

Novel Two-stage Nonlinear Interconnected Unknown Input Observer Design: Hardware & Experimental Vehicle Validation

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Abstract

This paper concerns both vehicle lateral and longitudinal nonlinear dynamics estimation. Consequently, the interlinked vehicle models dependency and the hurdle coupling features will be overcome here thanks to the NONLINEAR INTERCONNECTED UNKNOWN INPUTS OBSERVER (NI-UIO) framework. This interconnection scheme extends the estimation of the lateral motion to the longitudinal one with the unknown accelerator, brake pedal and driver steering torque inputs, as well as tire-ground pneumatic efforts to reduce conservatism and observability problems. The aspects of immeasurable real-time variation in the forward speed and tire slip velocities in front and rear wheels are taken particularly into account. Consequently, TAKAGI-SUGENO (TS) fuzzy form is undertaken to deal with these nonlinearities in the observer synthesis. The INPUT TO STATE STABILITY (ISS) of the estimation errors is exploited using Lyapunov stability arguments to allow more relaxation and additional robustness guarantee regarding the disturbance term of immeasurable nonlinearities. Therein, sufficient conditions of the ISS property are formulated as an optimization problem in terms of linear matrix inequalities (LMIs). Finally, hardware and experimental validation with robustness test are performed with the well-known SHERPA dynamic interactive driving simulator as well as TWINGO vehicle prototype to highlight performances and applicability of the outlined observer.

Full Text

This preprint is available for [download as a PDF](#).

