Centre for Sensors, Instruments and Systems Development
UNIVERSITAT POLITECNICA DE CATALUNYA
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3DMC 3D METROLOGY CONFERENCE

Bilbao 26-28th September 2023

High resolution lidar with embedded data fusion for all-weather robotic vehicles

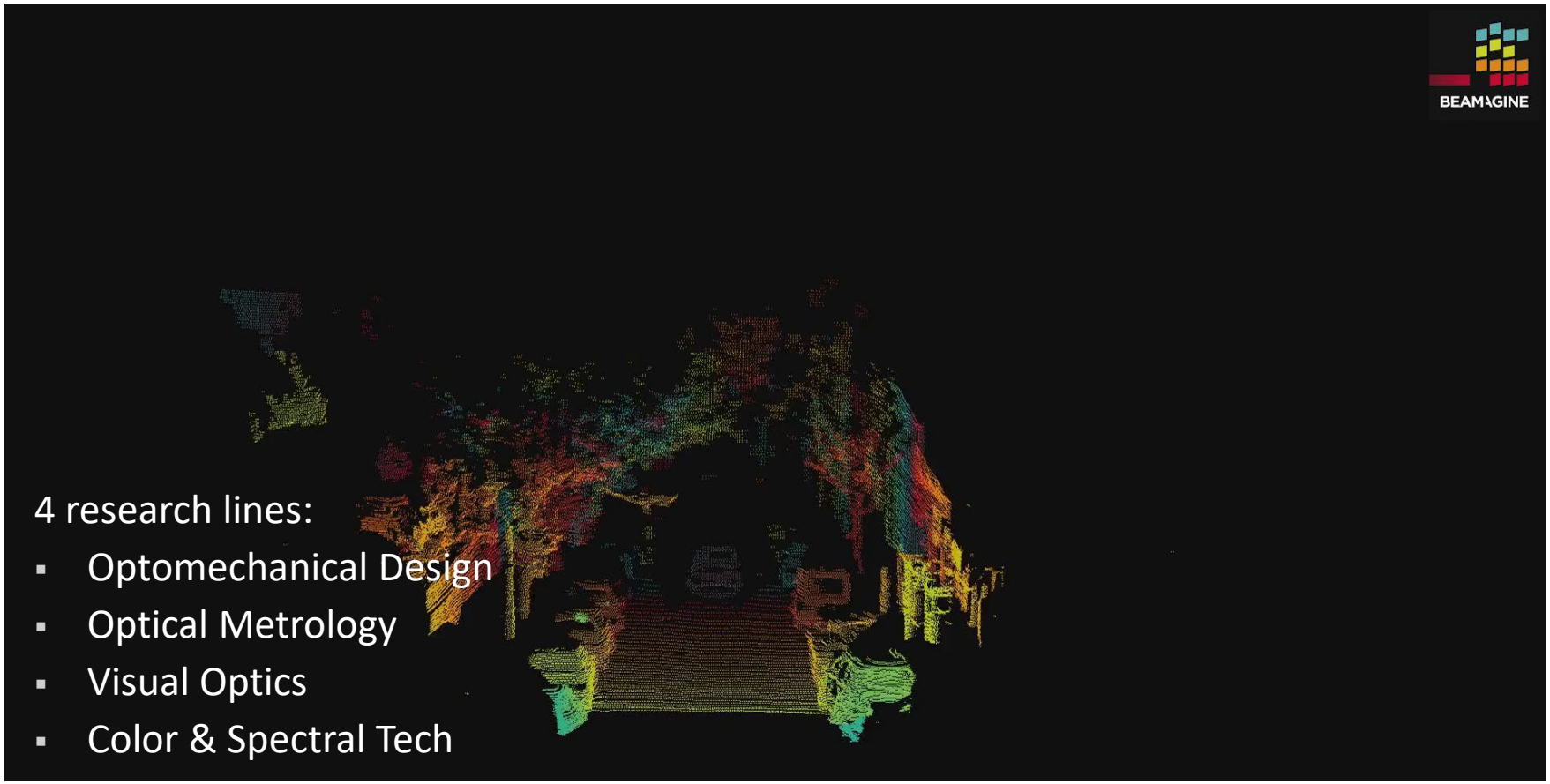
S.Royo, P.García-Gómez, G.DeMas, J.R.Casas, E.Bernal, J.Riu,

September 28th 2023

santiago.royo@upc.edu

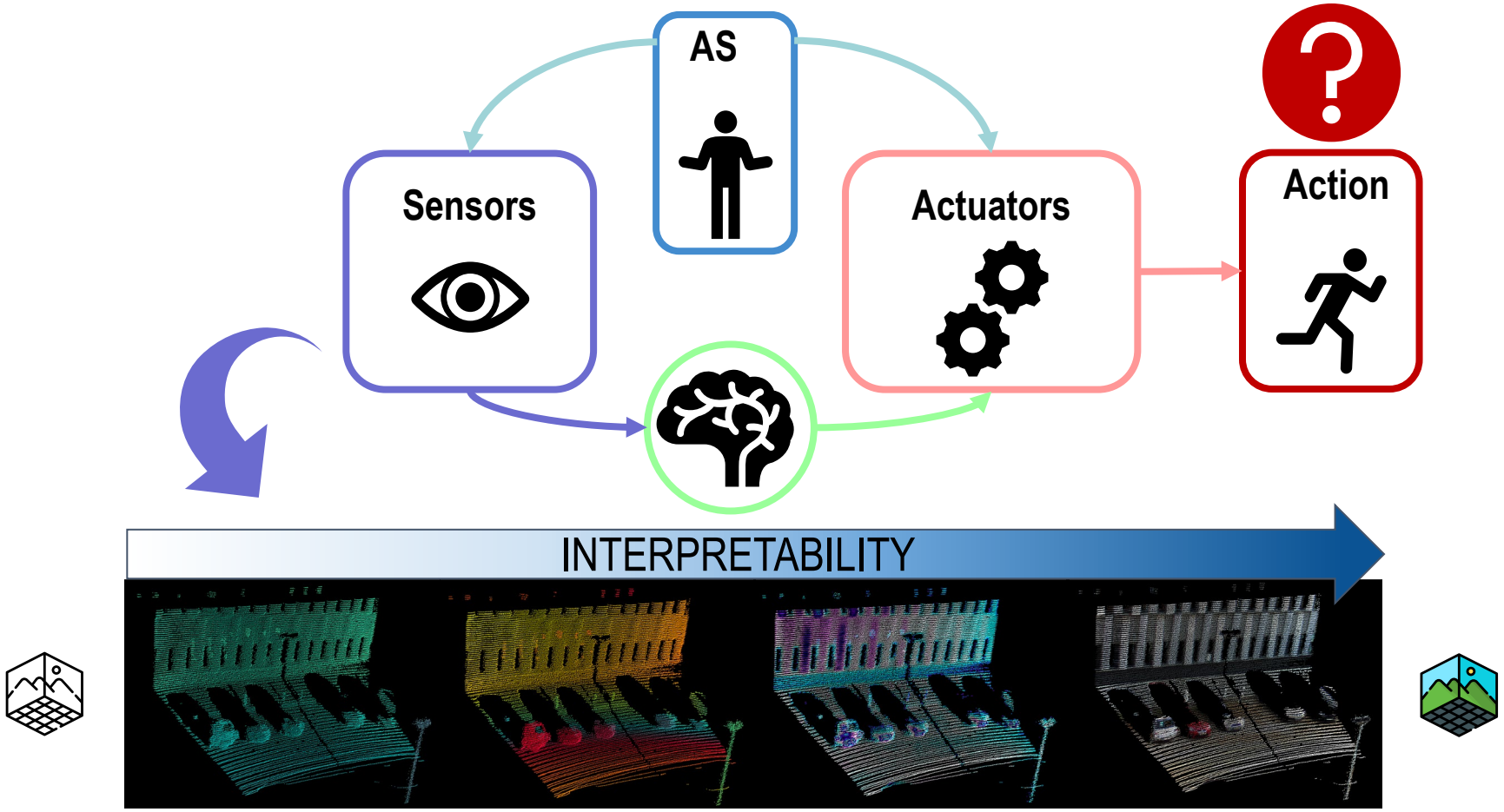
Optical Engineering CD6 - UPC

- Staff: 37 people
  - 10 researchers
  - 15 R+D Engineers
  - 8 PhD Students
  - 4 Management
  - 9+3 spin-off companies
- Multidisciplinary:
  - Optics
  - Mechanics
  - Electronics
  - Software
- Site:
  - 1800 m^2
  - Research labs
  - Mechanic & Electronic Workshops



