HAN AUTOMOTIVE RESEARCH

5G-Blueprint Project

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20/05/2022

Quiz time!

Quiz code: HETJES6994

5G BLUEPRINT

5G-Blueprint designs and validates **technical architecture, business,** and **governance model** for uninterrupted cross-border teleoperated transport based on 5G connectivity.

Teleoperation

The next step in logistics

Current situation in Transport and Logistics

- Shortage of Drivers: ±12.000 vacancies in the Netherlands (and increasing)
- Aging of drivers: average age of truck driver is 45.2 years (and increasing)
- Gender disbalance: only 2% are female drivers
- Other issues: Unused roads at night, waiting times, etc.

>100 million euros of unnecessary costs each year in the Netherlands & Belgium alone!

5G-BP – Teleoperated Transport

TELE-OPERATED TRANSPORT

TECHNOLOGY – 5G NETWORK & ENABLING FUNCTIONS

Fast **Reliable** **Secure** **Guaranteed** **Cross-border**

CHALLENGES

ECONOMICS

- Reduction of waiting time
- Reduction labour shortage
- Economic growth
- Safer driving
- Facilitator automated mobility
- Complex business model

GOVERNANCE

- MNO SLA's
- ToD service SLA's
- Legislation
- Certification
- Liability
- Data sharing and GDPR

5G-BP Use Cases

UC1: Automated barge control

Vlissingen and Antwerp ports

UC4: Remote take over

Cross border on public road

UC2: Automated driver in loop docking

Vlissingen and Antwerp ports

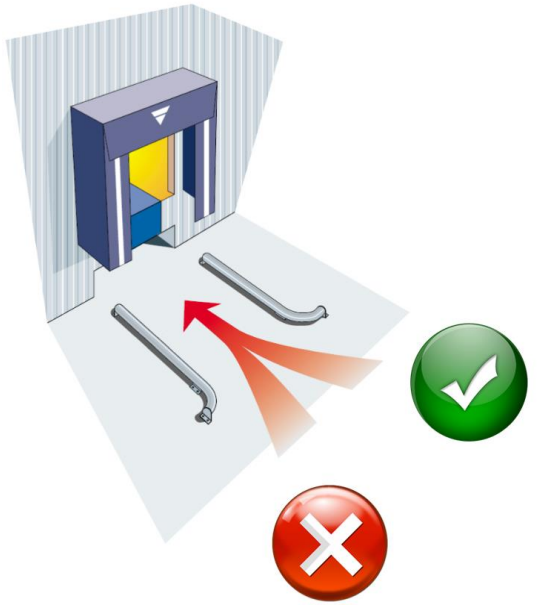
Teleoperated crane

UC3: CACC based platooning

Cross border on public road

Automated Driver in the Loop Docking

Why Automated Driver in the loop Docking?



- **The Problem: The reverse manoeuvring is recognized as one of the most critical tasks**
  - Limited Space at a Dock
  - Revere manoeuvring along a curve
  - Left side parking is doable, right side not (mirrors)

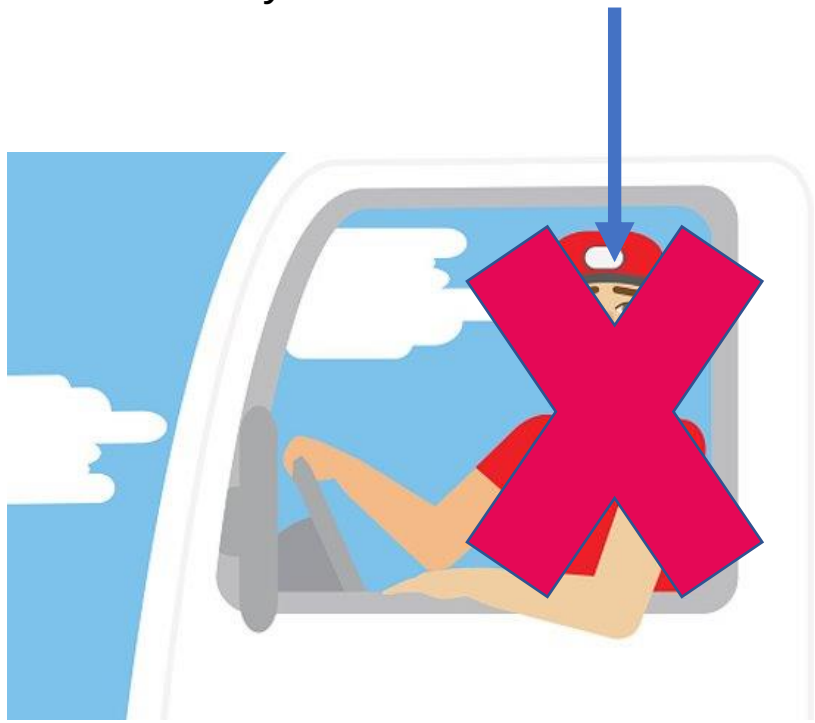
- **The Result: Trucks often end up crashing at the docking gates at DC's, warehouses and ports**
  - (Minor) Damage to the vehicles
  - (Minor) Damage to the property
  - Enormous costs due to transport delays!