Figures

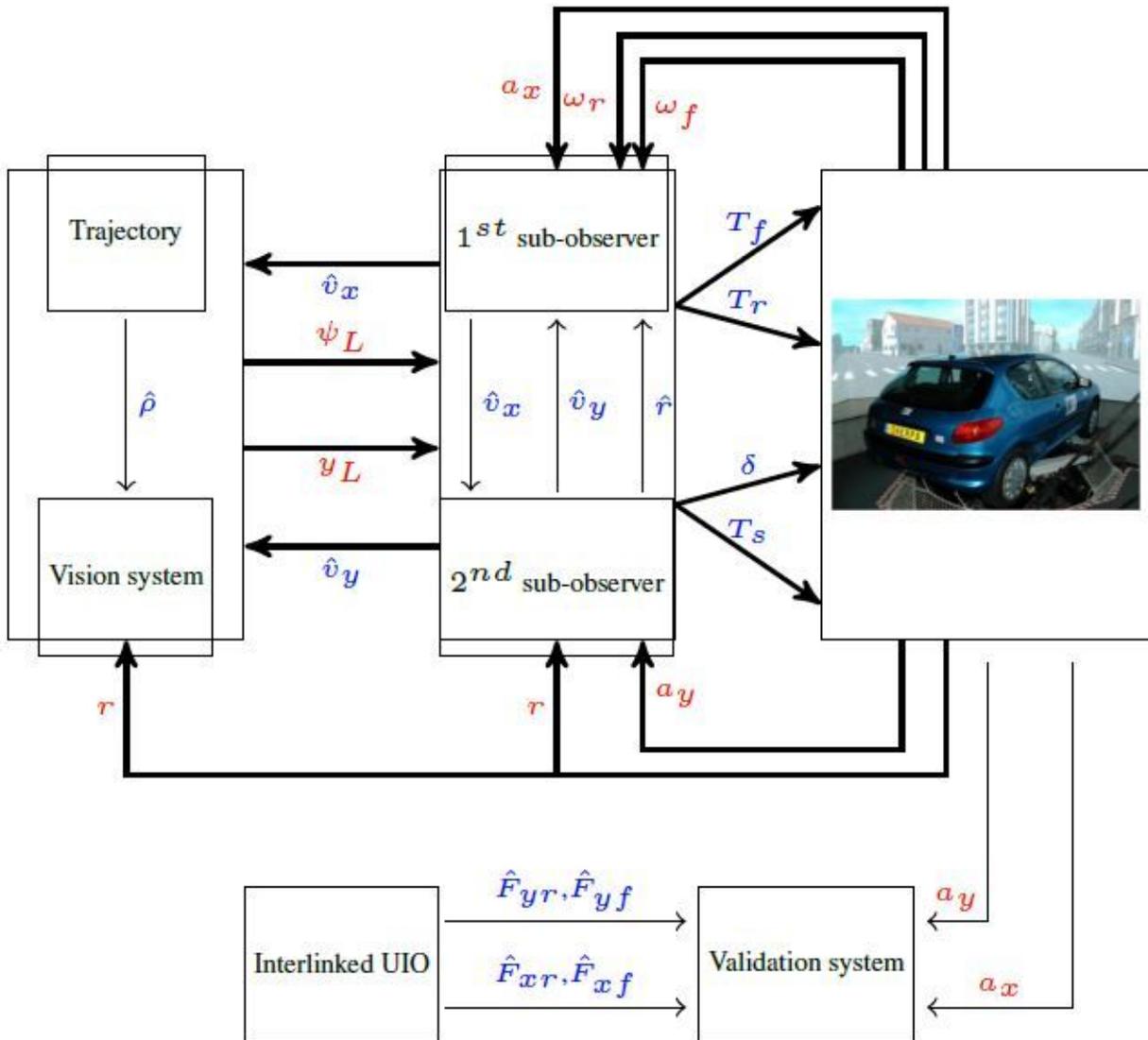
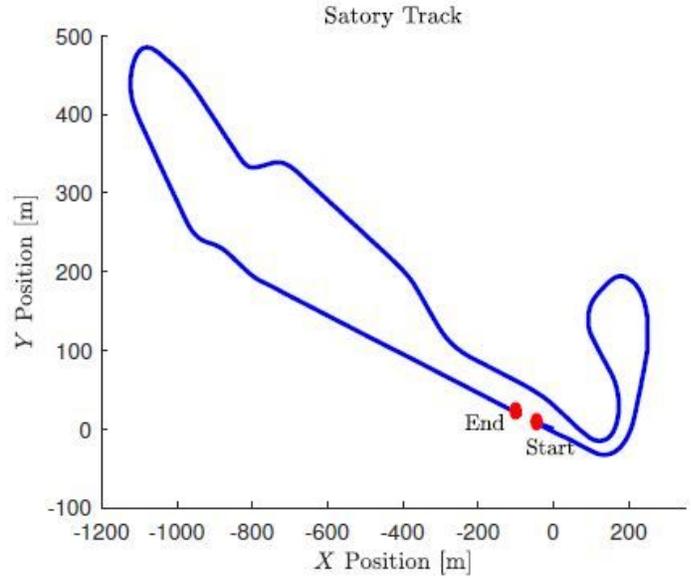


Figure 2

Flowchart of the interlinked UIO observer architecture.



(a) SHERPA-LAMIH driving simulator.



(b) SATORY test track.

Figure 3

LAMIH SHERPA car driving simulator.