Development of prototypes and turn-key instruments

Data fusion for autonomous systems

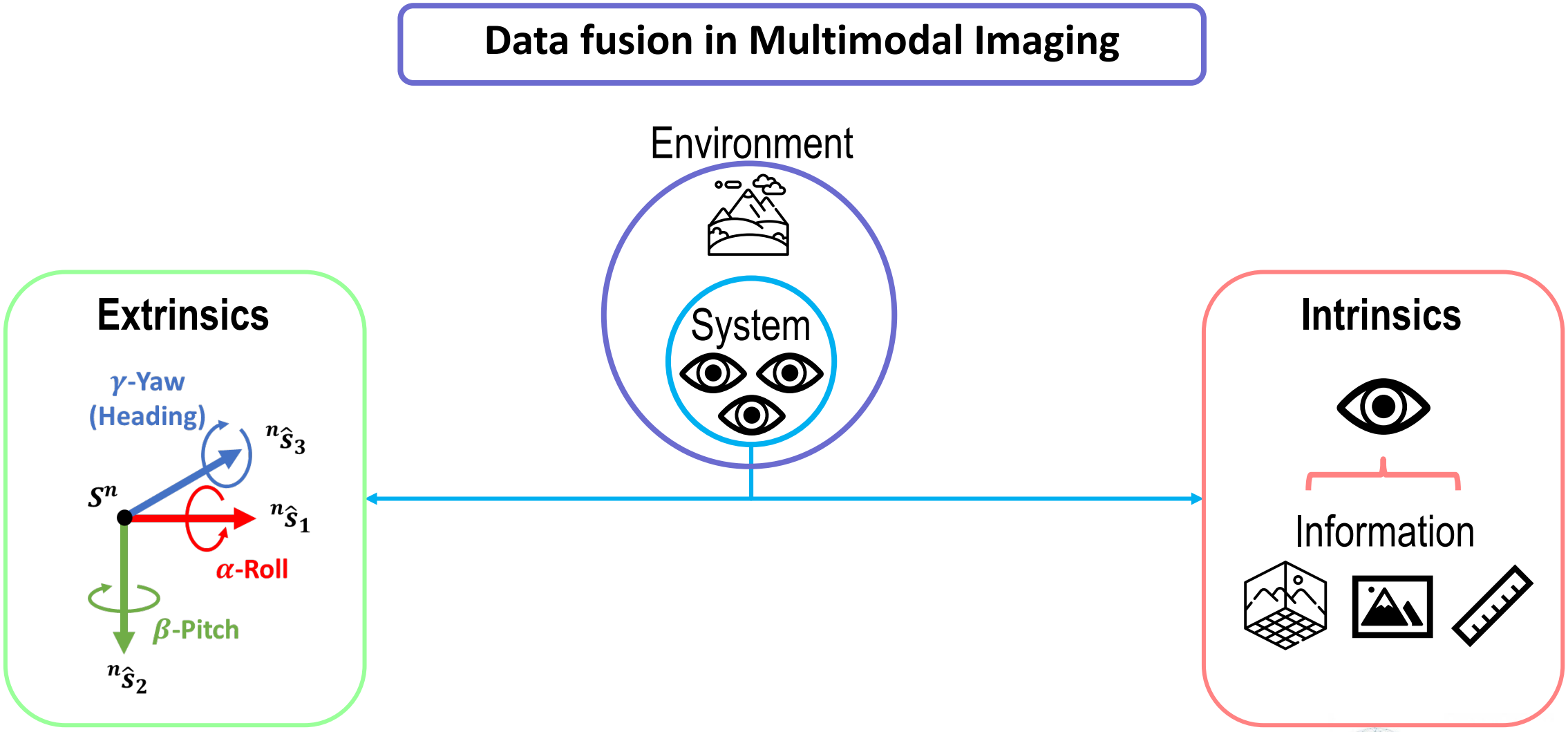


Guide

1. Motivation
2. Working Principle
3. Experimental setup
4. Results and Applications
5. Conclusions

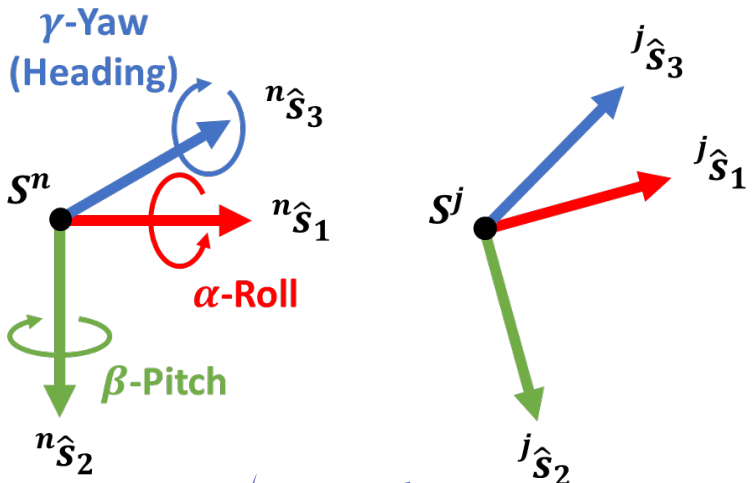
santiago.royo@upc.edu

Basics of image fusion in computer vision



Basics of image fusion in computer vision: extrinsics

- $\boldsymbol{p} = [X, Y, Z]$



6 DOF

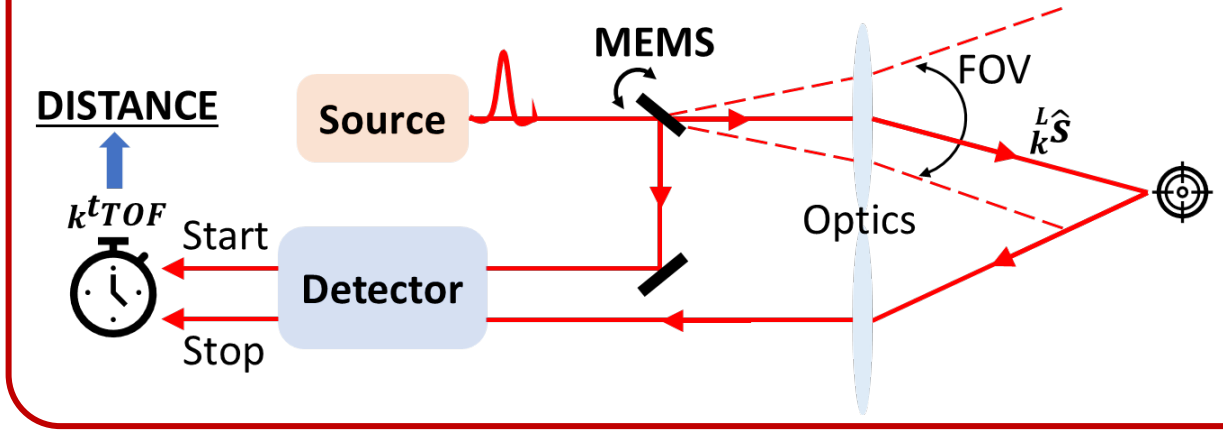
$$^{S^n}\boldsymbol{p} = \begin{bmatrix} ^{S^j}\boldsymbol{p} & 1 \end{bmatrix} \begin{bmatrix} \boldsymbol{O}_{S^j||S^n} \\ \boldsymbol{loc}_{S^j||S^n} \end{bmatrix} \longleftarrow \boldsymbol{H}_{S^jS^n}$$

