Context-Aware Collaborative Perception: Estimating Relevance through Knowledge Representation

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Collaborative Perception

Objective:

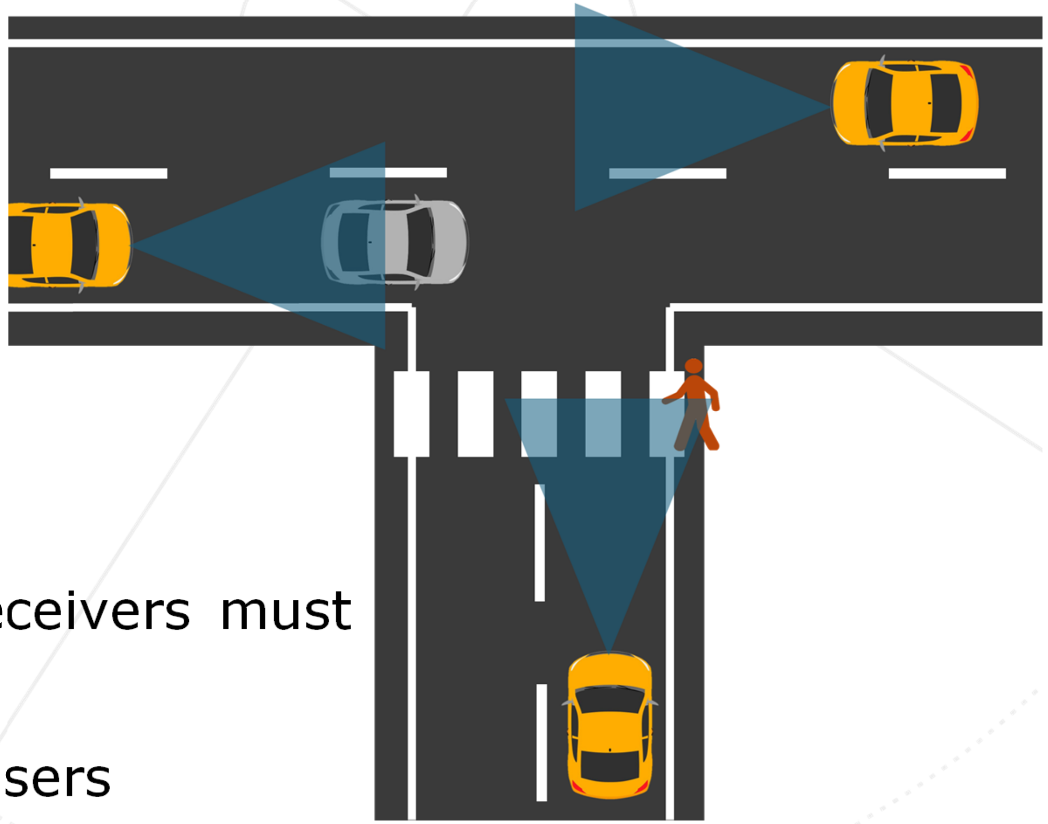
- Extend sensor range to detect occluded road users
- Enhance situational awareness

Protocol:

- Collective Perception Message (CPM)

Issues:

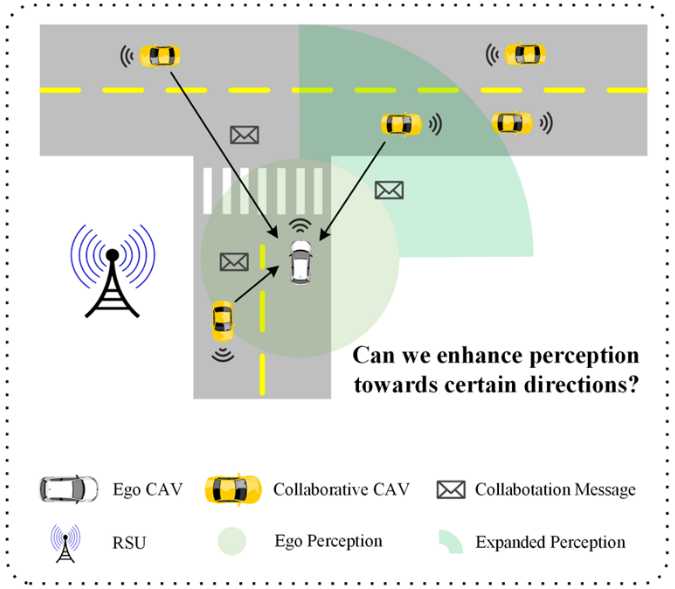
- **Data Overload:** Emitters send all detections → Receivers must filter irrelevant data
- **Dynamic Environments:** Changing scenario/road users