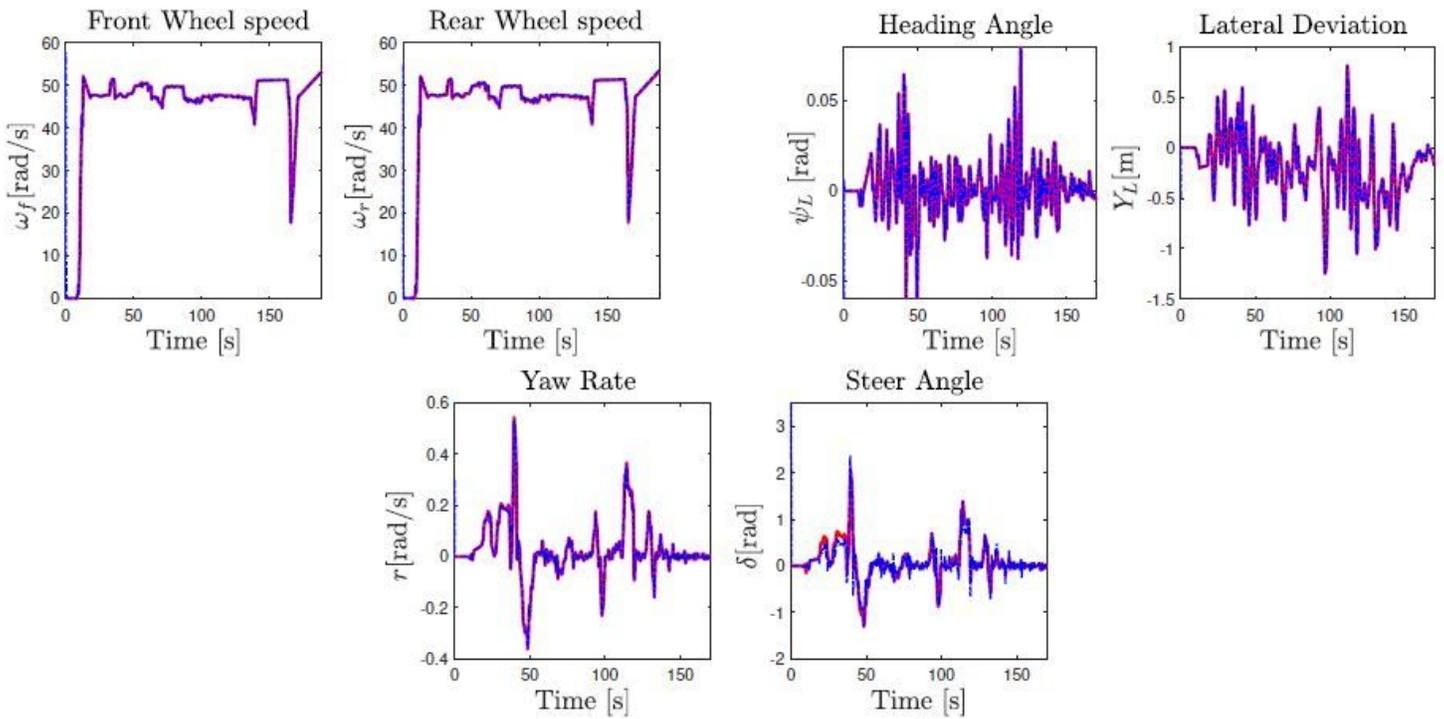


Figure 4

SHERPA data (red) and estimation (dashed blue).

