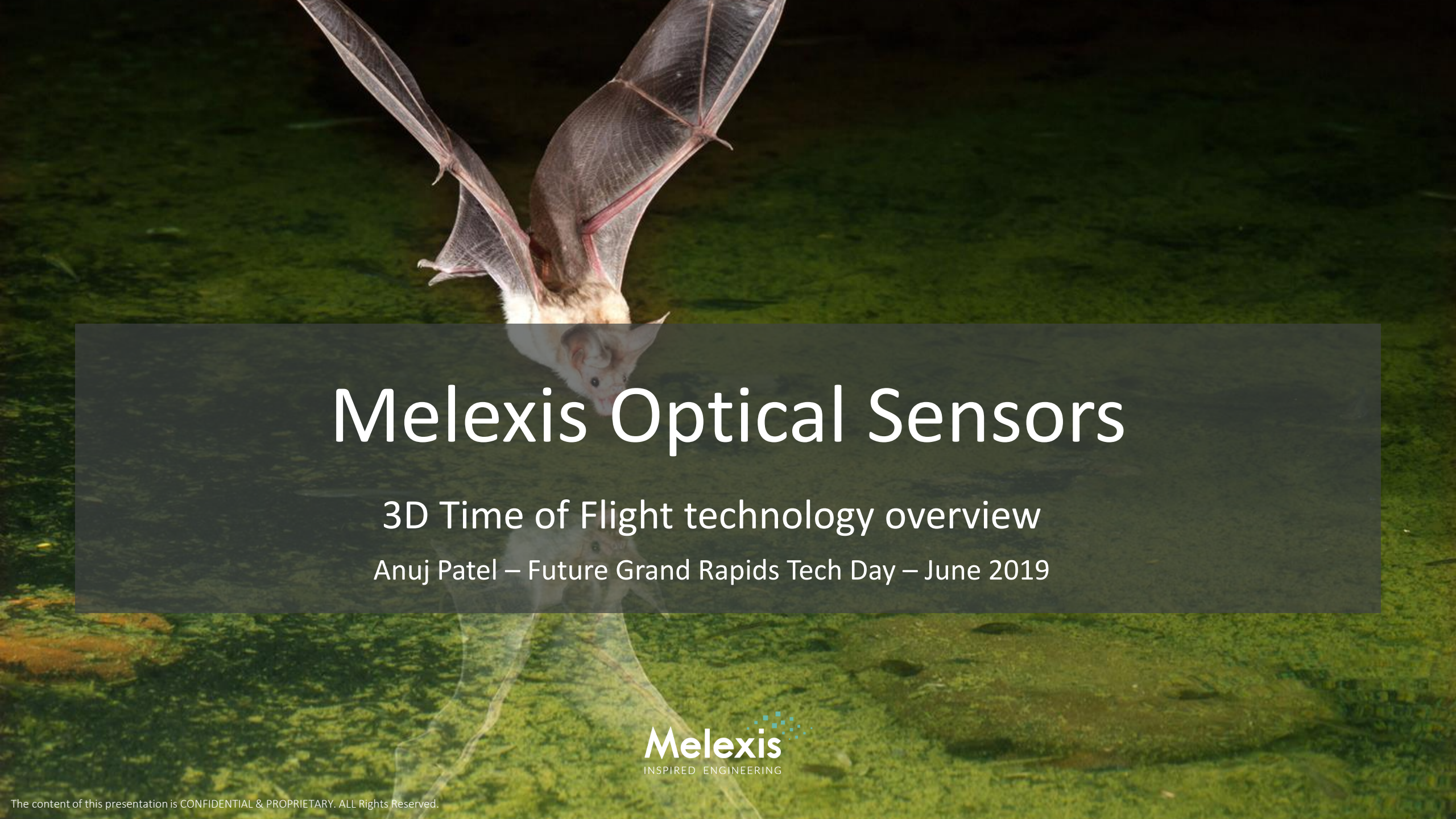


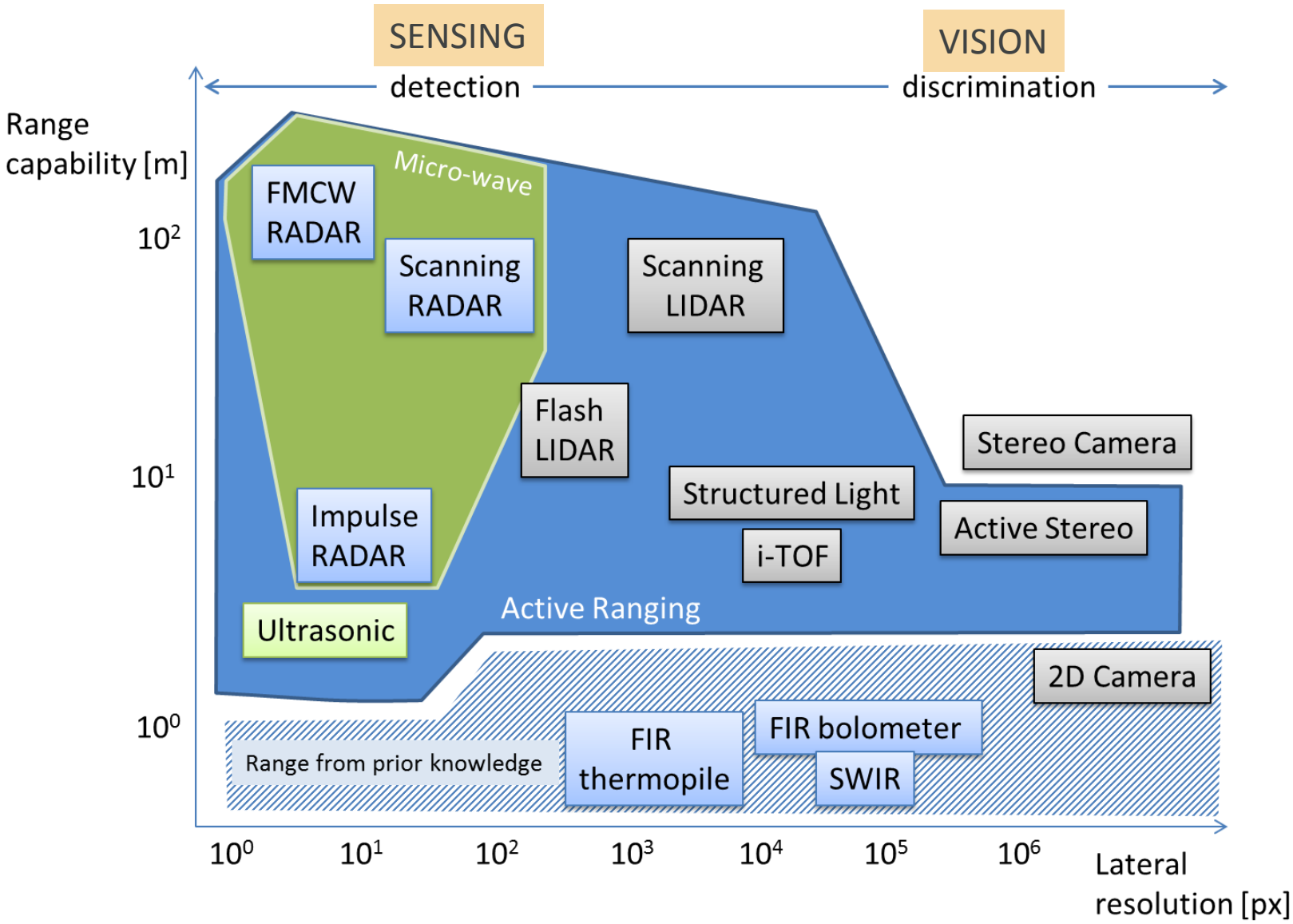
Melexis Optical Sensors

3D Time of Flight technology overview

Anuj Patel – Future Grand Rapids Tech Day – June 2019

Melexis
INSPIRED ENGINEERING

Range Sensing & 3D Vision Technologies



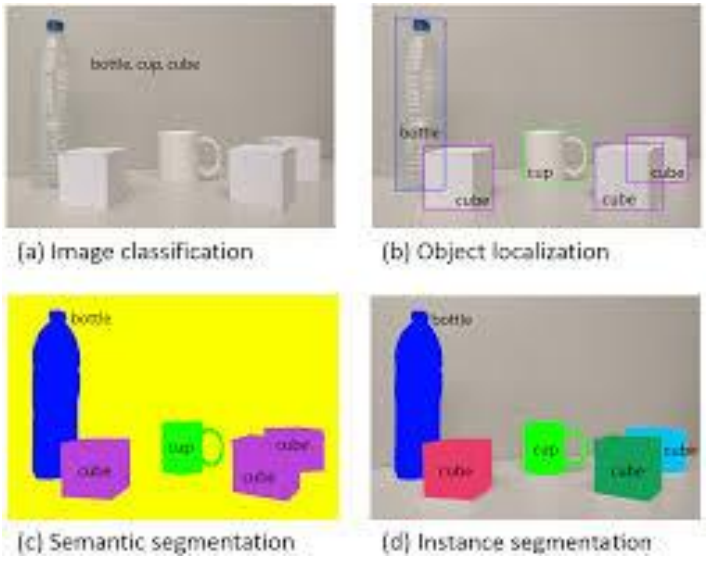
2D vs 3D sensing: what's the task?

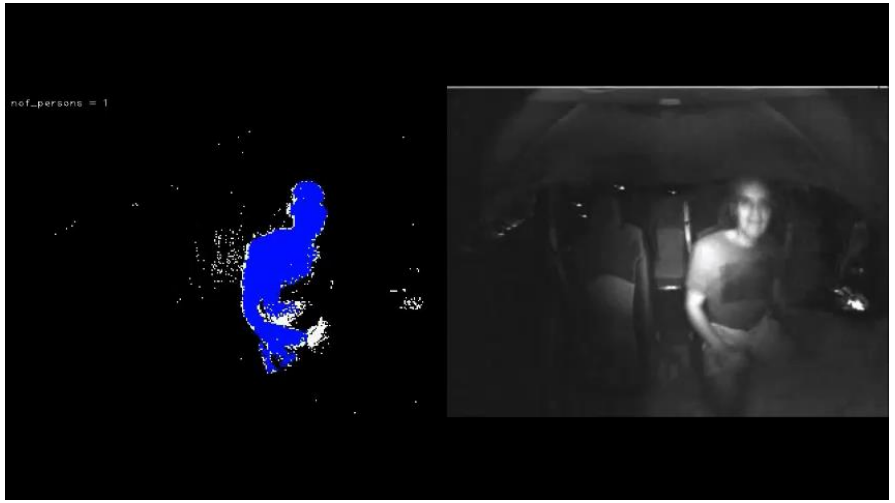
- 2D image processing
  - Suitable whenever the application offers high contrast or if the structure and colour of the object are decisive for the end result.
