Statistical Analysis of Propagation of Incidents for rescheduling simultaneously flights and passengers under disturbed operations

R. Acuna-Agost[1], P. Michelon[1], D. Feillet[2], and S. Gueye[3]

[1] Université d'Avignon et des Pays de Vaucluse, Laboratoire d'Informatique d'Avignon (LIA), F-84911 Avignon, France {rodrigo.acuna-agost,philippe.michelon}@univ-avignon.fr
[2] Ecole des Mines de Saint-Etienne, F-13541 Gardanne, France
feillet@emse.fr
[3] Laboratoire de Mathématiques Appliquées du Havre, F-76058 Le Havre, France
gueyes@univ-lehavre.fr

1 Introduction

Airline operations are usually perturbed by disruptions like mechanical failures, bad weather, and many other unexpected events. As a result, the original schedule may become suboptimal and, in extreme cases, infeasible. In this paper, we deal with the problem to reschedule aircrafts and passengers simultaneously. In particular, we consider the problem as it is presented in ROADEF 2009 Challenge *Disruption Management for Commercial Aviation* [1]: An original (unperturbed) schedule is known, that is departure/arrival times, aircraft rotation plan, and the itineraries (origin - destination - flights) for a set of passengers. Other important aspects are also given: airport capacities, final position of aircrafts, length of the recovery window, and all relevant unitary costs for calculating an objective function. Additionally, a set of different disruptions defines the initial status of the system at the beginning of the recovery window. The problem is then to calculate a new provisional schedule respecting all the constraints by minimizing an objective function that measures the difference between the new provisional schedule and the original one.

2 Solution method and results

We propose a mixed integer programming (MIP) formulation to model this problem. The model could be interpreted as two integrated multi-commodity flow problems. The first one is related to aircrafts flowing through airports, and the second one to passengers flowing through flights. As other multi-commodity flow problems, the mathematical formulation includes capacity, flow conservation and demand satisfaction constraints. Thus, our model leads to an NP-complete problem since the original multi-commodity flow problem is shown to be NP-complete for integer flows [2].

Because of the complexity of the instances [1], it is not possible to solve this model using directly a state-of-the-art MIP solver. We present three strategies to manage this problem: reducing the size of the MIP model (before to build it), applying **Statistical Analysis of Propagation of Incidents** (SAPI) to solve it quickly, and improving the final solution with a post optimization procedure.

First, we reduce the number of variables and constraints by limiting the search space with only "good" solutions. We define a "good" solution as a provisional schedule near, or similar, to the original schedule. The result is a compact search space in which aircraft (and passenger) moves are limited within a restricted set of possible flights.

We propose a new methodology called SAPI to solve this MIP model. This method was created originally for rescheduling trains after disruption [3] - [4]. The thesis of this method is that every schedule event could be affected (or not) by some given disruptions with a certain probability. A statistical analysis is used to estimate these probabilities and then reducing the complexity by fixing some integer variable. This version of SAPI is an iterative procedure that requires and initial (incumbent) solution calculated by **Right-Shift Rescheduling**. That is, fixing all integer variables in order to keep the original assignment of aircrafts and passengers without allowing changes. The next step of SAPI is to calculate the probabilities. We propose a logistic regression model because, in contrast to other regression methods, it allows to estimate multiple regression models when the response being modeled is dichotomous (i.e can be scored 0 or 1). For our method, the evaluation of this regression model gives the probability that a flight j has to be cancelled in the optimal solution. Using theses probabilities, it is possible to segregate the flights in two big sets : a) flights expected to be cancelled and b) the rest of the flights. At each iteration, the algorithm fixes the integer variables associated to flights that have already their expected value, while the remaining variables are computed by solving the resulting MIP. Additionally, this algorithm includes a diversification procedure to escape from local solutions.

Finally, we apply a post optimization procedure to improve the current solution. This function tries to assign cancelled passengers in any kind of flights in such a way to minimize cancelation penalties that are much more expensive than delays.

Our method has been implemented using MS Visual Studio 2005 (C♯) and ILOG CPLEX 11.1 as a MIP solver, on a PC Intel Core Duo 1.66 GHz 2 GB RAM over Windows Vista Operation System. We use the published results of the qualification phase of [1] in order to compare and evaluate the performance of our method. Using the average normalized score proposed by the organization, our last results have an average = 0.9997 (CPU time of 10 minutes for each instance of set A). Considering the sum of the total cost for all instances in set A, our method return a total cost 80.3% lower than our last version (without SAPI / post-optimization) and 37.2% lower than the best classified team.

References

1. ROADEF, Société française de Recherche Opérationnelle et Aide à la Décision, Challenge ROADEF 2009: Disruption Management for Commercial Aviation, http://challenge.roadef.org/2009
2. On the Complexity of Timetable and Multicommodity Flow Problems, S. Even and A. Itai and A. Shamir, SIAM Journal on Computing, 1976, 5, pp. 691-703
3. SAPI: Statistical Analysis of Propagation of Incidents A new approach applied to solve the railway rescheduling problem Acuna-Agost R., Feillet D., Gueye S., Michelon P. The international conference on NonConvex Programming: Local and Global approaches. Theory, Algorithms and Applications, NCP07, December 17-21, 2007, Rouen, France.
4. Méthode PLNE pour le réordonnancement de plan de circulation ferroviaire en cas d'incident. Acuna-Agost R., Feillet D., Gueye S., Michelon P. ROADEF 2008, 25-27 Février 2008 - Clermont-Ferrand, France