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Aachen, March 29, 2020

Danksagung

Danke.

Contents

Abstract Modern day railway system operations require automated train control mechanisms, e.g. European Train Control System ETCS, to maximize efficiency, which is often times limited by outdated infrastructure, as well as safety of operations. One way to achieve this is by lowering the required distance between two trains on the same track, which in turn demands a reliable method of predicting the braking distance at any given moment.

While determination of the necessary braking curves is feasible for a limited number of train formations, the large diversity of vehicles in freight operations poses an issue. One approach for a solution would be using Big Data, which would be able to process the required amounts of data to calculate reliable braking curves even for freight operations.

The problem here is there is simply not enough data available since freight trains usually don't have the sensory equipment needed. To circumvent that obstacle, this work proposes generation of artificial data via white box modeling to be then used in further big data operations.

Introduction

Introduction This section describes the background and motivation of the research (Sect. 1.1), the problem to be addressed (Sect. 1.2) and the proposed solution (Sect. 1.3)

1.1 Background

1.1.1 Railway Vehicle Operations

1.1.2 Train Protection Systems

1.1.3 Braking Curves

1.2 Problem

As has been shown, to predict the braking behavior of trains, readings of wagons and locomotives are needed. Unfortunately, freight vehicles do not currently posses the sensory equipment that would be necessary to obtain such data in an adequate quantity and quality, especially in regards to *big data processing*. Although it has been proposed to equip freight wagons accordingly **<TODO: ref zu wagon4.0>**, it will be years before enough rolling stock has been retrofitted as to make it possible to obtain the desired data.

1.3 Solution

This work proposes to circumvent the problem described above by creation of an artificial data set. The set must replicate the actual distribution of braking behavior as close as possible. It is therefore necessary to first create a model encompassing the braking process of a freight train. This model will be discussed in depth in chapter 3. It can then, once finished, be also used to generate the data set by simulation. This process will be discussed in chapter 4.

As real life operations would yield very high quantities of data, the simulation output must be stored in a data structure which is suitable for big data processing. This structure will also be discussed in chapter 4.

Fundamentals of Railway Vehicle Engineering

Modeling of Train Operations

Introduction As has been noted in 1.3, it is necessary to model the braking process of freight trains. All modeling work has been performed with Matlab Simulink.

3.1 Initial Model

The initial model to be expanded upon describes a single braking process. Let's take a look at the whole model first.

