Automated Car
Desing, Implementation and Experiment

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Thanks to: Jiri Zahora, Michal Sojka, David Kopecky, Martin Vajnar

HERCULES

Autonomous driving
Machine learning

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement: 688860.

High-Performance Real-time Architectures for Low-Power Embedded Systems

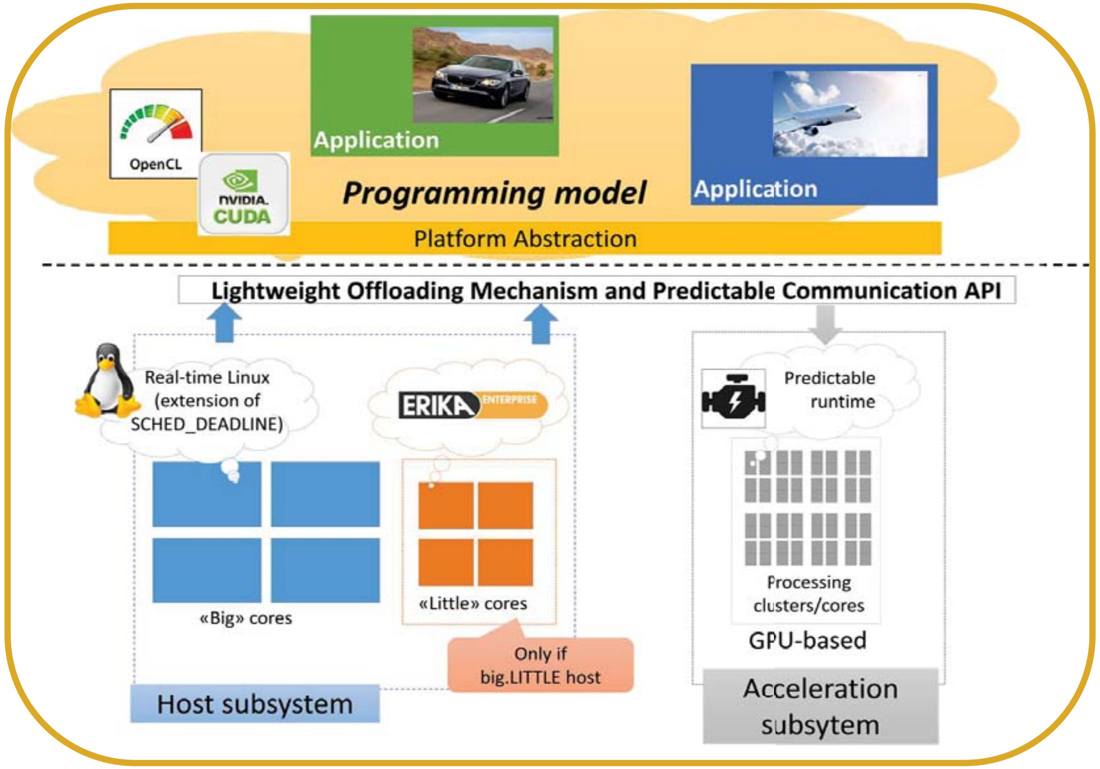
HERCULES industrial and academic consortium aims to establish reference architectures and platforms for customized low-power heterogeneous computing systems delivering high performance functionality under real-time constraints across two main application domains (Automotive & Avionics).