- 3D image processing
  - Required whenever volumes, shapes or the absolute position to the object in the space is required.

Task	2D	3D
Analysis of volumes and shapes		✓
Recognize structure and color	✓	
Good contrast information	✓	
Contrast information poor or missing		✓
Positioning/detects objects in the third dimension		✓

3D sensing – key advantages

- **Semantic segmentation**: dividing a picture into multiple meaningful parts
  - Partition of an image into several "coherent" parts
  - 3D depth data enables to easily distinguish foreground and background, or volume of interest (threshold algorithm)
  - Basic area-growing algorithm or clustering algorithm can then be used with lower computation load

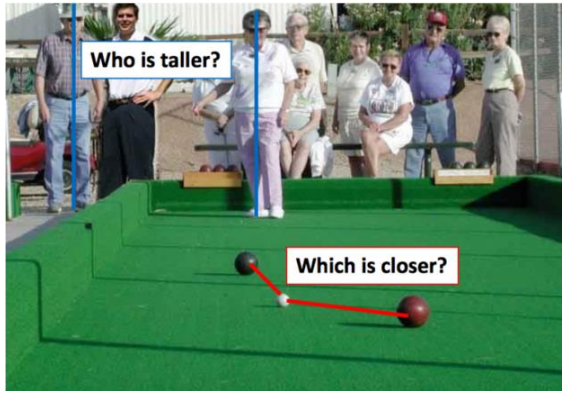




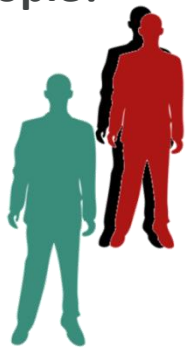
QVGA TOF Sensor: example of simple pixel clustering

3D sensing – key advantages

- **Absolute position**
  - Computer vision based on 2D sensor cannot easily resolve the position of **similar objects** in the space



2 or 3 people?



