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# CLOTHOID-BASED TRAJECTORY FOLLOWING APPROACH FOR SELF-DRIVING VEHICLES

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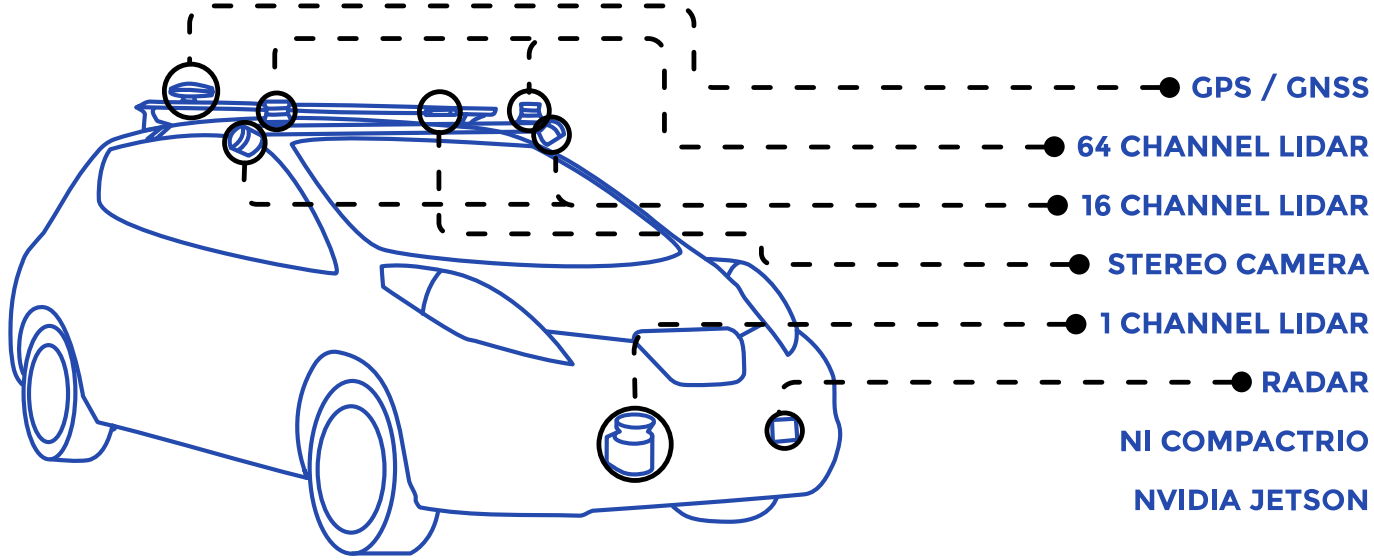
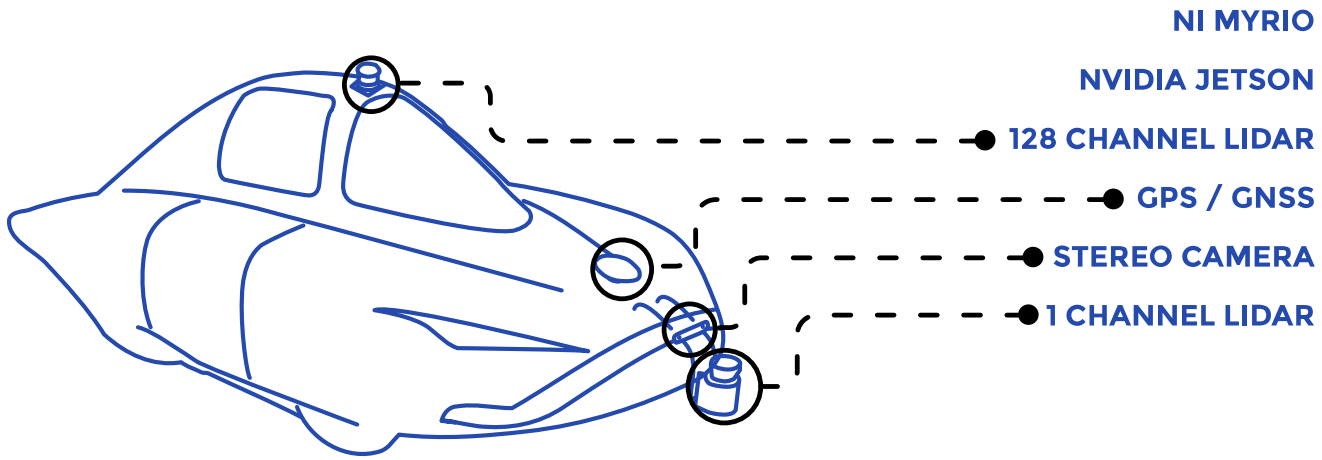
BEFEKTETÉS A JÖVŐBE

