Welcome!

Unlocking Level 3 Driving Automation Using Image Sensors: A Review of Automotive Corner Cases for Level 3+ autonomous driving

Presenter

Sergey Velichko
Sr. Manager,
Automotive Sensing Technology & Product Strategy
onsemi

BROUGHT TO YOU BY:

onsemi

ElectronicDesign

Unlocking Level 3 Driving Automation Using Image Sensors

Meeting Euro NCAP and NHTSA Requirements

Sergey Velichko

Automotive Sensing Division

September 12, 2024

onsemi

Agenda

- Introduction
- Automotive Objects: Vulnerable Road Users & Others
- Automotive Surround Sensing Scenarios Meeting Euro NCAP & NHTSA Requirements
- Object Detection Criteria: Ideal Observer SNR (SNRI)
- Detection of Various Objects
- Long Range & Ultra HDR Capabilities
- Conclusions

Final Automatic Emergency Braking Ruling

NHTSA

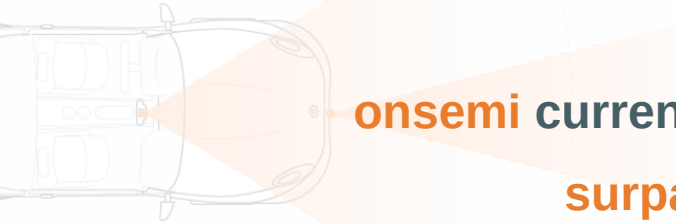
Starting 2029

All car systems **must apply brakes automatically**

145 km/h [90 mi/h]
with a **lead vehicle**

72 km/h [45 mi/h]
when a **pedestrian** is detected

Detect **pedestrians** in **both daylight and darkness**



onsemi current and future automotive image sensors

surpass NHTSA AEB requirements

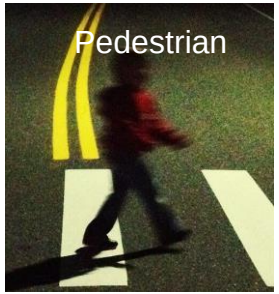
*NHTSA's AEB ruling link: https://www.nhtsa.gov/press-releases/nhtsa-fmvss-127-automatic-emergency-braking-reduce-crashes

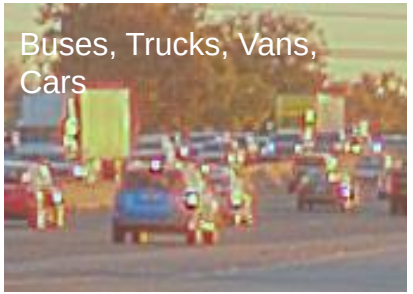
onsemi

Automotive Objects: Vulnerable Road Users (VRUs) & Others

Size	Pedestrian	Child	Bicyclist	Motorcyclist	Car	Tire	Brick	Curb
Width (m)	0.5	0.298	1.89	~2.0	~1.8	0.5	0.15	---
Height (m)	1.8	1.154	1.865	~1.8	~1.5	0.15	0.15	0.15

