Hand-in Vehicle State Estimation TME102

Data from a front steered passenger vehicle is logged for a short manoeuvre. The vehicle has the following inbuilt sensors:

Wheel angular sensors: measuring the individual angular wheel speed in rad/s

Steering wheel angle: measuring the steering angle at the steering-wheel in rad

GPS: measuring latitude, longitude and altitude in m and deg

Inertial Measurement Unit: measuring acceleration and angular speeds of the vehicle. The measurements are adjusted to be valid in CoG. In m/s^2 and rad/s

Brake actuator: measuring the brake torque at each wheel in Nm

Propulsion actuator: measuring the traction torque at each wheel in Nm

The vehicle is also equipped with an Oxford Instrument RT3000 (OTS), which is a high precision device measuring motion entities. Data from this instrument could in this hand-in be treated as the ground truth. The instrument is mounted in CoG of the vehicle. Note that this instrument should not be used to estimate states. It is only presented to allowing you to benchmark your results.

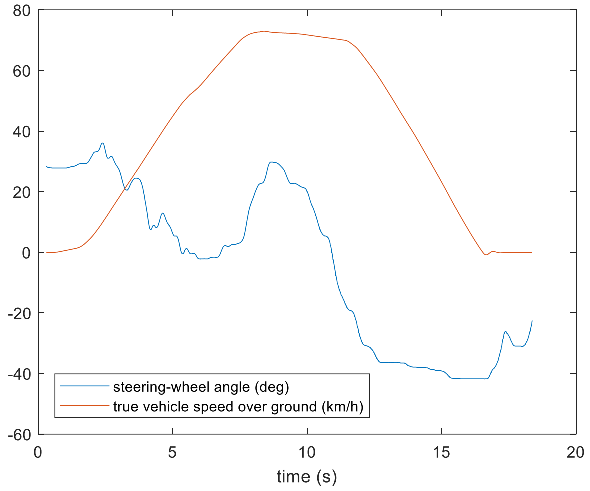
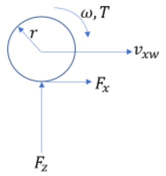


Fig 1: The logged manoeuvre.

Task 1: Wheel hub speed (1.5 p)

Compute the four wheel hub translational speeds v_{xw} relative to ground as a function of time. The hub speeds v_{xwi} for $i = FL, FR, RL, RR$ are defined as being directed in the same direction as the steering angle. The trivial solution would be to multiply the measured angular wheel speed with your individual tyre radius estimate, but you should also investigate if it is possible to account for the effect of longitudinal slip. Make a time series plot of the four wheel-hub speeds.



Use a linear tyre model where the longitudinal tyre force is a function of longitudinal tyre slip with a normalized tyre of stiffness $C_{nx} = 40\ N/N$. Use the wheel torque measurements together with your tyre model to find a way to adjust hub speed according to

$$v_{xwi} = r\omega_i\left(1 - \frac{T_i}{rC_{nx}F_{zi}}\right)$$

Assume that the normal force F_{zi} is the static normal load.

Task 2: Transformation to CoG (1.5p)

Project each hub speed v_{xwi} to CoG. This means that you should get four vehicle speeds over ground (as a function of time) directed along the vehicle's centreline and positioned in CoG.

You will need front axle steering angle (δ_{fr}) and yaw-rate (ω_z) measurement to do the projection. Assume parallel steering.

Task 3: Selection of the best projected vehicle speed (1.5p)

Design an algorithm that selects and switches to *one* among the four vehicle speed over ground signals from task 2. The selected signal is mentioned to as ”nominal”. The algorithm should at each time sample select the vehicle speed that has the highest quote of tyre normal load and wheel torque abs($\frac{F_{zi}}{T_i}$). Compute the rms error of the nominal estimated vehicle speed over ground (with the ground truth as the reference)

Task 4: Uncertainty (1.5p)

Assume that the tyre radius and tyre stiffness vary up to $\pm$10%. Explain how these factors will influence the uncertainty in vehicle speed estimate. Also indicate which driving cases that gives the largest uncertainty.

Logged data

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Time                          time,s
Vx_true                       OTS,true vehicle speed over ground, m/s
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z                                    GPS,height above seas surface, m
lon                                  GPS, longitude, deg
lat                                  GPS, latitude, deg

Ax                                   IMU, accelerometer x-dir, m/s^2
Ay                                   IMU, accelerometer, y-dir, m/s^2
Az                                   IMU, accelerometer, z-dir, m/s^2
Wz                                   IMU, gyro, yaw rate, rad/s^2

whlSpdFL                             Encoders, angular wheel speed, rad/s
whlSpdFR
whlSpdRL
whlSpdRR

TbFL                                 Brake torque at individual wheel, Nm
TbFR
TbRL
TbRR

TpFL                                 Prop. torque at individual wheel, Nm
TpFR
TpRL
TpRR

SWA                                  Steering wheel angle, rad
Gear                                 Actual gear, unit less
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Vehicle parameters

Steering gear ratio = 16

Track width = 1.65 m

Distance CoG to front axle=1.47 m

Distance CoG to rear axle=1.51 m

Height of CoG relative road= 0.65 m

Nominal wheel radius=0.36 m

Vehicle mass=2556 kg