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# A Modified Bee Colony Optimization Algorithm for Nurse Rostering Problem

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***Abstract*— Scheduling shifts to the nurses in the hospital is highly a complex problem. The Nurse Scheduling Problem (NRP) is considered to be a NP-Hard. It can be solved by combinatorial optimization problem. This paper proposes a modified BCO algorithm for solving the problem. The modified Bee Colony Optimization algorithm modifies the forward pass phases by introducing a pipelined constructive move followed by local search and discarding move for solving Nurse Rostering Problem.***

***Keywords*— Nurse Rostering problem, Combinatorial optimization problem, Modified Bee Colony Optimization algorithm. Local search move, Discarding move***

## I. Introduction

A nurse rostering is a highly complex problem to solve. The nurse rostering represents a task which consists of creating a schedule for the nurses in hospitals. The Nurse Rostering Problem (NRP) is a typical problem every hospital has to deal with every day. Its solution is a nurse roster, which is a weekly or monthly working plan for all available nurses, obtained by matching employees to shift categories. In most of the hospitals, the rostering is done by human scheduler. As the ward size gets bigger, the planning period becomes longer. So doing by manual, will take a lots of time.

Assigning shifts to the nurse should be automated. There are many optimization techniques are available to automate the nurse rostering. The nurse rostering problem deals with many number of constraints related to hospital legals, work, management and staff requirements. It has to satisfy all the constraints. Satisfying all the constraints is a difficult task. Many techniques were used to solve the nurse rostering problem. Some of them are Scatter search, memetic algorithms, Genetic algorithms, Shift Sequence, Variable depth search algorithms and so on. This problem can be solved by combinatorial optimization algorithm. The Bee Colony Optimization (BCO) algorithm is one of the combinatorial optimization algorithms. The BCO algorithm is a Swarm Intelligence algorithm; the agents can communicate with each other and with the environment. This BCO algorithm is inspired by the natural honey bees, artificial bees are used as the agents.

## II. Nurse Rostering Problem

The Nurse Rostering Problem (NRP) is defined to be a NP-Hard problem. It is a combinatorial optimization problem which is difficult to solve. There are many constraints have to be considered. The constraints may be related to the legal of hospitals, laws and rules of the government, covering requirements of various nurses. It is not possible to meet all the constraints. Most of the constraints may be violated.

### *A. Dataset*

The dataset is taken from the website http://www.cs.nott.ac.uk/~tec/NRP/. It consist of number of nurses, number of shifts, the planned period, skills, contracts and so on. The dataset instances used here are Business continuity Volume (BCV) is EMC corporations' term. It consists of independently addressable copy of the entire data volume. The BCV instances are represented as BCV-a.b.c, where a represents the ordinal number, b represents the number of nurses and c represents the version of the system. Some of the BCV instances are BCV- 1.8.1, BCV- 2.46.1, BCV- 3.46.1, BCV 4.13.1, BCV- 5.4.1, BCV- 6.13.1, BCV- 7.10.1, BCV- 8.13.1 and so on.Some of the possible shifts used here are Veroge V, Late L, Nacht N, Dag D, Dag DH. The shifts and its corresponding time is given as follows:paper must use a page size corresponding to A4 which is 210mm (8.27") wide and 297mm (11.69") long.  The margins must be set as follows:

TABLE I
SHIFT DETAILS

| Shift id | Label | Description | Start time | End time | Work Hrs |
|---|---|---|---|---|---|
| V | V | Veroge | 06:30:00 | 14:30:00 | 8.0 |
| L | L | Late | 14:00:00 | 22:00:00 | 8.0 |
| N | N | Nacht | 21:30:00 | 07:00:00 | 9.5 |
| D | D | Dag | 08:00:00 | 16:36:00 | 8.6 |
| DH | DH | Dag | 08:00:00 | 16:36:00 | 8.6 |

*B. Constraints*

There are two types of constraints. They are hard and soft constraints. The hard constraints should not be violated. But the soft constraints can be violated in some situations. Some of the hard and soft constraints are given as follows.