Orientation

Location

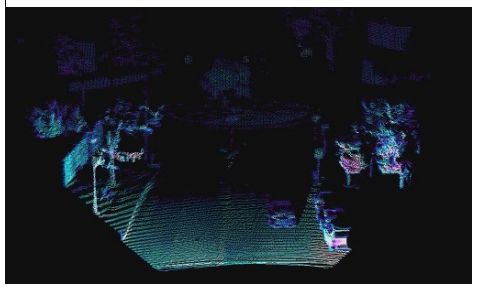
Basics of image fusion in computer vision: intrinsics

LiDAR (pulsed solid-state MEMS)



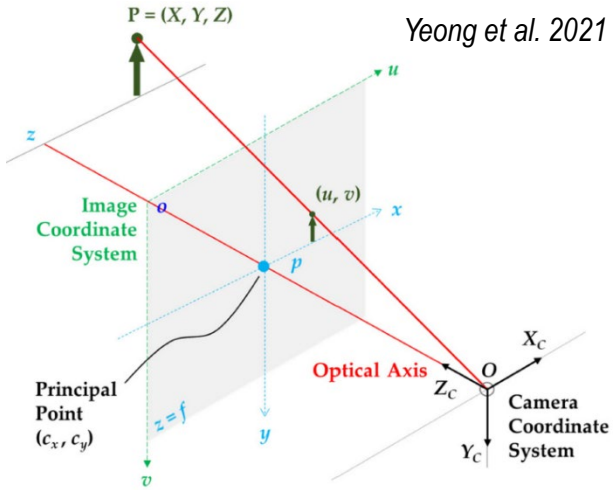
$$ {}^{L}_{k}\boldsymbol{p} = \frac{c}{2}\, {}^{k}t_{TOF}\, {}^{L}_{k}\hat{\boldsymbol{s}} $$

Point Cloud



Cameras

Camera Projection
- Projection
- Distortion

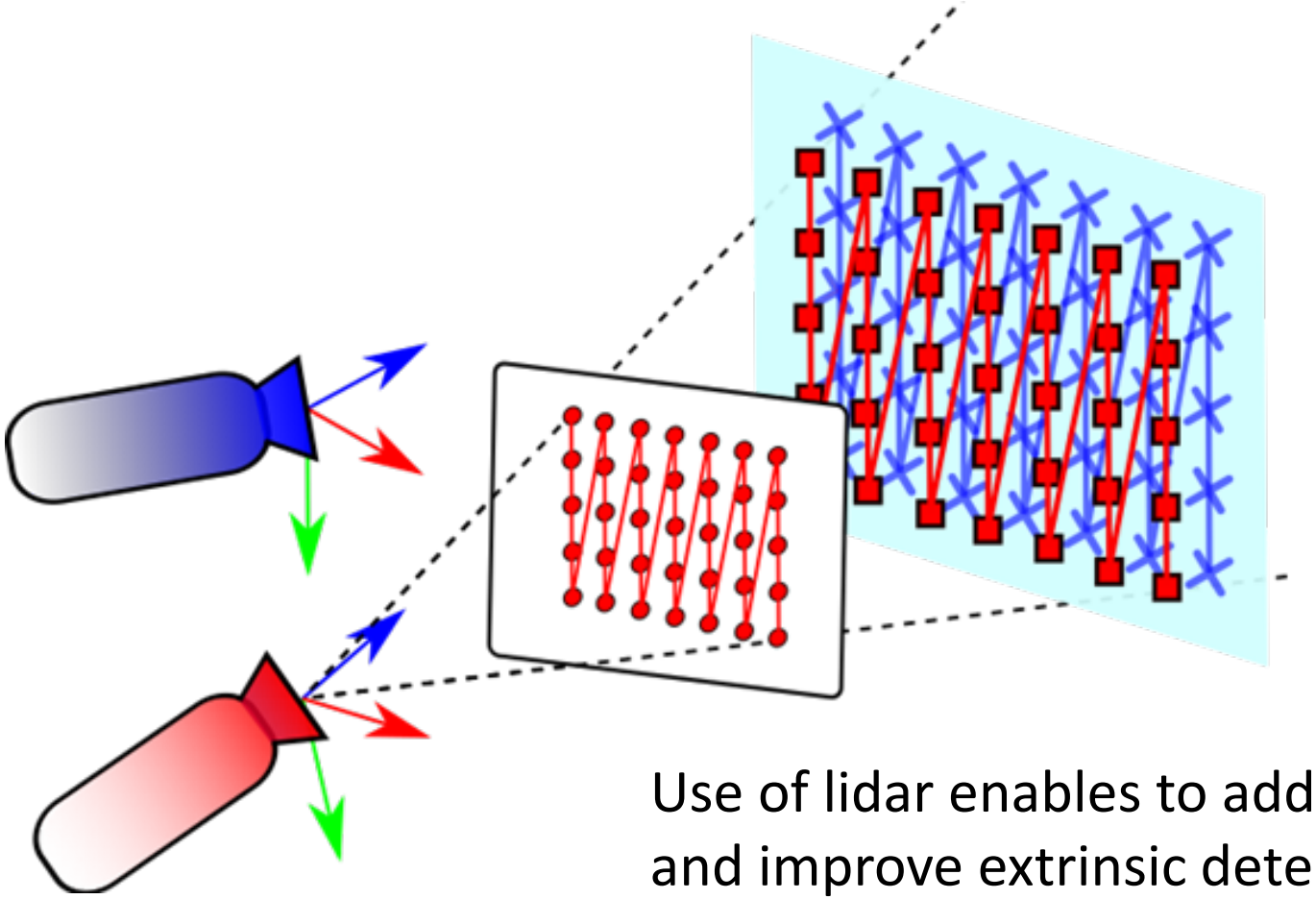


Yeong et al. 2021

$$ \lambda[u_k, v_k, 1] = {}^{C}_{k}\boldsymbol{p} \begin{bmatrix} f_x & 0 & 0 \\ s & f_y & 0 \\ u_c & v_c & 1 \end{bmatrix} $$

Image

Basics of image fusion in computer vision: calibration



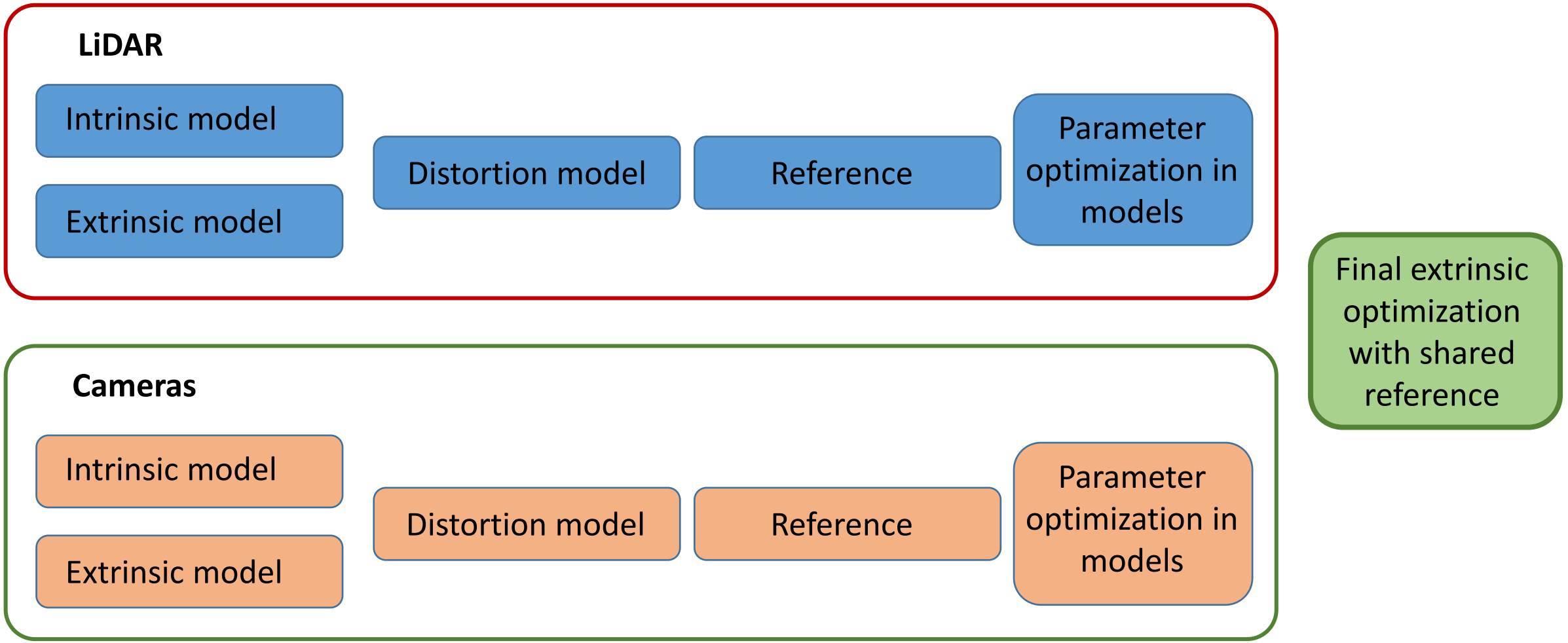
- Checkerboard as reference for calibration
- Distortion model [1]

Use of lidar enables to add on the depth information and improve extrinsic determination **:**

Improved data fusion error!

