
L3CAM
MULTIMODE LIDAR FUSION CAMERA
BEAMAGINE

PRESENTATION OUTLINE

Technology details: outstanding features of the L3CAM

Product

Use cases

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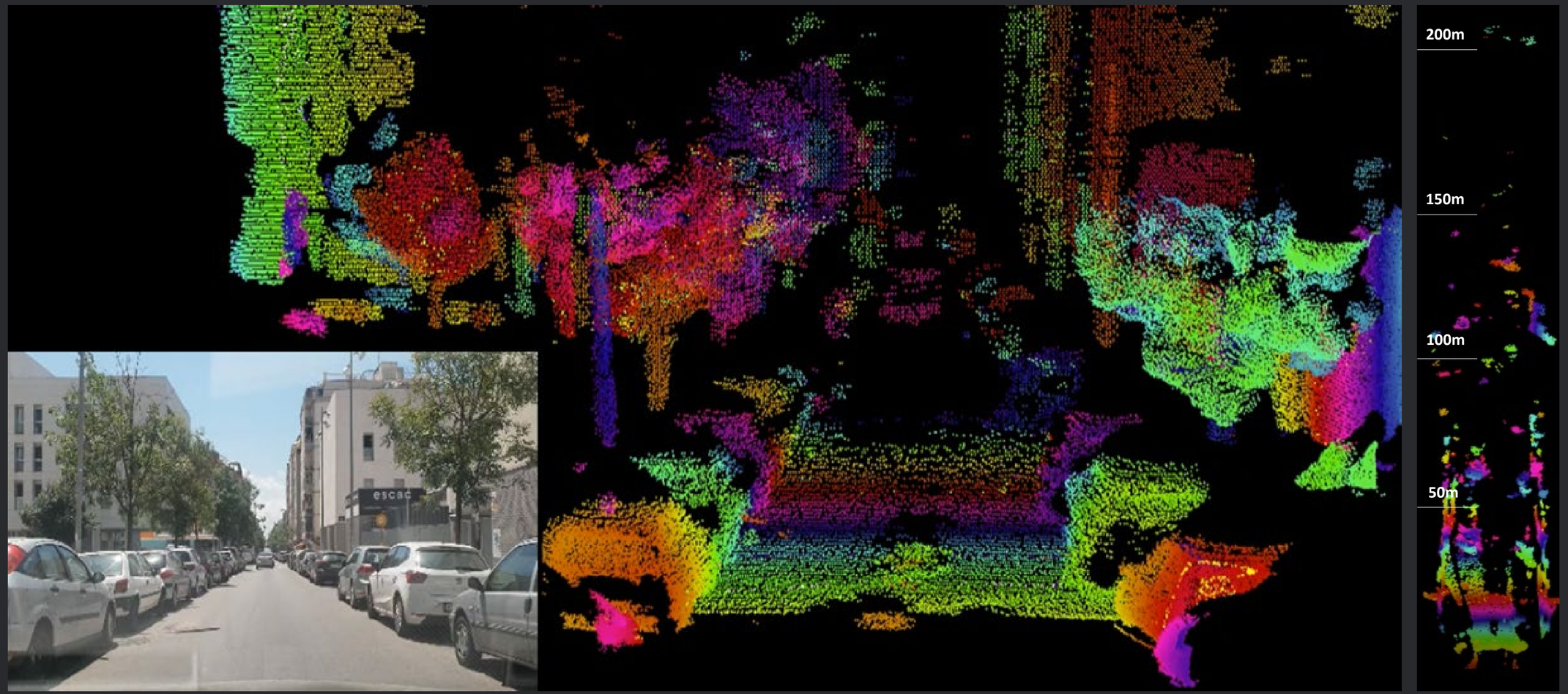
High-density point clouds and real-time frame rate



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Most distinctive features of the Beamagine LIDAR

1) SOLID-STATE DESIGN WITH LARGE ENTRANCE PUPIL DIAMETER (long range)

Mechanical Scanning:

- Most of the current imaging LIDAR devices contain macro moving elements like spinning mirrors, galvanometric scanners or rotating heads. Moving parts usually are not a problem in a car, but the ones contained in an imaging LIDAR sensor are highly precise optical elements that can be sensitive to shocks, temperature changes, and vibrations. The LIDAR's ability to function depends directly on the robustness/stability of such elements. High precision optomechanical elements may not be reliable at mid/long term when installed on a vehicle.

Flash:

- While it is an elegant solution (solid-state as well), it is impractical for mid/long range detection because the laser energy is spread over a large area. It results in low image spatial resolution.

MEMS based scanning:

- It offers a good balance between laser energy efficiency and solid-state solution. Its limitations related to the mirror aperture (~2mm) limit the achievable range.

Beamagine solution:

- Solid-state scanning Thanks to its patented double MEMS approach, Beamagine LIDAR combines the advantages of a solid-state scanning based on MEMS with a large entrance pupil diameter. A large entrance pupil enables long-range detection within eye-safe power levels.

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Most distinctive features of the Beamagine LIDAR

2) DRIVABLE SPACE DETECTION

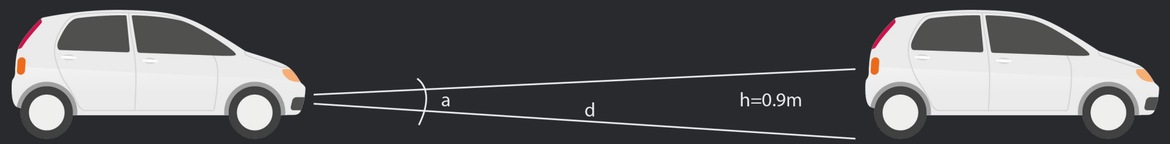
Range and resolution requirements are connected:

- Range determines how fast you can drive
- Resolution determines how small objects can be classified
- Range without resolution is not enough

Then: Max 2 spots on the height of a tall vehicle (SUV). Probably not enough for classification of a vehicle at measurement range. Definitely not enough for smaller objects.