# Introduction

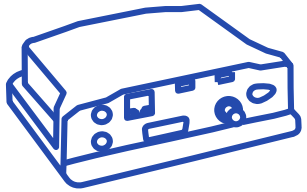
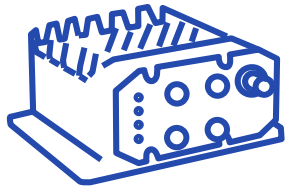
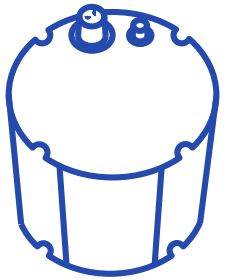
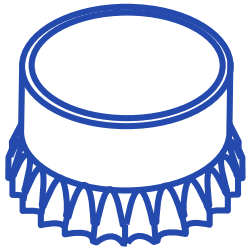
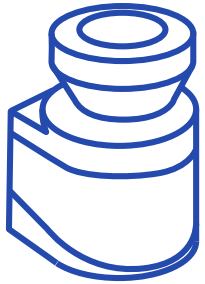
- Autonomous following subtask
- The paper proposes trajectory following approach which is designed for self-driving vehicles
- Trajectory composed of straight segments connected by clothoid curves

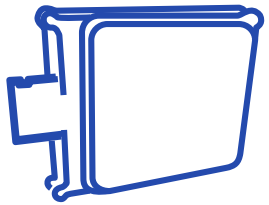
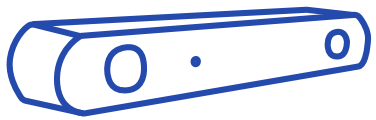
# Our vehicles



