Towards automatic driving – Collective Perception

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V2X Roadmap – Applications

Status Data
- GLOS 1.0
- In-Vehicle Information
- Roadworks W 2.0
- Connected ACC
- Overtaking W
- Intersection Collision W
- ...

Sensor Data
- GLOSA 2.0
- Roadworks Assistance
- Lane-Merge Assistance
- Area Reservation
- Cooperative ACC
- VRU Warning
- Platooning
- ...

Intention Data
- GLOSA 2.0
- Roadworks Assistance
- Lane-Merge Assistance
- Area Reservation
- Cooperative ACC
- VRU Warning
- Platooning
- ...

Coordination Data
- Cooperative Merging
- Overtaking Assistance
- Intersection Assistance
- Dynamic Platooning
- VRU Assistance
- ...

Take-over of the driving functions
- Fully Automated Driving
- Optimal Traffic Flow

100% installation of new vehicle sales
100% installation of new vehicle platforms
10 year ramp-up to 100% installation of new vehicles
Installation on select new vehicle type of luxury and upper middle class vehicles

Automation Level
- Phase 1: Awareness Driving
- Phase 2: Sensing Driving
- Phase 3: Cooperative Driving
- Phase 4: Synchronized Cooperative Driving
- Phase 5: Accident-free Driving

Dissemination
Cooperation
V2X Roadmaps – guiding principles inside C2C-CC

- **Focus on** information exchange
- **Cooperate** on providing information
  - Provide clearly defined/specifed information
  - Use commonly agreed air-interfaces
  - Focus on localized dissemination patterns
  - Use modular information which builds “on top of each other”
- **Compete** in capitalizing on the information
  - Each traffic participant can (freely) use the received information
  - Automatic driving functions can be enhanced (range, success rate)
Levels of Cooperative Systems
Which type of information is exchanged between vehicles?

- **Status Information**
  - “My status”

- **Environmental Information**
  - “My environment”

- **Intention Information**
  - “My intention and/or proposals for you”

- **Coordinated Driving Maneuvers**
  - “Plans for us”
Motivation

Local Perception Sensors
Red ego-vehicle knows about objects detected by its local perception sensors
Motivation

Local Perception Sensors

V2X Communication
- Red ego-vehicle additionally knows about V2X vehicles within the communication range
- Vehicles broadcast Cooperative Awareness Messages (CAMs)
Motivation

Local Perception Sensors

V2X Communication

Collective Perception
- V2X vehicles with local perception sensors broadcast their locally perceived objects
- Vehicles broadcast Environmental Perception Messages (EPMs)
Methodology

Scenario:
- 60% penetration rate
- Every V2X enabled vehicle is equipped with front- and rear- facing radar sensors
- CAM dissemination according to ETSI standard for every V2X vehicle
- Every vehicle within the local perception range of a V2X vehicle is broadcasted by an EPM [Environmental Perception Message] at a constant rate of 1 Hz

Simulations:
- 10 scenarios @ 7 different penetration rates
  ➔ 70 simulations with 2218 vehicles per variation of penetration rate
Methodology

Awareness Ratio

Description:
- Communication range for ego-vehicle is displayed (300 m reference range)
- In the vicinity of the ego-vehicle (ID 43) are several V2X vehicles as well as non-V2X vehicles (IDs 0, 17, 88, 100)

Concept:
- As a measure for the effectiveness of collective perception, the metric awareness ratio $k_{rel}^+$ is introduced:
- Possibility of receiving vehicles outside of the communication range: $k_{rel}$
Methodology
Awareness Ratio

Description:
• Communication range for ego-vehicle is displayed (300 m reference range)
• In the vicinity of the ego-vehicle (ID 43) are several V2X vehicles as well as non-V2X vehicles (IDs 0, 17, 88, 100)
• Ego-vehicle perceives all V2X objects within communication range
  • $k_{rel}^{CAM} = \frac{9}{13} = 0.69$
Methodology
Awareness Ratio

Description:

• Communication range for ego-vehicle is displayed (300 m reference range)
• In the vicinity of the ego-vehicle (ID 43) are several V2X vehicles as well as non-V2X vehicles (IDs 0, 17, 88, 100)
• Ego-vehicle perceives all V2X objects within communication range
  \[ k_{rel}^{CAM} = \frac{9}{13} = 0.69 \]
• Locally perceived objects by radar:
  \[ k_{rel}^{Radar} = \frac{4}{13} = 0.31 \]
Methodology
Awareness Ratio

