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FROM TPMS TO SMART TIRE TECHNOLOGY

Estimating the tyre operating conditions and performance capabilities | Dr. Antoine Schmeitz

TNO innovation for life

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- Smart tires
- Tire force estimation
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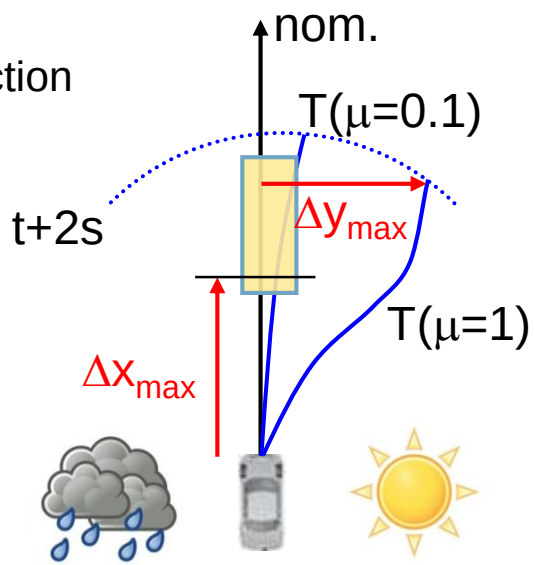
VEHICLE AUTOMATION AND TIRES

- Vehicle capabilities determined by tyre-road friction potential (braking, steering)
- For safe automated driving, real-time friction potential estimation is required
- Challenges:
  - Estimate tire-road friction in normal driving
  - Also at t+Δt s
  - Deal with inhomogeneous vehicles and bad weather conditions



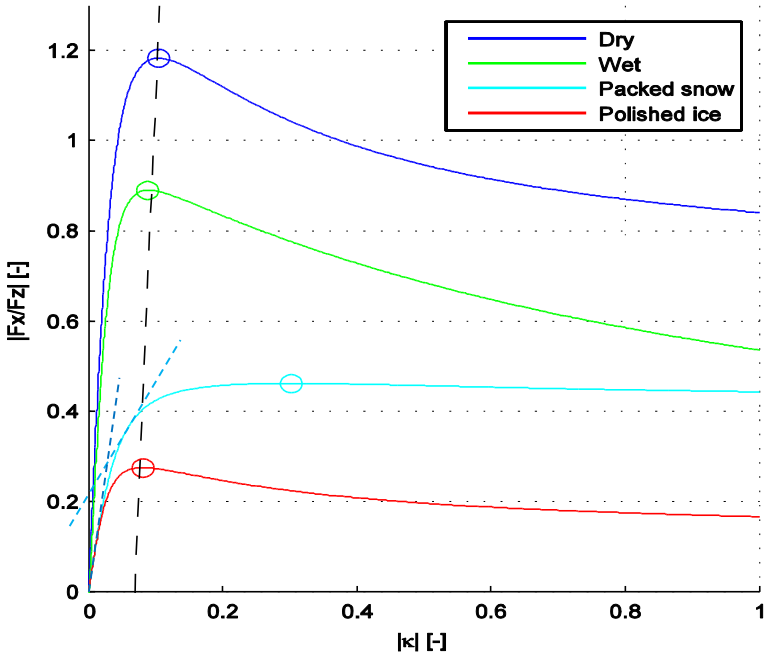
Cooperative Adaptive Cruise Control (C-ACC)

EU ministers to try out self-driving cars – April 2016

European Truck Platooning Challenge – April 2016

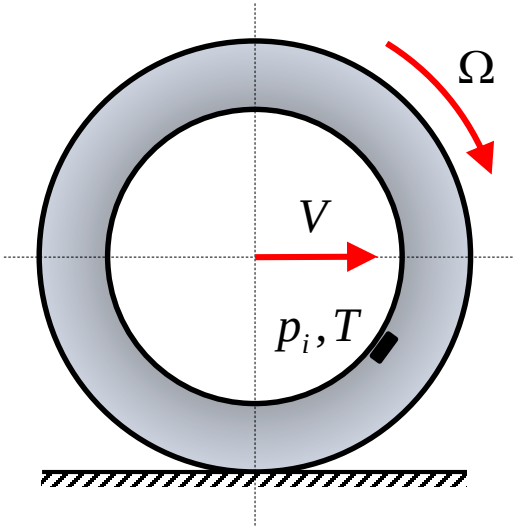
SLIP-BASED TYRE-ROAD FRICTION ESTIMATION

