

An orange abstract graphic consisting of multiple overlapping, curved lines that form a complex, organic shape, resembling a stylized leaf or a dynamic motion path. It is positioned on the left side of the top half of the slide.

FORSCHUNGSINITIATIVE
K O - F A S

Laser- and Video Based Detection of Road Users at Intersections

Laser- und videobasierte Erkennung von Verkehrsteilnehmern an Straßenkreuzungen

Elias Strigel

Institute of Measurement, Control, and Microtechnology
Ulm University

Supported by:



on the basis of a decision
by the German Bundestag

System Overview

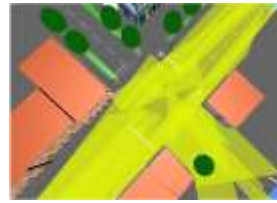


Cameras



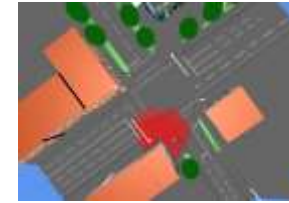
SD

Laserscanners



LS

HD Cameras



HD



Detection of Approaching
Vehicles

Detection of Moving
Objects

Search Area

Detection of Pedestrian
Movements

Classification
Car, Truck/Bus

Classification
Car, Truck/Bus, Pedestrian,
Two-wheeler

Detection of
Pedestrian intention



Fusion and Communication

Complementary Sensor Setup

Monochrome Cameras



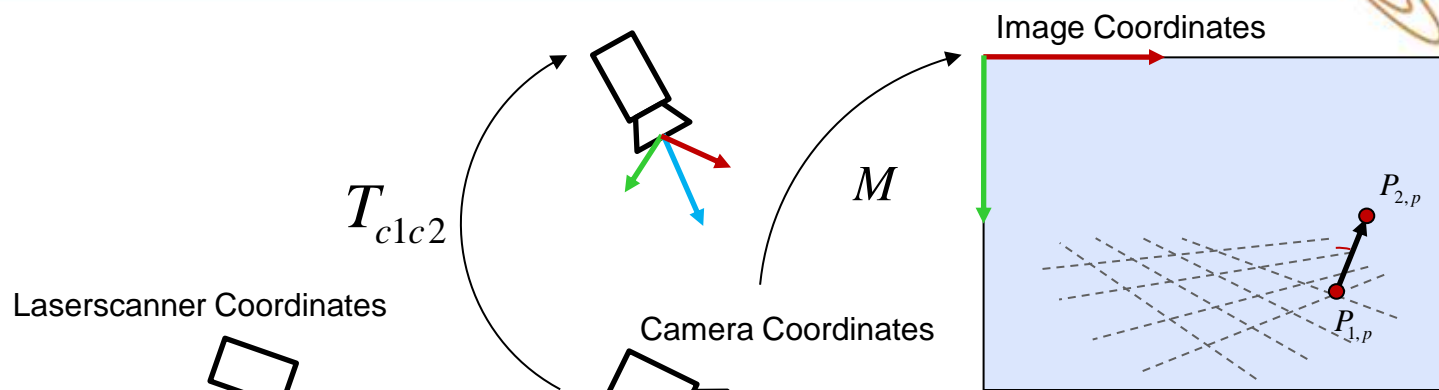
- + good resolution in application area
- + provides texture information
- + low price
- illumination dependent
- no depth information

Laserscanners



- + detection of surrounding with depth
- + illumination independent
- + good resolution in near regions
- low resolution in far regions
- no texture information

Sensor Calibration - Transformations



Laserscanner Coordinates

Camera Coordinates

Image Coordinates

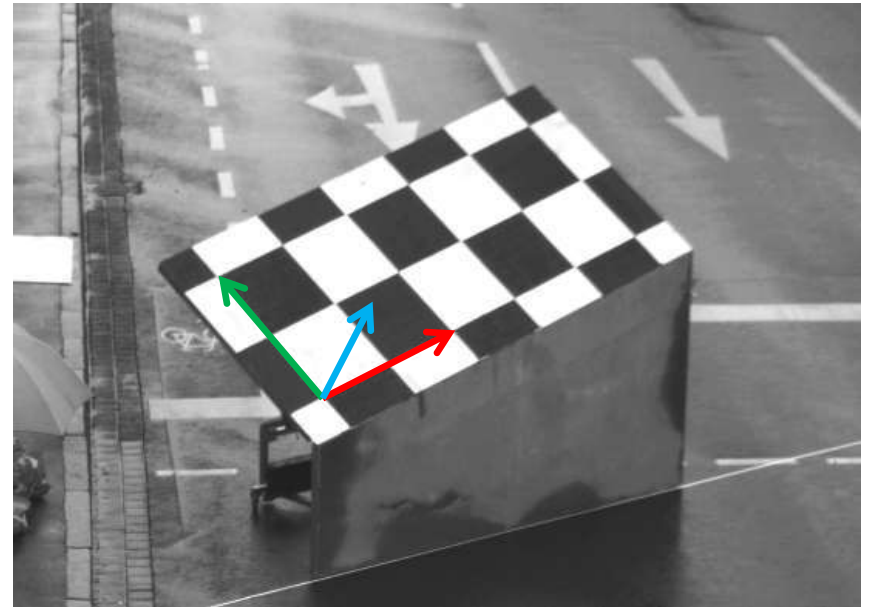
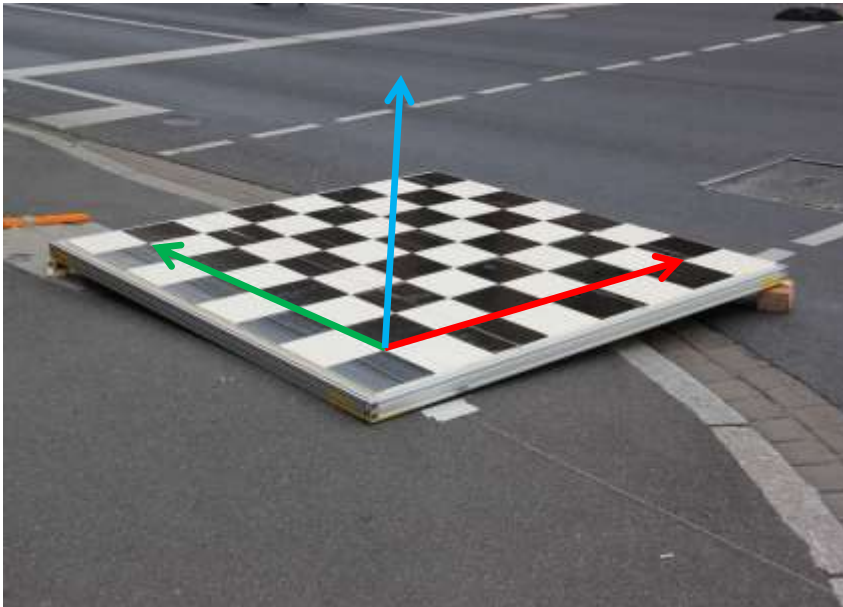
T_{w1l1}

T_{w1c1}

World Coordinates

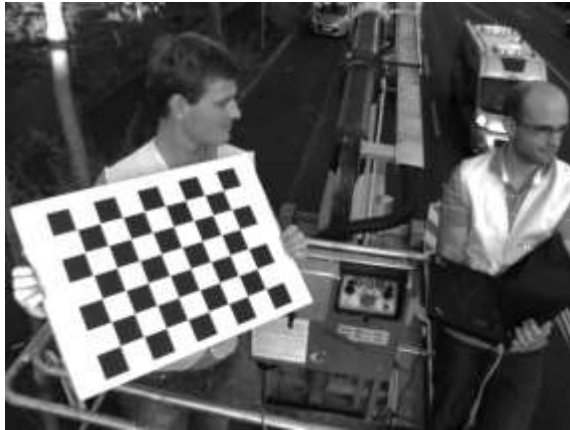
$$x_p = s \cdot \underbrace{\begin{bmatrix} f_x & 0 & c_x \\ 0 & f_y & c_y \\ 0 & 0 & 1 \end{bmatrix}}_M \cdot [R_{wc} \ t_{wc}] \cdot \begin{bmatrix} X_w \\ 1 \end{bmatrix}$$

Extrinsic calibration of all cameras and laserscanners using different target devices.