The hard constraints are: Some of the hard constraints are:

1. No more than one shift is assigned to each nurse on each day.
2. There should be no Minimum or maximum weekly working days
3. No under-/ over-staffing is assigned for a shift.
4. The nurse assigned for shift should exactly match the skills required for that shift they work

Some of the soft constraints are:

1. No maximum or minimum consecutive working days with the same shift.
2. No maximum or minimum consecutive working days.
3. Avoid minimum or maximum non working days (shift off).
4. No minimum or maximum consecutive working shifts per day.
5. Avoid the night shifts before the free weekend.
6. Increase the required shift patterns.
7. Decrease the less required shift patterns

## III. BEE COLONY OPTIMIZATION ALGORITHM

The Bee Colony Optimization algorithm is one of the nature inspired algorithm. It is derived from the behavior of honey bees. It mimics the food foraging habits of honey bees.

*A. Natural bees*

The BCO algorithm mimics the food foraging behavior of colony of honey bees. The foraging process begins in a colony by scout bees being sent to search for flower patches. Scout bees move randomly from one patch to another.

During the harvesting season, a colony continues its exploration, When they return to the hive, those scout bees that found a patch which is rated above a certain quality threshold (measured as a combination of some constituents, such as sugar content) deposit their nectar or pollen and go to the "dance floor" to perform a dance known as the waggle dance.

This dance is essential for colony communication, and contains three pieces of information regarding a flower patch such as the direction in which it will be found, its distance from the hive and its quality rating or fitness. This information helps the colony to send its bees to flower patches precisely, without using guides or maps. More follower bees are sent to more promising patches. This allows the colony to gather food quickly and efficiently.

*B. Bee Colony Optimization algorithm*

Bee Colony Optimization (BCO) algorithm is a population based algorithm. The bees are the artificial agents. Each bee will find its neighboring solution from its current path. The algorithm consists of forward and backward pass. Fig.1 is an example of forward pass. Initially, the solution in the hive is empty during the forward pass.

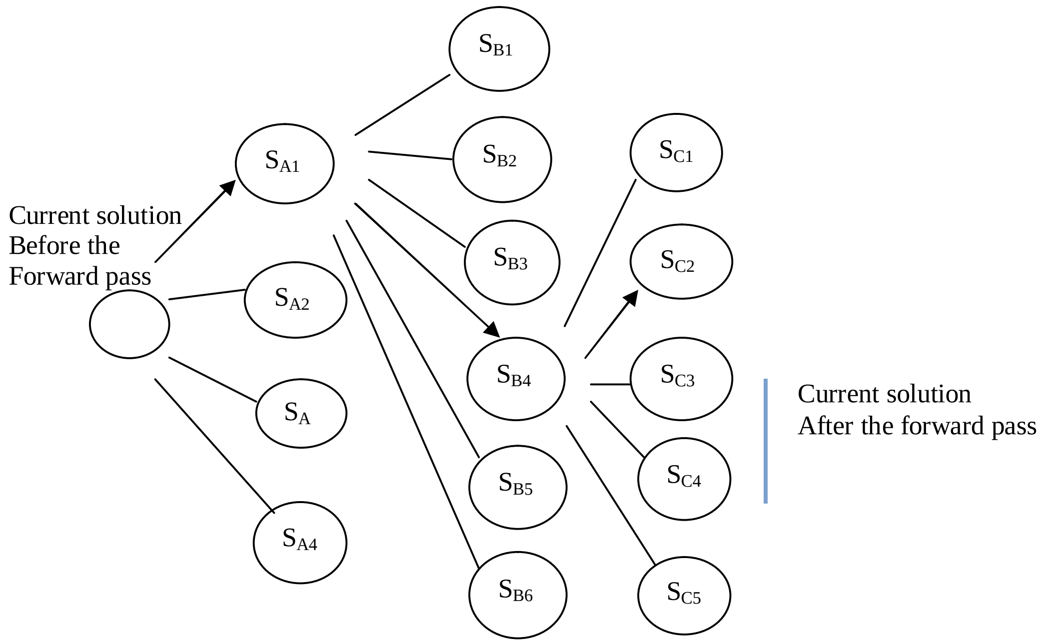


Fig 1.Forward Pass[2]

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Then all the bees in the hive will start searching for its neighborhood. The straight line denotes the possible moves and the single headed arrow denotes the path selected by the bee among the possible moves. The $S_{mn}$ represents current solution of each move.

