Driver Monitoring Systems: Present and Future

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CTO, Products
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XPERI Company Overview

40+ OFFICES WORLDWIDE
headquarters in San Jose, CA

1.5B$+ MARKET CAP
public company, trading under XPER

2000+ EMPLOYEES
1200+ engineers

10000+ PATENT ASSETS
strong focus on innovation

100B+ DEVICES WORLDWIDE
DTS, HD Radio, Invensas or TiVO
Driver Monitoring System
DMS Designed for ...

**DRIVER SAFETY**

- 100K fatigue accidents
- 5000 fatigue and distraction deaths
- 12.5B losses due to fatigue driving
- 1 in 5 crashes are caused by distractions

**SEMI-AUTONOMOUS DRIVING**

Understand the *driver state* before giving back control

**COMFORT & PERSONALIZATION**

Identify the *driver* and tailor comfort settings such as seat position and entertainment content

US figures, sources: ¹GHSA Drowsy Driving Report – Aug, 2016 ²³ NHTSA.gov ⁴Drivers.com
DMS Workflow

DMS Camera

> Adjust Parameters

NIR ISP

> Env. Analytics

Solution Reliability

DMS Core

> Face ROI
3D position
3D rotation

Eye Add-on

> Eye Gaze
Eye lid opening

DMS 1.x – hybrid tech (template matching + NN)

DMS 2.x – fully neural networks based

Attentiveness Add-on

> Attentiveness status

Drowsiness Add-on

> Drowsiness status

Classification Add-on

> Expression state

Biometrics Add-on

> Person identification

Status Add-on

> Driver state & gestures (DMS 2.x only)

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| **Features** | Competitive core functionality (driver presence, head pose, head location, eye lid & eye gaze monitoring) in wide range of head angles and face occlusions |
| **Platform requirements** | Operates on very light platforms (2.5GMAC or equivalent) such as iMX6, R-Car E2 or TI TDA 3X |
| **Camera support** | 850nm NIR  
VGA to FHD resolution  
Down to 35mm sensor to LED distance |
| **Timeline** | Production ready & already shipping. |
## DMS Product

<table>
<thead>
<tr>
<th>DMS 1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timeline</strong></td>
</tr>
</tbody>
</table>
| **Features** | Enhanced core performance (occlusion reliability, gaze stability)  
new driver analysis engines (biometrics, expressions, objects, occlusions)  
middle layer logic (attentiveness & drowsiness) |
| **Platform requirements** | Operates with light platform requirements (around 8 GMAC or equivalent) such as iMX8, R-Car E3/M3, QCM 8155 or TDA 2, 3X |
| **Camera support** | 850nm/940nm NIR  
VGA to FHD resolution  
Down to 18mm sensor to LED distance |
## DMS Product

### DMS 2.0

<table>
<thead>
<tr>
<th><strong>Timeline</strong></th>
<th>Research ready, proven algorithms by OEMs. Production target: Q1 2021</th>
</tr>
</thead>
</table>
| **Features** | High precision gaze  
Improved user behavior analysis (attentiveness, drowsiness, activity detection).  
Environmental analytics (camera blockage)  
Can integrate with other OMS features. |
| **Platform requirements** | Operates for mid/high end platforms (around 60 GMAC or equivalent) such as R-Car M3/H3, NVidia or TDA 4X |
| **Camera support** | NIR and RGBIR  
New camera position  
Multiple sensor support (dual camera, depth) |
DMS Transition to Occupancy Monitoring & Personalized Experience

- Continuous health & safety monitoring
- Personalized experience
- Authentication
- Human machine interface
- Social and work interaction
- Next Gen Entertainment

Human Driver Monitors Driving Environment

Automated Driving System Monitors Driving Environment
Occupancy Monitoring System
OMS Designed for ...

**OCCUPANTS SAFETY**

<table>
<thead>
<tr>
<th>37,133</th>
<th>47%</th>
<th>14,955</th>
<th>2,549</th>
</tr>
</thead>
<tbody>
<tr>
<td>lost lives in accidents¹</td>
<td>wore no seat belt¹</td>
<td>estimated saved lives by seat belt²</td>
<td>lives could have been saved³</td>
</tr>
</tbody>
</table>

**CONTINUOUS MONITORING FOR HMI AND HEALTH**

Understand **where** and **what** occupants do at any moment in time

**BETER EXPERIENCE**

Identify **who** the occupants are and tailor comfort settings such as seat position and entertainment content

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¹NHTSA. https://www.nhtsa.gov/risky-driving/seat-belts

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OMS Workflow

OMS Camera (RGB) (160-220 degree FOV)

NIR ISP & DCE & LTM

Env. Analytics

OMS Reliability

Face Detection

Body Detection

Hand Detection

Face ROI

Body ROI

Hand ROI

Face Direction & Position

Continuous Driver ID

Face Feature Points

Emotions & Face Classification

Body Pose

Hand Skeleton

Direction

Identification

Face Features

Emotions, Gender Ethnicity, Age

Body Points

Finger Points

Adjust Parameters

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## OMS Product

<table>
<thead>
<tr>
<th><strong>OMS 1.x</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target &amp; timeline</strong></td>
<td>light requirements OMS system, research ready, implementation ongoing. Production target: Q2 2021</td>
</tr>
</tbody>
</table>
| **Features** | Occupancy detection:  
• People/faces  
• Child seats  
• Pets  
• Unknown objects  

