Technische Universität München

Robust Design of Sensors and Functions in Vehicular Safety

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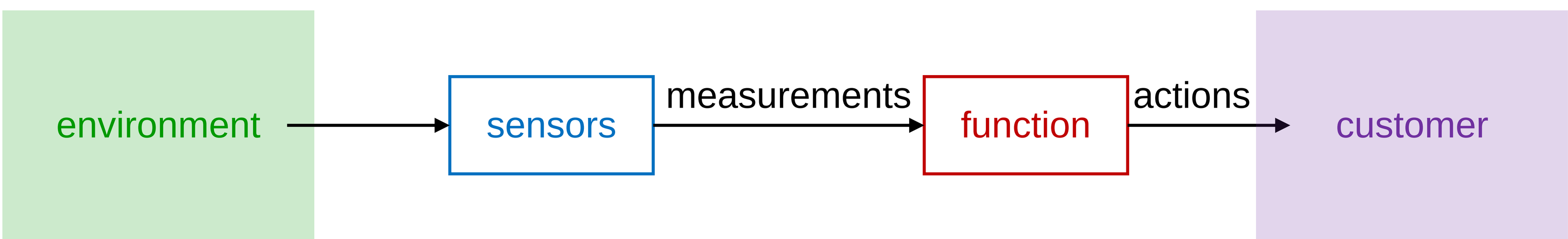
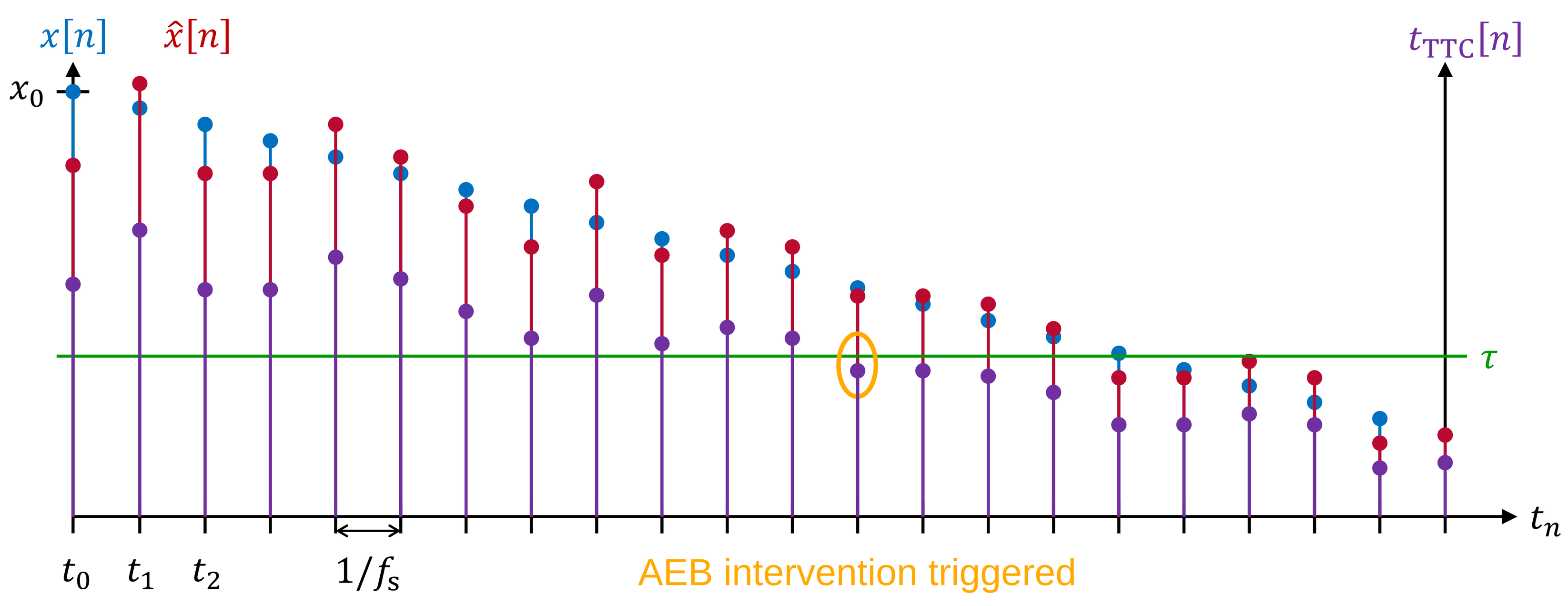
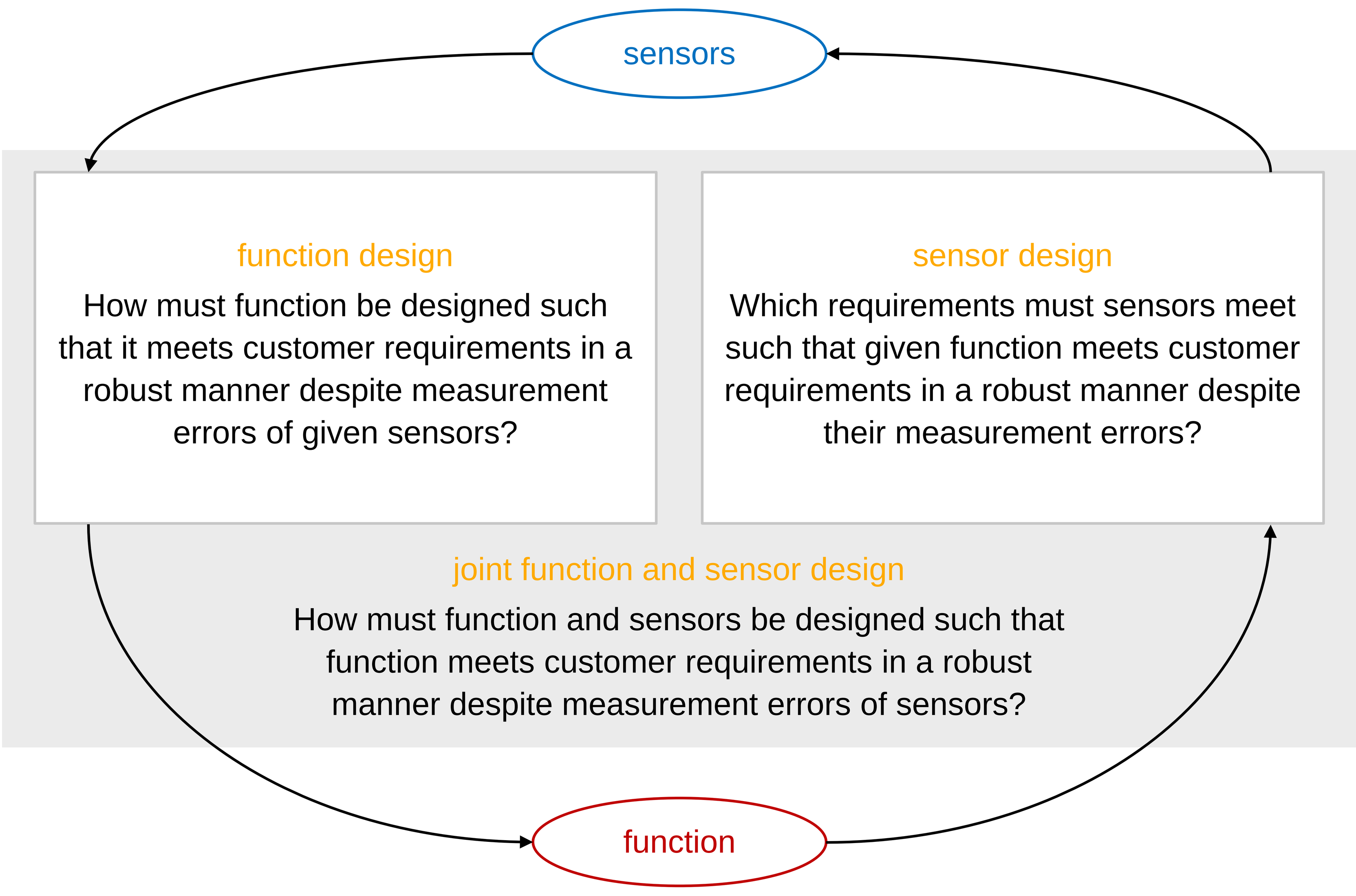
Motivation



