Importance of motorcycle rider upper body movement for rider intention detection and motorcycle state prediction

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Enable future Advanced Rider Assistance Systems (ARAS)

- **Overall goal:** Reduce risk of powered-two-wheeler accidents to lower number of injured riders and fatalities
- **Possible approach:** ARAS warn, prevent or intervene in dangerous situations

➔ Knowledge of motorcycle behaviour and rider behaviour / intention needed

Three level model of the driving task according to DONGES [1]

- PhD project rider intention and situation detection
- Aims at algorithms for rider & motorcycle situation determination and behaviour prediction
- **Focus today:** Understanding of different rider inputs for cornering
  - Steer torque
  - **Rider roll torque**

[1] Donges, E. (2015). Driver Behavior Models. In: Winner, H., Hakuli, S., Lotz, F., Singer, C. (eds) Handbook of Driver Assistance Systems. Springer, Cham. https://doi.org/10.1007/978-3-319-09840-1_2-1

From handling to virtual riders

- Research on rider inputs for cornering started late 1970s
  - Aim: handling improvements
  - Conclusion: motorcycle as single input system → **steer torque only**
- Rider input behaviour analysed in context of riding skill evaluation
  - Conclusion: partially **contradictory observations**

- Virtual rider development of interest with improved simulation capabilities (2000s)
  - Conclusion: realistic **high performance riding** only with **rider weight transfer** (mostly via upper body lean and offset)

➔ **Rider upper body position** is the quantity of interest

Shortcomings:

- Multiple operating points (stationary and transient dynamics) combined with multiple riders in experimental test
- Timing analysis of rider inputs (= quantitative description of rider inputs pattern)
- Partially contradictory obervations in qualitative description of rider inputs pattern

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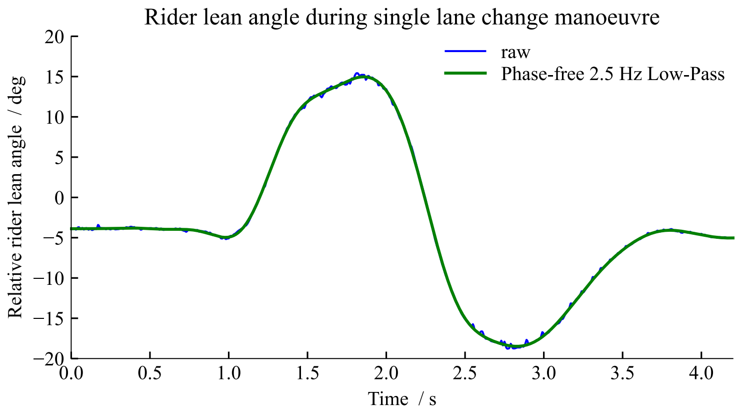
Sensing rider upper body position

- Rider upper body position via camera and **optical markers** (AprilTags [2])
- In-plane position accuracy:
  - 0.4 mm standard deviation
  - 10 mm spread (max. error)
- Rider lean angle error < 3 deg



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[2] J. Wang and E. Olson, “AprilTag 2: Efficient and robust fiducial detection,” in 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Daejeon, South Korea, 2016, pp. 4193–4198.

Sensing steer torque & defined test manoeuvres

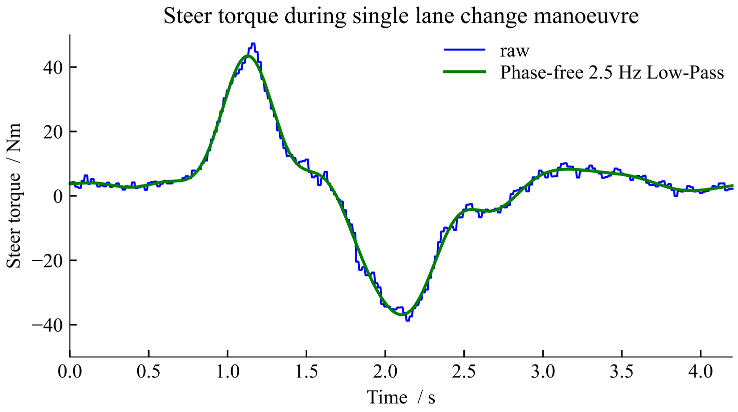
- Steer torque measurement via **strain gauges** on the handlebar
  - 1 Nm standard deviation (from straight running reference tests)

- Manoeuvres on test track ridden by 3 riders (no amateur, no expert riders)

TABLE I. DETAILS OF THE EXPERIMENTAL TEST MANOEUVRES

Manoeuvre	Geometries	Velocities
Constant cornering	Radius: 20, 25 m	20-50 km/h
Slalom	Cone spacing: 7, 14, 21 m	30-100 km/h
Lane change	Offset x Transition distance in m: 3.5 x 15, 3 x 20, 2 x 30 [a]	30-105 km/h

[a] Lane width of 1.5 m at the entry and exit of the lane change. Offset and transition geometry are repeated 2 m after the first lane change back to the original lane for double lane change manoeuvres. The geometries are types “TÜV slow”, “MDRG Touring” and “TÜV fast” from the publication by COSSALTER AND SADAUCKAS [17].