Example: Velodyne HDL-64 S3 (64 channels):

- Measurement range: up to 120m
- Vertical FOV (Y-axis): 26.9º -> Vertical angular resolution: 0.42º
- It gives h=120*rad(0.4) = 0.9m



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Most distinctive features of the Beamagine LIDAR

2) DRIVABLE SPACE DETECTION

ROAD DEBRIS USE CASE:

Systems mounted in fast-driving cars need to “see” a minimum of 150 meters forward and detect small objects down to 10cm in height. Translated to resolution requirements:

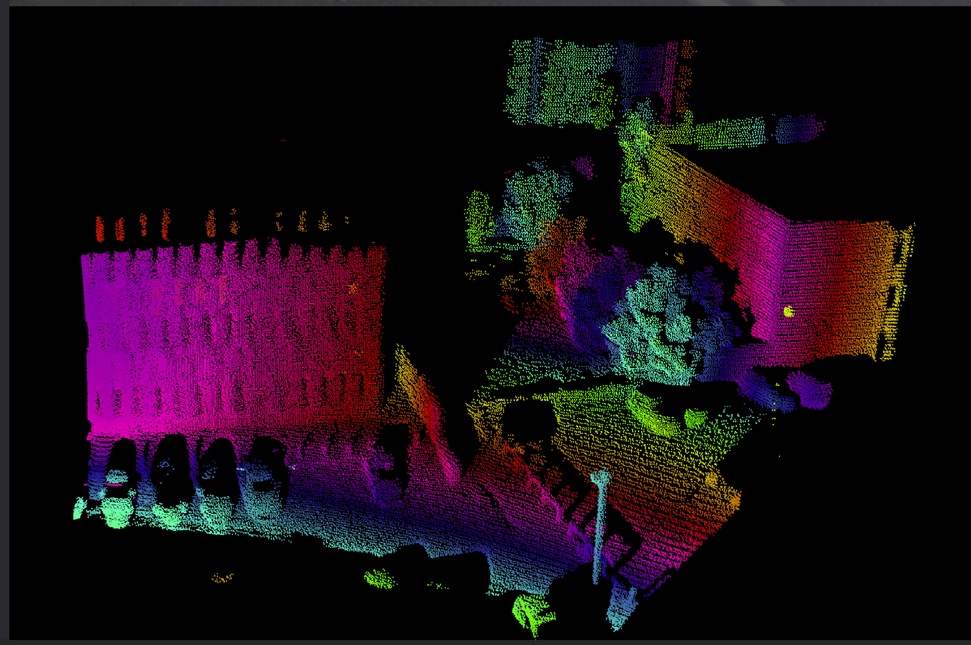
- Range: 150m
- Vertical minimum resolution given by road obstacle: 0.1m
- Then Minimum vertical angular resolution: 0.038º
- Vertical FOV assuming 128 vertical points:
  - vFOV = 128 * 0.038 = 4.9º
  - Vertical FOV < 5º is not enough for various amount of cargo in vehicle or driving in hilly streets

Beamagine solution:

Beamagine LIDAR provides good resolution not only on a horizontal axis, but also on a vertical axis. Depending on the OEM specs, it can be customized to achieve an angular resolution down to 0.05º. This ensures the capability to detect low height objects that the vehicle can’t run over.

Demo video:

Real-time raw lidar data



Most distinctive features of the Beamagine LIDAR

3) CONGRUENT DATA FUSION: 2D + 3D

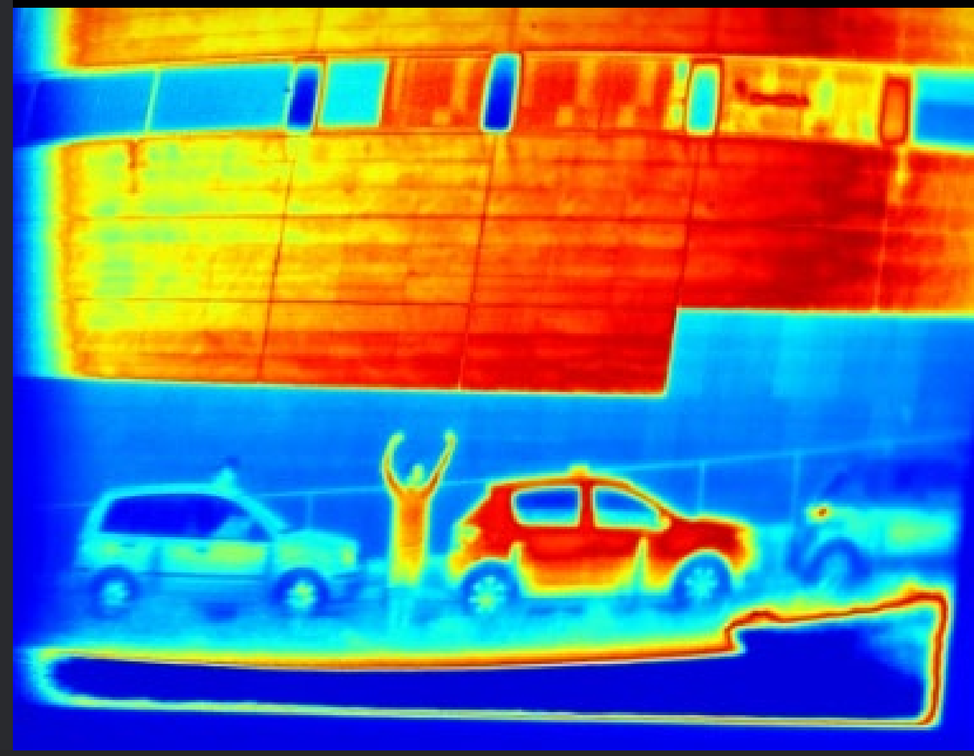
Problem:

When different sensors (LIDARs and cameras) are placed on a vehicle in a detached basis, parallax errors in the image fusion appear due to:

- Sensors being placed in different locations on the vehicle
- Different FOVs
- Different frame-rates
- Relative misalignments between sensors that occurred after the calibration process
- Traditional solutions, like transforming the LIDAR points into camera images, don't avoid the parallax misalignments

Beamagine solution:

Beamagine technology enables a unique feature: a self-registered 3D lidar image with another 2D imaging mode (RGB, NIR, SWIR, polarimetric, hyperspectral, and even thermal). This is possible thanks to a patented technique that collects both imaging modes through the same optical system. This allows for hardware-based automatic registration that avoids complex data fusion algorithms and parallax error at all distances, even in the smallest cross-section objects at long ranges. In addition, as long as both LIDAR and camera share position and optical system, it makes the system immune to misalignments generated by chassis deformation caused by the passage of time.



