ROADVIEW Robust and Automated Driving in Extreme Weather

Vehicle Dynamics Parameter Estimation Methodology for Virtual Automated Driving Testing

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Research motivation

The exclusive test of automated driving vehicles in **real test tracks is limited** by the **complexity** of the scenarios and the uncontrollability of factors such as **weather conditions.**

The use of **simulation** to support this testing process is being proposed by different **regulators** [1-3] in other to **accelerate the testing process as well as enable the testing of safety-critical situations.**

The behaviour of the **vehicle dynamics** has an important influence on the testing of controllers and decision-making systems [4,5]. **The proper virtualization** of the vehicle model requires parameters, mainly inertia [6] and suspension characteristics, which can only be acquired in **complex test benches.**

Introduction

This work defines a **methodology for the estimation of the vehicle dynamics parameters** based on the conduction of simple maneuvers combined with the **data acquisition from the test vehicle and optimisation algorithms.** It enables the parametrization of the vehicle dynamics without the implementation of expensive test benches. Furthermore, a compressive vehicle dynamics model is made available in this project.

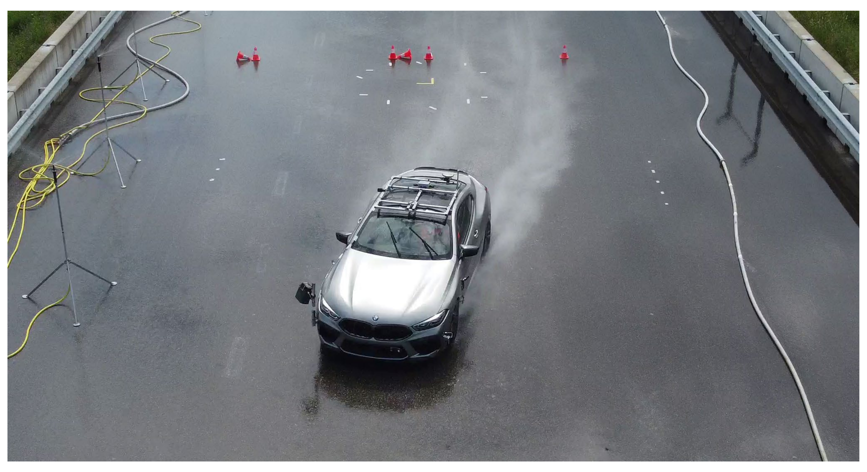

Figure 1. Double Lane change under rainy conditions

Methods & Materials

- The vehicle dynamics model consists of an **11 DoF** model, including 6 DoF of the chassi, individual rotation of each wheel and the rotation of the engine.
- The **simplification** of the model contemplates a comprehensive description of the movement required for automated driving while **minimizing the amount of parameters** to be estimated.
- The model is implemented in Python in order to enable a straightforward integration with the optimization algorithms.
- The model contemplates 3 modules (**Powertrain, Wheels and Body**). The engine, torque converter and transmission are based on empirical data and implemented with lookup tables. Tyres are implemented using the model described in the ISO 3373:2024 [8].