- **The Solution: Automated Driver in the loop Docking?**

Why Automated Driver in the loop Docking??

The solution: Automated Driver in the loop Docking (Based on INTRALOG HAN)

Solution: Take away human error?



But how? What is needed?

What is needed?

- Position:
  - Where are the truck and trailer?

- Path Planner:
  - To plan a path from starting point to end point
  - Take Truck-Trailer kinematics in consideration
  - Lay-out of the distribution centra must be known

- Path Tracking Controller:
  - To follow the planned path
  - Take Truck-Trailer kinematics in consideration
  - Balance between good following behaviour & smooth control

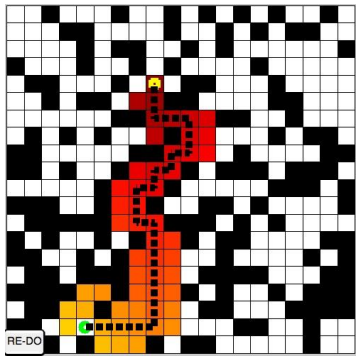
- Vehicle model:
  - What are the dimensions of the Truck-Trailer?

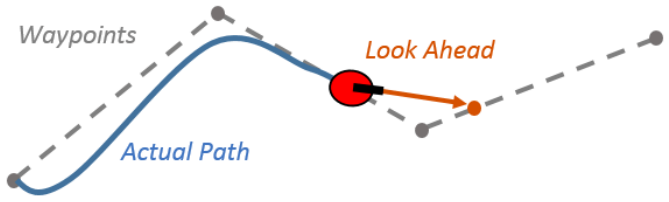
How?

Virtual to Reality! INTRALOG!

Virtual to Reality! 5G-Blueprint!

PP & PTC





RTK GPS System

1:3 Scaled Truck

Path Planner

- **Path Planner**
  - To plan a path from a starting point to an end point
  - Plant lay-out must be known

- **Challenges**
  - What are the constrains & costs of finding a path?
  - What are the truck-trailer kinematics?
  - Planning speed vs smooth path
  - Making it real time

- **A* algorithm**
  - Path search algorithm based on costs / weighted graphs (least distance travelled, shortest time, etc.)
  - It maintains a tree of paths originating at the start node and extending those paths one edge at a time until its termination criterion is satisfied.

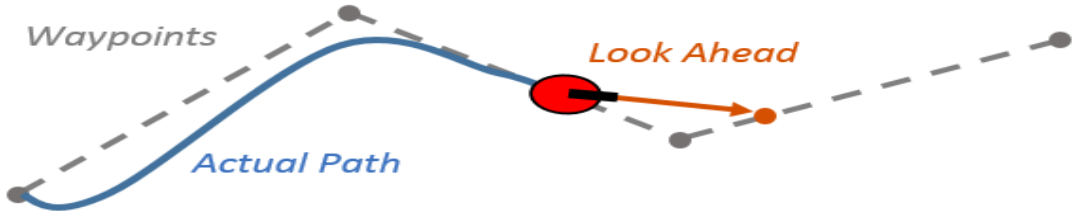
Path Tracking Controller (PTC)

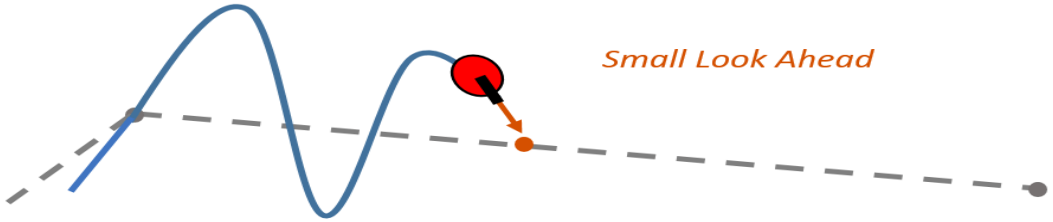
- **Path Tracking Controller**
  - Make the truck follow the planned path
  - Take Truck-Trailer kinematics in consideration

