Title: Train Scheduling and Routing under Dynamic Headway Control

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Project Objective

Railways, as one of the most cost-efficient ways to transport goods and people, serve a major part of the transportation demand, especially for freight transportation in the United States. Based on the statistics given by the Federal Railroad Administration, the railway system will experience a 22% increase in the amount of tonnage from 2010 to 2035. However, it is very expensive to extend the current railway's infrastructure. Therefore a better way of managing the railway system is needed. Our research seeks to improve the railway system by developing an efficient method to manage and schedule the trains' movement.

Problem Statement

Trains are controlled by signals in order to avoid collision. The track segment between two consecutive signals works as headway between two consecutive trains. Therefore the railway track is typically modeled as a set of blocks, where each block can hold only one train at any time. As a consequence, headway between two consecutive trains is represented as a block with fixed length in most of the simulation modelling approaches. We refer it to the fixed headway model.

The introduction of a Positive Train Control (PTC) system enlarges the limited control given by the signals. The trains can be controlled to decelerate, accelerate and travel at a constant speed in real time at any point, resulting in dynamic headway between two consecutive trains. As a result existing simulation modelling approaches using fixed headways cannot be used to represent dynamic headway control. Thus, we propose a new simulation model for a PTC system together with a dynamic headway control rule taking the train's dynamics into consideration, furthering the state-of-the-art of the train scheduling and routing problem taking into consideration the new capabilities that PTC systems provide through (1) developing a simulation framework to represent dynamic headway and (2) formulating an optimization model and proposing a heuristic method to schedule trains in the new framework.

Research Methodology

To develop a dynamic headway model, the railway track is divided into shorter segments compared with the fixed headway model. Then a network is constructed where each node corresponds to one segment and each arc corresponds to one connection between two segments.

Then a train's movement through the railway network can be modelled as movement through the constructed network. And we require there can be at most one train within each node at any time. So the headway is modeled as all the available nodes between two consecutive trains.

Velocities and headway are jointly controlled to obtain the optimal travel time without collision. In this framework, three decisions need to be made: routing decision (the choice of the next headway node if there are alternatives), headway decision (the number of new headway nodes to occupy) and velocity decision (the exiting velocity at current node). For the routing decision, we apply a greedy algorithm, i.e. always pick the next headway node which has the highest speed limit. For the headway decision, we apply the rule that a train seizes enough headway nodes until it can reach the speed limit outside the current node. Figure 1 shows how it works. For the velocity decision, we solve a sequence of optimization problems to obtain the optimal exiting velocity at the current node so that the train can come to a full stop within its headway nodes.

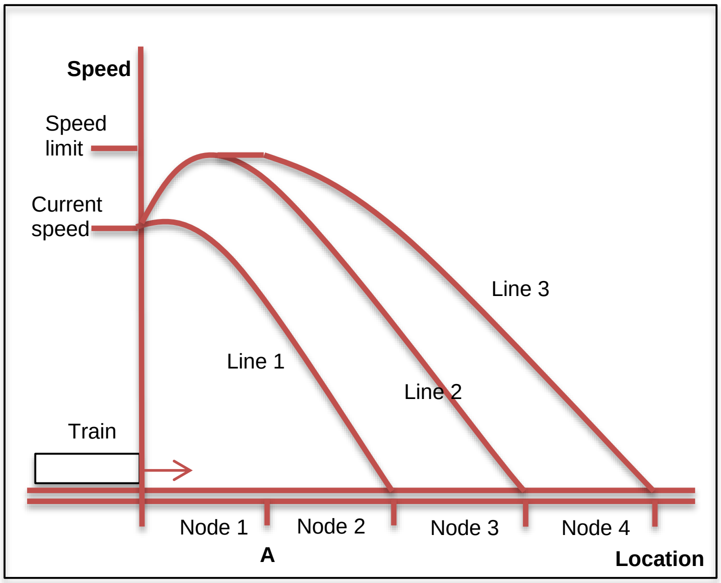

Figure 1

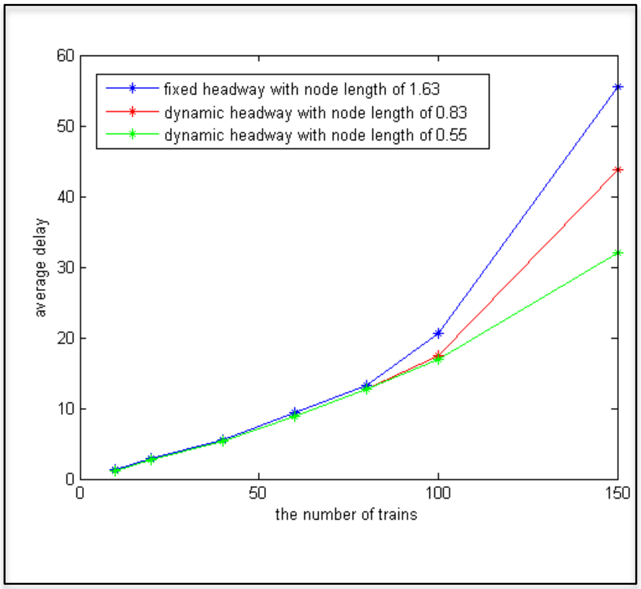

Figure 2

Numerical Results

Simulation results are shown in Figure 2. It shows in terms of minimizing delay that (1) the dynamic headway model performs better than the fixed headway model and (2) the dynamic headway approach provides lower delay if we construct a network with a smaller node size.