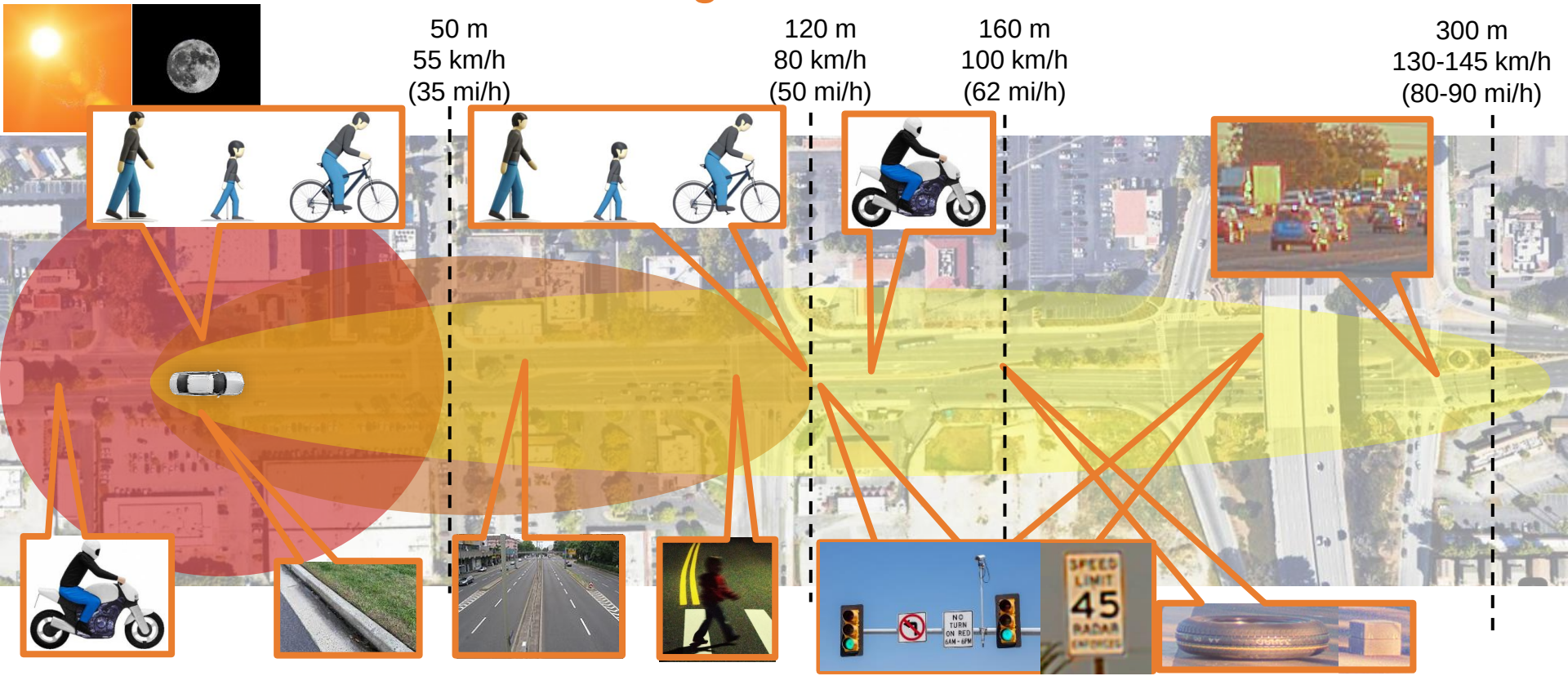
ISO 19206 Euro NCAP/ACEA and NHTSA VRUs [1, 2], cars, and most dangerous smaller objects





- Camera is the only source of shape and color information for automotive objects
- VRUs require special attention, smaller objects are most difficult for reliable detection

Automotive Surround Sensing Scenarios



- Euro NCAP and NHTSA requirements stipulate reliable recognition at maximum speeds, day and night
- AEB requires detection at 150-160 m and beyond with 130-145 kph speeds

Object Detection Criteria: Ideal Observer SNR (SNRI)[3, 4]

$$SNRI^2 = \int\int \left(\frac{MTF^2(\nu_x, \nu_y) \cdot \mu^2}{NPS(\nu_x, \nu_y)} \right) \Delta S^2(\nu_x, \nu_y)\, d\nu_x\, d\nu_y.$$

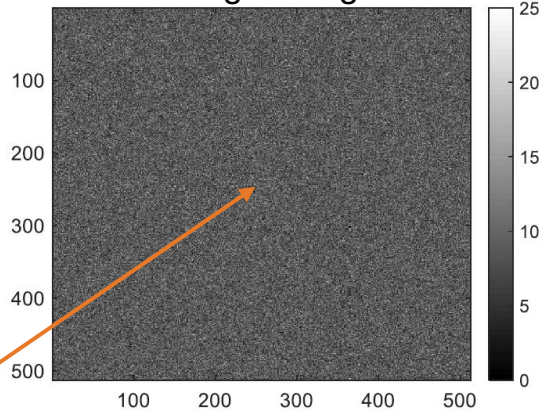
- ***MTF*** is the Modulation Transfer Function
- ***NPS*** is the Noise Power Spectrum
- μ is the mean linear signal
- ΔS is the Fourier Transform of the *difference* object (H1-H2) for the given task
- SNRI is equivalent to a template match in the spatial domain

