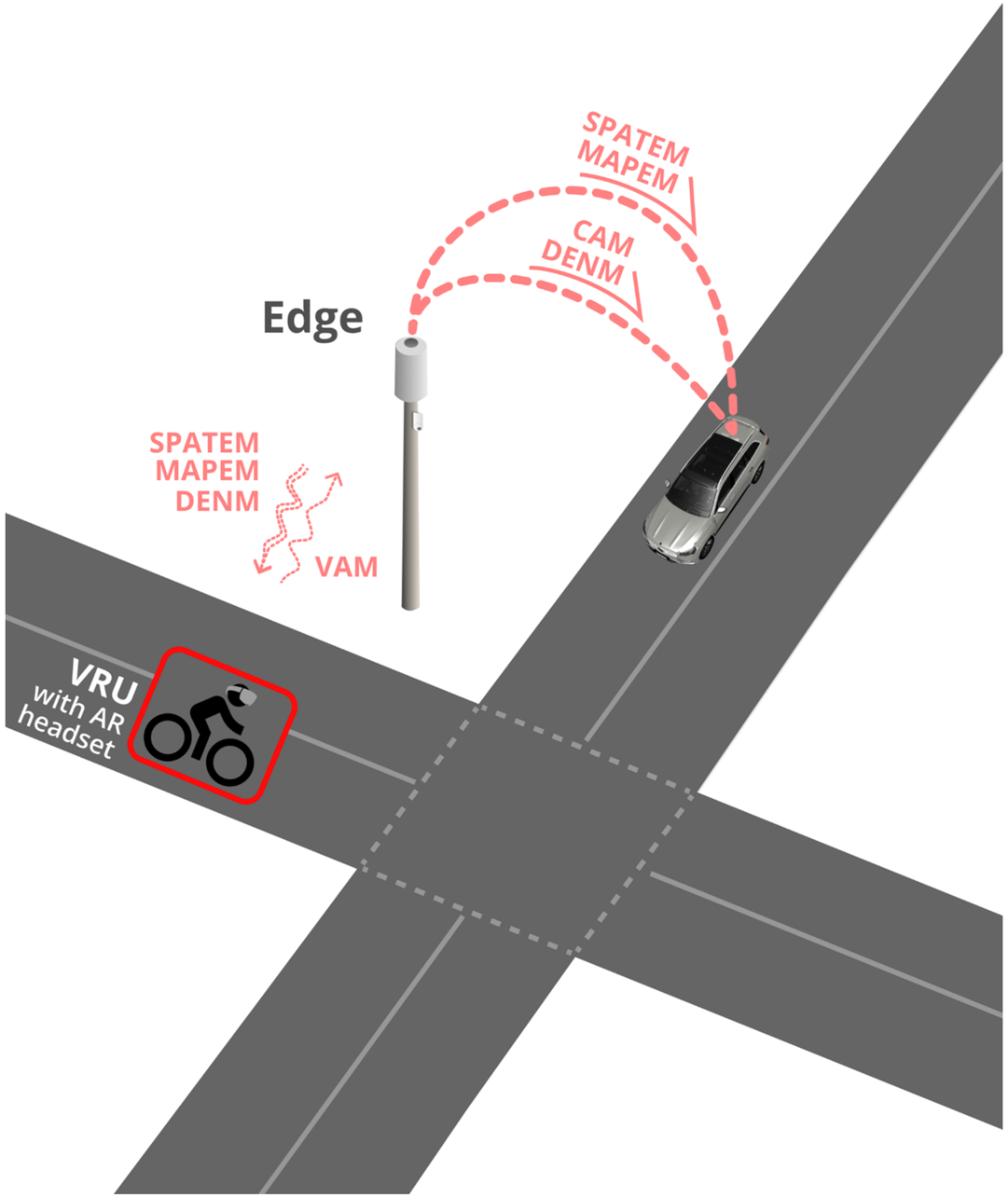

Towards New Interaction Techniques for Micromobility using V2X and AR

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22nd September 2024

September 2024 · 16th AutomotiveUI '24

An Overview

1 Background and Motivation

2 Related Work

3 Methodology

4 Results

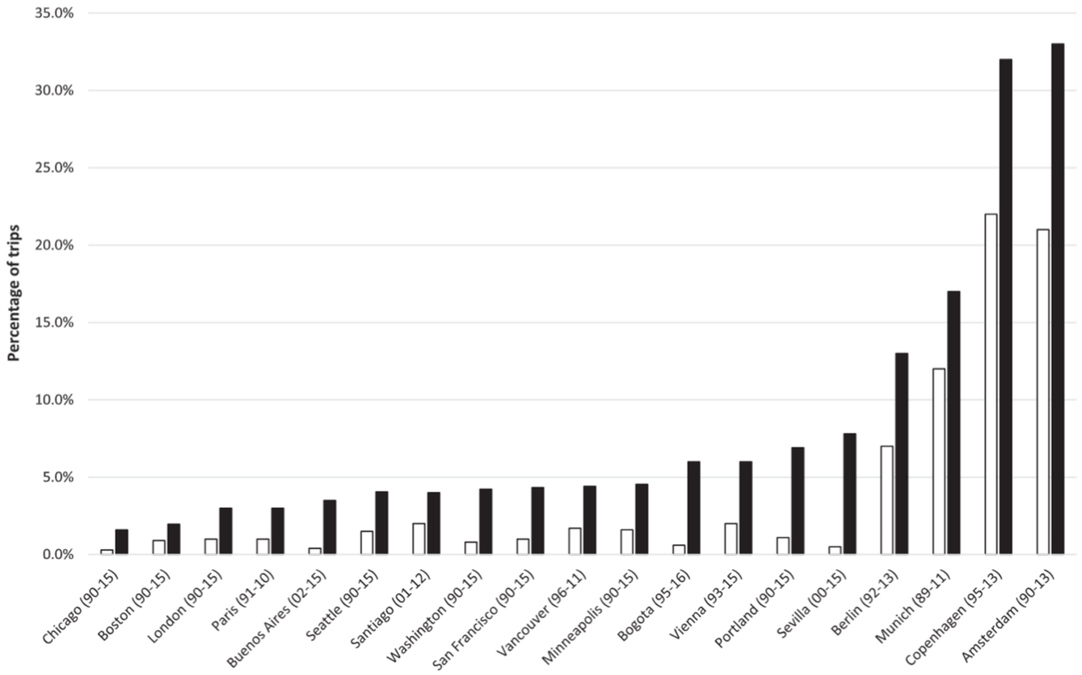
5 Discussion

6 Conclusions & Future Work

7 Demonstration

Micromobility Safety: Challenges and Opportunities

- Over 1.19 million fatalities in road accidents (2023). **More than half** involving VRUs [1].
- Bicyclists in road traffic is **rising**, specially in **Europe** [2].
- **Uncontrolled intersections** in low LoS urban areas are reported as the most dangerous for cyclists [3].