Position and size of objects

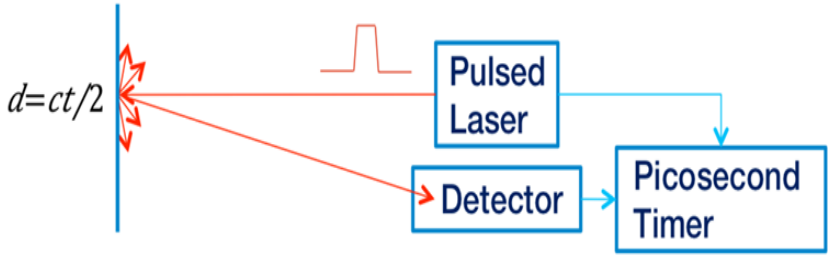
Face recognition

  - Example:
    - Passenger classification can be carried out with 2D sensor and CV (*), using the shape of the seat as reference
      - Seat position sensor is needed to estimate the absolute position
      - Thickness of the passenger is not available
    - 3D sensor gives the absolute position of the passenger
    - Seat position sensor is not needed

(*) Computer Vision

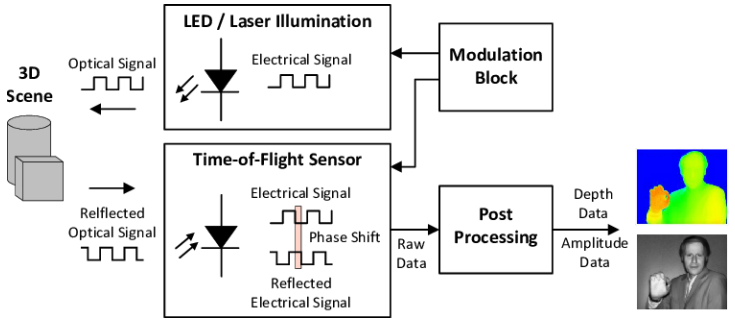
Time of Flight for 3D Sensing

- Reliable operation in sunlight
- Direct TOF (LIDAR) = time sensing
  - Complex electronics!
  - Ideal for long range 50-250m, **low** pixel count