Sensor Calibration – Examples

Intrinsic Calibration



Extrinsic Calibration

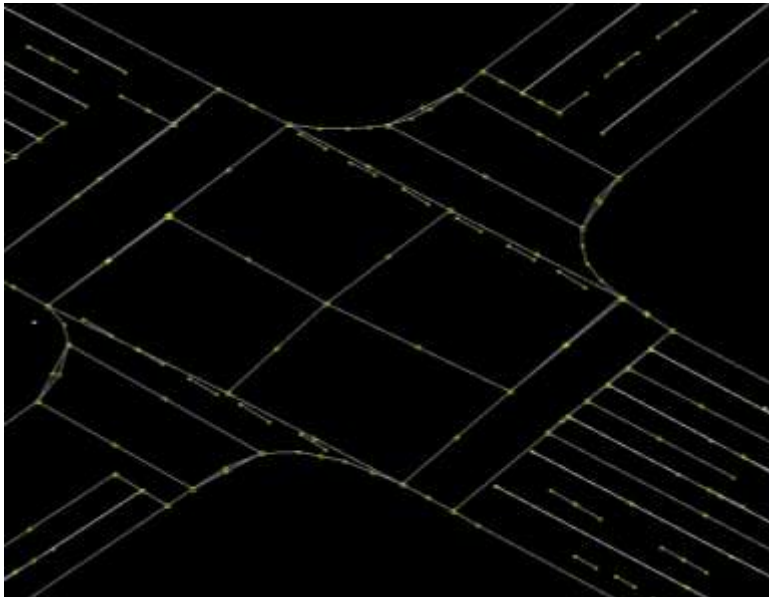


Sensor Calibration – Digital Map

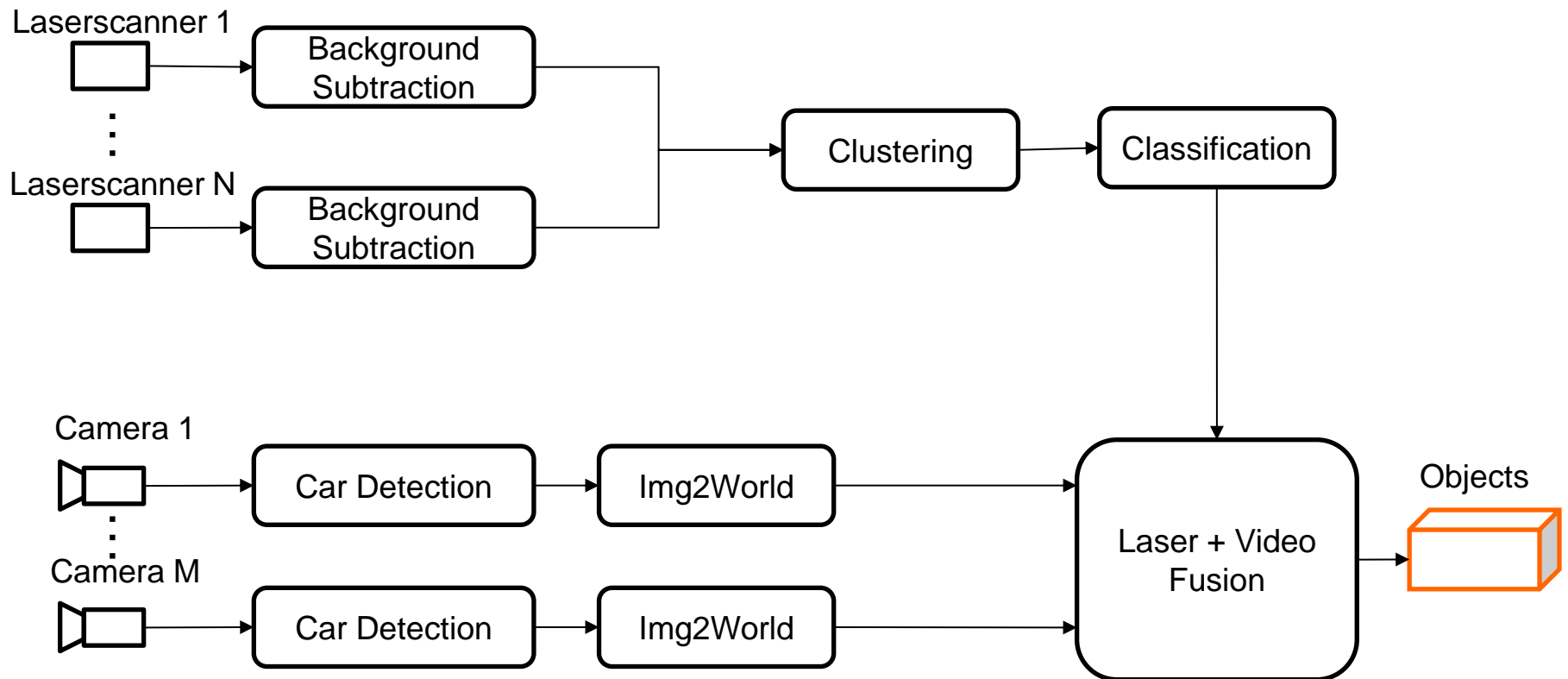


FORSCHUNGSINITIATIVE
K O - F A S

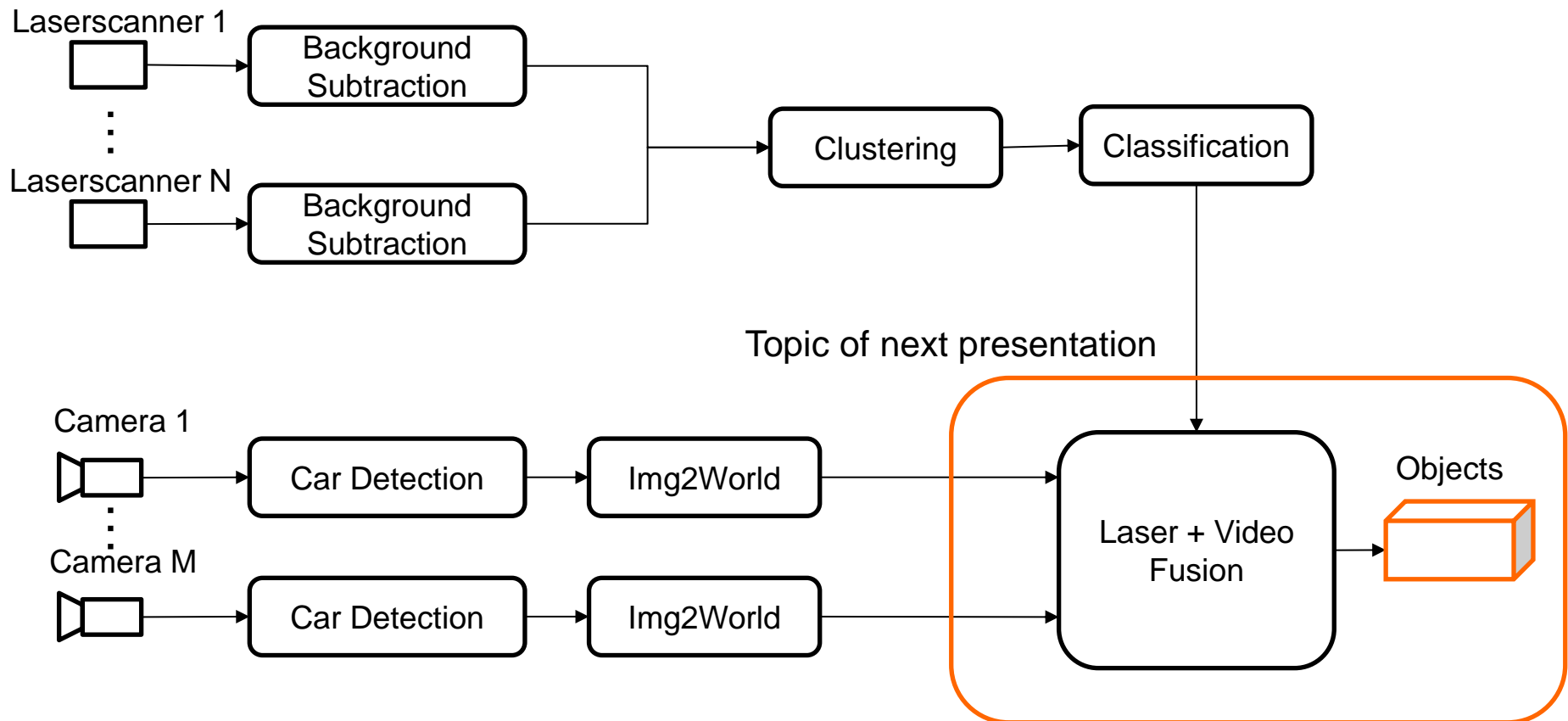
Global reference by DGPS measurements (WGS84) and digital map matching.