- sensors:
  - measure quantities like distances, velocities, accelerations, etc.
  - serve perception of environment of vehicle
- (vehicular safety) function:
  - uses measurements of sensors
  - interprets driving situation
  - triggers actions in dangerous situations like automatic emergency braking (AEB)
- problem: measurements of sensors are erroneous
- goal: function meets customer requirements in a robust manner despite measurement errors



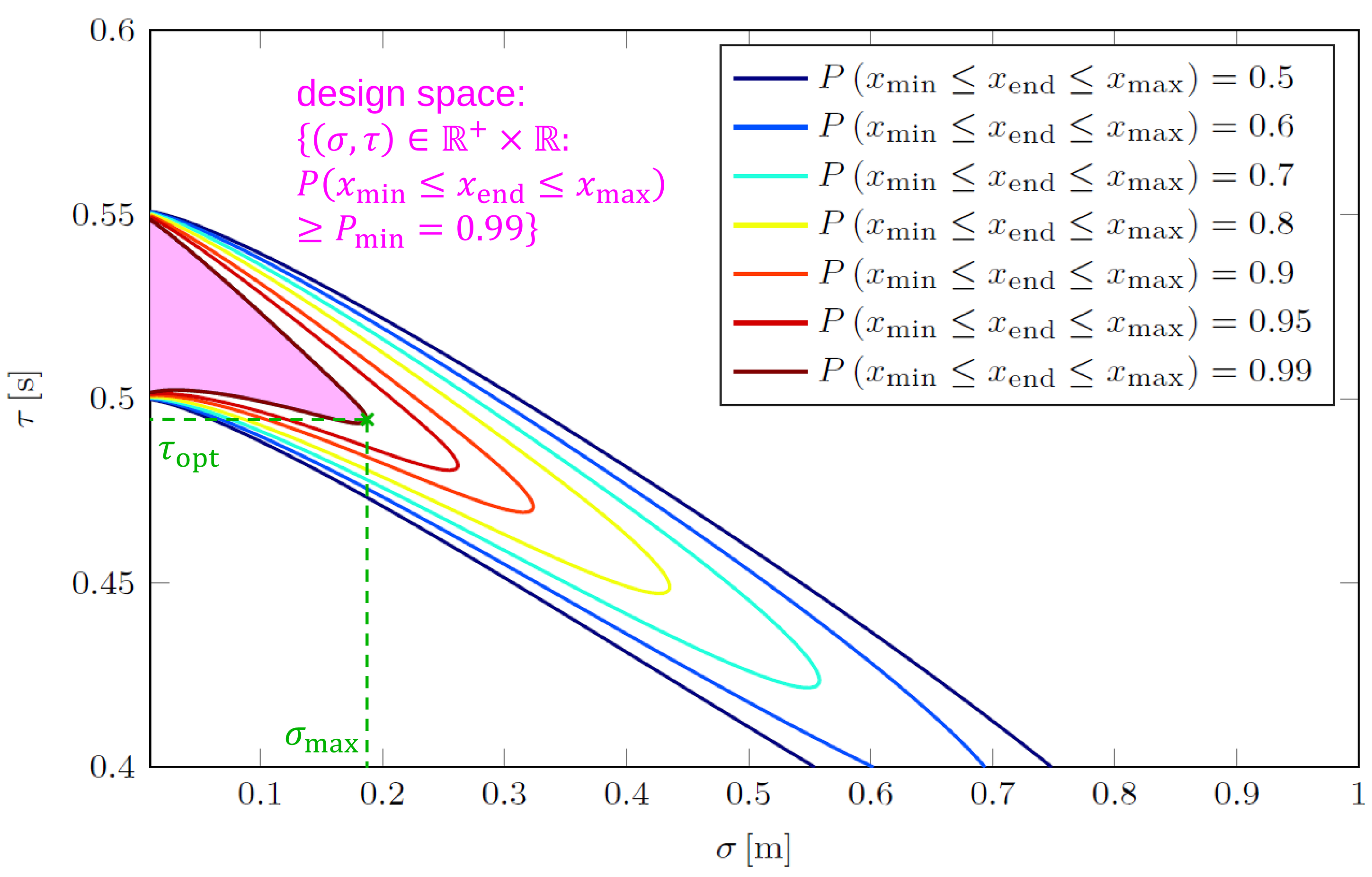
Problem Formulation



Joint Function and Sensor Design for AEB System

$$(\sigma_{\max}, \tau_{\mathrm{opt}}) = \operatorname*{argmax}_{\sigma \in \mathbb{R}^+, \tau \in \mathbb{R}} \sigma \quad \text{s.t.} \quad P(x_{\min} \le x_{\mathrm{end}} \le x_{\max}) \ge P_{\min}$$

- $P(x_{\min} \le x_{\mathrm{end}} \le x_{\max})$: probability that distance x_{end} from object after AEB intervention when relative velocity vanishes lies in acceptable interval $[x_{\min}, x_{\max}]$ (quality measure)
- $P_{\min}$: required minimum probability for fulfilling specification $x_{\min} \le x_{\mathrm{end}} \le x_{\max}$
- $\sigma_{\max}$: maximal tolerable standard deviation of sensor measurement errors
- τ_{opt}: optimal threshold of function

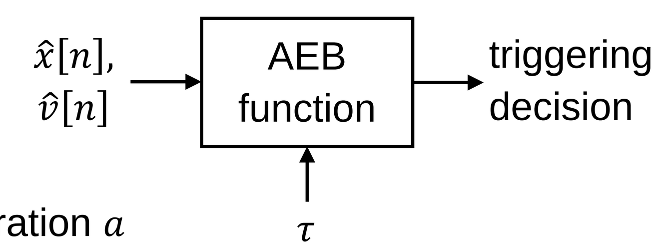