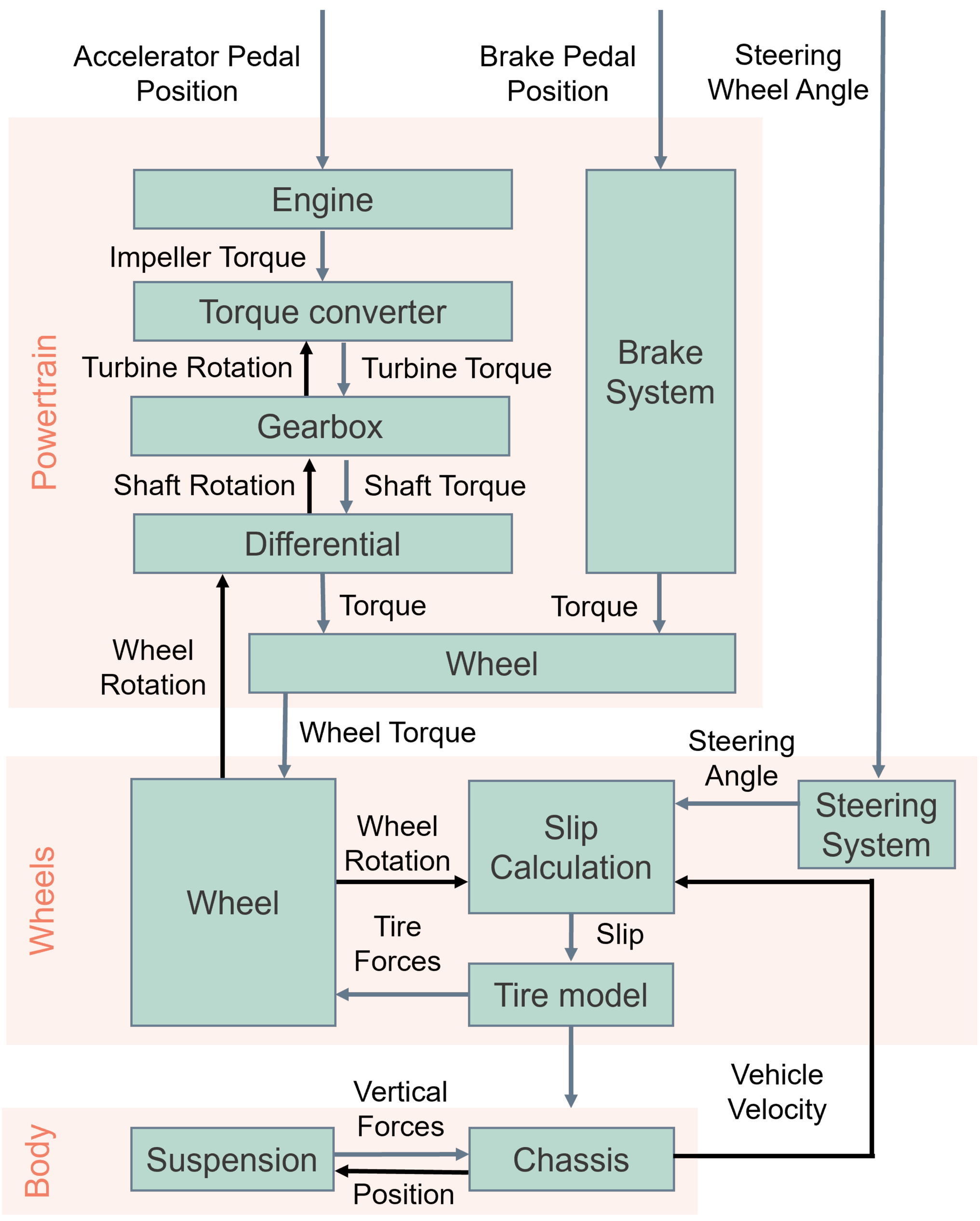

Figure 2. Implemented modules.

- Parameters that can be directly measured or calculated are obtained in a previous step. **Vehicle dimensions, gear ratio, differential ratio and aerodynamics resistance** are taken from the vehicle manual. **Vehicle mass and centre of gravity** are measured using scales and a vehicle lifter. Tyres cornering stiffness are obtained from the test bench in VTI facilities.

Figure 3. Measurement of CG position at C-IAD.

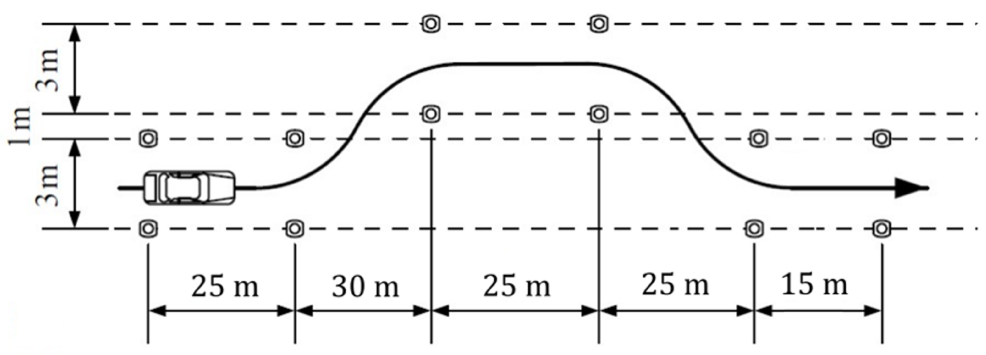

Figure 4. Double Lane Change maneuver [7]

- **Accelerating and Braking, Step Steering and Double Lane change** manuevres are conducted in speed ranges between 30km/h and 70km/h.
- Parameters such as ratios from the **torque converter** are calculated using **physical/empirical equations.**
- The **Differential Evolution** [9] method is used to minimize Root Mean Square Error (RMSE) between the **simulation** and the data collected on the **test track**.
- The recorded inputs (**accelerator pedal, brake pedal and steering wheel**) are given into the model and variables are chosen to be minimized in **three different steps**, which aim to optimize the vehicle's **powertrain, and lateral and longitudinal characteristics separately**. The optimization used the **longitudinal velocity, roll and yaw, and pitch respectively.**

