Motorcycle Dynamics as a Driver of Road Safety

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Abstract

My research activity focuses on defining methodologies and models to facilitate research on motorcycle safety. I defined a new tyre model formulation with the peculiarity of being characterisable through riding data. I proposed and validated a simplified model to estimate the steering torque signal; this also led to the proposal of a dynamic model to provide steering realism to low-complexity simulators. A data-driven approach for the automatic identification of riding conditions was defined. Lastly, I conducted an exploratory study on steering assistance systems' applicability, effectiveness, and feasibility.

Introduction and Research Aim

Improving motorcycle safety through innovative assistance systems and improved design and rider training requires understanding the human-vehicle system's behaviour. To facilitate their development, I focused my research activity on defining suitable methodologies, models, and tools aiding research concerning motorcycle safety, with a particular focus on motorcycle dynamics.

Tyre Modelling from Riding Data

A motorcycle changes its state of motion primarily through the tyre-road interaction; therefore, correctly describing the forces and moments generated by its pneumatic tyres is crucial. Traditionally, tyre models are characterised through bench tests; however, benches dedicated to motorcycle tyres are rare and expensive. To make tyre characterisation more accessible, I defined a novel tyre model conceived to be characterised through riding data. The model was validated in a simulation environment and partially through experimental tests, showing modest error. This approach makes the tyre characterisation problem more accessible.

Steering Torque Estimation Model

Steering torque constitutes the primary motorcycle control input for lateral dynamics; conventionally, it is estimated through complete motorcycle models, requiring significant identification effort. Therefore, I proposed a simplified steering assembly model to estimate the steering torque for stationary and transient manoeuvres. The model was validated using the measured steering torque from different datasets, including diverse motorcycle classes: a good agreement resulted between the estimated and measured torques. The model allowed for estimating motorcycle manoeuvrability and assessing the impact of the manoeuvre and the motorcycle design on the steering effort required.

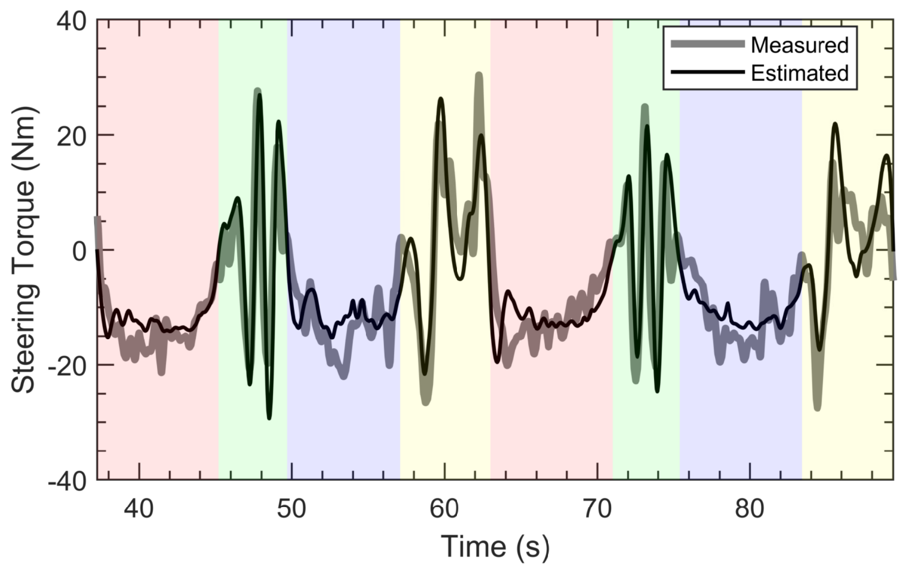

Figure 1: Measured and estimated steering torque in four different manoeuvres.

Simulator With Realistic Steering Feedback

Motorcycle simulators are employed for rider training, studying human–machine interaction, and developing assistance systems. However, existing simulators are too simple, unsuitable, or significantly complex. Therefore, I defined a novel approach to achieve steering realism: a tuned single-track car model as the basis of a motorcycle simulator, leading to considerable software simplification while preserving its fidelity. The experimental results of the simulator test validated the approach concerning a diverse set of manoeuvres.