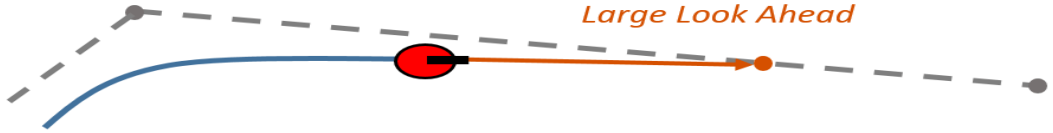
- **Challenges**
  - Adapting to latencies
  - Choosing the right parameters
  - Balance between following behavior & smooth control

- **Pure pursuit controller**
  - Forward velocity assumed as constant
  - Moves the “robot” to reach some look-ahead point in front (constantly chasing a point in front of the robot)

- **Model Predictive Controller**
  - Still studied by thesis student





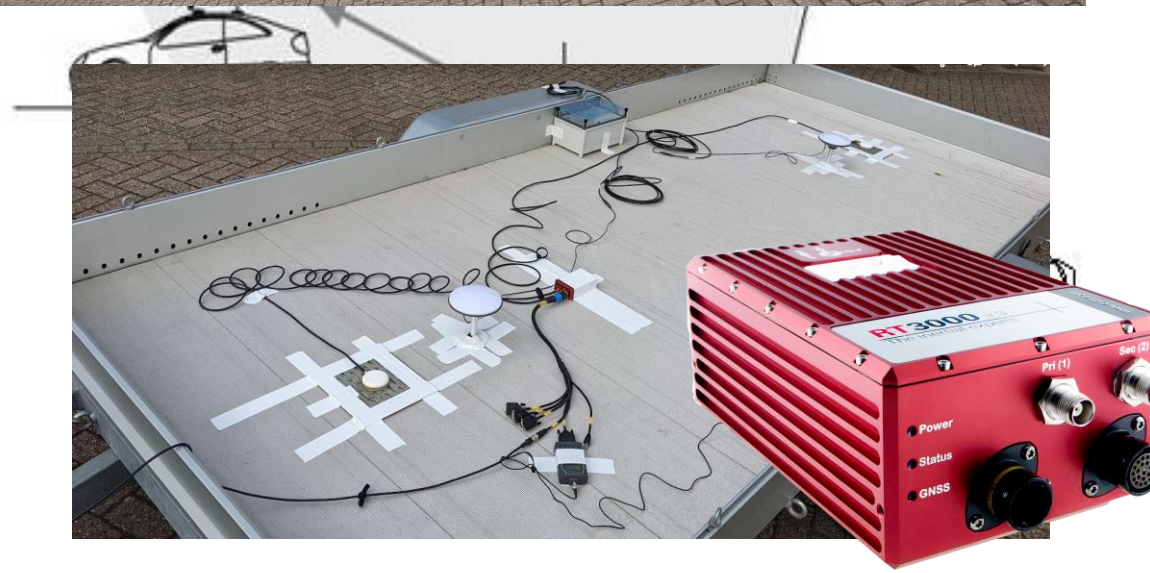


Real Time Localization System (RTLS)

- **Real Time Localization System (RTLS)**
  - Real time localization data is necessary for the path planner (PP) & the path tracking controller (PTC)
  - X,Y position data of axle trailer
  - Articulation angle truck-trailer

- **Challenges**
  - Positional accuracy <10cm & very precise heading data
  - Finding a system with high accuracies was challenging.
  - Get all the position & heading data to 1 access point
  - Establishing CAN communication

- **OXTS RTK (Real Time Kinematic) System**
  - Heading / orientation data up to 0.1° with dual antenna
  - Positional accuracy up to 2cm with base station
  - 2x XLAN to transmit data to 1 single point
  - RT3000v3, RT1003 & a Base Station



1:3 Scaled Truck Trailer

- **Truck & Trailer**
  - Directly going to full scale is not desired
  - Scaled set-up necessary → MVP

- **Challenges**
  - Hard to develop own scaled Truck/Platform
  - Realistic tuck behavior (steering)
  - Realistic truck dimensions (1:?)
  - Steer, throttle & brake by wire

