Casual Employee Scheduling with Constraint Programming and Ant Colony Optimization

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We consider an employee scheduling problem where many casual employees have to be assigned to shifts defined by the requirement of different work locations. For a given planning horizon, locations specify these requirements by stating the number of employees needed at specific times. Employees place offers for shifts at locations they are willing to serve. The goal is to find an assignment of employees to the locations' shifts that satisfies certain hard constraints and minimizes an objective function defined as weighted sum of soft constraint violations. The soft constraints consider ideal numbers of employees assigned to shifts, distribution fairness, and preferences of the employees. The specific problem originates in a real-world application at an Austrian association.

The problem falls into the broad class of personnel scheduling [2] with strong ties to the nurse rostering problem [3] with the following specific features.

1. The substantial fluctuation of employees and the high variance of their availabilities over different planning horizons and within each; therefore employees are coined "casual".
2. Employees specify individual maximum numbers of shifts they desire to work. The variance of the ratio of actual shifts assigned divided by the desired shifts should be minimized to balance the fulfillment of the workers' desires. Likewise, the fulfillment ratio of the locations' requirements shall be balanced as well.

We propose a Constraint Programming (CP) model which we implemented using MiniZinc [7] and tested with different backend solvers supporting float decision variables including Gecode, JaCoP, and ECLiPSe. As the application of this exact approach is feasible only for small to medium sized instances, we further consider the following hybrid CP/metaheuristic approach.

1. Using the MiniZinc model considering only the hard constraints, enumerate a number of basic feasible solutions. From those, choose in a randomized fashion a subset of dissimilar solutions as initial solution set.
2. These solutions typically have a high objective value and can be substantially improved by assigning further employees. This is done by a successive Ant Colony Optimization (ACO) [4, 5] with a min/max pheromone model [9]. Randomly chosen initial solutions are iteratively extended according to the ACO's usual probabilistic principles in combination with certain greedy criteria.
3. When a candidate solution cannot be extended further, a local search similar to the one described in [1] is applied.

4. Perturb a candidate solution by an iterated greedy mechanism [8]. Ruin a random part of it and greedily recreate it until a better solution is found or a time limit is hit.
5. In each iteration, the so-far-best solution is conditionally updated and used for pheromone upgrade.

Search neighborhoods are defined via shift moving, swapping and reassignment operators. Each operator has impact on a different set of soft constraints. For example, swapping the assignment of two employees keeps the distribution fairness among locations unchanged but may improve the preference satisfaction of the employees.

As ruin operator, we randomly choose a number of employee-to-shift assignments to be destroyed. Recreation is done by randomly assigning eligible employees to these open shifts.

Computational experiments are conducted on both simulated and real-world data. The parameter configuration of the metaheuristic is selected with irace [6] using medium-sized simulated instances. Experts for the real-world data manually inspect and rate solutions of preliminary algorithm versions. This is important for tuning the weights of the soft constraints and to get an impression of the practical suitability of determined solutions.

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