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Entwicklung eines Motorradfahrendenmodells zur Trajektorienprädiktion

Development of a motorcyclist model for trajectory prediction

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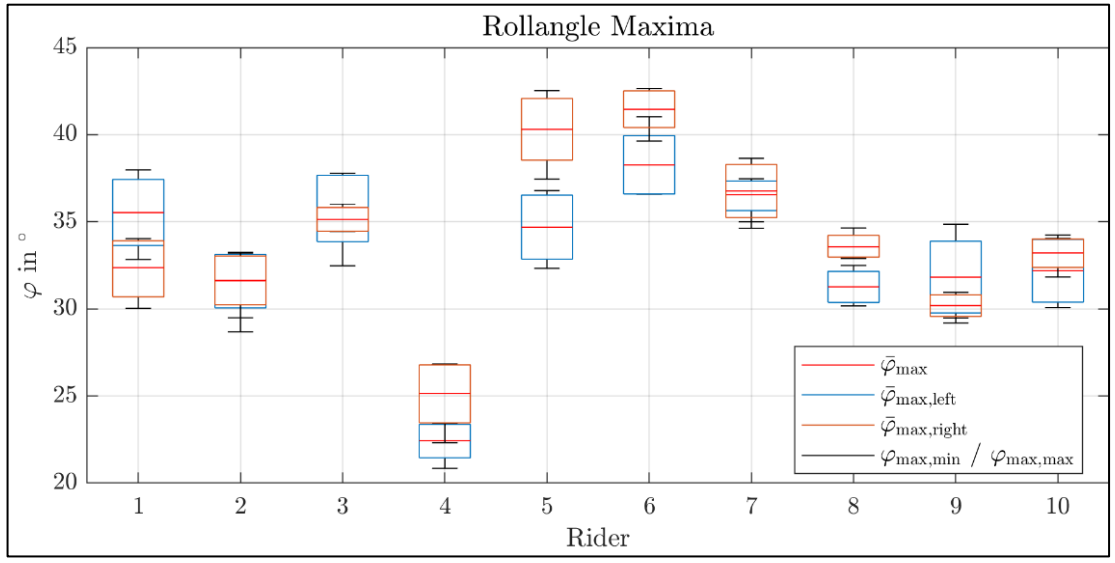
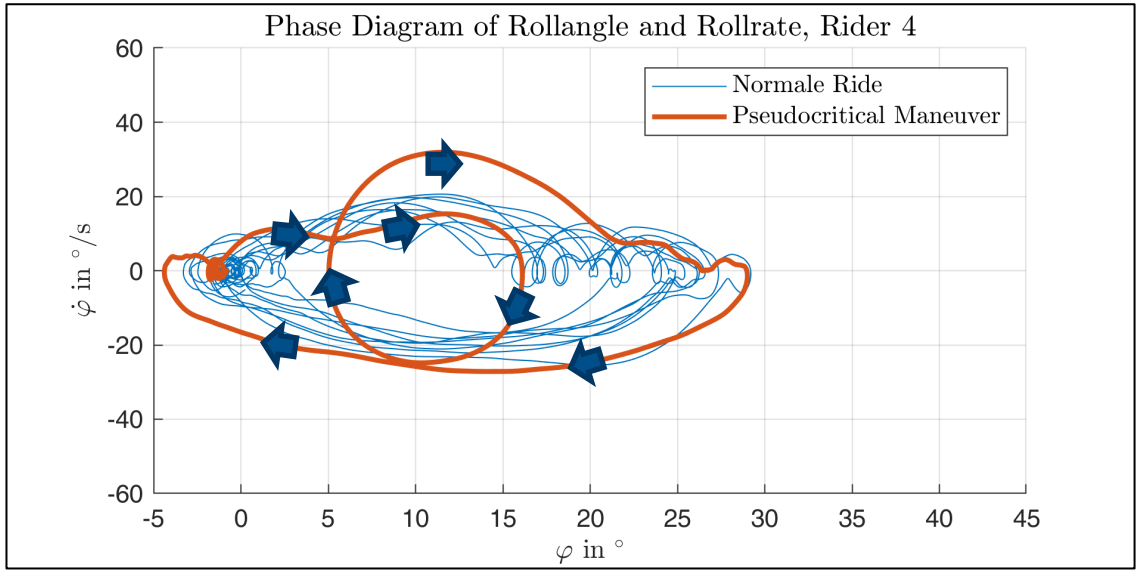
Motivation: Comfort Roll Angle and Maneuver-Based Behaviour





[1]

Motivation: Statistical Rider Skill and Fear

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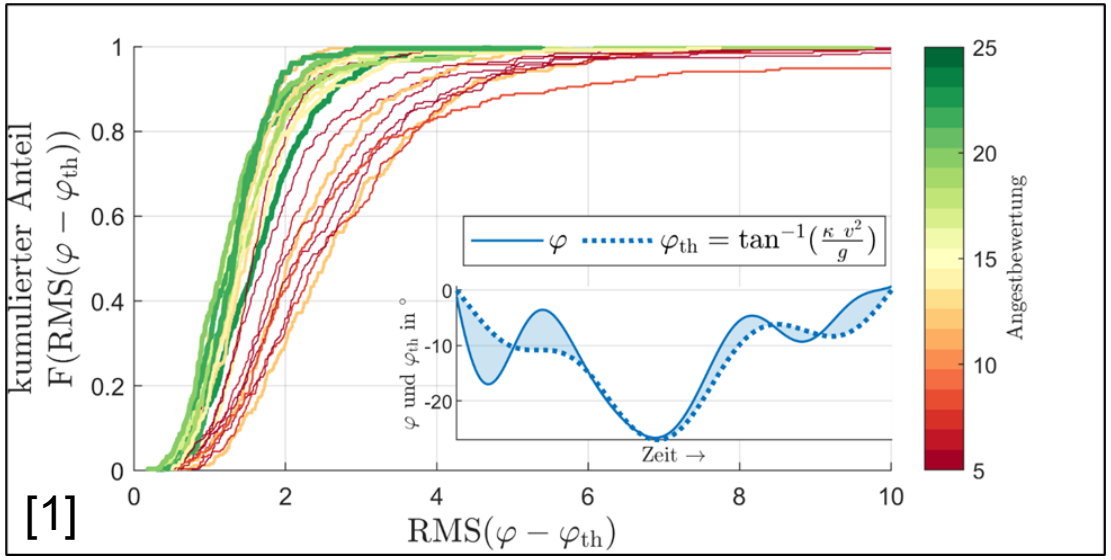
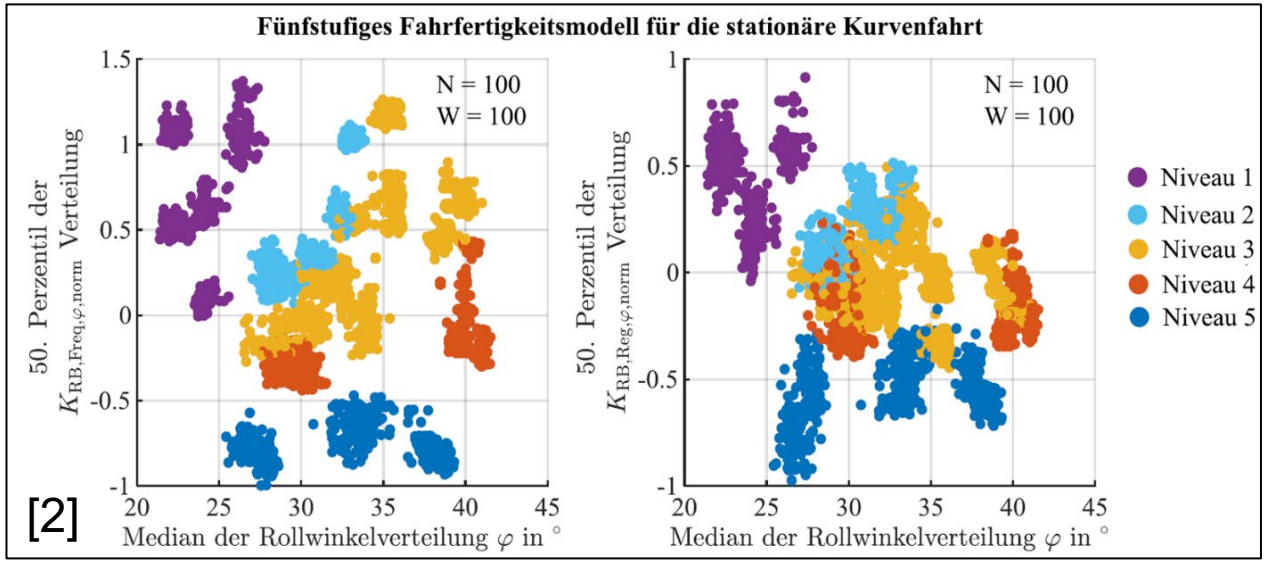
Cornering Fear