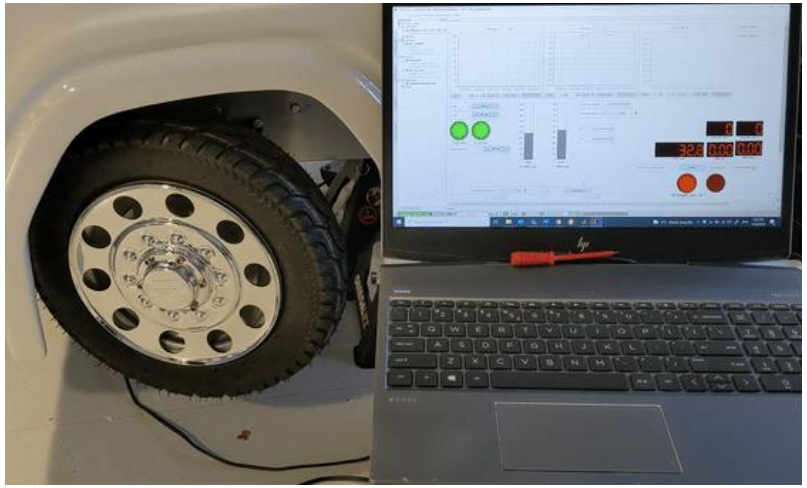
- **1 to 3 scaled Truck**
  - Power is increased with dual engine
  - Steering angle is increased to 35 degrees
  - Steering motor (DC) installed to have steer-by-wire
  - Trailer has a custom-made container with a hatch at the rear
  - NO braking system, but stops by friction when releasing throttle

1:3 Scaled Truck Trailer Controls

- **1:3 Truck Trailer Controls**
  - Longitudinal control (throttle)
  - Lateral control (steering)

- **Challenges**
  - Controlling electromotors for longitudinal movement with existing motor controller (or develop own motor controller)
  - “Steer-by-wire” & knowing the actual wheel positions / angles
  - Calibration for steered axle (knowing where steering angle 0 is)
  - Installing safety features (stall current prevention, kill switch, etc.)

- **E407 (microcontroller / ECU)**
  - Variable longitudinal control with existing controller
  - “Steer-by-wire” is established with DC motor & PID controller
  - Encoder read out created to know actual wheel positions / angles
  - Calibration of wheels + the stall current prevention are established
  - CAN connection between PP + PTC & microcontroller is established



Let’s go to the results! What do you expect?

How good will the truck-trailer follow the planned path?

Max (later) tracking error of 0.5meter

How well will the end pose of the truck-trailer be?

Max (later) error of 0.1 meter
Max pose error of 2^{o}

How long will it take to plan the path?