HERCULES Main Goals:

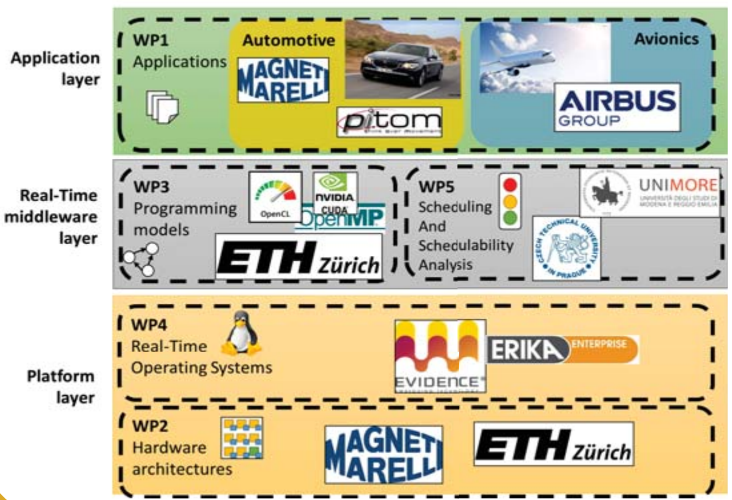
G1. Demonstrate and implement the first industrial-grade framework to provide real-time guarantees on top of cutting-edge heterogeneous COTS platforms for the embedded domain.

G2. Obtain an order-of-magnitude improvement in the energy efficiency and cost of next generation real-time systems.

G3. Provide a homogeneous programming interface to simplify the development of future real-time application on top of heterogeneous COTS platforms.



Partners roles – operational layer



HERCULES will contribute to solve many present constrains of Advanced driving assistant systems (ADAS):

- Low-power budgets
- Space constrained
  - Move to embedded platforms
- Tight interaction with environment
- Hard Real-Time constraints
  - Still, poor research in this field

NVIDIA TEGRA

Project Consortium

https://www.hercules2020.eu

UNIMORE · ETH Zürich · pitom · MAGNETI MARELLI · EVIDENCE · AIRBUS GROUP

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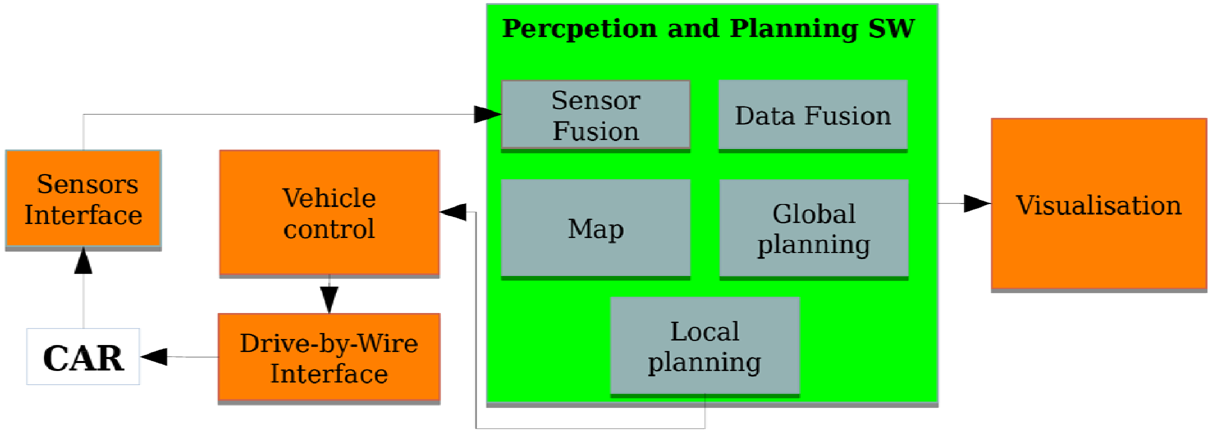
Formula 1/10th
1/10th the scale 10 times the fun

Scaled down model for experiments

- Ubuntu and Robot Operating System (ROS) on NVIDIA Jetson TX2
- sensors: LiDAR, Inertial unit
- actuators: servo and moment controlled 3-phase Brushless DC motor



Our experiments:

- Trajectory planning
- Indoor GPS
- Sensor/data fusion
- Dynamics and MPC

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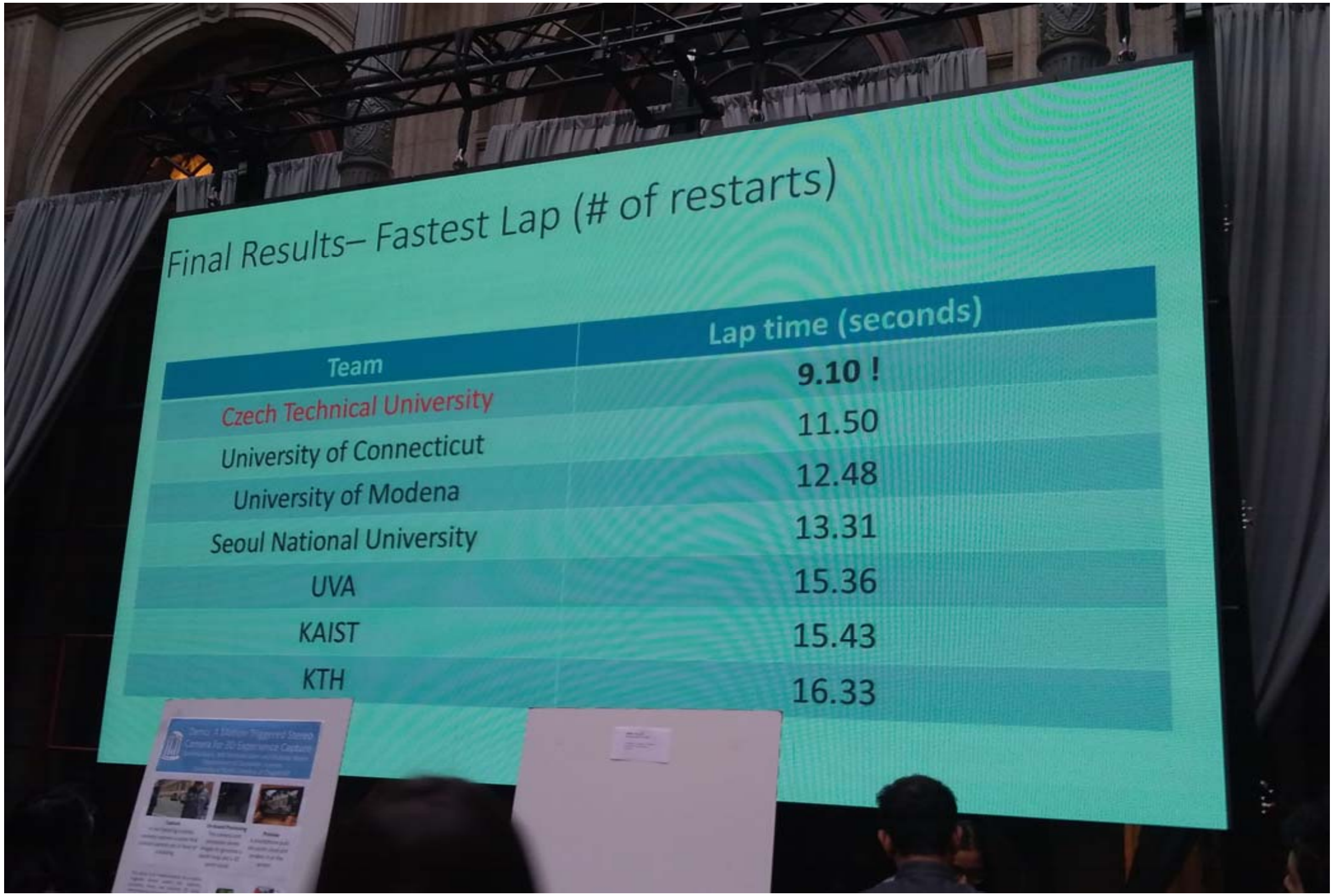
Formula 1/10 Autonomous Racing Competition
Our team won at the CPS Week, Porto April 2018



Organizers:

- University of Pennsilvania, USA
- University of Virginia, USA
- University of Modena, Italy

Our team: Jan Bednář, Jaroslav Klapálek, David Kopecký, Anders Solberg Pedersen, Joel Matějka, Martin Vajnar

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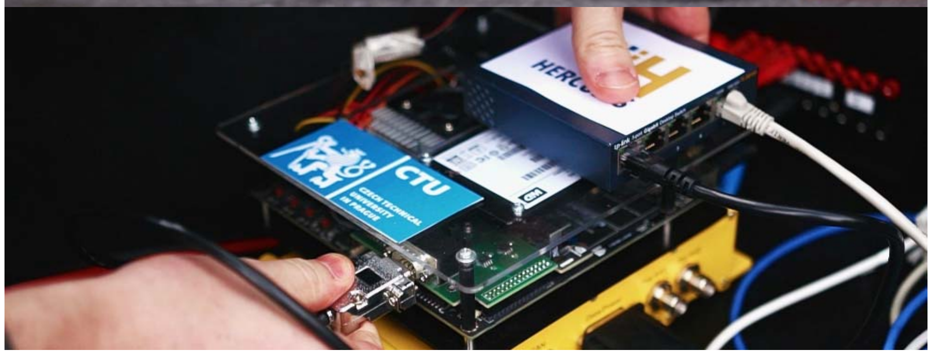
Autonomous Car Slalom with Porsche Panamera

PORSCHE



- DGPS, Camera, Lidar, car sensors (via FlexRay)
- NVIDIA TX2 with ROS
- Cone detection by camera
  - Color filtration
  - Contours detection
  - Triples detection + ROI setup
  - Creating feature vect. with HOG descr.
  - SVM clasification
- Data fusion
- Trajectory planning
- Trajectory following, lateral & longitudinal control

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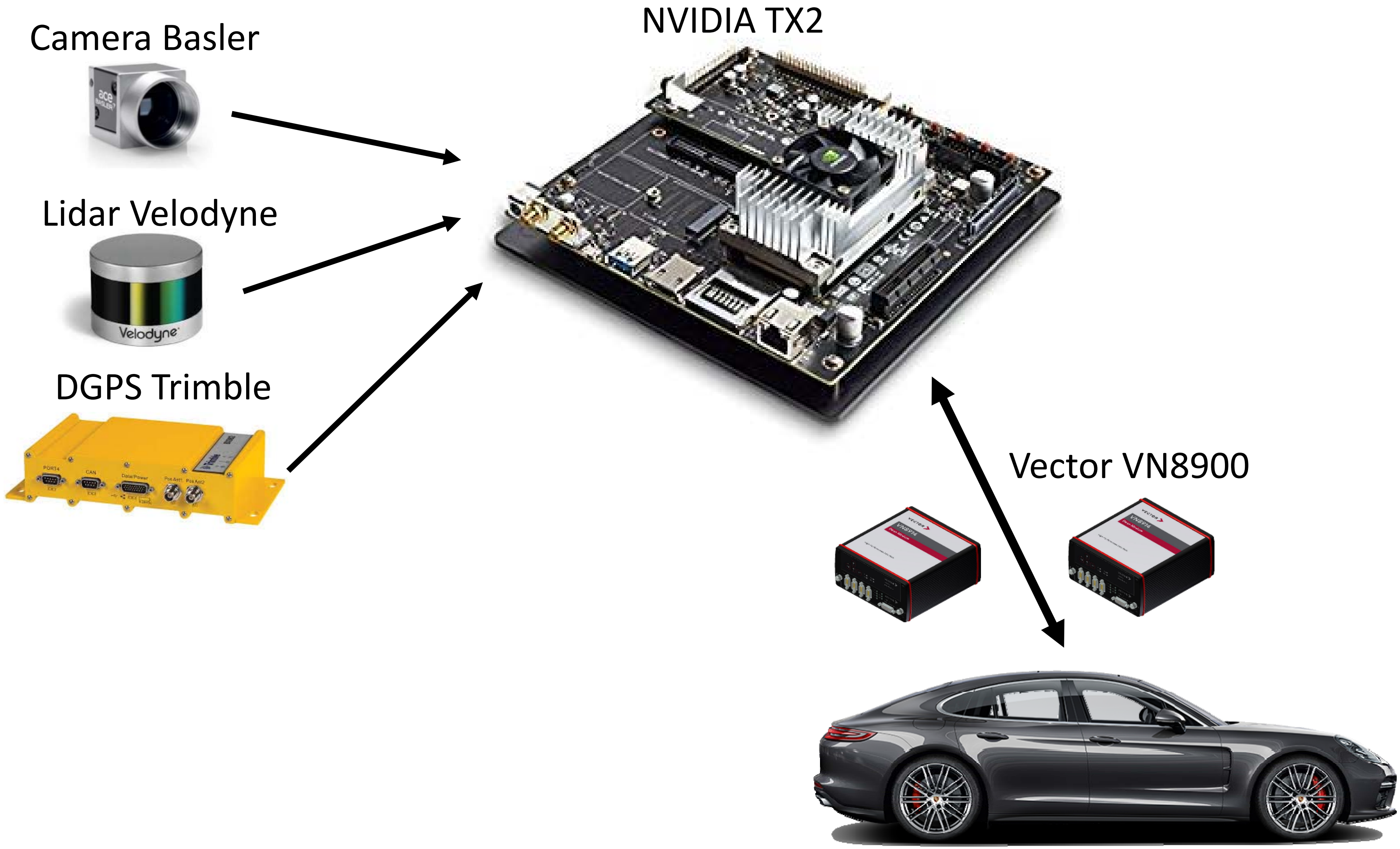
Hardware and Sensors



