

Mobility Maps as Input for Automatic Vehicle Control

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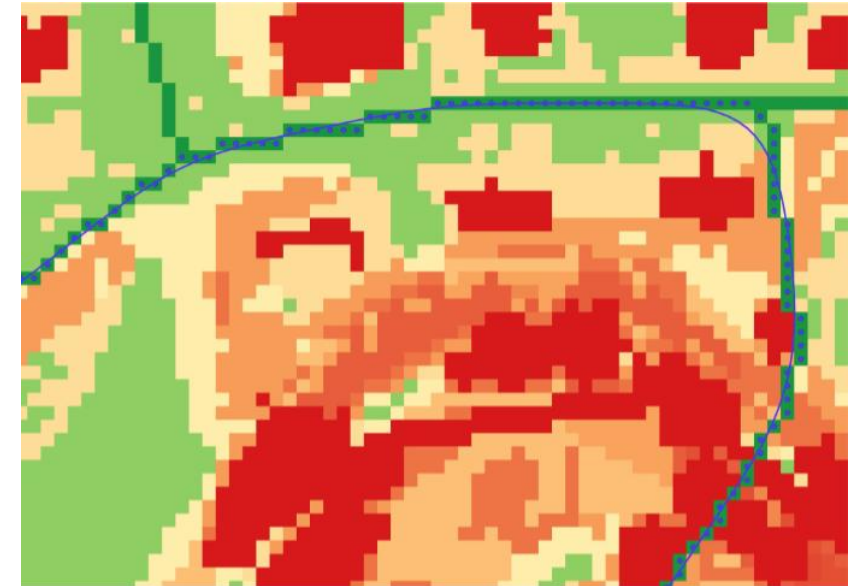
1 Translating routes to CAN-BUS commands

CAN-BUS interface by setpoint values for

- speed [m/s] and
- steering angle [$mrad$]

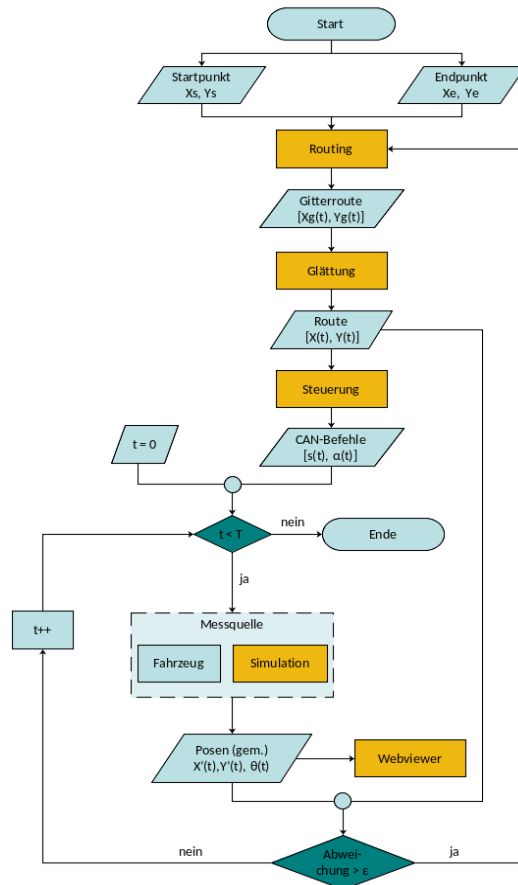
Procedure:

- Calculation of Route
- Smoothing with regard to vehicle's turning circle
- Creation of control commands for speed and steering angle setpoints taking into account the acceleration and braking capacity of the vehicle [m/s^2] and the responsiveness of the steering [$mrad/s$].