No blur, flat NPS,
simple shape objects

$$SNRI \approx C \cdot SNR \cdot \sqrt{A}$$

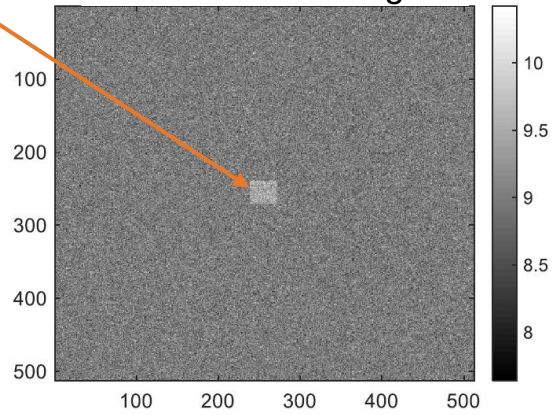
- ***C*** is the object contrast
- ***SNR*** is the signal-to-noise ratio on object
- ***A*** is the object area in pixels

Single image



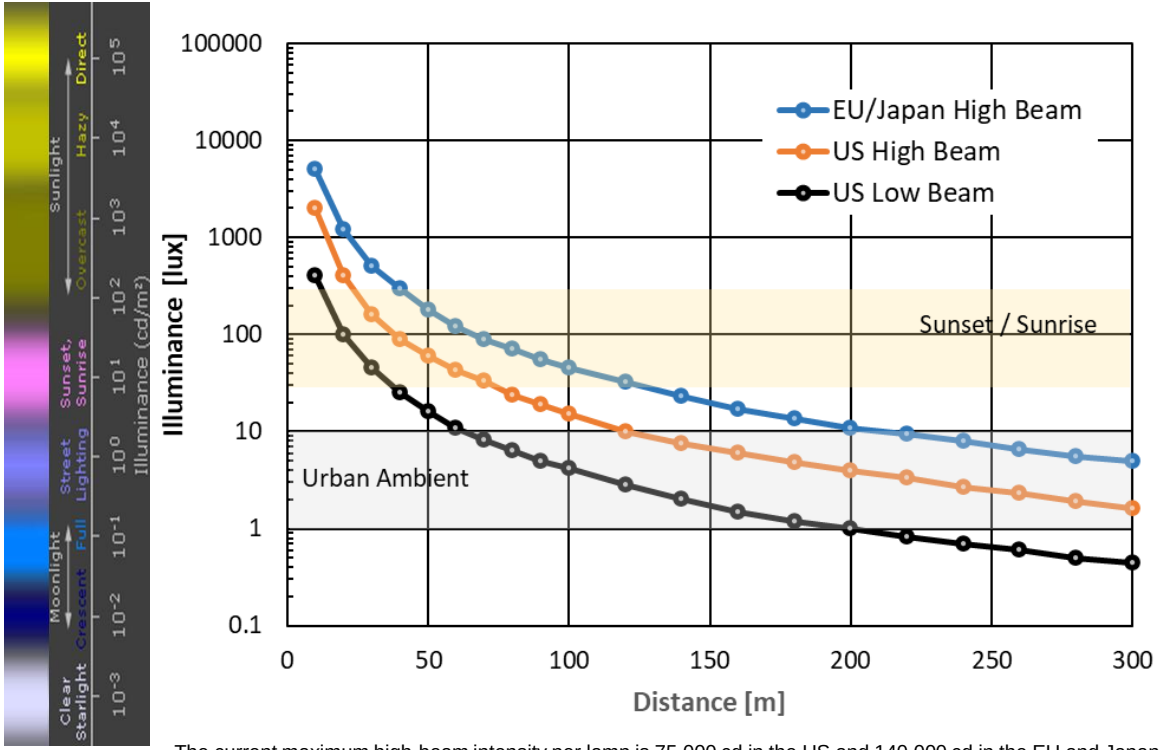
512x512 image
32x32 pixels object
Contrast 0.052 (~5%)
SNR=3 (~10 dB)
SNRI=0.052*3*32
SNRI=5

100 frames averaged



- SNRI defines in-image *a priori located* object detection criteria
- SNRI=5 is the minimum 99% confidence detectability level

Illumination for Day & Night Conditions



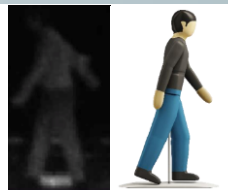
The current maximum high-beam intensity per lamp is 75,000 cd in the US and 140,000 cd in the EU and Japan.