- Basic idea:
  - slope of tire slip characteristic:
    - reduces to zero when reaching the peak friction
    - many measurements show relation slip stiffness (slope at zero slip) and peak friction
- So:
  - measure forces and slip
  - consider additional information:
    - tire inflation pressure, temperatures, …
  - estimate the peak friction

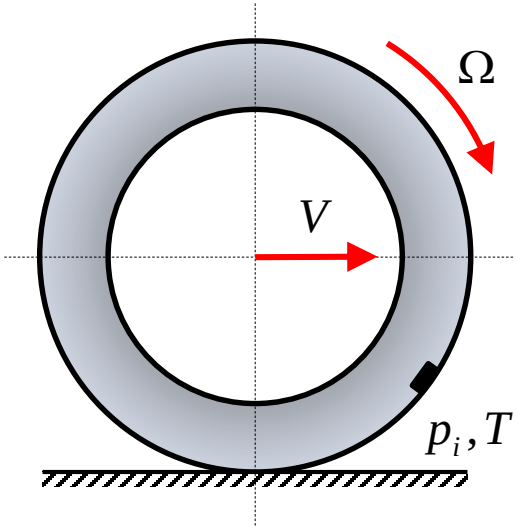


slip

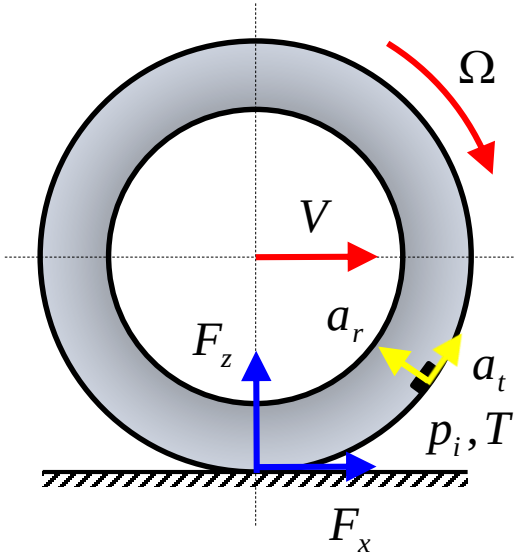
FROM TPMS TO SMART TIRE



- Tire Pressure Monitoring System
- On valve or rim



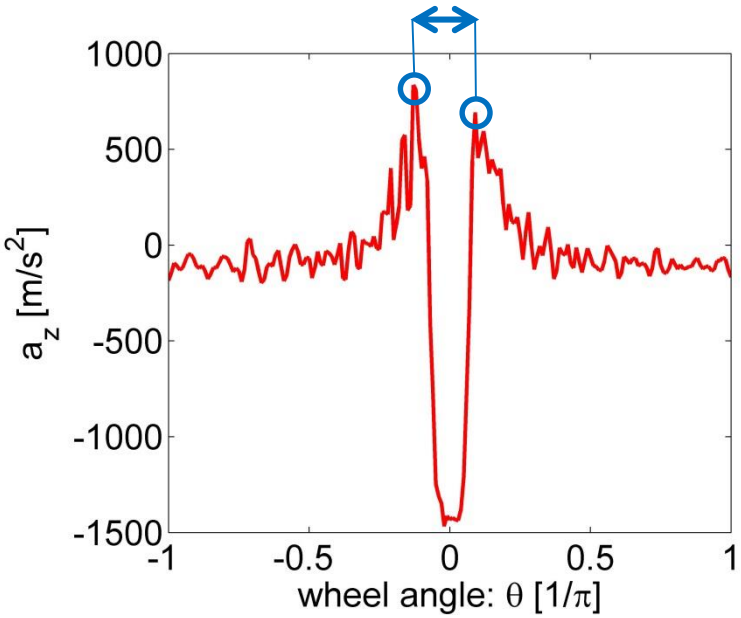
- Tire Pressure Monitoring System
- On inner liner



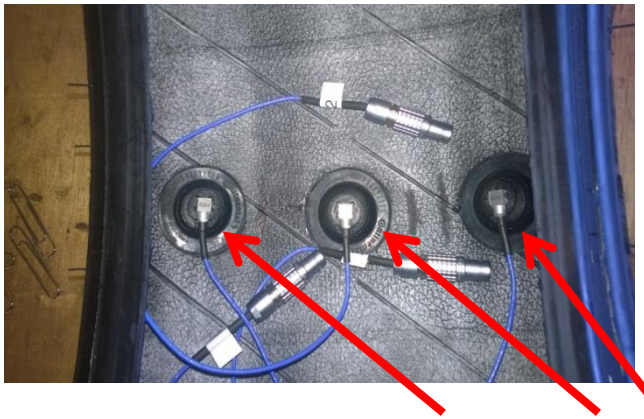
- Smart Tire: additional sensors & functionality
- Example: accelerometer