*Trajectory (blue line) on 2m-raster Speed-Made-Good mobility map
(red: nogo, green to yellow: slow to fast speed)*

2 Automatic vehicle control by control loop



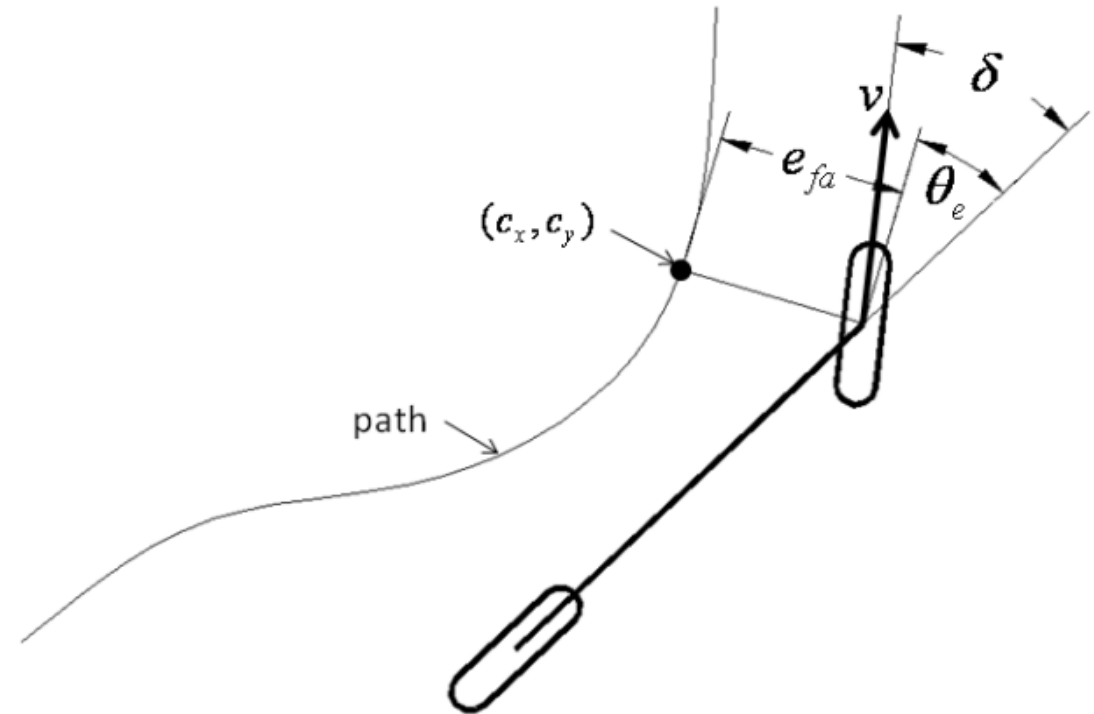
Procedure:

- Control commands for steering and velocity setpoints in the time interval 0.1 s.
- Checking the consistency of expected and actual vehicle position. (simulation)
 - Differences between the specified route and the actual position occur already due to numerical effects of discretization. Other error factors, such as GPS measurement errors or deviations from characteristic curves and actual vehicle behavior, can be included in the simulation.
- Adjustment of control commands taking into account deviations
 - Use of suitable controllers. The Pursuit and Stanley controllers were examined. Even though in 2005 DARPA was won using the Stanley controller, the Pursuit controller has shown better results so far (smoother trajectory, less “fluttering” of the steering without use of IMU).
- In case of significant deviations: Adjustment of the route