.[1] https://doi.org/10.3390/s20102898

Overall approach



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Hardware arrangements

TRL7

Max dimension 20 cm

Courtesy of Beamagine SL

TRL 9

Max dimension 18cm

Courtesy of Beamagine SL

SENSOR		FOV [º]	Size [pix]	Measure
Lidar	L3CAM	60 x 20	480 x 150 (72 kpx)	3D point cloud
RGB	See3CAM CU130	68 x 40	4224 x 3156 (13Mpx)	Colour
Pol	PHX050S-QC	56 x 42	2448 x 2048 (5 Mpx)	Colour & Linear Pol.
LWIR	MosaicCORE C3	69 x 60	320 x 240 (76.8 kpx)	Temperature

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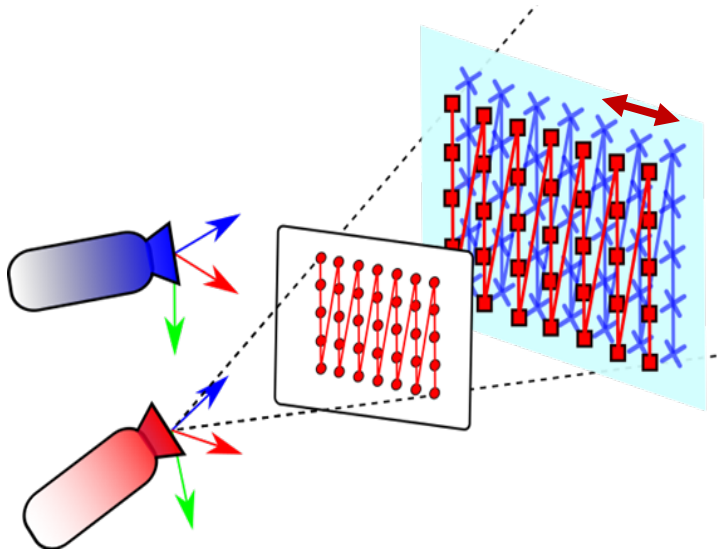
Fusion results: parallax error

Direct measure of the **parallax error** of the fusion



Literature mainly based on Location of sensors

Sensor Pair	Parallax Error [deg]	Parallax Error [mrad]
Lidar-RGB	0,271	4,7
Lidar-Pol	0,288	5,0
Lidar-LWIR	0,300	5,2
RGB-Pol	0,120	2,1
RGB-LWIR	0,183	3,2
Pol- LWIR	0,234	4,1
Average System	0,232	4,1

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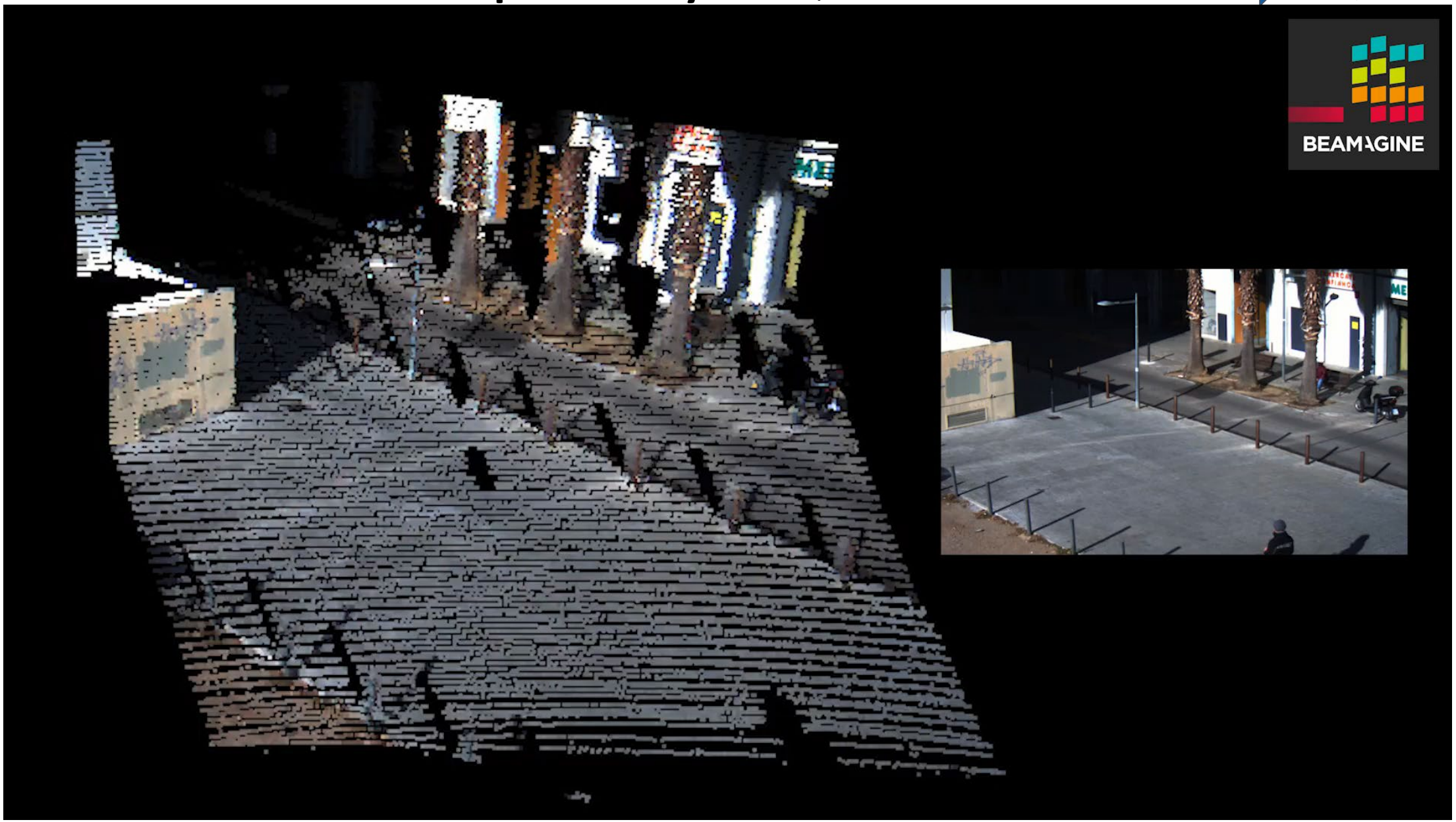
Fusion results: enhanced interpretability



