Probability Learning Based Feasible and Infeasible Tabu Search for Airport Gate Assignment

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1 Introduction

Airport gate assignment is an important decision problem that airport professionals must face every day. The problem involves in assigning each aircraft to an available gate to meet operational requirements while maximizing the convenience for passengers and airport operation efficiency. In this work, we study the passenger-oriented gate assignment problem (GAP) that aims to minimize the total walking distance.

In this model, $G$ is the set of airport gates, $F$ is the set of aircraft, $a_i$ is the arrival time of aircraft $i$, $d_i$ is the departure time of aircraft $i$, $c_{ij}$ is the number of passengers transferring from aircraft $i$ to aircraft $j$, $w_{lm}$ is the walking distance between gates $l$ and $m$, $x_{il}$ is a binary decision variable taking the value of 1 if aircraft $i$ is assigned to gate $l$, and it is 0 otherwise. On the basis of these parameters and decision variables, GAP can be formulated as the following mixed integer nonlinear program:

$$\min \ Z(S) = \sum_{i \in F} \sum_{j \in F} \sum_{l \in G} \sum_{m \in G} c_{ij} w_{lm} x_{il} x_{jm} + \sum_{i \in F} \sum_{l \in G} (c_{i0} w_{l0} + c_{0i} w_{0l}) x_{il}$$  \hspace{1cm} (1)

s.t. \hspace{1cm} \sum_{i \in G} x_{il} = 1, \forall i \in F \hspace{1cm} (2)

\hspace{1cm} x_{il} x_{jl} (d_j - a_i)(d_i - a_j) \geq 0, \forall i, j \in F, \forall l \in G \hspace{1cm} (3)

\hspace{1cm} x_{il} \in \{0, 1\}, \forall i \in F, \forall l \in G \hspace{1cm} (4)

This model is the basis of many GAP variants and has been extended in the literature to other GAP formulations. As such, an algorithm designed for this model can be adapted to solve other related problems. We investigate the GAP by proposing an effective heuristic algorithm.

2 Probability learning based feasible and infeasible tabu search

We propose a probability learning based feasible and infeasible tabu search (PLFITS) algorithm to solve the GAP [3], which integrates a feasible and infeasible tabu search procedure within the probability learning based framework [4]. During the PLFITS search process, problem-specific knowledge is learned via its probability learning procedure. The learned information, recorded in a probability matrix, is applied to guide the algorithm toward promising search regions. As such, PLFITS iteratively explores the given search space by alternating between probability learning and local search to attain a better balance of search diversification and intensification. Its general scheme is composed of four main components: a gate selection strategy (to select a gate for each aircraft according to the probability matrix), a strategic oscillation procedure (to allow the search to oscillate between the feasible and infeasible search spaces to find high-quality local optimal solutions), a probability updating rule (to
update the probability that each aircraft should be assigned to each gate according to feedback information), and a probability smoothing technique (to forget some aged decisions that are considered obsolete). The algorithm repeats these four components until a stopping condition is reached.

3 Computational results

We report computational results of the proposed algorithm on a set of 20 real-world benchmark instances collected by Cheng et al. [1] arising from Incheon International Airport (ICN). These instances can be classified into three groups by setting the percentage of transfer passengers $\pi$ respectively to 0.1, 0.3, and 0.5. Comparisons are made with two reference algorithms, including a simulated annealing tabu search (SATS) [1], and a tabu search with path relinking (TSPR) [2]. We run ten times our PLFITS algorithm to solve each instance with the same time limit (200 seconds on Intel Xeon E5-2670 2.5GHz). Table 1 shows the comparative results, including the best and average objective values, the average computing times, and the gaps between the best objective values attained by PLFITS and the best-known results, indicating the PLFITS algorithm dominates the reference algorithms (better results are highlighted in bold). In particular, PLFITS reports improved best-known solutions (new upper bounds) for all the 20 ICN instances with improvements ranging from 2.6% up to 11.85%.

Finally, the probability learning and the mixed feasible-infeasible search strategies are general and can be used to tackle other airport gate assignment problems with different objectives and constraints or other problems with complex constraints. For further research, more efforts are needed to investigate exact and approximation methods with quality guarantees.

Références