Description:
• Communication range for ego-vehicle is displayed (300 m reference range)
• In the vicinity of the ego-vehicle (ID 43) are several V2X vehicles as well as non-V2X vehicles (IDs 0, 17, 88, 100)
• Ego-vehicle perceives all V2X-objects within communication range
  \[ k_{rel}^{CAM} = \frac{9}{13} = 0.69 \]
• Locally perceived objects by radar:
  \[ k_{rel}^{Radar} = \frac{4}{13} = 0.31 \]
• Knowledge due to exchange of locally perceived objects (EPM):
  \[ k_{rel}^{EPM} = \frac{11}{13} = 0.85 \]
Methodology
Awareness Ratio

Description:
• Overall awareness ratio:

\[
 k_{rel}^{tot} = \frac{|\text{unique IDs}|}{|\text{vehicles within communication range}|} = \frac{|0, 9, 17, 46, 62, 65, 70, 79, 81, 88, 98, 107|}{|0, 9, 17, 46, 62, 65, 70, 79, 81, 88, 98, 100, 107|} = \frac{12}{13} = 0.92
\]
Methodology
Awareness Ratio

Description:
- Overall awareness ratio: 
  \[ k_{rel}^{tot} = \frac{|\text{unique IDs}|}{|\text{vehicles within communication range}|} \]
  \[ = \frac{|\{0,7,9,17,36,62,65,70,79,81,84,88,94,98,107\}|}{|\{0,9,17,46,62,65,70,79,81,88,98,100,107\}|} \]
  \[ = \frac{16}{13} = 1.23 \]
- It is possible to gain information about vehicles outside of the communication range
- Advantageous in situations of limited and obstructed communication range
- Redundant information
Findings

Awareness ratio over time

Day-1 scenario (Radar & CAM)

Day-2 scenario (Radar & CAM & EPM)

- Radar - $\mu$: 0.178, $\sigma$: 0.0235
- CAM - $\mu$: 0.61, $\sigma$: 0.0244
- Radar & CAM - $\mu$: 0.659, $\sigma$: 0.0252
- EPM - $\mu$: 0.792, $\sigma$: 0.0827
- Radar & CAM & EPM - $\mu$: 0.96, $\sigma$: ...
Findings

Awareness ratio from Radar

- Independent of the penetration rate, the relative knowledge for objects perceived by radar is almost constant.
- Outliers are very specific to traffic scenarios (i.e. vehicles located around a junction).
Findings

Awareness ratio from CAMs

- Awareness ratio for objects perceived by CAM is equal to the penetration rate.
- Depending on the traffic scenario, higher local penetration rates can be observed.
Findings

Awareness ratio from EPMs

- When rebroadcasting objects that could be perceived by both, V2X and local sensors, the perception range can be extended beyond the communication range.

- Even at a penetration rate of 100%, not all vehicles can be perceived by local sensors (only).
Findings

Combined awareness ratio

- Combination of all three sources (local sensors, CAM and EPM) results in leverage for all penetration rates.
- Especially for low penetration rates, collective perception unveils its largest potential.
Findings

Relative knowledge standard deviations

- CAM: mediocre variance
- Radar: potential relative awareness specific to scenario
- EPM: Very specific to scenario: Even at high penetration rates, 100% awareness based on radar cannot be reached as there may be situations with no vehicles in local perception range
Conclusion

• Enables vehicles to get a more **complete picture** of their **environment**

• At low penetration rates offers considerable **enhanced awareness ratios**

• Additional “views” of individual objects might prove helpful **with functional safety issues**.

⇒ Collective Perception is a crucial step towards fully automatic-driving!
V2X Roadmap – Technology

Phase 1
- CAM
- GN-SHB
- single-channel
- G5A-CCH
- Day1 CC
- Simultaneous multi-channel

Phase 2
- CAM
- GN-DENM
- GN-GBC
- GN-GN6
- GN-Groupcast
- GN-UNICAST
- Simultaneous dual-channel
- G5D-SC5
- G5B-SC4
- G5B-SC3
- G5A-SC2
- G5A-SC1
- switched-mode
- dual-channel
- multi-channel CC

Phase 3
- CAM
- GN-Groupcast
- GN-UNICAST
- Simultaneous dual-channel
- G5D-SC5
- G5B-SC4
- G5B-SC3
- G5A-SC2
- G5A-SC1
- switched-mode
- dual-channel
- dual-channel CC

Phase 4
- CAM
- GN-Groupcast
- GN-UNICAST
- Simultaneous multi-channel
- G5D-SC5
- G5B-SC4
- G5B-SC3
- G5A-SC2
- G5A-SC1
- switched-mode
- dual-channel
- multi-channel CC

@ETSI TC ITS

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WG Roadmap

CAR 2 CAR COMMUNICATION CONSORTIUM
Thank You!

Questions?

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Sensor Properties

V2X communication range
(reference range)

Local perception sensor
(local perception range)

300 m

60°

80 m

60°

80 m