- Correlation between cornering fear rating and chosen line
- Higher fear rating leads to more direct line

Riders Skill

- Statistical difference between different rider skill levels
- Grouping of five rider level skills during rural riding possible





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Rider Model for Trajectory Prediction

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Research Question:

Is it possible to model and predict the future state of a motorcycle on the basis of recorded vehicle dynamics data, taking into account specific rider influences, without presupposing knowledge of fixed vehicle parameters?

Requirements

- **Respecting rider-specific limits**
- **Interpretability of parameters**
- **No vehicle parameter knowledge**

Rider Model & Position Calculation / Trajectory Prediction

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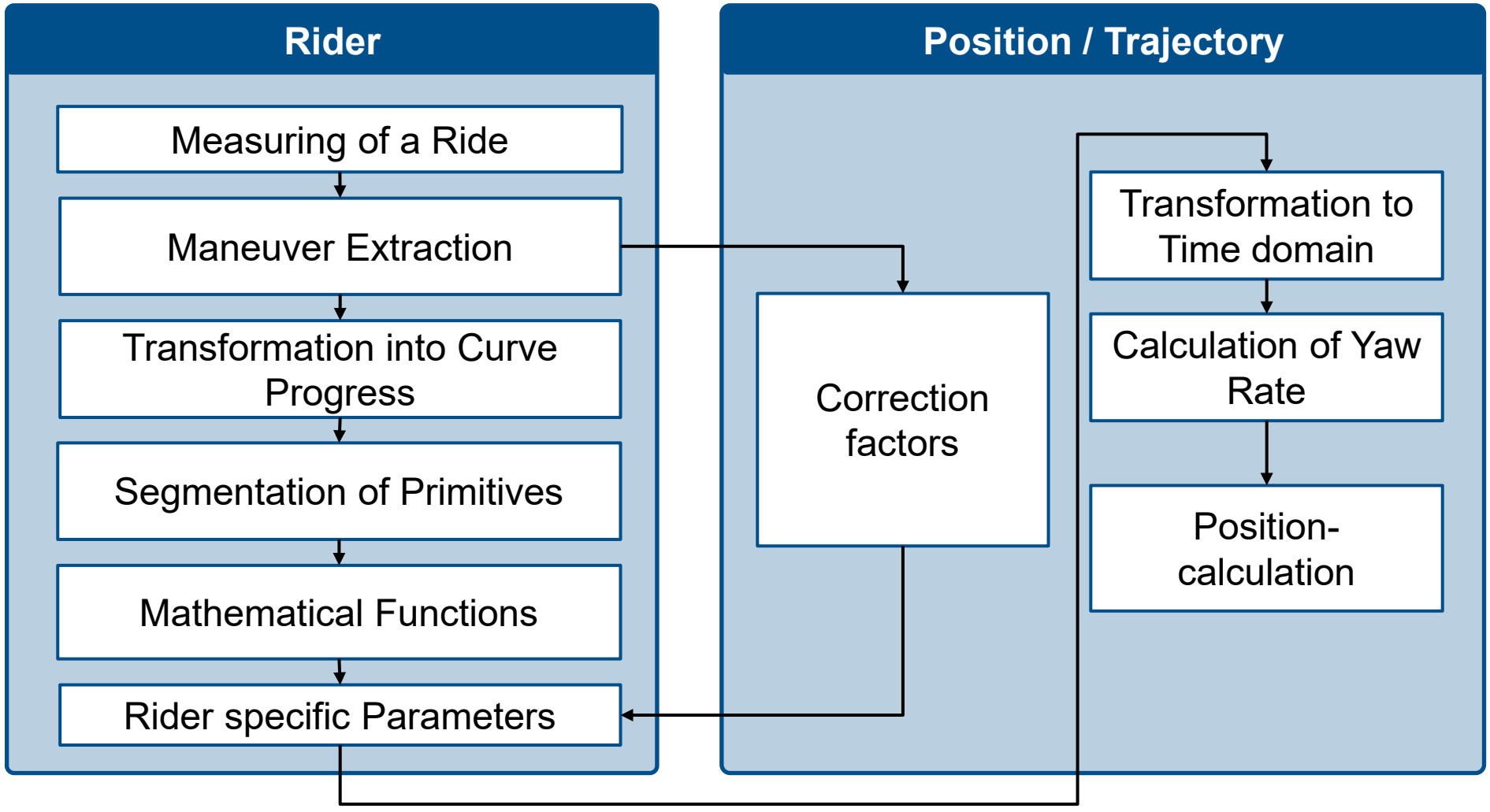

