Driver Monitoring: A Deep Learning Approach for Gaze Estimation

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The KOSTAL Group

1912: Foundation of parent company Leopold KOSTAL in Lüdenscheid
1973: Start of activities in first plant abroad (Mexico)
1978: Production of first automobile electronics
1987: Start of mechatronics (first sensor systems)
2013: Start of power electronics for electro mobility
2016: Revenues: 2.366 bn €
       Employees: 17 075 (79% abroad)
       Subsidiaries in 21 countries on 4 continents

Business areas

KOSTAL Automotive Electrical Systems
- Mechatronic modules
- Electronic control units
- Switch panels/switches

KOSTAL Industries
- Connectors
- Industrial Electronics
- SOMA Test Systems

The KOSTAL Group is acting globally as a successful family-owned company.
KOSTAL Automotive Electrical Systems: Business fields

- KOSTAL Automotive Electrical Systems develops and manufactures all over the globe integrated mechatronic solutions based on three business fields.

Switch Panels / Switches

Electronic Control Units

Mechatronic Modules

Misc.

34% 49% 17%

Source: AVP, ACT prelim 2016
Deep Learning Activities

- **Pupil Detection**
- **Age & Gender Estimation**
  - Female: 47
  - Male: 25
- **Gaze Estimation**
- **In-Cabin Monitoring**
- **Lip Reading**

Gender: Female  
Age: 47  
Gender: Male  
Age: 25
Market Drivers for Driver Monitoring Cameras (DMC)

"Eyes on Road!" - Driver Awareness Monitoring SAE Level 2

Driver Drowsiness Recognition
- Sleepiness Scale / Microsleep / Sleep

HMI Control via Eye Gaze

3D Displays / AR HUD via Eye Position

Driver Availability Detection for SAE Level 3/4

Smart Airbag
- Occupant position detection

Driver Drowsiness Recognition
- Take-Over- Time Adaption

Micro Gesture Detection

Driver Identification / Personalization

CE Business Models
- Video chat, Emotional Analytics, ...

KOSTAL Driver Monitoring Cameras

DMC mandatory

DMC supportive

Add On Business Models

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Imaging Technologies for In-Cabin Camera @ KOSTAL

**Hardware building blocks**

- **Illumination**
  - LED
  - VCSEL

- **Imager**
  - Time-of-Flight
  - 2D high res.

- **Mainboard for Computer Vision**

- **Debug Hardware**

- **Video Links**
  - LVDS
  - Ethernet

**Derived configurations**

- **“OneBox” Cameras**
  - 2D high resolution
  - 3D Time-of-Flight

- **Separate Camera Head**
  - ECU (with Debug Hardware)
  - Single Camera Head
  - Single Illumination

Camera Head with integrated Illumination
Implemented Functions

- Head Pose
  - Attention Awareness
  - AR-HUDs
  - 3D-Displays
  - Smart Airbag

- Eye Lid Closure (PERCLOS)
  - Drowsiness
  - Micro Sleep Detection

- Driver Identification
  - Personalization
  - Driver Change Detection

- Speech Activity Detection
  - Beamforming
  - Authorization

- Eye Gaze
  - Attention Awareness
  - AD „Eyes on Road“
  - HMI
Data Acquisition Lab and Car

Lab Setup
- Moving Target used as Ground Truth
- Projector Calibrated to Cameras

Car Setup
- Multi Camera Setup

Moving Target
Projector Calibrated to Cameras
Multi Camera Setup
Data Labeling with AMT: Pupil DNN Example

- 300k Labels produced with Amazon Mechanical Turk
  - Problems:
    - Label accuracy approx. 2 pixel
    - Complete outlier
    - Sometimes glint is labeled instead of pupil

DNN Results
Video Annotation

- Annotation of ground truth information to the video data
- KOSTAL internal and external labelling resources

KOSTAL team:
- 1 Team Leader
- 3 persons for DM labelling

typical team setup @ external service partner
- Team size 25-30 persons
- 1 to 2 Team Leader
- 1 Quality Responsible

Video data annotation @ external service partner
Eye Gaze with Corneal Reflection

Reflections

Dark Pupil

Bright Pupil

Eye model

LED

Offset

Gaze α

Cam β

Camera

Separation in Image

Eye model

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End-to-End Learning

Right Eye

Conv
ReLU
Max Pool

Conv
ReLU
Max Pool

... Gaze in Head Coordinates

Left Eye

Conv
ReLU
Max Pool

Conv
ReLU
Max Pool

Conv
ReLU
Max Pool

...
Video Eye Gaze with End-to-End Learning
End-to-End Learning

Right Eye

Left Eye

Head Orientation (input)

Gaze in Camera Coordinates

User Selection

User Specific Parameters

Automatically learned

Estimated online

User 1
User 2
User 3
User 4
User n-2
User n-1
User n
Development Cycle

Images / Reference Data

Record Data

Design DNN

Convert

Train

Evaluate Model

Caffe

Optimize Execution Time

NVIDIA TensorRT

Deploy

Deploy

Embedded Hardware

Performance

High

Low

Grid Search Parameters

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Driver Monitoring Demonstration Vehicle in Germany

Equipped with two cameras: Combidisplay and Head Unit Display

Display of detection results

3D-Display of head pose and gaze direction
Video of Driving Situation

AUTOMOBIL ELEKTRIK - Developer View

Head Position

Amplitude Image

Eyelid Closure

PERCLOS

ATTENTION ON STREET

Results
- Horizontal Angle [°]: 13
- Vertical Angle [°]: 10
- Nasion Point [mm]: 45
- Exposure Time [μs]: 1981
- Gain Status: AG 1, DG 1

Mouth Open Level

Speech Detection

Recording Name
- Start Recording
- Stop Recording

Recognized Driver

Eyes

Histogram

Keyboard Shortcuts:
- Escape: Cancel program
- Enter: Open current visualization
- F4: Show keyboard shortcuts

Connect

Default Settings

Restart

Close

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