SMART TIRES

- Smart/intelligent tire systems under development for more than a decade
- Basic principle:
  - Measuring tire deformation and relate it to tire states or road conditions:
    forces, slip angle, camber angle, ...
    aquaplaning, road condition (wet, snow,…)
  - Sensors: strain, acceleration, distance, …
- Most promising solution:
  accelerometer at the tire inner liner
- Feature extraction algorithms
  to estimate tire states
  (e.g. distance between peaks in signal)



MANY CHALLENGES

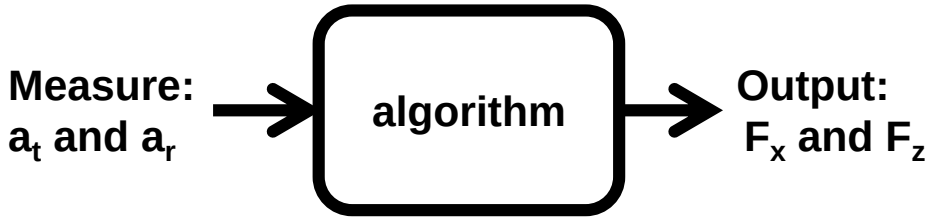


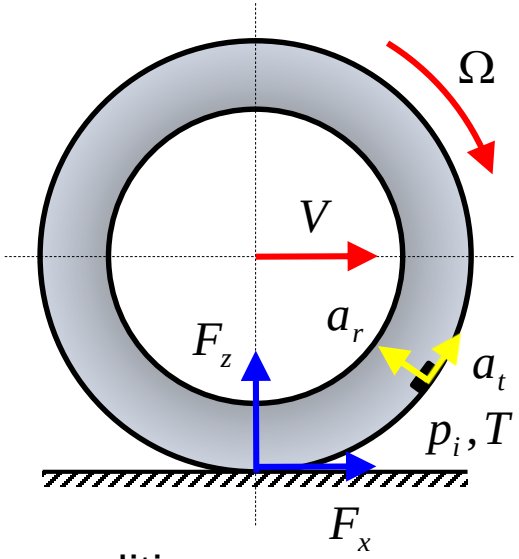
- Technology:
  - sensors
  - wireless communication
  - energy
  - algorithms
  - computation power
  - added value for applications (ABS/ESC, ADAS, automated driving)

- Competing technologies:
  - algorithms that use standard vehicle sensors (similar to indirect TPMS)
  - new vehicle sensors, e.g. wheel force bearings, optical sensors, cameras
  - I2V (infrastructure to vehicle) applications

TIRE FORCE ESTIMATION

- Force estimation example:

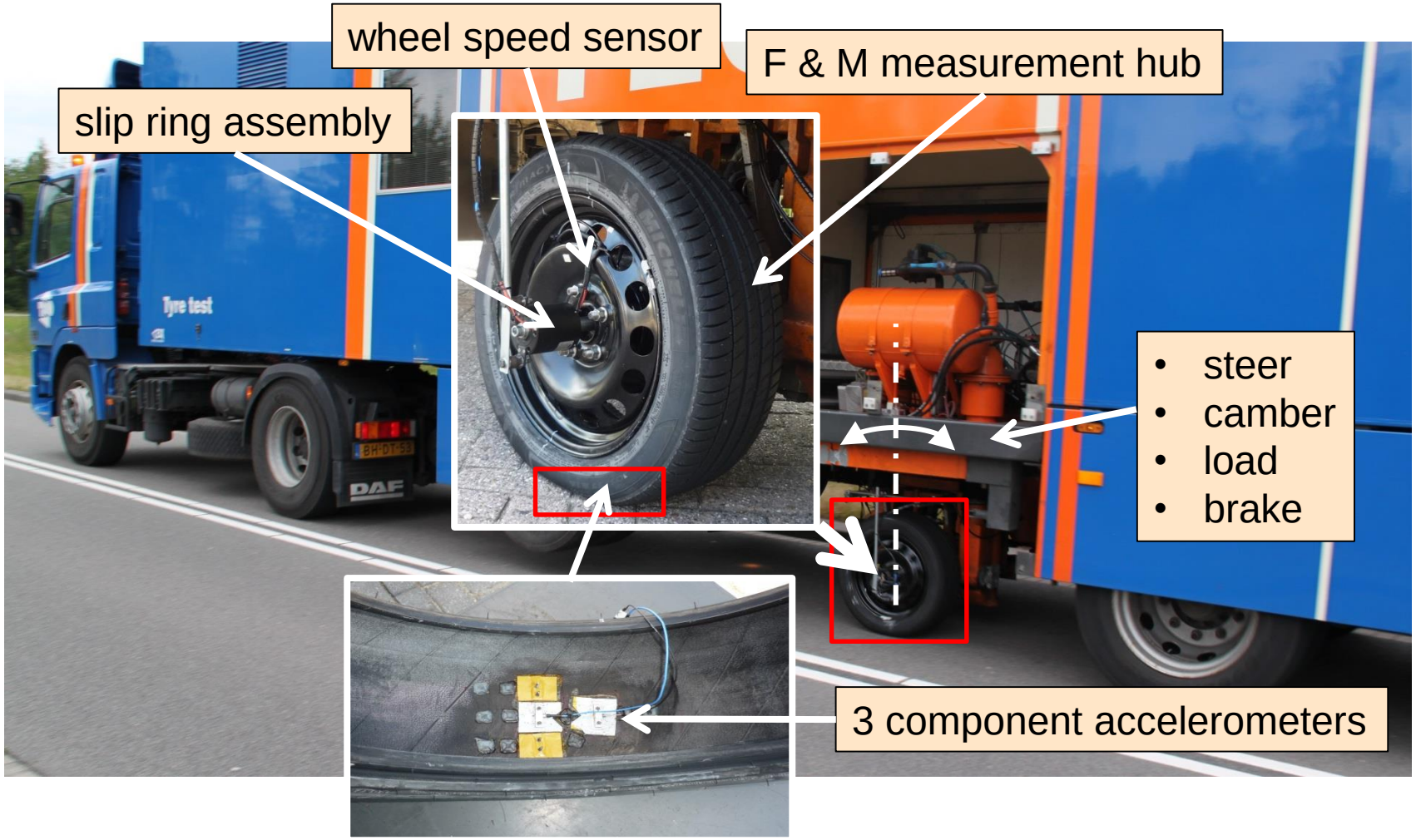




- Challenges:
  - robust algorithm working under various/all operating conditions
  - accuracy, delay, …

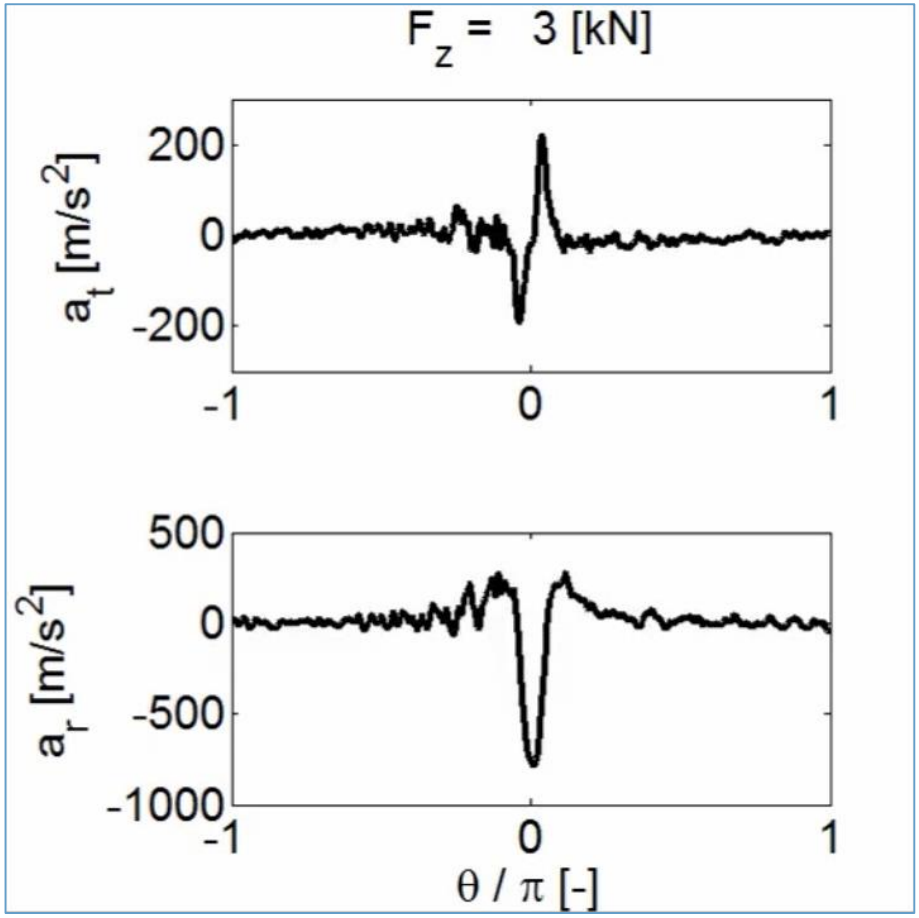
- Novel solution:
  - model-based force estimator

