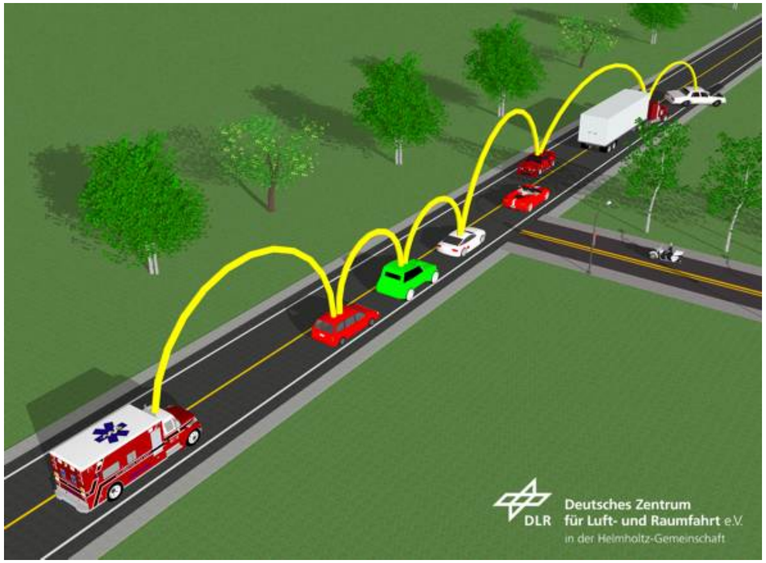
Sensing the environment for future driver assistance combining autonomous and cooperative appliances

Matthias Röckl, J. Gacnik, J. Schomerus, T. Strang, M. Kranz

Deutsches Zentrum
DLR für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

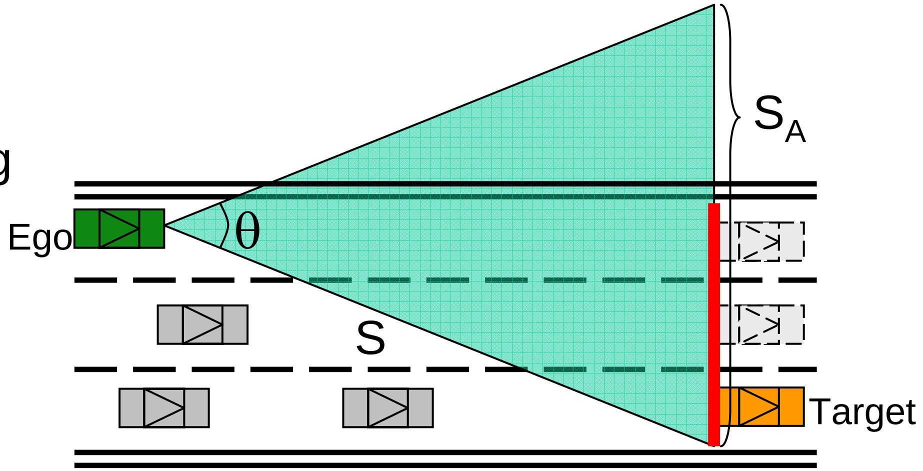
Introduction

- Situation-aware Driver Assistance:
  - Collision Avoidance
  - Traffic Jam Warning
  - Cooperative ACC
- Extended sensing of the environment beyond the autonomous sensing area required
- Incorporation of autonomous and cooperative sensing appliances



Autonomous Detection and Ranging (DaR)

- *Autonomous DaR*: Sensing **without** active interaction of the target vehicle
- Sensing based on evaluation of received signal characteristics (e.g. transit times, signal attenuation, phase shifts)
- Drawbacks:
  - Limited detection zone
  - Restricted angular separation
  - Constrained to line of sight
  - Positioning errors due to signal reflections, scattering
- Appliances:
  - Radar
  - Lidar
  - Camera