Rider Model – Measured Data & Maneuver

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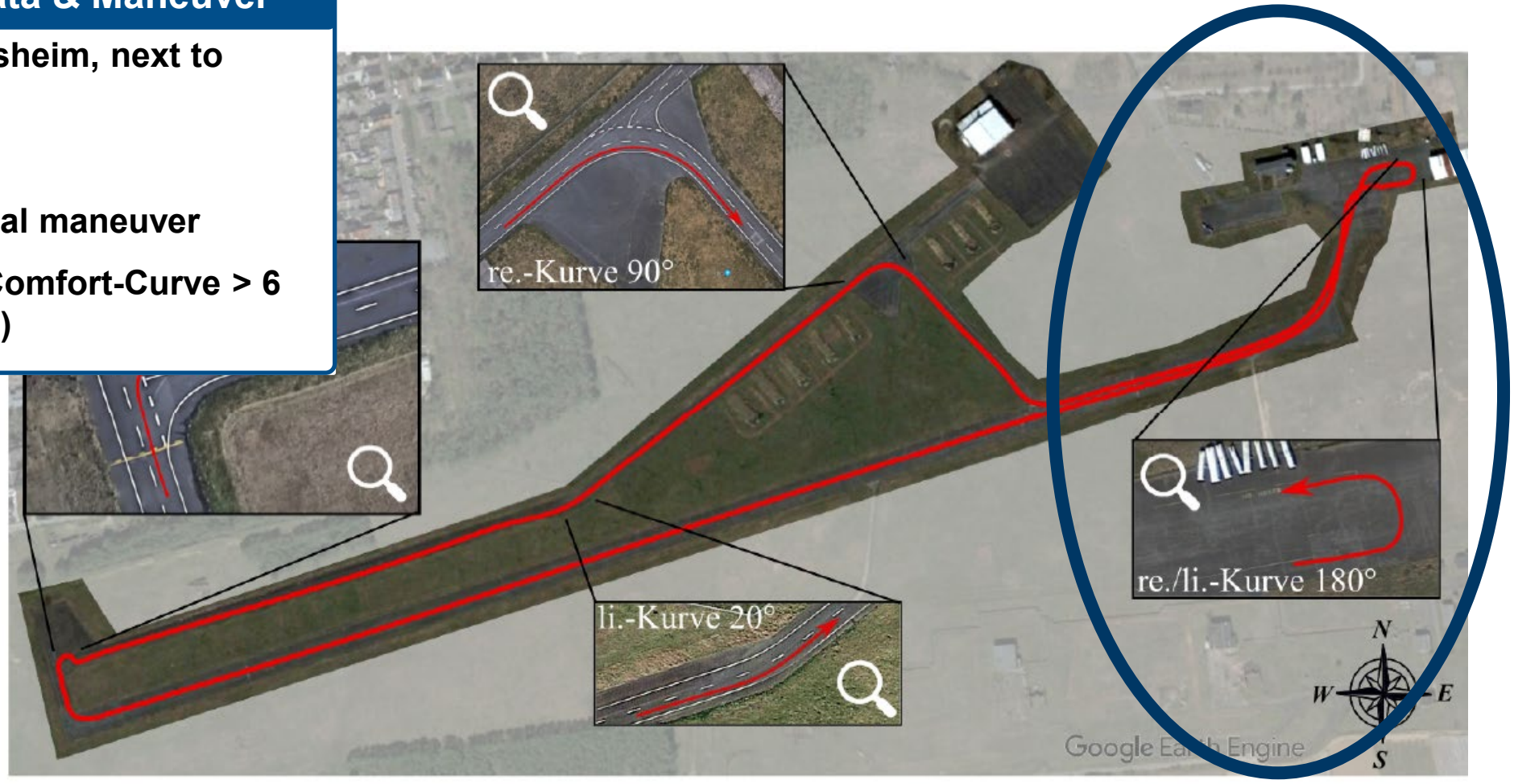
Rider

- Measured Data
- **Maneuver**
- Curve-Progress
- Segmen-tation
- Math. Functions
- Rider-parameter

Measured Data & Maneuver

- **Airfield Griesheim, next to Darmstadt**
- **10 Rider**
- **Pseudocritical maneuver**
- **Every 180°-Comfort-Curve > 6 Times (turns)**



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Rider Model – Curve Progress & Maneuver Segmentation

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Rider

- Measured Data
- Maneuver
- Curve-Progress
- Segmen-tation
- Math. Functions
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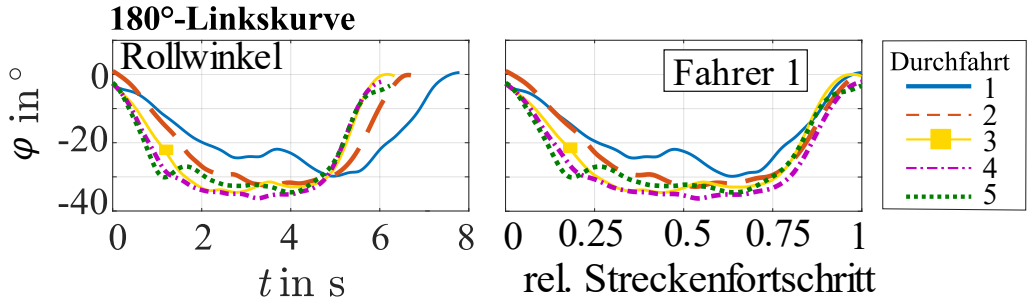
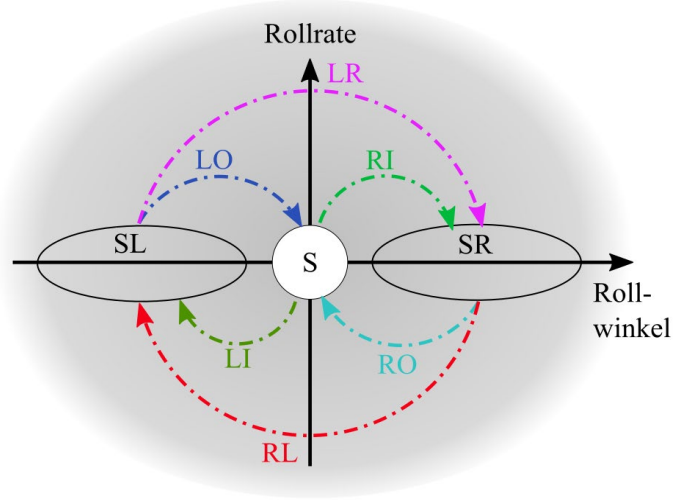
Curve Progress

- **Time Domain: Comparison of different rides through same curve difficult**
  - ➢ **Transformation into curve progress**
  - ➢ **Starting with 0 %, Ending with 100 %**



Maneuver Segmentation

- **Every curve consists of the same primitives**
- **Segmentation via rollangle**
- **Differentiation into:**
  - **Dynamic Primitives (RI, RL, LO, RO)**
  - **Stationary Primitive (SR, SL)**



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Rider Model – Dynamic Primitives