Algorithm Overview

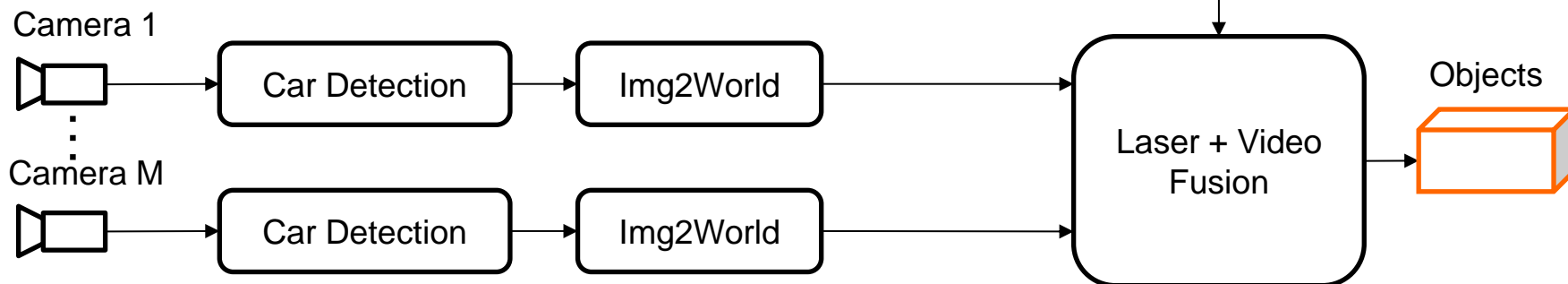
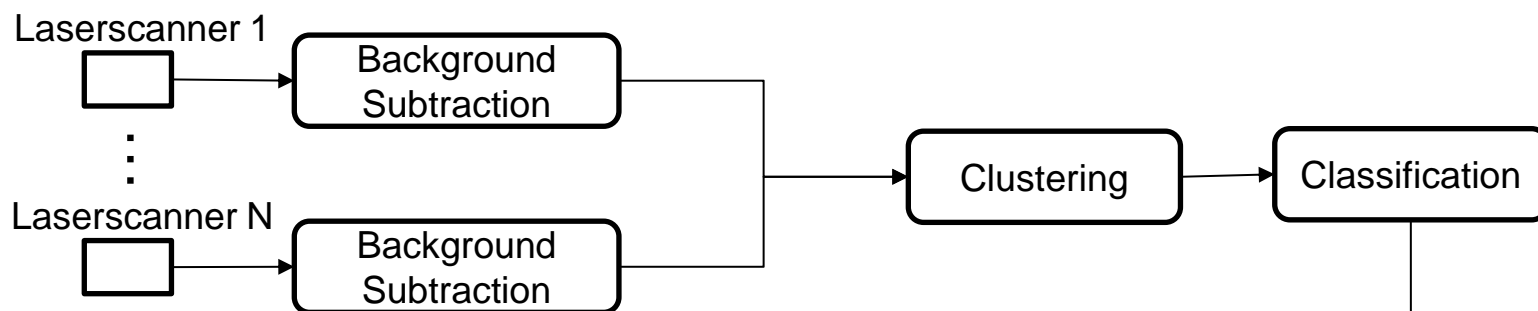


Algorithm Overview

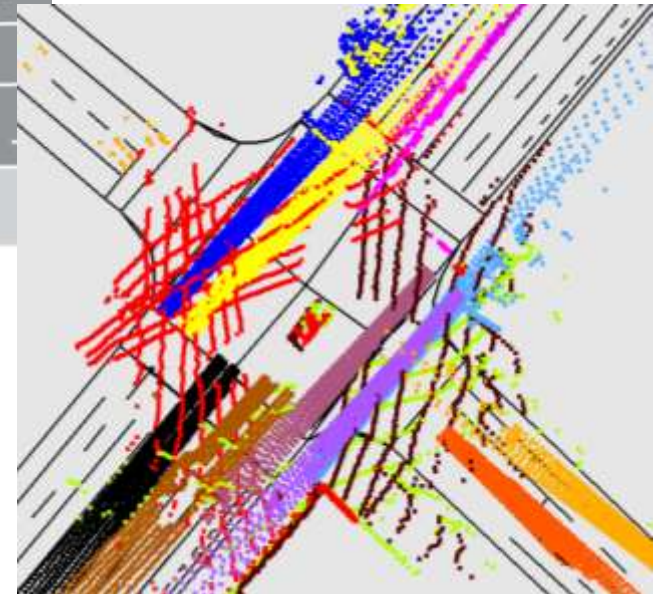
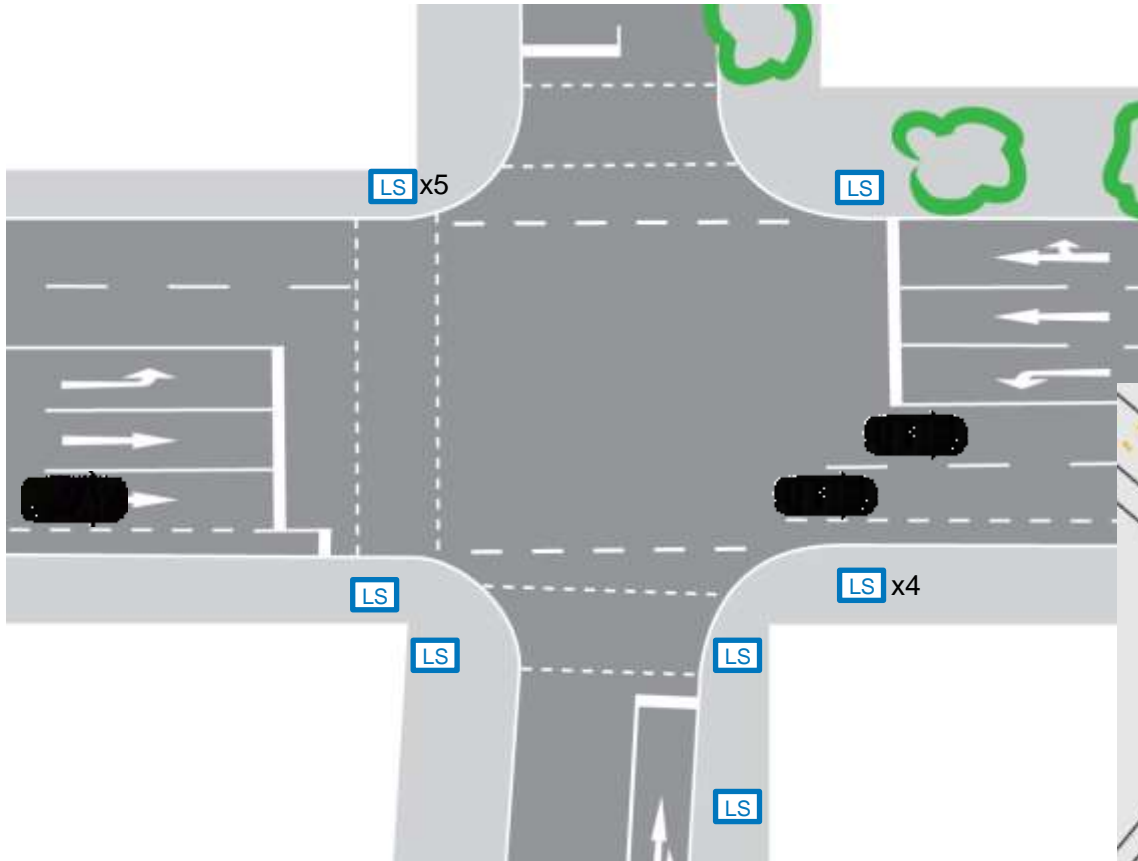