3 Stanley Controller

Principle

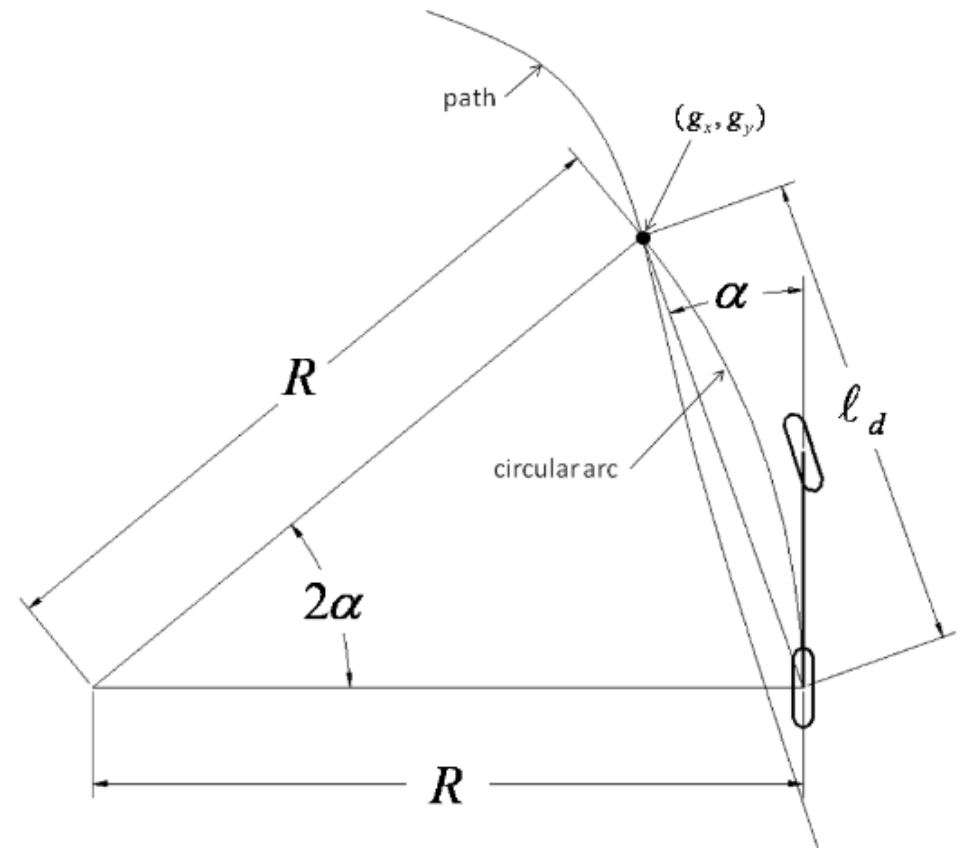
Steering angle θ_e is calculated from deviation between vehicle's orientation, direction of the route and a correction term based on the cross-track deviation e_{fa} .



