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## RESEARCH ARTICLE

# A 2-Stage Approach for the Nurse Rostering Problem

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**ABSTRACT** In this paper, we are addressing the NP-hard nurse rostering problem utilizing a 2-stage approach. In stage one, Monte Carlo Tree Search (MCTS) and Hill Climbing (HC) are hybridized in finding a feasible solution (satisfying all the hard constraints). We propose a new constant  $C$  value (which balances search diversification and intensification of MCTS) and tree policy/node selection function in the selection procedure of MCTS. In stage two, the feasible solution is further improved using Iterated Local Search (ILS) with Variable Neighbourhood Descent as the local search component. We introduce several unique neighbourhood structures for the ILS. In addition, we propose a novel perturbation strategy to allow the search to escape from local optimum. The proposed methodology is tested on the Shift Scheduling dataset (24 benchmark instances). New best results are reported for seven and two instances for the 10 and 60 minutes run respectively. An in-depth discussion on the attributes of the proposed methodology that lead to its good performance is provided.

**INDEX TERMS** Nurse rostering, hill climbing, Monte Carlo tree search, iterated local search, variable neighbourhood descent.

## I. INTRODUCTION

Combinatorial Optimization Problems (COP) involve finding the values for a set of variables from a discrete search space which maximizes or minimizes an objective function. Examples of these type of problems include vehicle routing [38], traveling salesman, bin packing, minimal spanning tree and timetabling. There are many types of timetabling problems e.g. educational timetabling [12], [41], [42], transportation timetabling [29] and personnel scheduling [46]. Nurse rostering is a specific type of personnel scheduling problem and plays an important role in healthcare management. It involves the assignment of shifts to nurses on a planning horizon (e.g. one month), satisfying a set of hard and soft constraints. The aim is not only to improve the operational efficiency of hospital wards by having an effective utilization of the limited resources, but also to focus on the well-being and job satisfaction of nurses.

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Due to the number and nature of constraints, nurse rostering is complex and challenging for both researchers and administrators (personnel managers and head nurses) in hospitals. In fact, the nurse rostering problem is NP-hard [24]. Until recently, most nurse rosters were still constructed manually which can be tedious and time consuming. Having an effective automated nurse roster is crucial. Among issues that may be addressed by having a good roster in hospitals include:

- Under or over staffing. The automated nurse rostering system will ensure that the right number (within a predefined range) of nurses will be assigned to a ward for each shift in a day. This will not only improve the operational efficiency but also reduce the operational cost of the ward.
- Skills mismatch. Nurses with the right qualifications and skills will be assigned to shifts so that healthcare services can be delivered smoothly which will enhance the well-being and life span of the patients.