Fig 2. is an example of backward pass. All the bees will back to its hive with its associated solutions. Here there are 7 bees with its associated solutions like for B1, its associated solution is S1,for B2, solution S2 and so on. The bees decide whether they want to advertise their solutions and become recruiters. In this case, bees *B*1 and *B*3 have become recruiters. In Fig. 2(c), some of the bees decide to follow the recruiters and become a follower of any one recruiter. The bees *B*4 and *B*7 follow the bee *B*1 and obtain the solution *S*1, likewise the bee *B*6 follows the bee *B*3 and reached the solution *S*3. Bees *B*2 and *B*5 is not following any of the recruiters and become an individual.

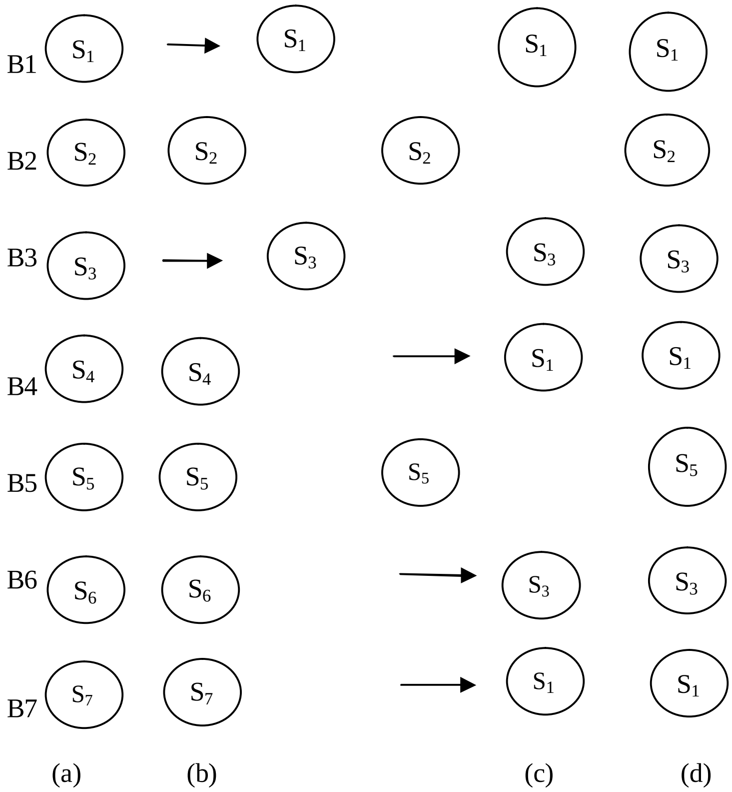


Fig 2. Backward Pass[2]

## IV. THE MODIFIED BCO ALGORITHM FOR NURSE ROSTERING PROBLEM

The constructive move of the forward pass is modified by introducing the pipelining concept in the constructive move. Instead of using simple constructive and local search with discarding move, the pipelined constructive followed by local search and discarding move will give more optimal solutions. The occurrences of more non improving move after local search move can be avoided.

Each forward pass applies the constructive and improving moves. The local search move has predefined number of moves. During the first forward pass, the entire bee in the hive will start the constructive move. After finishing the constructive move, the predefined number of local search move will begin. During the constructive move the number of iterations has to be set. Therefore the penalty for constraint violations can be reduced in the constructive move itself. The quality of the solution is improved by applying the local search move. During the local search move more number of penalties can be eliminated. The quality of the solution is improved by swapping assignments between the nurses and reassigning the shifts to the available nurses. The Roulette wheel method is used to select the solutions.