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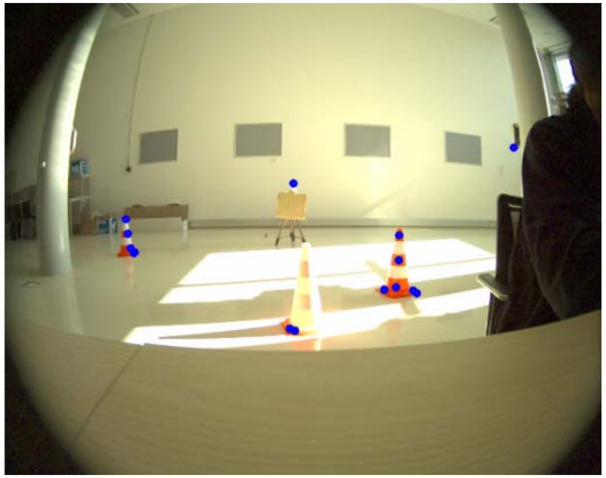
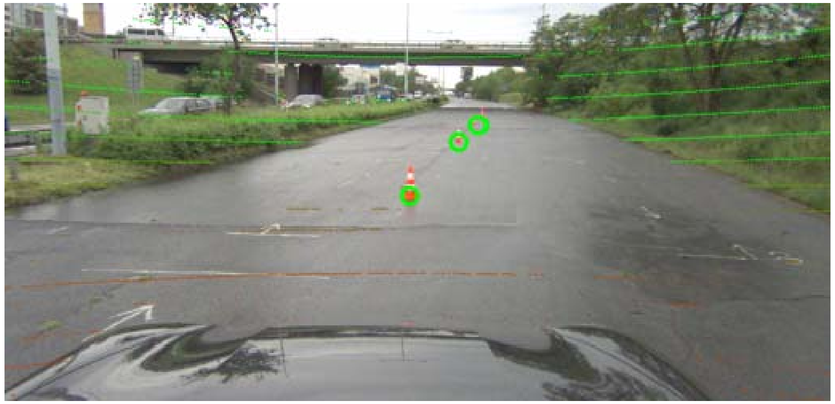
Hardware and Sensors - Parameters