4 Pure Pursuit Controller

Carrot Principle

Steering is adjusted to reach a point ℓ_d meter ahead on the route.
This depends on speed. When going slowly, the distance ℓ_d is decreased.

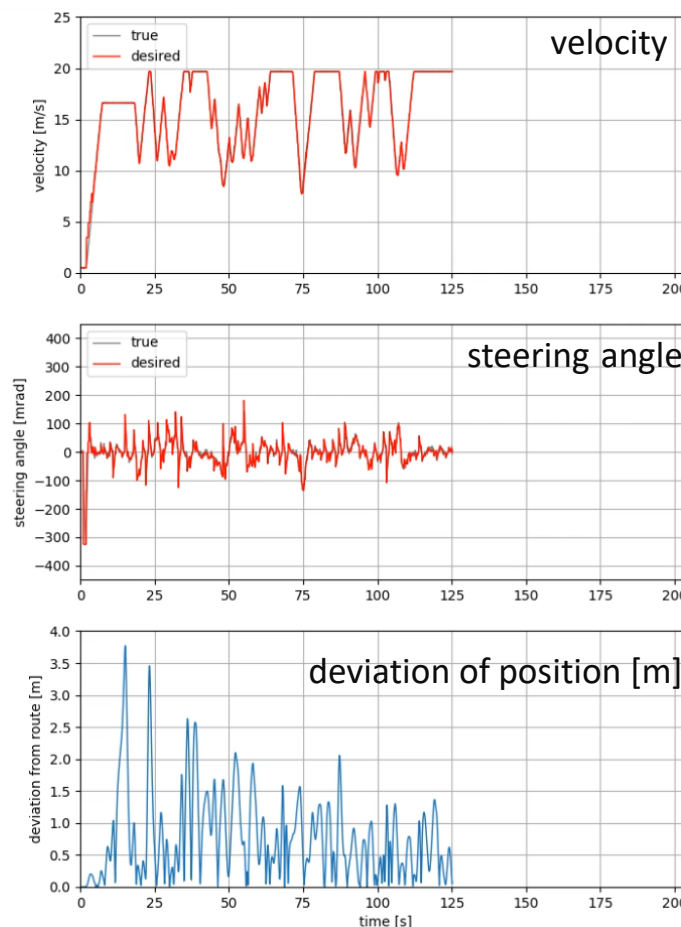
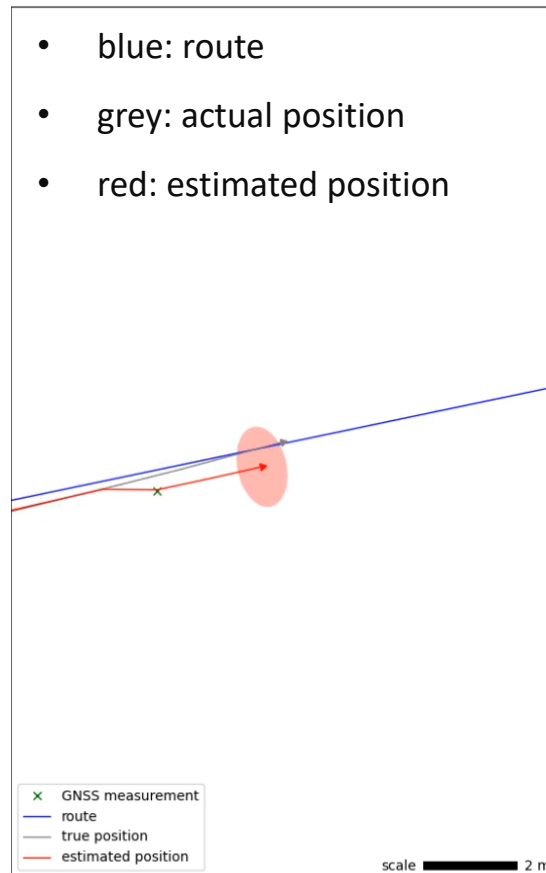