- **MR** is promised as a solution for enhancing road safety.
- **Smart Cities** are implementing **ITS** applications that transform mobility.
- Anticipated that V2X technology will be **integrated** into everyday devices by **2027**, enhancing connectivity and safety of road traffic [4].

[1]: https://www.who.int/publications/i/item/9789240086517
[2]: https://www.tandfonline.com/doi/full/10.1080/01441647.2017.1340234
[3]: https://cordis.europa.eu/project/id/634149/results
[4]: https://5gaa.org/content/uploads/2020/09/A-Visionary-Roadmap-for-Advanced-Driving-Use-Cases-Connectivity-Technologies-and-Radio-Spectrum-Needs.pdf

Research Focus

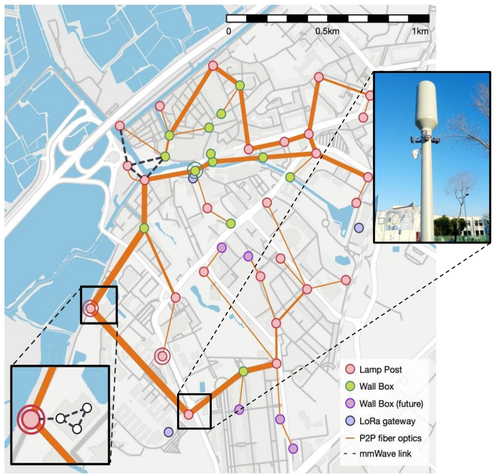
In this work we explore an innovative solution to aid cyclists at **uncontrolled intersections** with **low visibility conditions** within urban environments, leveraging AR systems, and ITS devices.

- Can AR **improve** cyclist safety at this **dangerous situations**?
- How does AR **impact** the workload and **performance** of cyclist while riding in real road traffic?

- Can **ITS and Smart City integration** be used to create a dynamic system that augments road user awareness?

Cyclist's POV

No Assistance **AR Assistance**



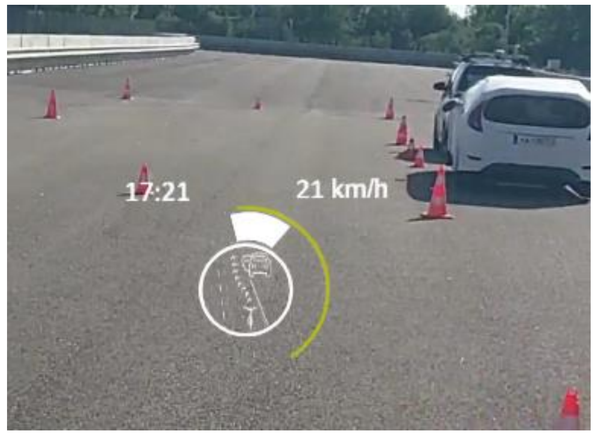
Rito et al., 2023 [5]

[5]: P. Rito et al., "Aveiro Tech City Living Lab: A Communication, Sensing, and Computing Platform for City Environments," in IEEE Internet of Things Journal, vol. 10, no. 15, pp. 13489-13510, 1 Aug.1, 2023, DOI: 10.1109/JIOT.2023.3262627

Related Work

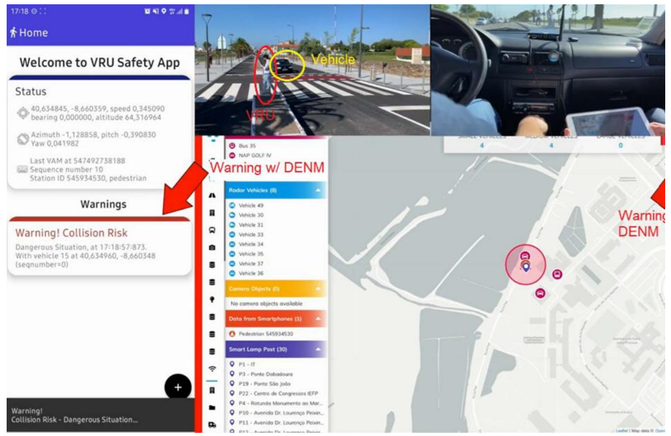
Given the scope of this problem, we analyse prior work through the prism of these three areas.

Hazard Notifications for Cyclists



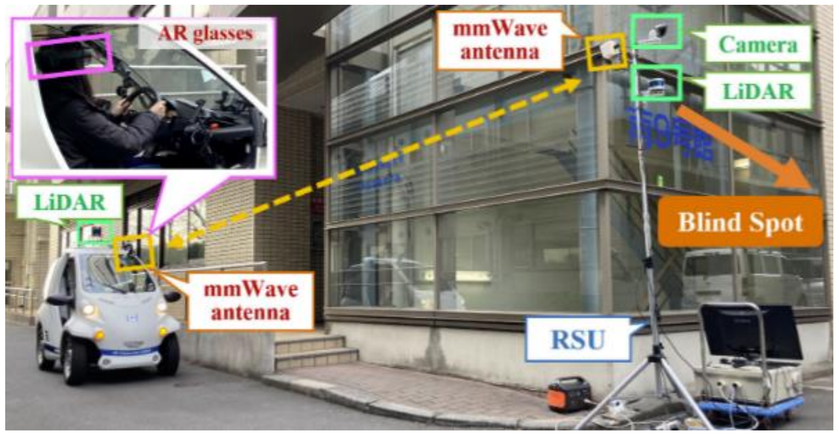
von Sawitzky et al., 2023 [6]