Source: SensL, http://sensl.com/applications/lidar1/adas/

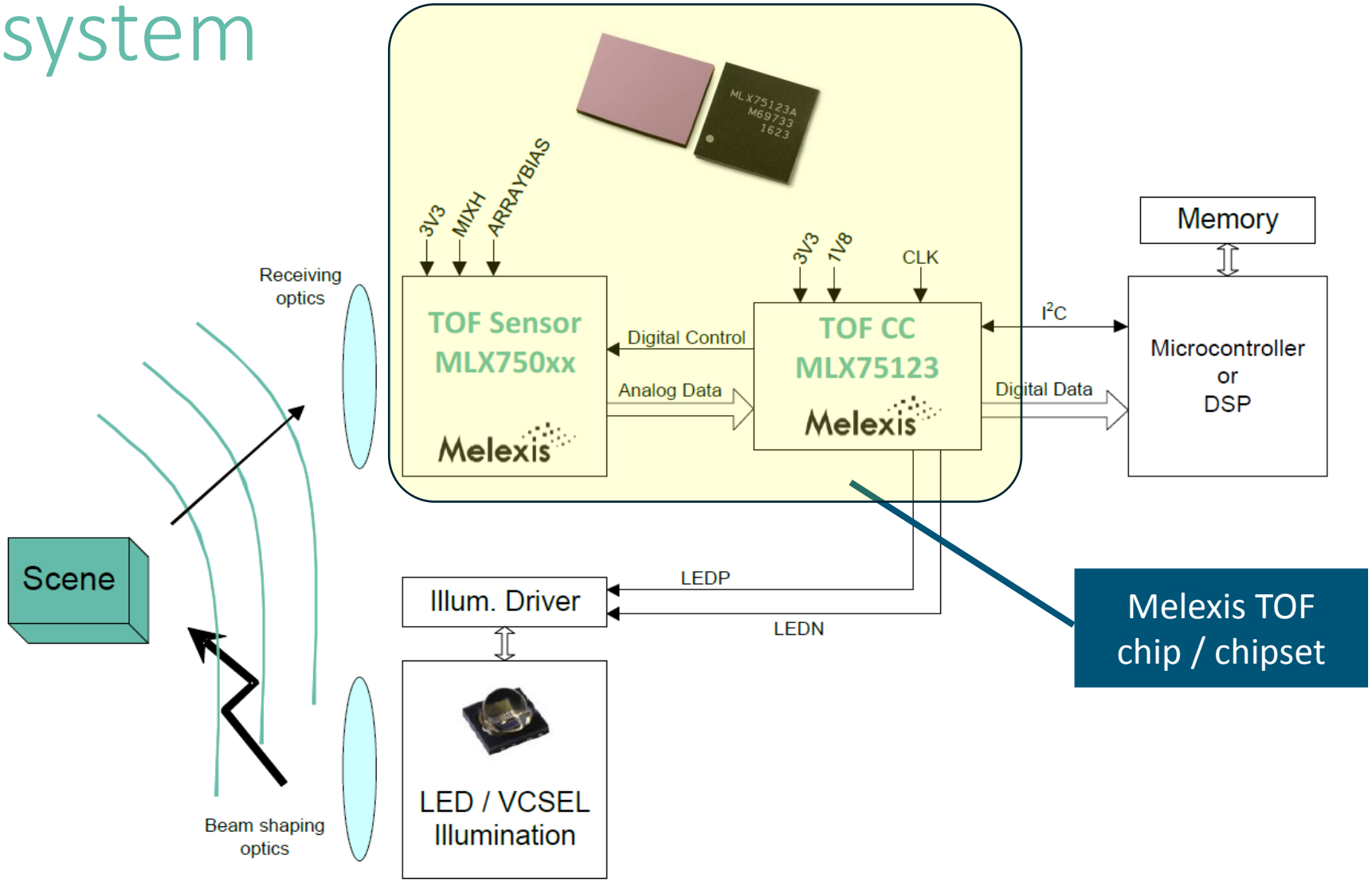
- Indirect TOF (iTOF) = phase sensing
  - CMOS compatible
  - Compact
  - Cost effective
  - Ideal for short range, **high** pixel count, wide FOV, @video frame rate



Source: ResearchGate, https://www.researchgate.net/figure/302302710_fig1_Fig-1-The-working-principle-of-an-indirect-PMD-based-Time-of-Flight-depth-sensing