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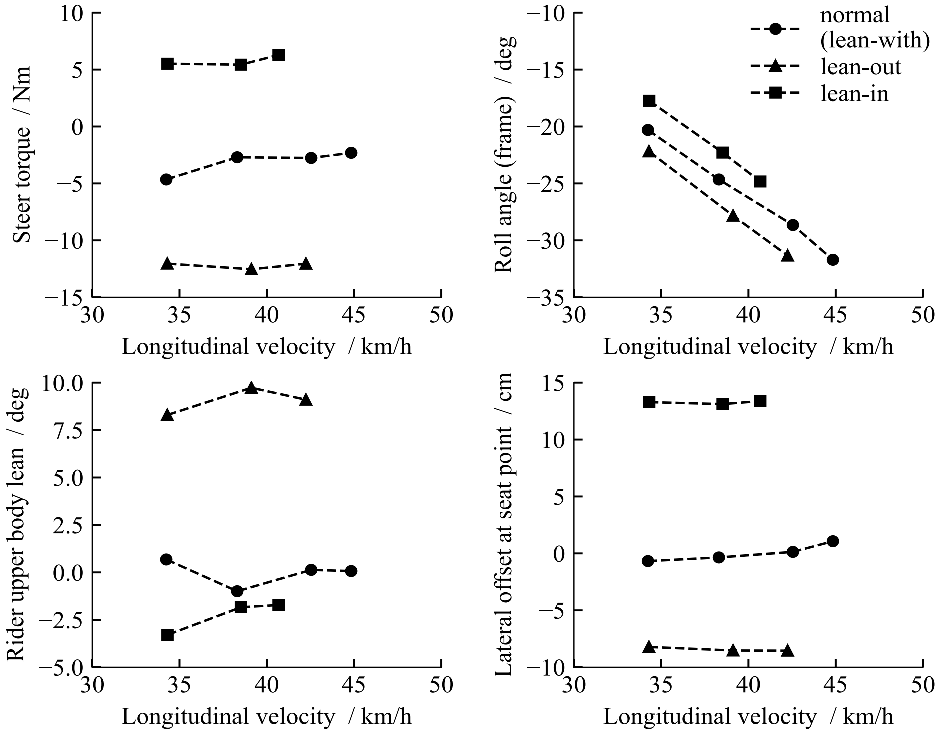
Rider movement influence on stationary cornering

- Constant cornering on R=25 m skid pad
- 1 rider doing **conscious changes of upper body position**: lean-with, lean-out, lean-in
- Conclusions:
  - **Steer torque demand significantly altered** by different rider upper body positions
  - State prediction based on steer torque in stationary cornering only feasible with rider upper body position information



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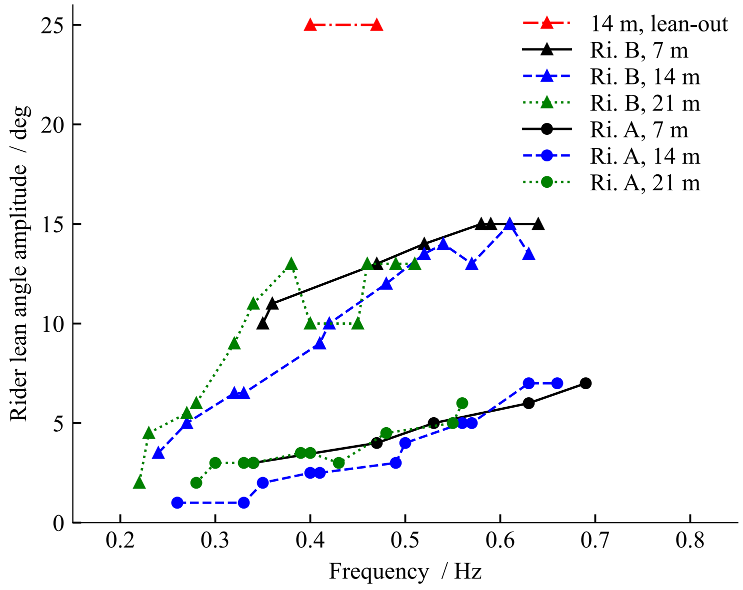
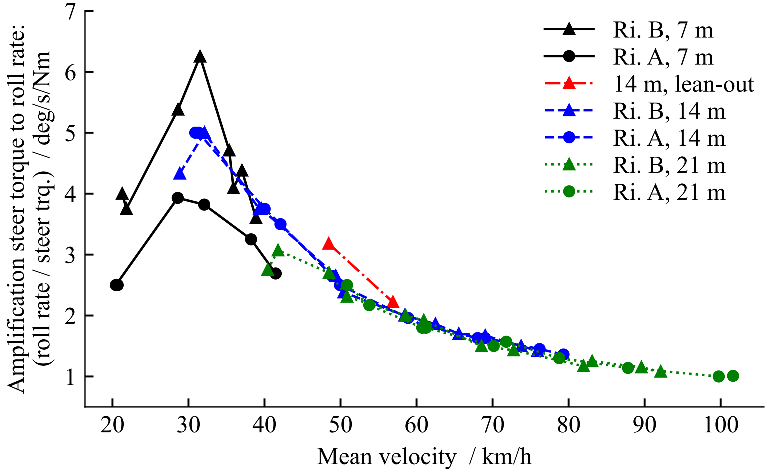
Rider movement influence on transient lateral dynamics