Most distinctive features of the Beamagine LIDAR

4) EMBEDDED PERCEPTION FOR AI

Problem:

Normally LIDAR sensors only provide the raw point cloud information, unprocessed. The processing is usually implemented by the integrators or the end users. Unlike the 2D domain, the 3D point cloud processing algorithms is quite a novel field, and the existing techniques are not so mature. Additionally, there is a lack of data sets with which to train the neural networks, so end users have to make large data collection sessions to have enough data to train their own AI.

That makes the integration by the users quite difficult and requires long developing times. Because of this, the potential customers are limited to research-oriented entities like Universities and R+D departments of large companies. Outside of the research environment, customers don't want to deal with point clouds and complex AI developments. They are not AI experts; therefore, they prefer to have processed information instead of raw imaging data.

Beamagine solution:

L3CAM includes an embedded high-performance computer within its IP67 casing. This processing unit incorporates all the data fusion and perception AI functionalities. This solution's goal is to process the information on-board.

This makes it more accessible to customers who don't want or don't have the capabilities to process 3D point clouds.

The computer serves a double purpose as well, it can also be used by the customers to implement their own embedded AI functions.
The embedded AI is a work in progress, and we study our customers' needs on a case-by-case basis. Beamagine's preliminary solutions are oriented to automatic human detection.

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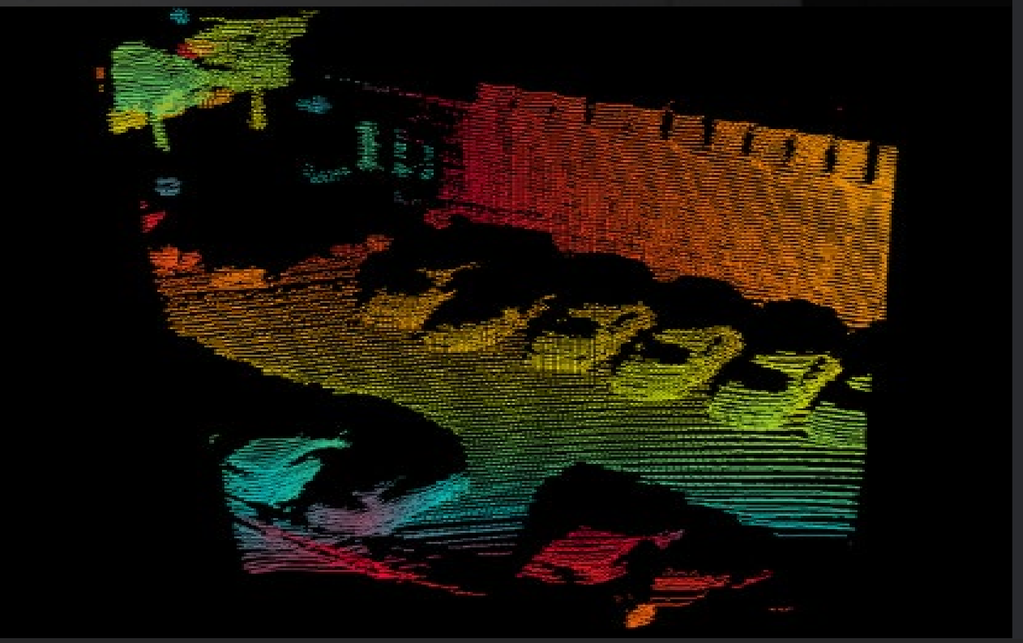
L3CAM summary

At a glance:

- Camera system composed by three complementary imaging technologies:
  - High resolution solid-state 3D LIDAR (12 patents)
  - CCTV (RGB) camera
  - Thermal camera
- In-house calibrated embedded data fusion
- Embedded AI perception software for automatic human detection, tracking and classification
- Perception software that can be trained on demand for any other kind of object detection
- Zero false alarms due to the triple imaging analysis approach
- Performance guaranteed in all environmental conditions: day/night or bad weather (rain, fog, snow, dust or wind)
- Compact size: 10x17x15 cm



