

REMOTE DRIVING OPERATION (REDO)

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vti

SAFER project result day #1

REMOTE DRIVING OPERATION (REDO)

with funding from:

VINNOVA
Sweden's Innovation Agency

- January 2020 – February 2023 coordinated by VTI
- Focus on different aspects of **remote driving**:
 - Challenges for remote drivers
 - Driving feedback to remote drivers
 - Network architecture and supporting 5G infrastructure
 - Laws and regulations



ictech

CEVT



einride



ERICSSON

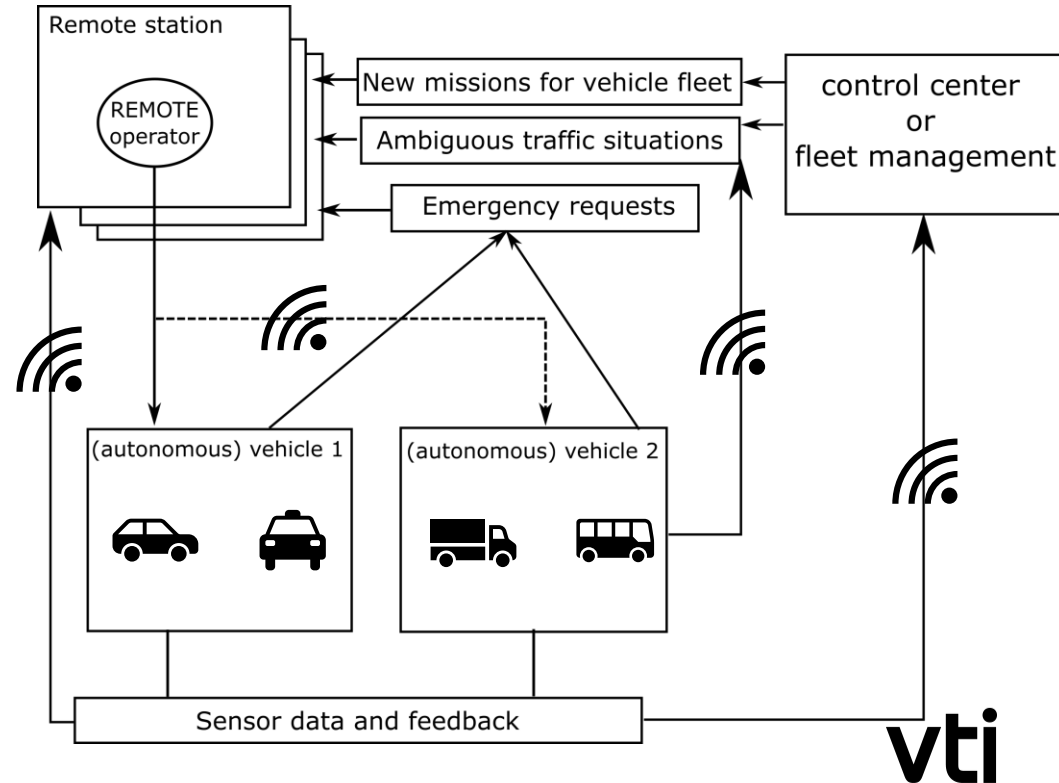
voysys



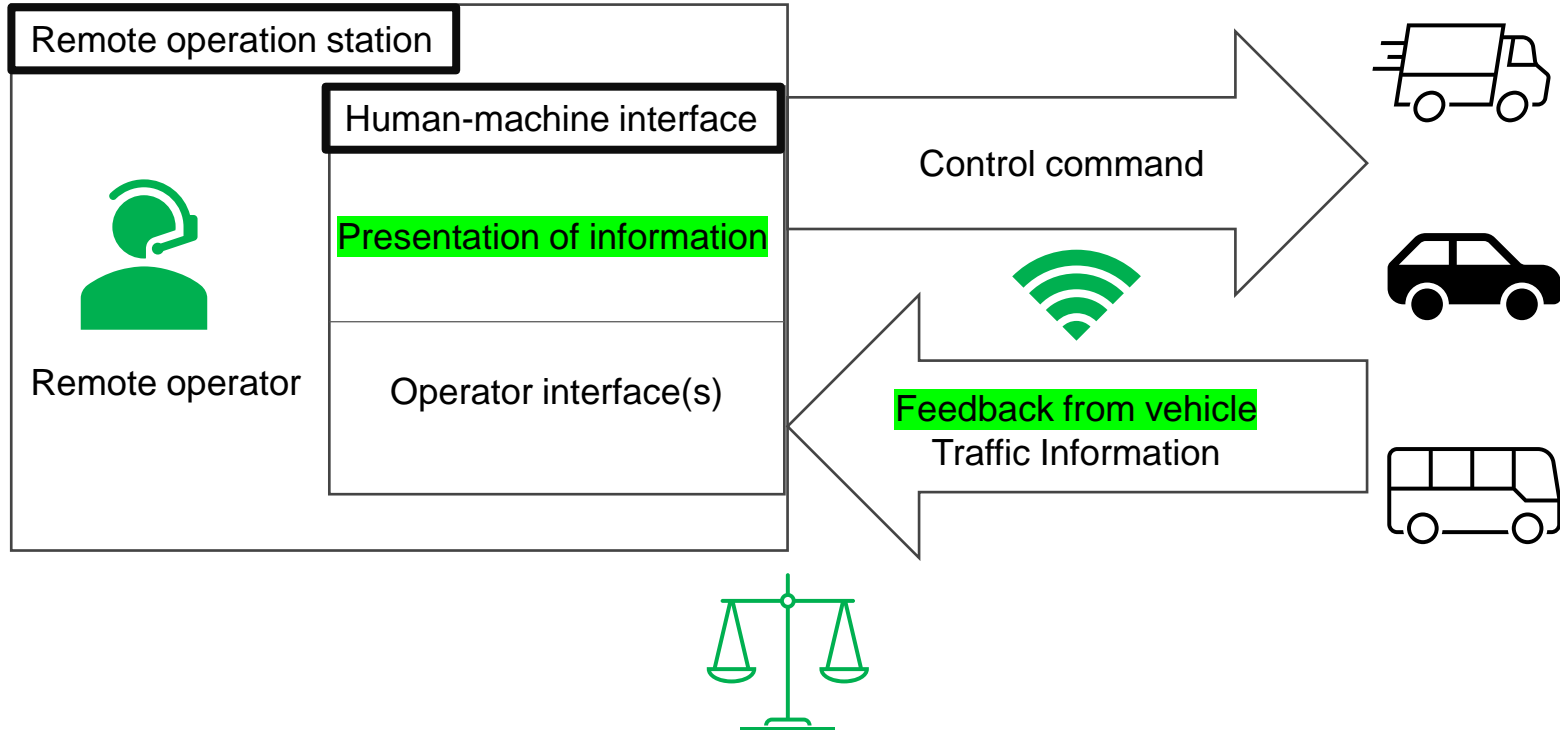
NEWS vti

REMOTE DRIVING OPERATION

- Fallback solution to ADS
- (Remote) safety drivers
- Increase up-time for AVs
- “Teach” ADS
- Relocate (autonomous) vehicles
- Many more...



SCOPE OF THE PROJECT



EFFECTS OF LATENCY AND FIELD-OF-VIEW

- Driving scenario in 50 km/h (urban road) and 70 km/h (rural road)
- 2 experiments with different combination of latencies:
 - Baseline (BL); BL+100; +150 ms; +200 ms
- 2 field-of-views: normal vs “camera on the roof”
- Participants were not informed about the change in latency
- Include experience gamers and professional (taxi) drivers



EFFECTS OF LATENCY AND FOV

- The reaction time increased more than the manipulation of delay in the simulator (for some tasks)
- A higher latency affected the self-assessed sense of performance negatively
- Overall, the participants adapted their behavior to the latency, although they were not aware of the change
- Field-of-view effect is still under analysis