- Two riders with different riding styles doing multiple **slalom** runs + 2 intentional high lean-out runs



- Conclusion: **Rider movement** influence on steer torque amplification is **negligible above 60 km/h**



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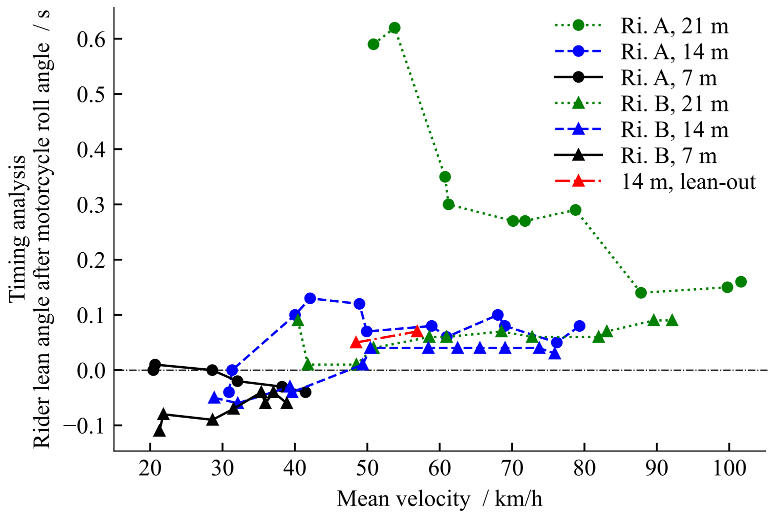
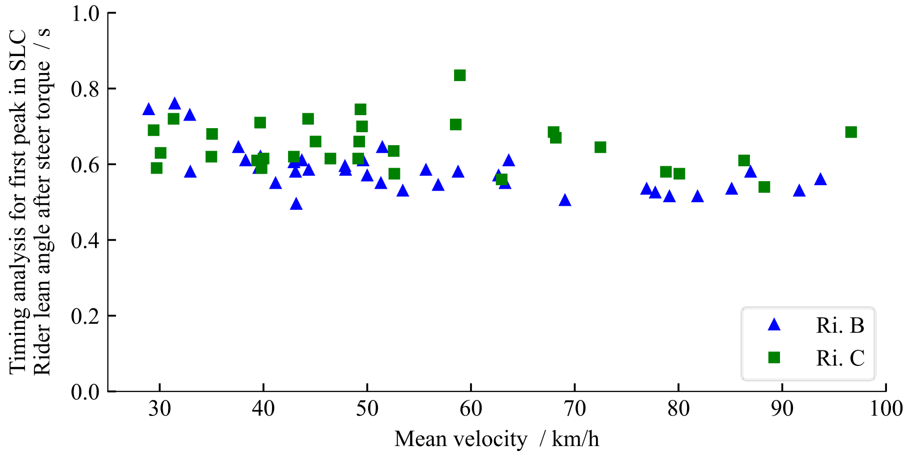
Timing of rider lean input during transient manoeuvres

- Only **reactive rider lean** compared to roll angle above 50 km/h in the slalom tests
- Check reactive lean behaviour on realistic single lane change manoeuvres





- Conclusion: **Rider lean** movement is **reactive**, no „input“ ➔ no direct predictor for upcoming manoeuvre