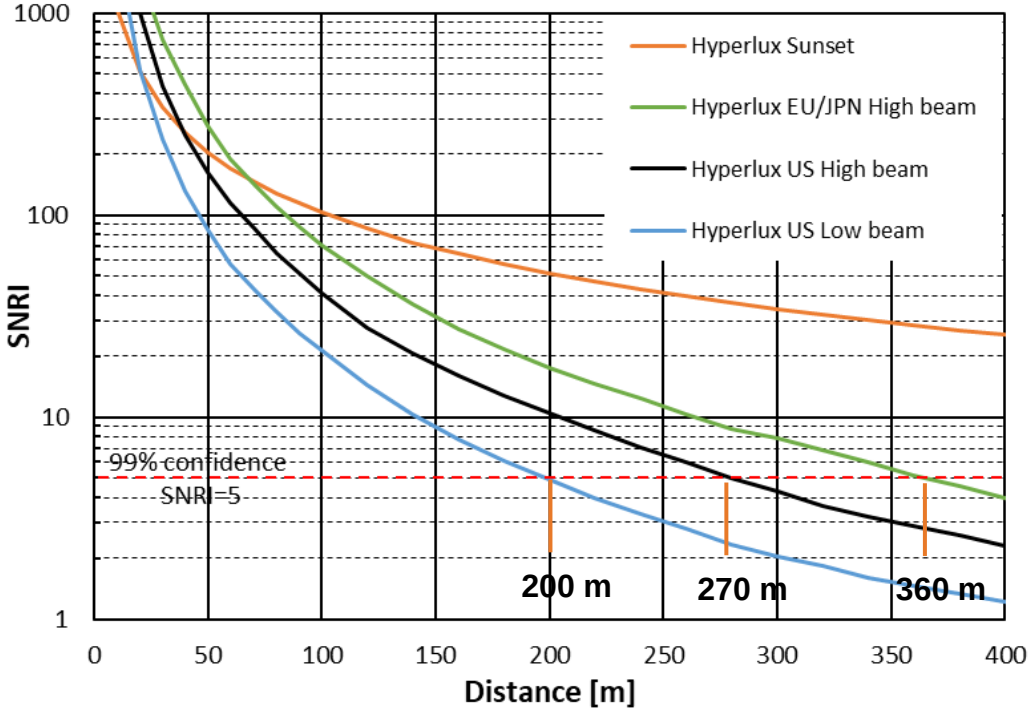
- Sun is main source of illumination during day, sunset / sunrise conditions are most challenging
- Night condition are more complex:
  - Urban with some light ambient vs rural without any ambient light, side of the car without any illumination is most challenging
  - Headlights in low and high beam
  - There is difference between EU/Japan and US maximum headlight illumination levels
- For this study we focus on sunset and rural night with front high and low beam headlights conditions

Hyperlux™ Detection: Pedestrian

Pedestrian, 20% reflection, 20% contrast

Hyperlux AR0823 8.3 MP sensor, 3840x2160 pixels, lens 120-deg FOV, F#1.4, 0.9 lens transmission, Tint=12 ms daylight, Tint=25 ms night, **green** pixel





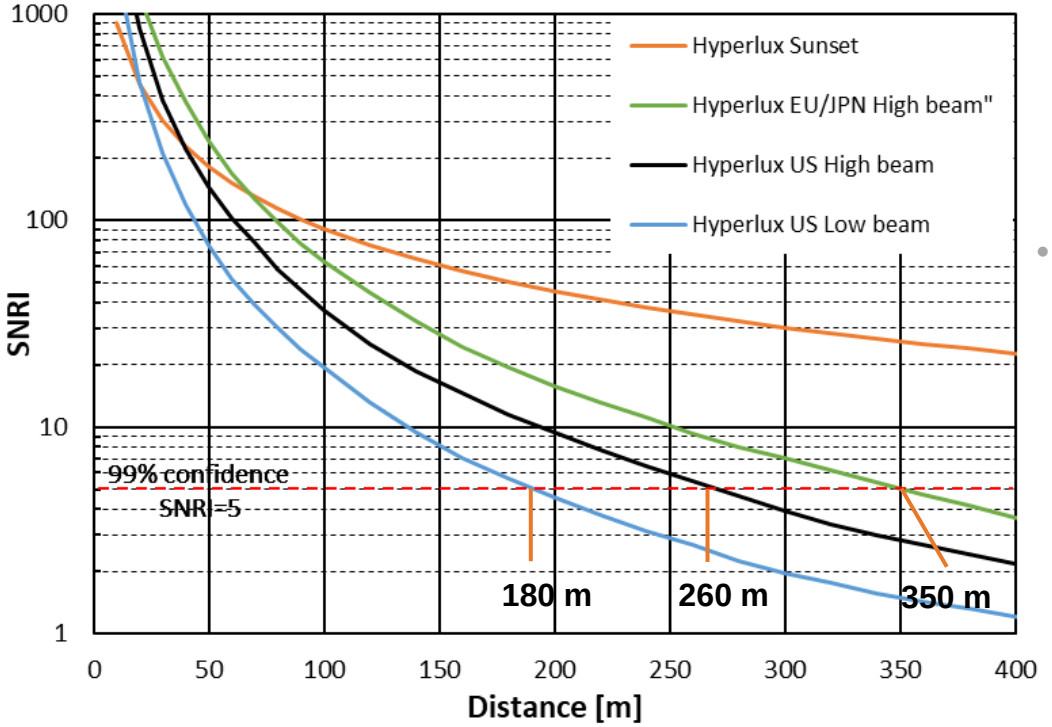
- Hyperlux sensor [7] enables pedestrian detection:
  - Well beyond 400 m in daylight
  - 360 m with EU/JPN high beam
  - 270 m with US high beam
  - 200 m with US low beam