Results

The estimated parameters show a **reasonable correlation with physically measured parameters for sport vehicles.**

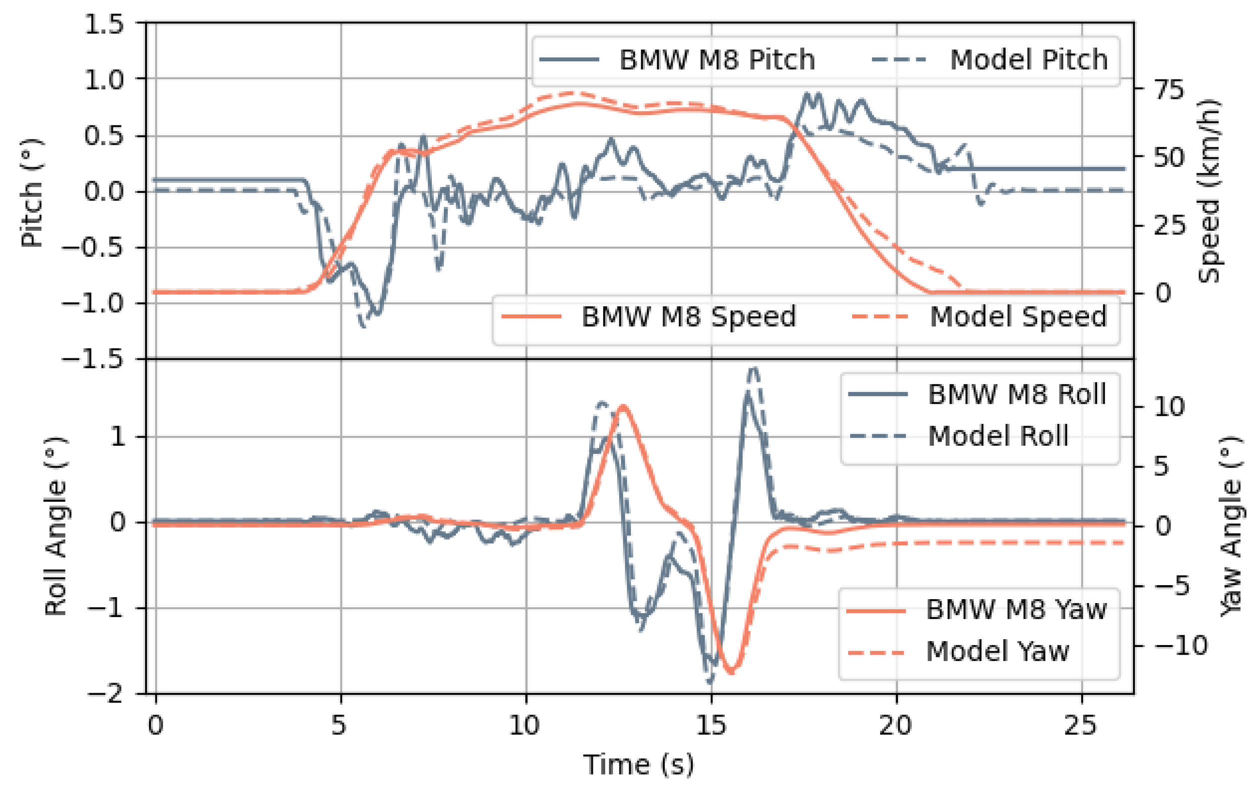

Figure 5. Longitudinal and Lateral behaviour of the model in comparison to data collected from the real vehicle.

Despite the simplifications of the model and assumptions on the data collection, the results obtained from the optimization of the double lane change maneuver **reproduces the real behaviour to a satisfactory level.**

Some **high peaks** can be identified in the **pitch simulation**, which is not visible in the real data **due to simplifications on the model or insufficient damping of the suspension or pitch inertia**. **Deviations in the braking phase** combined with the **simplifications of the steering system** lead to **errors in the lateral behaviour**.

Conclusions & Outlook

The parameters obtained from the proposed methodology **enable faithful reproduction of a specific manoeuvre**, including linear and angular movements. Future work will focus on the definition of a **methodology for enabling the generalization** of the model for different maneuvers. Further research can be conducted on the **definition of the variables and manuevres chosen for the optimization.** Furthermore, the application of this **methodology in other vehicles and road conditions such as snow and ice** shall be conducted.

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