- Camera – Basler ace
  - 1920x1200 px, 40 fps, widescreen lens, USB 3.0
  - Manual color and brightnes settings
  - Fish-eye distortion
- Lidar – Velodyne VLP-16
  - 16 layers, rotation range 5-20 Hz
  - Range: +-15 deg vertical, 360 deg horizontal, 100 m
  - Doesn't work with shiny surfaces (e.g. wet road)
- DGPS – Trimble BX982
  - All positioning systems (GPS, GLONASS, GALILEO, …)
  - 50 Hz output, correction inputs (RTCM)
  - Real accuracy 10 cm (cca 95% of time, depending on signal)
  - Very imprecise heading measurement
- Vector VN8900
  - FlexRay and CAN interfaces
  - CANoe, CANape support
  - Intel Core-i7 processor
- NVIDIA TX2
  - ARM cores: 2x Denver + 4x cortex A57
  - 256 cores in GPU





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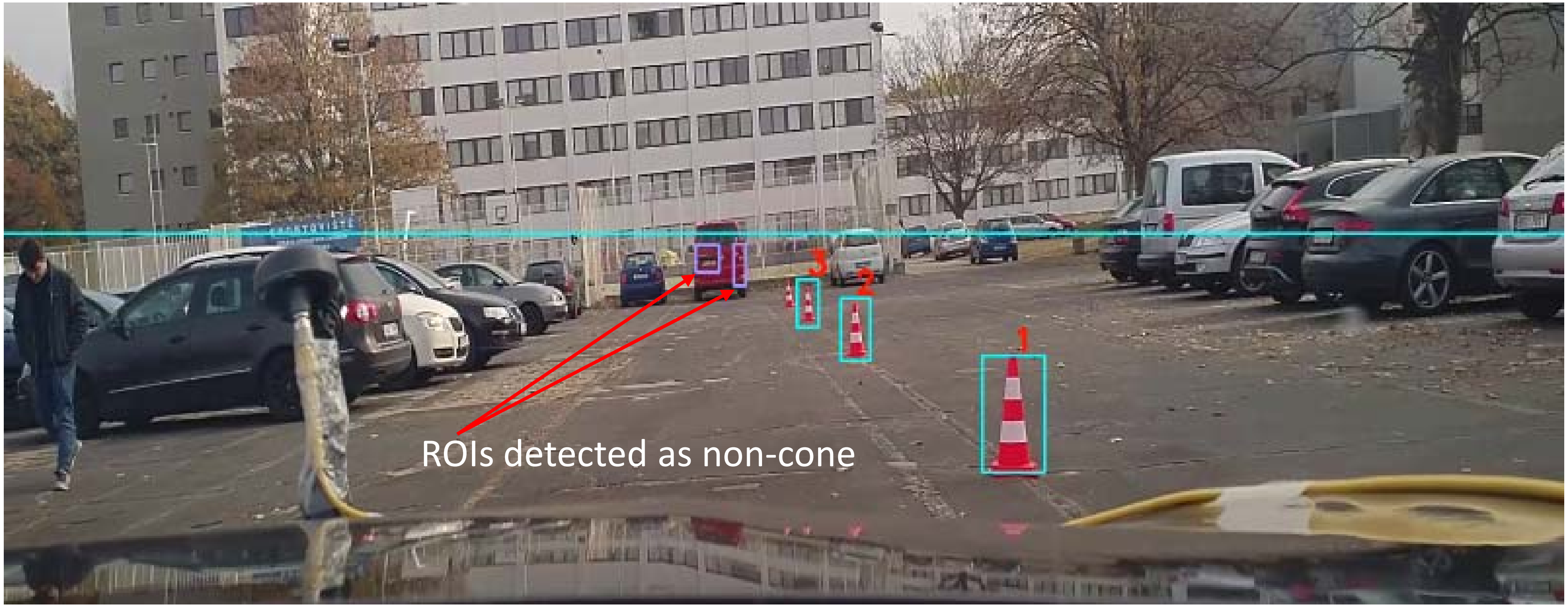
Cone Detection by Camera
- HOG Feature Descriptor