Algorithm Overview

Laserscanner Subsystem

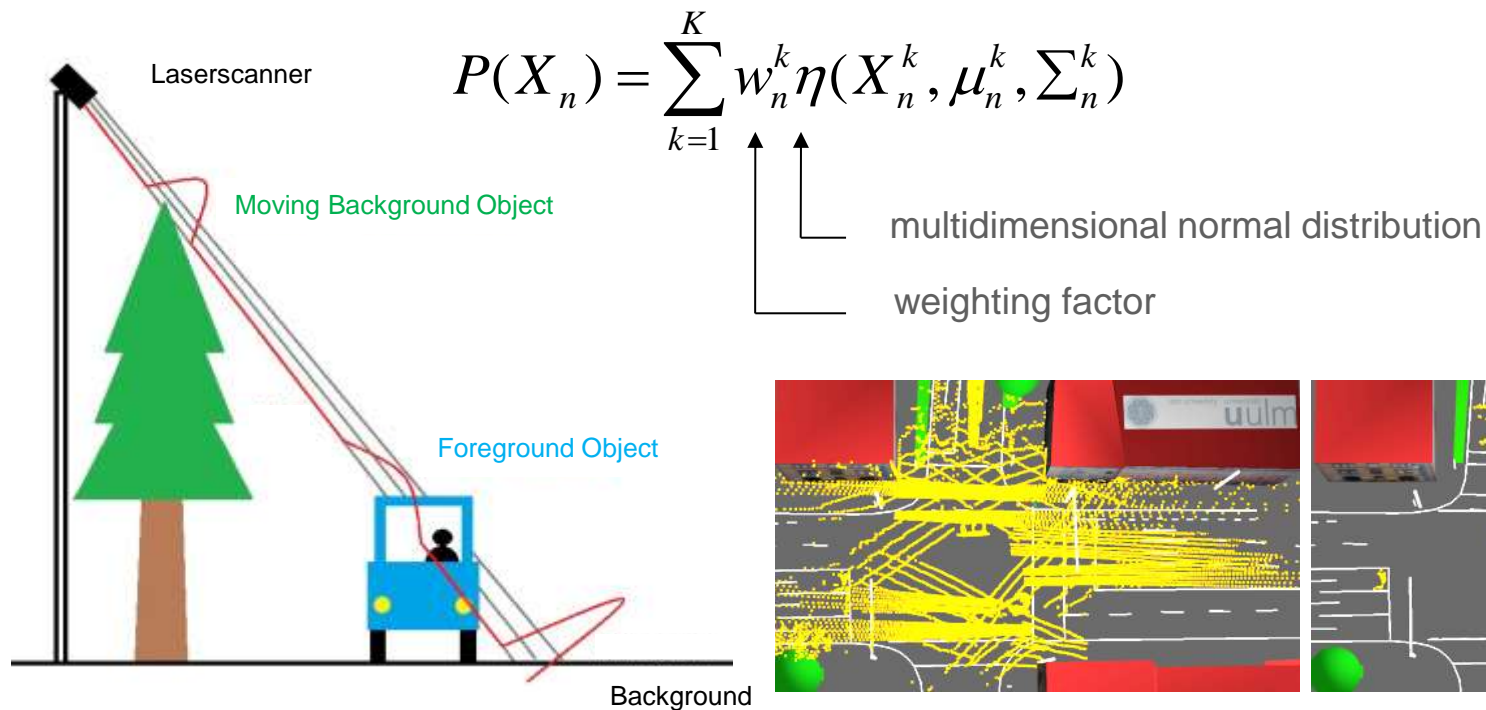


Perceiving the Intersection



Background Subtraction

- Gaussian Mixture Model (GMM) for every laser beam
- Online adaption of model to background changes
- Robust against moving background objects



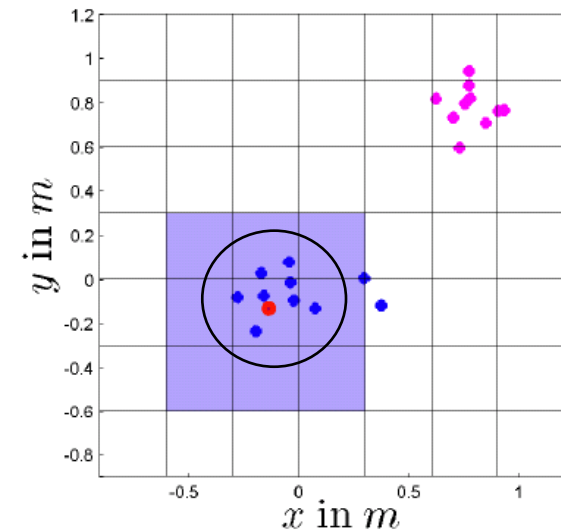
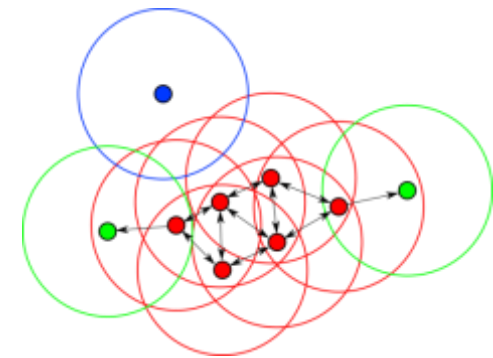
- Density-Based Spatial Clustering of Applications with Noise (DBSCAN)

- Principle:

Measurements with a minimum number C_{\min} of other measurements within an area ϵ are clustered.