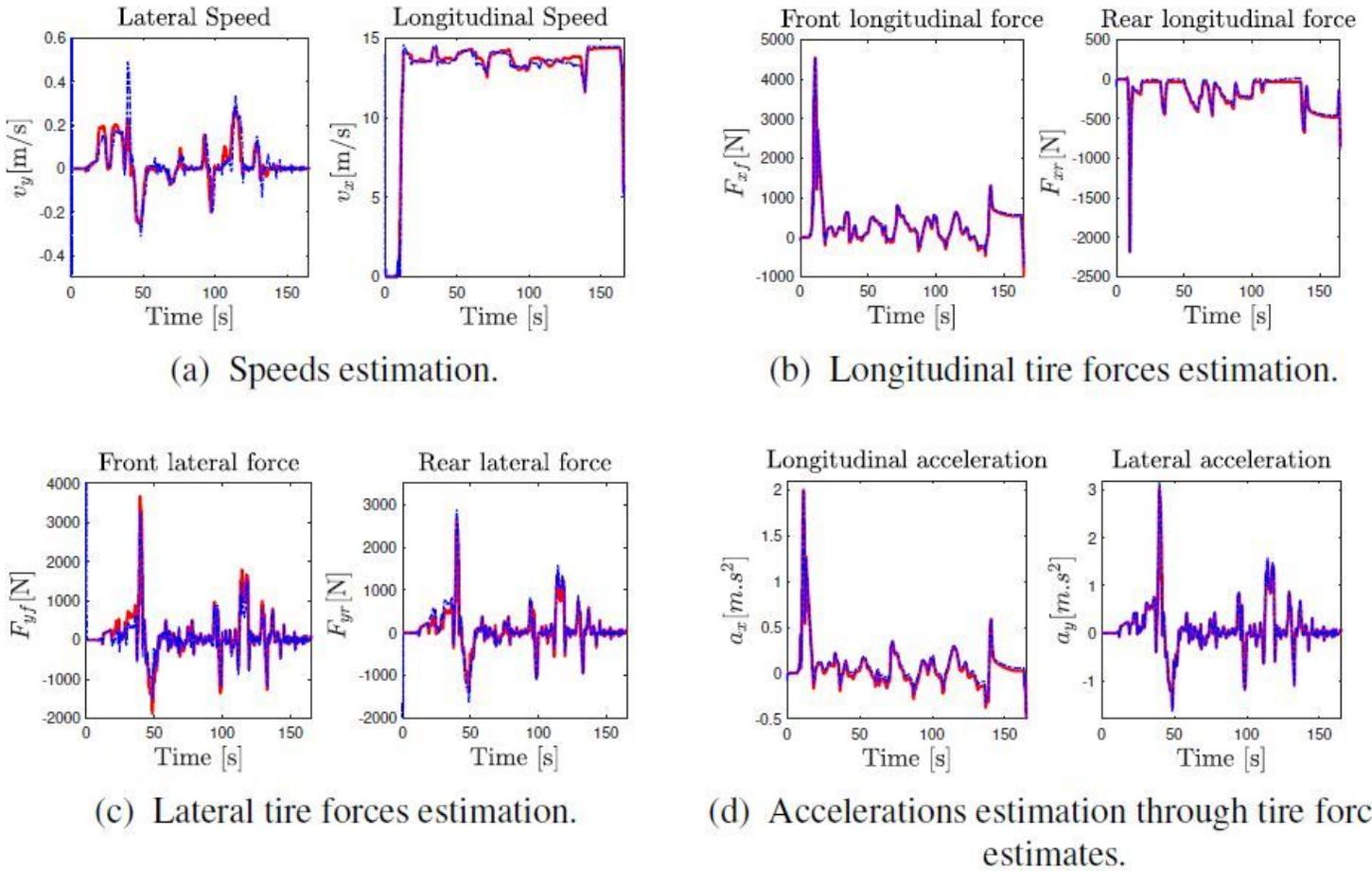


Figure 5

Performance: SHERPA (red) and observer(dashed blue).

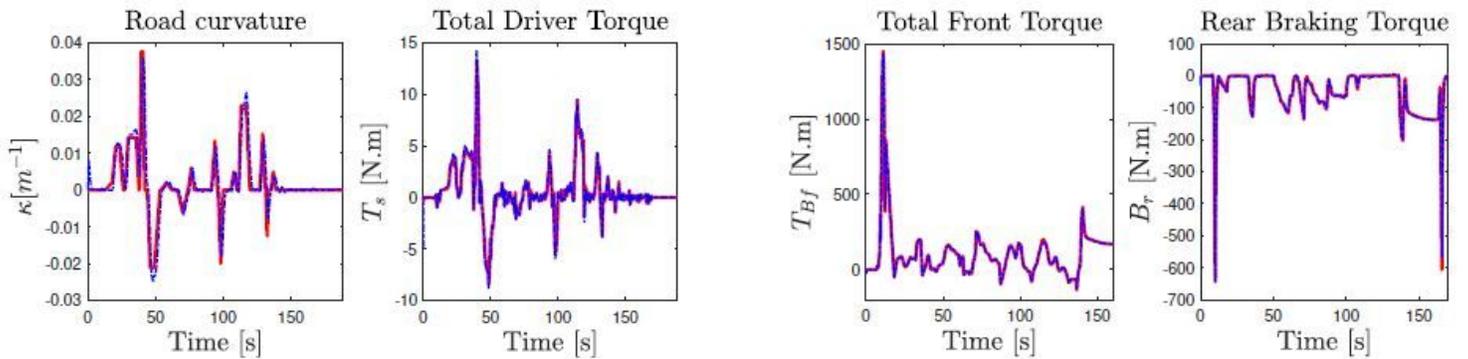


Figure 6

Manual driving experiment on the Satory test track: Braking, traction torques and steering angle inputs.