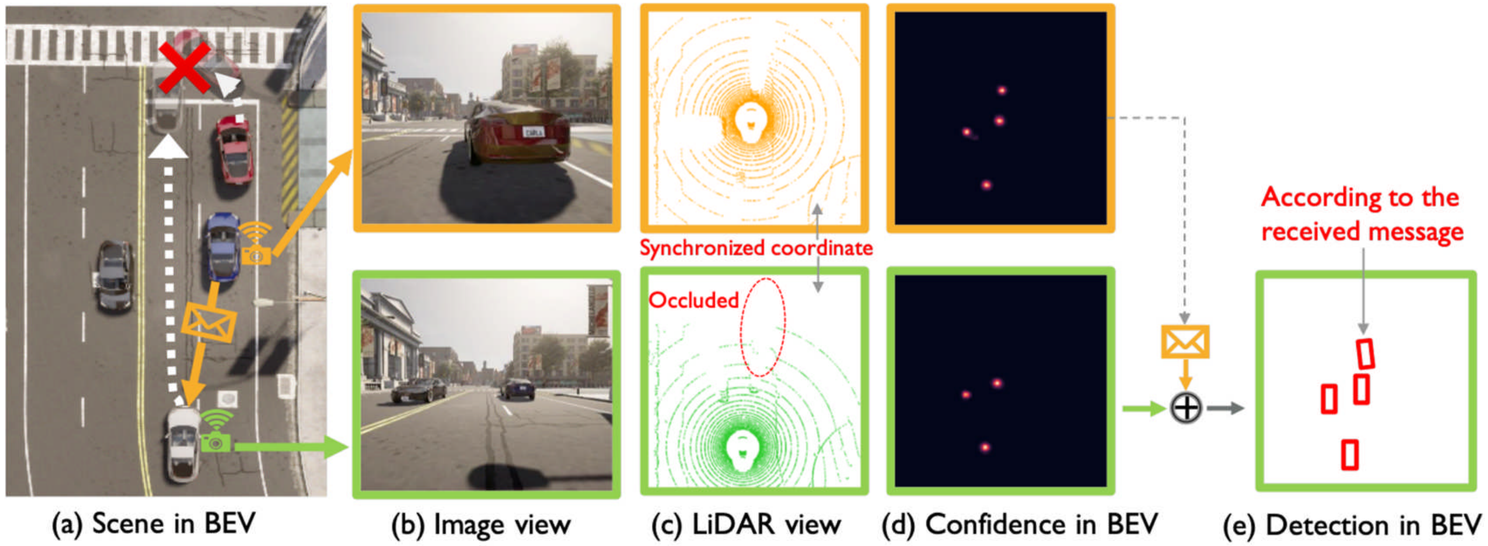
➔ Data congestion, Latency, Information Gap, Computation resource, Energy consumption

Key Problems

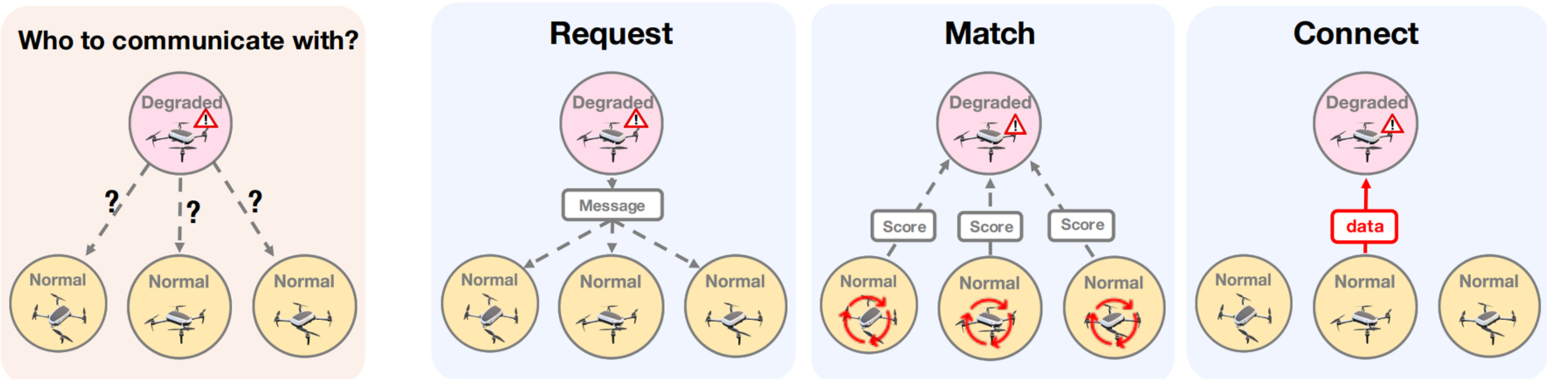
*What information are **relevant** ?*



Y. Tao, S. Hu, Z. Fang, et Y. Fang, « Direct-CP: Directed Collaborative Perception for Connected and Autonomous Vehicles via Proactive Attention », http://arxiv.org/abs/2409.08840