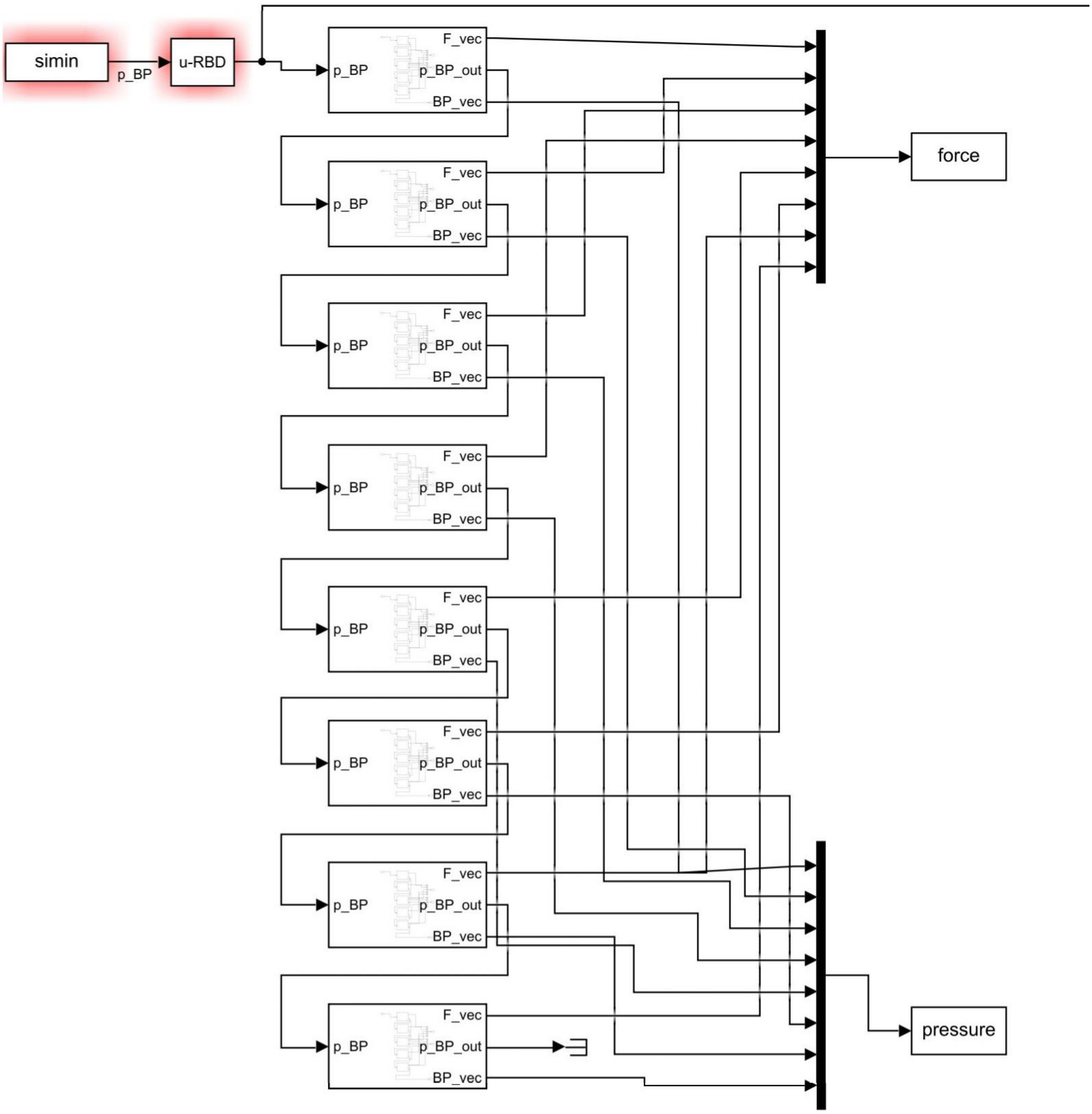

Figure 3.1: Initial model

Here we see a model of a freight train of fixed length, consisting of 40 wagons, which are, for better readability, further condensed to subsystems of five wagons each, so there are eight of these subsystems. They are interconnected via braking pipe, which is also the sole input to each system. Outputs are braking pressure and braking force. We will take a look at the actual wagon model next.

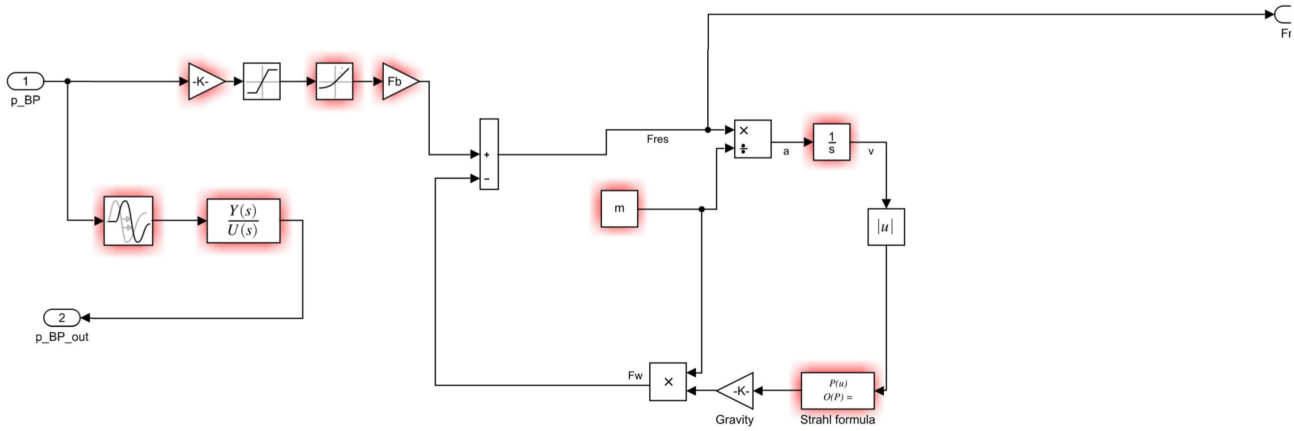

Figure 3.2: Initial model - Wagon

Above is the initial wagon model. NOTE: All 40 wagon models are identical here. This will be addressed in section 3.2. It consists of three main components.

In the upper left corner is the input, which is the current pressure in the braking pipe. In the lower left corner, the propagation delay of the braking pipe is calculated. This is done by **<TODO: >**. Top center describes the calculation of the actual braking force, which is achieved by **<TODO: >**. Finally, the **<TODO: Formulieren: Fahrzeugwiderstand>**.

3.2 Model Expansion

3.3 Further Expansion

Data Generation

4.1 Data Structure

4.2 Analysis of generated Data

Performance Analysis

Conclusion

List of Figures

List of Tables

Quellcode

1. Source 1
2. Source 2

Rohdatenvisualisierungen

1. Graustufen
2. Verteilungen