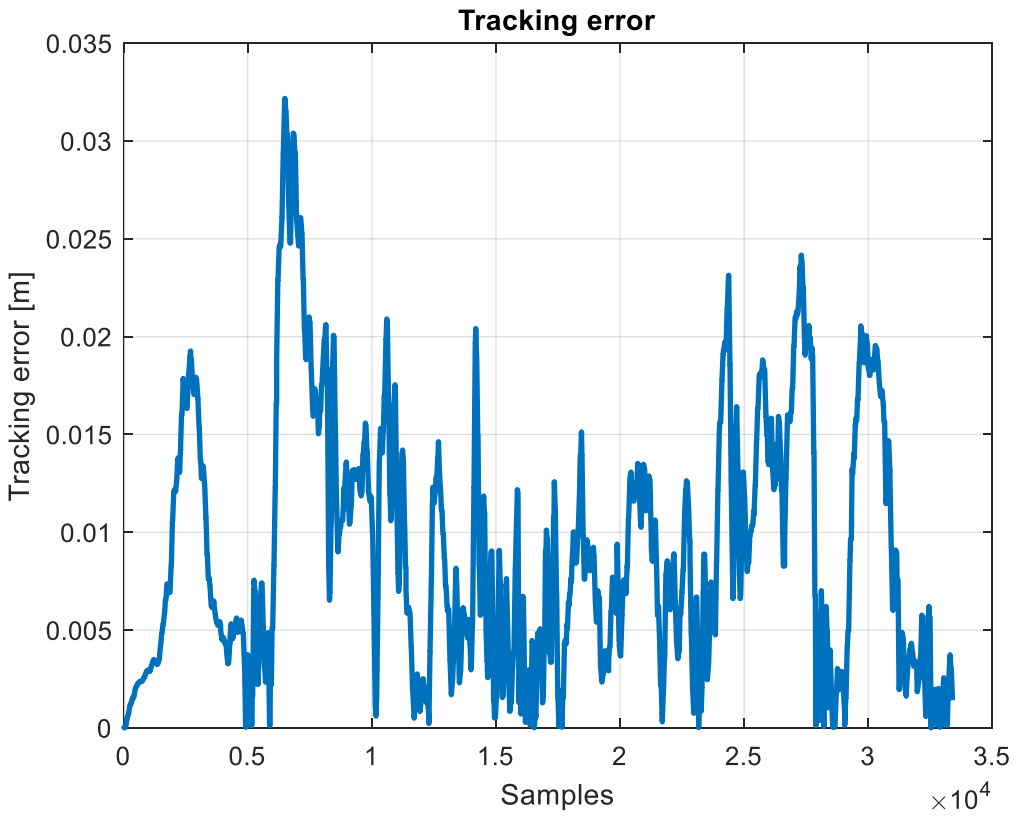
“Hardware-in-the-loop” test

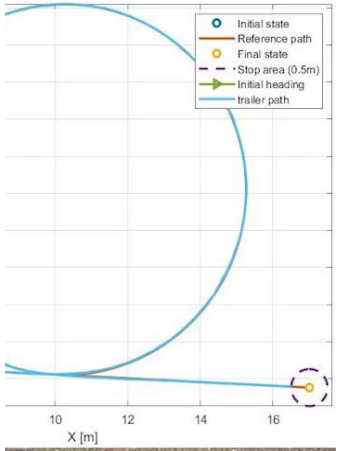
- **“Hardware-in-the-loop” test:**
  - 1:3 scaled truck with developed control unit
  - GPS data of Truck & Trailer→ control PC (on truck) via CAN
  - Extra PC at the Truck to monitor the behavior & overwrite control

- **Test procedure:**
  - Type of test / maneuver is selected
  - Path planner receives initial position & heading of Truck & Trailer via CAN
  - The end point is determined & the Path Planner calculates a path towards it
  - The Path Tracker Controller starts controlling the truck (both steering & throttle)
  - Once the end point is reached by the Trailer the Path Tracker will stop the truck

- **Types of test:**
  - Driving a straight line (forward / reverse)
  - Driving a 90-deg turn (forward / reverse)
  - Driving a 360 circle (forward / reverse)
  - Parallel parking maneuver
  - Autodocking maneuver

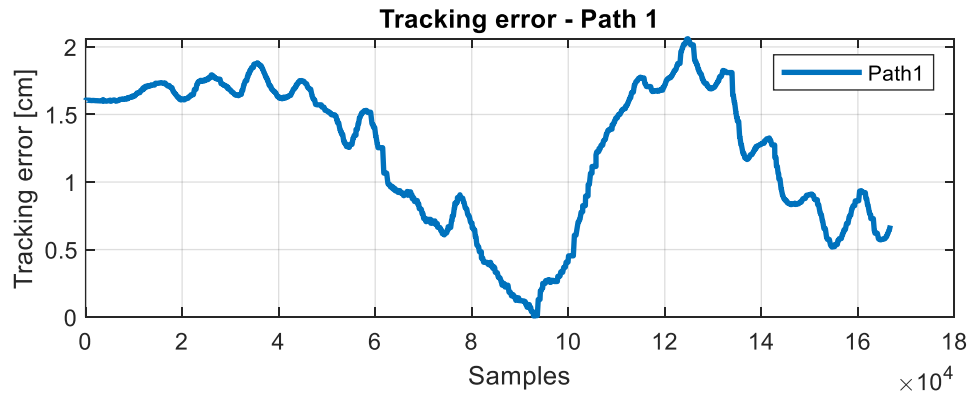
360 Circle (Forward)