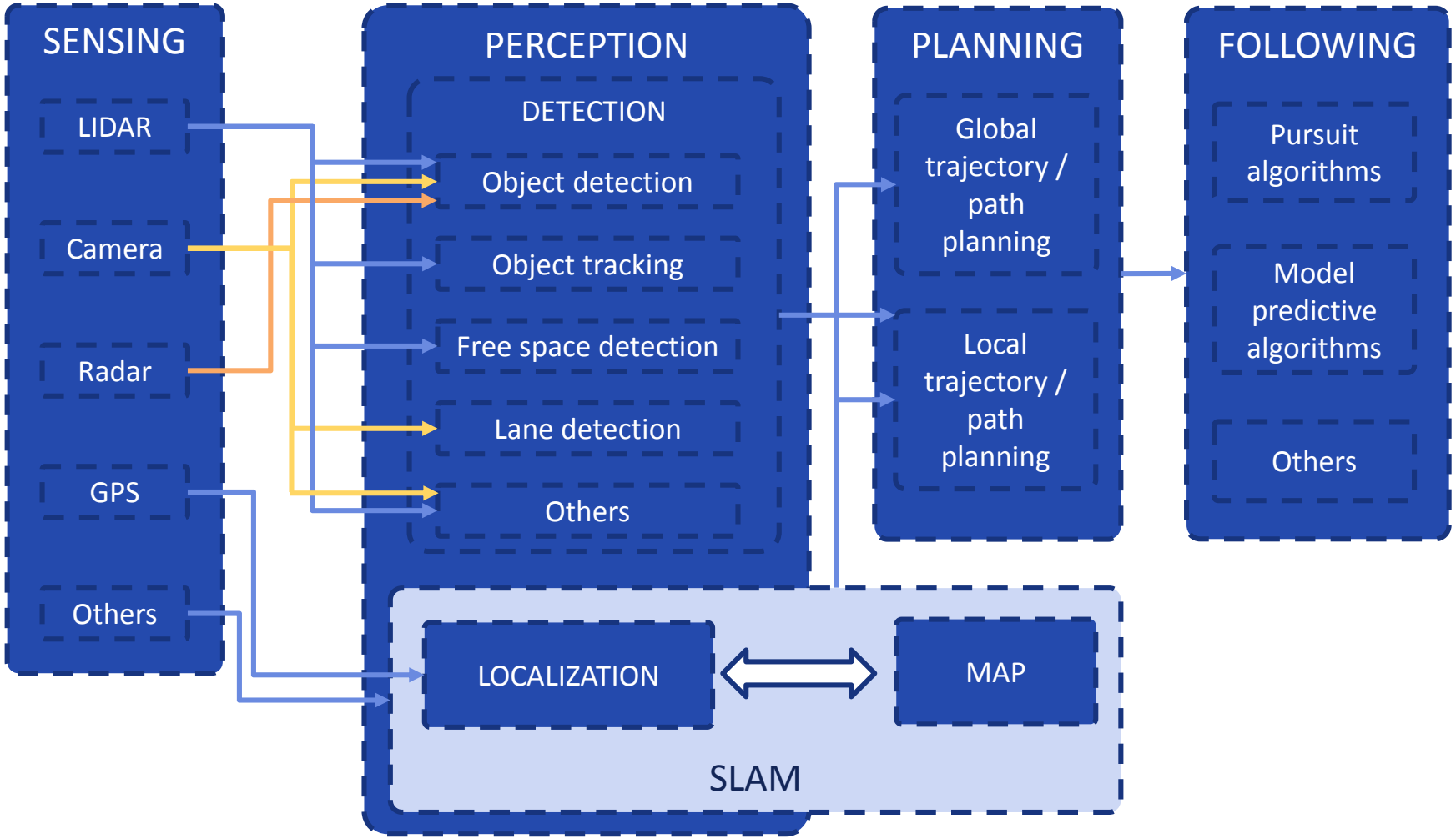



# Sensors

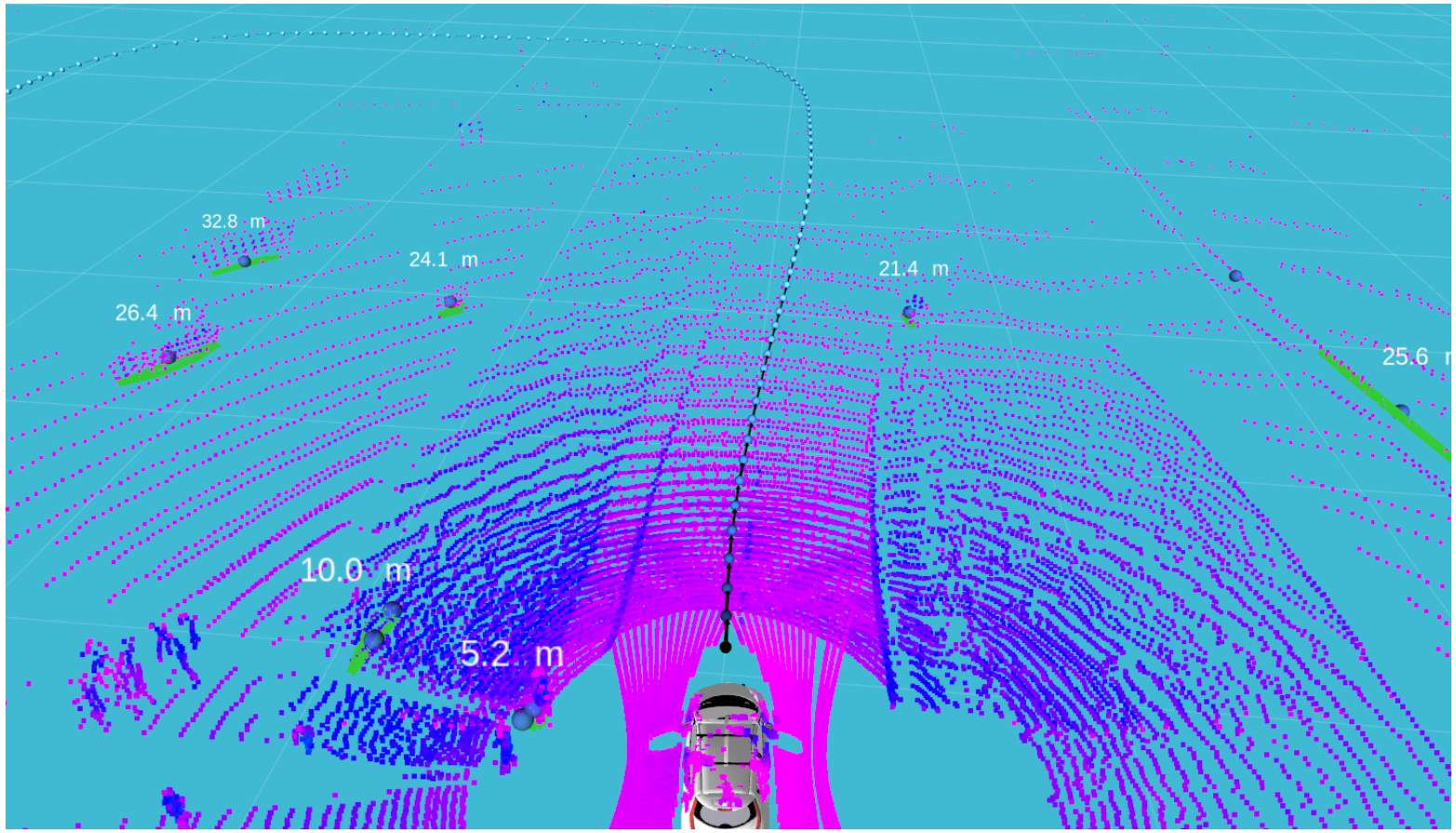






# An example scenario

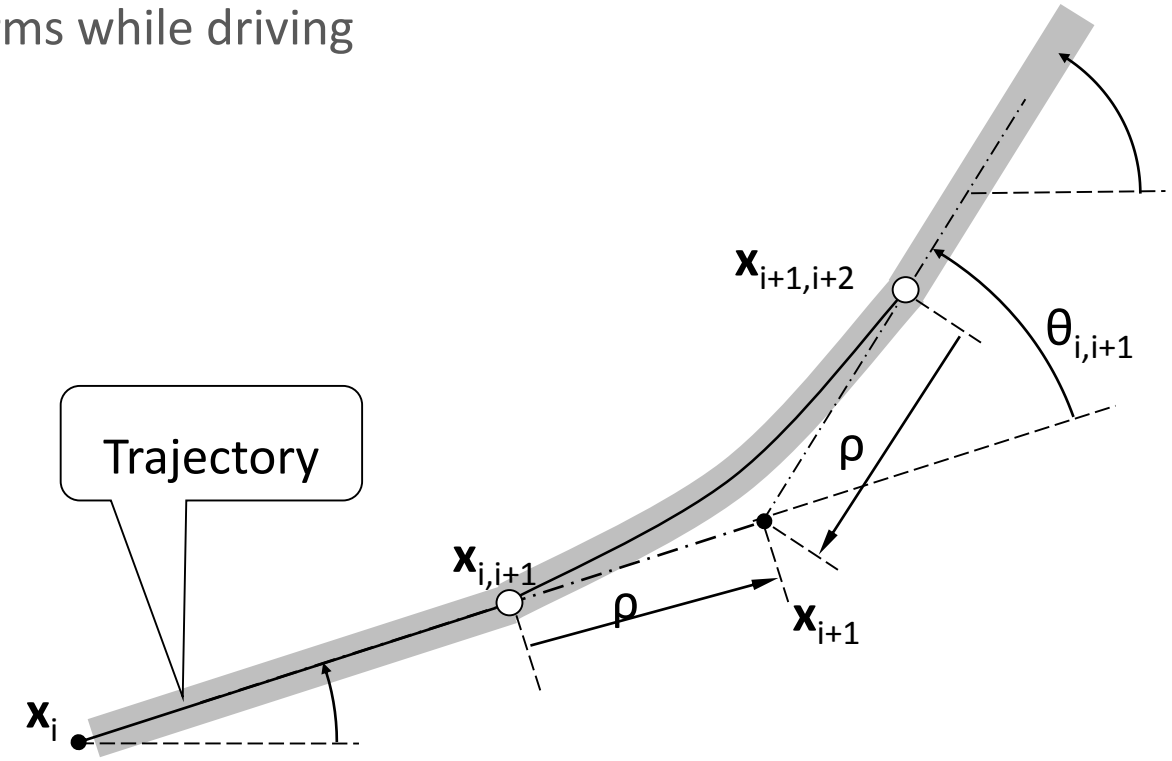


SENSING | PERCEPTION | PLANNING | FOLLOWING



# The proposed solution

- The proposed solution is a trajectory composed of straight segments connected by clothoid curves
- The rotation of the steering wheel (with the angle γ) will be done only on the connecting sections, on the straight parts the steering wheel will not rotate
- This provides a more realistic approximation of the manoeuvres that a driver performs while driving