Y. Hu, S. Fang, Z. Lei, Y. Zhong, et S. Chen, « Where2comm: Communication-Efficient Collaborative Perception via Spatial Confidence Maps », 26 septembre 2022, http://arxiv.org/abs/2209.12836



Y.-C. Liu, J. Tian, C.-Y. Ma, N. Glaser, C.-W. Kuo, et Z. Kira, « Who2com: Collaborative Perception via Learnable Handshake Communication », 21 mars 2020, http://arxiv.org/abs/2003.09575

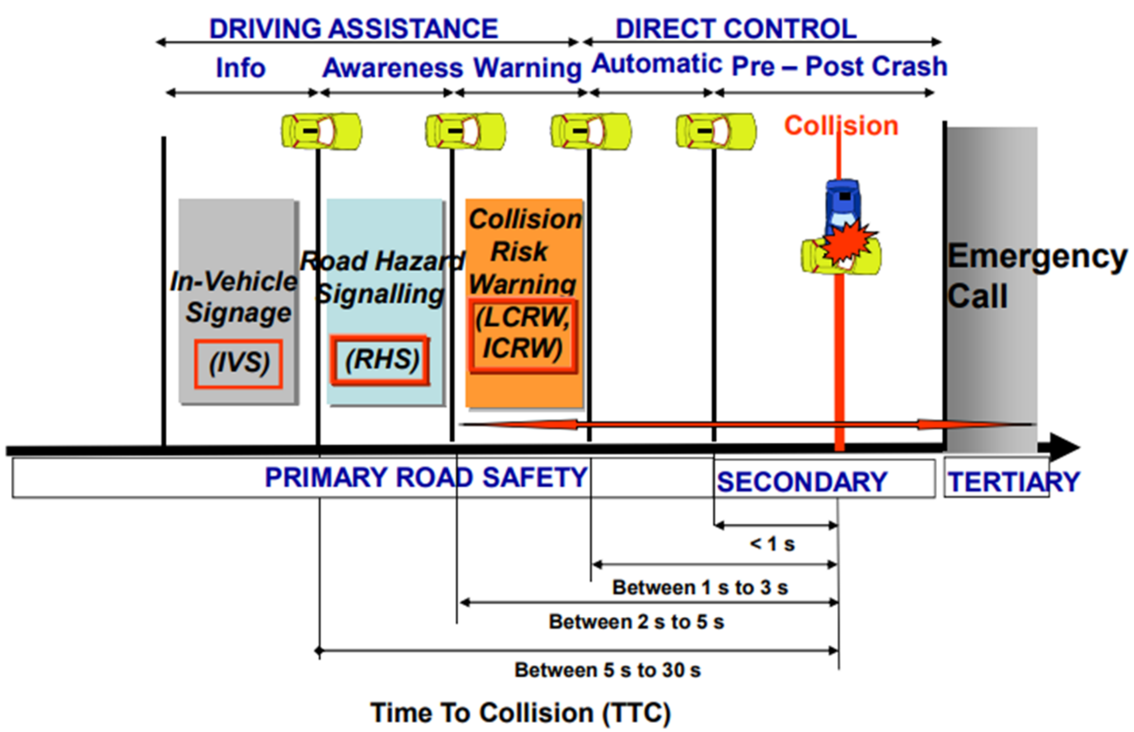
Context not <u>explicitly</u> taken into account !