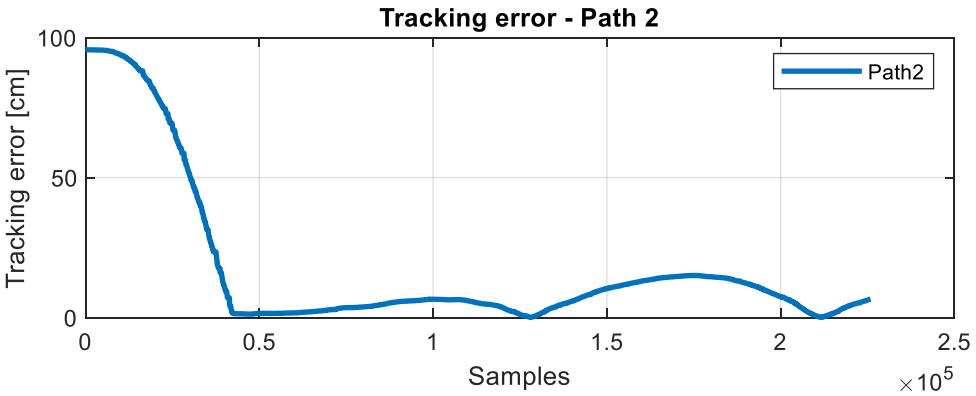


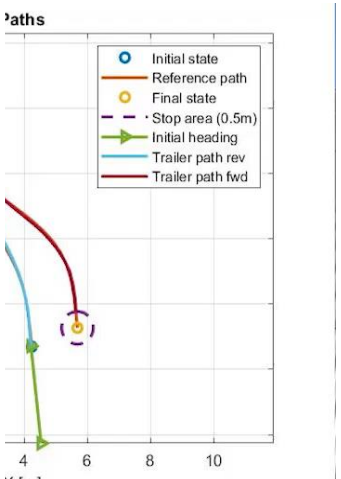


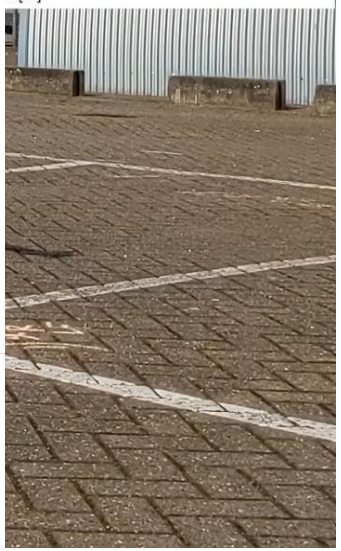
Maximum lateral tracking error:	3.2cm
End position tracking error:	0.2cm
End position angle:	-0.75°