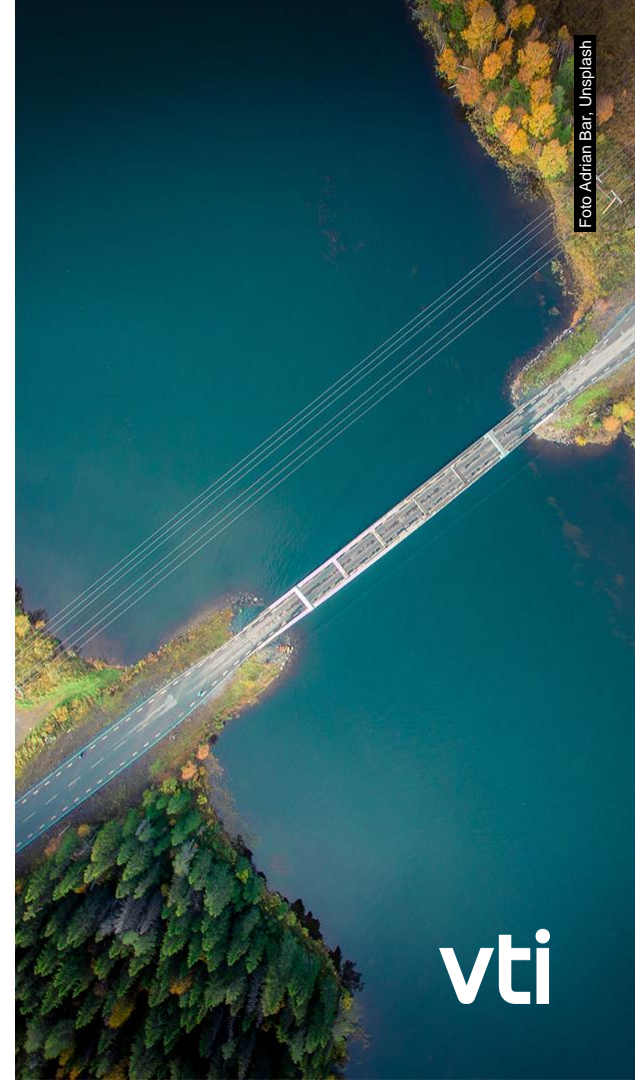


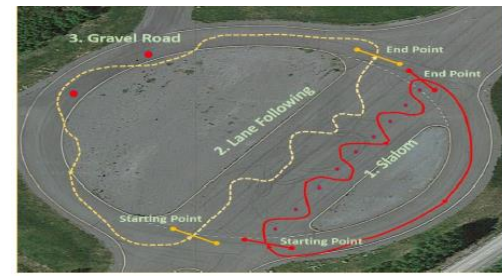
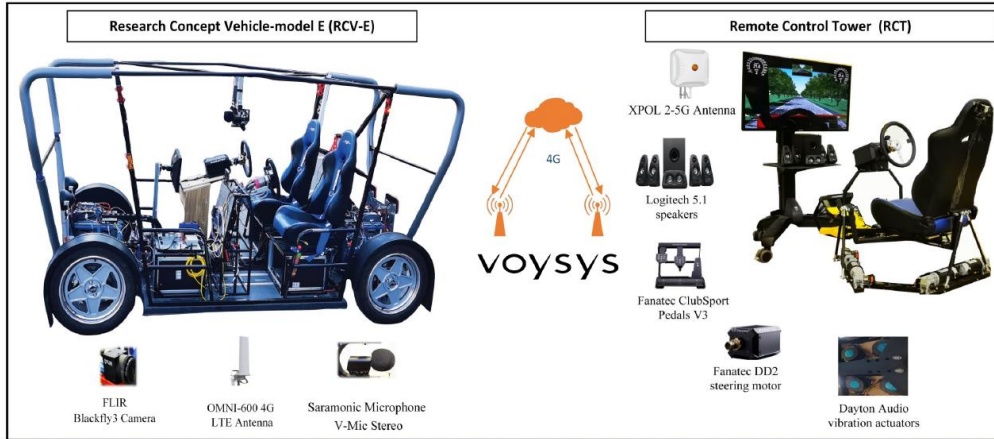
Foto Adrian Bar, Unsplash

REMOTE DRIVING FEEDBACK

- Steering force feedback, motion feedback, sound feedback
- 2 experiments were conducted