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Rider

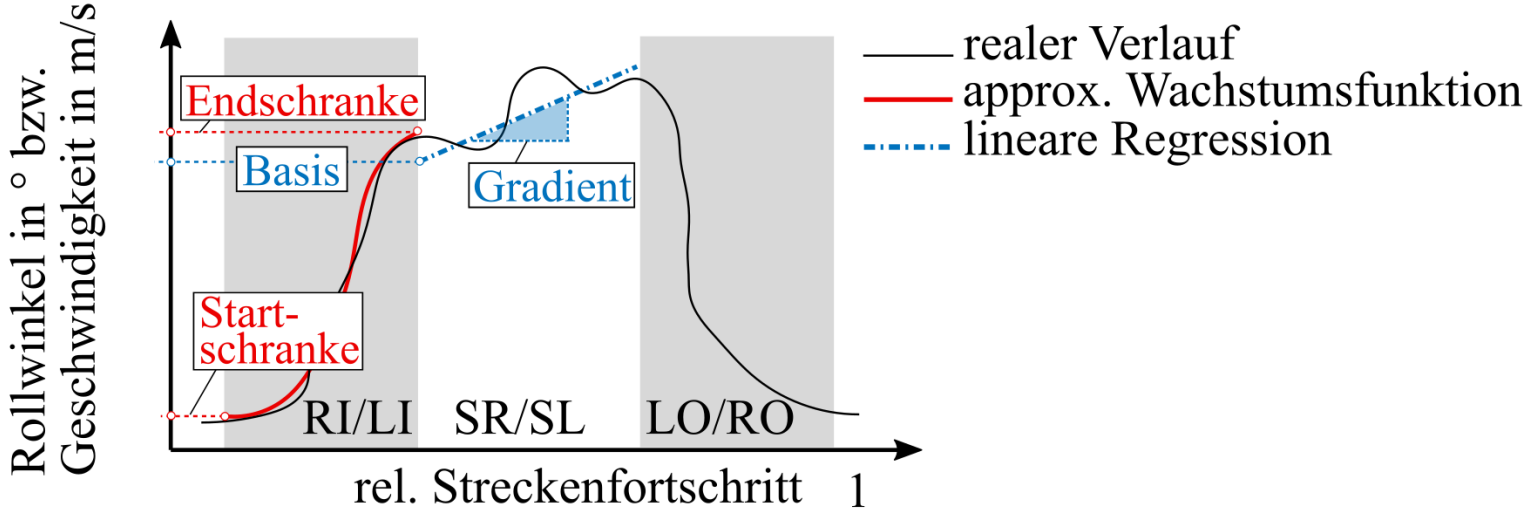
- Measured Data
- Maneuver
- Curve-Progress
- Segmen-tation
- **Math. Functions**
- Rider-parameter

Mathematical Functions

Dynamic Primitives (RI, LI, RO, LO)

- **Logistic Growth Function**
- **Overlaid Sine Function**

$$f(x) = vz \cdot \left(\frac{a \cdot c \cdot e^{b \cdot x}}{c + a \cdot (e^{b \cdot x} - 1)} + d \right) + \tilde{a} \cdot \sin\left(2\pi \cdot \tilde{f} \cdot (x + \tilde{l})\right)$$



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Rider Model – Stationary Model

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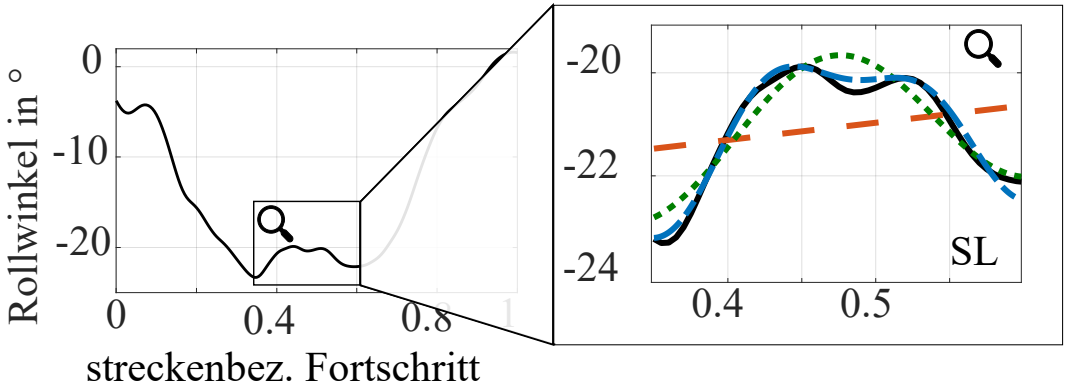
Rider

- Measured Data
- Maneuver
- Curve-Progress
- Segmen-tation
- **Math. Functions**
- Rider-parameter

Mathematical Functions

Stationary Primitive (SR, SL)



Rollwinkelverlauf

$base + g \cdot x$

$\ldots + \tilde{a}_1 \sin(2\pi \tilde{f}_1 (x + \tilde{l}_1))$

$\ldots + \tilde{a}_2 \sin(2\pi \tilde{f}_2 (x + \tilde{l}_2))$

➢ **18 interpretable coefficients for dynamic and stationary primitive**

Rider Specifity – Rollangle & Velocity

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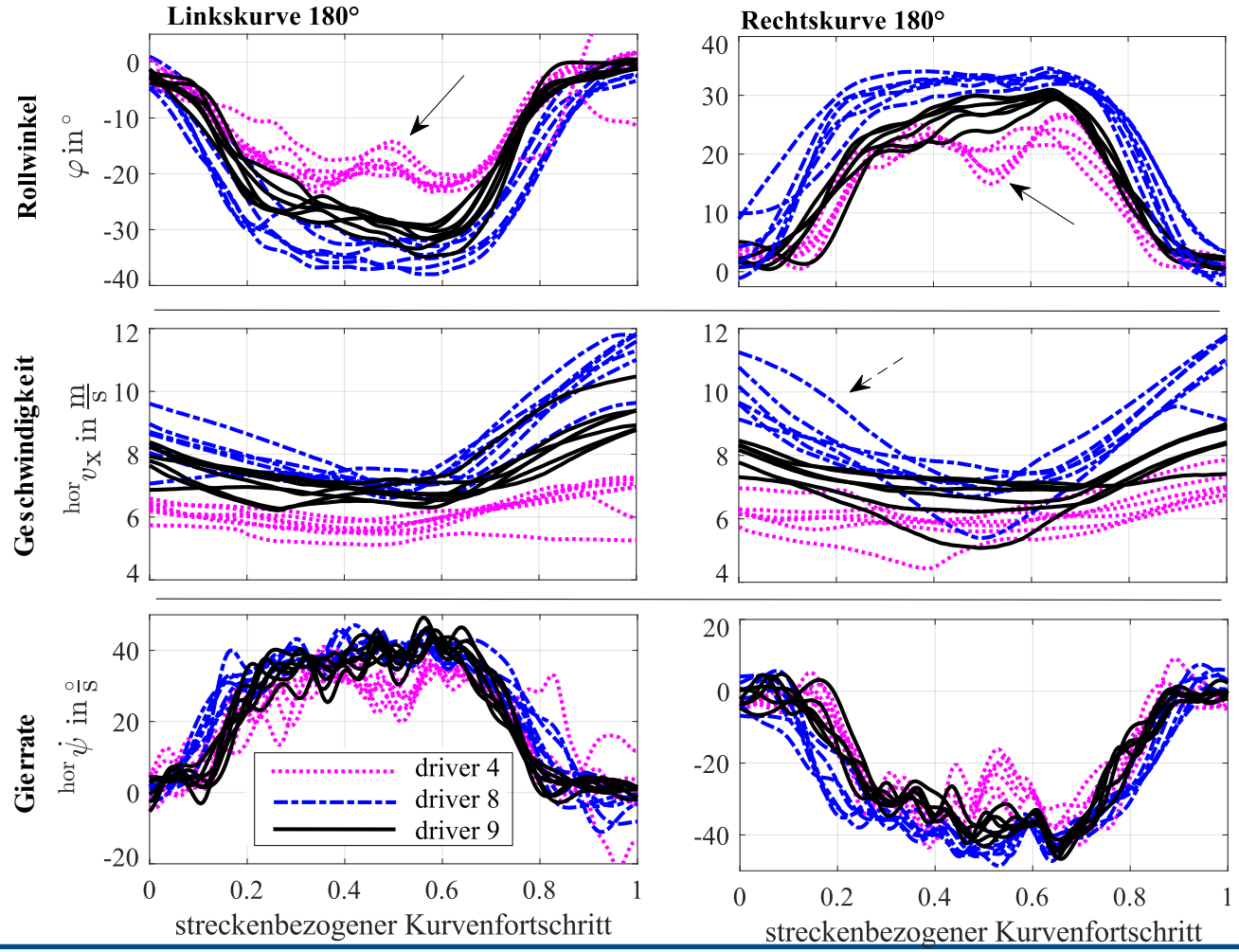
Rider