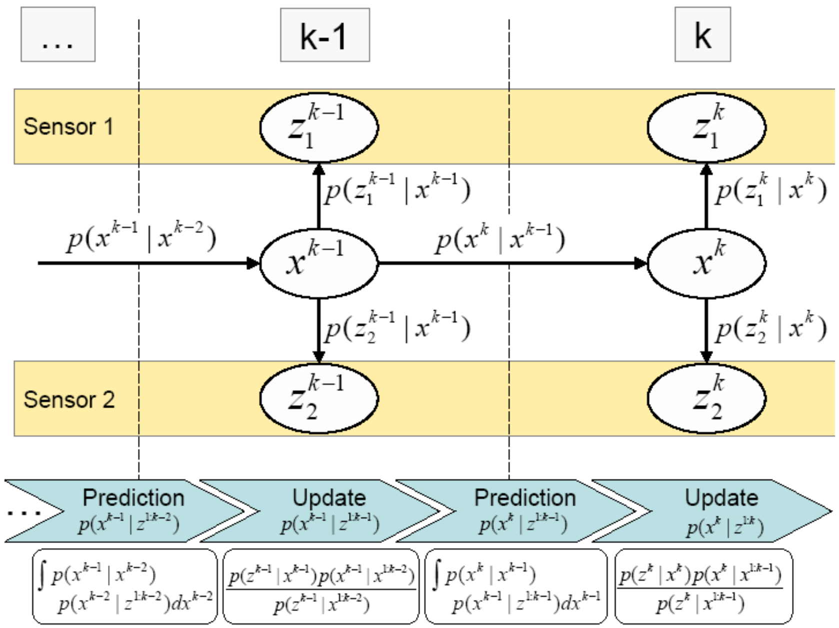


Cooperative Detection and Ranging

- *Cooperative DaR*: Sensing **with** active interaction of the target vehicle
- Sensing based on:
  - Self-localisation of the target vehicle
  - Distribution of position information to the surrounding vehicles via ad-hoc Vehicle-2-Vehicle communication (broadcast)
  - Relative position estimation by the ego vehicle based on remote and local position information
- Drawbacks:
  - Positioning errors
  - Packet collisions
  - Active participation of target vehicle essential
- Appliance: GNSS positioning and IEEE 802.11p

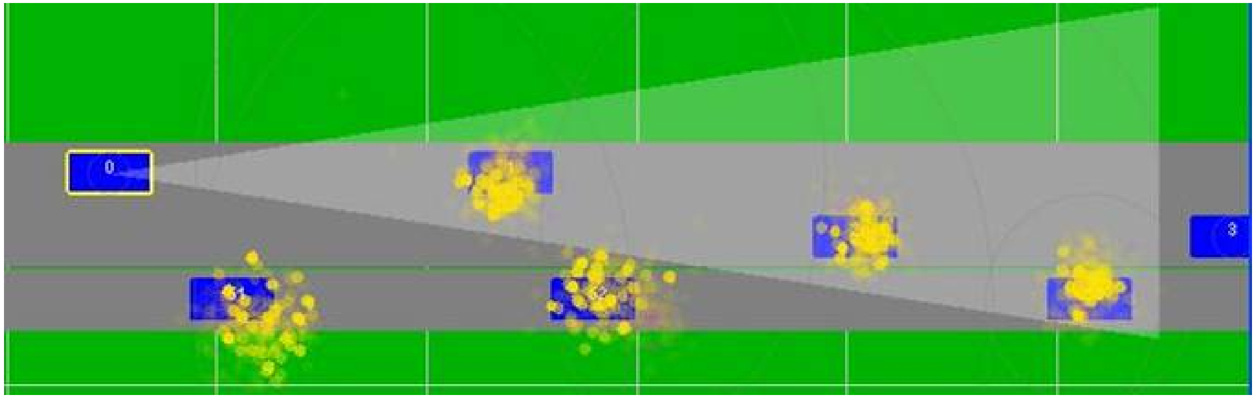
Dynamic multi-sensor state estimation

- Single DaR technology can not cope with the requirements of future driver assistance
- Solution: Combination of autonomous and cooperative DaR
- Weighting of sensors by measurement quality (e.g. confidence, HDOP)
- Dynamics:
  Evaluation of measurement sequences and their causal relations
- Probabilistic state and measurement model
- Recursive predication-correction process