Specifications: general purpose unit

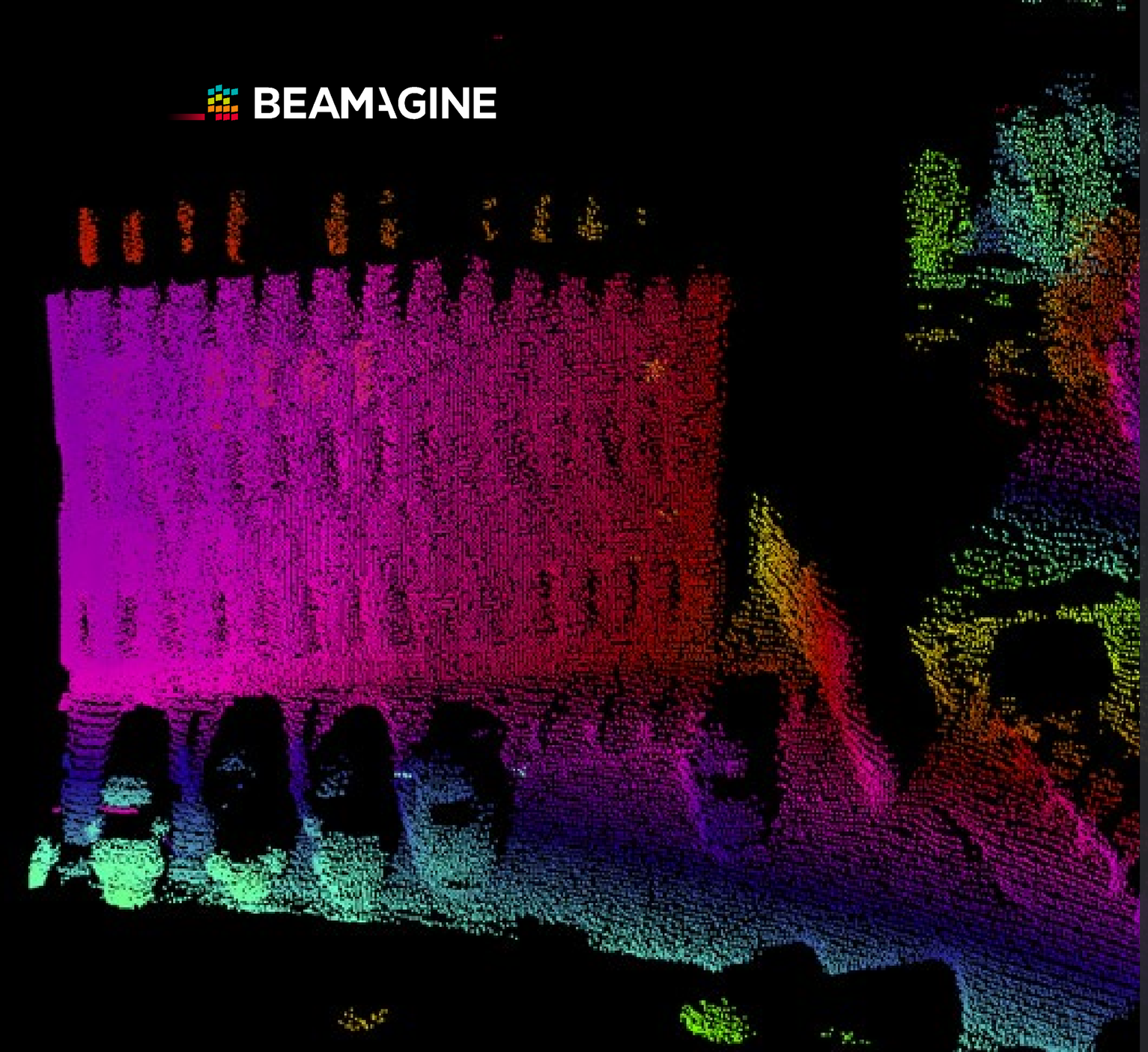
SYSTEM Specs	
Connection	1000Mbit Ethernet – UDP packets
Drivers	Windows, Linux and ROS. ONVIF possible
Operating voltage	12V-36V (regulated)
Power consumption	20W
Size (HxWxD)	10x17x15 cm
Weight	1.5Kg
Mounting	4 M4 screws at the bottom
Case protection	IP67
Temperature	-20ºC to +60ºC
Certification	CE, FCC, RoHS
Eye-safety	Class 1 eye-safe per IEC 60825-1:2014 (Class 3E available under demand)

LIDAR Specs	
Laser wavelength	1064nm
Range @ Class 1 **Solar background 250W/m²**	100m @ 10% reflectance 220m @ 50% reflectance
Range @ Class 3R **Solar background 250W/m²**	180m @ 10% reflectance 400m @ 50% reflectance
Resolution (HxV)	460 x 150 px
Angular resolution (HxV)	0.13º x 0.13º
FOV (HxV)	60x20º
Frame rate	10 fps
Point rate	700 Kpx/s

Specifications: general purpose unit

CCTV Specs	
Mono/Color	Color
Resolution (HxV)	4224 x 3156 (13MP) and 3840x2160 (UHD)
Shutter	Rolling shutter
FOV (HxV))	65x42º
Frame rate	20 fps
Pixel Bit Depth	12 bits
Sensor type	CMOS
Lens	S-mount or C-mount

THERMAL Specs	
Spectral response	7.8 to 14 microns
Resolution	640 x 240 px
FOV (HxV)	68 x 25º
Frame rate	25 Hz
Scene Dynamic Range	-40ºC to 330ºC
Sensor Sensitivity	65mK (typical), <100mK (max) @ 25ºC
Non-Uniformity Correction (NUC)	Automatic NUC (with shutter)
Focus	Fixed



LIDAR Imaging

Competitive advantages of LIDAR imaging

- It works in complex environments with crowds, buildings and cars (radar cannot)
- It functions in the presence of metallic objects (radar cannot)
- 3D data can be fused with other cameras
- It is unaffected by illumination or weather conditions
- 3D information is useful to determine the size of the objects because of the distance and volume data, which allows for better object classification and avoids errors generated by the aspect ratio at different distances

More advantages: LIDAR + CCTV + Thermal

- It guarantees minimum false alarms in any environmental condition (weather and day/night). At least two sensors are performing at all times
- Redundancy guarantees unprecedented robustness and reliability when it comes to AI perception algorithms
- Data fusion and calibration is carried out in house, unlike the cases where detached sensors are used

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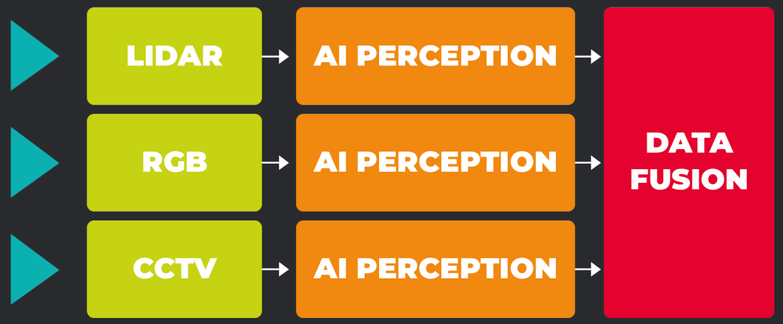
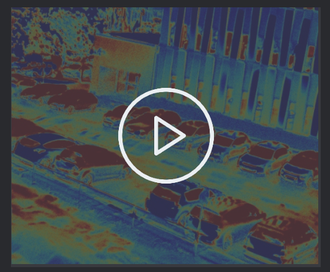
Congruent Data Fusion: Object vs Early Level

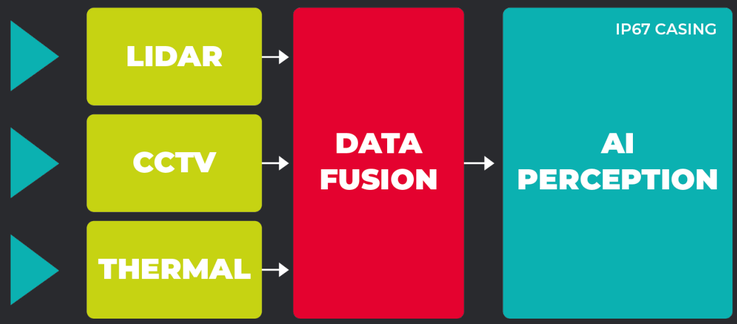
OBJECT LEVEL DATA FUSION APPROACH



- Parallax issues
- Insufficient reliability
- Not scalable



EARLY DATA FUSION APPROACH



- More processing strategies available
- Safer and more reliable
- More accurate environmental model
- Less processing power required