Teleoperation prototype



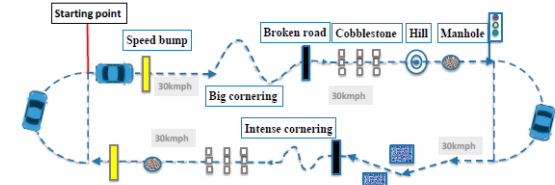
Steering wheel in teleoperation station

The same steering motor

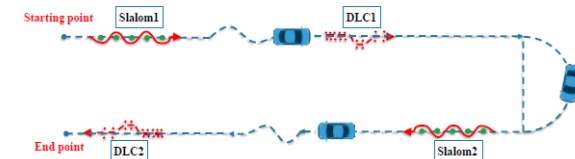


Steering wheel on the car

Scenario 1 (Low speed disturbance scenario)



Scenario 2 (High Speed dynamic scenario)



Region Stockholm



TRAFIKVERKET

ITRL – INTEGRATED TRANSPORT
RESEARCH LAB
KTH ROYAL INSTITUTE OF TECHNOLOGY

REMOTE DRIVING FEEDBACK

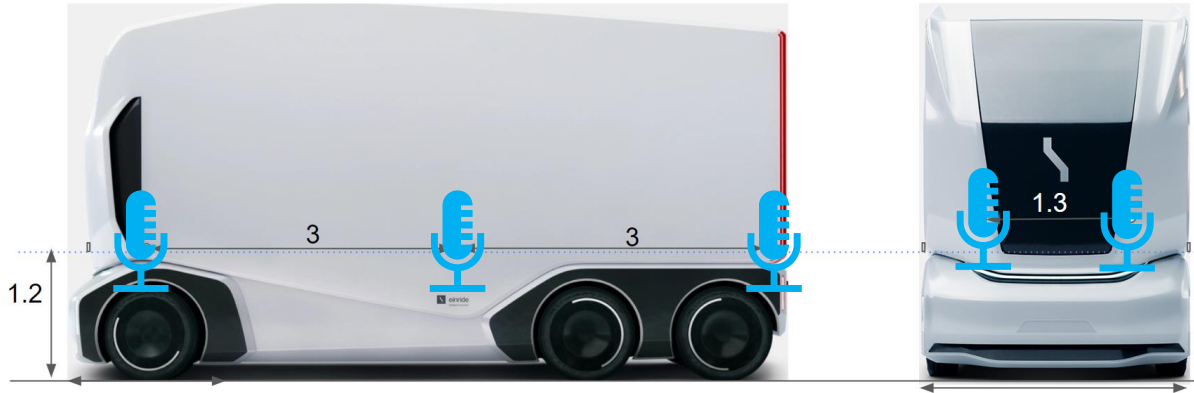
- Required level of feedback seems to be lower than the actual level in real car
- Driving performance is worse compared to real driving
- Steering feedback is needed for better driving experience
- Sound and vibration feedback are important for speed awareness
- Workload in teleoperation is higher than real driving

L. Zhao,
'Teleoperation and the influence of driving feedback on drivers' behaviour and experience',
Licentiate dissertation, KTH Royal Institute of Technology, Stockholm, 2023.



AUDITORY FEEDBACK

- Concept study
 - Equipped microphone to Einride's "Pod" to give spatial sound feedback
 - Tested on AstaZero
- Driving simulator experiment
 - CARLA simulator with engine sound and augmented(surrounding road users) sound



AUDITORY FEEDBACK

Concept study

- Allowing the operator to hear all the minor sounds that the Pod makes (e.g., when the brakes engage or that the backup alarm is sounding) is a quite useful feature of the spatial sound transmission and rendering

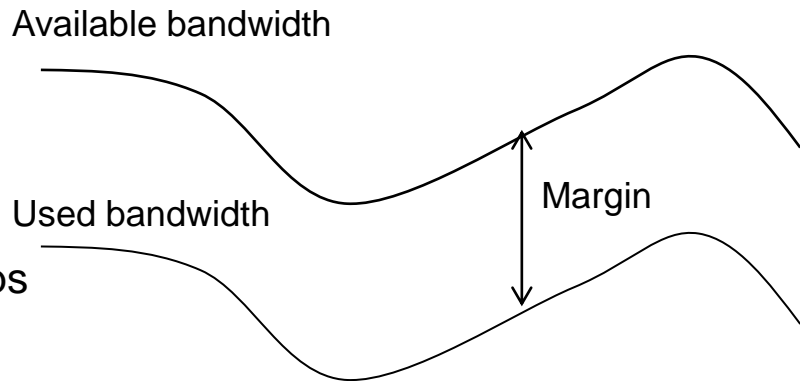
Driving simulator study

- Participants were more accurate in keeping the speed of 50 km/h with sound
- Subjective and objective measures can be improved by engine sound and augmented sound in terms of presence, awareness, ego-motion, and speed keeping