Equidistant camera model [5], SNRI [3,4], and Johnson criteria [6] were used

Hyperlux™ Detection: Rock / Brick

Small Rock / Brick, 20% reflection, 20% contrast

Hyperlux AR0823 8.3 MP sensor, 3840x2160 pixels, lens 30-deg FOV, F#1.4, 0.9 lens transmission, Tint=12 ms daylight, Tint=25 ms night, **clear** pixel



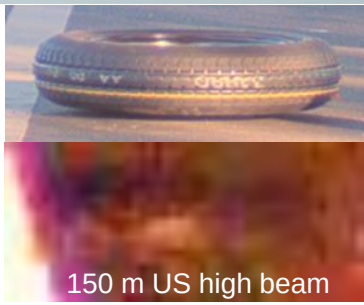
- Hyperlux sensor [7] enables brick detection with 30-deg FOV lens:
  - Beyond 400 m in daylight
  - 350 m with EU/JP high beam
  - 260 m with US high beam
  - 180 m with US low beam

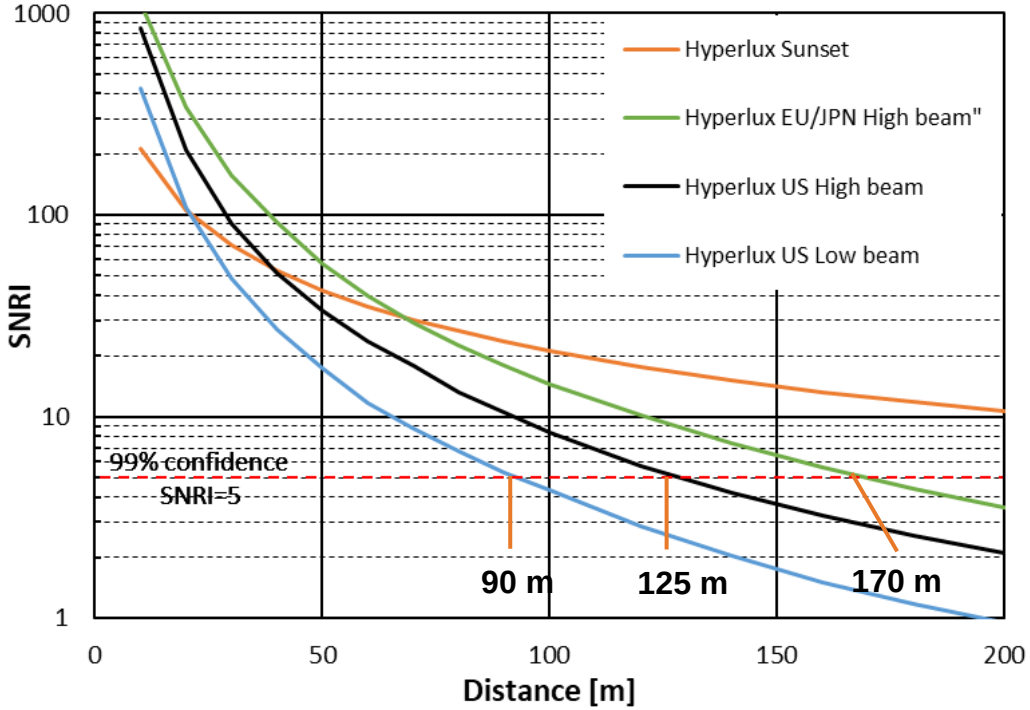
Equidistant camera model [5], SNRI [3,4], and Johnson criteria [6] were used

