L/ Case 4	E/ Case1	N/ Case5	N/ Case3	L/ Case2	E/ Case1	N/ Case5	L/ Case4
Nurse2	E/ Case4	N/ Case 1	L/ Case5	L/ Case3	Holiday Case 1	E/ Case2	N/ Case1	L/ Case5	E/ Case4
Nurse3	N/ Case 4	L/ Case1	E/ Case5	E/ Case3	N/ Case2	L/ Case1	E/ Case5	N/ Case4	Holiday Case 1
Nurse4	N/ Case 4	Holiday Case 1	L/ Case1	E/ Case5	E/ Case3	N/ Case2	L/ Case1	E/ Case5	N/ Case4
Nurse5	L/ Case 4	E/ Case1	N/ Case5	N/ Case3	L/ Case2	Holiday Case 1	E/ Case1	N/ Case5	L/ Case4
Nurse6	E/ Case4	N/ Case1	L/ Case5	L/ Case3	E/ Case2	N/ Case1	Holiday Case 1	L/ Case5	E/ Case4
Nurse7	E/Case4	N/ Case1	Holiday Case 1	L/ Case5	L/ Case3	E/ Case2	N/ Case1	L/ Case5	E/ Case4
Nurse8	N/Case4	L/ Case1	E/ Case5	Holiday Case 1	E/ Case3	N/ Case2	L/ Case1	E/ Case5	N/ Case4
Nurse9	L/Case4	E/ Case1	N/ Case5	N/ Case3	L/ Case2	E/ Case1	N/ Case5	Holiday Case 1	L/ Case4

Figure 10. Shifts generated by proposed algorithm for 9 nurses with 9 days

3.1. Proposed algorithm for building of cyclic schedule

Below, sections of pseudo-code for building the cyclic schedule for the problem as shown:

```
Begin                          {Shift Assignment}
Generate matrix by n×n divided into n submatrices has size 3×3.
         That n = 9 and represent the number of nurses.
Assign three of shift's type in first, second, and third columns in matrix n×n as
Let column1 =E;     where E is the Early shift in a day
Let column2 =L;     where L is the Late shift in a day
Let column3 =N;    where N is the night shift in a day
 Assign each column in first, fourth, and seventh submatrices as E, L, N by:
j = 1
For i = 1 to 3;     where i number of submatrices
      Ordersubmatrix[i] = j
       j = j + 3
End
```

Apply rotate operation about E, L, N columns. Column E rotate to the right. Assign each column in second, fifth, and eighth submatrices as E, L, N in Figure 11.

```
For i = 1 to 3
 new_Ordersubmatrix = Ordersubmatrix [i] + 1
 Ordersubmatrix [i] = new_Ordersubmatrix
End
```

Apply rotate operation about E, L, N columns. The column N rotates to the left in Figure 12.

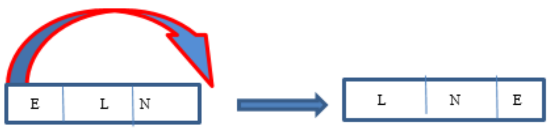

Figure 11. Rotate operation to right

Figure 12. Rotate operation to left

Assign each column in third, sixth, and ninth submatrices as N, L, E by

```
For i = 1 to 3
    new_Ordersubmatrix = Ordersubmatrix [i] + 1
  Ordersubmatrix [i] = new_Ordersubmatrix
End
End                             {Shift Assignment}
Begin                           {Pseudo-code for building holiday day}
For i = 1 to 9
  Count = 0
    For j = 1 to 9
      If i == j                  ; check the diagonal
                   For m = 1 to 9
          If case5[m, m] = blank
          Count = count + 1
                        End
                 End
              If count == 1
                 Then assign Holiday to nurse "satisfy constraints of Sudoku grid"
              End
            End
             If case5[i, j] = blank
      Position_of_blank = j
      Count = count + 1
              End
       End; end for j
                If count == 1         ; check blank in the row is done
        For k = i + 1 to 9
                           If case5(k, position_of_blank) = blank
          Count = count + 1
                             End
                          End; end for k
                            If count == 1       ; check blank in the column is done
                      Then assign Holiday to nurse "satisfy constraints of Sudoku grid"
                              Else
                              End
                  End
End            {Pseudo-code for building holiday day}
```

Figure 13 illustrated the building of cyclic schedule as shown:

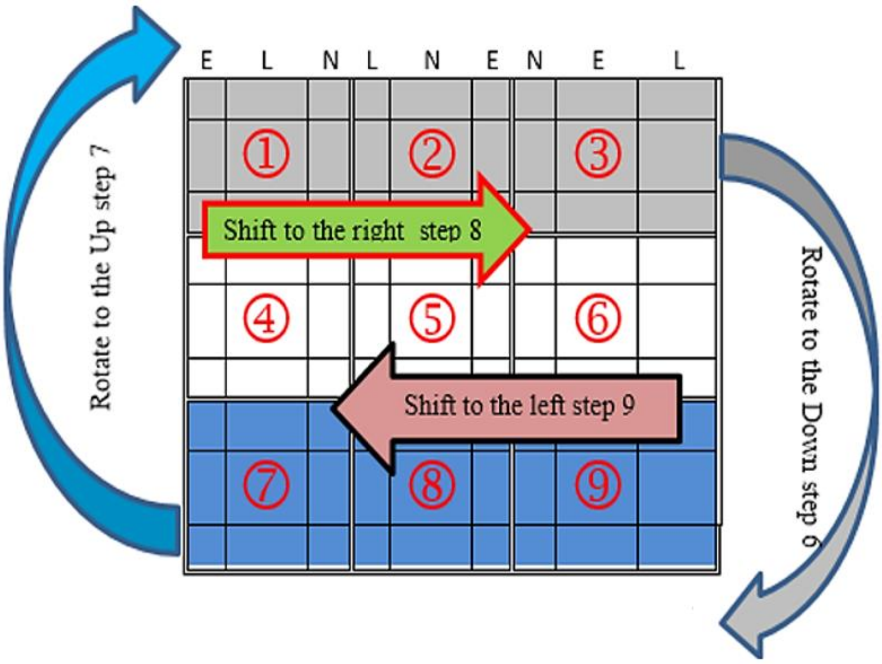

Figure 13. Buliding of cyclic schedule

4. RESULTS AND DISCUSSION

In this research, we obtain the heuristic approaches that produced satisfactory results in a reasonably short time. For example, when assigned all shifts to nurse1 over the nine days as follows:

– For the first day, since the first position in the matrix of Figure 5 case1, has the letter x and this indicates the blank of 8-Puzzle, this is reserved for the holiday for this nurse.
– As for the second day, as the allocation was made from Figure 8 case 4, as it is noted that the blank of 8-Puzzle in the column with the late shift.
– For the third day, from Figure 5 case 1, we notice the blank (letter x) in the column with the early shift. For this reason, the early shift is dedicated to the nurse.
– For the fourth day, from Figure 9 case 5, we notice the blank (letter x) in the column with the night shift. For this reason, the night shift is dedicated to the nurse.
– For the fifth day, from Figure 7 case 3, we notice the blank (letter x) in the column with the night shift. For this reason, the night shift is dedicated to the nurse.
– As for the sixth day, the allocation was made through Figure 6 case 2, we notice the blank (letter x) in the column with the late shift. For this reason, the late shift is dedicated to the nurse.
– For the seventh day, from Figure 5 case 1, we notice the blank (letter x) in the column with the early shift. For this reason, the early shift is dedicated to the nurse.
– For the eighth day, from Figure 9 case 5, we notice the blank (letter x) in the column with the night shift. For this reason, the night shift is dedicated to the nurse.
– For the ninth day, from Figure 8 case 4, we notice the blank (letter x) in the column with the late shift. For this reason, the late shift is dedicated to the nurse.
– In the final solution, Figure 10, We now have one holiday in the row, column, and diagonal, as well as not duplicate the holiday in submatrix 3×3, so we say there is no violation for Sudoku restrictions. The reason for used Figure 5, because it begins with an x in the first position of the first submatrix, and this is useful for including holidays for all nurses. So, for the rest of the nurses are assigned to the shifts. Creating this cyclic scheduling without violating the constraints of the problem.

Here, we find that all nurses deserved the holiday break, where one holiday in the row, column, diagonal of the final solution matrix, and submatrices as Figure 10, thus constraints Sudoku approach are met. Also, we notice in our final solution that in one day there are all types of shifts in the health unit as well as a holiday for one of the nurses and therefore we have achieved the hard and soft constraints proposed by the research. In this research, we used the track {4,1,5,3,2,1,5,4} for the cases and including holidays, thus the path will be shifted a day when the holiday is evened. In our research, we have adopted several tracks for cases, but we have found a case of violation of constraints of the problem, but the track in its above order is better not to violate of constraints of the problem. Each submatrix in our solution is the cases of 8-Puzzle's blank with different directions with constraints Sudoku approach and for this we have said that our research includes intelligent techniques with the heuristic approach to cyclic scheduling of the nursing. In our research, each case in the above-mentioned figures represents cases of 8-puzzle's blank with different directions, and at the same time, it represents the Sudoku approach. We found in our research, that Figure 5 case 1 is the cornerstone in preparing this proposed algorithm and that the mentioned Figure achieves the final good solution. If there are more nurses than mentioned in the proposed algorithm, it is possible to repeat the proposed cyclic scheduling.

