interactIVe

Accident avoidance by active intervention for Intelligent Vehicles

A Road Edge Detection Approach for Marked and Unmarked Lanes Based on Video and Radar

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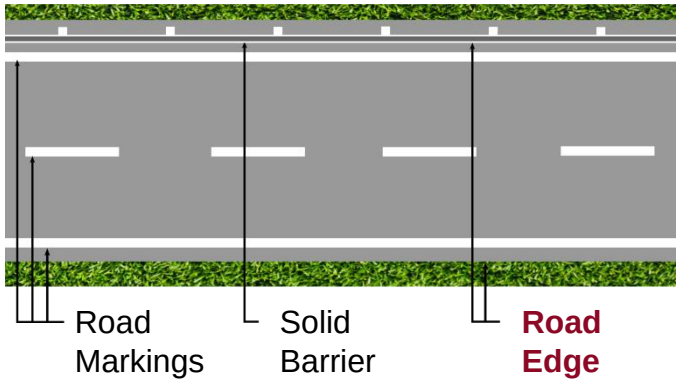
Motivation

Road Edge Detection is crucial for ADAS:

- Free space modeling
- Dynamic environment representation
- Path planning in hazardous situations
- Avoidance of single vehicle crashes



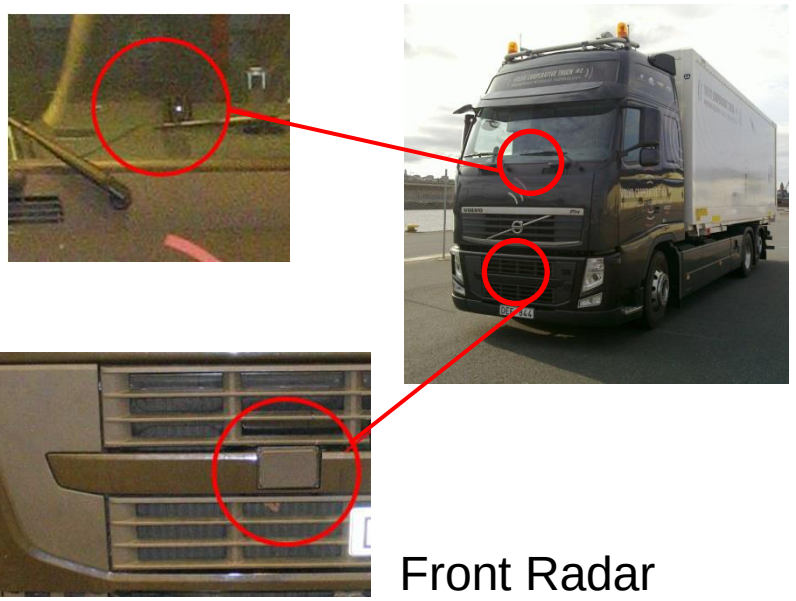
Border of the driveable area:

- Homogeneous road ↔ off-road area (e.g. grass)
- Solid barrier (e.g. guardrail)

Setup

- **Input:**
  - Grey value images of a mono camera
  - Radar data
  - Map data
- **Output:**
  - Best Road Edge Hypothesis
  - Confidence
- **Scenarios:**
  - Highways, rural roads
  - No urban roads

Camera



Front Radar

Road Edge Model and State Estimation

- The left/right road edge is modeled by a third order **polynomial**:

$$x \rightarrow \frac{c_1}{6}x^3 + \frac{c_0}{2}x^2 + \varphi x + o \pm \frac{r}{2}$$

- **Particle filtering** with $n = 200$ particles

- **Particle p_i** describes the following state of the road edge model:

$$p_i = \begin{pmatrix} \varphi^{(i)} \\ c_0^{(i)} \\ c_1^{(i)} \\ r^{(i)} \\ o^{(i)} \end{pmatrix} = \begin{pmatrix} yaw\ angle \\ curvature \\ curvature\ rate \\ offset\ of\ the\ road\ center\ to\ the\ vehicle\ center \\ width\ of\ the\ road \end{pmatrix}$$

