Camera-based Active Real-Time Driver Monitoring Systems

A Practical Next Step in Vehicle Safety including SAE Level 2+ Semi-/Conditional-Automated Vehicles

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Automotive Problem Statement

• Driver Drowsiness and Driver Distraction has surfaced as a major safety issue worldwide

• Trend looks to continue in SAE Level 2+ Partial and Conditional Automated Vehicles
  • Drivers become less engaged in the dynamic driving task
  • Sudden unexpected hand-off of dynamic driving task from the automated driving system back to the human driver and the driver’s ability to immediately assume control (safe transition)
  • Issues with driver misconception on vehicle automated driving capabilities (e.g. – using a Level 2 system as a Level 3+ system)
Facts and Figures

- **1.25M**: People killed worldwide annually in road accidents - WHO
- **95%**: Of fatal vehicle accidents caused by human error - NHTSA
- **40%**: Of all US trucking accidents caused by operator fatigue – NHTSA
- **9.5%**: Of all US car accidents are caused by drowsiness - AAA SHRP 2 NDS
- **15%**: Of all US injury crashes involve distraction - NHTSA
- **7%**: Of US drivers involved in fatal crashes were distracted - NHTSA
- **11**: US Teens die each day from Texting & Driving - US CDC
- **30%**: Total car driver time spent on distracting activities while driving - European RSO
Driver Monitoring – Automotive Regulatory & Rating Environment (1/2)

Drowsy and Distracted Driving in focus
• Both Manual (Human Driver) and Automated Driving

Recent Examples:
• Euro NCAP Roadmap 2025
  • Driver Monitoring as primary safety systems starting in 2020 (likely required for 4/5 star)
  • Targets elimination of accidents associated with driver Distraction and Drowsiness
• NTSB Recommendation
  • Prompted by fatal AutoPilot Crash
  • Driver Monitoring to assure appropriate driver engagement on all Level 2+ vehicles
Driver Monitoring – Automotive Regulatory & Rating Environment (2/2)

- European Commission SWD (2018) 190 Final - Proposal for Regulations

Actions to be considered: Mandatory application of drowsiness and attention detection and mandatory application of drowsiness (including distraction) recognition

- Uber Arizona Accident Fallout

Addition of Camera-based Active Back-up Driver Monitoring Systems to monitor safety drivers in SAE Level 2+ Test Vehicles? Use DMS to TRAIN drivers to remain attentive to the driving task.
Types of Driver Monitoring Systems

• Inferred Passive DMS
  • Steering (torque), braking, capacitive (touch for steering wheels) or front camera LDWS data inputs utilized to “infer” that the driver is either drowsy or distracted
  • Mostly time-based and no direct view of the driver leads to inaccurate triggering of warnings (or no warnings)

• Camera-based Active DMS
  • Utilizing real-time video data of the driver’s face to actively measure driver attention, engagement and impairment levels
  • Track head position, head pose, face direction, eyelid closure and eye gaze direction
Camera-based Active Driver Monitoring for Passenger Vehicles – The Why

Connected Car
- Car Awareness of the Driver (missing V2X link)

ADAS => Autonomous
- Address existing ADAS handicaps (false alarms, co-pilot)
- Match driver attentiveness to AD capability (Levels 2-4)

Comfort & Convenience (AD Level 1-5)
- Advanced Displays (Driver Info/Comfort/Safety)
- Advanced Driver/Occupant State (e.g. Health/Wellness)
Camera-based Active Driver Monitoring for Passenger Vehicles – The What & How

• Real-time tracking / analysis of Head Pose, Eyelids, Face, Eyes, Pupils
• Intelligent Computer Vision interprets and translates into understanding of the driver (e.g. Attention, Engagement, Impairment)
• Practical implementations must be cost effective and highly available/reliable
  • Embedded Vision Processor (2-3 Watts)
  • NIR Sensors (specific perf requirements)
  • Direct sunlight to complete darkness
  • Sunglasses, scarves, face masks, steering wheel, etc.
  • Human population (Gender, age, ethnicity, race)

Technical Achievement:
Track Pupil Contour @ 1.8mm dia., locate IR reflection on cornea <0.25mm, at 1.5m range, within few degrees accuracy, with no user calibration. (17 years work)
State of the Art – In Vehicle, Real World, Head/Eye Tracking

- Extreme Angles
- Sunglasses
- Hats
- Occlusions
- Rapid Acquisition
- No dependence on head tracking

Attention Region
Configured to vehicle geometry (CAD) including “driver lap” to capture glances to mobile phones for email or texting.

Attention Visualization
Driver attention, head pose & eye gaze direction visualized with 3D vehicle geometry in real-time.