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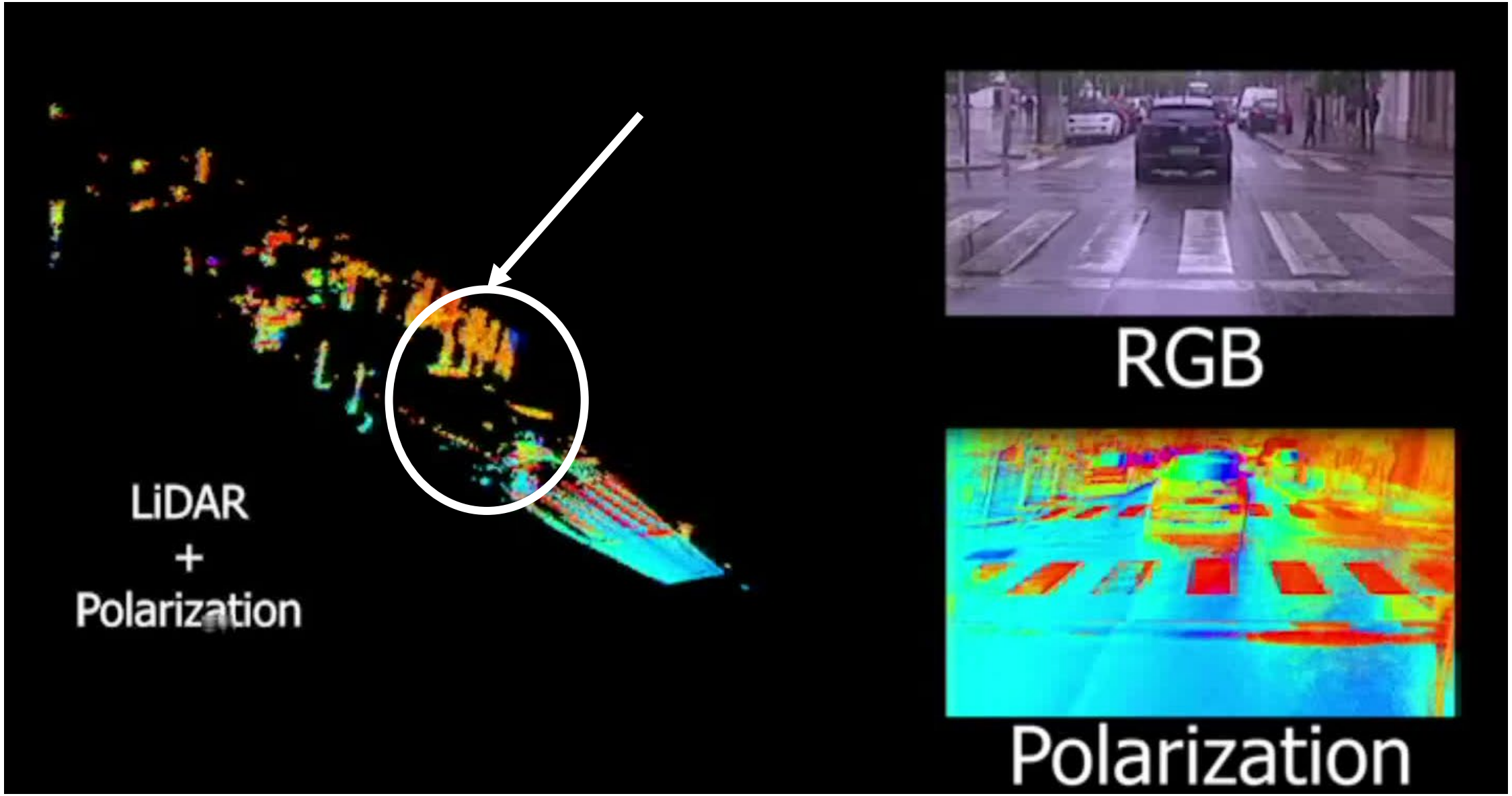
Fusion results: improvement of failure modes (automotive, adverse weather)



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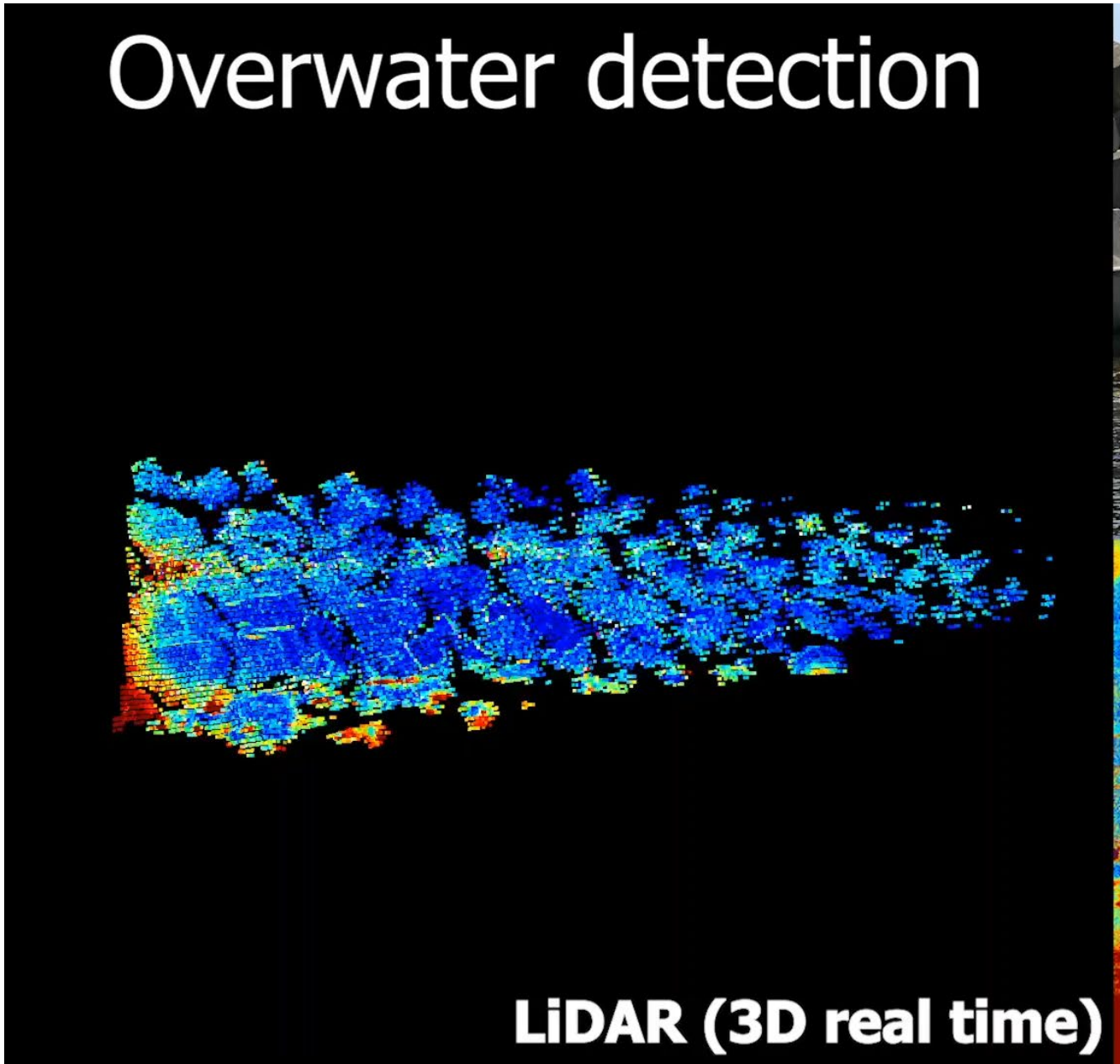
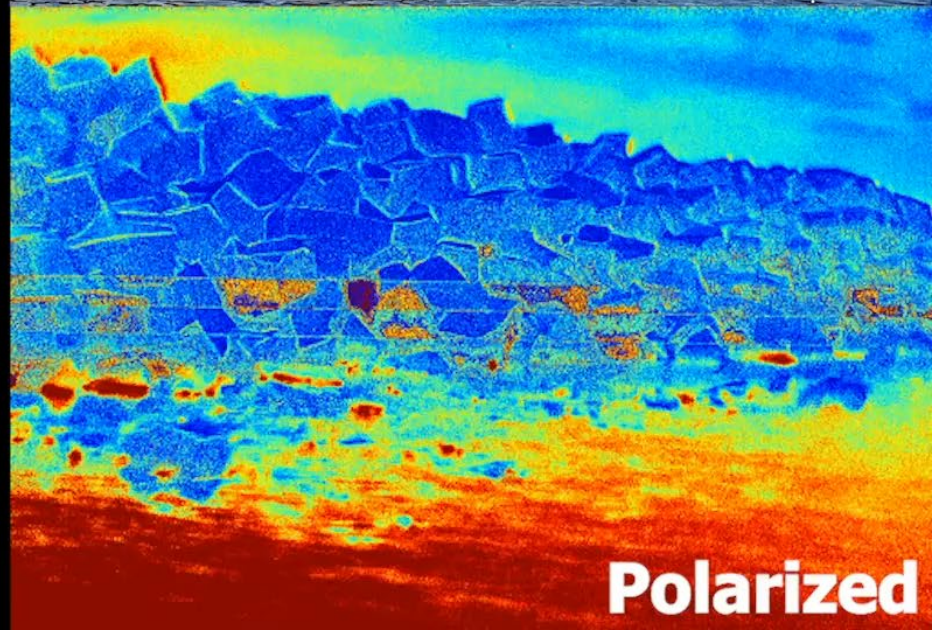
Fusion results: redundancy of imaging modes (maritime)