Passengers identification  
Passengers classification:  
• Emotions / expression  
• Age / gender classification |
| **Platform Requirements** | Operates on platforms with limited resource availability, Intel or ARM CPUs (around 6 GMAC) |
| **Camera Support** | Single NIR, RGB or RGBIR camera |
# OMS Product

## OMS 2.x

<table>
<thead>
<tr>
<th>Target &amp; timeline</th>
<th>Advanced OMS-DMS, research ready, proven algorithms by OEMs. Production target: Q2 2022</th>
</tr>
</thead>
</table>
| **Features**      | **Enhanced occupancy:**  \* Body detection \* Seatbelt detection \* Body Size: Baby, Child, AF05, AM50, AM95 \* Generic object detection \* Environment analytics / camera blockage  
UX: \* Hand & gesture detection - front passengers \* Video enhancement (distortion correction, Selfie enhancements, LTM) \* Iris recognition (payments)  
Can integrate xperi DMS 2.0. |
| **Platform Requirements** | Targeted to operate on mid/high end platforms (100 GMAC or equivalent) such as NXP, R-Car, QCM, Nvidia, TDA 4x. |
| **Camera Support** | Single or Dual NIR, RGB or RGBIR Camera |

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### Target & timeline
high performance system (UX and Safety), research ongoing. Production target: Q2 2023

### Features

**Enhanced occupancy:**
- High precision body shape and body pose for safety
- Improved behavior analysis (attentiveness, drowsiness, activities, emotions state, impairment).
- Medical biometrics (vital signs, pulse, breathing)
- Enhanced object classification

**Enhanced UX**
- Precise gaze and hand gestures

Can integrate xperi DMS 2.x

### Platform Requirements
Targeted for mid/high end platforms (computational requirements TBD)

### Camera Support
- Single or Dual NIR Camera or RGBIR camera
- FIR camera, Time event camera
- Audio Support
DMS/OMS Implementation Agnostic to System

Tier 1 / OEM Integrations

- Stand alone DMS unit implementations
- Cluster integrated DMS implementations
- Head unit OMS implementation
- Stand alone DMS implementation
- To be announced

Available Platform Ports

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### DMS/OMS Implementation Agnostic to Camera Placement & Design

Camera placement color legend: Blue: Supported / Purple: Roadmap

**SENSOR**
- VGA to FHD, RGBIR or NIR

**OPTICS**
- DMS: 50–60 HFoV
- OMS: 160 – 220 HFoV

**SPECTRUM**
- Visible
- 850nm NIR
- 940nm NIR

**SENSOR TO LED CONFIGURATION**
- Single location
  - (down to 1.8cm minimum distance)
- Different locations

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<table>
<thead>
<tr>
<th>Camera Location</th>
<th>Sensor Technology</th>
<th>Optics</th>
<th>Spectrum</th>
<th>Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Pillar</td>
<td></td>
<td></td>
<td></td>
<td>Single location (down to 1.8cm minimum distance)</td>
</tr>
<tr>
<td>Steering Wheel</td>
<td></td>
<td></td>
<td></td>
<td>Different locations</td>
</tr>
<tr>
<td>Dashboard</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rear View Mirror</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instrument Panel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In Cabin Monitoring Future
XPERI In Cabin Long Term Vision

<table>
<thead>
<tr>
<th>NO AUTOMATION</th>
<th>HANDS ON</th>
<th>HANDS OFF</th>
<th>EYES OFF</th>
<th>MIND OFF</th>
<th>FULL AUTOMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ DMS for DROWSINESS OR INATTENTION</td>
<td>✓</td>
<td>✓ DMS FOR SEMI-AUTO DRIVING</td>
<td>✓ DTS CONNECTED RADIO</td>
<td>✓ IN CABIN MONITORING FOR SAFETY AND PERSONALIZED EXPERIENCE</td>
<td></td>
</tr>
<tr>
<td>✓ HD-RADIO</td>
<td></td>
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</tr>
</tbody>
</table>

**CONNECTED RADIO**

**HD RADIO**

**IMAX ENHANCED**

**WE BELIEVE THAT**

**ALL THE VEHICLES OF TOMORROW WILL HAVE IN-CABIN SENSING, IMAGING AND PERSONALIZED ENTERTAINMENT AT THEIR CORE**

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What is ICM (In-Cabin Monitoring)?