VIDEO TRANSMISSION

- Always keep a margin to available bandwidth
- Quickly reduce bandwidth when bandwidth drops
 - Image size
 - Frame rate
 - Encoding quality
- Use several links to protect against congestion on single links
- Safety stop when severe latency peak is detected

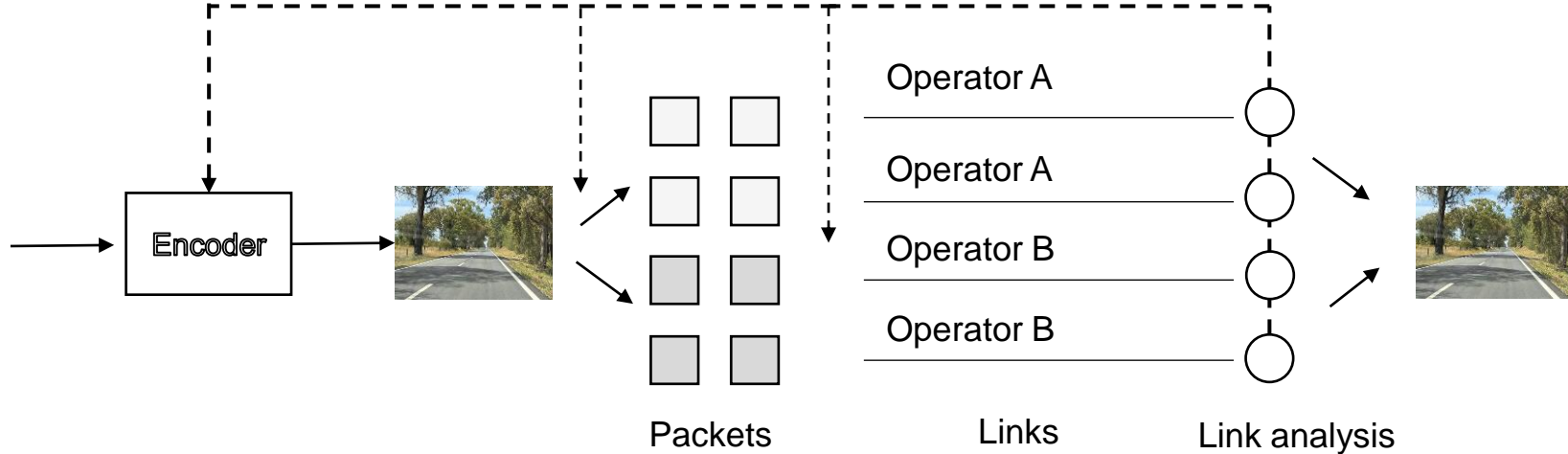


voysys

*Phantom Auto acquired Voysys in 2022

VIDEO TRANSMISSION

- Utilize multiple links from different operators
- Test made in Norrköping using Telia and Tele2



