Optimizing Airspace Closure with Respect to Politicians’ Egos

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Abstract. When a president is landing at a busy airport, the airspace around the airport closes for commercial traffic. We show how to schedule the presidential squadron so as to minimize its impact on scheduled civilian flights; to obtain an efficient solution we use a “rainbow” algorithm recoloring aircraft on the fly as they are stored in a special type of forest. We also give a data structure to answer the following query efficiently: Given the president’s ego (the requested duration of airspace closure), when would be the optimal time to close the airspace? Finally, we study the dual problem: Given the time when the airspace closure must start, what is the longest ego that can be tolerated without sacrificing the general traffic? We solve the problem by drawing a Christmas tree in a delay diagram; the tree allows one to solve also the query version of the problem.

1 Introduction

Airspace closure due to military activities is a pain for civilian air traffic controllers (ATCOs), pilots, airlines and other stakeholders; the issue is especially notorious in countries with heavy military control of the skies (such as China). Military flight operations range from strike and defense missions to drills to humanitarian airdrops. The missions are impossible to reschedule, and military ATCOs are entitled to ceasing airspace from civilian use at any time when the traffic could conflict with the mission aircraft. Drills are better in this regard because they are planned in advance, but nevertheless airspace closure due to drills harms commercial airlines. On the contrary, humanitarian aid delivery typically has little effect on general air traffic – not the least due to the fact that the aid is often delivered to places far from mainstream airports.

There is one activity involving military air force, however, whose scheduling most certainly could have been done wiser than it is done today: air transfer of VIPs (presidents and other high-ranked politicians). We trust that planners of such activities are instructed by their superiors (the VIPs at hand) to take civilian needs into account when planning the flights – all VIPs are conscientious citizens putting needs of the people above their personal comfort. Unfortunately, no matter how hard the planners strive to follow the instructions, the civilians do get annoyed with delays caused by VIP flights.

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For instance, the recent visit of the US President to Sweden disrupted air traffic to Stockholm area and gave rise to heated discussions among professionals in the Malmö Air Traffic Control Center (in the south of Sweden) about possible measures that could have been taken to diminish the disruption [2]. Apparently, the only reason preventing the planners of VIP flights from requesting airspace closure with minimum impact on scheduled traffic is the absence of efficient algorithms for computing the optimum.

In this paper we set out to alleviate the difficulty by providing algorithms for deciding the optimal airspace closure timing. Employing our solutions will make the general public happier about VIPs, which will eventually pay back to politicians at future elections.

1.1 Model

For every aircraft the optimal flight plan exists (it can be fuel-optimal or time-optimal or optimal according to another objective) which includes both the altitude profile and the speed at every point along the path. Whether the aircraft is able to execute such a plan depends heavily on the other aircraft around. In the uncongested enroute portion of the flight aircraft with similar headings can generally “overtake” each other; to quote Director General of Luftfartsverket (Swedish air navigation service provider) [1], the uncontrolled oceanic airspace witnesses “air race over the Atlantic” on a daily basis. On the contrary, in the vicinity of an airport, the arrival manager sequences aircraft “ducks-in-a-row” to the approach (the final phase of the flight); here, faster aircraft (those whose desired speed is larger) must slow down in order to maintain separation from the preceding slower plane. This latter scenario is the one considered in this paper.

Assume that the approach to an airport is a “single-lane road” of length 1. The approach does not have to be a straight-line segment (in fact, in real world, approaches to many airports are curved); the important thing is that it is a one-dimensional curve. Aircraft enter the approach at times $t_1, \ldots, t_n \in [0, 1]$ (known from the schedules or flight plans) and have desired speeds $v_1, \ldots, v_n$ (known from communication between pilots and ATCOs or from automated flight management systems); $n$ is the number of the aircraft. For simplicity assume all $t_i$s and all $v_i$s are distinct. In absence of the other planes, aircraft $i$ would traverse the approach uniformly at speed $v_i$, arriving at the airport at time $\tau_i = t_i + 1/v_i$; this is an oversimplification, but our solutions can be modified to work with arbitrary desired speed profiles. Since passing is not allowed on the approach, any aircraft must slow down to the speed of the preceding plane as soon as the aircraft catches up with a slower plane; thus the actual aircraft location on the approach is a concave piecewise-linear function of time, and in the $tx$-plane the trajectories get merged into trees corresponding to platoons of aircraft (Fig. 1, left).