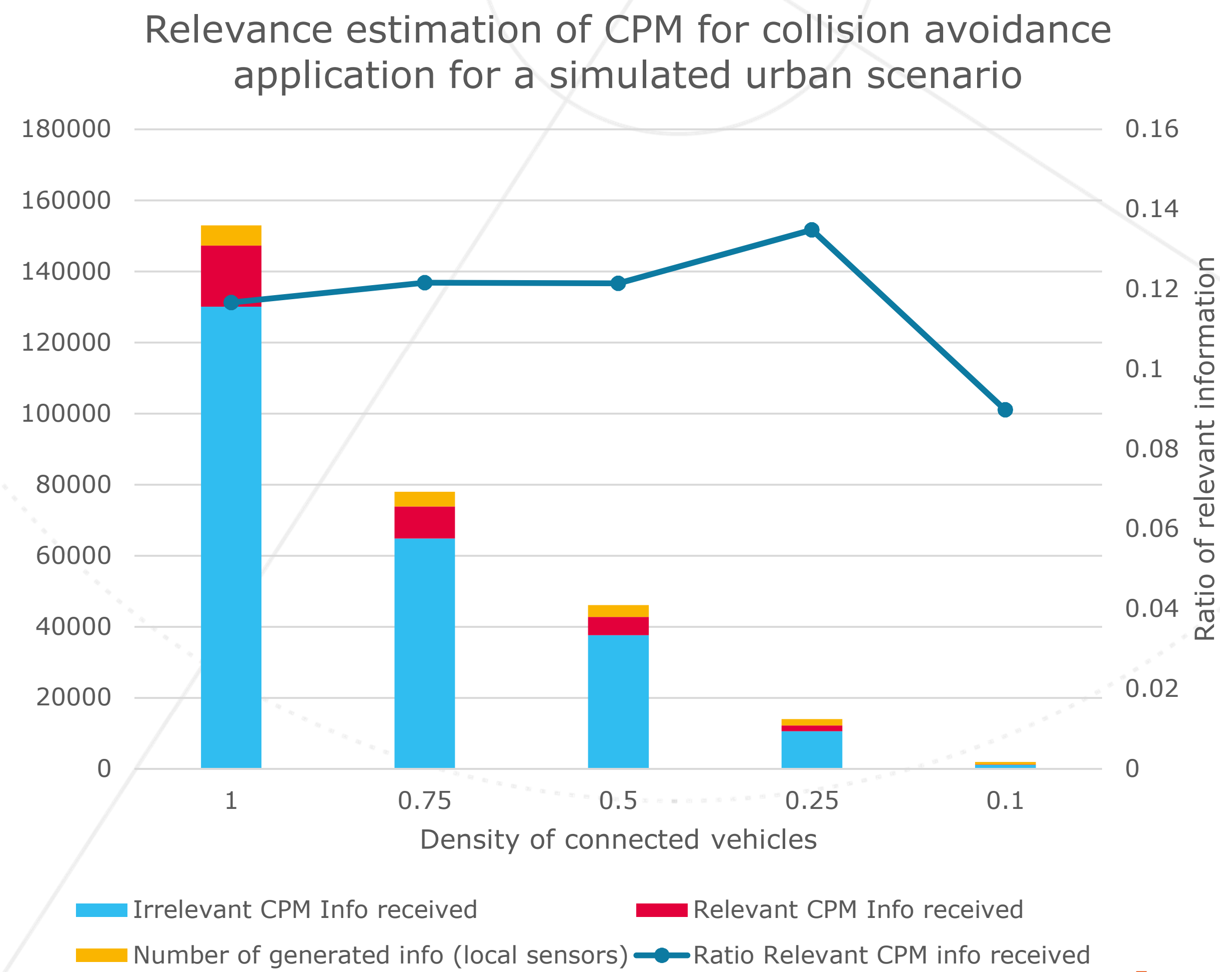
Assessing relevance– Consumer-based

Will this information affect my controls or decision-making?

An info about an object is relevant for collision avoidance when:

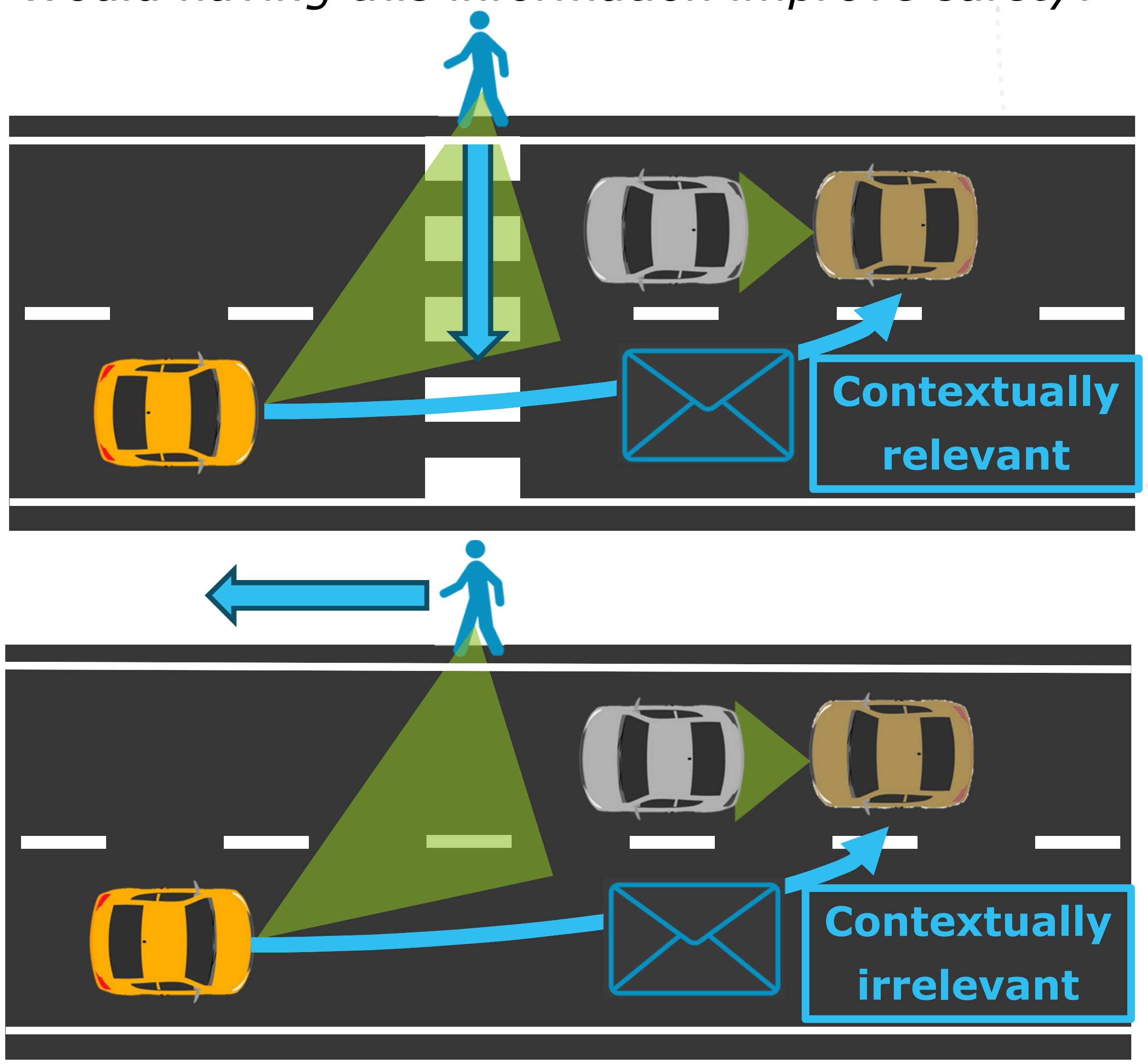
- Not detected locally
- 1s < TTC < 30s

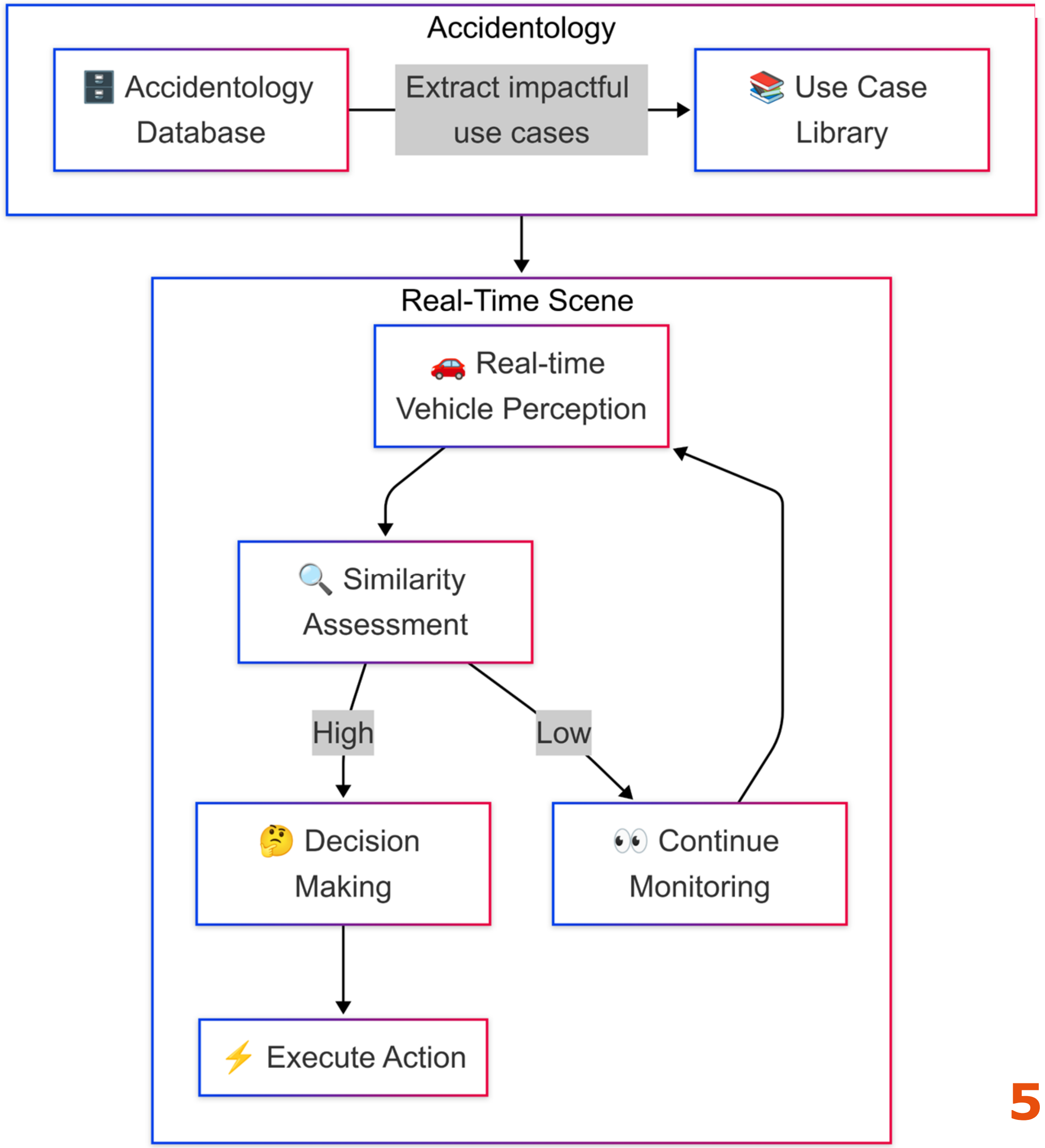




Assessing relevance– Scene recognition

Is this situation risky?
Would having this information improve safety?



