Abstract

A crucial component of a flight plan to be submitted for approval to a control authority in the pre-flight phase is the flight route. The flight route is a path in a flight network through a sequence of airways and waypoints that the aircraft follows in order to travel from one airport to another. Due to a large strain on the European flight network, a large amount of side-constraints is used to regulate traffic flow and ensure safe flights. The constraints generally state that if a set of waypoints or airways is visited then another set of waypoints or airways must be avoided or must be visited. Paths are selected on the basis of cost considerations. The cost of traversing an airway depends, directly, on fuel consumption and on flight time, and, indirectly, on weight and on weather conditions.

Classic pathfinding algorithms such as Dijkstra's algorithm and A* search are commonly used in automatic planning. However, the constraints and the dependency structure of the costs invalidate the domination criterion used in these algorithms, since the FIFO property no longer holds true. Additionally, costs on arcs cannot be computed before the search due to the dependency structure. Along with the immense size of flight networks, these difficulties make the generation of flight routes a computationally expensive task. A common approach to reduce computation time is to decompose the problem into a sequence of horizontal and vertical route optimizations.

We study the feasibility of addressing flight routing directly as a 3D problem. Both stages of the decomposed problem were implemented and the combination of these is compared with the direct 3D approach. Several improvements were implemented and tested for both approaches. We consider the complicated problem of determining efficient A* estimates in a setting with a complex cost function. We provide a framework, usable in both settings, for the description, representation and propagation of the constraints during the search in pathfinding algorithms. In addition, we study lazy approaches for dealing with the constraints and the use of geographic considerations to ignore them. We further enhance our algorithms with heuristics that exploit the expected vertical profile of flight routes to reduce the search space. Real-life data is used for experimental analysis. We find that, in the vertical setting, the FIFO property can be assumed on cost with only a negligible reduction in solution quality. We also find that our techniques for constraint propagation work best together with an iterative search approach, in which only constraints that are violated in previously found routes are introduced in the constraint set before the search is restarted. Finally we conclude that the direct 3D approach is computationally feasible and leads to flight routes of better quality than the decomposition approach.