# Proposed algorithm

**0 Initial data**

**Parameter $a$**
**Set of points $x_i$;**
**Vehicle velocity $v$;**
**Wheelbase $L$ ;**
**Max turning angle: $\gamma_{max\_a}$**
**Max speed: $\dot{\gamma}_{max\_a}$**
**Max acceleration $\ddot{x}_{n,max\_acc}$**
**Domain of locomotion: Domain**

**1** Calculation of connection duration and length of connection segments

$$T = \sqrt[3]{\frac{6\Delta\theta \cdot L}{va}}, \rho = \frac{\Delta r}{\sqrt{2(1+cos(\Delta\theta))}}$$

**2** Calculation of the maximum steering wheel rotation angle

$$\gamma_{max} = tan^{-1}\left(a\frac{T^2}{4}\right)$$

**3** Checking the wiring condition, changing the parameter $a$

$$\gamma_{max} \leq \gamma_{max\_a}, a \propto \gamma_{max}$$

**4** Calculation of the maximum angular velocity of rotation of the steering wheel

$$\dot{\gamma}(aT)_{max}$$

**5 Checking the maximum speed of rotation of the steering wheel, changing the parameter $a$**

$$\dot{\gamma}_{max} \geq \dot{\gamma}_{max\_a}, a \propto \dot{\gamma}_{max\_a}$$

**6** Calculation of the maximum inertial acceleration

$$\ddot{x}_{n,max} = \frac{v^2}{R_{min}} = \frac{v^2}{L}\tan(\gamma_{max})$$

**7** Checking the maximum centrifugal acceleration condition, changing the parameter of and / or speed

$$\ddot{x}_{n,max} \leq \ddot{x}_{n,max\_a}, \begin{matrix} a \propto \ddot{x}_n \\ v \propto \ddot{x}_n \end{matrix}$$

**8** Calculation of connection points (fig 1)

$$\boldsymbol{x_{i,i+1} = x_{i+1} - \frac{(x_{i+1} - x_i)}{(x_{i+1} - x_i)}\rho}$$

**9** Numerical calculation of the connection trajectory

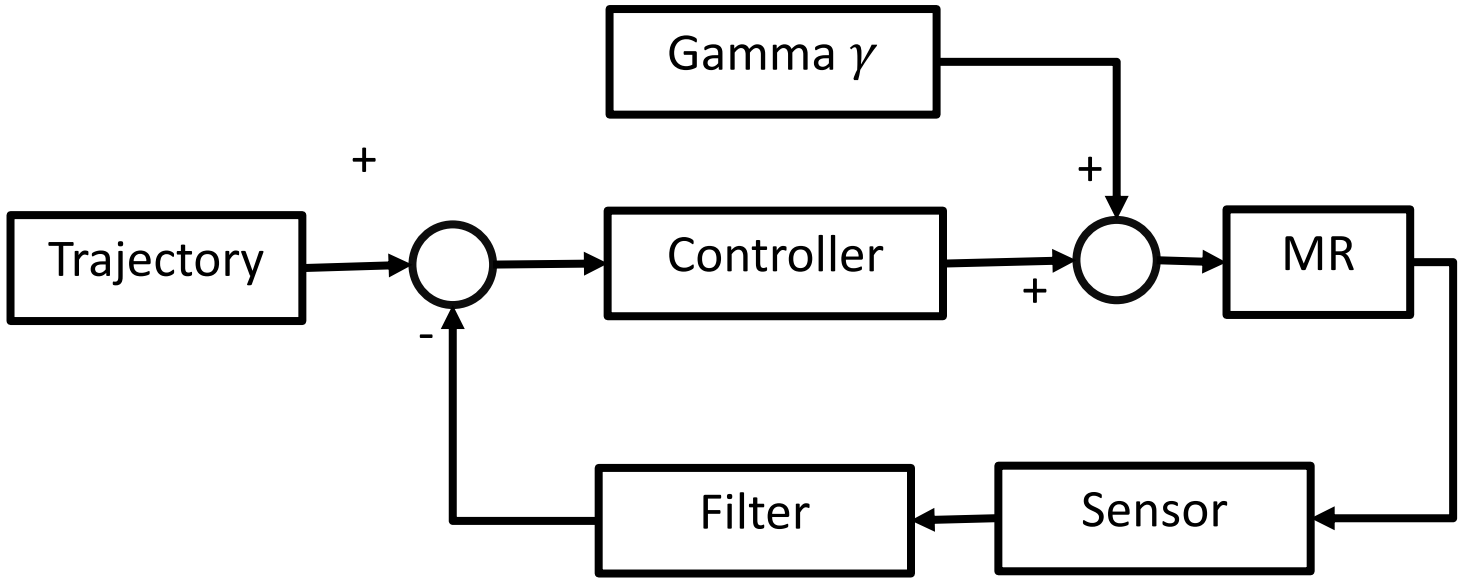
$$\boldsymbol{r(t) = \begin{bmatrix} \int_0^t v\,cos(\theta)dt \\ \int_0^t v\,sin(\theta)dt \end{bmatrix} + x_{i,i+1}}$$