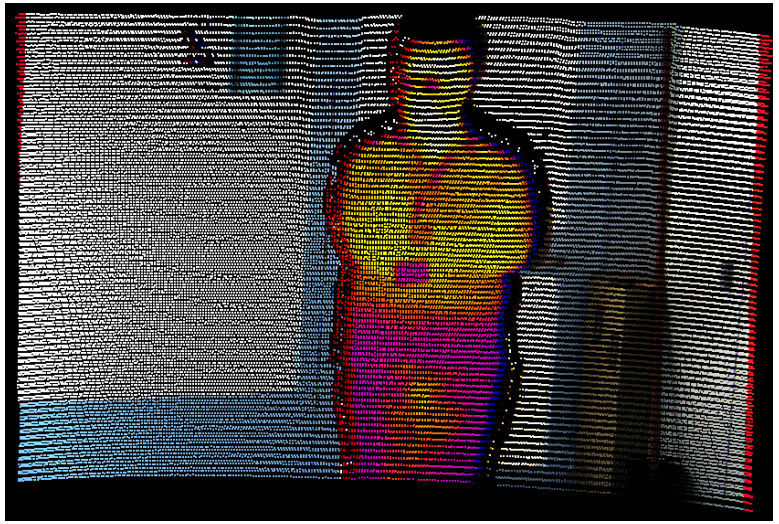


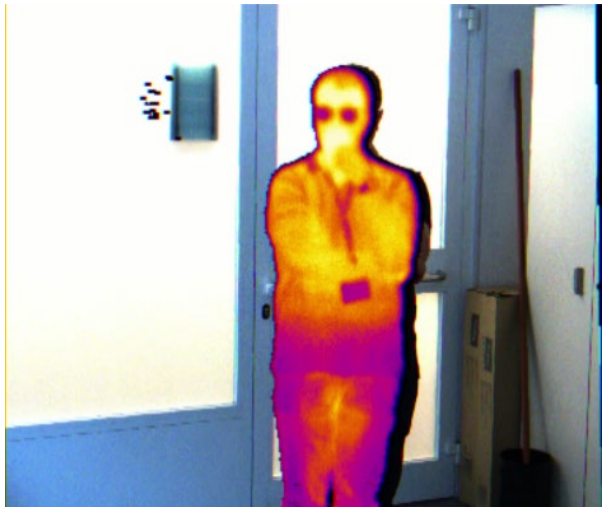


Fusion results: high accuracy 2D registration through 3D

Fused Point Cloud

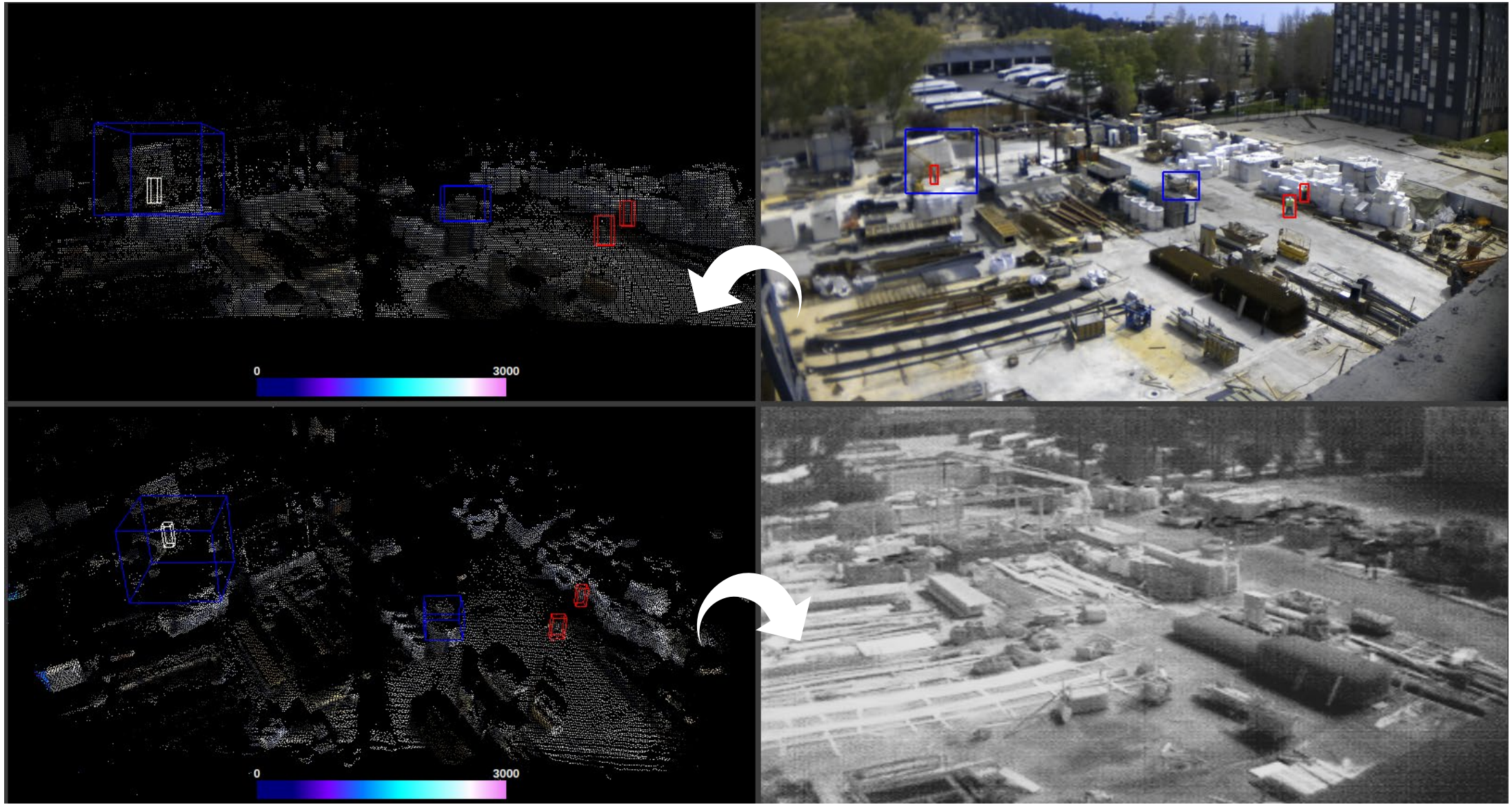
- Colour
- Thermal





Registered LWIR+RGB image

