

Variable neighborhood search accelerated column generation for the nurse rostering problem

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Abstract

The Nurse Rostering Problem (NRP) is an optimization problem where nurses with specific skills must be assigned shifts in a schedule. The objective is to obtain a feasible solution while minimizing the number of soft constraint violations. This work presents a Variable Neighborhood Search accelerated Column Generation procedure for the NRP in addition to a Relax-and-fix Heuristic for obtaining feasible solutions. The algorithm improved the best known solutions by at least 10% for all 29 hidden instances from the Second International Nurse Rostering Competition (2014) with 4 weeks. The improved solutions have an optimality gap of at most 8%.

Keywords: nurse rostering · column generation · integer programming · heuristics

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1 Introduction

There has been much research regarding solution methods for the Nurse Rostering Problem (NRP) [1]. In 2010, the First Nurse Rostering International Competition (INRC-I) was proposed [5] and a significant number of different algorithms were presented for its large set of proposed instances. Most instances were exactly solved by [9] in 2012.

The Second International Nurse Rostering Competition (INRC-II) occurred during 2014 [10]. In contrast to the first competition, a smaller set of constraints was introduced. However, multiple planning horizons were considered, simulating real-world situations [3].

This work presents an Integer Programming formulation for the INRC-II problem with an exponential number of variables. Various Column Generation techniques are evaluated for handling this formulation. Besides solving the pricing problem using Integer Programming, we show how combining the method with heuristics significantly accelerates the method's convergence. Our computational experiments showed that methods for the production of good primal and dual bounds can be obtained using the proposed techniques.

The paper is organized as follows: Section 2 the NRP problem is formally stated by the proposed Integer Programming formulation. Section 3 introduces the Variable Neighborhood Search (VNS) heuristic applied to accelerate column generation. Section 4 presents Relax-and-fix Heuristics approaches for obtaining feasible solutions from linear-relaxed fractional solutions. Section 5 describes the computational experiments conducted and evaluates the performance of our proposal. Finally, conclusions and future works are detailed in Section 6.

2 The Nurse Rostering Problem Formulation for INRC-II

The present paper proposes a formulation for the INRC-II problem containing a large number of variables. The relaxation of this formulation is solved by Column Generation [2] and generally provides strong lower bounds.

In the proposed formulation, N , D , S and K_n represent the set of nurses, days, shifts and skills of nurses n , respectively. Ω_n represents the set of all possible allocation patterns for nurse n , λ_{np} indicates whether allocation $p \in \Omega_n$ is selected for nurse n ($\lambda_{np}=1$) or not ($\lambda_{np}=0$) and v_{dsk} measures the difference between the required and allocated number of nurses on day d and shift s for skill k . Equations and inequalities (1)–(5) present the proposed

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