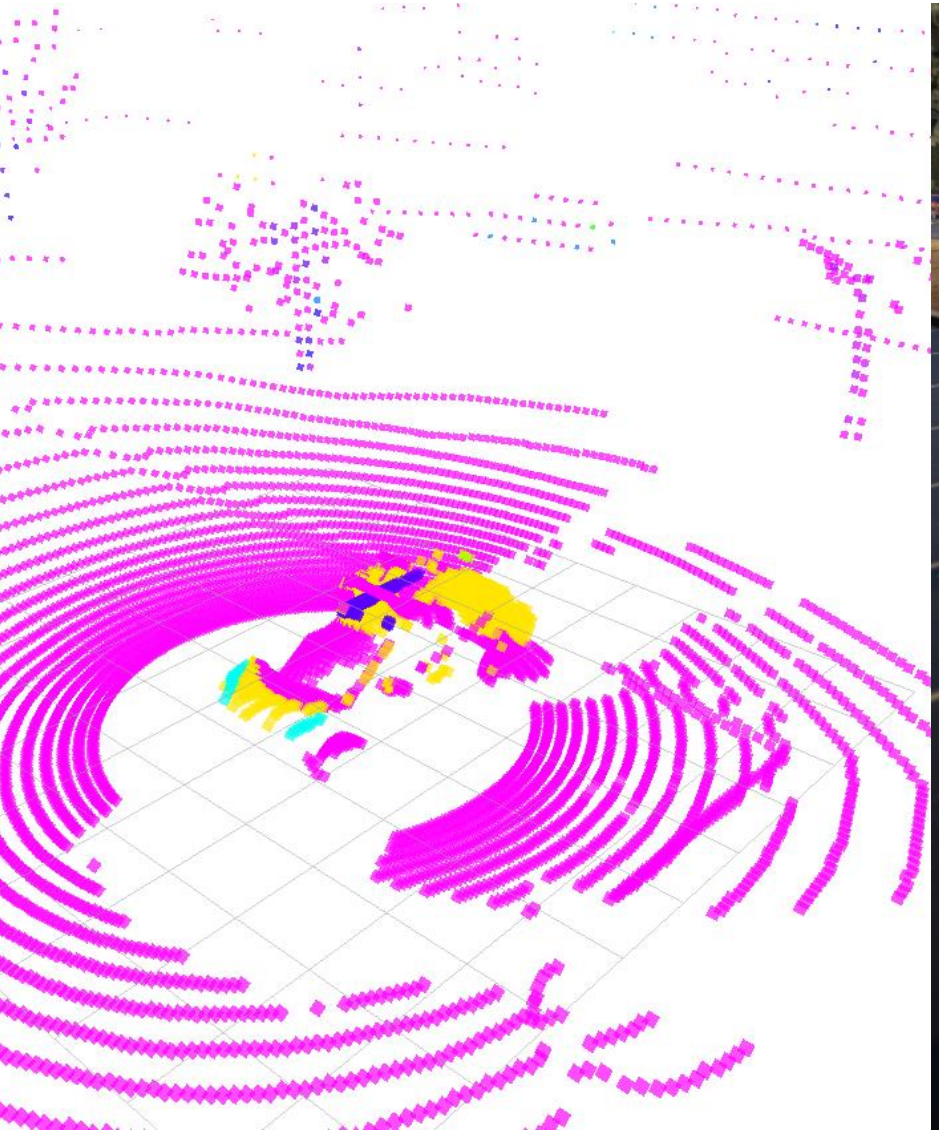
**10** Trajectory verification

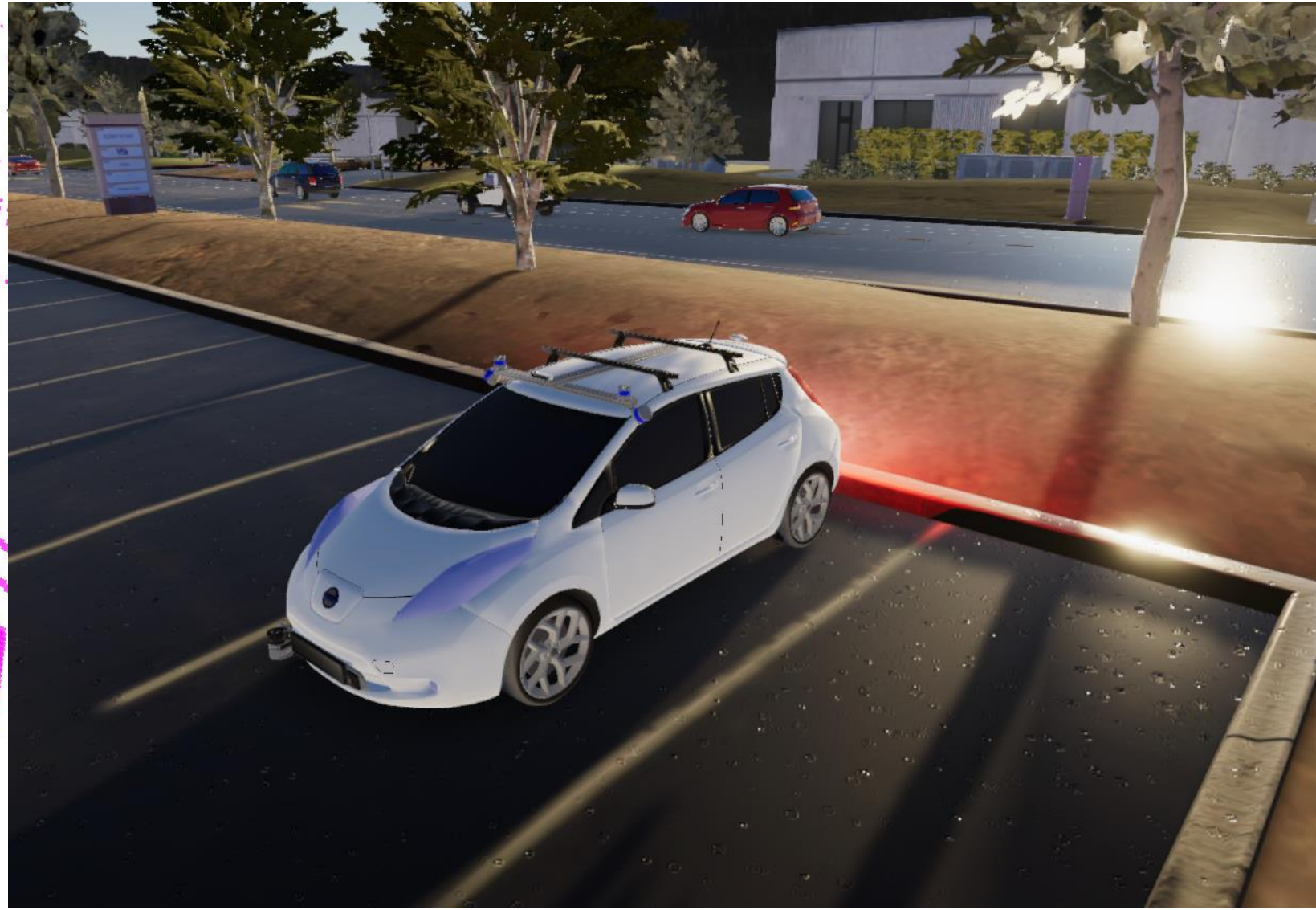
$$\Delta \boldsymbol{r}(t) \in Domain$$

# Block diagram

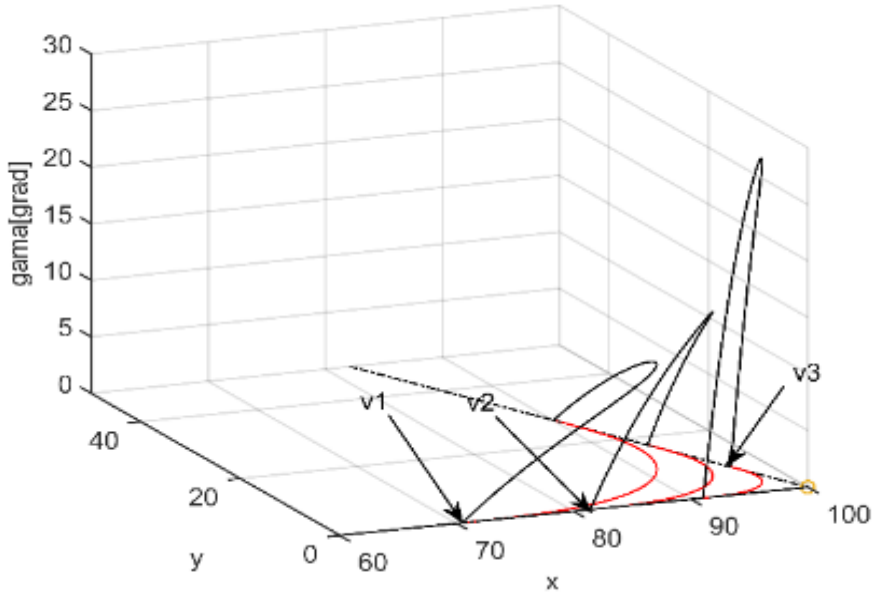