- Measured Data
- Maneuver
- Curve-Progress
- Segmen-tation
- Math. Functions
- Rider-parameter



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Rider Specifity – Rollangle & Rollrate Phase Diagram

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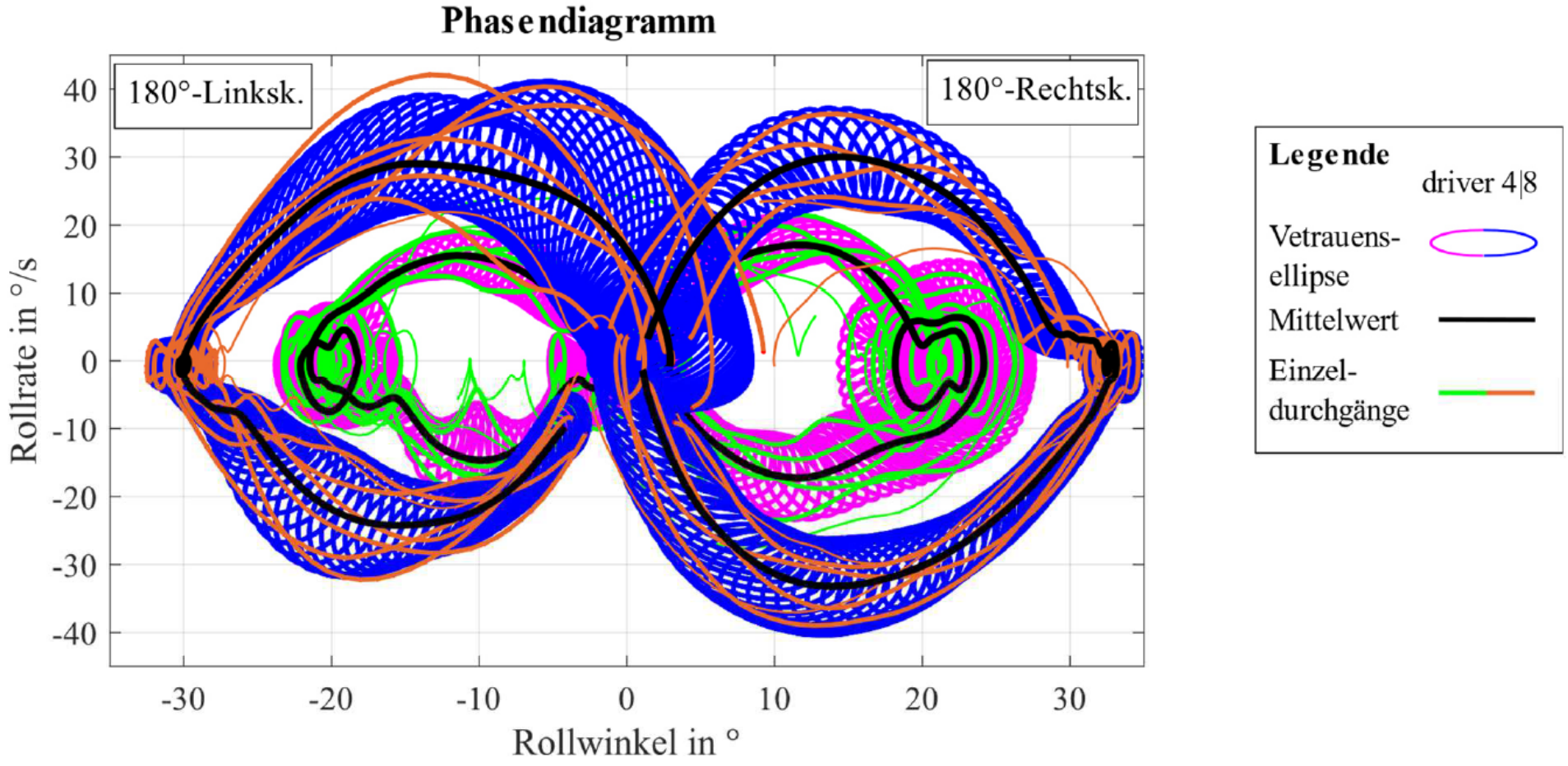
Rider

- Measured Data
- Maneuver
- Curve-Progress
- Segmen-tation
- Math. Functions
- Rider-parameter



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Rider Parameter – Rider Specifity