For the backward pass, the recruiter bee is selected by using the Roulette wheel method. The first ranked bee has the probability one. Still there will be more non improving moves that slow down the computational time. Therefore a noval discarding move is used to discard all the non-improving moves. Such moves are identified by the improvement indicator, denoted as I(m,S) [2]

$$I(m, S) = f(S) - f(m(S)) = f(S) - f(S'). \quad (1)$$

Where m is the move from solution S to S', f(S) is the fitness function of S. If the value of I results in positive value, then there exist improved move. If it results in non positive value, then there exist non- improving move.

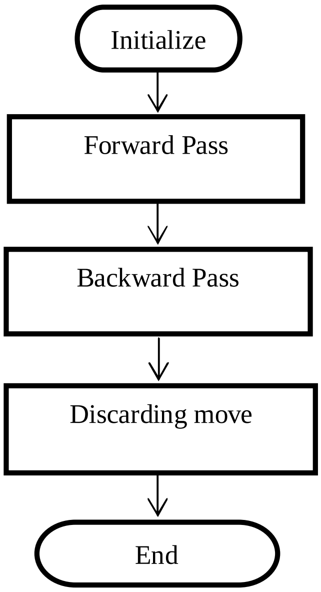


Fig 3. Flow Chart for BCO Algorithm

The non improving moves are discarded using the hybrid approach. The hybrid approach is nothing but the combination of knowledge based and aging approach. In the forward pass, initially the system will be empty. During the start of the pipelined constructive move, one of the bee assign the shifts randomly for the first participating nurse in the roster. Then the entire shift pattern is followed by all other bees in the pipelined manner. The structure of the pipelined constructive move is given in fig 4.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N1 | D | V | V | | D | D | | D | V | N | | D | D | N | V | | L | L |
| N2 | L | D | V | V | | D | D | | D | V | N | | D | D | N | V | | L |
| N3 | L | L | D | V | V | | D | D | | D | V | N | | D | D | N | V | |
| N4 | | L | L | D | V | V | | D | D | | D | V | N | | D | D | N | V |
| N5 | V | | L | L | D | V | V | | D | D | | D | V | N | | D | D | N |

Fig 4. Solution structure of the pipelined constructive move

This may create much penalty. But the penalty value charged for each bee will not be much deviated. But the values may be increasing in the order of bee's assignment. This solution can be improved by using the local search move. There are three types of approaches in the local search move. They are: 2-opt, 3-opt and reassigning move. But 2-opt move is found to be the best move in improving the quality of the solution by reducing the penalty incurred by violation of constraints.

## V. Results

The bee colony optimization algorithm with pipeline constructive move is compared with the bee colony optimization algorithm[2] with simple constructive move. The pipelined constructive move produces the optimal result in some instances but the time consumption is very less when compared with the other algorithm. The system is constructed and run using the simple java program and tested with 15 run and took the best result among them.

TABLE 2
COMPARISON TABLE

| Algorithms | BCV- 1-8-1 | | BCV-2-46-1 | | BCV-4-13-1 | | BCV-8-13-1 | |
|---|---|---|---|---|---|---|---|---|
| | Best value **252** | | Best value **1572** | | Best value **10** | | Best value **148** | |
| | Value obtained | Time (Sec) | Value obtained | Time (Sec) | Value obtained | Time (Sec) | Value obtained | Time (Sec) |
| Construction and local search with discarding[2] | 261 | 423 | 1572 | 829 | 10 | 250 | 148 | 170 |
| Pipelined construction and local search with discarding | 290 | 45 | 1590 | 50 | 33 | 17 | 207 | 21 |

## VI. CONCLUSION

The bee colony optimization algorithm with pipelined constructive move for nurse rostering is a combination of pipelined constructive and local search phases. On comparing the results with other algorithm [2], it can be seen that the combination of local search and pipelined construction produces better results with less computational time.