voysys

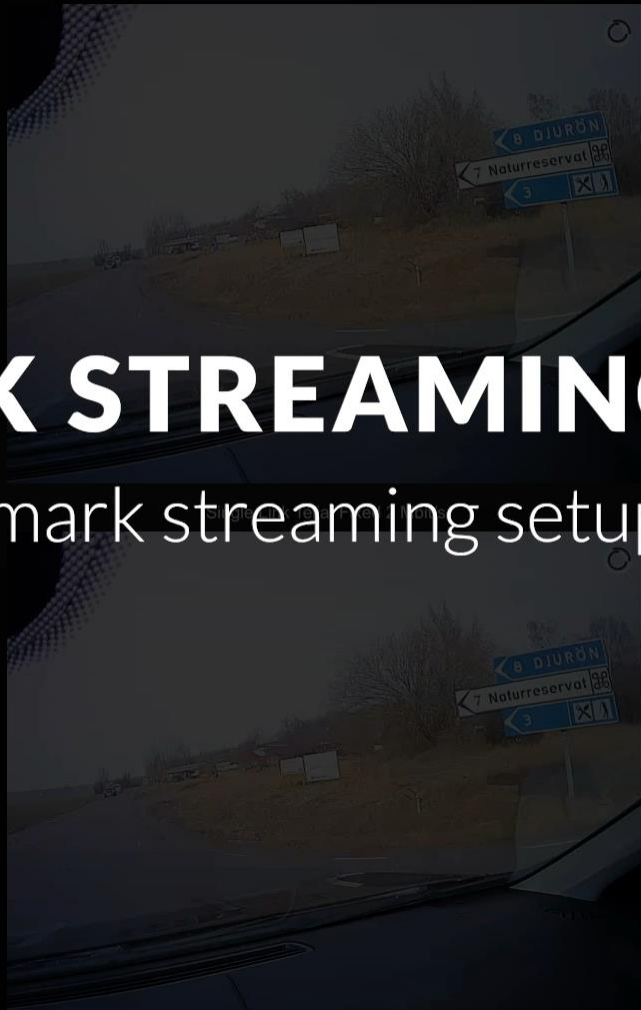
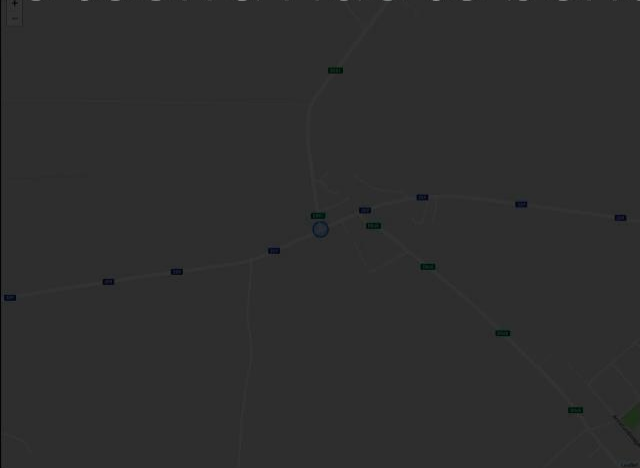
*Phantom Auto acquired Voysys in 2022

Quad link Redundancy: 2x Telia + 2x Tele2

Single Link Tele2, Fixed 2 Mbit/s

MULTIPLE LINK STREAMING

We took a ride to benchmark streaming setups



RELEVANT LAWS AND REGULATION

EU

- Commission Implementing Regulation (EU) 2022/1426 of 5 August 2022 (type-approval of ADS of fully automated vehicles)
- Definition of remote intervention operator

Sweden

- Draft proposal of an Automated Traffic Act (2018)
- Swedish Ministry Memorandum (Ds 2021:28)
- Introduction of a new legal actor, a driver-on-standby (förare i beredskap)

Germany

- Act on automated driving, 2017, amending the Road Traffic Act (SAE level 3)
- Act on autonomous driving, 2021, (SAE level 4-)
- Introduction of a new legal actor, a technical supervisor (technische aufsicht)

LAWS AND REGULATION

- Current regulations aim at a future with high-level AVs
- Remote driving sparsely treated
- Absence of generally agreed definitions
- Terminology used inconsistently - urgent to determine and regulate

P. A. Linné and J. Andersson, "Regulating Road Vehicle Teleoperation: Back to the Near Future," 2021 IEEE Intelligent Vehicles Symposium Workshops (IV Workshops), 2021, pp. 135-140.



REMOTE AUTOMATED VEHICLE OPERATION 2 (REDO2)

with funding from:



- January 2023 – December 2025
- Extends scope from REDO:
 - More vehicle fleet perspective vs one vehicle
 - Consider other operation mode (i.e., assistance and supervision)
 - Remote station design
- Coordinator: Swedish National Road and Transport Research Institute (VTI)



THANK YOU

Final report



REDO2



Upcoming workshop
@ IV 2024



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