V2X applications in living labs



Teixeira et al., 2023 [7]

Blind-spot visualization

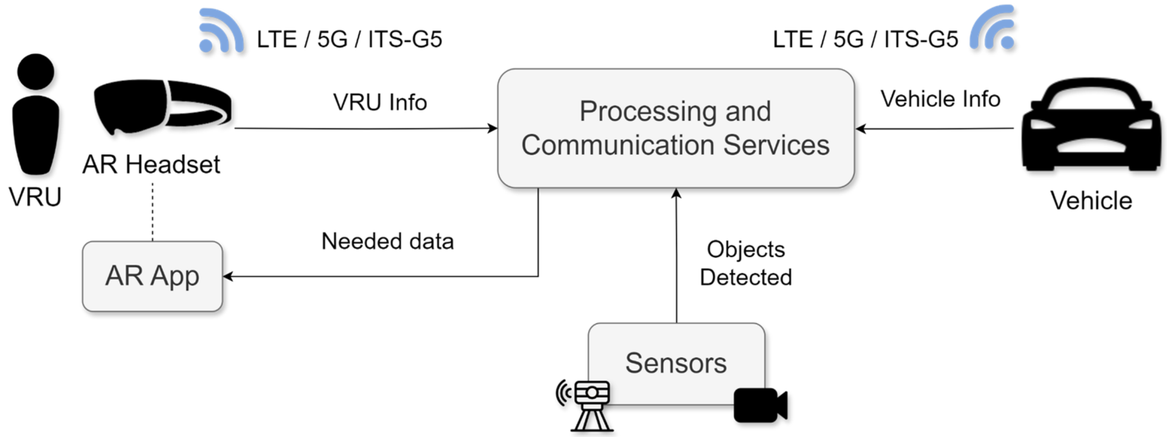


Maruta et al., 2021 [8]

[6]: T. von Sawitzky, et al., “Investigating Hazard Notifications for Cyclists in Mixed Reality: A Comparative Analysis with a Test Track Study”, Proceedings of the 15th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '23), DOI: 10.1145/3580585.3606282
[7]: P. Teixeira, et al., “A Sensing, Communication and Computing Approach for Vulnerable Road Users Safety”, In IEEE Access, vol. 11, pp. 4914-4930, DOI: 10.1109/ACCESS.2023.3235863
[8]: K. Maruta, et al., "Blind-Spot Visualization via AR Glasses using Millimeter-Wave V2X for Safe Driving", 2021 IEEE 94th Vehicular Technology Conference (VTC2021-Fall), DOI: 10.1109/VTC2021-Fall52928.2021.9625498

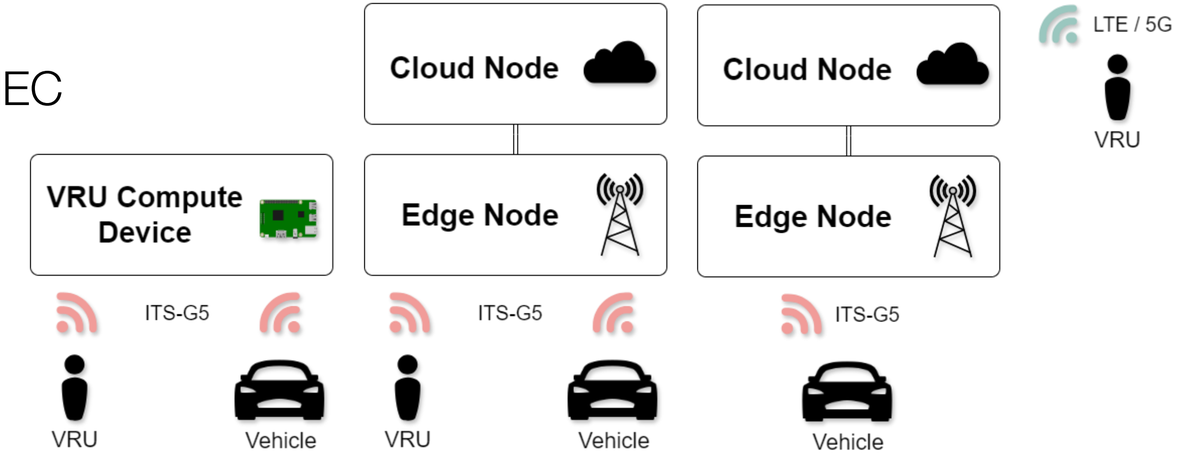
Communication Setup

The development of a safety system that **assists cyclists** requires an architecture that enables seamless interactions among road users.



Using **ITS-G5 and 5G** technologies, with possibility for MEC we can create scenarios:

- Using **cloud computing** to inform road users.
- Using **peer-to-peer communications**, without relying in smart infrastructure.



AR Assistance

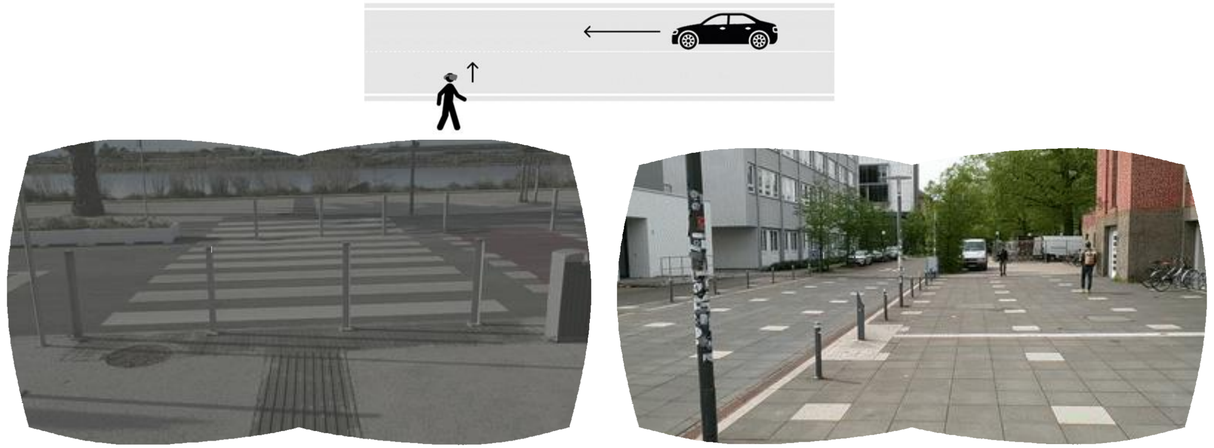
Three AR applications were developed in Unity to enhance VRU safety.