Solid optical path and high availability of signals allows for development up the stack:
- Driver Drowsiness Level
- Driver Engagement Level
- Driver Impairment Level
- Driver ID
Camera-based Active Driver Monitoring for Passenger Vehicles — Important Outputs

- **Driver Attention State & Engagement Level (DAS, DEL)**
  - Eyes on/off road, Eyes open/closed (Basic)
  - Attentive, Distracted, Inattentive, Disengaged (Advanced)
  - AD Levels 0-4

- **Driver Impairment Level (DIL)**
  - Alert, Drowsy, Microsleeping, Sleeping, Incapacitated
  - AD Levels 0-4

- **Comfort & Convenience**
  - Driver Viewpoint for 3D display and AR HUD
  - Driver ID for convenience, security, Enhanced DEL/DIL
  - AD Levels 0-5
Importance of Human Factors Research in DMS Technology

• Utilizing video of the ultimate analog signal - the human face – and applying analytics to output digital signals that vehicle systems can understand
  • Understanding of driver psychology and physiology required
  • Deep Learning / Neural Networks alone cannot solve this problem

• Linking sensing technology to real world risk
  • What should the system do and what are the identified risks?
  • How should the system do it?
  • Communication (how humans interact with technology)
  • Prove it (ground-truthing and development of metrics)

SAE Level 2+ example: Unexpected sudden take-over request versus Driver Engagement Level
Importance of Human Factors Research in DMS Technology

• Capturing data from drowsy or distracted drivers takes time
  • A key challenge is capturing data at the time drivers are drowsy or distracted – can be inherently dangerous
  • Concurrent need to capture complementary data streams in lead-up to drowsiness events for event prediction

• Must utilize mixed-method approach to collect extensive data using DMS and other sensing

• Must validate (ground-truth) and develop metrics
  • Including physiological sensing suites such as EEG, ECG, etc.
Types of Human Factors Research in DMS Technology

• Simulator studies to induce and observe extreme levels of drowsiness and impairment (with university partners)

• Test track studies with human factors instrumented vehicle to observe time course and impact of drowsiness in real-world conditions
  • Subjects kept awake 30+ hours and then drive test track for 2.5 hours (with safety driver)

• Naturalistic on-road study with shift workers with human factors instrumented vehicles

• Naturalistic on-road studies with car and truck drivers
Other Human Factors Data Inputs and SAE L2+ Driver Research

• Video and analytics data from Fleet (20K+ long haul trucks and buses)
  • Study of corner cases for improvement of algorithms (e.g.-driver sleeping with eyes open)

• World’s first automotive research study focused on semi-automated cars:
  • Behavior of drivers behind the wheel of automated vehicles
  • How they react when they need to re-take the wheel
Real World Data – Driver Monitoring Effectiveness Study

Retrospective analysis of de-identified real-time driver fatigue event data
• Commercial Fleet – Australia (short, medium, long-haul freight company Australia)
• Data collection period – 2011 to 2015
  • 342 vehicles over 1.1M operational hours and 45.9M miles

Real World Data - Reduction of Fatigue Events Study*

Significant reduction in the duration of fatigue events from baseline (%,
distance, time) & fewer trips with multiple events.

Significant reduction in the incidence\(^1\) of fatigue events, adjusted for hours and
distance travelled.

Baseline (silent) 3.7% (of 4539 trips)

Driver alarm 1.3% (of 161,541 trips)

Alarm + Feedback 0.18% (of 530,075 trips)

Baseline (silent)

Driver alarm 66.2% ↓

Driver alarm + Feedback 94.4% ↓


\(^1\) Incidence rates and differences determined using a random-effects negative binomial regression (with beta effect) controlling for trip distance / hours, and repeated trips undertaken by each truck (using truck identifier); reductions p<0.001.
Real World Data – Seeing Machines Guardian Fleet

Camera-based real-time driver fatigue and distraction detection and intervention PROVEN to positively change outcomes in Fleets

-90%

>:90% Reduction in fatigue events
>:80% Reduction in cell phone use
>: 4M events detected ; : 40K interventions

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Conclusions

• Driver Monitoring for fatigue and distraction has become a major focus of automotive safety regulators and governments worldwide

• Camera-based real time Active Driver Monitoring Systems is the only way to directly track driver drowsiness and distraction

• Human Factors research into psychology and physiology is an important requirement to building driver monitoring systems that can bridge the divide between human drivers and vehicle systems

• Real-world driving data is proving out that camera-based DMS can change driver behaviors with respect to driving impaired (drowsy, etc.) and distracted driving (cell phone use and texting)

• Camera-based DMS in SAE L2+ systems will help the vehicle systems to understand if the driver is prepared to take over control of the dynamic driving task through direct monitoring and analysis of driver activity and attention state