MEASUREMENT SETUP & EXPERIMENTS

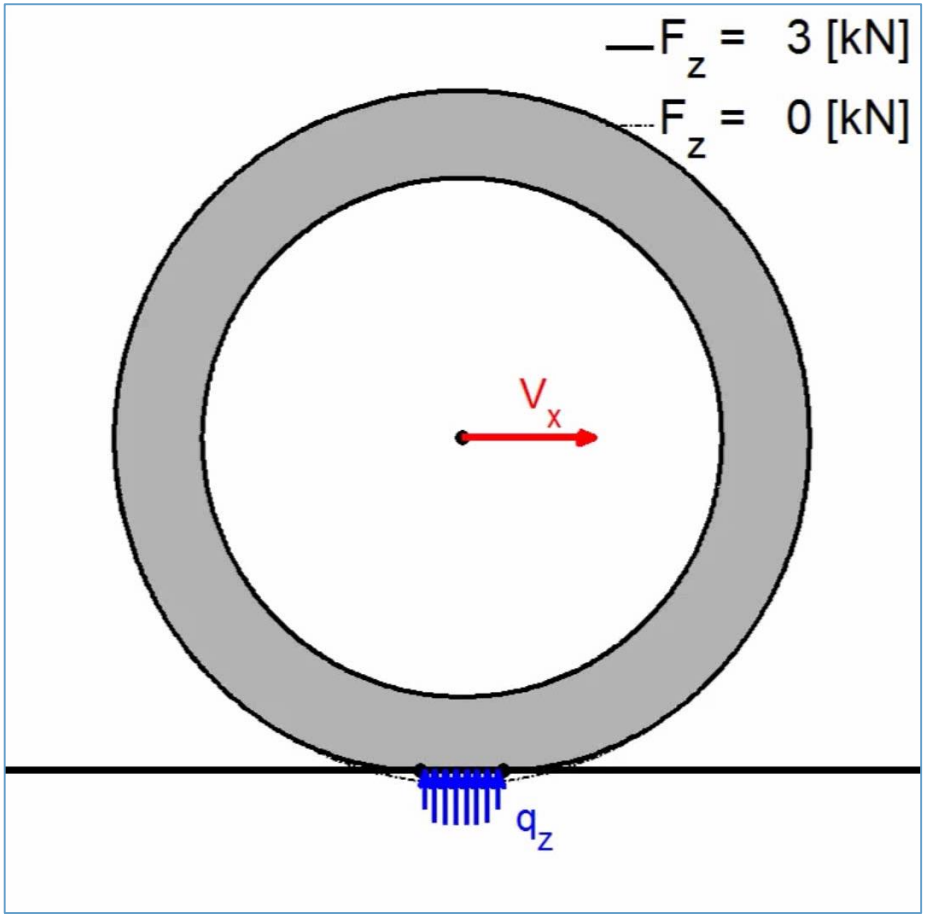


VERTICAL TIRE BEHAVIOUR

inner liner accelerations

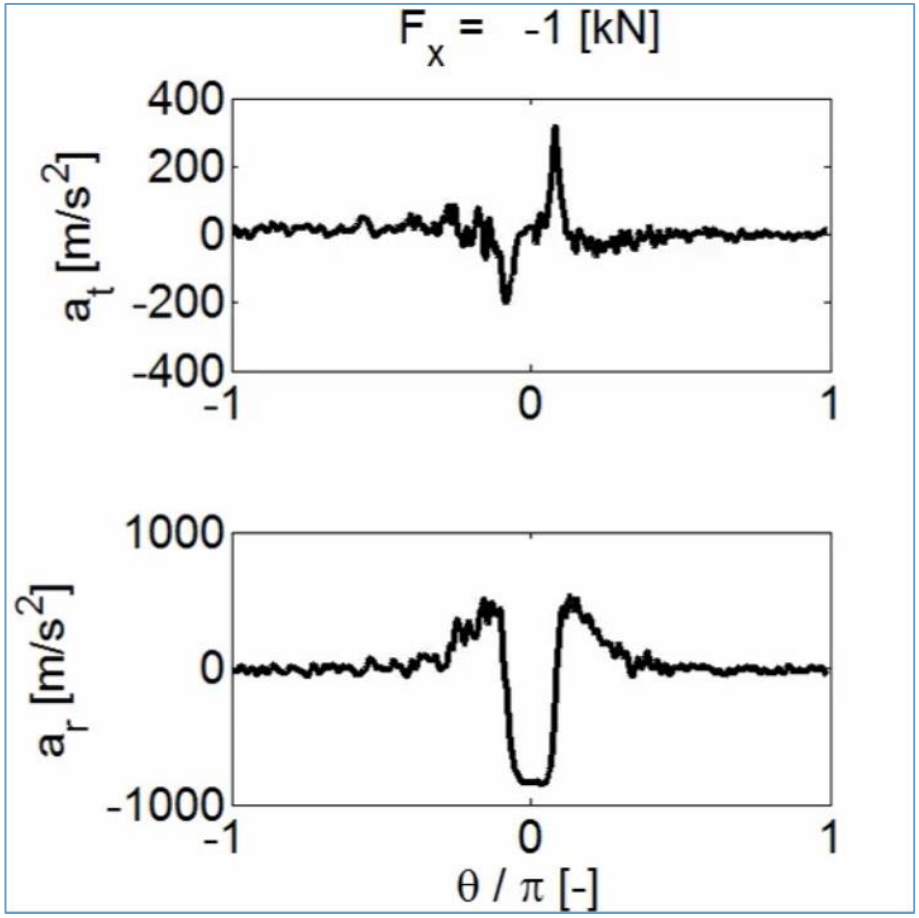