Properties:

- ✓ Does not require a priori knowledge on the number of clusters
- ✓ Search area can have an arbitrary shape
- ✓ Outlier detection
- ✗ Quadratic complexity

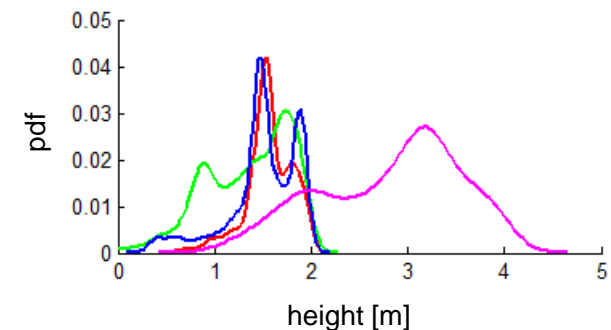
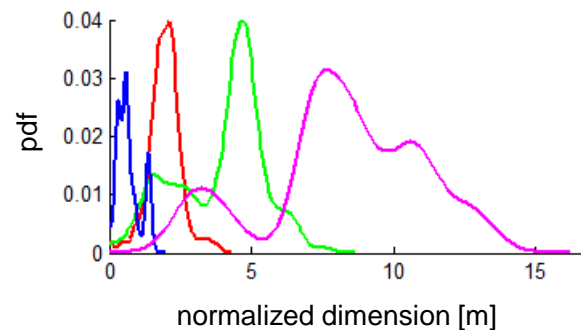
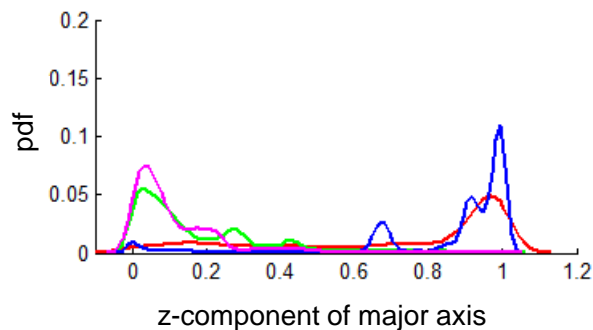
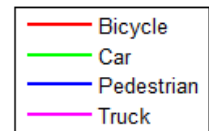


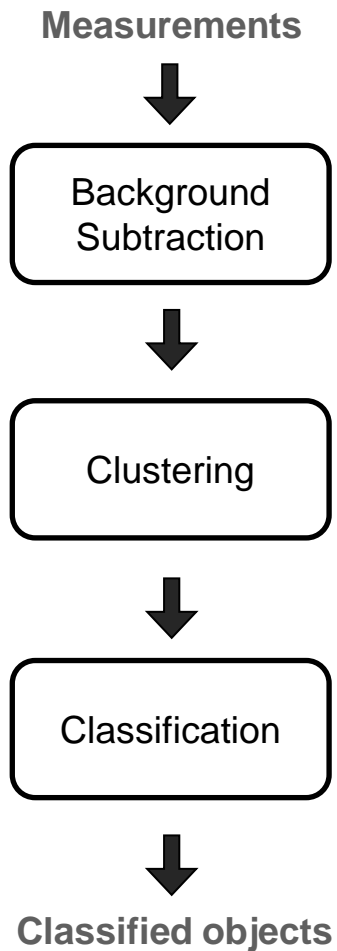
Search area limitation due to
Grid Based DBSCAN

- Bayes classifier

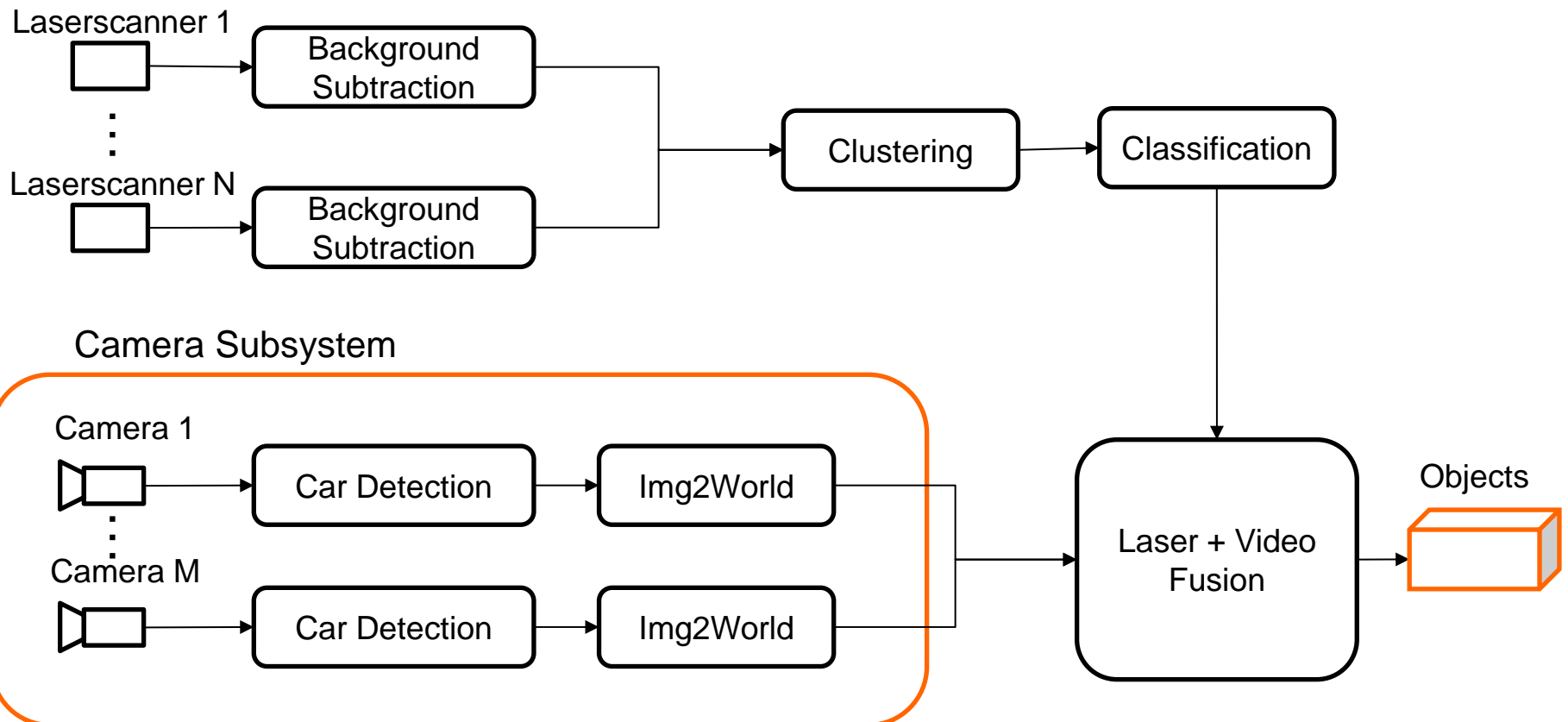
$$P(C_i|x) = \frac{p(x|C_i)P(C_i)}{p(x|C_1)P(C_1) + p(x|C_2)P(C_2)}$$

- Distinguish pedestrians, bicycles, cars, and trucks
- Static features of point clouds
 - x-, y- and z-component of the major axis
 - Height
 - Standard deviation of the measurement points