Particle Filter

- Particle filtering is a promising solution to perform the dynamic state estimation using multiple noisy sensor measurements
- Particle filters use sequential Monte-Carlo method with discrete samples
- Particle filters allow non-linear non-Gaussian state transition and measurement models
- Particles encode potential hypotheses (i.e. relative position of target vehicle) with respective weight



Performance Measures
Recall, Precision & Position Error

- Recall:

$$R = \frac{TruePositives}{TruePositives + FalseNegatives}$$

- Precision:

$$P = \frac{TruePositives}{TruePositives + FalsePositives}$$

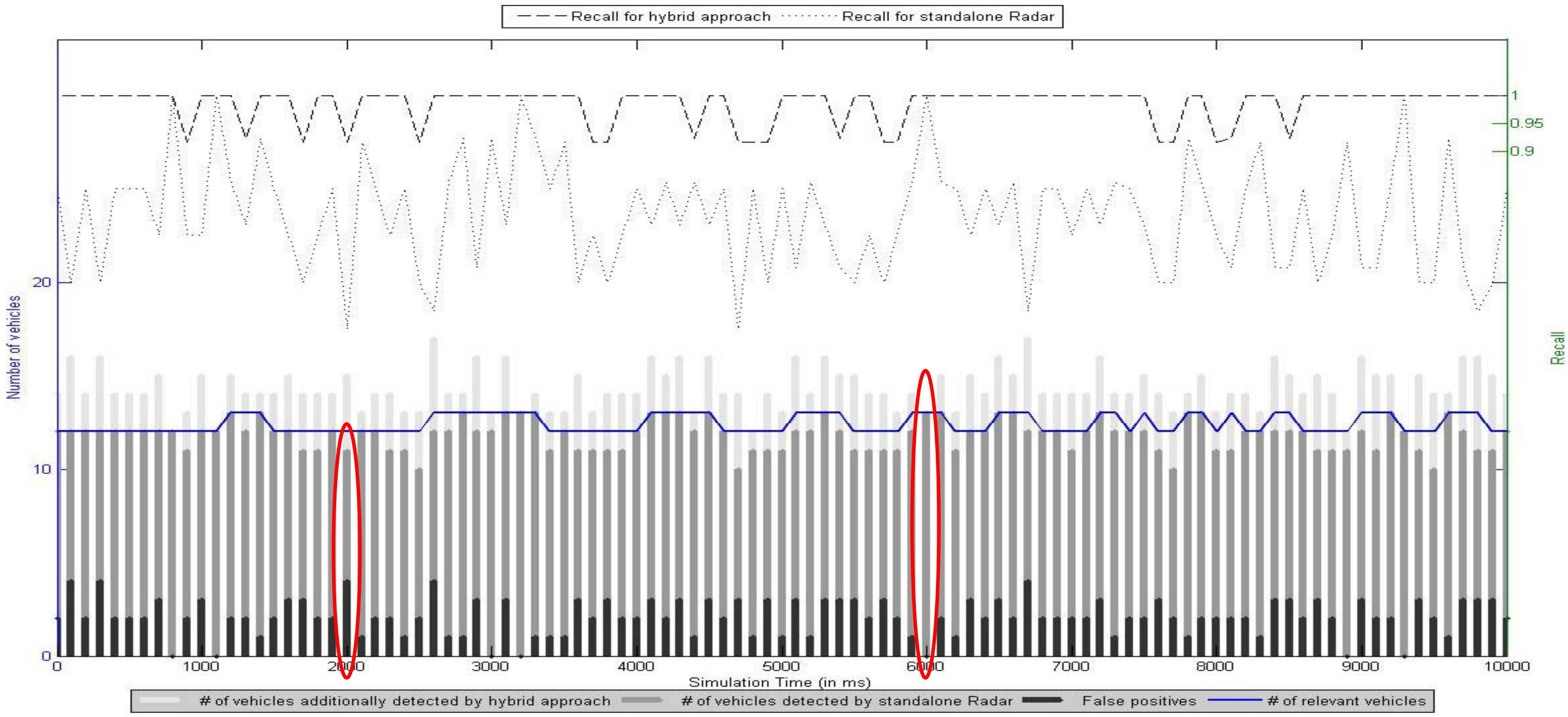
- Position Error:

$$PE = \sqrt{E\left\|\hat{X} - X\right\|_2}$$

$\hat{X}$ Real distance to the target vehicle

X Estimated distance to the target vehicle

Simulation Results
Recall for standard ACC scope



$$R = \frac{TruePositives}{TruePositives + FalseNegatives}$$

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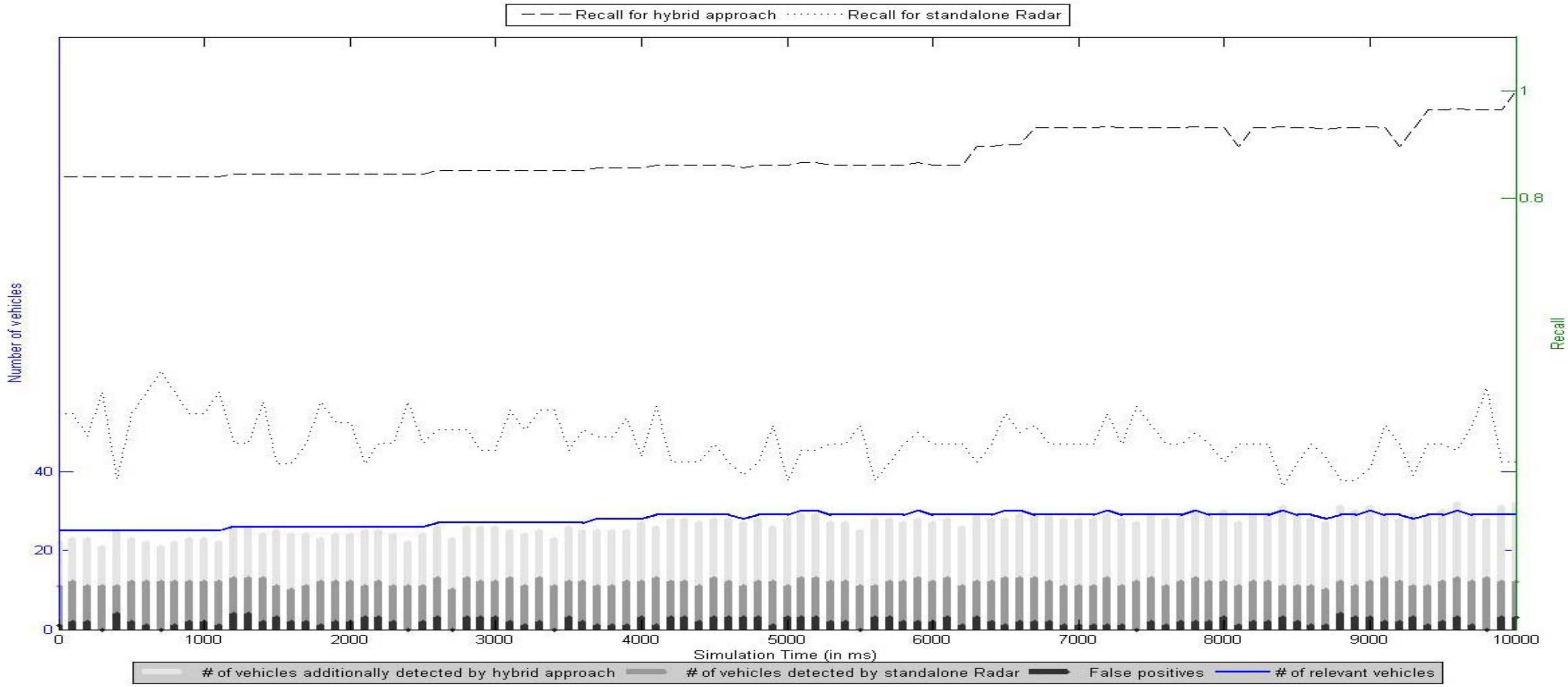
Simulation Results
Recall in Full Headway Scope