Hyperlux™ Detection: Black Tire

Black tire, 5% reflection, 5% contrast

Hyperlux AR0823 8.3 MP sensor, 3840x2160 pixels, lens 30-deg FOV, F#1.4, 0.9 lens transmission, Tint=12 ms daylight, Tint=25 ms night, **clear** pixel





- Lost black tire on the road is the most challenging scenario in rural night conditions!
- Hyperlux sensor [7] enables black tire detection with 30-deg FOV lens:
  - Well beyond 300 m in daylight
  - 170 m with EU/JPN high beam
  - 125 m with US high beam
  - 90 m with US low beam

Equidistant camera model [5], SNRI [3,4], and Johnson criteria [6] were used

Hyperlux™ 150 dB Ultra HDR (70-deg FOV lens)

Hyperlux sensors handle challenging sceneries, including direct sun and long-range detection, that enable systems designs with higher safety levels and at higher speed operation

* Using NVIDIA Drive

Hyperlux™ Pitch Dark Tunnel Long Range (120-deg FOV lens)

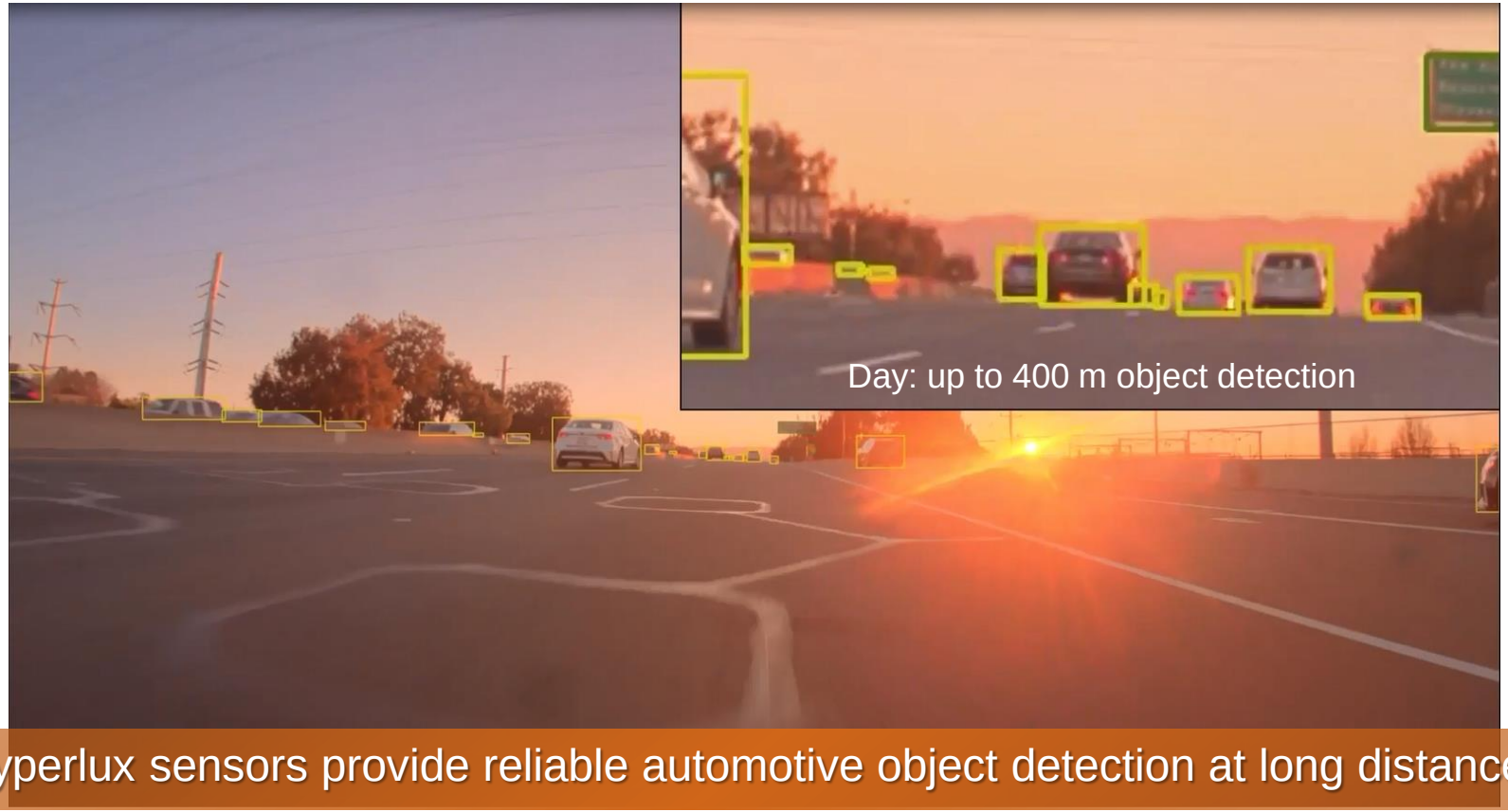
Hyperlux sensors provide image clarity for long distance detection at very dark conditions for automatic emergency braking protocols, ensuring driving safety.