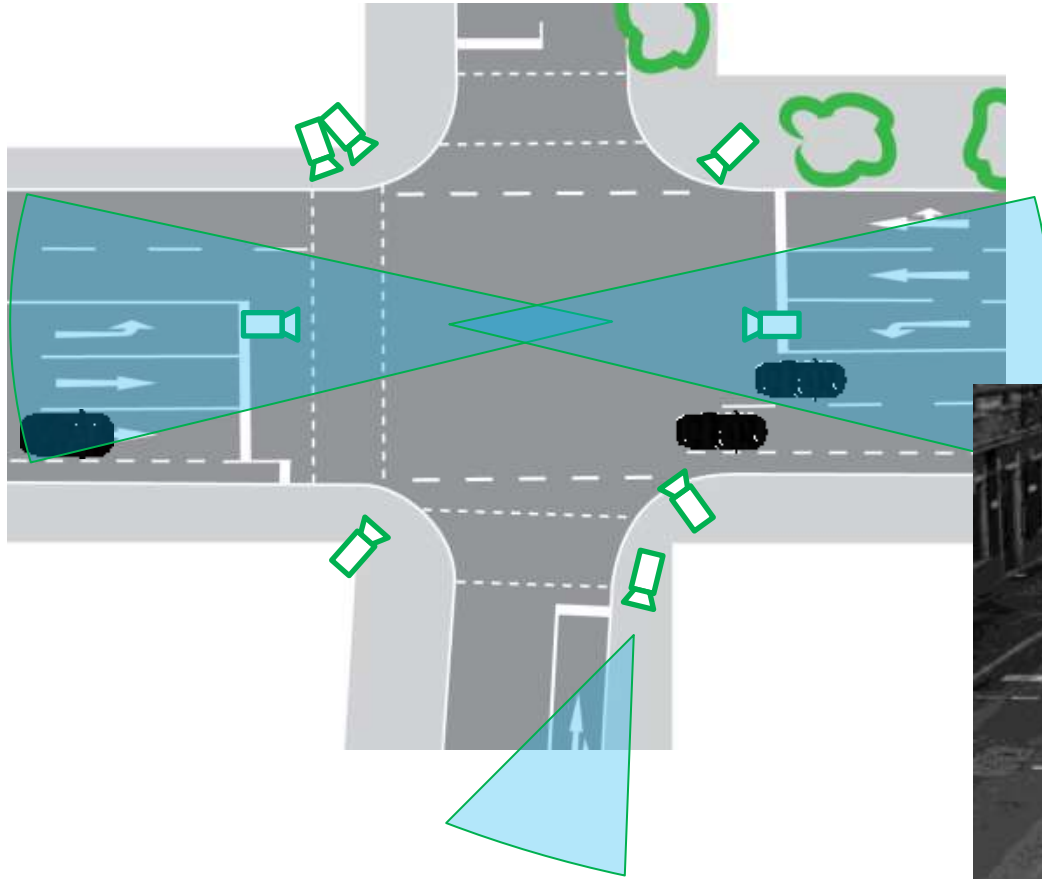
Algorithm Overview



Perceiving the Approaches

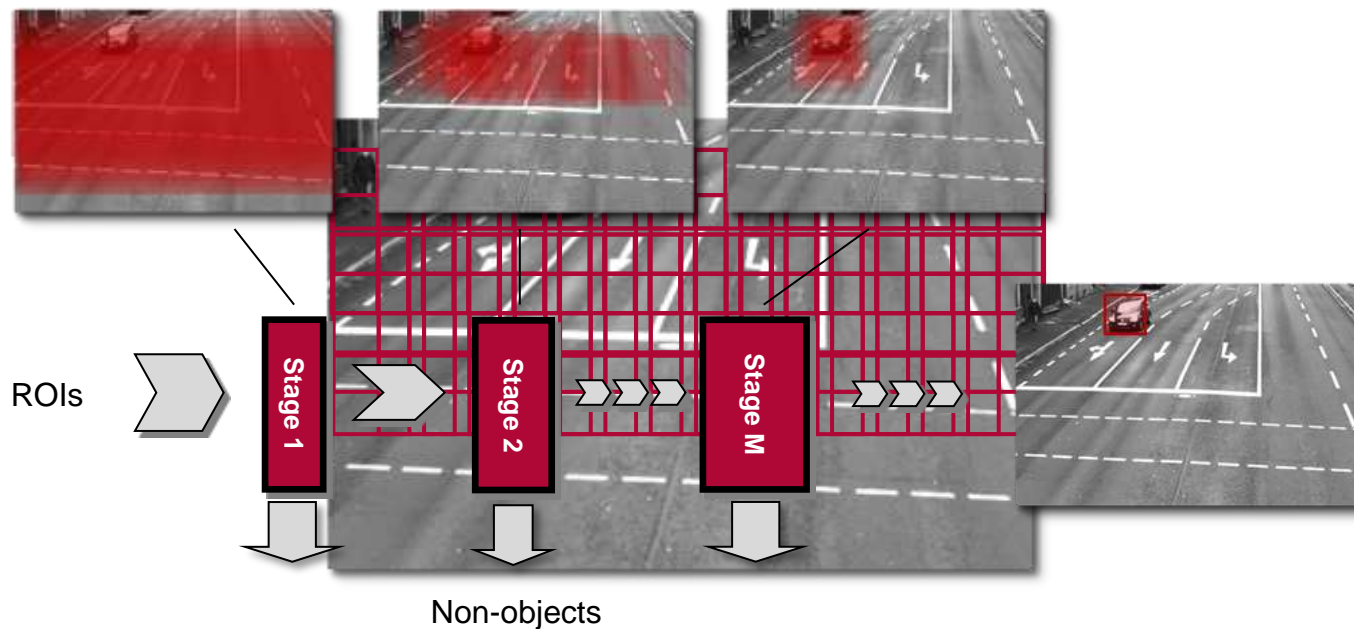


FORSCHUNGSINITIATIVE
K O - F A S

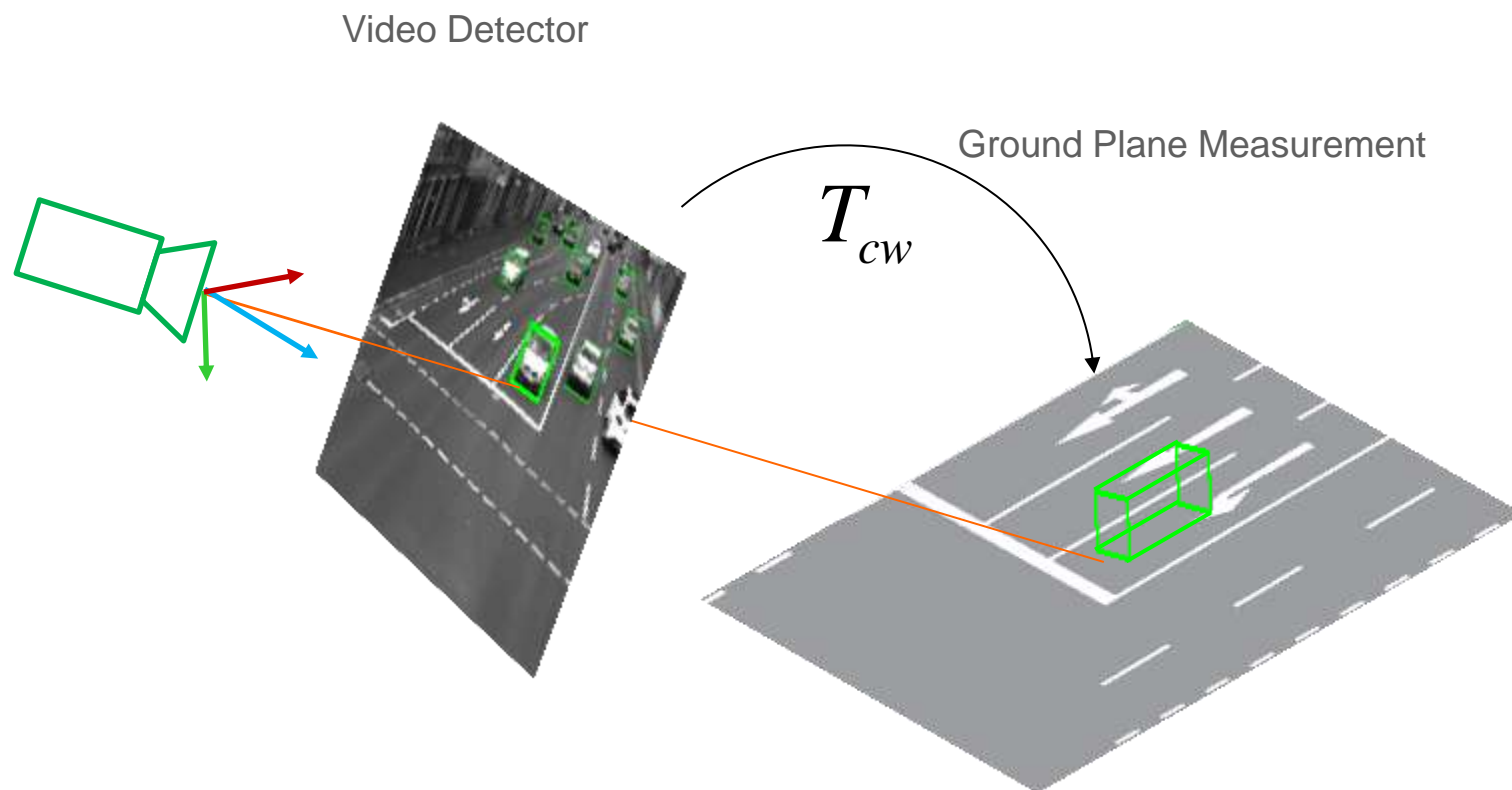


Monocular Object Detection with the Boosted Cascade

- Approach: „Detection by classification“