Collision Warning System:

- Interacts with CAMs, VAMs and DENMs.
- Notification in the top centre of the user's FOV.
- 3D arrow pointing to direction of the hazard.
- 800 Hz tone for 1 second.

Virtual Traffic Lights:

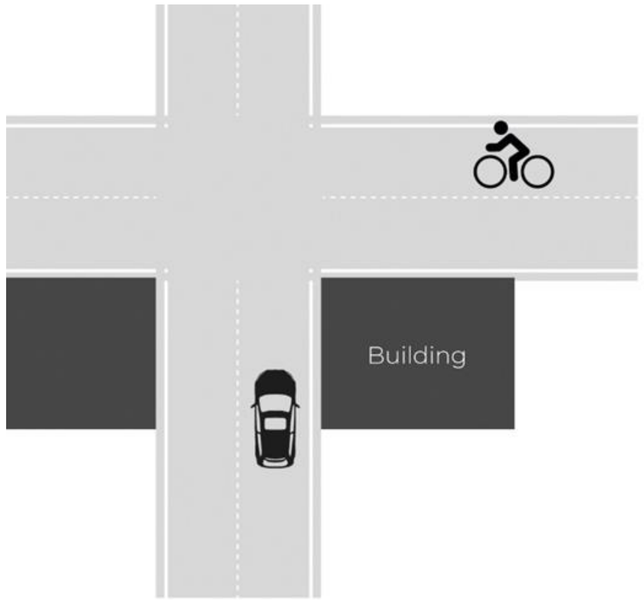
- Interacts with VAMs, SPATEMs and MAPEMs.
- Detects the traffic lane of the road user and presents the correct light.
- Bell-like sound for 1 second at light change.

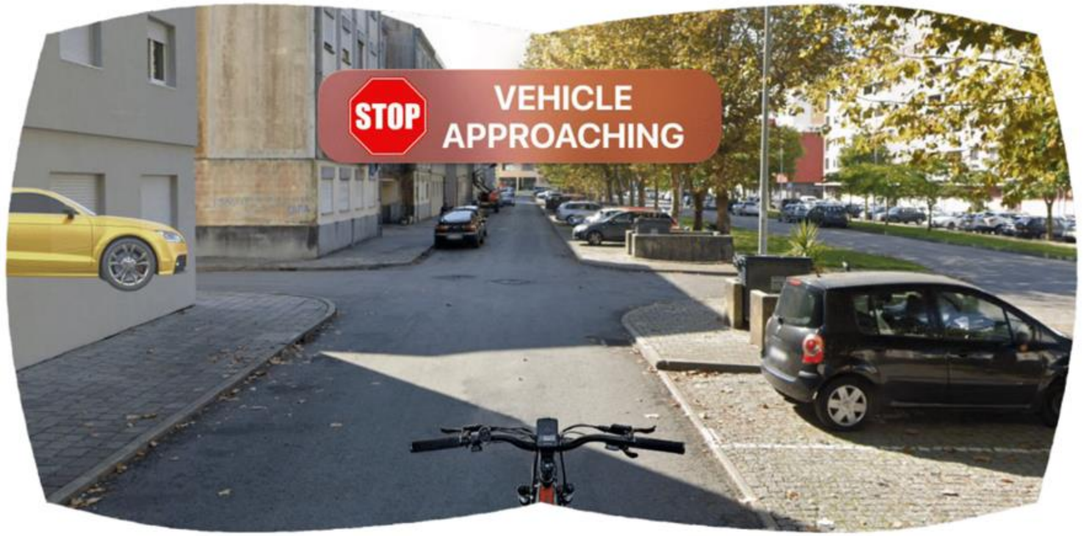


AR Assistance

X-Ray:

- Interacts with CAMs, VAMs and DENMs.
- Presents a virtual vehicle in the virtual world superimposing the vehicle in the real world.
- Utilizes the VRU’s GPS coordinates and heading.
- Utilizes the vehicle’s GPS coordinates.