tire deformation

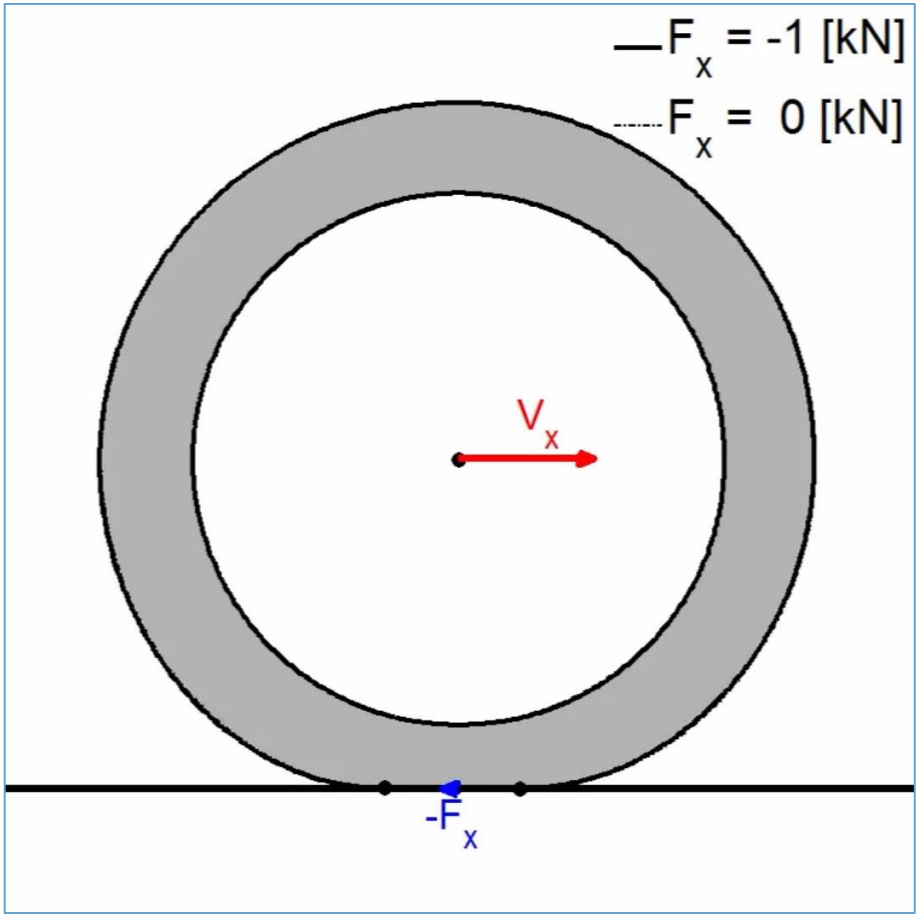


TIRE BEHAVIOUR WHILE BRAKING

inner liner accelerations

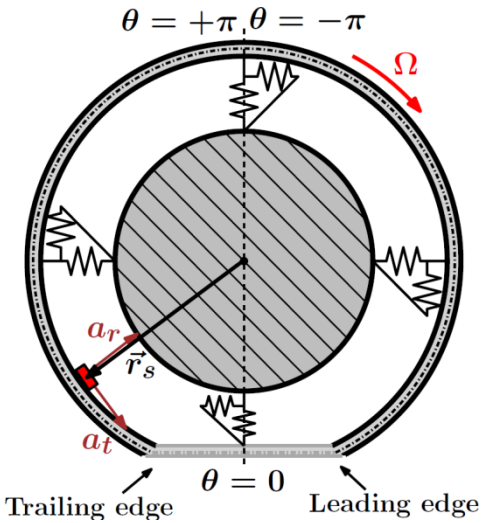


