Fast Passenger Assignment for Public Transport Services

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In public transport planning, properly modelling how passengers will use a proposed transport service is crucial. This aspect of the planning process, known as the Passenger Assignment Problem (PAP), involves modelling passenger behaviour on a transport network and poses significant computational challenges [1]. The PAP must be solved repeatedly during many planning processes [2]. A common approach is to calculate all-to-all shortest paths on the network, which are then combined with passenger demand to estimate average travel times—a key metric in transportation planning.

To address this challenge, we propose a novel transit network representation that enables the decomposition of the original networks into smaller networks, thereby reducing redundant calculations and the required computational time for solving the PAP. This structure enables existing algorithms to run faster and more efficiently. The core idea is to decompose the network into several subgraphs that contain only the nodes that recur in many partial paths. An example of such a partial network is a subgraph containing only transfer nodes, where passengers can change lines, or a node placed on a bridge separating two parts of the network. The complete path of the traveller can then be split up into a path from an origin to a subgraph, a path over the subgraph and a path from the subgraph to the destination. As a result, the paths in (and through) the subgraph only need to be calculated once. This method is furthermore recursive and allows for breaking down the initial network into several layers.

The main problem with solving the PAP in a transit network is that oftentimes a cost is incurred at the nodes of the graph, either through dwell or transfer times. To overcome this difficulty, a graph transformation is necessary, after which a shortest path algorithm can be executed. In the current state of the art, initial graph transformations, such as the change&go network [3], add dummy nodes between which the transfer times can be modelled as an arc cost. This increases the number of nodes in the network significantly, and hence the calculation time.

Instead of adding additional nodes, Aktaş, Vermeir, and Vansteenwegen [1]

introduce a network transformation that introduces only additional edges, no additional nodes, called the Direct Link Network (DLN). We expand on this concept by showing how this network representation can be adapted to include dwell times, frequencies, and even complete time tables. In the latter case, we consider periodic time tables, which allow for a more compact graph version of the network compared to alternative representations, and show an efficient way to perform an assignment of all passengers on this network.

When this network transformation is combined with the network decomposition, the PAP for many real-sized instances can be calculated in a negligible amount of time. e.g. A rural network containing 500 stops and 70 distinct buslines can be solved in ∼0.01s when every transfer is penalised with a general transfer penalty. With the DLN approach, it would take ∼0.1 seconds to calculate the same result, an additional order of magnitude. With our decomposition, the same network can be solved in ∼0.34s when the problem is extended and waiting times are modelled as a function of the frequency of the departing line, and lines are given dwell times. When detailed timetables are included, the same instance takes ∼2.74s to perform a full passenger assignment. In this last case, the transfer time depends on the time difference between arriving and departing vehicles, while the initial waiting time for the first vehicle depends on the difference between the desired moment of departure and the scheduled departures. When timetables are included, individual vehicles with unique driving and waiting times need to be modelled, along with individual passenger requests. Because of the additional complexity, the increase in calculation time seems reasonable.

Future research can determine whether a more efficient implementation of a shortest path algorithm, or a combination with other state-of-the-art techniques, can lead to further reduction in calculation times. We consider this research a significant step forward in showing the increase in complexity when passenger assignment is performed with increasing levels of detail.

References

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