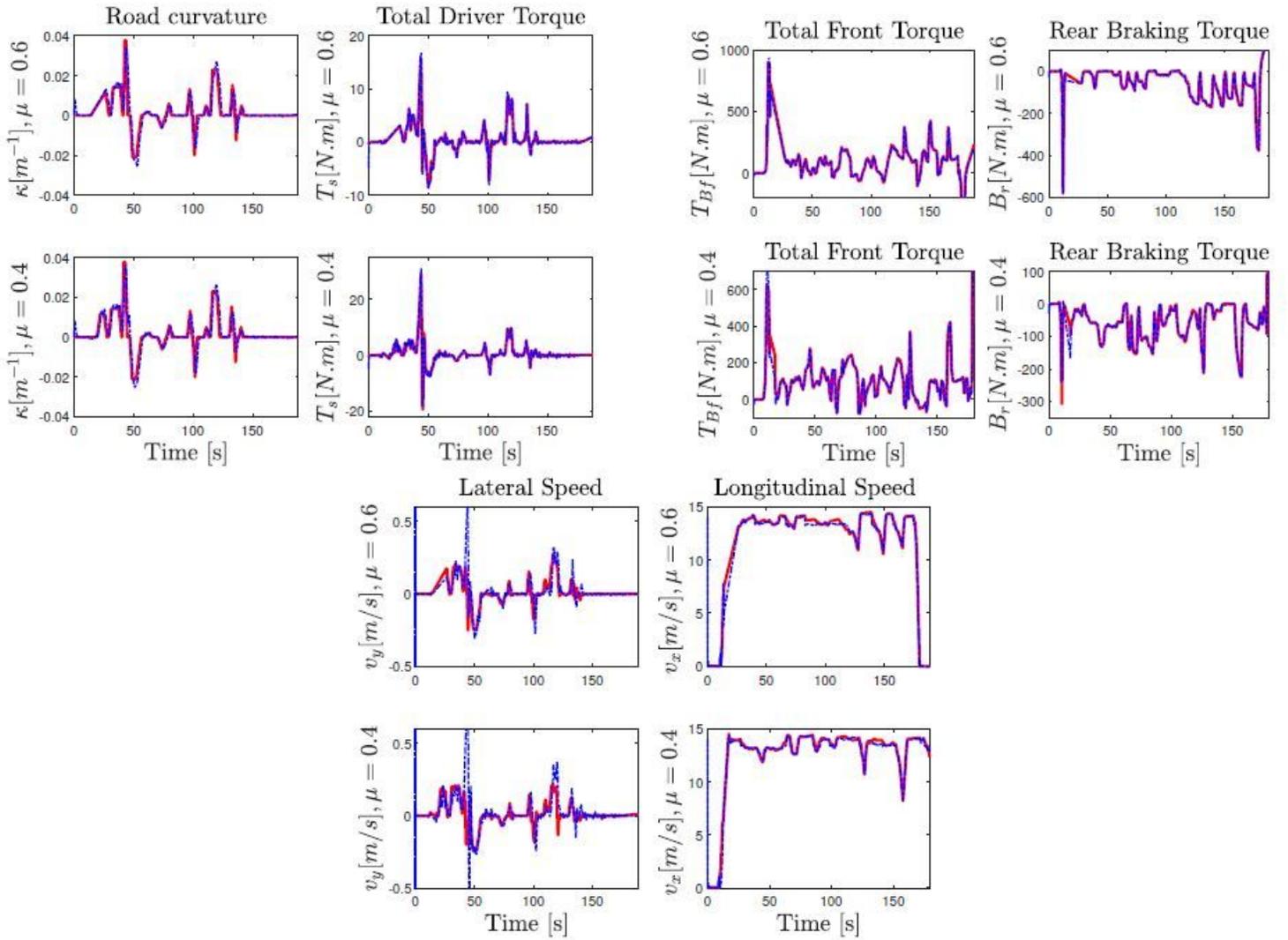


Figure 7

Overview of NI-UIO robustness test.