- BEAMAGINE CONGRUENT EARLY DATA FUSION
- No parallax error
- Calibrated in-house
- Embedded fusion and perception
- Alignment guaranteed for the whole sensor lifetime

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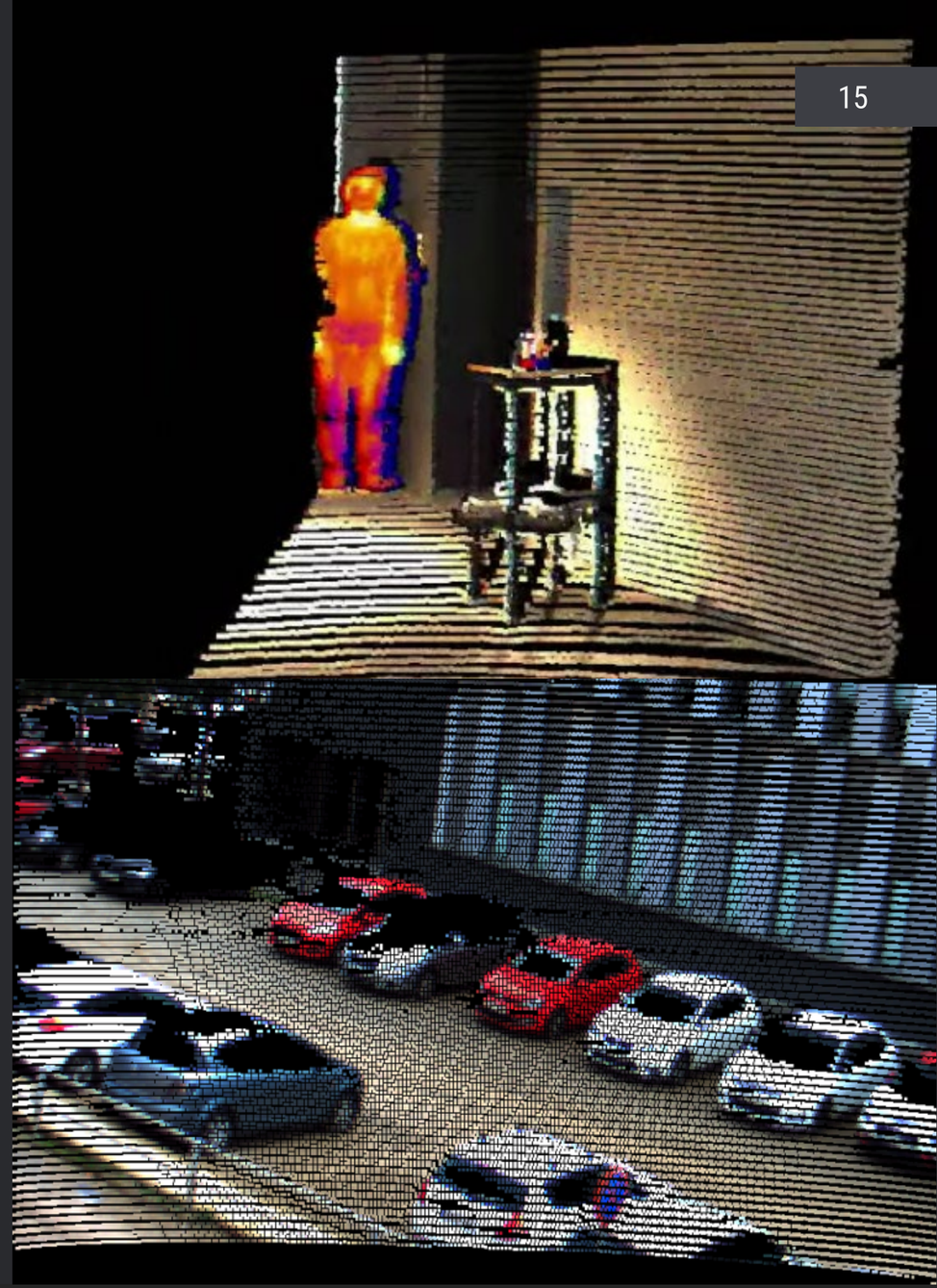
Congruent Data Fusion: Integrated vs Detached

Beamagine's Congruent Data Fusion is based on an integrated approach that has major advantages over the traditional detached concept.

	DETACHED	INTEGRATED
	The cameras are placed in different locations	Cameras are integrated into the same housing unit
Mechanical alignment	Performed by the user	Set in factory
Calibration	Performed by the user	Set in factory
Software integration	Complex, completed by the user	Completed in the factory
Data fusion	Performed by the user	Set in factory
Misalignments	Very likely	No
Parallax error	Yes	No
Recalibrations	Yes	No
Installation cost	High	Minimal



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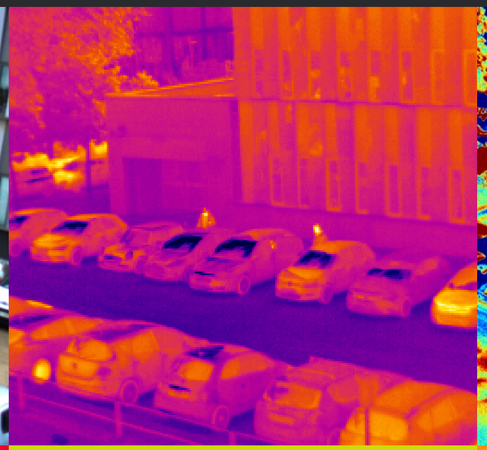
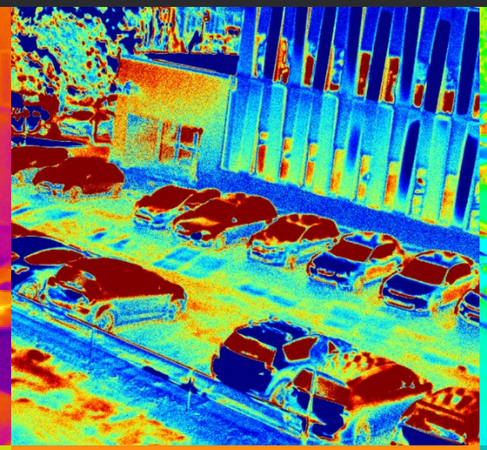
Congruent imaging modes