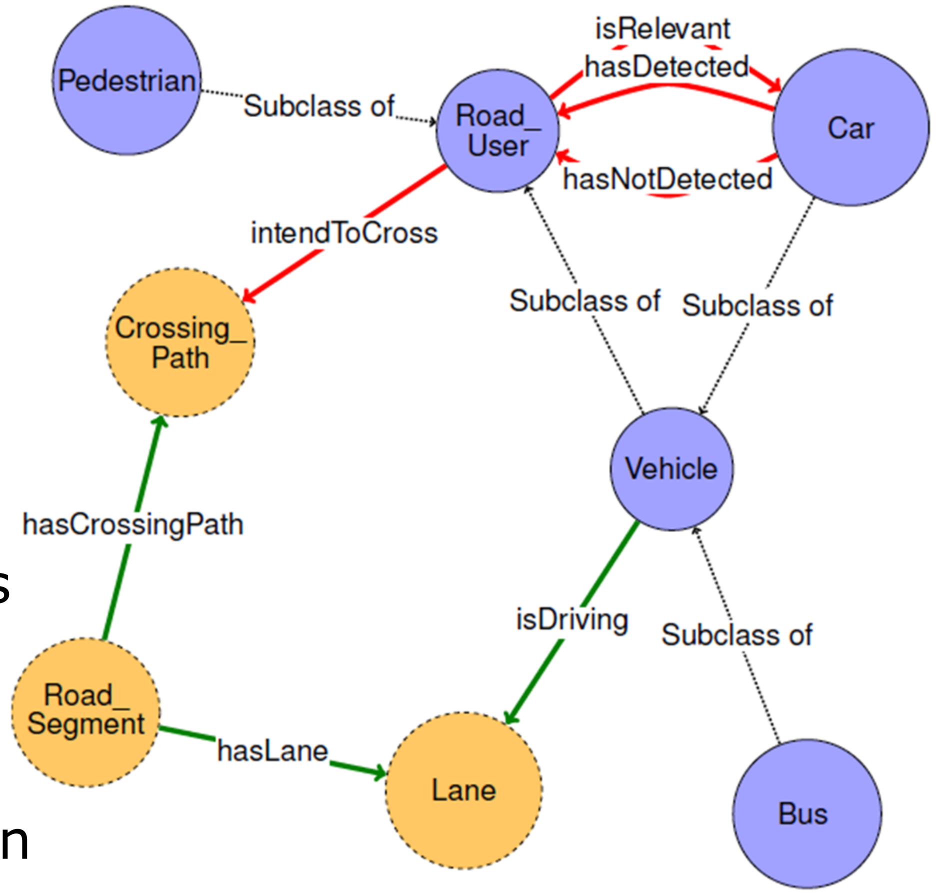


Representing the driving environment

Ontology:
- Defines key concepts (vehicles, pedestrians, road signs)
- Specifies relationships & attributes (spatial, temporal, event types)
- Provides a standardized schema for diverse sensor data