HOG (Histogram of Oriented Gradients) feature descriptor
- **object appearance and shape** within an image can be described by the distribution of **intensity gradients** or edge directions
- the concatenation of histograms is represented as **vector of numbers**



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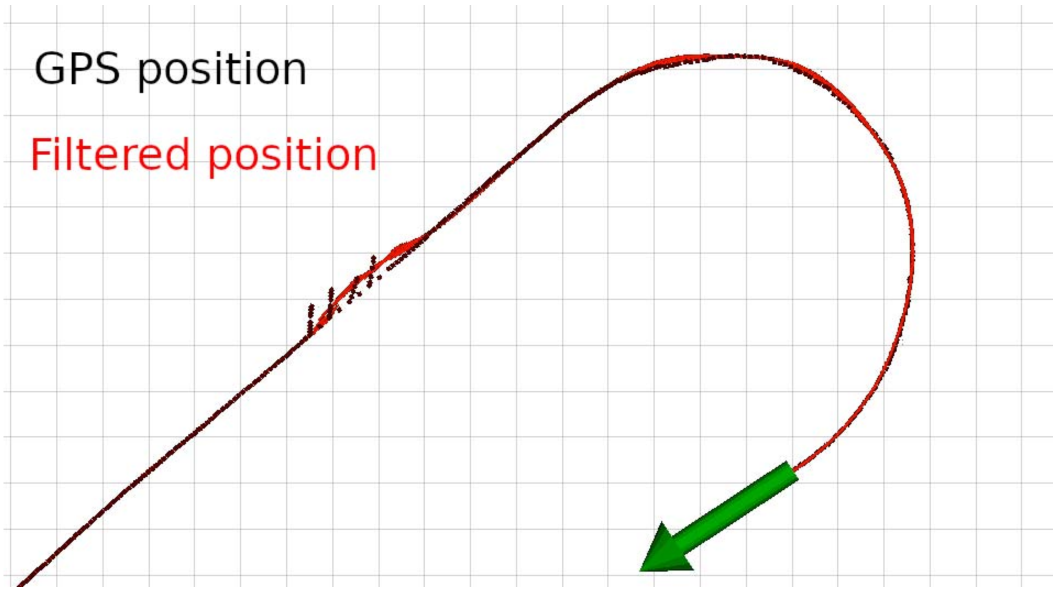
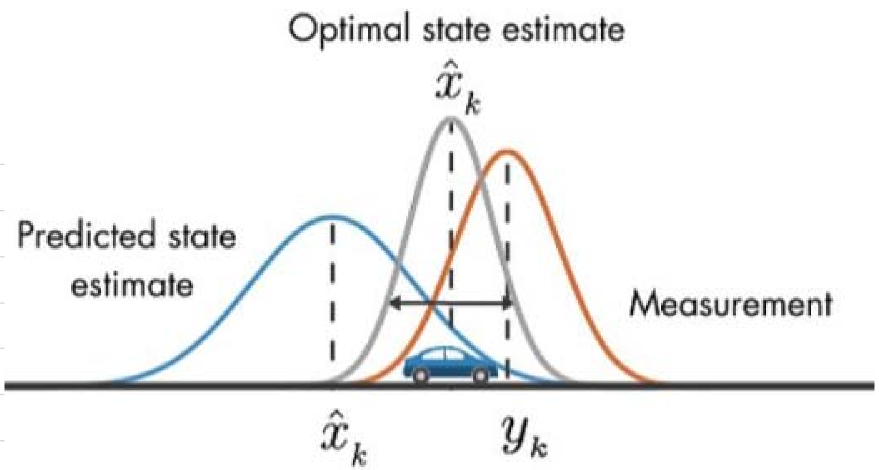
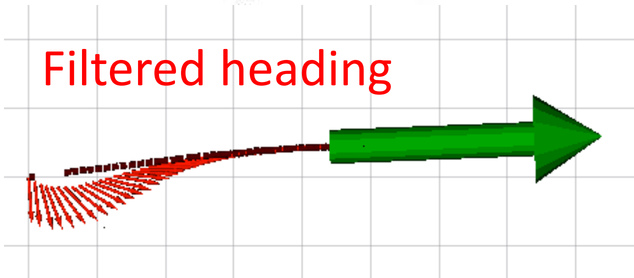
Kalman Filter to Derive Possition and Heading