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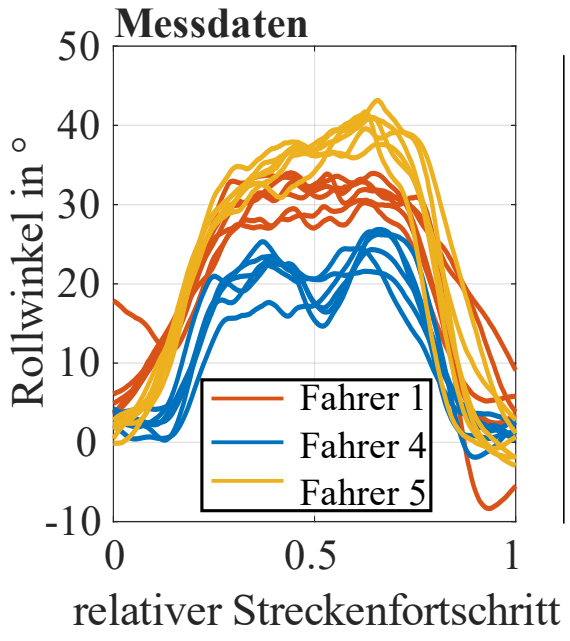
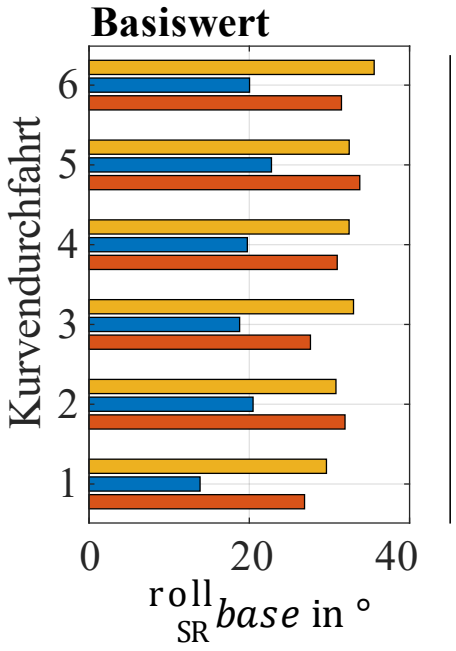
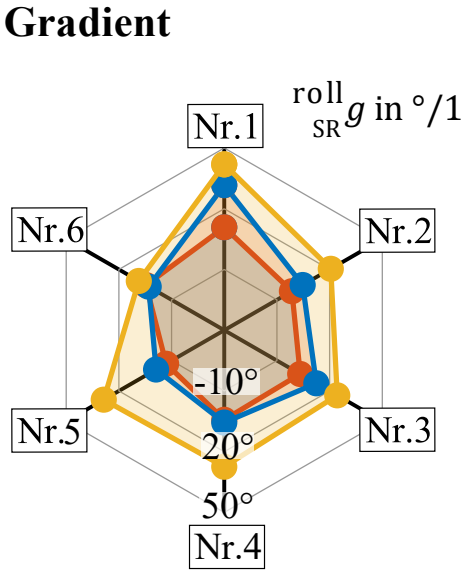
Rider

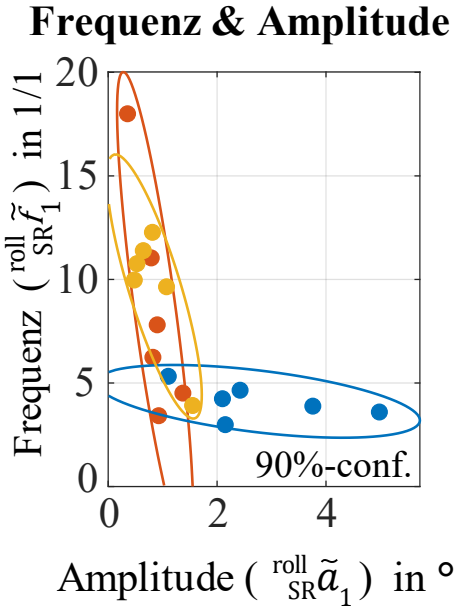
- Measured Data
- Maneuver
- Curve-Progress
- Segmen-tation
- Math. Functions
- Rider-parameter

Rider Parameter| 180°-Right Curve | Rollangle









- **Rider specifity is included in dynamic coefficients**
- **Velocity parametrisation same way as with rollangle**

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Position / Trajectory - Summery

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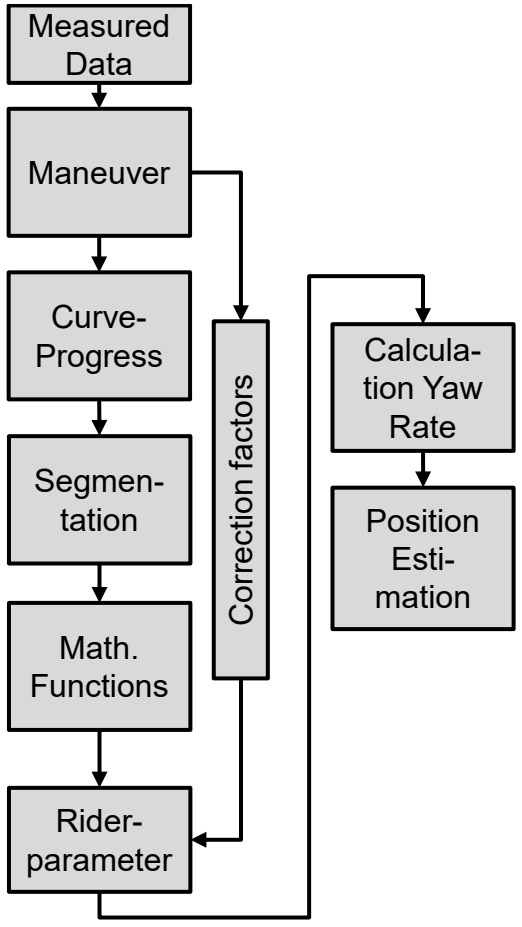
Model Overview



Short Summary & Approach for Trajectory Prediction

- **Roll angle & speed characteristics are rider-specific and describable**
- **Unknown Vehicle Parameters**
  - ➢ **Use of the relationship of stationary cornering**
  - ➢ **Need for dynamic correction**

$$ {}^{\mathrm{e}}\begin{pmatrix} x \\ y \end{pmatrix}_{i+1} = {}^{\mathrm{e}}\begin{pmatrix} x \\ y \end{pmatrix}_{i} + {}^{\mathrm{hor}}v_{x_i} \cdot \Delta t \cdot \begin{pmatrix} -\sin\left(\psi_i + {}^{\mathrm{hor}}\dot{\psi}_i \Delta t\right) \\ +\cos\left(\underbrace{\psi_i + {}^{\mathrm{hor}}\dot{\psi}_i \Delta t}_{\psi_{i+1}}\right) \end{pmatrix} $$