$$R = \frac{TruePositives}{TruePositives + FalseNegatives}$$

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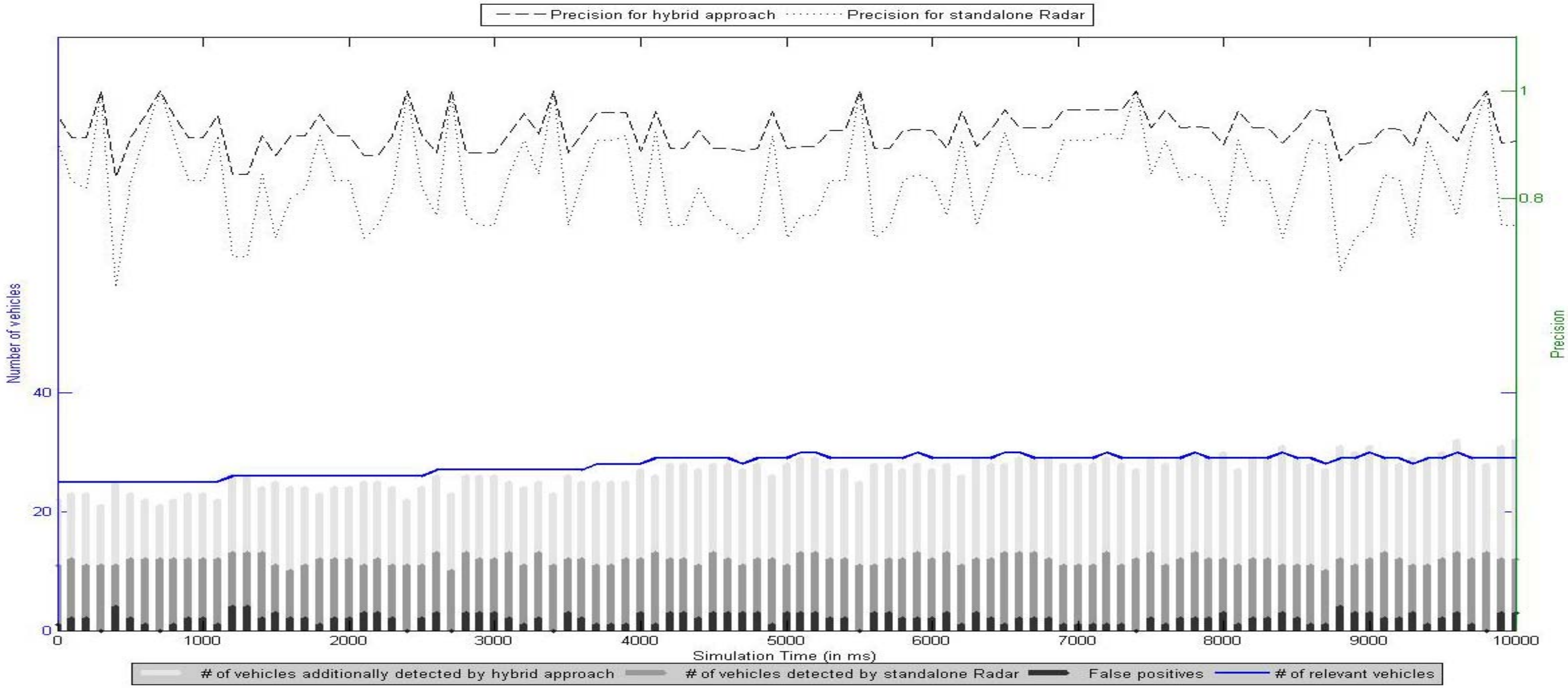
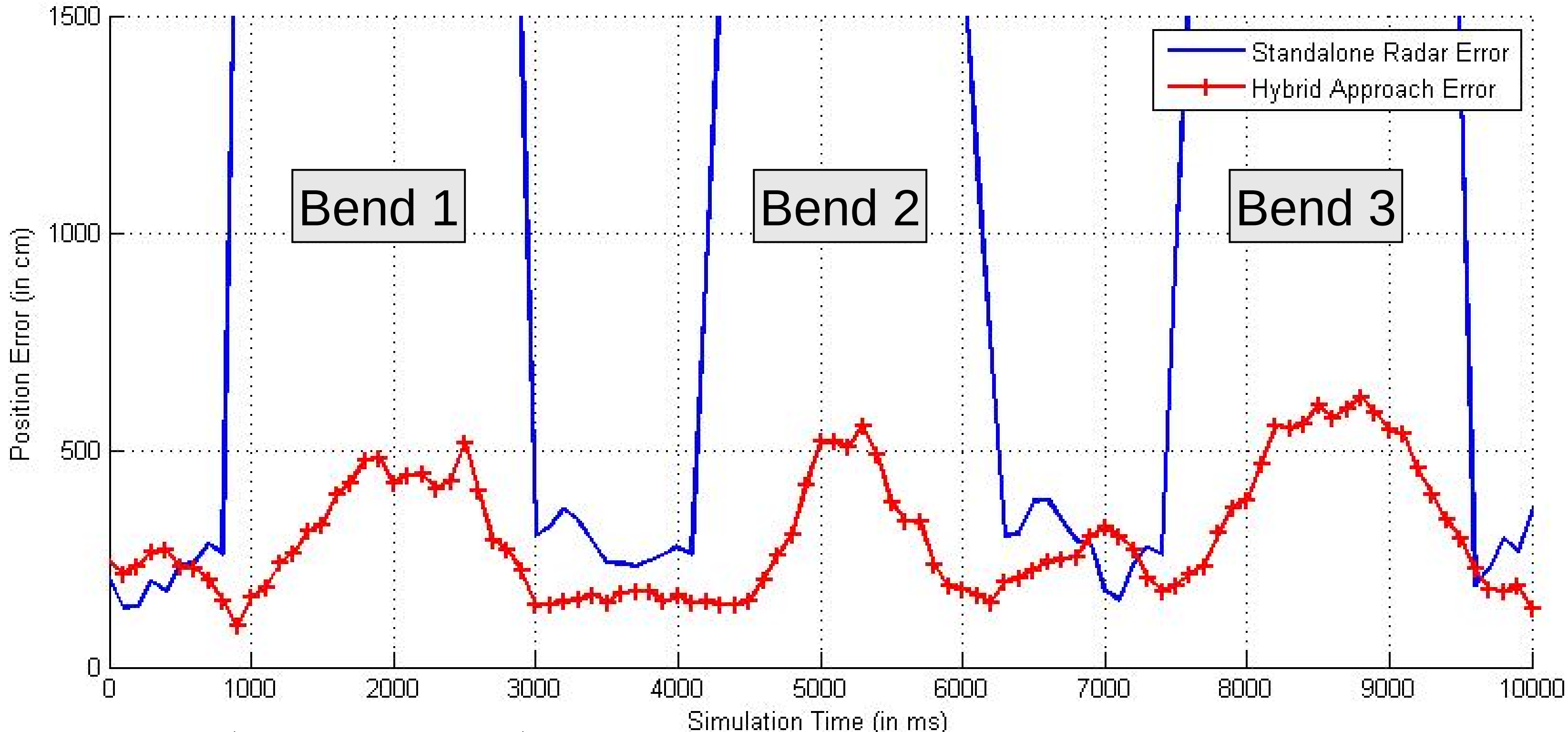
Simulation Results
Precision



$$P = \frac{TruePositives}{TruePositives + FalsePositives}$$

Simulation Results
Position Error



No radar target measurement

$$PE = \sqrt{E\left\| \hat{X} - X \right\|_2}$$

Conclusions

- Standalone autonomous or cooperative sensing technologies cannot cope with demanding requirements of situation-aware driver assistance
- Combination of autonomous and cooperative sensing technologies results in an increased *Recall* and *Precision* and decreased *Position Error*
- Benefit increases with growing penetration rate of V2V communication

Thank you for your attention!

Questions?

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