Knowledge Graph:
- Graph structure with nodes (entities) & edges (relations)
- Unifies multi-modal data (camera, LiDAR, RADAR) into a semantic view
- Enables automated reasoning & link prediction

Combined Benefit:
- *S*cene understanding for automated driving
- Reason over the graph



Infer on Knowledge Graph

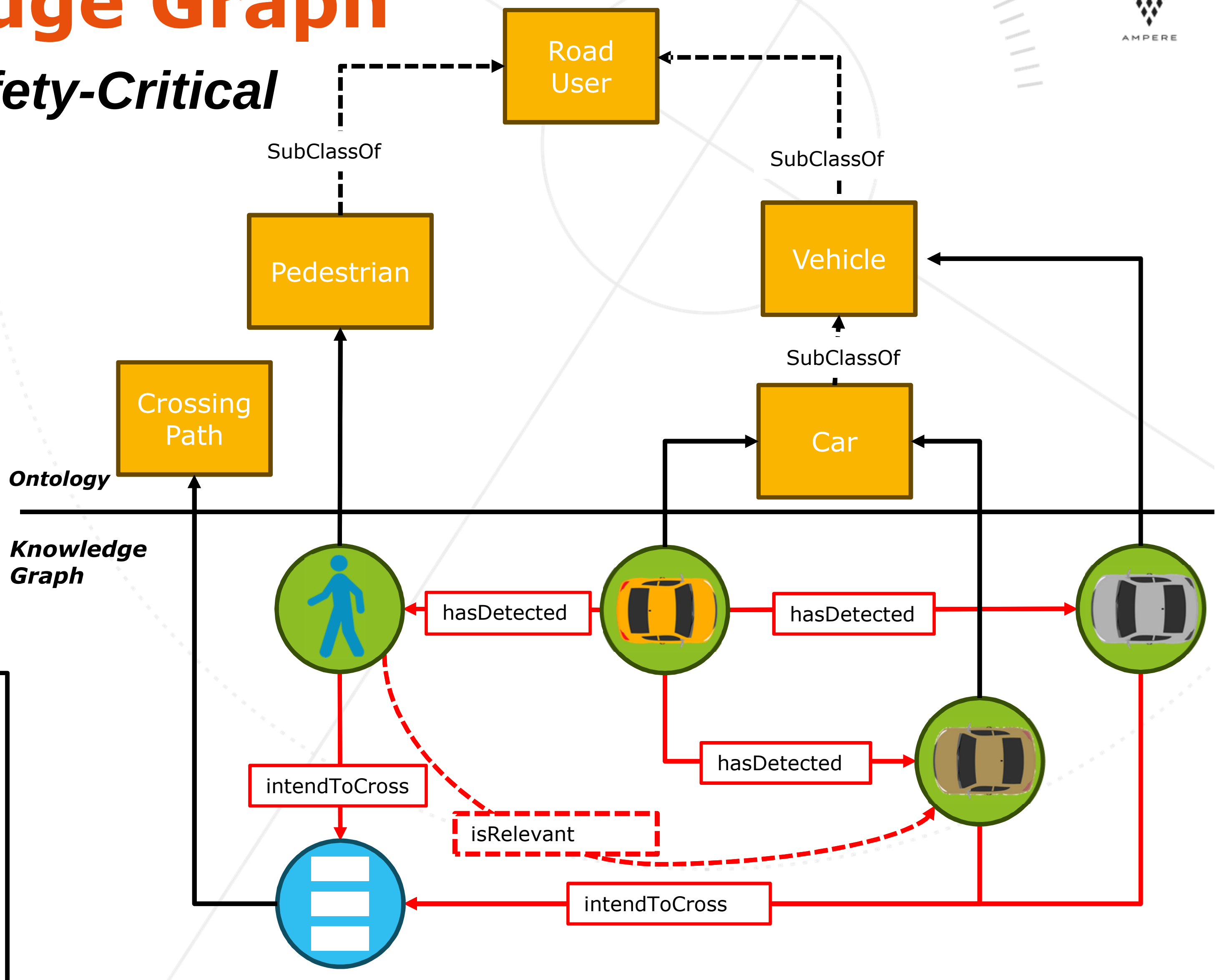
Interpretable Inference for Safety-Critical Systems

Core Idea
Derive **explicit logical rules** from the knowledge graph to predict missing links.