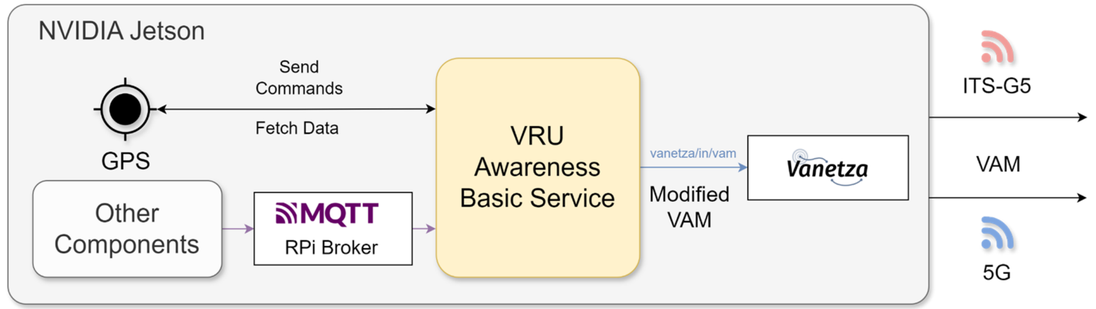




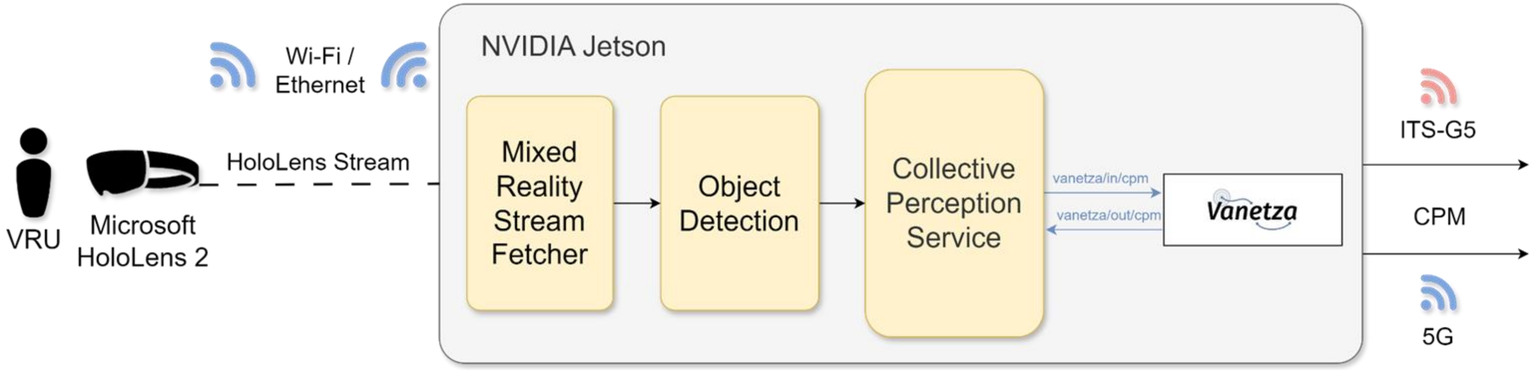
Enhancing Infrastructure Insights with the HoloLens

The AR headset can be used as a device that enhances infrastructure insights either through **ITS-G5 or 5G**.

- Using a **computational unit** with a GPS module, VAMs with **additional** information can be generated by the VRU.



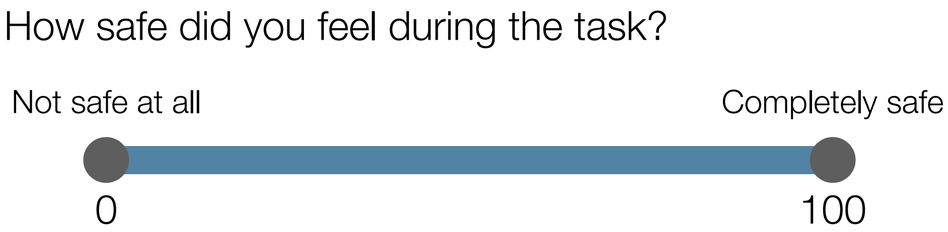
- A **NVIDIA Jetson** can retrieve video stream feed from the Microsoft HoloLens 2 to detect objects. The AR headset is used as a **mobile camera**.



Measurements to Consider

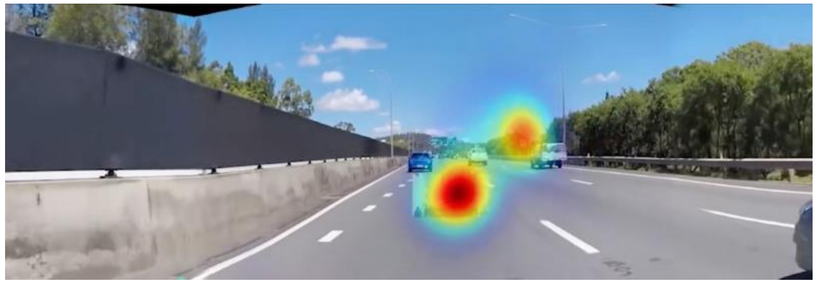
Subjective measurements:

- System Usability Score **(SUS)**.
- NASA Task Load Index **(NASA-TLX)**.
- Perceived Safety **(Slider 0-100)**.



Objective measurements:

- Reaction time.
- Minimum distance to vehicle.
- Eye tracking.

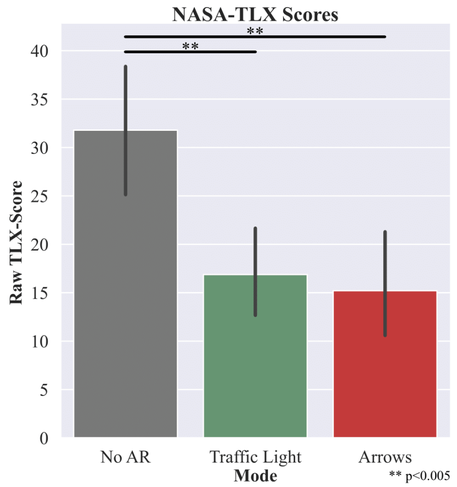


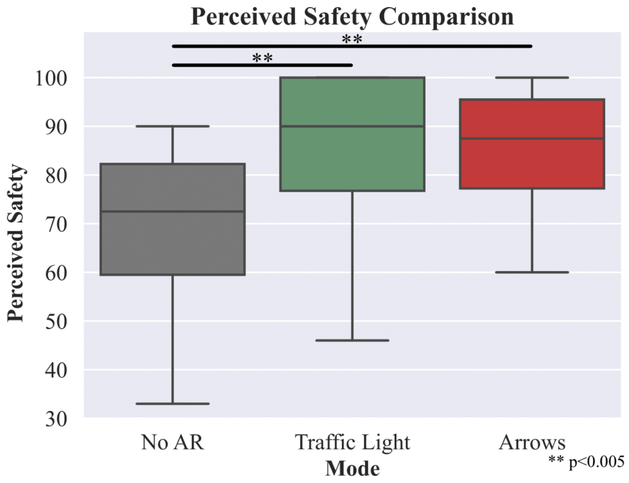
Gerber et al., 2021 [9]