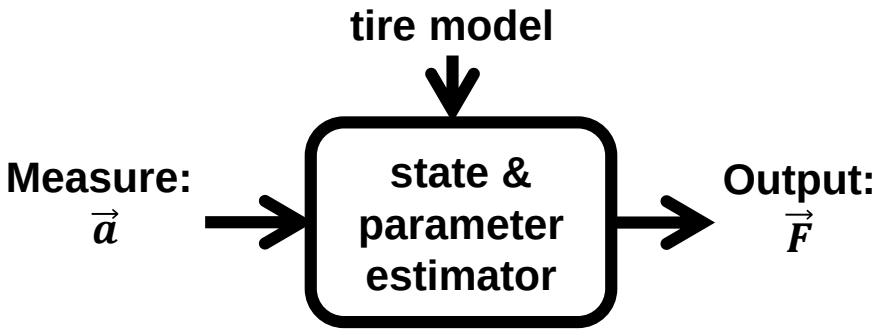
tire deformation

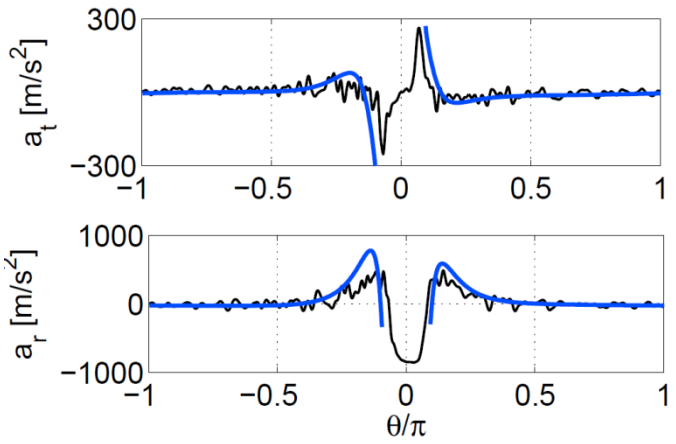


MODEL-BASED TIRE FORCE ESTIMATION

tire model:

