Interior Camera - A solution to Driver Monitoring

Status
Driver Monitoring in the Context of Automated Driving
Ensure Smooth Transition Phases

Current status
Camera is able to monitor whether the driver is
- present
- awake (eyes open)
- attentive (eyes on road)

Transition Phase
Need to know whether the driver is
- present
- ready to take over (awake & ready)
- really taking over (within given timeframe, avoid misuse)

One key factor in take-over scenarios is
Driver Availability Recognition

Drives are attentive when their eyes are on the road

To know if a driver has the eyes on the road, it is crucial to monitor the eyes

Eye gaze can only be monitored with a visual system

Interior Camera is suitable for Driver Monitoring
Driver Monitoring via Interior Camera
Head-Eye-Tracking System

Head-Eye-Tracker (based on visual features)

- Global Shutter Camera
- IR Illumination (850 nm or 940 nm)
- Potential Mounting Positions:
  - First SOP: February 2018
  - More SOPs: 2019, 2020 and 2021

The Interior Camera can look through ‘normal’ glasses and through sunglasses¹
(also deals with e.g. face masks, beard)

¹Exception: IR blocking sunglasses

Occlusions are handled dynamically

Stand-alone: Steering Column, Center Display Area
Integrated: Full Digital/Instrument Cluster, Center Display

Eye gaze
Eye lid movement

Head pose/orientation based on landmarks:
- eyes
- nose ridge (important)
- lower nose
- face contour
- eye brows
- mouth/lips

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Driver Monitoring via Interior Camera
Current Use Cases (Examples)

### Driver Drowsiness Detection

#### Diagnostic from **Eye Lid Behavior**

- Developed from real driving tests using EEG/EOG expertise

  - Eye lid open
  - Eye lid closed

  → based on blink duration and velocity

- E.g. 4 levels derived from Karolinska Sleepiness Scale (KSS)

#### Driver Attentiveness Detection

**“On-road” gaze classification**

→ Fusion of head pose and eye gaze:
  “Virtual window” defined for on-road

- Glance duration (eye gaze being off-road) and frequency
- Gaze area (e.g., mirrors, cluster)
- Vehicle speed (influences classification sensitivity)

### Event Detection

- **Detection if the eyes are open, closed, or partially open/closed:**
  - Percentage of Closure (PerClos)\(^1\)

\(^1\) Knippling, R. and P. Rau (1998) PERCLOS: A valid Psychological Measure of Alertness as Assessed by Psychomotor Vigilance
Driver Monitoring via Interior Camera
Robustness and Safety Functionality

• **Fail Safe** Functions: Camera blockage, fake detection

• **Online Extrinsic Calibration**
  – Misalignment calibration of the camera pose w. r. t. the car coordinate system
  – Robust against environmental light and occlusions

• **Algorithms** Performance
  – Test Data base:
    • Variety of faces and attributes to faces (e.g. hairstyle, glasses)
    • Illumination
    • Driving data sequences
    • Ground Truth¹ data
  – Ground Truth and Reference System

¹Ground Truth = Reference system
## Driver Monitoring via Interior Camera
### System Capabilities & Limitations

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Specification</th>
<th>Capabilities</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver Presence</td>
<td>Yes/No</td>
<td>✓ detects head and/or body</td>
<td>Must be within sensor range</td>
</tr>
<tr>
<td>Driver Readiness</td>
<td>Attentive</td>
<td>✓ eye gaze, head pose (position/orientation)</td>
<td>Must be within sensor range; Reduced reliability if eyes are not visible to the camera</td>
</tr>
<tr>
<td>Awake (drowsiness)</td>
<td></td>
<td>✓ multiple levels</td>
<td>Must be within sensor range; Reduced reliability if eyes are not visible to the camera</td>
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<tr>
<td></td>
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<td>→ direct detection of closed eyes; high correlation of drowsiness detection</td>
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<td></td>
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<td>via eye opening, behavior: yawning, speaking, head movement</td>
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Possible Future Testing Concepts
Combination of Basic and Virtual Testing

A. Normed dummy (incl. eye blinking, head movements)
   – Defined test scenario for basic functionality of Driver Presence and Driver Readiness
     (attentive, awake)
   – Physical test (spot sample), e.g. detect eye lid behavior (open/closed), body/ head rotation

B. Virtual/ simulated tests
   – Cover variations for different people, situations, driving
     scenarios, etc.
   – Verification of the function

Other hairstyle, glasses