Solving the Problem of Gate Assignment to the Flights Using a Modified Shuffled Frog Leaping Algorithm

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Abstract
Since gate assignment to flights is a complicated problem, then different approaches is offered to cope with. Most of the studies in this field are based on mathematical models. In this paper considered three objectives for increasing passengers’ satisfaction, developing agencies performance and declining airport expenses. Forasmuch as gate assignment and reassignment problem are an NP-hard problem, they need to be solved in the shortest time, Therefore MSLF algorithm was used to solve the problem which gives reasonable results in desire time.

Keywords: Gate assignment, Meta-heuristics, Frog Leaping algorithm

1. Literature Review
With the ever-increasing development of technology, the need for effective global communication, and the high demand for aviation facilities, airports are considered to be critical factors relating to social welfare and the economic state. The complexity of flight schedules in metropolitan airports has resulted in the gate assignment problem becoming of particular importance.

Gate assignment operations should be carried out in the shortest time due to the probability of flight disruption. As the gate assignment and reassignment problem is non-deterministic polynomial-time hard, it is impossible to solve the problem with classical solution methods, which is why a MSLF algorithm has been applied.

2. Literature Review

3. Problem Statement
Here we introduce the mathematical model.

3.1. Parameters

- \( f_i \): Number of passengers;
- \( f_{ik} \): Number of flight \( i \) passengers to flight \( k \);
- \( w_j \): Gate \( j \) passengers’ walking distance;
- \( w_{ij} \): Transferring passengers; walking distance from gate \( j \) to gate \( l \), \( l=1,2,... \);
- \( A_i \): Scheduled arrival time for flight \( i \);
- \( G_i \): Sufficient stand time for flight \( i \) in gate;
- \( T_j \): Latest available time for gate \( j \) at the end of the timetable;
- \( B_j \): Earliest available time for gate \( j \) at the beginning of the timetable;
- \( m \): Available gates in the scheduled time with index \( j,l \);
- \( n \): Number in the timetable;
- \( \bar{H} \): Mean working time of the gates throughout the planning period.

3.2. Variables

- \( A_{ij} \): Arrival time of flight \( i \) to gate \( j \);
- \( X_{ij} \), \( X_{ij} \): Decision variable zero; which is one if flight \( i \) or \( k \) is assigned to gate \( j \) or \( l \) is equal to one, otherwise it is zero.
- \( Y_{ikl} \): Decision variable zero; which is one if flight \( i \) is assigned to gate \( j \) and flight \( k \) is assigned to gate \( l \) is equal to one, otherwise it is zero.

3.3. Model

\[
\begin{align*}
\text{Min} & \sum_{i=1}^{n} \sum_{j=1}^{m} \left( f_i - \sum_{k=1}^{n} f_{ik} \right) w_{ij} X_{ij} + \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{m} \sum_{l=1}^{m} f_{ik} w_{ij} Y_{ikl} \\
\text{Min} & \sum_{j=1}^{m} \sum_{i=1}^{n} \left( A_i - A_{ij} \right) X_{ij} \\
\text{Min} & \sum_{j=1}^{m} \left| H_j - \bar{H} \right| \\
\text{Subject to:}
\end{align*}
\]

\[
\begin{align*}
\sum_{i=1}^{n} \sum_{j=1}^{m} X_{ij} &= 1 \\
\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{m} \sum_{l=1}^{m} Y_{ikl} &= 1 \\
X_{ij} + X_{ij} - 2 * Y_{ikl} &\geq 0 \quad i \neq k, j \neq l \\
A_{ij} &\leq T_j X_{ij}
\end{align*}
\]
4. SOLVING THE MULTIPURPOSE OF MATHEMATICS USING L-P METRIC METHOD

L-P metric method is one of the methods to find the Parreto answers (non-dominant) for the multipurpose problem.

\[ L_p = \left\{ \sum_{j=1}^{p} f_j(x^*) - f_j(x) \right\}^{\frac{1}{p}} \]

where \( f_j(x^*) \) is the best objective amount and \( f_j(x^*) \) is the worst objective amount. The solutions of LP metric problems are the solutions of Parreto of multipurpose problem and the solutions for the amounts of \( p \) are calculated as 1, 2 or infinite.

5. MSFL DESCRIPTION

MSFLA is a population based optimization algorithm inspired from the memetic evolution of a group of frogs when searching for food. Since the algorithm has an insufficient learning mechanism and cause premature convergence and lead the algorithm to be trapped in local optimum easily, a new method is presented for local search in the memepxes. The steps of the MSFLA is given as bellow:

1. Initialize (Population size (N), Number of memepxes (m), Number of evolution step within each memepxe);
2. Generate population (P) randomly;
3. Evaluate the fitness of (P);
4. Sort (P) in descending order;
5. Partition (P) into m memepxes;
6. LOCAL search;
7. Shuffle the memepxes;
8. If convergence criteria is satisfied, then return the best solution, else go to step (4);
9. End.

5.1. METHA-HEURISTIC ALGORITHM OF MSLF

Tguhi method is used for estimating of algorithm parameters.

<table>
<thead>
<tr>
<th>Table 1: Numerical Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective function</td>
</tr>
<tr>
<td>Z1</td>
</tr>
<tr>
<td>Z2</td>
</tr>
<tr>
<td>Z3</td>
</tr>
</tbody>
</table>

As it can be observed the amount of total objective function in both mathematics and Metha-heuristic models are very close to each other.

<table>
<thead>
<tr>
<th>Table 2: The Final Results of MSLF in the Real Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective function</td>
</tr>
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</tr>
<tr>
<td>Z3</td>
</tr>
<tr>
<td>Calculated time Iterations</td>
</tr>
</tbody>
</table>

6. CONCLUSION

The complexity of airport operations and increase flights to major airports and traffic of them caused gate assignment problem is of particular importance. These operations should be carried out in the shortest time. As the gate assignment and reassignment problem is NP-hard, it is impossible to solve the problem with classical solution methods.

In order to investigate the model objectives namely minimizing the walking distance, minimizing the delay times and minimizing each gate’s work time deviation from the mean of all gates’ work times, a case study research has been conducted in one of the international airports in Iran. The result of comparison of the problem answer in small scale in Lingo and MSLF algorithm was very desirable. Also the problem was investigated with the real scale and data and the results indicated costs decrease in a logical period of time.

7. REFERENCES