- Sample all possible ROIs in an input image
- Classify each ROI individually
- V&J: Improve speed by cascading increasingly complex classifiers



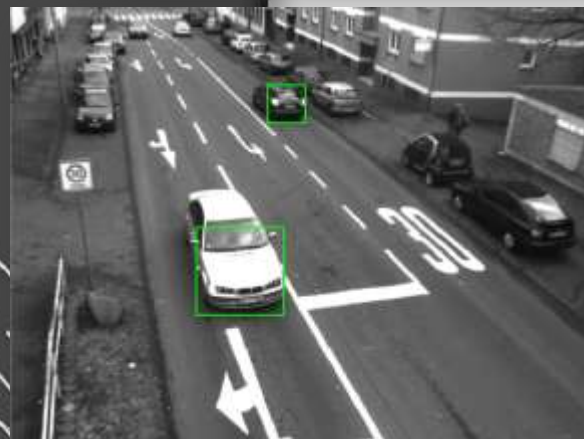
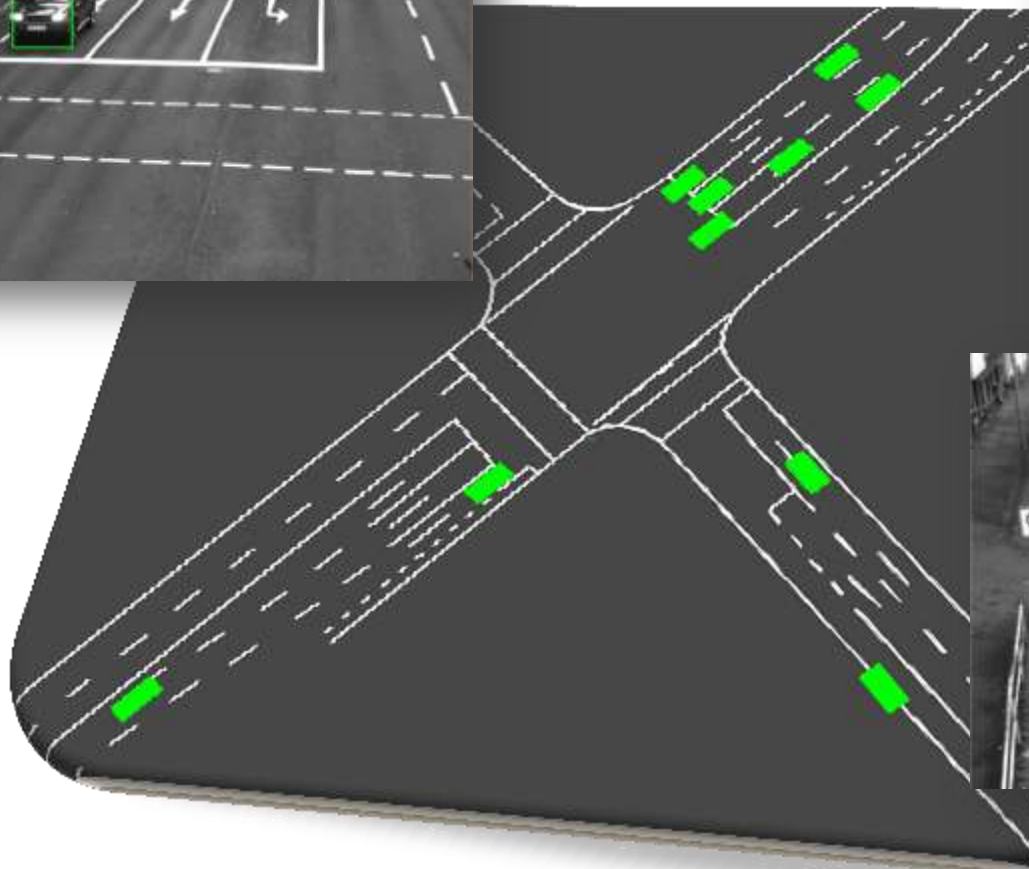
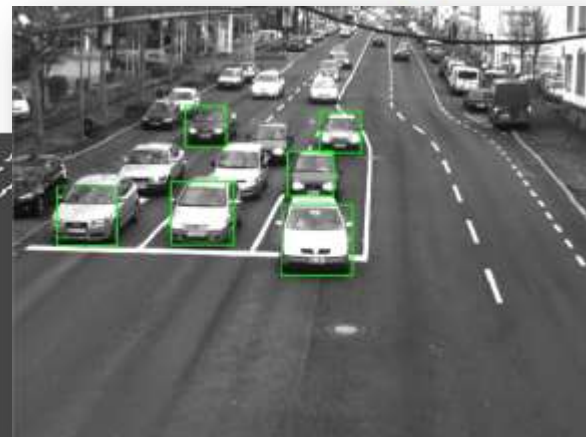
Transformation Image to World