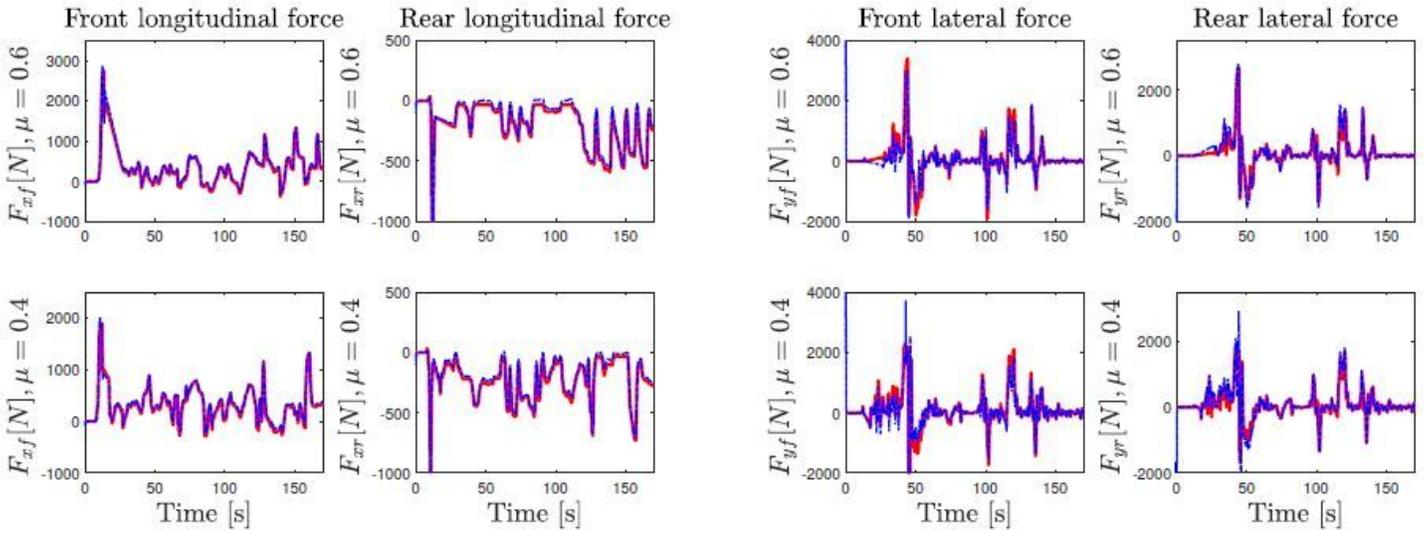
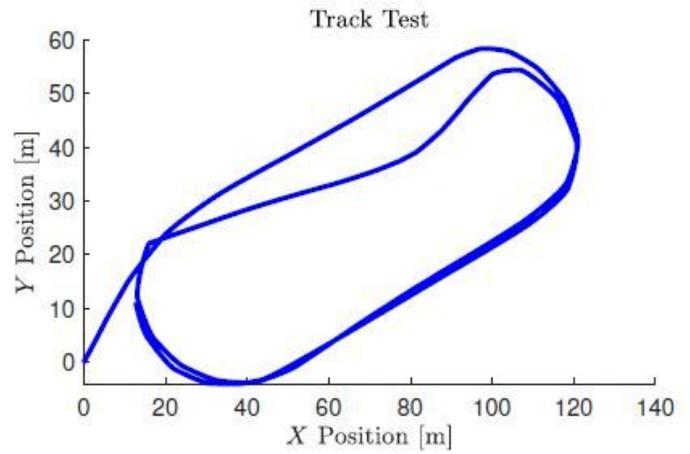


Figure 8

Overview of NI-UIO robustness test.



(a) LAMIH Renault TWINGO experimental vehicle.



(b) X-Y positions of test track.

Figure 9

LAMIH experimental test track.