5 Simple CAN-BUS steering simulator

The adjustment of the CAN-BUS commands is calculated on the basis of the estimated position.

- blue: route
- grey: actual position
- red: estimated position

The actual position is unknown to the system and used as a benchmark to assess expected deviations.



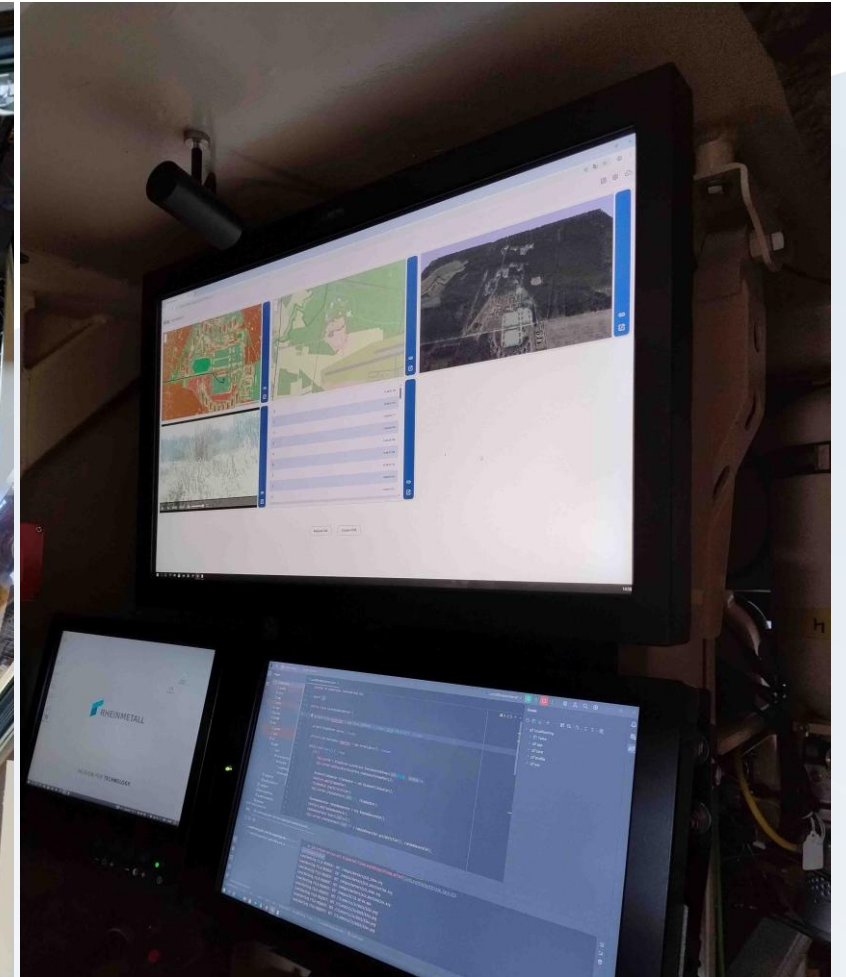
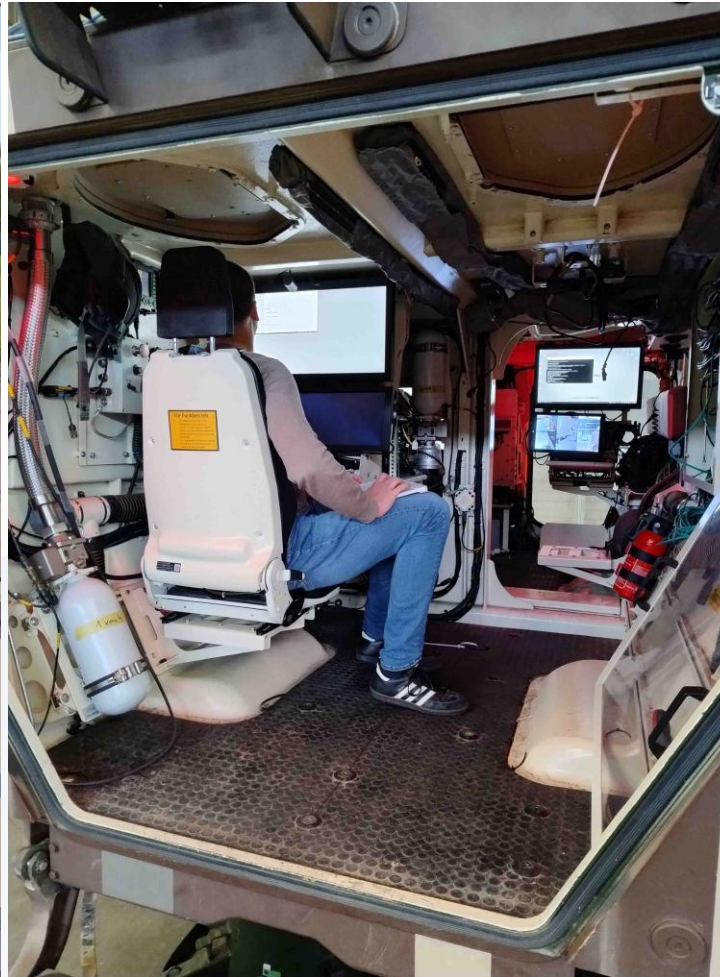
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[123.1] 0A2551xx [4] 0x01 0x01 0x1B 0x4C
[123.1] 0A0001xx [4] 0x01 0x02 0xEB 0xFF
t= 123.2s, velocity= 19.65 m/s, steering angle= -12 mrad
[123.2] 0A2551xx [4] 0x01 0x01 0xC4 0x4C
[123.2] 0A0001xx [4] 0x01 0x02 0xF1 0xFF
t= 123.3s, velocity= 19.66 m/s, steering angle= -6 mrad
[123.3] 0A2551xx [4] 0x01 0x01 0xC9 0x4C
[123.3] 0A0001xx [4] 0x01 0x02 0xFA 0xFF
t= 123.4s, velocity= 19.66 m/s, steering angle= -11 mrad
[123.4] 0A2551xx [4] 0x01 0x01 0xC9 0x4C
[123.4] 0A0001xx [4] 0x01 0x02 0xF5 0xFF
t= 123.5s, velocity= 19.69 m/s, steering angle= -5 mrad
[123.5] 0A2551xx [4] 0x01 0x01 0xE6 0x4C
[123.5] 0A0001xx [4] 0x01 0x02 0xFB 0xFF
t= 123.6s, velocity= 19.69 m/s, steering angle= -3 mrad
[123.6] 0A2551xx [4] 0x01 0x01 0xE9 0x4C
[123.6] 0A0001xx [4] 0x01 0x02 0xFD 0xFF
t= 123.7s, velocity= 19.71 m/s, steering angle= 1 mrad
[123.7] 0A2551xx [4] 0x01 0x01 0xFB 0x4C
[123.7] 0A0001xx [4] 0x01 0x02 0x01 0x00
t= 123.8s, velocity= 19.68 m/s, steering angle= 5 mrad
[123.8] 0A2551xx [4] 0x01 0x01 0xE1 0x4C
[123.8] 0A0001xx [4] 0x01 0x02 0x05 0x00
t= 123.9s, velocity= 19.65 m/s, steering angle= 2 mrad
[123.9] 0A2551xx [4] 0x01 0x01 0xC0 0x4C
[123.9] 0A0001xx [4] 0x01 0x02 0x02 0x00
t= 124.0s, GNSS measurement [5318.535, 5640149.494]
[124.0] 0A2551xx [4] 0x01 0x01 0xDC 0x4C
[124.0] 0A0001xx [4] 0x01 0x02 0x0C 0x00
t= 124.1s, velocity= 19.66 m/s, steering angle= 12 mrad
[124.1] 0A2551xx [4] 0x01 0x01 0xCF 0x4C