Data-Driven Riding Dynamics Investigation

Analysing riding data is the primary approach to studying the rider-motorcycle interaction, but becomes challenging when using extensive datasets; segmenting the riding data would help identify events of interest. Hence, I proposed an automatic, unsupervised tool for in-depth segmenting and clustering signals acquired during a riding session to study motorcycle dynamics. Analysing the segmented trial revealed the effectiveness and usefulness of the approach: it simplified the in-depth corner entry analysis and allowed early detection of the manoeuvre start. The proposed tool can aid research on motorcycle dynamics, PTW-rider interaction, and riding preferences in bends.

Exploratory Study on Steering Assistance

Braking assistance systems are already contributing to improving motorcyclists' safety; however, research on emergency systems acting on the steering is lacking. Three emergency steering assistance systems were defined in terms of Functionality, Purpose, and Applicability: Motorcycle Curve Assist (MCA), Motorcycle Stabilisation (MS), and Motorcycle Autonomous Emergency Steering (MAES). Experts evaluated each system's applicability and effectiveness using three approaches: MAES got the best scores, and the union of the three systems covered a sizeable fraction of the crashes considered. The potential injury mitigation due to MAES was also estimated. A field test evaluated the feasibility of its intervention using a real motorcycle, showing no instability or loss of control.

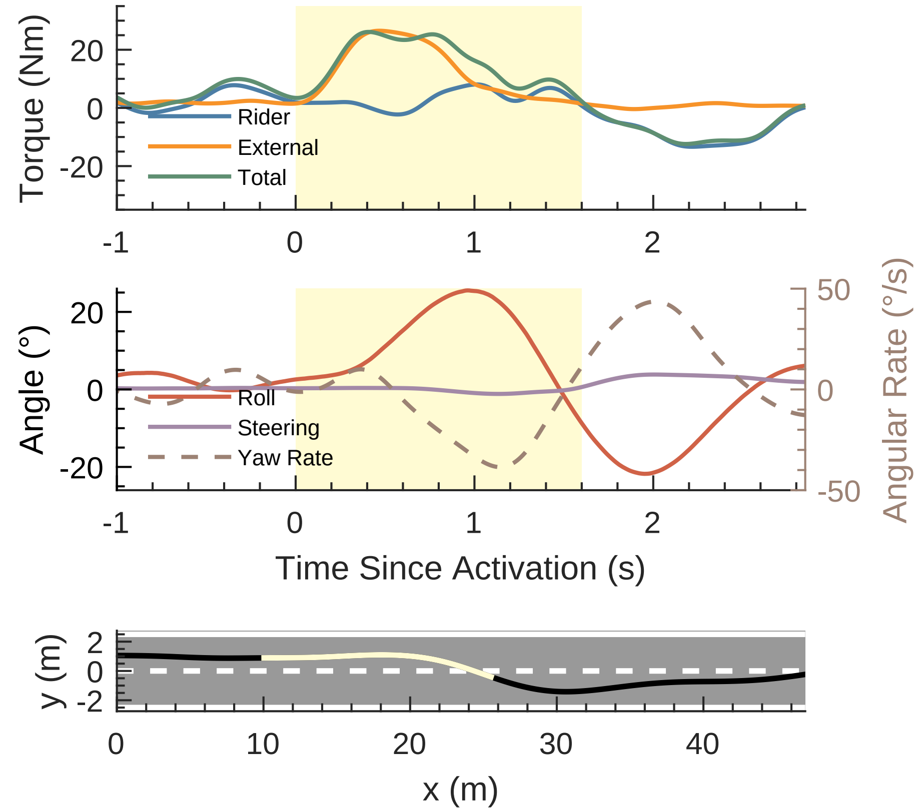

Figure 2: Steering input (top), motorcycle response (middle) and trajectory (bottom) during a lane change initiated through an external steering action.

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