Parallel Parking



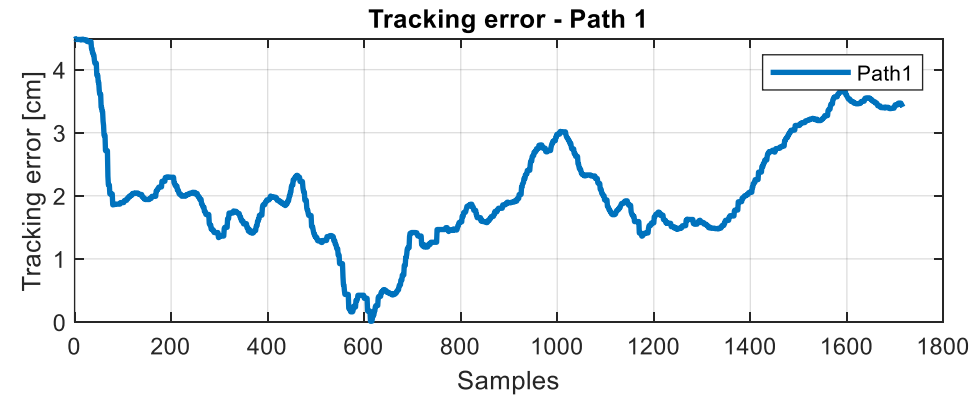


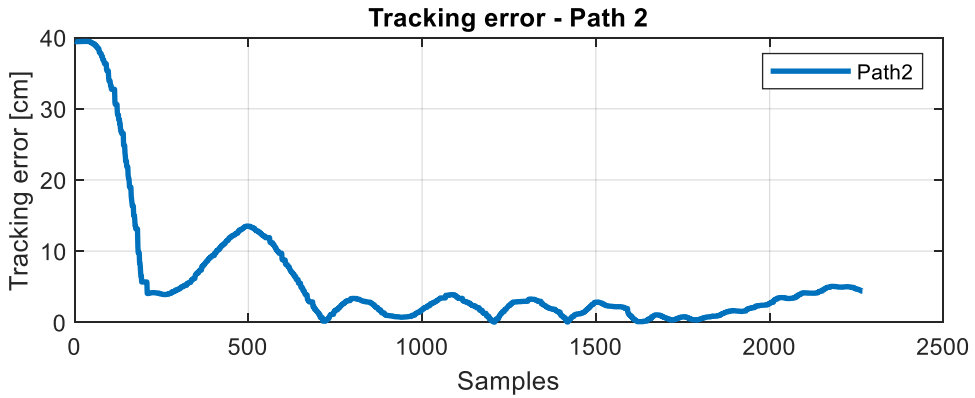


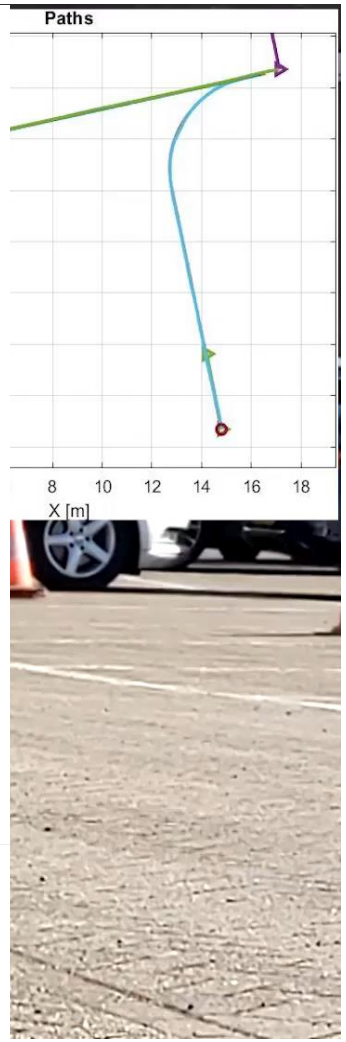


Maximum lateral tracking error:	2.1 | 95.7 cm
End position tracking error:	0.7 | 6.60 cm
End position angle:	0.2 | -15.14 °

Auto-Docking





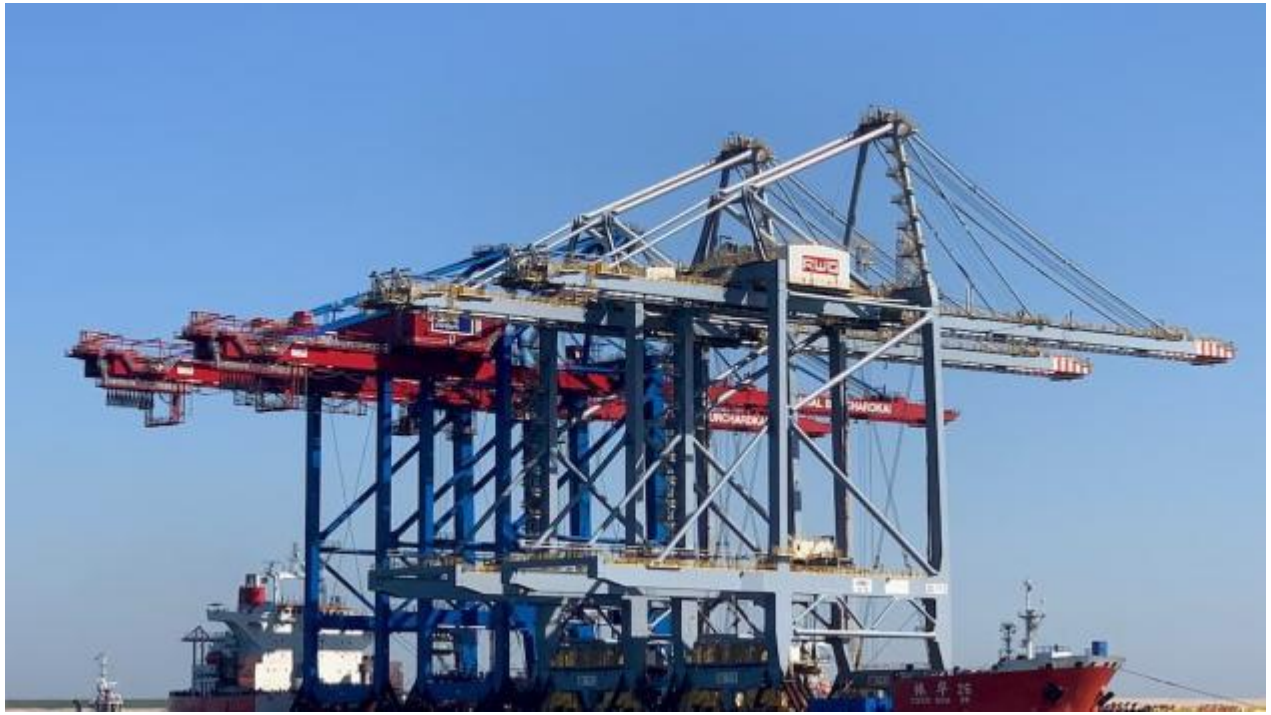


Maximum lateral tracking error:	4.5 | 39.5 cm
End position tracking error:	3.4 | 4.40 cm
End position angle:	-4.7 | 2.47 °

Remote Take Over / Remote Driving

What is Teleoperation?