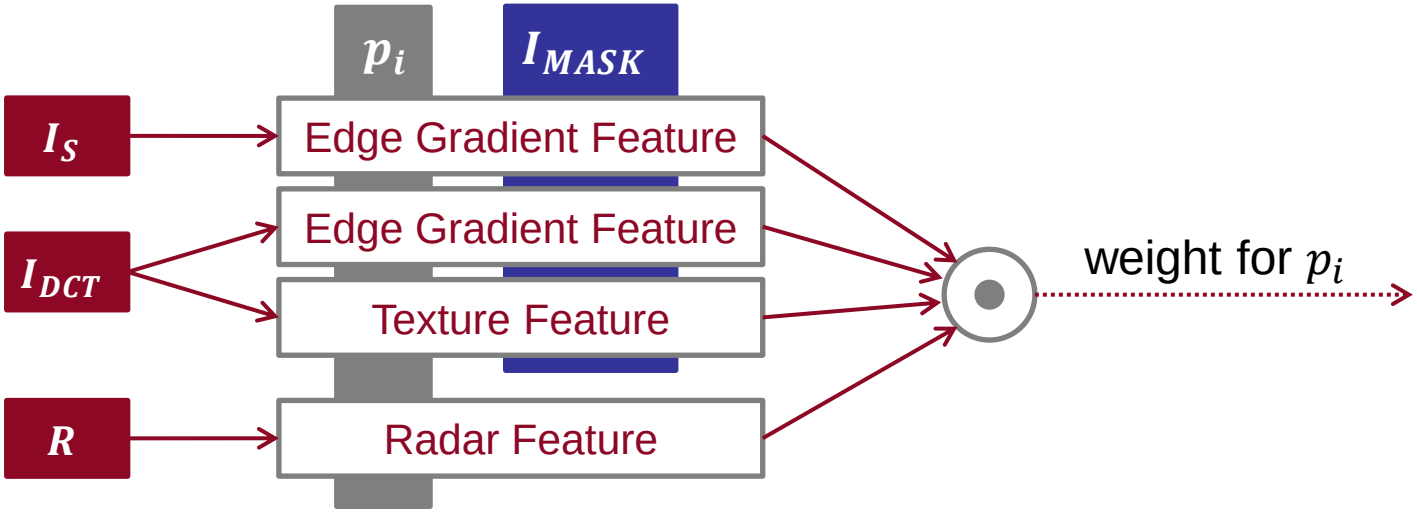
Image Pre-processing

- Create Masking Image (I_{MASK})

- Create Texture Variance Image (I_{DCT})

  - Apply 2D DCT to 8x8 windows on the input image
  - Calculate variance of the last 63 DCT coefficients for each window
  - Shift window by 3 pixels

Overview of the Algorithm



- Simple features, that are fast to calculate (real-time)
- Easy integration of additional features and more sensors
- The total weight for a particle is the product of the single feature weights
- Map data helpful for good initialization and feature selection

Edge Gradient Feature

Contours are strong indicators for road edges

- Energy image with modified distance transform (Franke 07)
- The weight of p is the higher, the projected road hypothesis is to a contour and the higher the gradient of a contour is

$$\omega_{edge}(p) = \prod_{i \in B_I} w(i)$$

cropped input image

distance transform of input image

distance transform of masked input image

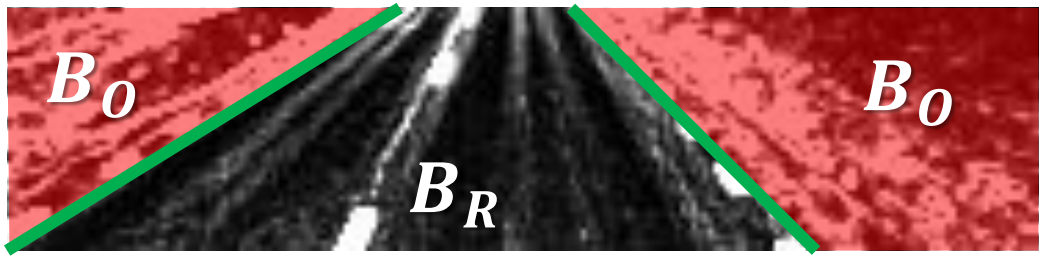
Texture Feature

Variance of the texture is higher in non-road areas

- Texture variance image
- Calculate the mean squared grey value in the off-road area

