Evasive manoeuvre assist

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Many accidents can be avoided by evasive manoeuvres …but drivers have difficulties to handle them …and the state-of-the-art assistance is emergency braking
**DECISION MAKING IN EMERGENCY SITUATIONS**

*Ego vehicle*

_Bosch 2010_

50% of rear-end collisions can be avoided by turning around object

…82% do not steer

_Iowa studies 1990_

Drivers brake when TTC is high
Drivers steer when TTC is low

_Eckert 2011_

TTC=2.0 s and full overlap
Brake 46%, steer 16%, combined 38%

Half overlap: 38% steer
TTC=1.5 s: 57% combined

_Ferrandez, Fleury, and Lepesant, 1984_

The driver “reacted too late, or too violently, or tried to combine braking with a sideways avoidance movement, which often resulted in loss of control”
Vehicle potential to brake vs. steer

Steering must here be used to avoid collision

100 km/h  40 m  34 m

Point of no return braking  Point of no return steering

Steering must here be used to avoid collision

Particle model approximations

\[ x_{\text{brake}} = \frac{1}{2\mu g} (\nabla v)^2 \]
\[ x_{\text{steer}} = \frac{\sqrt{2w}}{\sqrt{\mu g}} \nabla v \]
Can we help the driver to move $\Delta x$ without compromising vehicle stability?
How to assist the driver?

- Autonomously or driver assist?
- Driver trigged?
- Intrusiveness?
- Which actuators to use?
CONCEPTUAL FUNCTION DESIGN
– EVASIVE MANOEUVRE ASSIST (EMA)

Driver initiates steering
AND
Threat detected

An escape path is generated

Steering-wheel torque overlay
AND
Differential braking

Excessive steering will deactivate EMA
WHAT ABOUT ESC?

Driver initiates steering AND Threat detected

ESC Under-steering control

ESC Over-steering control

• ESC understeering is engaged too late
• EMA deactivated if vehicle becomes too over-steered
Evasive manoeuvre assist (EMA)

- EMA is a threat depending under-steer control
- EMA gives over-steering, which is dangerous
- However, risk of instability/nervousness behavior must be balanced with risk of collision
EBA increases brake gain if brake pedal is rapidly engaged
EMA increases lateral displacement gain if steering wheel is rapidly engaged

EBA is deactivated by ABS to avoid wheel lock
EMA is deactivated by ESC to avoid over-steering
**STEER BY DIFFERENTIAL BRAKING**

Bode plot "bicycle model", magnitude of transfer function from $F_b$ to $Y$

From $F_b$ to $Y$

- $V_x = \infty$
- $V_x = 140$ km/h
- $V_x = 120$ km/h
- $V_x = 100$ km/h
- $V_x = 80$ km/h
- $V_x = 60$ km/h
- $V_x = 50$ km/h

Magnitude (dB)

Frequency (Hz)

$V_x = \infty$

$V_x = 140$ km/h

$V_x = 120$ km/h

$V_x = 100$ km/h

$V_x = 80$ km/h

$V_x = 60$ km/h

$V_x = 50$ km/h

$Y \sin(\omega t)$

$F_b \sin(\omega t)$

6 dB
RAPID PROTOTYPING TOOLS FOR ALGORITHM DEVELOPMENT
FUNCTION RESULTS

Robot test vs. CarMaker with steering-wheel torque as input

\[ \Delta x, \Delta y \]

\begin{align*}
\text{Lateral coordinate } Y, \text{ [m]} & \quad \text{Longitudinal coordinate } X, \text{ [m]} \\
\text{Simulation: CABS on} & \quad \text{Field Test: CABS on} \\
\text{Simulation: CABS off} & \quad \text{Field Test: CABS off}
\end{align*}

Average \( \Delta x \) trend for velocity

\begin{align*}
\text{Average } \Delta x \text{ trend for velocity} & \\
\text{Speed [km/h]} & \quad 0.317, 1.496, 1.684, 2.048, 2.217
\end{align*}
FUNCTION RESULTS

\[ \Delta x \text{ large when:} \]
- vehicle speed is high
- steering-wheel frequency low
- steering-wheel torque amplitude low

**Interpretation:** drivers with low steering input would benefit from function
DRIVER EXPERIENCE OF EMA

Initial real car test from test subjects have shown:

• Drivers feel ”a magic hand on the car body”
• Drivers find it more easy to evade
• Drivers have fun (was not intended)
• Drivers particularly appreciate the ”push back kick”
CONCLUSION

- EMA increases Δx, which is roughly in the order of 1m
- Δx higher for weak steering-wheel torque and high vehicle speed
- The view of understeer control must be changed by balancing the risk of collision
- EMA is an example of where Collision Avoidance and Electronic Stability Control are merged