An Investigation of Squeaky Wheel Optimization Approach to Airport Gate Assignment Problem

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Abstract. This paper investigates a squeaky wheel optimization (SWO) approach to the airport gate assignment problem (AGAP). A graph coloring method is incorporated into the SWO procedure to construct solutions in our approach. Some initial experimental results are presented towards the validation of this approach.

Keywords: Airport Gate Assignment Problem, Squeaky Wheel Optimization, Graph Coloring Heuristic.

1 Introduction

Airport gate assignment problem involve scheduling a number of arriving and departing flights into a set of airport gates with the aim to satisfy certain objectives and constraints. A typical objective is to minimize the number of the delayed gates. A number of constraints need to be considered in the procedure of constructing solutions. Such as: only one flight is allowed at one gate within the same time interval; each flight should not be assigned to more than one gate at the same time; the time interval between the flight arriving and departing should not be longer than the minimum ground time;

This paper addresses the AGAP problem with the dispersion of gate idle time period as the objective. The purpose is to improve the robustness of the schedule, which expects that slight time variation won't cause too much disruption in the original plan.

It has been proved that AGAP is a combinatorial problem. Heuristic method is generally applied to obtain approximate optimal solutions with reasonable cost. In the literature, there are a number of state of art works on AGAP. Ahmet Bolat [1] used the branch and bound method to assign commercial service aircrafts to the available airport gates ; Loo Hay Lee [2] et al. developed a multi-objective genetic algorithm to schedule the flights to gates; Rosenberger [3] et al. constructed a fleet assignment model that can be used to improve robustness based on the structure of a hub-and-spoke flight network to create a partial rotation with many short cycles.

The contribution of this paper is to present a Squeaky Wheel Optimization approach to the AGAP. The Squeaky Wheel Optimization [6] algorithm can be divided into three steps—Construct / Analyze / Prioritize. Firstly, an initial elements ordering can be

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acquired by evaluating the difficulty of these elements. According to this ordering, an initial solution is constructed element by element. Then, this solution is analyzed to find those elements that can't work well and a strategy is used to increase their priorities while others' stay unchanged. Finally, a new sequence of elements ordering is obtained by prioritizing the elements in descending order of their priorities. The SWO algorithm cycles around these three steps until certain stop criteria are met. Some initial experimental results show that the proposed SWO approach to AGAP can be used to improve the schedule quality.

This paper is organized as follows. The proposed SWO algorithm to AGAP is given in Section 2. Section 3 describes the experimental data and discusses the results. A conclusion is provided in Section 4.

2 The Proposed Method

In this section, A Squeaky Wheel Optimization algorithm incorporated with the graph coloring method as the basic heuristic is provided to solve the airport gate assignment problem.

The three steps of SWO are termed constructor / analyzer / prioritizer respectively. On each iteration, the constructor gives a solution (may violate some hard constraints), and the analyzer finds those "difficult points" ("squeaky wheels") and at the same time increases their priorities, the prioritizer reprioritizes these elements in descending order of their priorities (measured by difficulty). Iteration after iteration, these difficult points are given more and more attention and move to the front of the elements sequence gradually ("It is the squeaky wheel that gets the oil."). In the gate assignment problem domain, these elements are the flights to be assigned.

A graph coloring method derived from the literature [7],[8] and [9] is applied as the basic heuristic in the constructor to obtain a solution in each cycle. In this work, two graph coloring heuristics, Largest Degree First (LDF) and Saturation Degree (SD), are used to construct a solution.

The difficulty which measures how difficult a flight can be assigned, and the heuristic modifier which helps to dynamically alter the overall difficulty of a flight, are applied in the analyzer. The difficulty of flight f at iteration i is given in the following equation:

$$difficulty(f,i)=heuristic(f,i)+heurmod(f,i) \tag{1}$$

The $heuristic(f,i)$ is measured by the conflict number of flight f with the other flights at iteration i . The $heurmod(f,i)$ is a variable which is altered dynamically in each iteration. Four types of heuristic modifier proposed in [9] are applied in our work. They are: custom (C), additive (AD), Multiplicative (MP), Exponential (MP).

After the prioritizer has set an order of flights, a shuffle strategy is applied on the sorted flight sequence. The sorted flights are divided into fixed size blocks, and within each block, the flights are shuffled randomly. The idea behind that is that the diversity of the schedule might be improved.

The pseudo code of the proposed SWO algorithm to AGAP is presented in Figure 1.

3 Experiments

The test data used in the experiments is generated by the following method: the integer arriving time of each flight is drawn from a uniform distribution between 0 and 48. Similarly, the ground time for each flight is from a uniform distribution between 6 and 18. Each gate has two attributes: the gate number and gate type value. The gate number is the same as the sequence number generating the gate. While, the gate type value is drawn from a uniform distribution between 1 and 3.

Since a random function is used to shuffle the ordering of flights, the results of each run are different. Thus, the best result of 10 runs is recorded for each method. We have carried out two group experiments. One group use LDF heuristic in SWO, and the other use SD heuristic. For each group experiment, four type of modifier with different shuffle strategies are tested. Table 1 presents the two group experimental results, which are by LDF and SD respectively.

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Algorithm 1. Pseudo code of the SWO methodology to AGAP
Do
 Applying graph color method to construct a solution;
 calculate the fitness value of the current solution;
 if current solution is better than the best solution ever
found
 then replace best solution with current solution;
 sort all the flights by the value of difficulty in the
descending order;
 partition all the ordered flights into fixed size bolcks;
 shuffle all flights within each block randomly;
while stop critera aren't met;
return best solution;
```

Fig. 1. Pseudo-code of the SWO algorithm to AGAP

It can be seen from table 1 that the performance by SD is generally better than by LDF. For each group experiment, there is a possibility to have the improved performance by applying different shuffle strategy.

Table 1. Experimental results

LDF			*SD*		
run number	method	fitness value	run number	method	fitness value
1	C--0	238925	1	C—0	144200
2	C--2	238925	2	C--2	90875
3	C--3	238925	3	C--3	91275
4	C--4	238925	4	C--4	89700
5	C--5	238925	5	C--5	72325
6	C--6	238925	6	C--6	81775
7	AD--0	235875	7	AD--0	144200
8	AD--2	228350	8	AD--2	90875
9	AD--3	235875	9	AD--3	93075
10	AD--4	193350	10	AD--4	85525
11	AD--5	235875	11	AD--5	71700
12	AD--6	235875	12	AD--6	79575
13	MP--0	238925	13	MP--0	144200
14	MP--2	221950	14	MP--2	90875
15	MP--3	194475	15	MP--3	94750
16	MP--4	186150	16	MP--4	89700
17	MP--5	103700	17	MP--5	67050
18	MP--6	186950	18	MP--6	76300
19	EX--0	235875	19	EX--0	144200
20	EX--2	228350	20	EX--2	90875
21	EX--3	194475	21	EX--3	93075
22	EX--4	191925	22	EX--4	87100
23	EX--5	142525	23	EX--5	64275
24	EX--6	186150	24	EX--6	79000

4 Conclusions

In this paper, we initially apply the Squeaky Wheel Optimization algorithm to the airport gate assignment problem. And preliminary experimental results show that our method can be used to improve the robustness of the flight schedule. In the future, we will try to investigate how to combine the SWO with other intelligent algorithm

(Evolutionary algorithm e.g.) so as to solve the gate assignment problem more effectively.

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