A Hybrid Variable Neighborhood Search and Dynamic Programming-Based Heuristic Approach for Solving the Nurse Rostering Problem

by

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SUMMARY

Human resources are one of the major pillars in any healthcare organization besides other physical resources such as facilities, operating rooms, equipment, drugs, as examples. As human resources are limited, healthcare organizations have to efficiently manage them.

One of the important human resource management problems in healthcare is the Nurse Rostering Problem (NRP). The NRP deals with the assignment of nurses to daily shifts in order to satisfy the cover requirements while considering other legal regulations and nurses preferences. Preparing such rosters manually is a hard and time consuming task. Therefore, healthcare organizations use computerized/automated rosters construction in order to save the time and effort as well as achieve higher quality rosters. Thus, many solution approaches were proposed by researchers to tackle the NRP .

In this thesis, a comprehensive review for recent literature discussing the NRP is presented for a good exploration of the problem and its solution approaches. The review discusses the different solution approaches reported in literature, and categorizes them into two main categories; individual (exact or heuristic), and hybrid (exact, heuristic and/or multiple heuristics) approaches. The review also reports the application context for each study (a real case study or a benchmark dataset). The review showed the limited utilization of hybrid approaches compared to individual ones. In addition, it showed the extensive use of the Variable Neighborhood Search (VNS) heuristic compared to other metaheuristics.

In this thesis, a new hybrid approach using VNS and Dynamic Programming (DP) is proposed for solving the NRP. The proposed approach has three main features; introduction of two new High-Weight-Constraint-Focused (HWCF) structures, embedding of a DP-based heuristic, and adoption of two different perturbation mechanisms simultaneously within the VNS heuristic.

Firstly, a VNS algorithm with two new HWCF structures is proposed for solving the NRP benchmark instances proposed by Curtois and Qu in 2014. The objective of the new structures is to give more priority in the search process for satisfying the problem's soft constraints with higher penalty-weights. The effectiveness of the new HWCF structures is demonstrated.

Secondly, a DP-based heuristic is incorporated with the VNS through a destroy-and-recreate perturbation mechanism. After a certain number of non-improving VNS iterations, a set of nurses' schedules are destroyed and recreated using the DP-based heuristic. Such a perturbation mechanism help improving the individual nurses' schedules as well as diversifying the search process.

Thirdly, the approach is enhanced by adopting two perturbation mechanisms instead of the single destroy-and-recreate mechanism. In addition to the destroy-and-recreate mechanism, a classical perturbation mechanism is adopted. At each perturbation step, a mechanism is chosen randomly with fifty-fifty probability for each mechanism. Thus, the approach can benefit from the advantages of each mechanism in handling small as well as large size instances.

The proposed approach is tested on two different benchmark datasets; the Curtois and Qu NRP benchmark instances, and the First International Nurse Rostering Competition dataset. The approach results were compared to multiple state-of-the-art approaches from literature. The results demonstrated a competitive performance of the proposed approach compared to other approaches.

The proposed approach was able to outperform most of the compared approaches except a recent hybrid integer programming and variable neighborhood search approach that showed a better performance in most of the tested instances excluding the largest size one. Therefore, multiple suggested improvements for the proposed approach are presented as a future work, and testing the approach on large size instances to verify the approach capability in handling large size problem instances. In addition, a modification for the proposed approach is suggested to enable utilizing it in facing the implications of the spread of COVID-19.