Detection Examples



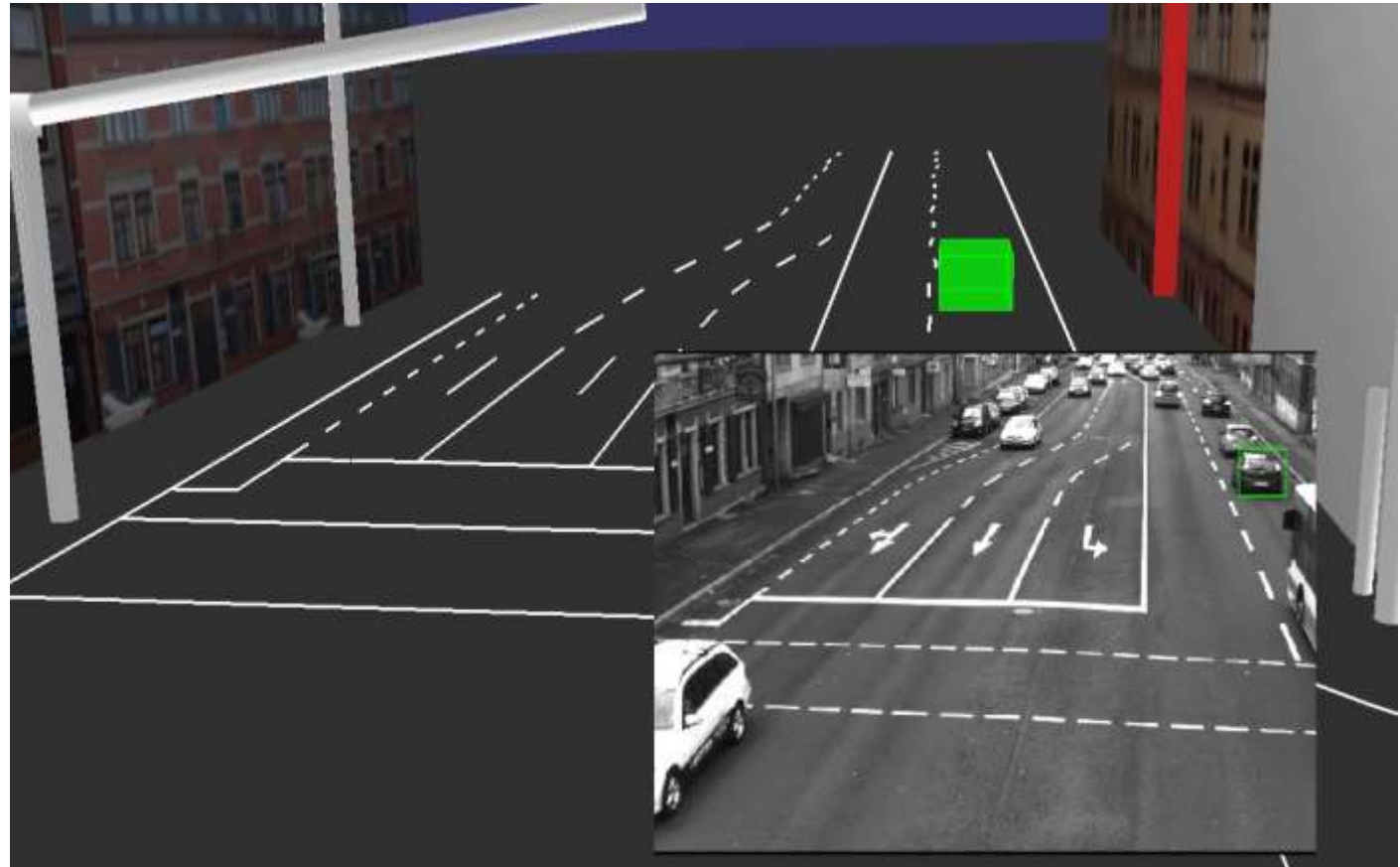
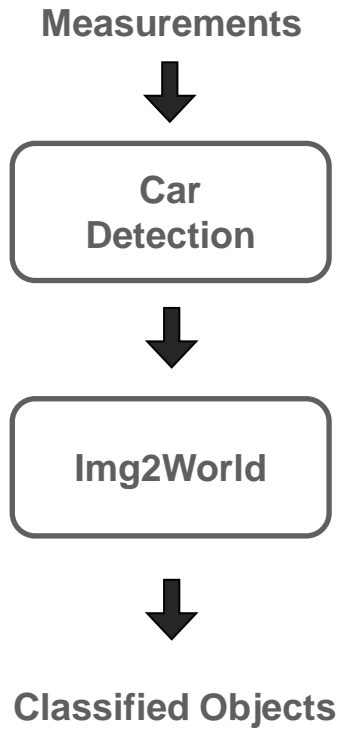
FORSCHUNGSINITIATIVE
K O - F A S



Video – Camera System

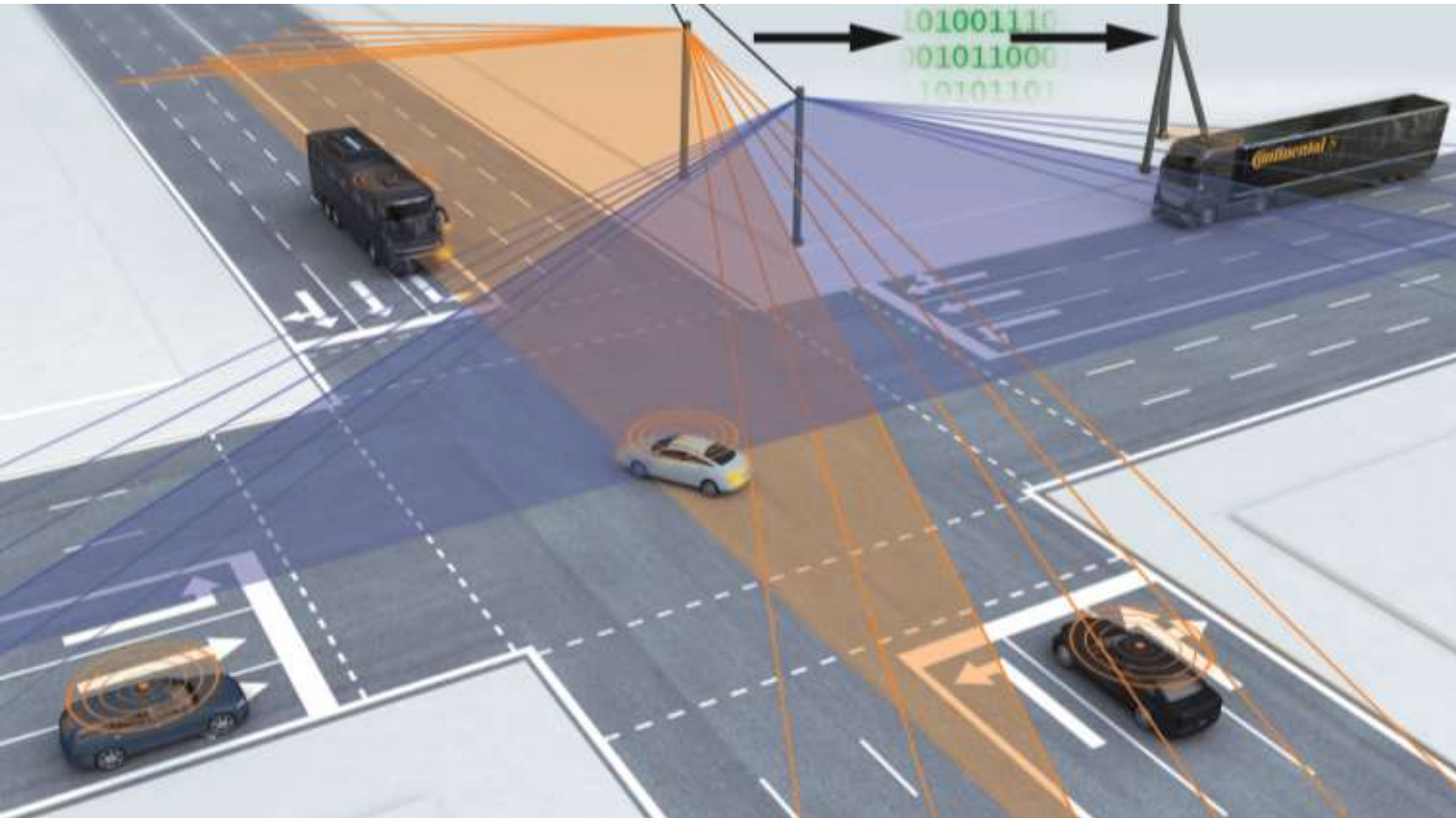


FORSCHUNGSINITIATIVE
K O - F A S



- A complementary sensor setup is used
- Calibration of sensorsystem with special designed target devices and an accurate digital map
- Detection and classification of objects at intersection using laserscanners
- Recognition of approaching vehicles using monocameras

Questions?



Supported by:



on the basis of a decision
by the German Bundestag

The highly innovative activities of the Ko-FAS research initiative are supported with funds from the German Federal Ministry of Economics and Technology.