$$\omega_{texture}(p) = \frac{\left(\sum_{i \in B_0} I_{DCT}(i)\right)^2}{card(B_0)}$$

cropped input image



texture image

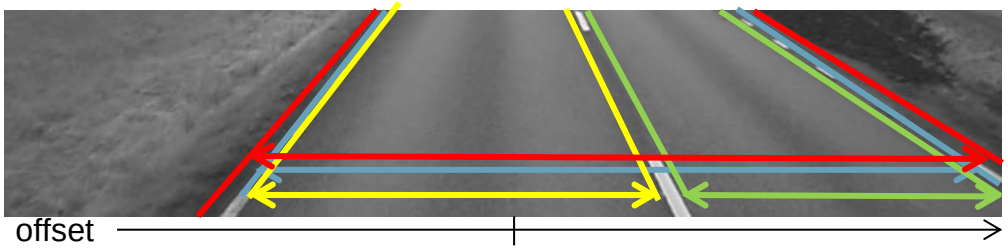
Radar Feature

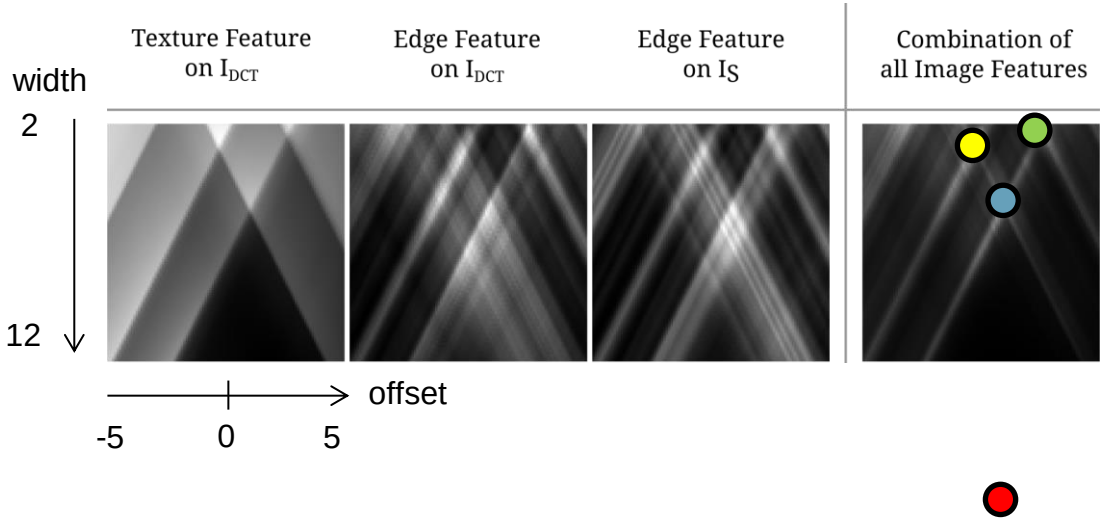
Solid barriers indicate a road edge

- Separate measurements M according to the best road edge hypothesis
- $\eta(e, m)$ assigns a weight to a radar measurement $m \in M$ for an edge hypothesis e

$$\omega_{radar}(p) = \sum_{m \in M_l} \eta(e_l, m) + \sum_{m \in M_r} \eta(e_r, m) + 1$$