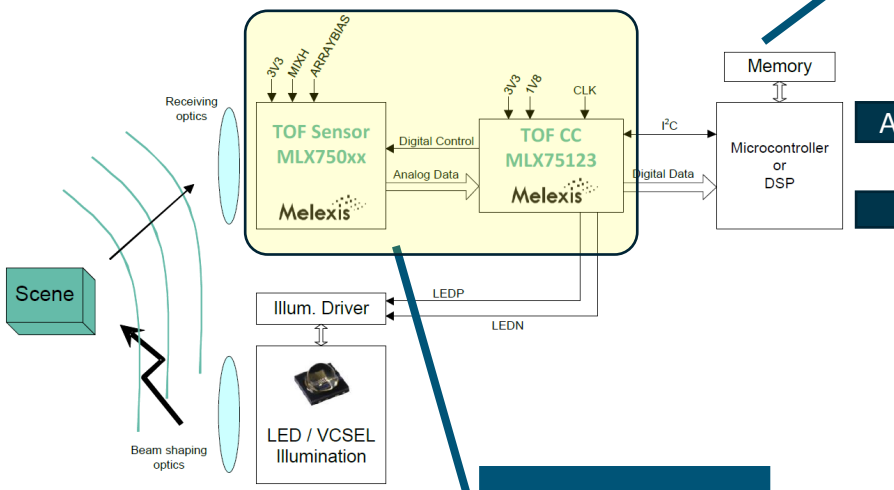
Products and System

iTOF system



iTOF data processing steps

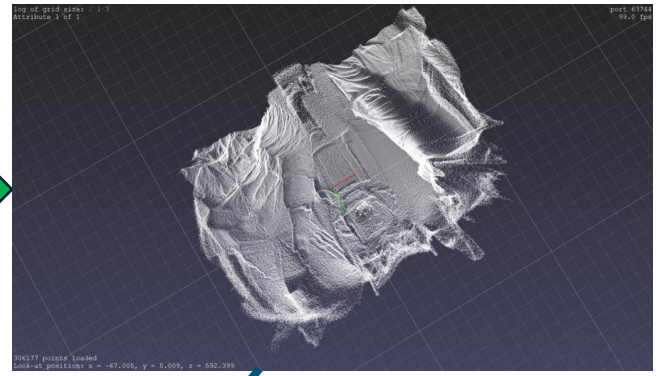
Host controller depth & amplitude calculation



Amplitude

Depth

Pointcloud (FOV lens)

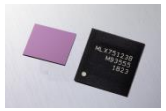
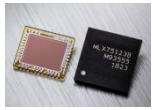
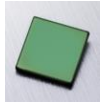


ToF sensor or chipset

3D image, can be viewed from different perspective

ToF sensor portfolio - overview

Feature	Gen 1 QVGA chipset MLX75023+MLX75123	Gen 2 QVGA chipset MLX75024+MLX75123	Gen 3 VGA Single chip MLX75027
Resolution	320 x 240		640 x 480
Pixel size	15x15um^2		10x10um
External quantum efficiency (Typ)	10% @ 850 nm	23% @ 850 nm 13% @ 940 nm	44% @ 850 nm 25% @ 940 nm
Full Well Capacity	240 ke-	450 ke-	160 ke-
Integrated optical filter or ARC	850nm BP filter	Double-sided ARC, No BP filter	
Sensor format	1/3”		1/2”
Pixel gain	fixed	x1…x3 selectable	fixed
Built-in temp. sensor	N/A	Tj accuracy +/-5 ^{o}C absolute	
Max modulation Frequency	40 MHz		100 MHz
Data interface	Parallel Video port		CSI-2 D-Phy 2 or 4-Lane

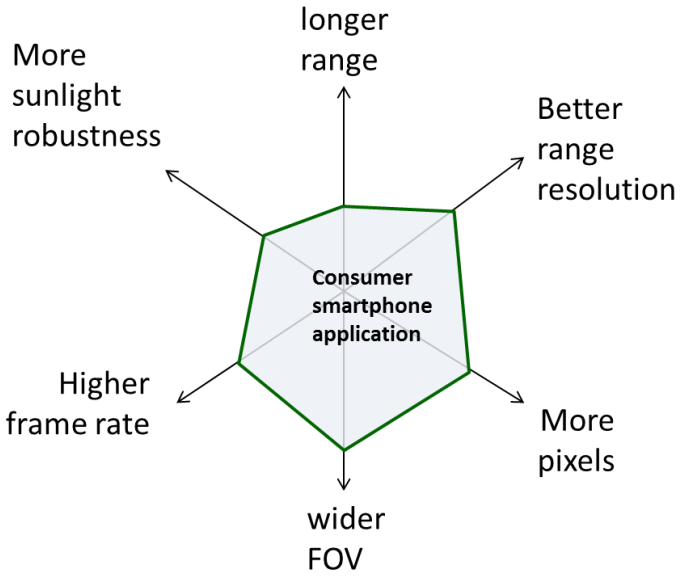




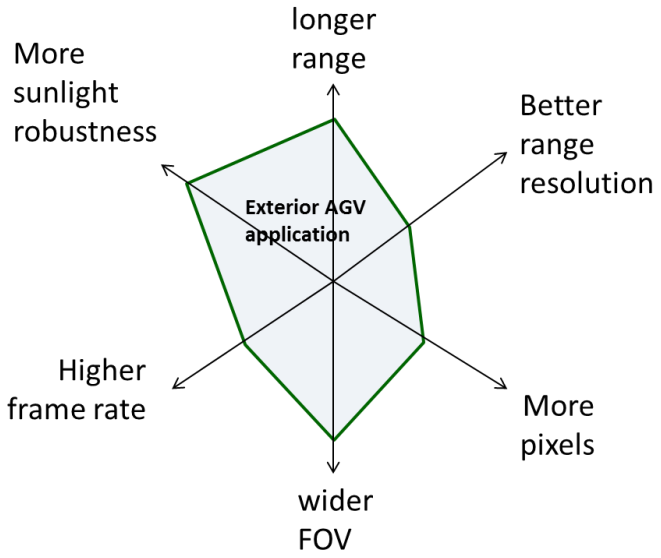
Applications

iTOF – typical application challenges

- Range accuracy
- Sunlight
- Frame rate
- Temperature
- Calibration
- Size
- Cost