$x_0 = 10\,\mathrm{m}$, $v_0 = -10\,\frac{\mathrm{m}}{\mathrm{s}}$, $a = 10\,\frac{\mathrm{m}}{\mathrm{s}^2}$, $f_s = 1\,\mathrm{kHz}$, $x_{\min} = 0$, $x_{\max} = 0.5\,\mathrm{m}$

Mathematical Model for Design of AEB System

- state: $\boldsymbol{x}[n] = \begin{bmatrix} x[n] \\ v[n] \end{bmatrix}$
- measurement: $\boldsymbol{y}[n] = \begin{bmatrix} \hat{x}[n] \\ \hat{v}[n] \end{bmatrix}$
  - obtained by sensors with sampling rate f_s at $t_n = n/f_s, n \in \mathbb{N}_0$
  - measured distance: $\hat{x}[n] = x[n] + \epsilon[n]$, i.i.d. $\epsilon[n] \sim \mathcal{N}(0, \sigma^2)$
  - measured relative velocity: $\hat{v}[n] = v[n]$

  →predicted time-to-collision (TTC): $t_{\mathrm{TTC}}[n] = -\frac{\hat{x}[n]}{\hat{v}[n]}$
- AEB intervention
  - triggered by function at time instant t_n if $t_{\mathrm{TTC}}[n] \le \tau$ with threshold τ
  - reduces velocity of ego vehicle with constant deceleration a



Conclusion

- new methodology for robust design of AEB system considering sensor measurement errors
- future work: transfer of developed design methodology to further vehicular safety systems

References

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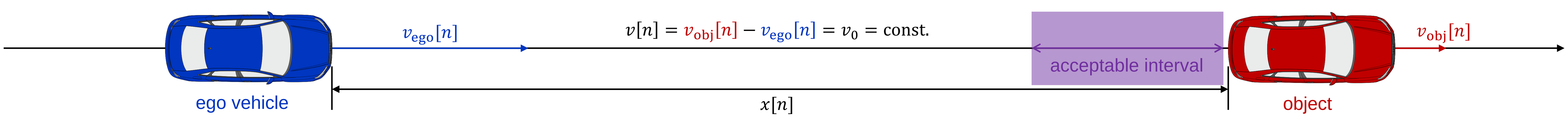

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