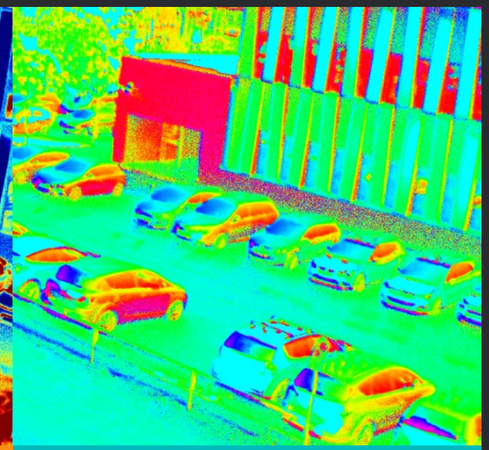
1) CCTV



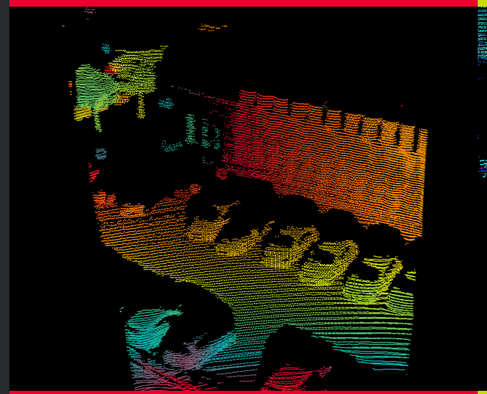
2) Thermal



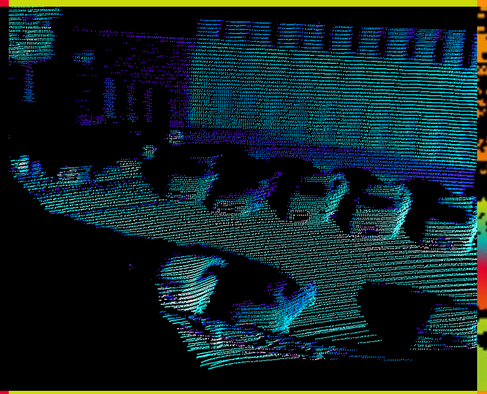
3) Polarimetric DoLP



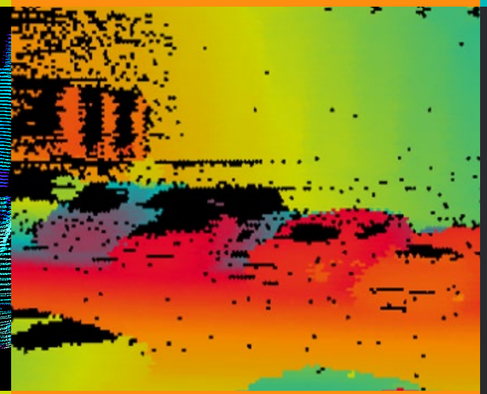
4) Polarimetric AoLP



5) 3D range LIDAR



6) 3D reflectance LIDAR



7) Depth map

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Congruent data fusion modes

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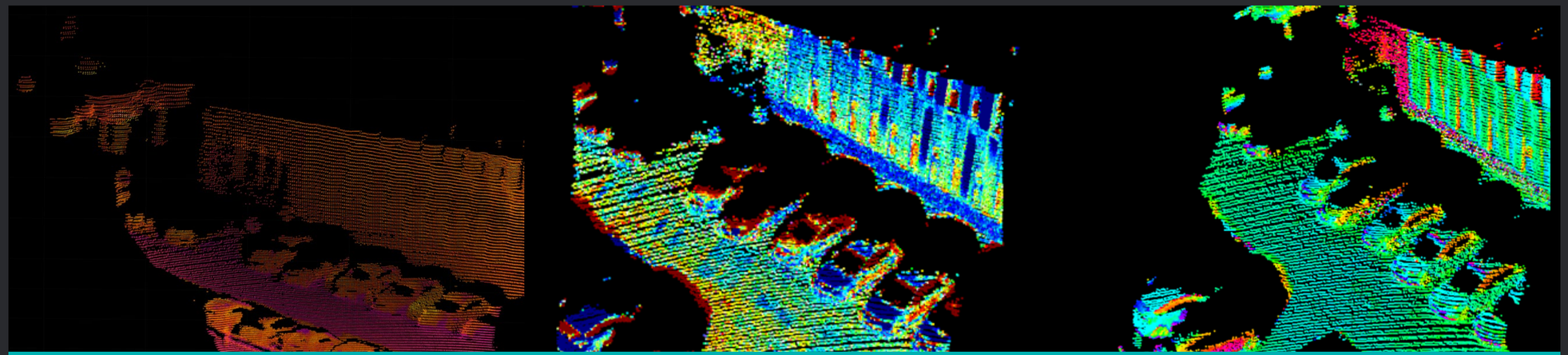
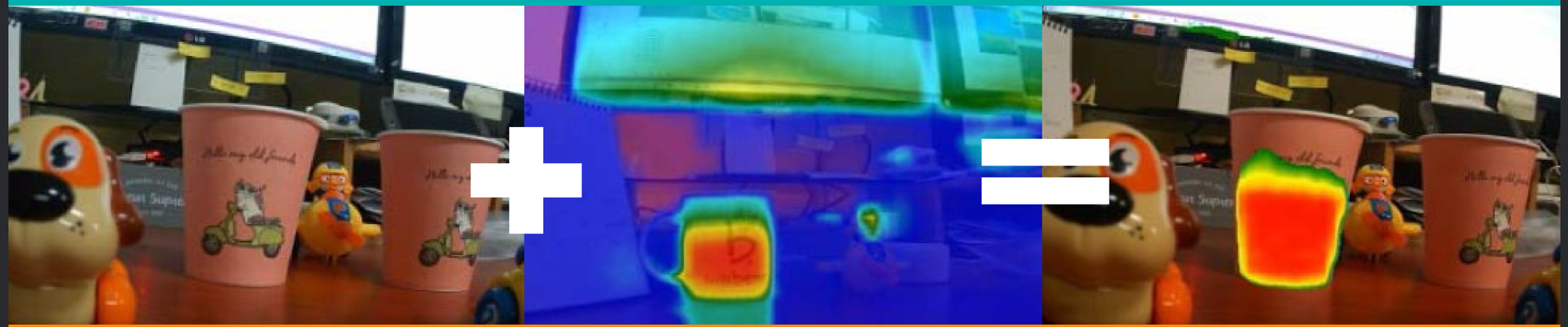
Congruent data fusion modes