- Non-holonomic constraints
- Simple control





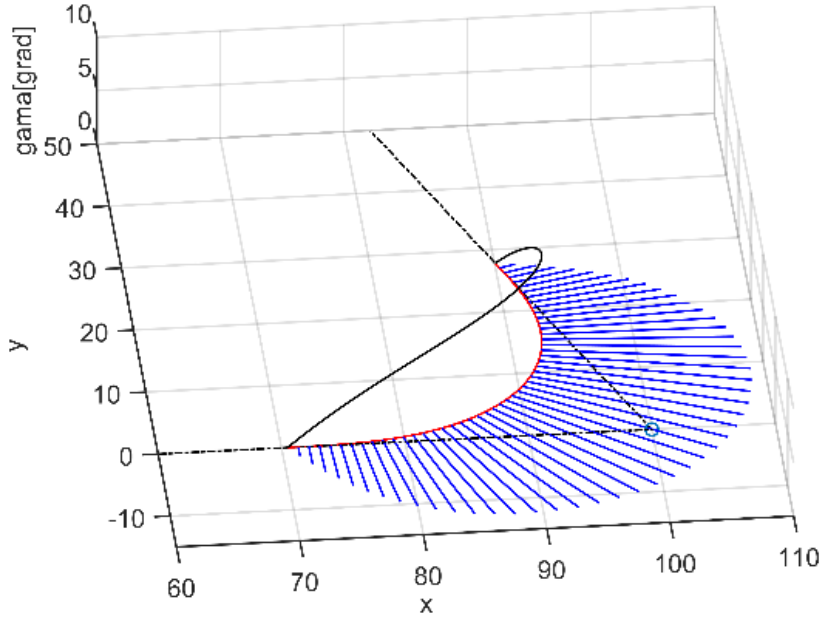


# Results




$a_1$=0.001
T=11.22 s
$\gamma_{max}$=1.8 grad
$\dot{\gamma}_{max}$=0.64 grd/s
$\ddot{x}_{n,max}$ =0.8747m/s²

$a_2$=0.01
T=5.2 s
$\gamma_{max}$=3.88 grad
$\dot{\gamma}_{max}$= 2.98 grd/s
$\ddot{x}_{n,max}$ =1.88 m/s²



# THANK YOU FOR YOUR ATTENTION!

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