DMS

ICM

SKIN HEALTH
BEAUTY
HDR & LTM

OCCLUSIONS
OCCLUSIONS

GAZE
GAZE

EYE ANALYTICS

IRIS ID
FACE ID
FACE ID
FACE CLASSIF
FACE CLASSIF

EXPRESSIONS
EXPRESSIONS

OBJ DET
OBJ DET

BIOMETRICS

HEAD POSE
HEAD POSE

ACTIVITY
ACTIVITY

FACE ID
FACE ID
FACE CLASSIF
FACE CLASSIF

MICROGESTURES

GESTURES

PRESENCE
PRESENCE

BODY SIZE
BODY SIZE

BODY CLASSIF
BODY CLASSIF

ENVIRONMENT

BACKGROUND

MICROGESTURES

GESTURES

PRESENCE
PRESENCE

BODY SIZE
BODY SIZE

BODY CLASSIF
BODY CLASSIF

ENVIRONMENT

BACKGROUND

MICROGESTURES

GESTURES

PRESENCE
PRESENCE

BODY SIZE
BODY SIZE

BODY CLASSIF
BODY CLASSIF

ENVIRONMENT

BACKGROUND

MICROGESTURES

GESTURES

PRESENCE
PRESENCE

BODY SIZE
BODY SIZE

BODY CLASSIF

RGB & NIR

BREATHING

THERMAL

RGB

NIR

THERMAL+NIR

EVT
ICM & Experience Questions

**MONITORING FEATURES**
- PD, HP, Gaze (what precision)? Identity (how strong)? Fatigue (how many levels?), Biometrics (what type)? Health monitoring (what)?

**SOUND SYSTEM**
- How many speakers? What configuration? What types?

**EXPERIENCE FEATURES**
- HMI, Video conferencing, Beautification, Background replacement, personalized sweet spot sound;

**PROCESSING**
- Centralized vs Decentralized? TOPS? Memory? ISPs?

**IMAGING SYSTEM**
- Movies (back seat or main windshield), active noise cancellation,

**SAFETY**
- ASIL Levels? Redundancy? For which systems/features?

**SENSOR FUSION**
- What sensors? How to fuse? What for?
Total Flexibility is Required ...

... in cabin monitoring and personalized experience use-cases are diverse

... needed to be powered by ultimate flexible platform with built in domain expertise (XPERI with partners)
In Cabin Monitoring Enabling Technology & Infrastructure
Enabling Technologies

MULTI-SPECTRAL SENSING
Visible + NIR + LWIR Analytics

DEPTH SENSING
Neural network based stereo depth engine

IMAGE ENHANCEMENT
EIS with RS correction, LTM, portrait enhancement, De-fogger and de-warping

TIME EVENT
Analytics based on time event sensors to capture information never seen before

BIOMETRICS
Production ready biometrics all the way from 2D FR on visible or NIR, 3D-FR with iTOF/SL/Stereo to IRIS recognition

Dual Camera Sensing
WFOV RGB-IR + AF PT NFOV NIR tightly connected to provide better features for ICM (DMS + OMS)
Computer Vision Infrastructure

Acquisition – 3D Images

Setup (visible «& NIR») | Photogrammetry | 3D Model

Mesh
Texture (vis)
Texture (nfr)

Generating Marked 2D Renders

Marked 2D Samples

Auto-marking 3D Model

CUSTOM BACKGROUNDS

3D ACCESSORIES

CUSTOM LIGHTING

Rendering (lens/sensor/ISP model)

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Test Framework (a.k.a. Image DB)

Image Acquisition
- Collect Images
  - Select from ImageDB
  - Photo-shoot
- Import Images
- Organize Images

Image Marking
- Mark features in Images
- Feature Hierarchy
  - Face->Eye (max=2)
- Various Geometries
  - Rectangle, Ellipse, Polygon, Point
- Features Attributes
  - Face=gender=male

Test Implemented
- Create / Edit / Save Tests
- Test Input
  - Image set
  - Parameters
- Implement Test Code
- Create Test-Suites

Testing and Reporting
- Test Run produces Result Data
- Test Results History
- Compare Test Results
- Create Reports

ImageDB Size

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In-car driving scenarios strong value comes from ensuring ground truth data is available.
More Testing and Acquisition Infrastructure
Conclusions & Resources
In Cabin Monitoring & Personalized Experience

Image (Pre)Processing
On the fly input signal processing for optimum analytics

Analytics, Enhancement & Strong Biometrics
Core research for facial, people analytics, recognition, scene understanding and enhancement

IP Cores
Dedicated IP Cores for Extreme Performance and PCNNs for Flexibility

DBI® – Direct Bond Interconnect
3D ASIC Enabler for Distributed and Hybrid Processing

Automotive Proven
Shipping DMS, HD Radio & Connected radio technologies

CV & Test R&D Infrastructure
Computer generation and real images ground truth data-sets for effective NN training, testing and validation

Sound & Video Rendering
DTS & IMAX ENHANXED for ultimate living room experience on wheels

System level packaging
Enables high performance, high-integration low cost intelligent camera modules & sensors
Resources

NCAP
https://www.euroncap.com/en

JSA
https://www.jsa.or.jp/en/

NHTSA
https://www.nhtsa.gov/

2020 Embedded Vision Summit

“Driver Monitoring Systems: Present and Future”

Thursday, September 17, 2020 from 12:00 PM – 12:30 PM PT
Thank you!