Position / Trajectory – Yaw Rate Estimation

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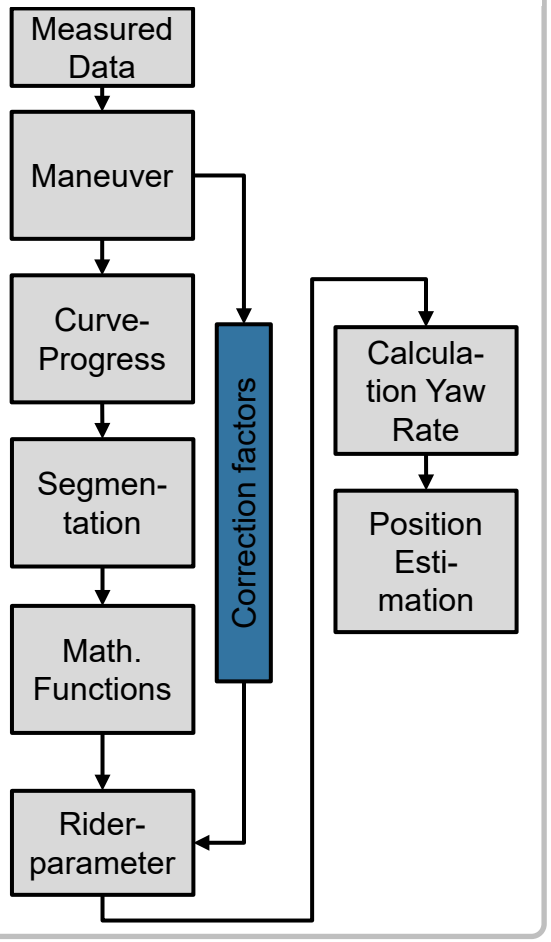
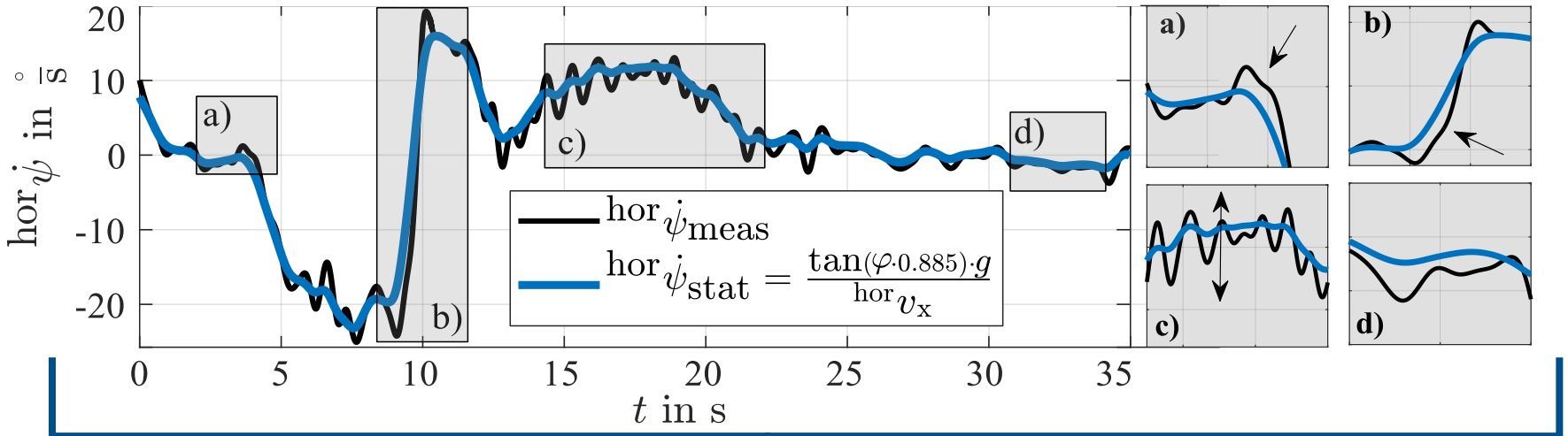
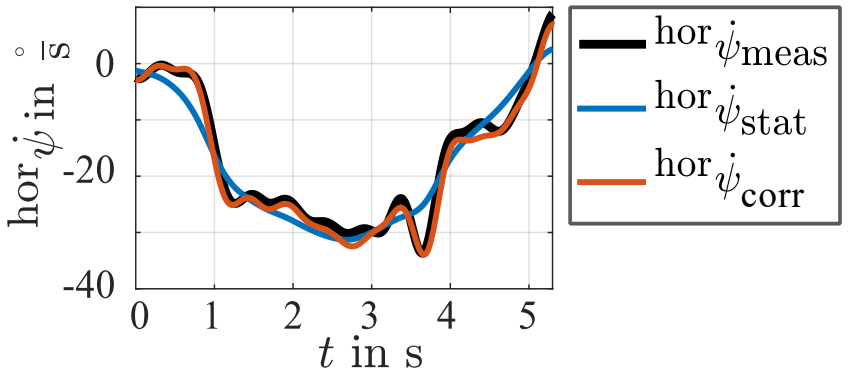
Model Overview





$$\mathrm{hor}\dot{\psi}_{\mathrm{corr}} = f(\mathrm{hor}\dot{\psi}_{\mathrm{stat}}, \mathrm{hor}\ddot{\psi}_{\mathrm{stat}}, \mathrm{hor}\dddot{\psi}_{\mathrm{stat}})$$



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Position / Trajectory – Position Estimation

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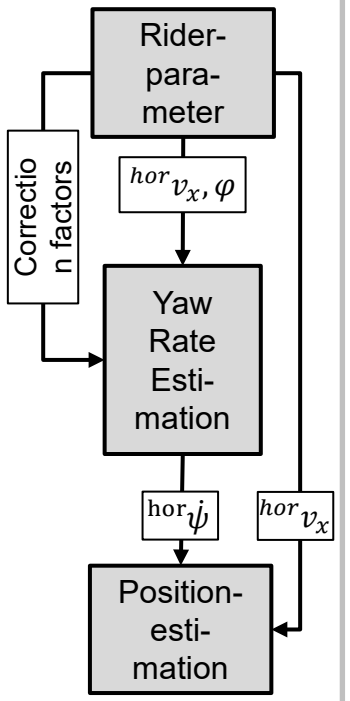
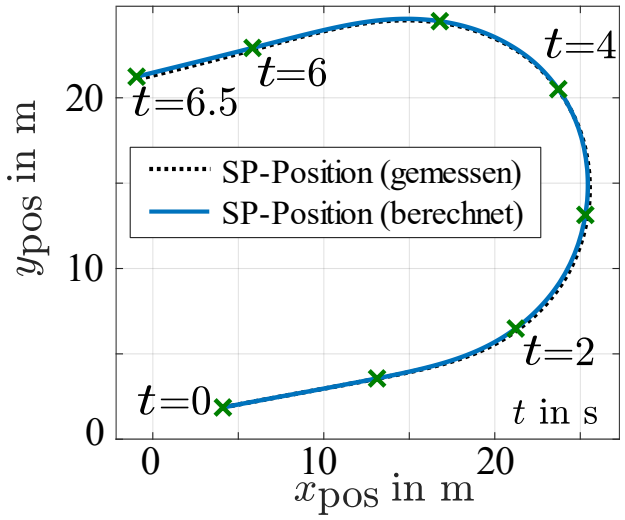
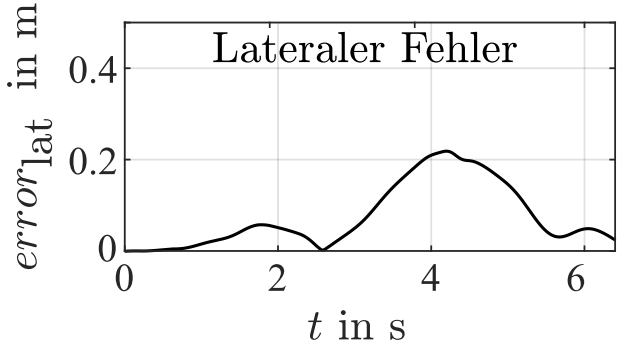
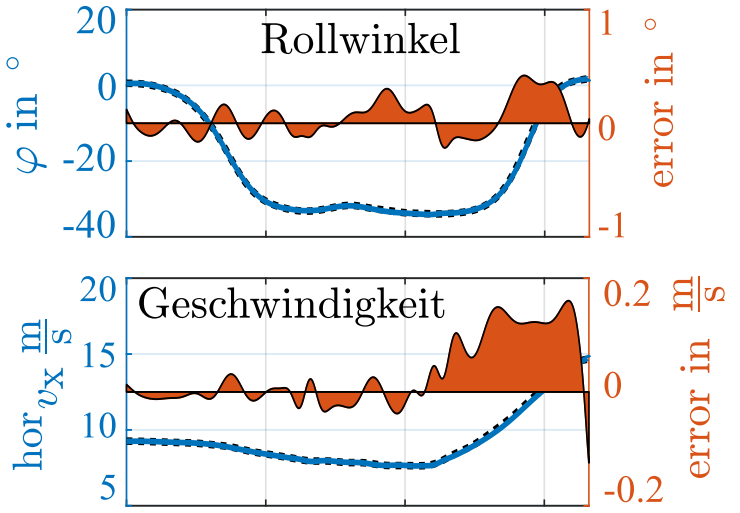
Position