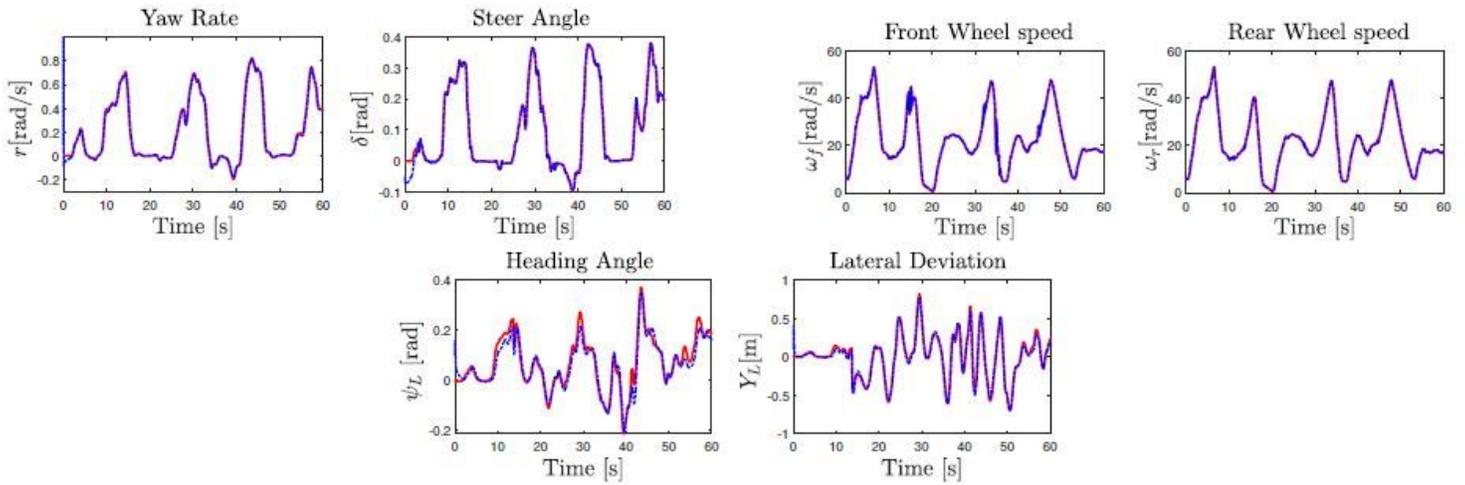


Figure 10

Real measurements (red) and observer estimation (dashed blue).