5. CONCLUSION

This research presents the artificial intelligence approach for cyclic scheduling. It becomes very attractive research in Artificial Intelligence. Two approaches taken from 8-puzzle and Sudoku grid are presented for nurse scheduling to choose a schedule from a set for each nurse assignment. A heuristic method, combining 8-puzzle and sudoku grid for scheduling techniques proved to be very suitable for this combinatorial problem in which as the attempt to find a near-optimal solution. This research eliminated the gap between the classical method and practice of nurse rostering by approaches of artificial intelligence. The proposed algorithm meets the requirements in question as much as possible. In this research, the proposed algorithm coverage requirements as each day require three shifts and, in each shift, present nurse at the time to work during the day. The heuristic of solutions makes it easy to tackle complex goals, for violating the desired constraint. Hence the heuristic has facilitated the solution. The current study deals with heuristic with a hybrid to obtain the solution for the hard combinatorial problem as nursing rostering. The result shows the nurse rostering problem can be simplified by combining the direction of tiles for the 8-puzzle sudoku approach to reach the solution. We concluded through the research that the proposed algorithm is the first of its kind in scheduling nurses by using artificial intelligence methods.

ACKNOWLEDGMENT

The authors are very grateful to the College of Nursing and College of Medicine at the University of Mosul for their provided facilities, which helped to improve the quality of this work.

REFERENCES

[1] J. Li and U. Aickelin, "The application of bayesian optimization and classifier systems in nurse scheduling," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 3242, Springer Berlin Heidelberg, 2004, pp. 581–590.

[2] G. Beddoe, S. Petrovic, and J. Li, "A hybrid metaheuristic case-based reasoning system for nurse rostering," *Journal of Scheduling*, vol. 12, no. 2, pp. 99–119, Sep. 2009, doi: 10.1007/s10951-008-0082-8.

[3] P. Brucker, R. Qu, E. Burke, and G. Post, "A decomposition, construction and post-processing approach for a specific nurse rostering problem," *Proceedings of the 2nd Multidisciplinary Conference on Scheduling: Theory and Applications*, no. January 2005, pp. 397–406, 2005.

[4] L. Hakim, T. Bakhtiar, and Jaharuddin, "The nurse scheduling problem: A goal programming and nonlinear optimization approaches," *IOP Conference Series: Materials Science and Engineering*, vol. 166, no. 1, Jan. 2017, doi: 10.1088/1757-899X/166/1/012024.

[5] L. Altamirano, M. C. Riff, I. Araya, and L. Trilling, "Anesthesiology nurse scheduling using particle swarm optimization," *International Journal of Computational Intelligence Systems*, vol. 5, no. 1, pp. 111–125, 2012, doi: 10.1080/18756891.2012.670525.

[6] P. Brucker, E. K. Burke, T. Curtois, R. Qu, and G. Vanden Berghe, "A shift sequence based approach for nurse scheduling and a new benchmark dataset," *Journal of Heuristics*, vol. 16, no. 4, pp. 559–573, Nov. 2010, doi: 10.1007/s10732-008-9099-6.

[7] T. Gonsalves and K. Kuwata, "Memetic algorithm for the nurse scheduling problem," *International Journal of Artificial Intelligence & Applications*, vol. 6, no. 4, pp. 43–52, Jul. 2015, doi: 10.5121/ijaia.2015.6404.

[8] R. Bai, E. K. Burke, G. Kendall, J. Li, and B. McCollum, "A hybrid evolutionary approach to the nurse rostering problem," *IEEE Transactions on Evolutionary Computation*, vol. 14, no. 4, pp. 580–590, Aug. 2010, doi: 10.1109/TEVC.2009.2033583.

[9] E. K. Burke, P. De Causmaecker, S. Petrovic, and G. Vanden Berghe, "Metaheuristics for handling time interval coverage constraints in nurse scheduling," *Applied Artificial Intelligence*, vol. 20, no. 9, pp. 743–766, Dec. 2006, doi: 10.1080/08839510600903841.

[10] E. K. Burke, J. Li, and R. Qu, "A hybrid model of integer programming and variable neighbourhood search for highly-constrained nurse rostering problems," *European Journal of Operational Research*, vol. 203, no. 2, pp. 484–493, Jun. 2010, doi: 10.1016/j.ejor.2009.07.036.

[11] M. B. S. Kumar, M. G. Nagalakshmi, and D. S. Kumaraguru, "A shift sequence for nurse scheduling using linear programming problem," *IOSR Journal of Nursing and Health Science*, vol. 3, no. 6, pp. 24–28, 2014, doi: 10.9790/1959-03612428.