- Extended Kalman filter uses system dynamic model
  - Input: GPS position 50 Hz, car data (speed, angular speed)
  - Output: Car x,y position and **heading**
  - to initialize heading it is needed to move the car and collect several GPS samples







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Trajectory Planner

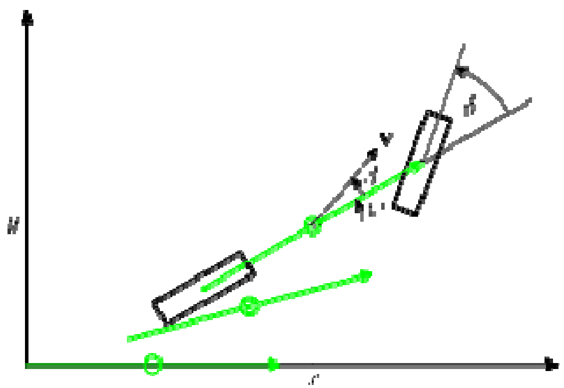
Goal: plan optimal trajectory with respect to car kinematics

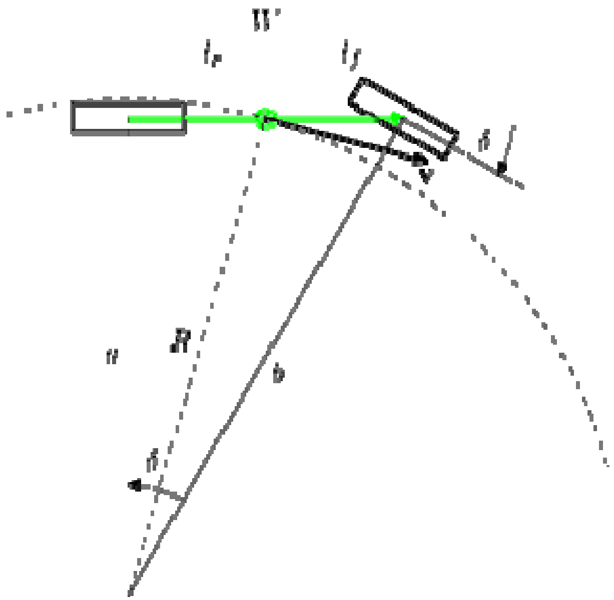
- we formulate the optimization problem (similar to LQ control):

minimize the cost function along the trajectory

$$\begin{aligned}
\underset{\mathbf{x}_1 \dots \mathbf{x}_N, \mathbf{u}_0 \dots \mathbf{u}_{N-1}}{\text{minimize}} \quad & \sum_k (q_k x_k^2 + r_k u_k^2) \\
\text{subject to} \quad & \mathbf{x}_{k+1} = \mathbf{f}(\mathbf{x}_k, \mathbf{u}_k), \ k = 0, \dots, N-1 \\
& \mathbf{x}_N = \mathbf{x}_f
\end{aligned}$$

Bicycle kinematics model





δ	-	steering angle
$\mathbf{v}$	-	velocity vector
β	-	slip angle between velocity vector and longitudinal direction
R	-	radius of car movement curve

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