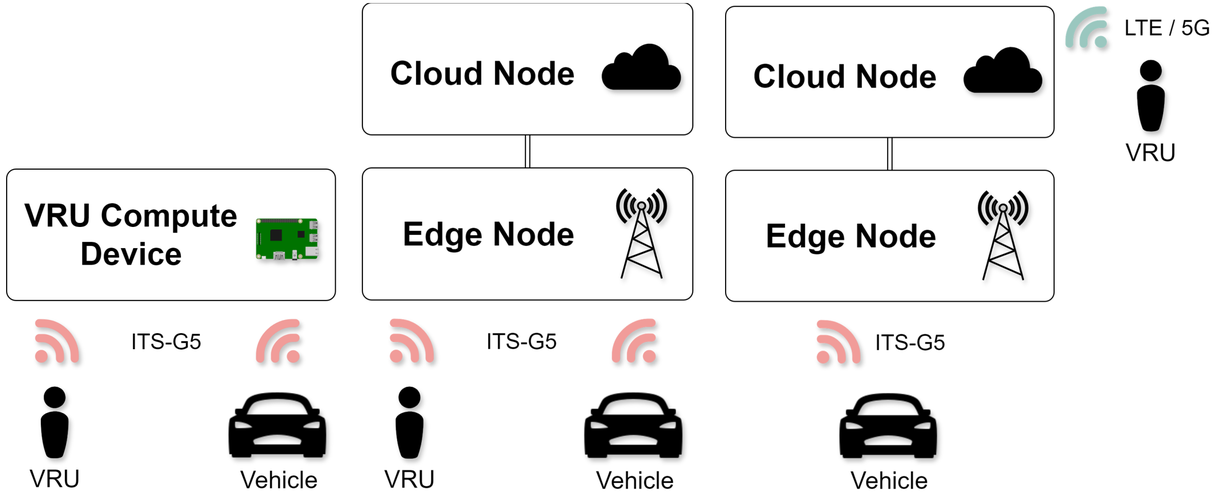
[10]: Michael A. Gerber et al, “Eye-Gaze Analysis of HUD Interventions for Conditional Automation to Increase Situation Awareness”. In 13th International Conference on Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI '21 Adjunct), DOI: 10.1145/3473682.3481872

Preliminary Outcomes

Our previous work, “SafeARCross” demonstrated the benefits of such systems through a real-life user study (N=20) aimed at pedestrians at crossing scenarios.







- **Perceived safety** was **lower** without AR support.
- **Perceived workload** was significantly **reduced** when using AR support.

Latency (E2E)
93.84 ms ± 20

Latency (E2E)
73.30 ms ± 12

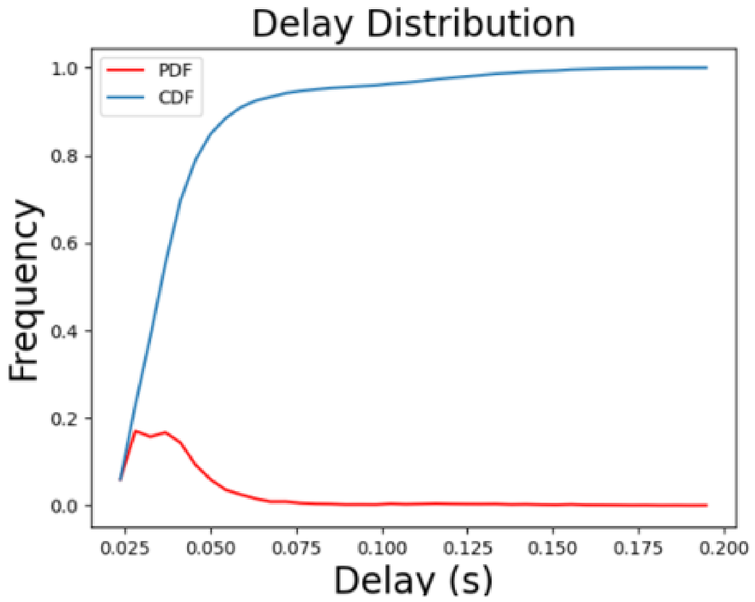
Latency (E2E)
110.83 ms ± 16

Computational Offload

Previous studies explored the possibility of using **stationary cameras** throughout a **smart city** to detect road users using **YOLO**.

Findings have suggested that the object detection processing time takes **~80 ms**.

The **high latency** of the **camera's video stream** could become a bottleneck for the system's overall end-to-end latency.



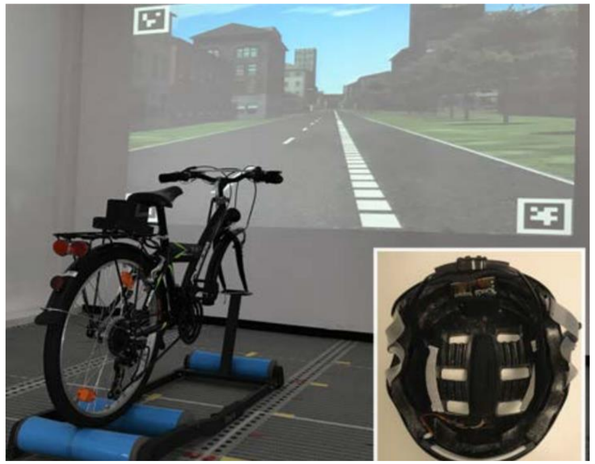
Mendes et al., 2024 [9]

[9]: M. Mendes, et al., “Real-time Object and Event Detection Service through Computer Vision and Edge Computing”, ITS World Congress 2024, Accepted

Contributing to Ecological Validity

We aim to work here!

Stationary cycling



Matviienko et al., 2018 [11]

BikeAR

Matviienko et al., 2022 [12]

Cycling in the real world

Figure [13]

Safe and artificial

Realist and dangerous

[11]: A. Matviienko, et al., “Augmenting bicycles and helmets with multimodal warnings for children”, In Proceedings of the 20th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '18), DOI: 10.1145/3229434.3229479

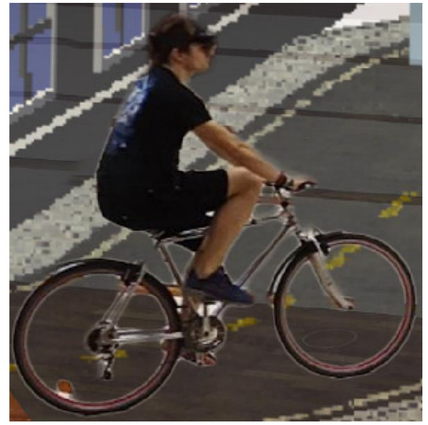
[12]: A. Matviienko, et al., “BikeAR: Understanding Cyclists’ Crossing Decision-Making at Uncontrolled Intersections using Augmented Reality”, In Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22), DOI: 10.1145/3491102.3517560

[13]: https://upload.wikimedia.org/wikipedia/commons/6/62/Urban_cycling_III.jpg

Challenges and Limitations

Limitations of wearing an AR headset:

- Extended use could lead to **discomfort** or **fatigue**.
- Device may **malfunction** in **unfavorable weather** conditions.
- **AR's FOV** might not be sufficient for **cycling scenarios**.
- Social acceptance.