Fusion results: Perception in complex scenarios



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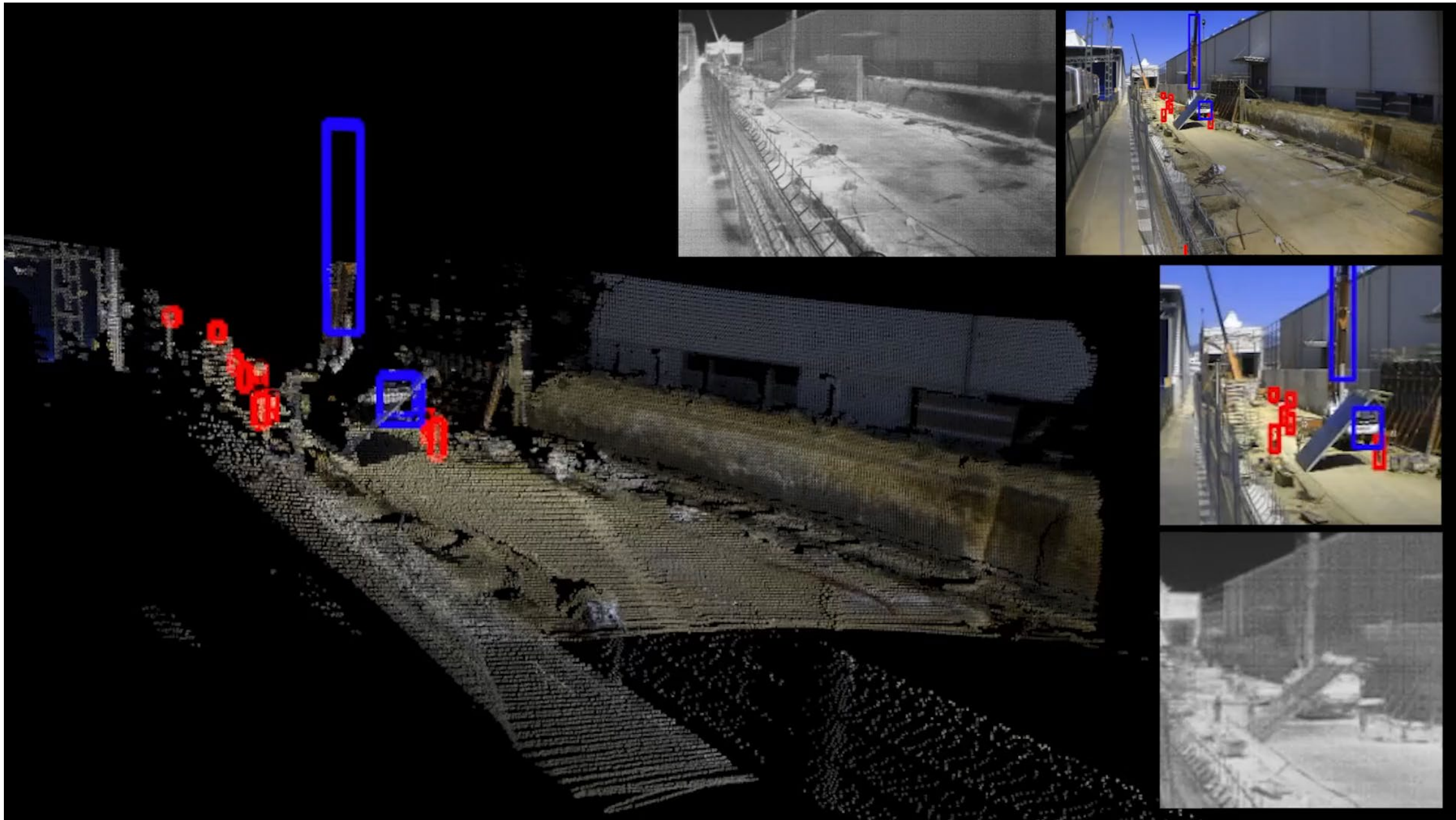
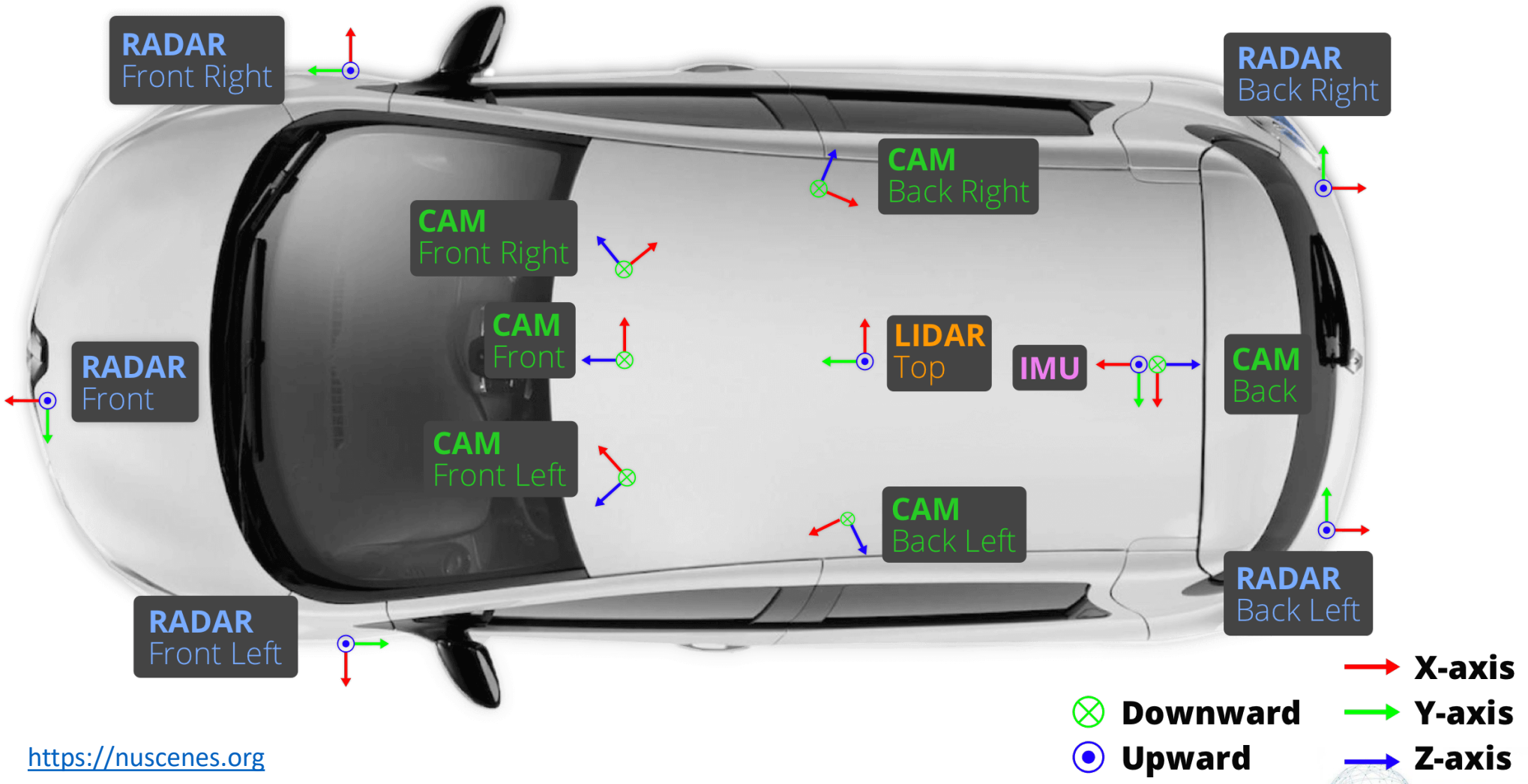
Fusion results: Perception in complex scenarios