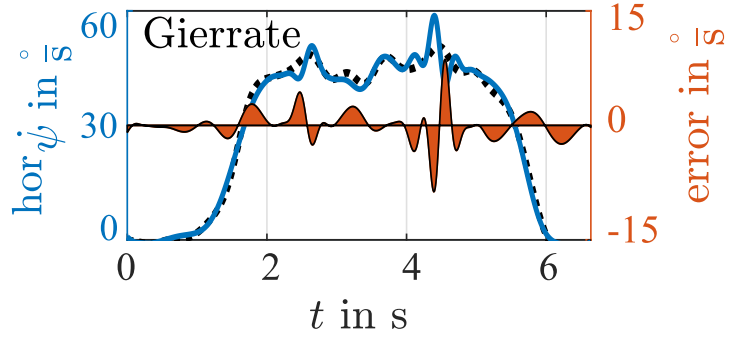


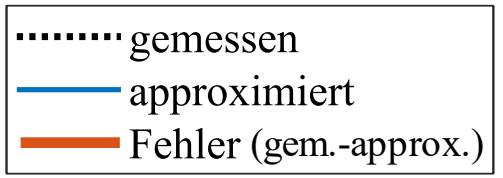
Position Estimation











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Position / Trajectory – Error

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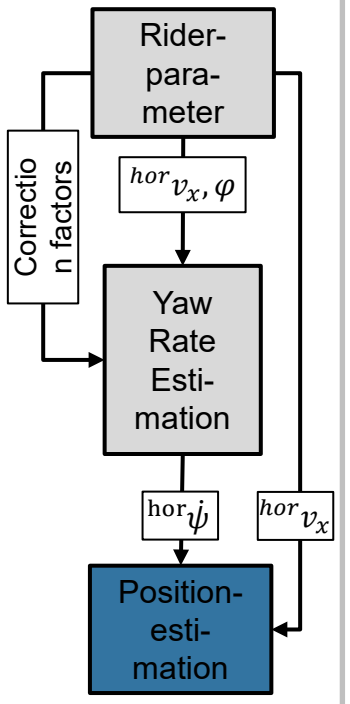
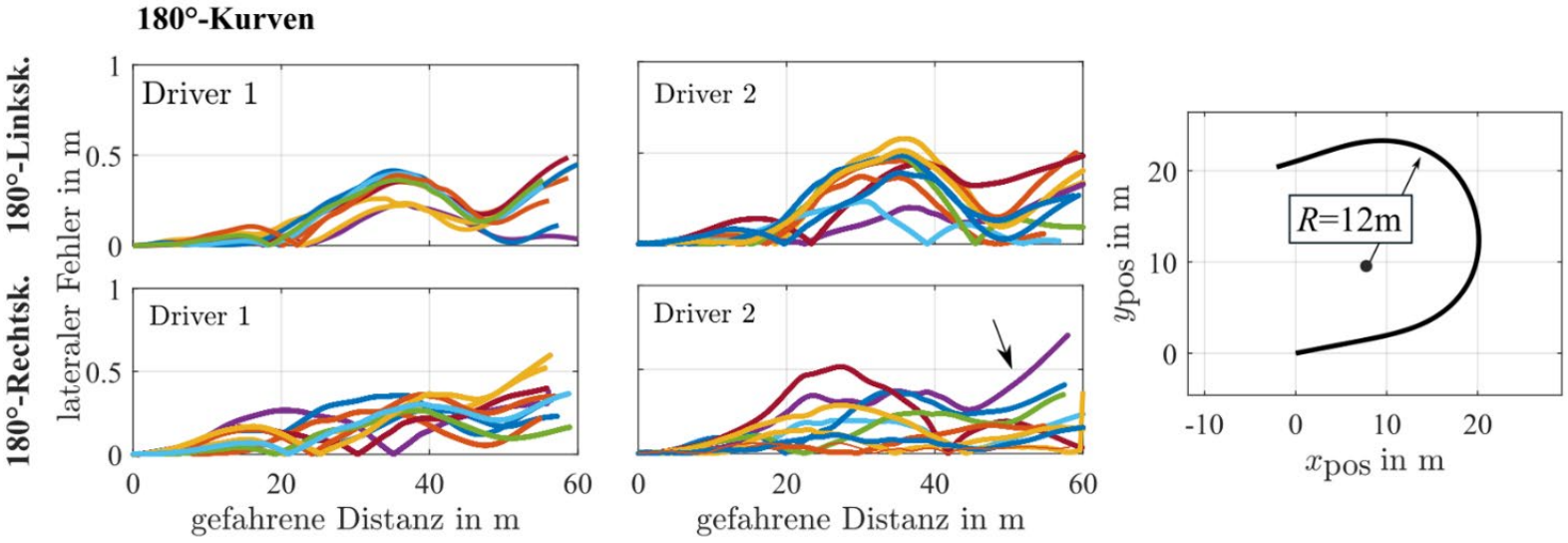
Position



Gesamtgenauigkeit | Manöverübersicht



- **Accuracy depends on rider and maneuver**
- **Rel. lateral error for 97% of the runs < 0,5m**

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Conclusion and Outlook

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Conclusion

- Simple and interpretable description of motorcycle dynamics data possible
- Rider specific parameters found in rollangle and velocity data
- Position estimation and trajectory prediction with these parameters possible

Outlook

- Optimisation of the approach functions of the velocity signals
- Recalculation after certain time
- Real world validation

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Thank You!

Questions?

Sources

[1] Pleß, R.; Will, S.; Neukum, A.; Scherer, F.: *Untersuchung der Existenz einer Schräglagenschwelle bei Motorradfahrer*innen*, Proceedings oft he 13th International Motorcycle Conference 2020, Institute for Motorcycle Safety e. V. (2020)

[2] Magiera, N.: *Identifikation des Fahrfertigkeitsniveaus von Motorradfahrern in Kurvenfahrt im Realverkehr*, Dissertation, TU Darmstadt (2020)

[3] Basten, T.: *Konzeption und Bewertung eines Modells zur Prädiktion von Motorradfahrdynamikdaten mit Berücksichtigung des Fahrereinflusses*, Masterthesis, TU Darmstadt (2021)


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DURCH VERSTÄNDNIS