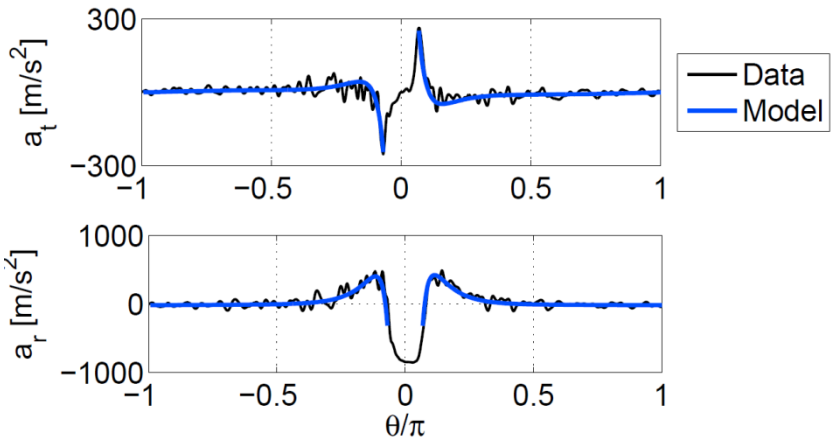




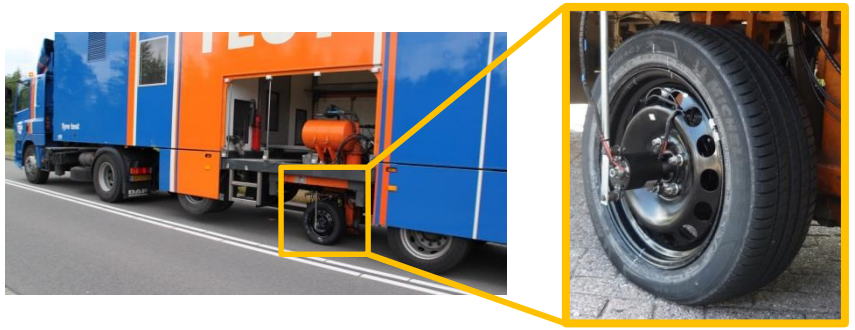


find forces that minimise

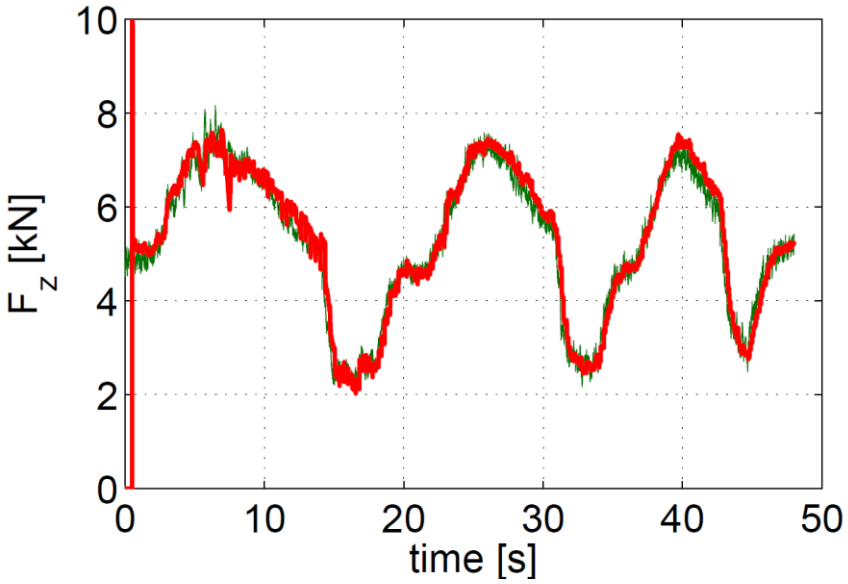
error between measurement and model



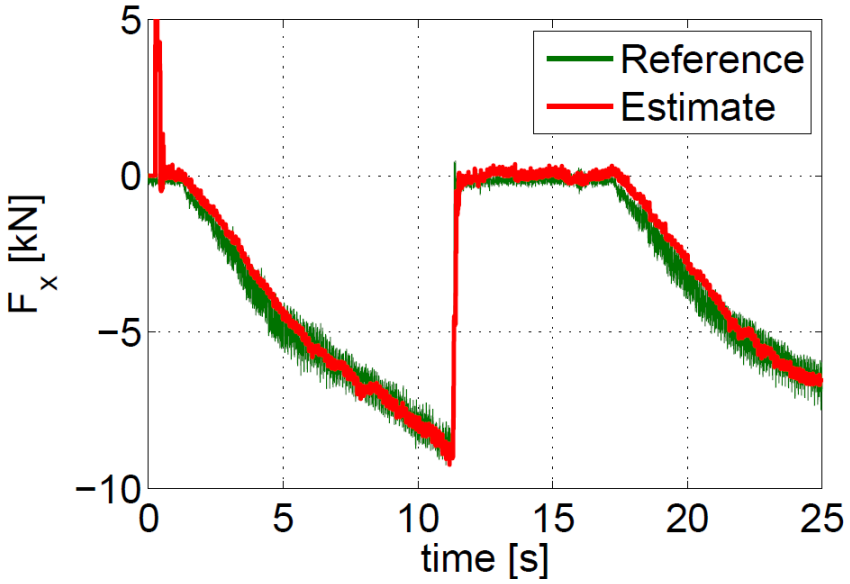
SOME RESULTS



- Vertical load estimation during load and velocity changes



- Brake force estimation at constant vertical load



CONCLUDING REMARKS

- Future automated riving (AD) functions require real-time friction estimation
- Next step after inner liner TPMS is a smart tire that offers more functionality
- Opportunity for a smart tire that senses tire forces and eventually predicts friction
- TPMS + accelerometer at inner liner is promising solution
- Novel model-based tire force estimator has been developed to estimate vertical and longitudinal tire forces

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