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# An A-Star Approach for the Quickest Path Problem with Time Windows

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**Abstract :** As air traffic increases, more airports are interested in utilizing optimization methods. Many processes happen in parallel at an airport, and complex models are needed in order to have a reliable solution that can be implemented for ground movement operations. The ground movement for aircraft in an airport, allocating a path to each aircraft to follow in order to reach their destination (e.g. runway or gate), is one process that could be optimized. The Quickest Path Problem with Time Windows (QPPTW) algorithm has been developed to provide a conflict-free routing of vehicles and has been applied to routing aircraft around an airport. It was subsequently modified to increase the accuracy for airport applications. These modifications take into consideration specific characteristics of the problem, such as: the pushback process, which considers the extra time that is needed for pushing back an aircraft and turning its engines on; stand holding where any waiting should be allocated to the stand; and runway sequencing, where the sequence of the aircraft that take off is optimized and has to be respected. QPPTW involves searching for the quickest path by expanding the search in all directions, similarly to Dijkstra's algorithm. Finding a way to direct the expansion can potentially assist the search and achieve a better performance. We have further modified the QPPTW algorithm to use a heuristic approach in order to guide the search. This new algorithm is based on the A-star search method but estimates the remaining time (instead of distance) in order to assess how far the target is. It is important to consider the remaining time that it is needed to reach the target, so that delays that are caused by other aircraft can be part of the optimization method. All of the other characteristics are still considered and time windows are still used in order to route multiple aircraft rather than a single aircraft. In this way the quickest path is found for each aircraft while taking into account the movements of the previously routed aircraft. After running experiments using a week of real aircraft data from Zurich Airport, the new algorithm (A-star QPPTW) was found to route aircraft much more quickly, being especially fast in routing the departing aircraft where pushback delays are significant. On average A-star QPPTW could route a full day (755 to 837 aircraft movements) 56% faster than the original algorithm. In total the routing of a full week of aircraft took only 12 seconds with the new algorithm, 15 seconds faster than the original algorithm. For real time application, the algorithm needs to be very fast, and this speed increase will allow us to add additional features and complexity, allowing further integration with other processes in airports and leading to more optimized and environmentally friendly airports.

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