Matviienko et al., 2022 [12]

Technical challenges:

- Video stream latency.
- Detecting **lack of LoS** remains a significant challenge.
  - **Expectation** of an object (through V2X messages).
  - **Detection** of an object (by the camera).
  - **Reconfirmation** by the depth sensor.

Conclusions

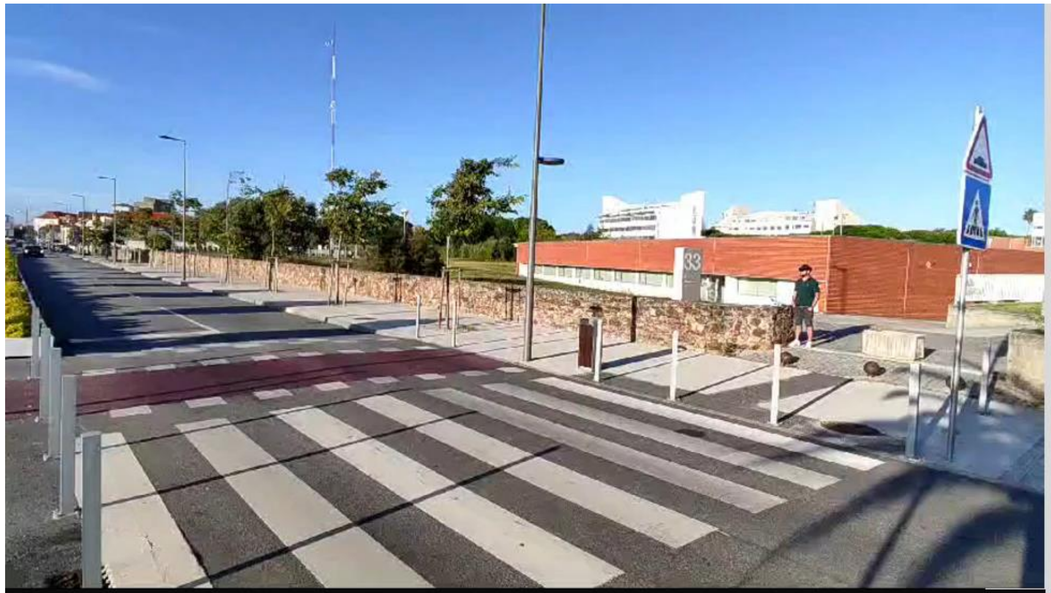
- The integration of **AR with V2X** technologies is a promising approach to **enhancing cyclist safety**.
- **V2X communications** are crucial for dynamic safety systems in the **real-world**.
- **Offloading** complex calculations to an **external compute unit** is key for complex AR systems, but may hinder the system latency.

Future Work

There are several areas that can be extended and others that can be analysed in more detail:

- Focusing on the development of more **intuitive**, non-overwhelming UIs and their **effects** on cyclists in **real world scenarios**.
- Leverage advanced **AR devices** like HoloLens 2 and **its sensors** for new safety applications in a **connected environment**.
- Integrate with **autonomous vehicles**.