Single Feature Evaluation





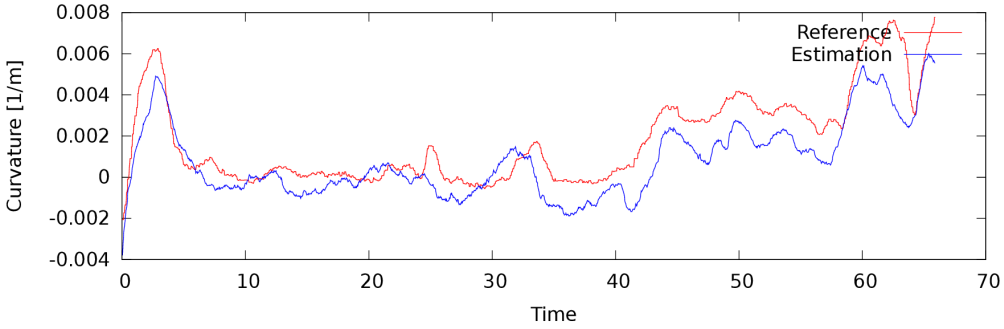
- Yaw, curvature and curvature rate are **set to 0**

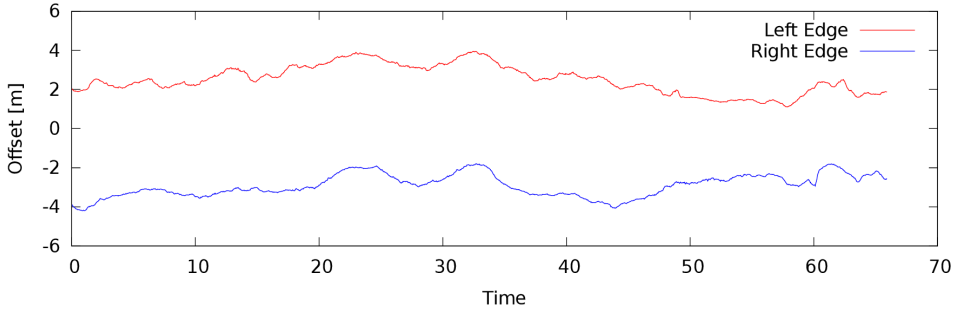
- **Width**: 10cm steps, [2,12] m
- **Offset:** 10cm steps, [-5,5] m

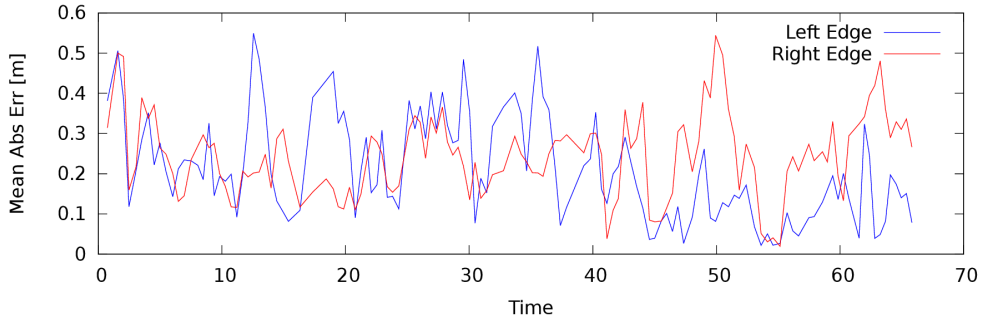
Qualitative Evaluation

- Online testing in different vehicles: Volvo Truck, Ford and Fiat
- Part of the *interactIVe* (EU project) perception platform
- Running in parallel with other perception modules

Quantitative Evaluation







- Manual labeling of reference data
- Reference points up to 30m in front of the vehicle
- Mean error: $\mu = 22cm$

Future Tasks

- Improved confidence estimation
- Feature weighting
- Comprise guideposts
- Separate models for the left and the right road edge
- Improved integration of the map service
- Urban scenarios

Thank you.

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SEVENTH FRAMEWORK PROGRAMME