Semantic Web Rule Language:
- Safety parameters (Position, distance,...)
- Scenario-specific
- Extracted from accidentology database

```
RoadUser(?pedestrian) ∧ Car(?car) ∧
CrossingPath(?cp)
∧ hasSpeed(?car, ?speed)
∧ hasNotDetected(?car,?pedestrian)
∧ intendToCross(?car,?cp)
∧ intendToCross(?pedestrian,?cp)
∧ swrlb:greaterThan(?speed,MinSpeed)

⇒ isRelevant(?pedestrian,?car)
```



Semantic Enhancement of CPM

Object detection:

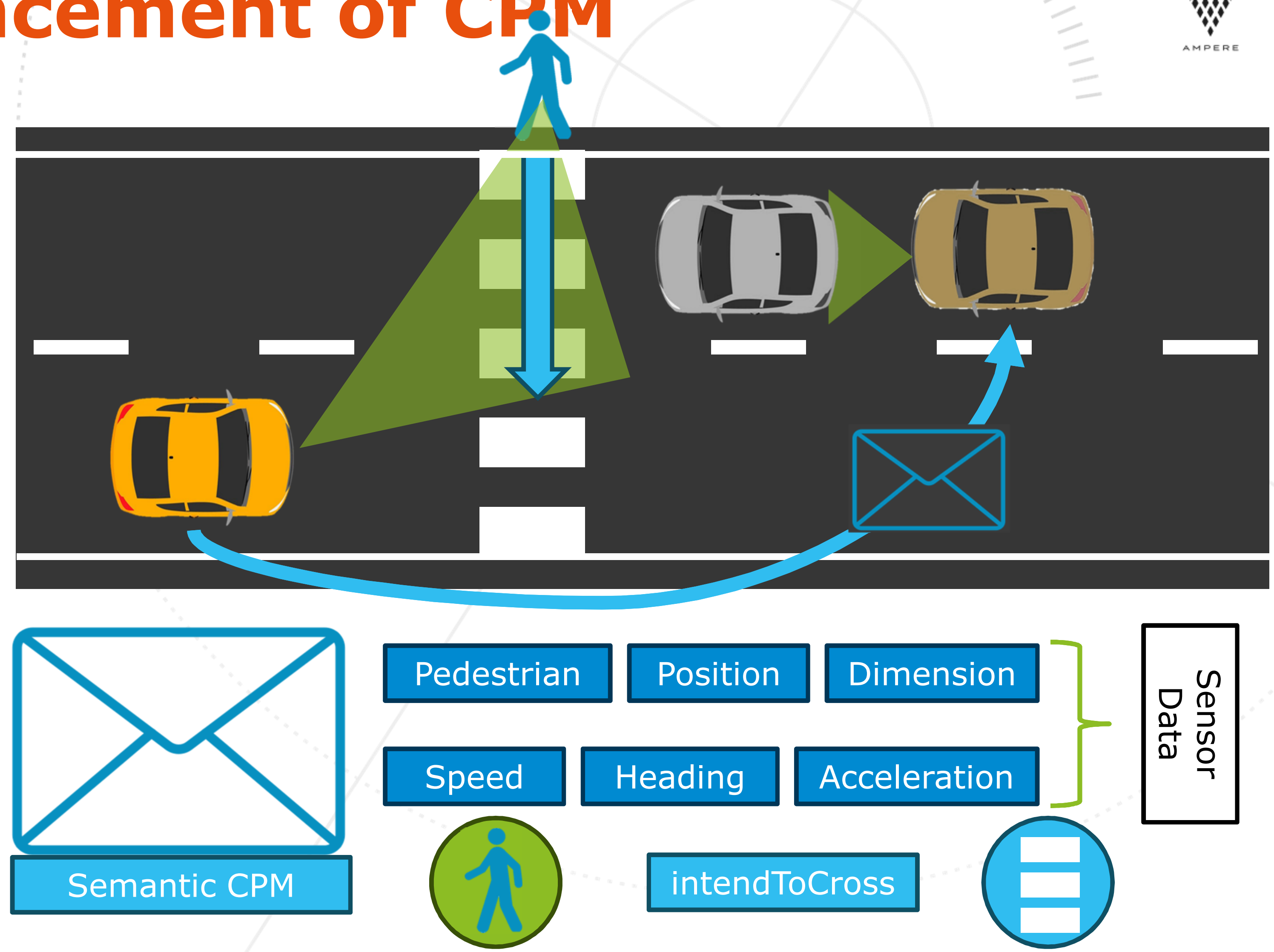
- Type, Position, Speed,… ➔ Sensor Data
- Primary goal of CPMs
- Suffer from precision, reliable, multiple POV, fusion

Scene understanding:

- Object detection + link between entities

Scene prediction:

- Crucial for fully automated vehicle



Conclusion

Key Contributions:
Introduction of ontology-based relevance estimation.
Enhanced situational awareness through semantic communication.

Future Directions:
Evaluate two **relevance estimation approaches**:
Scenario-specific (expert-defined criteria)
Machine Learning-based (data-driven pattern extraction)