SENSOR FUSION

Odometric Motion Model

Sensor Fusion

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Purpose

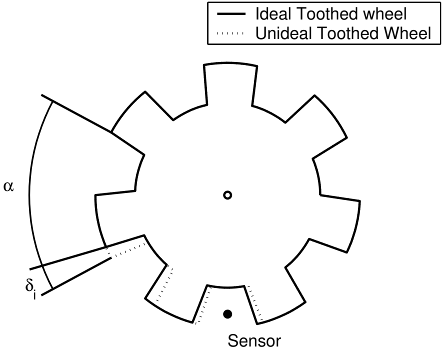
Provide example of a versatile sensor that can be used in many ways in a sensor fusion framework.

- How the sensor works.
- Virtual sensor of speed and yaw rate.
- Odometry: special motion models for navigation.

Sensor Principle

Each tooth passing the sensor (electromagnetic or Hall) gives a pulse. The number n of clock cycles between a number m of teeth are registered within each sample interval.

$$\omega(t_k) = \frac{2\pi}{N_{\text{cog}}(t_k - t_{k-1})} = \frac{2\pi}{N_{\text{cog}} T_c} \frac{m}{n}.$$



Problems:

- Angle quantization, N_{cog} is an integer.
- Time quantization (n is an integer).
- Synchronization, samples do not come at regular sampling intervals.
- Angle offsets δ in sensor teeth size.

Wheel Speed Spectrum

- The wheel is the only contact point with the road, and thus has the potential as a virtual sensor for more or less anything relating to vehicle dynamics.
- Different parts in the speed spectrum contains different information.

0-2	2-10	10-15	15-30	30-60	60-80	80-100	100–
Motion	Damper Speed	Mode 1	Noise	Mode 2	Noise	Mode 3	Noise
Vehicle Dynamics		Road-induced noise passing through wheel dynamics					

- Focus here on the motion information. Most computational problems disappear for such low frequencies.

Virtual Sensors of Motion

Longitudinal velocity, yaw rate and slip on left and right driven wheel (front wheel driven assumed) can be computed from wheel angular speeds **if** the radii are known:

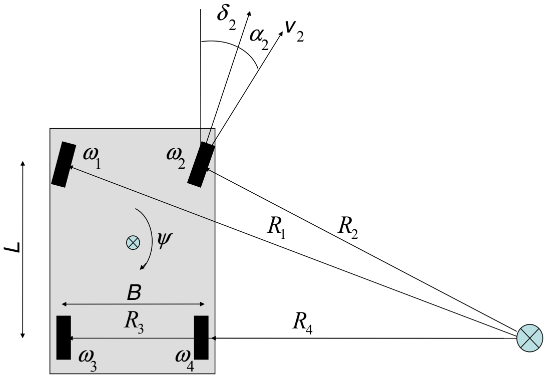
$$v_x = \frac{v_3 + v_4}{2} = \frac{\omega_3 r_3 + \omega_4 r_4}{2},$$

$$\dot{\psi} = v_x^m \frac{2}{B} \frac{\frac{\omega_3}{\omega_4}\frac{r_3}{r_4} - 1}{\frac{\omega_3}{\omega_4}\frac{r_3}{r_4} + 1} = \frac{\omega_3 r_3 - \omega_4 r_4}{B},$$

$$s_1 = \frac{\omega_1 r_1}{v_1} - 1, \quad s_2 = \frac{\omega_2 r_2}{v_2} - 1,$$

$$v_1 = v_x \sqrt{(1 + \tfrac{1}{2} R^{-1} B)^2 + (R^{-1} L)^2},$$

$$v_2 = v_x \sqrt{(1 - \tfrac{1}{2} R^{-1} B)^2 + (R^{-1} L)^2}.$$



The formulas are based on geometry, and the relation $\dot{\psi} = v_x R^{-1}$.

Odometry

Odometry is based on the virtual sensors

$$v_x^m = \frac{\omega_3 r_3 + \omega_4 r_4}{2}$$
$$\dot{\psi}^m = \frac{\omega_3 r_3 - \omega_4 r_4}{B}.$$

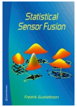
and the model

$$\psi_t = \psi_0 + \int_0^t \dot{\psi}_\tau \, d\tau,$$
$$X_t = X_0 + \int_0^t v_\tau^x \cos(\psi_\tau) \, d\tau,$$
$$Y_t = Y_0 + \int_0^t v_\tau^x \sin(\psi_\tau) \, d\tau.$$

to dead-reckon the wheel speeds to a relative position in the global frame.
The position $(X_t(r_3, r_4), Y_t(r_3, r_4))$ depends on the values of wheel radii r_3 and r_4. Further sources of error come from wheel slip in longitudinal and lateral direction. More sensors needed for navigation.

Summary

- Odometry allows integration of wheels speeds into a trajectory.
- However, more sensors are needed to get absolut position and stabilize the unavoidable drift.
- The odometric model then becomes a motion model where the wheel speeds are inputs in a Kalman filter in a larger sensor fusion framework.



Section 14.3