Conclusions

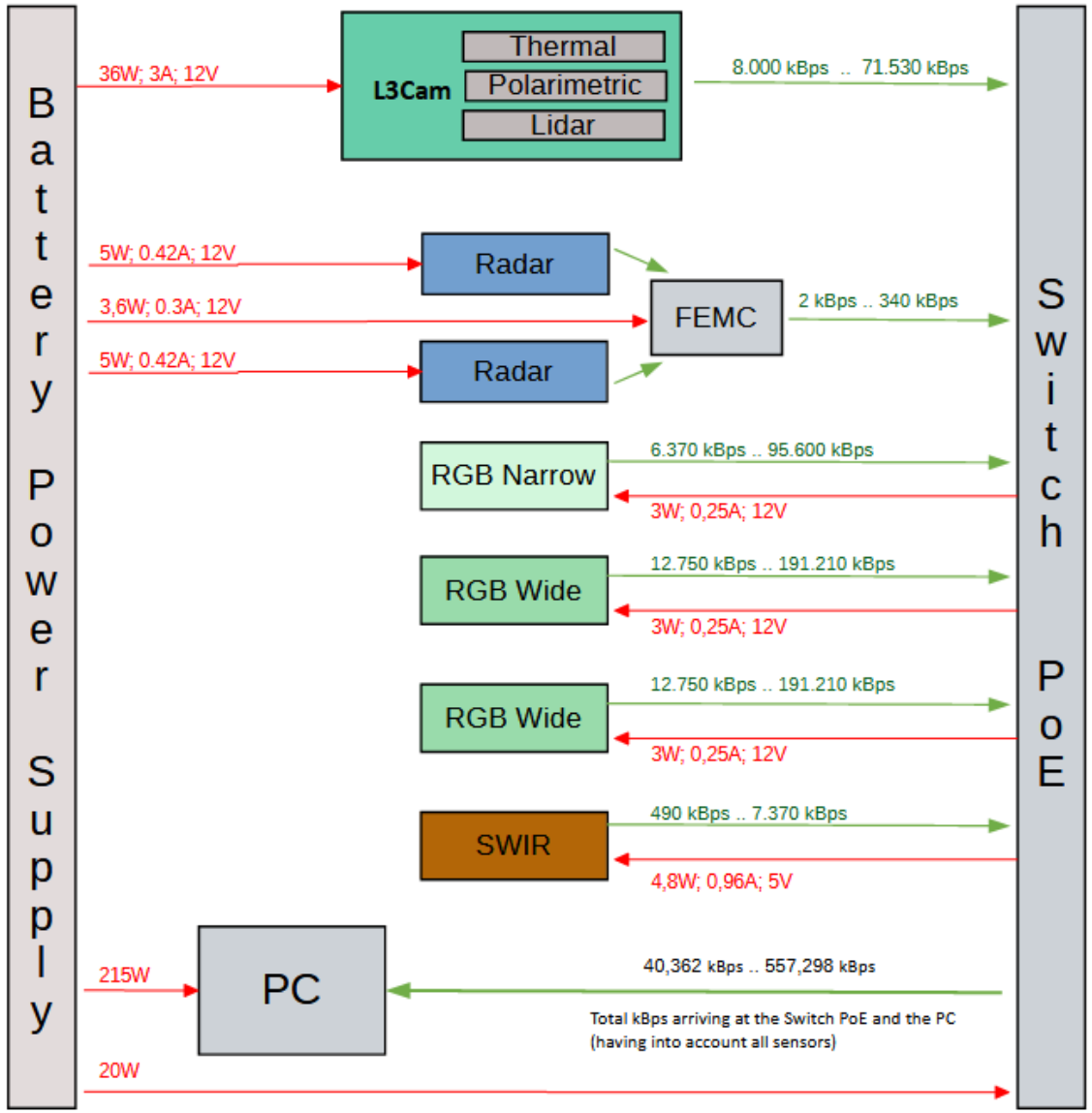
- Data fusion is a critical tool for AS technology and robotics, as failure modes are compensated and redundancy of perceptions/complementary information achieved
- Using depth information from a high-density LiDAR device enables improving data fusion (both 2D-3D and 2D-2D) to the 4mrad regime
- Multimodal imaging enhances perception of the environment: complementary data with unshared failure modes, redundant data, management of complex scenes,…
- Perception based on multimodal imaging systems demonstrates greater accuracy and robustness in different working conditions & scenarios easing AI applications.

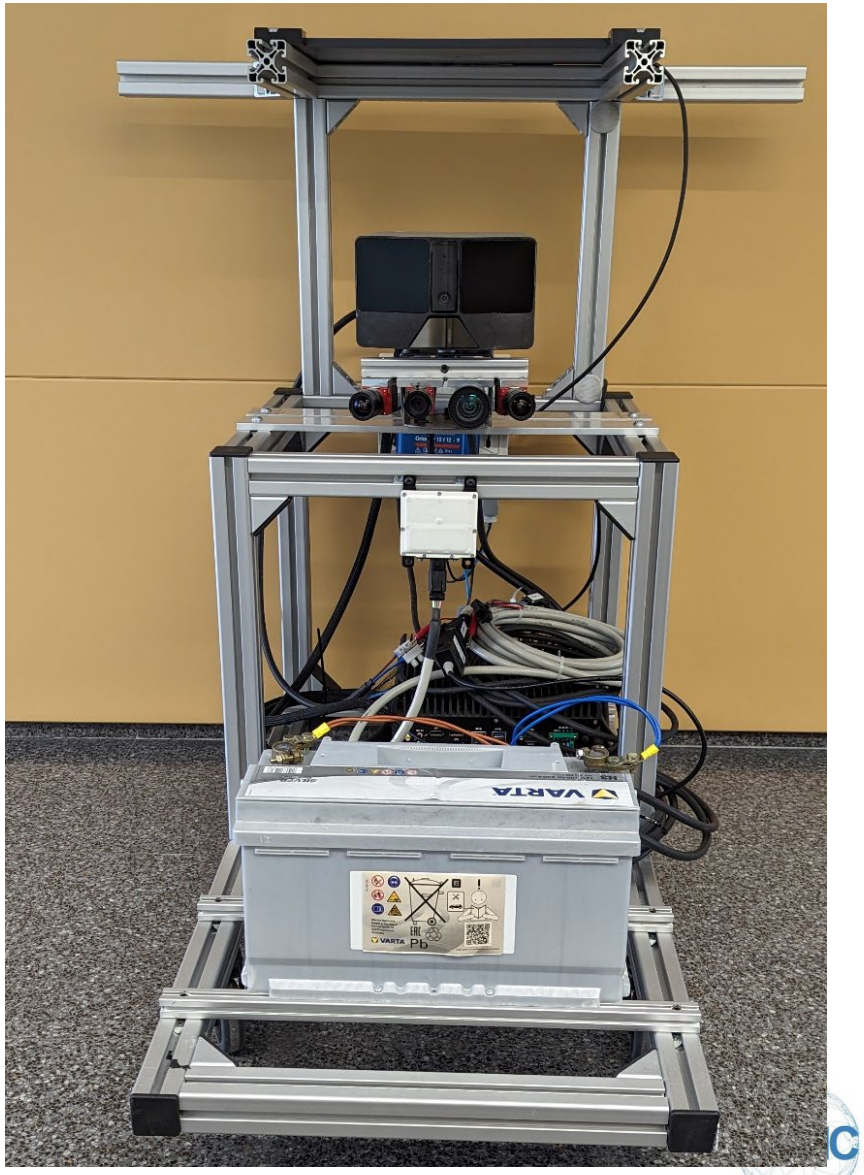
Multimodal sensing vehicle under construction (end 2023)



https://nuscenes.org

Multimodal sensing vehicle under construction (end 2023)





Team

Senior researchers

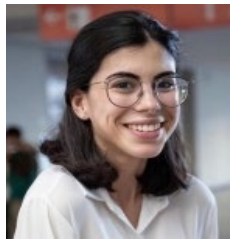

Frédéric Bernardin


Josep R.Casas

Posdoctoral researchers


Pau Santos


Pablo García


Sara Peña

Research Engineers


Adriá Subirana


Jordi Segura


Noel Rodrigo

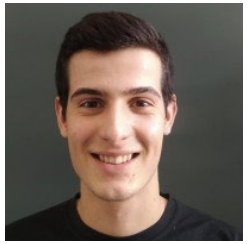

Eduardo Bernal

PhD students


Carlos Yáñez


María Ballesta


Gerard de Mas

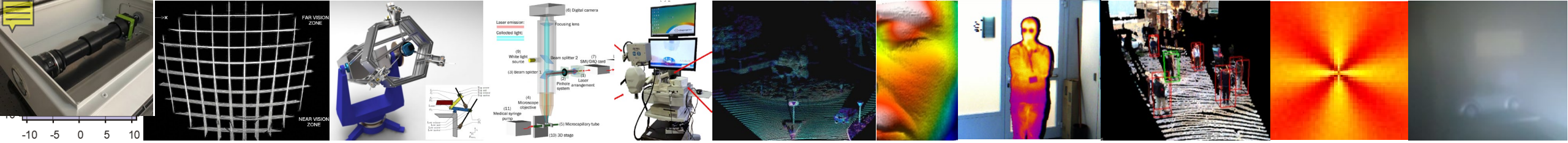

Aleix R.Bobi


Sara Giménez

Workshop technicians


Xavier Murcia


Fermín Alarcón



Thank you!

Santiago Royo
santiago.royo@upc.edu

Acknowledgment

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