9) 3D LIDAR + Thermal

10) 3D + Polarimetric DoLP

11) 3D + Polarimetric AoLP



12) CCTV + Thermal

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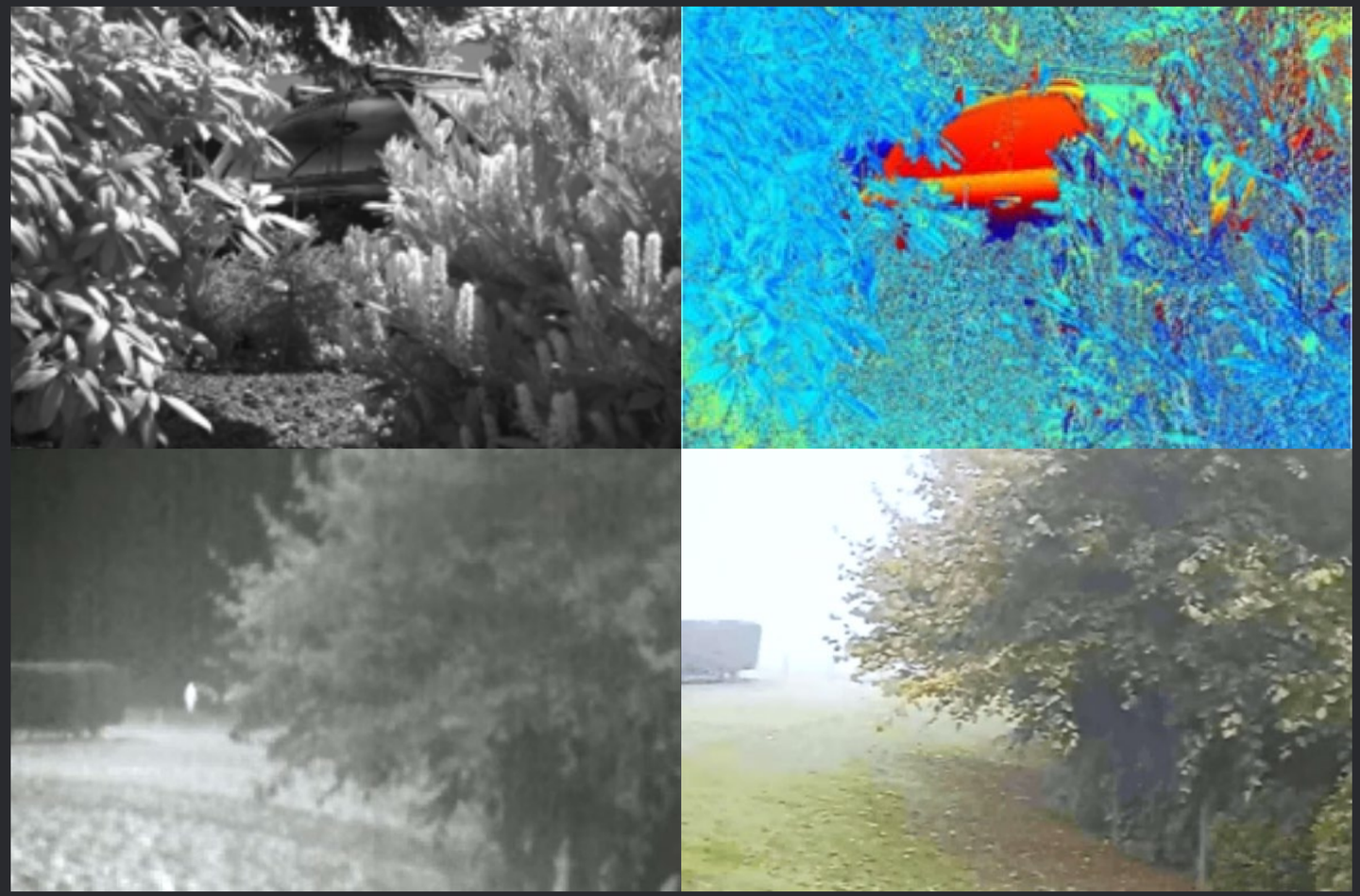
Congruent data fusion modes



- Polarimetry is ideal for detecting man-made objects that would otherwise be difficult to identify using traditional visible or thermal imagery. Camouflaged vehicles or structures still reflect polarized light oriented parallel to the surface. It stands out clearly in AoLP mode
- LIDAR in reflectance mode can detect materials according to its reflectance rate
- Day & night operation: LIDAR and thermal cameras work regardless of ambient light

- All weather operation:
  - LIDAR is not sensitive to heavy rain
  - SWIR or thermal imaging can penetrate fog or dust

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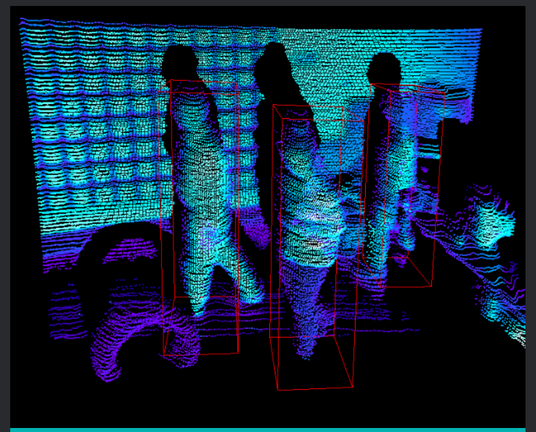
Perception AI: Towards zero false alarms

The combination of different imaging technologies and their advantages, ensures the system remains reliable in all operational scenarios, regardless of object type, material or weather conditions. False alarms can be eliminated by combining and capitalizing the information from these three sources.