It’s a technology that allows an operator (driver) to remotely control a vehicle (or vehicles) from a place somewhere else. The operator is not physically in the vehicle.



But how? What is needed?

What is needed?

- Environment for the operator
  - Different actuators to control the vehicle (steering wheel, pedals, etc.)
  - (Multiple) screens to get visual feedback to perceive the surroundings
  - Other types of feedback? Sound? Feeling? Speed?

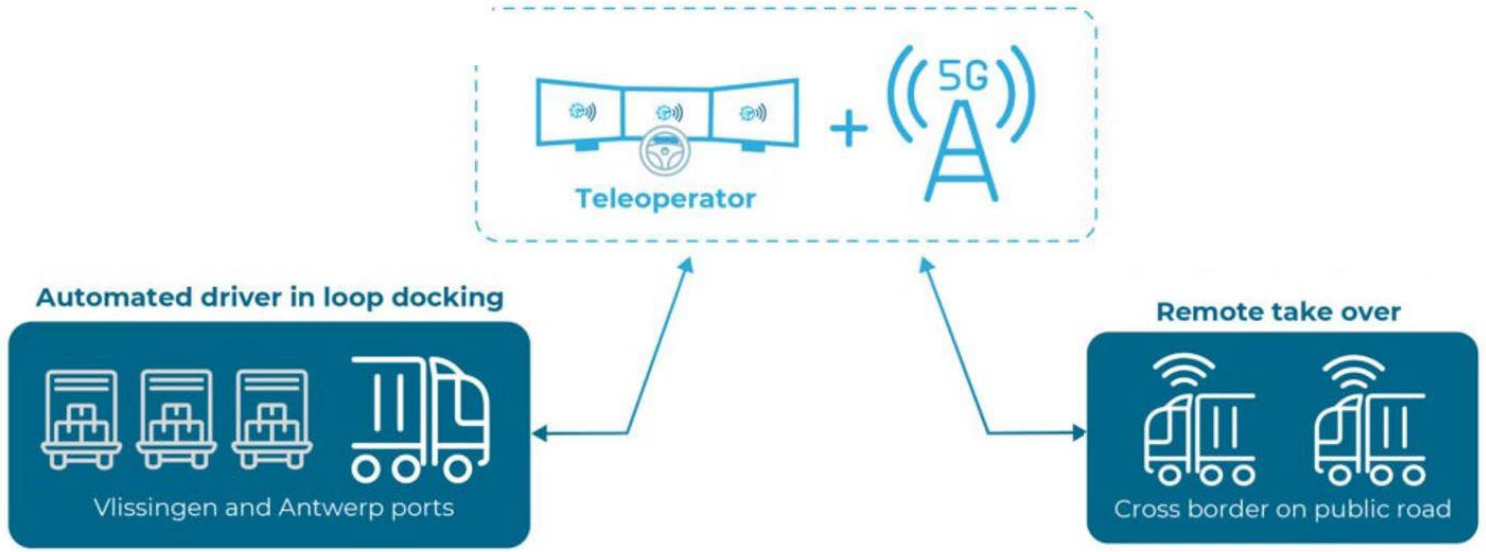
- Connection / Communication
  - Communication network to stream videos (4G/5G)
  - Safety features! What if the connection is lost?
  - Redundancy! What if the connection is lost?

- Vehicle:
  - Have lateral control by wire
  - Have longitudinal control by wire
  - Cameras to give visual feedback to operator

Teleoperator in 5G-Blueprint

Where are we now?

5G BLUEPRINT



Ultimate Goal

Fully functioning Driver-in-the-Loop at full scale

What do you think about teleoperation?

Team Dreamers

You think this is an excellent technical solution / idea. You will try to convince everyone that this must be implemented!

Think of all the advantages and great things this technology will bring!

Team Doomsayers

You think this is the worst technical solution / idea you have every hear of. You will try to convince everyone that this should never be implemented!

Think of all the disadvantages and challanges this technology will bring!


thank you
danke
謝謝
ngiyabonga
شكراً جزيلاً
рахмат
teşekkür ederim
gracias
Баярлалаа
спасибо
faafetai lava
vinaka
спасибі
blagodaram
dank je
misaotra
matondo
paldies
grazzi
mahalo
tapadh leat
хвала
asante
manana
obrigada
tenki
murakoze
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