[12] C. Valouxis and E. Housos, "Hybrid optimization techniques for the workshift and rest assignment of nursing personnel," *Artificial Intelligence in Medicine*, vol. 20, no. 2, pp. 155–175, Oct. 2000, doi: 10.1016/S0933-3657(00)00062-2.

[13] A. Youssef and S. Senbel, "A Bi-level heuristic solution for the nurse scheduling problem based on shift-swapping," in *2018 IEEE 8th Annual Computing and Communication Workshop and Conference, CCWC 2018*, Jan. 2018, vol. 2018-January, pp. 72–78, doi: 10.1109/CCWC.2018.8301623.

[14] M. J. Bester, I. Nieuwoudt, and J. H. Van Vuuren, "Finding good nurse duty schedules: A case study," *Journal of Scheduling*, vol. 10, no. 6, pp. 387–405, Oct. 2007, doi: 10.1007/s10951-007-0035-7.

[15] M. Liogys and A. Žilinskas, "On multi-objective optimization heuristics for nurse rostering problem," *Baltic J. Modern Computing*, vol. 2, no. 1, pp. 32–44, 2014.

[16] B. M. S. Kundu and M. Mahato and S. Acharyya, "Comparative performance of simulated annealing and genetic algorithm in solving nurse scheduling problem," in *Proceedings of the International MultiConference of Engineers and Computer Scientists 2008 Vol I IMECS 2008*, 2008, pp. 19–21.

[17] B. Cheang, H. Li, A. Lim, and B. Rodrigues, "Nurse rostering problems-a bibliographic survey," *European Journal of Operational Research*, vol. 151, no. 3, pp. 447–460, Dec. 2003, doi: 10.1016/S0377-2217(03)00021-3.

[18] R. Z. Shaban and I. N. Alkallak, "Organizing sports matches with a hybrid monkey search algorithm," *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 22, no. 1, pp. 542–551, Apr. 2021, doi: 10.11591/ijeecs.v22.i1.pp542-551.

[19] I. N. Alkallak and R. Z. Sha'ban, "Tabu search method for solving the traveling salesman problem Isra Natheer Alkallak Ruqaya Zedan Sha' ban," *Journal of Computational Mathematics*, vol. 5, no. 2, pp. 141–153, 2008.

[20] A. T. Ernst, H. Jiang, M. Krishnamoorthy, and D. Sier, "Staff scheduling and rostering: A review of applications, methods and models," *European Journal of Operational Research*, vol. 153, no. 1, pp. 3–27, Feb. 2004, doi: 10.1016/S0377-2217(03)00095-X.

[21] E. Burke and P. Causmaecker and, G. Vanden Berghe and H. Van Landeghem, "The state of the art of nurse scheduling," *Journal of Scheduling*, vol. 7, no. 6, pp. 441–499, 2004.

[22] J. F. Bard and H. W. Purnomo, "Cyclic preference scheduling of nurses using a Lagrangian-based heuristic," *Journal of Scheduling*, vol. 10, no. 1, pp. 5–23, Feb. 2007, doi: 10.1007/s10951-006-0323-7.

[23] R. Sha'ban, "Applying the intelligence of ant and tabu search to solve the 8-puzzle problem," *AL-Rafidain Journal of Computer Sciences and Mathematics*, vol. 10, no. 2, pp. 101–112, Jul. 2013, doi: 10.33899/csmj.2013.163477.

[24] I. Alkallak, "Using magic square of order 3 to solve sudoku grid problem," *Tikrit Journal of Science*, no. April 2012, 2012.

[25] I. N. Alkallak, Y. H. Alnema, and R. Z. Sha'ban, "A proposed hybrid algorithm for constructing knight tour problem by sudoku grid," *Journal of Advanced Research in Dynamical and Control Systems*, vol. 10, no. 10, pp. 2333–2342, 2018.

BIOGRAPHIES OF AUTHORS

Isra Natheer Alkallak completed her M.Sc. in computer science/ Artificial Intelligence in 2003 and B.Sc. in computer science in 1991. She has worked in the Basic Science department in the College of the Nursing University of Mosul. Her research interests include Optimization algorithms, Heuristic, and Swarm Intelligence for applications. She can be contacted at email: alkalak.isra@uomosul.edu.iq.

Rukaya Zedan Sha'ban completed her M.Sc. in computer science/Artificial Intelligence 2001 and B.Sc. in computer science in 1989. She has worked in the computer unit in the College of the Medicine University of Mosul. Her research interests include Optimization algorithms, Heuristic, and Swarm Intelligence for applications. She can be contacted at email: rzs@uomosul.edu.iq.