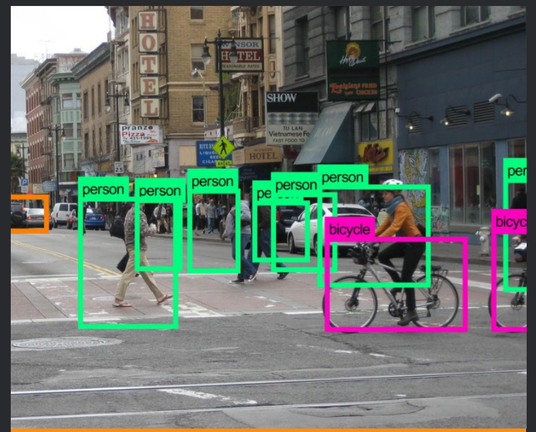
3D LIDAR

Pros:

- 3D information
- Small cross-section object detection
- Reliable data (day, night, and bad weather)

Cons:

- Sensitive to fog
- Short-medium range (<500m)
- Power consumption (20W)



CCTV

Pros:

- High-definition
- Color information
- Mature AI algorithms for perception

Cons:

- Sensitive to fog
- Unstable at night and low light
- No depth info

THERMAL

Pros:

- Stable in day and night conditions
- Fog penetration
- High contrast in human detection

Cons:

- Low resolution
- No depth info
- Less mature AI algorithms for perception

PRESENTATION OUTLINE

Technology details: outstanding features of the L3CAM

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Applications

CRANES

VEHICLE AUTOMATION

SECURITY AND SMART CITIES

AERONAUTICS

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Use cases

L3CAM is suitable for application in:

RAILWAY

- The sensor must be reliable enough to stop a train when an object is detected; false alarms are not permitted
- Automated trams
- Invasion of railway and metro tracks in stations
- Tram crossings monitoring
- Rail worker safety for maintenance tasks
- Level-crossing monitoring
- Suicide prevention

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Use cases

L3CAM is suitable for application in:

UNATTENDED CONTROL CENTERS

An excess of false alarms can lead to decreased attention from the operators and leave the infrastructure exposed.

ON-SITE SAFETY

Accident prevention in working areas with heavy machinery and people.

Use cases

L3CAM is suitable for application in:

PERIMETER PROTECTION OF CRITICAL INFRASTRUTURES

- Installations that already have a security system but want to improve or eliminate false alarms with the implementation of new technologies
- Facilities that trigger complex protocols when an intrusion is detected (whether false or not) and that have serious consequences when a mistake is made
- Installations with large metallic objects or with a lot of activity (radar has issues with these)

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Use cases

L3CAM is suitable for application in:

ACCESS CONTROL

Reporting on tailgating or unauthorized entry into restricted areas for immediate warning.

CROWD ANALYTICS

Keeping track of crowd flow and room occupancy.

Use cases

L3CAM is suitable for application in:

AUTONOMOUS OFF-ROAD VEHICLES

- Construction vehicles
- Airports service vehicles
- Resort vehicles
- Defense AGV
- Container platforms in ports
- Among many others

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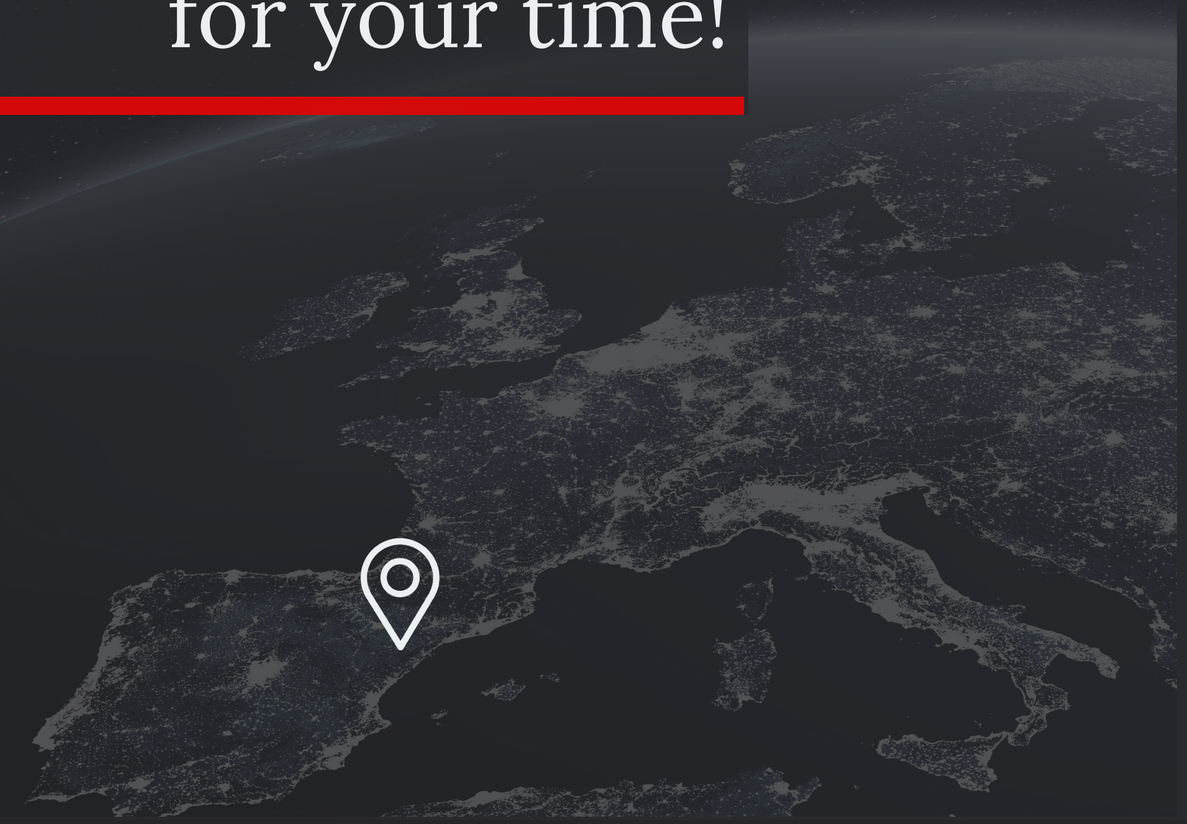
Thank you for your time!



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