Segment Based Modeling for Running Time Estimation of Rail Vehicles

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In a railway network, limited resources are available, which adds some constraints for operating rail vehicles. For instance, multiple trains are operated simultaneously on same tracks routinely. To ensure smooth operation and avoid/ minimize delays in services, proper planning and scheduling is required. To achieve this, running time estimation is crucial. A summary of works in running time estimation are presented in (2) & (3). In this work, Segment Based Modeling (SBM) (5) is adapted to estimate running time. Multiple speed limits because of physical contours, crossovers, or other safety are accounted in running time calculations. The results of running time using SBM were compared with results from a software used by the Indian Railways (IR).

A general procedure applied in calculating instantaneous running time is described as follows. A rail vehicle is often modeled as a single point mass, this is done to reduce the computational complexity. Newton's second law for longitudinal motion, as shown in equation (1) is solved to estimate running time.

$$F_{net} = ma \tag{1}$$

where, F_{net} is the resultant of forces acting on the rail vehicle. F_{net} primarily consists of traction (T) and resistance forces (R). Resistance forces arise from several sources, such as Journal, bearing, flange, wind, gradient and curvature. A summary of resisitive forces is presented in (1). Also, a and m are the acceleration and mass of the simplified rail vehicle respectively. It is important to note that traction and resistance forces depends on speed and therefore requires computation at each step. Once relevant functions are incorporated to calculated traction and resistance forces, the instantaneous acceleration and running time are calculated using basic equations of motion, shown below

$$v_i^2 = v_{i-1}^2 + 2as \;\; and \;\; t = s/v_{ave} \tag{2}$$

where, v_i and v_{i-1} are the speed at 'i' th and 'i-1' st step respectively, s is the distance, t is time taken and v_{ave} is the average of v_i and v_{i-1}. The running time are concatenated in each iteration to get overall running time.

In railway system, several constraints are present such as speed limitations, halt time, etc. For Example: while moving on a curved track, a rail vehicle is expected to operate at a lower speed. These restrictions are essential for safe operation. Therefore, the limitation are accounted in modeling and an overall speed restriction profile is generated for a given section. A typical speed restriction profile is shown in Figure 2 (Red Colour).

The running time estimation is done is several steps. Firstly, the speed restrictions are systematically divided and numbered. Each division is called as a segment and they are created based on their shape. In general, segments are classified into four types: T, U, R, and N respectively. A schematic of different segment types are shown in Figure 1.

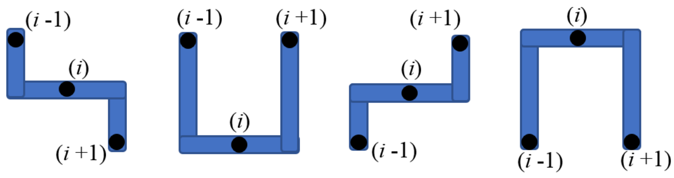

Figure 1: Segment Types

For each segment type, unique conditions are defined. Further, each segment is divided into sub - segments whose size can be modified according to the requirements. The speed profile is then computed by solving forward acceleration trajectory - acceleration calculated using initial point and backward deceleration - acceleration calculated using final point of a segment. Finally, the maximum allowable speed at each segment is taken as the minimum of three speeds: forward trajectory speed (v_{ft}), backward trajectory speed (v_{bt}) and speed in the speed restriction (v_{sr}). Speed restrictions and the computed speed profile with respect to distance is shown in Figure 2.

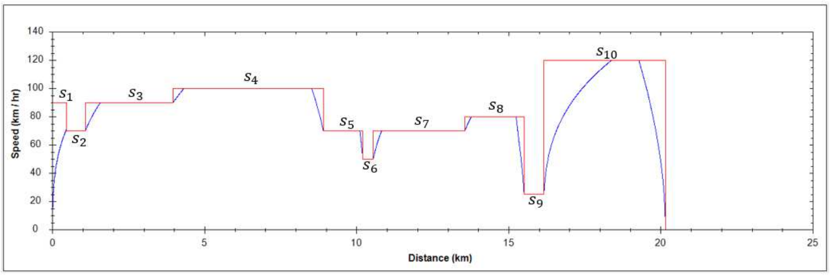

Figure 2: Speed profile

The running time was compared with the existing software used by the the IR for fifty sections and the mean difference was estimated to be 0.1%. Moreover, the GUI was developed— using Object-Oriented Programming (OOP) concept (4)—for the software to be more user friendly and convenient to use by the monitoring personnel.

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