[124.1] 0A0001xx [4] 0x01 0x02 0x0C 0x00
t= 124.2s, velocity= 19.67 m/s, steering angle= 8 mrad
[124.2] 0A2551xx [4] 0x01 0x01 0xD7 0x4C
[124.2] 0A0001xx [4] 0x01 0x02 0x08 0x00
t= 124.3s, velocity= 19.64 m/s, steering angle= 12 mrad
[124.3] 0A2551xx [4] 0x01 0x01 0xB8 0x4C
[124.3] 0A0001xx [4] 0x01 0x02 0x0C 0x00
t= 124.4s, velocity= 19.66 m/s, steering angle= 12 mrad
[124.4] 0A2551xx [4] 0x01 0x01 0xCF 0x4C
[124.4] 0A0001xx [4] 0x01 0x02 0x0C 0x00
t= 124.5s, velocity= 19.67 m/s, steering angle= 2 mrad
[124.5] 0A2551xx [4] 0x01 0x01 0xD4 0x4C
[124.5] 0A0001xx [4] 0x01 0x02 0x02 0x00
t= 124.6s, velocity= 19.69 m/s, steering angle= 11 mrad
[124.6] 0A2551xx [4] 0x01 0x01 0xEB 0x4C
[124.6] 0A0001xx [4] 0x01 0x02 0x0B 0x00
t= 124.7s, velocity= 19.67 m/s, steering angle= 4 mrad
[124.7] 0A2551xx [4] 0x01 0x01 0xD4 0x4C
[124.7] 0A0001xx [4] 0x01 0x02 0x04 0x00
t= 124.8s, velocity= 19.68 m/s, steering angle= -3 mrad
[124.8] 0A2551xx [4] 0x01 0x01 0xE1 0x4C
[124.8] 0A0001xx [4] 0x01 0x02 0xFD 0xFF
t= 124.9s, velocity= 19.65 m/s, steering angle= -0 mrad
[124.9] 0A2551xx [4] 0x01 0x01 0xBF 0x4C
[124.9] 0A0001xx [4] 0x01 0x02 0x00 0x00
t= 125.0s, GNSS measurement [531837.321, 5640152.993]
[125.0] 0A2551xx [4] 0x01 0x01 0xDB 0x4C
[125.0] 0A0001xx [4] 0x01 0x02 0x13 0x00
t= 125.1s, velocity= 19.66 m/s, steering angle= 14 mrad
[125.1] 0A2551xx [4] 0x01 0x01 0xC9 0x4C
[125.1] 0A0001xx [4] 0x01 0x02 0x0E 0x00
t= 125.2s, velocity= 19.69 m/s, steering angle= -8 mrad
[125.2] 0A2551xx [4] 0x01 0x01 0xEA 0x4C
[125.2] 0A0001xx [4] 0x01 0x02 0xF8 0xFF

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6 First steps of integration into Boxer

1cm-precision DGPS



Contact Information



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Thank You!

Mobility Maps as Input
for Automatic Vehicle Control

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