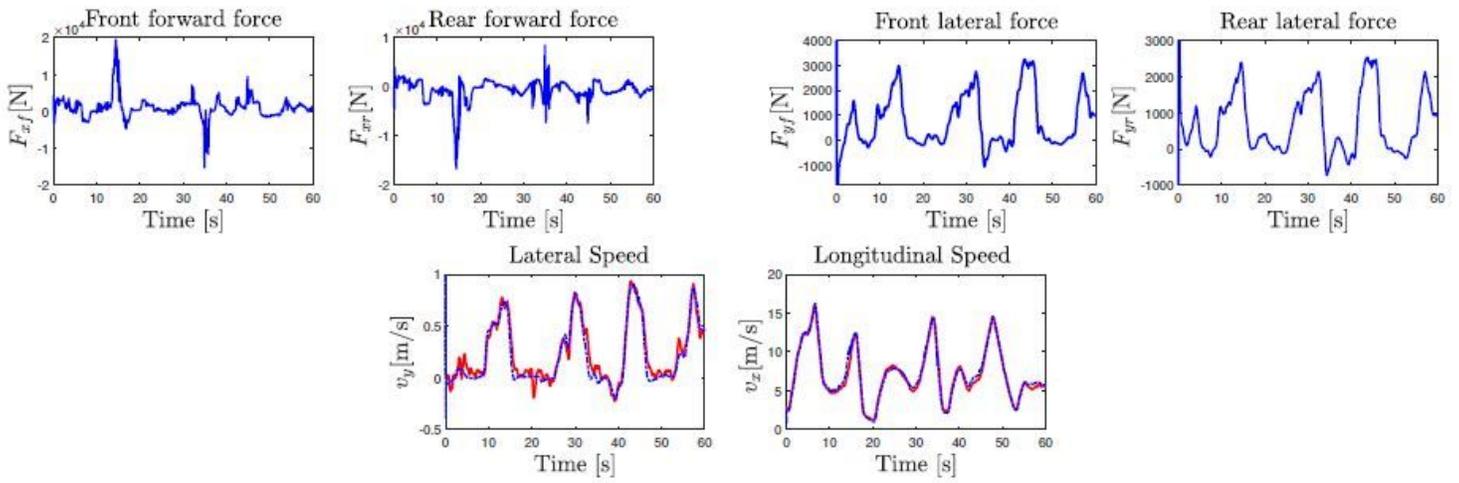


Figure 11

Estimation results and performance.

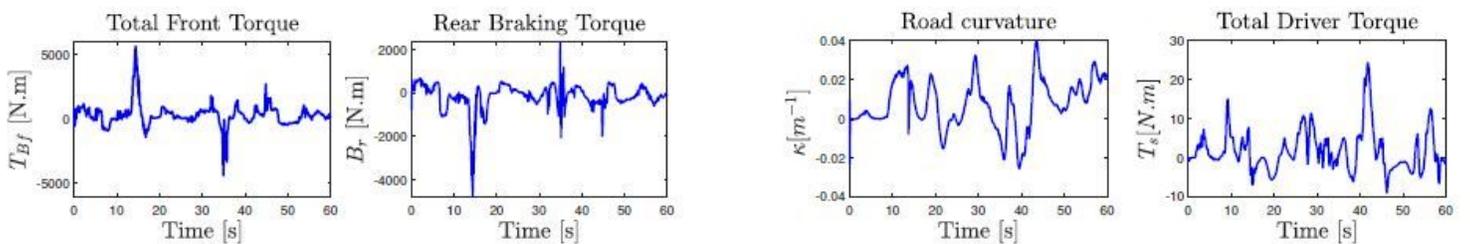


Figure 12

Unknown input reconstruction in LAMIH test track.

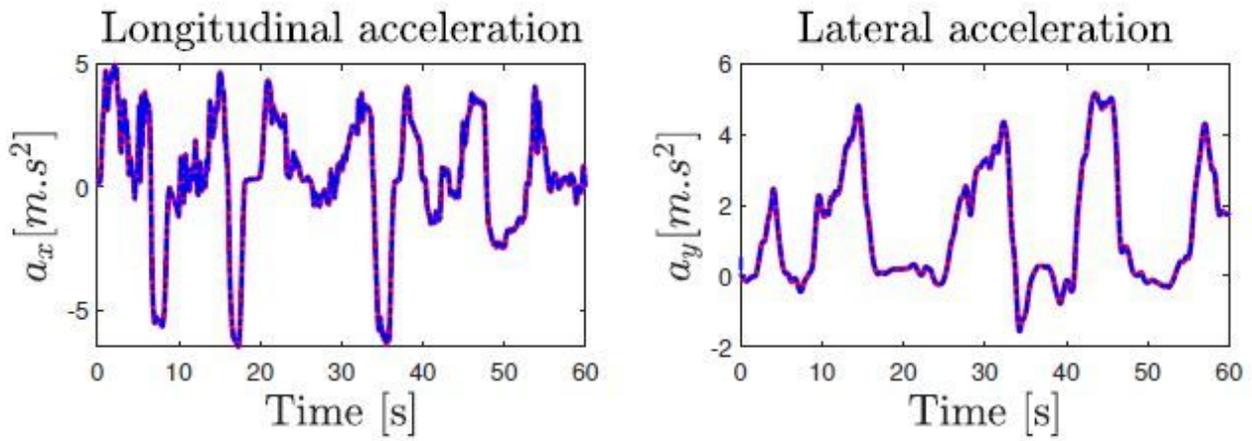


Figure 13

Validation performance for LAMIH test track.