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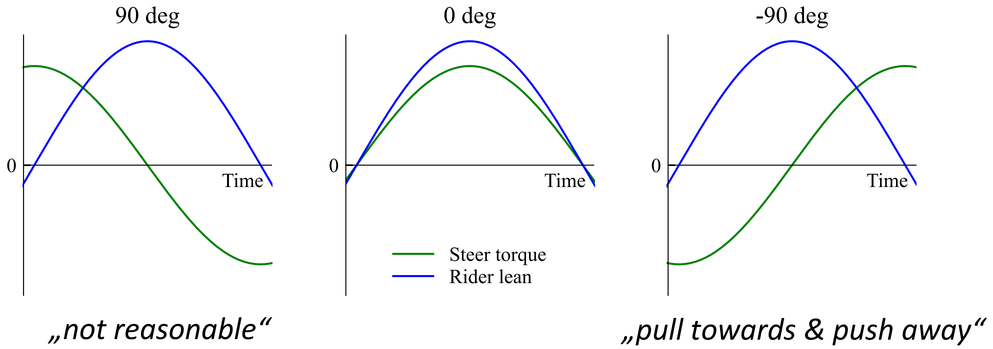
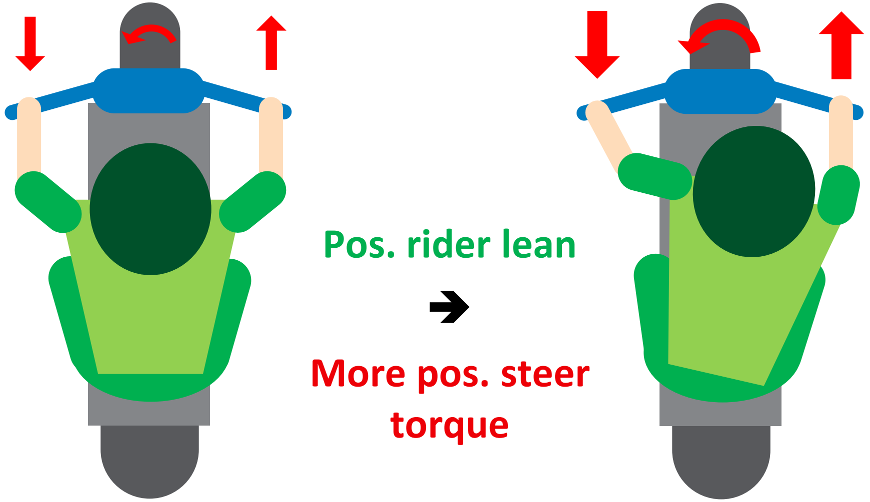
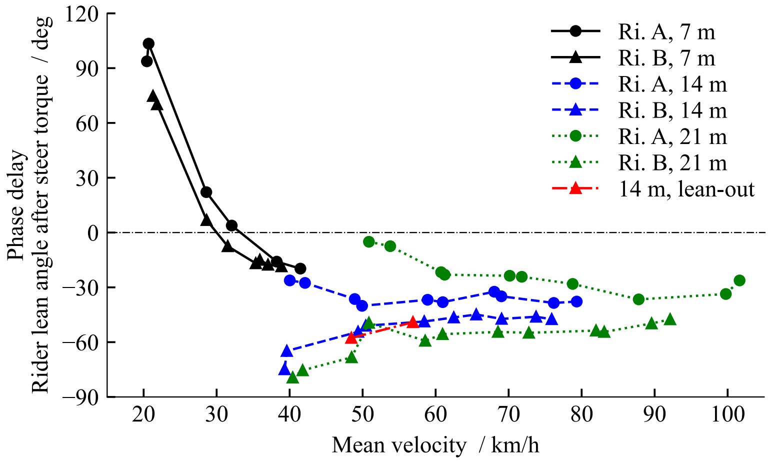
Physiological explanation for rider movement timing

- Hypothesis: upper body lean angle influences **physiological effort** to apply certain **steer torque** at the handlebar
- Phase delay between steer torque and rider lean angle analysed in slalom







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Summing up & Outlook

- Steer torque significantly altered in stationary cornering by rider upper body position
  - ➔ **Rider upper body position needed** for state prediction based on steer torque **in stationary cornering**
- **Transient** lateral transfer **behaviour not changed above 60 km/h** by upper body movement
- **Rider lean** movement is **reactive**
  - ➔ No direct predictor for rider intention
- Riders lean opposite to the motorcycle‘s roll for comfort and control, **lean timing** choosen **for low steer effort**

Hypothesis for further research on rider upper body movement:

- Typical **rider** upper body **movement patterns** exist that are indication of rider intention
  - ➔ Extensive measurements in real road traffic targeted

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