* Using NVIDIA Drive

Hyperlux™ Rural Night Ambient Sub-lux

Hyperlux™ Rural Night Ambient Sub-lux

Hyperlux™ Daylight Automotive Object Detection



Hyperlux sensors provide reliable automotive object detection at long distances

120-degree field-of-view lens, Hyperlux 8.3 MP sensor, 10 ms integration, no filtering, no corrections, Devware color processing, YOLOv5 recognition stack detection

Hyperlux: Night Automotive Object Detection

Hyperlux sensors provide reliable automotive object detection at long distances

120-degree field-of-view lens, Hyperlux 8.3 MP sensor, 33 ms integration, no filtering, no corrections, Devware color processing, YOLOv5 recognition stack detection

The Power of Hyperlux™: Beyond “Good Enough”

70-degree HFOV lens

onsemi

Conclusions

- Following Euro NCAP and NHTSA requirements, long range object recognition at maximum speeds defines safety on the road for cars and light trucks
- Hyperlux image sensors have superior performance and advanced features that go beyond “good enough” thus helping to meet all Euro NCAP and NHTSA mandates including AEB scenarios, as well as providing margins for future more stringent requirements
- Hyperlux sensors enable reliable surround sensing for higher levels of autonomous driving at high speeds and improved safety on the road

Many thanks to my colleagues at onsemi for contribution to this study and presentation!

References

1. ACEA Articulated Pedestrian Target Specification document version 2.0 https://www.acea.auto/publication/articulated-pedestrian-target-acea-specifications/
2. ACEA Bicyclist Target Specification document version 1.0 https://www.acea.auto/uploads/publications/Bicyclist_target-ACEA_specifications.pdf
3. P. Kane, “Signal Detection Theory and Automotive Imaging,” in Proc. IS&T International Symposium on Electronic Imaging 2019.
4. O. Skorka and P. Kane, “Object Detection Using an Ideal Observer Model,” in Proc. IS&T International Symposium on Electronic Imaging 2020.
5. C. Sahin, “The Geometry and Usage of the Supplementary Fisheye Lenses in Smartphones,” 2017. https://www.intechopen.com/chapters/56044
6. J. Johnson, “Analysis of Image Forming Systems,” Image Intensifier Symposium, Fort Belvoir, Va., 1958. P.249.
7. M. Innocent, S. Velichko, et al., “Automotive CMOS Image Sensor family with 2.1 µm LFM pixel, 150 dB Dynamic Range and High Temperature Stability”, 2023 International Image Sensors Workshop, May 2023.

Sergey Velichko
sergey.velichko@onsemi.com

onsemi™

Intelligent Technology. Better Future.

Follow Us @onsemi





www.onsemi

Q&A Session

Use the Ask a Question box to ask a question to our speakers and click on the Send button

Presenter

Sergey Velichko
Sr. Manager,
Automotive Sensing Technology & Product Strategy
onsemi

BROUGHT TO YOU BY:

onsemi

ElectronicDesign

Thank you for attending!

Unlocking Level 3 Driving Automation Using Image Sensors: A Review of Automotive Corner Cases for Level 3+ autonomous driving

Presenter

Sergey Velichko
Sr. Manager,
Automotive Sensing Technology & Product Strategy
onsemi

BROUGHT TO YOU BY:

onsemi

ElectronicDesign