Demonstration



```
root@atcll-nos:~/app# ./start.sh
Waiting for data...
Writer is running...
MQTT Publisher connected with code 0
Subscriber matched publisher 1.f.e4.56.2c.1.a4.40.0.0.0.0.0.0.1.3
Received ID: 146
/root/app/app.py:327: FutureWarning: The behavior of DataFrame concatena
precated. In a future version, this will no longer exclude empty or all-
dtypes. To retain the old behavior, exclude the relevant entries before
  data = pd.concat([data, new_entry_df], ignore_index=True)
Received ID: 44793
/root/app/app.py:327: FutureWarning: The behavior of DataFrame concatena
precated. In a future version, this will no longer exclude empty or all-
dtypes. To retain the old behavior, exclude the relevant entries before
  data = pd.concat([data, new_entry_df], ignore_index=True)
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/root/app/app.py:327: FutureWarning: The behavior of DataFrame concatena
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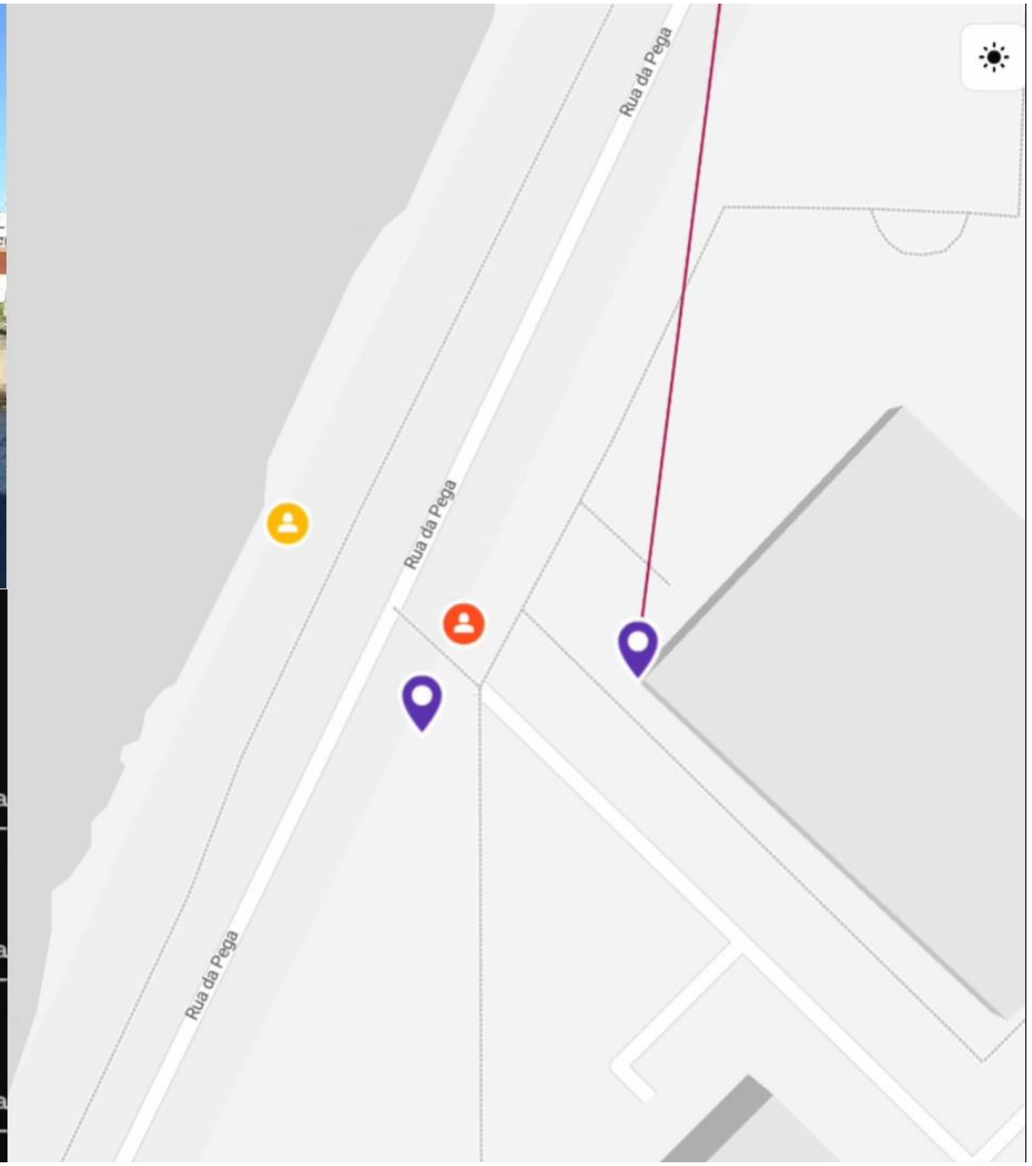
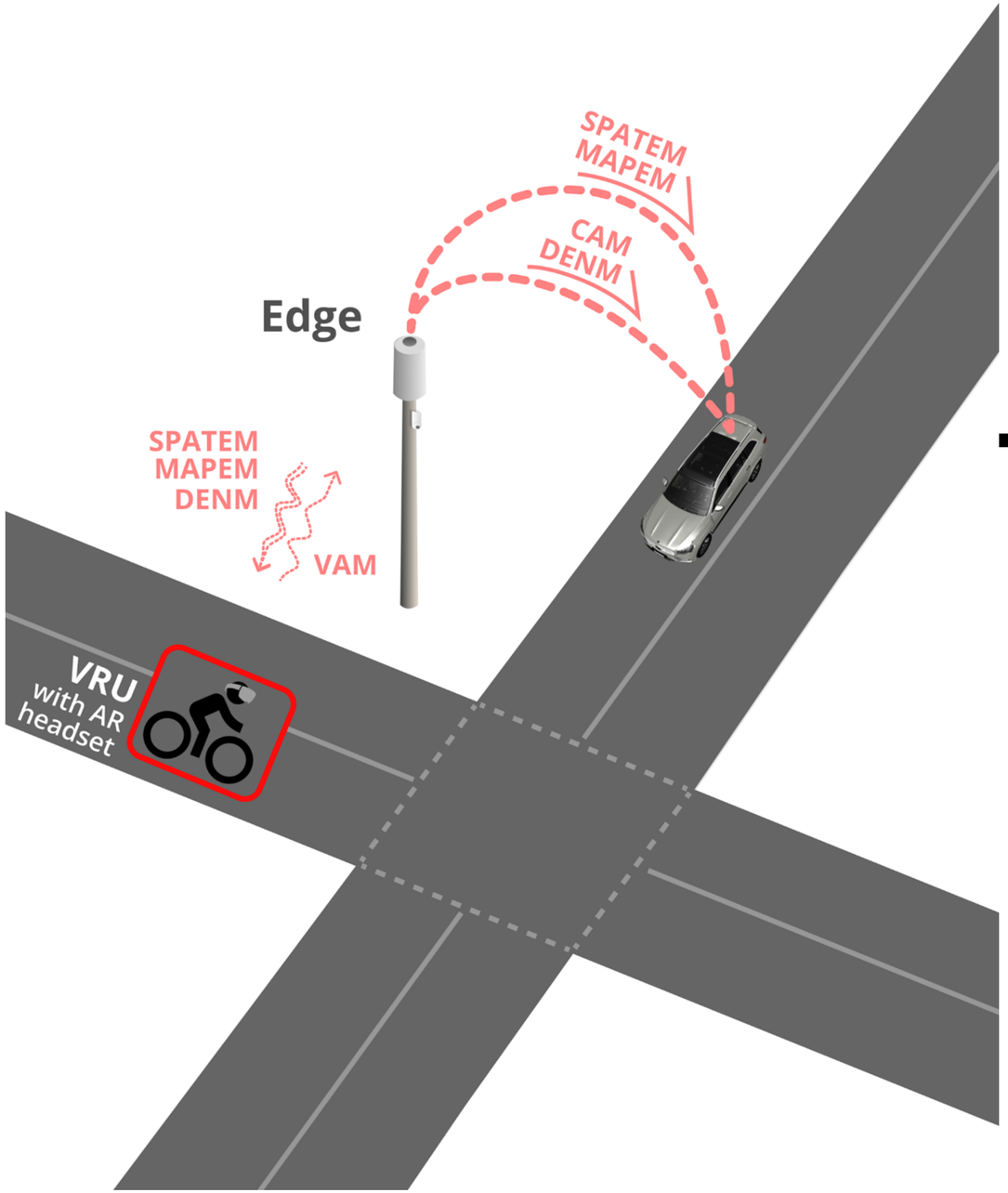


Thank you

This work is supported by the European Union / Next Generation EU, through Programa de Recuperação e Resiliência (PRR) Project Nr. 29: Route 25 (02/C05-i01.01/2022.PC645463824-00000063). We also acknowledge the support of the Excellence Strategy of the German Federal and State Governments and of the Helmholtz Program “Engineering Digital Futures”.



Any Questions from the Audience?