## REFERENCES

[1] D. Teodorovic and M. Orco (2008) "Mitigating traffic congestion: Solving the ride matching problem by bee colony optimization," Transp. Plan. Technol., vol. 31, 135–152.
[2] N. Todorovic and S.Petrovic, "Bee Colony Optimization Algorithm for Nurse Rostering", ITOS MACS., vol.43,no.2,pp.467–473,March 2013
[3] D. Pham, A. Afify, and E. Koc (2007) "Manufacturing cell formation using the bees algorithm," in Proc. IPROMS, Cardiff, U.K.
[4] D. Pham, A. Ghanbarzadeh, E. Ko, S. Otri, S. Rahim, and M. Zaidi (2006) "The bees algorithm—A novel tool for complex optimisation problems" in Proc. IPROMS Conf.,
[5] D. Karaboga, B. Akay, and C. Ozturk (2007) "Artificial bee colony (abc) optimization algorithm for training feed-forward neural networks," in Proc. 4th MDAI, Berlin, Germany, 318–329.
[6] D. Karaboga and B. Basturk (2008 )"On the performance of artificial bee colony (abc) algorithm," Appl. Soft Comput., vol. 8, 687–697.
[7] E. Ozcan (2005) "Memetic algorithms for nurse rostering," in Proc. ISCIS, vol. 3733, 482–492.
[8] E. Burke, T. Curtois, R. Qu, and G. Vanden Berghe (2012)"A time pre-defined variable depth search for nurse rostering," INFORMS J. Comput.
[9] E. Burke, P. Cowling, P. De Causmaecker, and G. Vanden Berghe (2001) "A memetic approach to the nurse rostering problem," Appl. Intell., vol. 15,199–214.
[10] E. Burke, P. De Causmaecker, and G. Vanden Berghe (1999) "A hybrid tabu search algorithm for the nurse rostering problem" Simul. Evol. Learn, 1585,187–194.
[11] E. Burke, T. Curtois, R. Qu, and G. Vanden Berghe (2010.) "A scatter search for the nurse rostering problem," J. Oper. Res. Soc., vol. 61, 1667– 1679.
[12] G. Beddoe, S. Petrovic, and J. Li (2009) "A hybrid metaheuristic case-based reasoning system for nurse rostering," J. Sched., vol. 12, 99– 119.
[13] H. Lau, "On the complexity of manpower shift scheduling (1996.)" Comput. Oper. Res., 23, 93–102.
[14] H. Miller, W. Pierskalla, and G. Rath (1976) "Nurse scheduling using mathematical-programming," Oper. Res., 24, 857–870.
[15] G. Markovic, D. Teodorovic, and V. Acimovic-Raspopovic (2007)"Routing and wavelength assignment in all-optical networks based on the bee colony optimization," AI Commun., vol. 20, 273–285.
[16] L.-P. Wong, M. Low, and C. S. Chong (2010)"Bee colony optimization with Local search for traveling salesman problem," Int. J. Artif. Intell. Tools, 19, 305–334.
[17] M. Moz and M. Pato, (2007)"A genetic algorithm approach to a nurse rerostering problem," Comput. Oper. Res., vol. 34, 667–691.
[18] P. Lucic and D. Teodorovic (2001) "Bee system: Modeling combinatorial optimization transportation engineering problems by swarm intelligence," in Proc. Preprints TRISTAN IV Triennial Symp. Transp. Anal., Sao Miguel, Azores Island, Portugal, 441–445.
[19] P. Brucker, E. Burke, T. Curtois, R. Qu, and G. Vanden Berghe (2010) "A shift sequence based approach for nurse scheduling and a new benchmark dataset," J. Heurist., vol. 16, 559–573
[20] P. Lucic and D. Teodorovic (2003) "Computing with bees: Attacking complex transportation engineering problems," Int. J. Artif. Intell. Tools, vol. 12, 375– 394.
[21] S. C. Chin, H. L. Malcolm Yoke, I. S. Appa, and L. G. Kheng (2006) "A bee colony optimization algorithm to job shop scheduling," in Proc. 38th WSC, 1954–1961.
[22] U. Aickelin and K. Dowsland (2000) "Exploiting problem structure in a genetic algorithm approach to a nurse rostering problem," J. Sched., 3,139–153.
[23] W. Gutjahr and M. Rauner, (2007)"An ACO algorithm for a dynamic regional nurse-scheduling problem in Austria," Comput. Oper. Res.,34, 642–666.