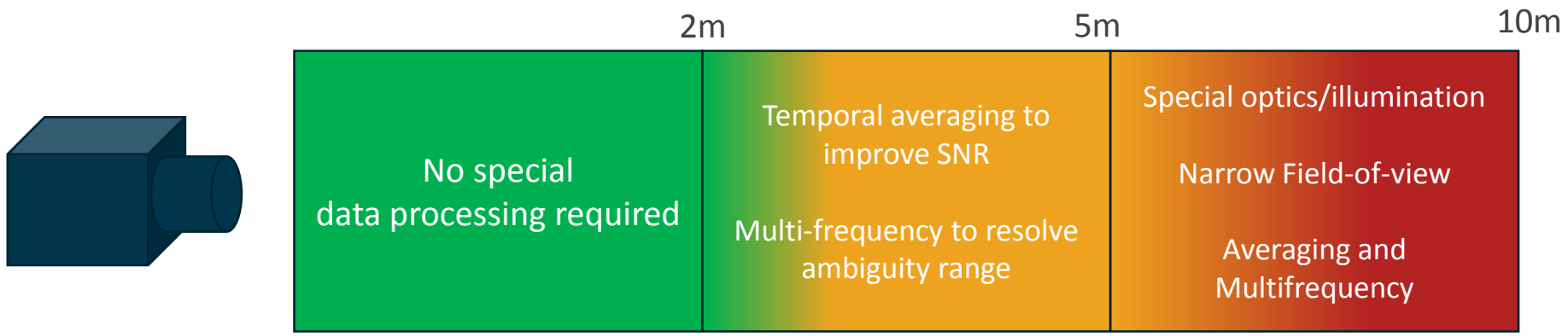
Trade off examples



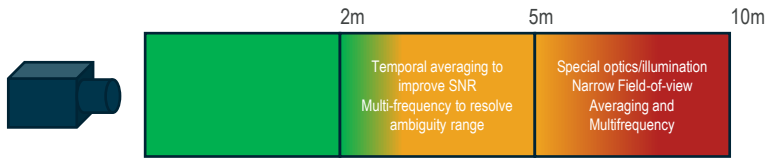


iToF technology typical range

- Achievable distance range depends on several factors
  - Reflectivity of the target (10%..90%)
  - Illumination power on the scene
  - Field of view: less useful signal with larger FOV and same illumination power

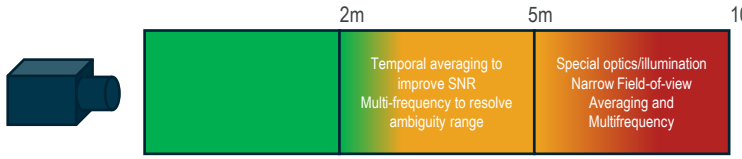


iTOF sensor – Typical Use Cases



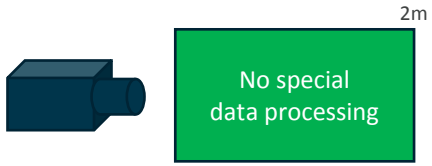
	range	Gen 1 QVGA chipset MLX75023	Gen 2 QVGA chipset MLX75024	Gen 3 VGA Single chip MLX75027	
Object Identification & Tracking		✓	✓	✓	Gen1 has 850nm integrated IR BP filter
Object Sizing & damage control			✓	✓	Depending on the size of the object and required spatial resolution
Obstacle detection & collision avoidance		✓	✓		
Approach & Docking			✓	✓	Depending on Field of View and required spatial resolution
Dynamic safety perimeter			✓	✓	Depending on Field of View and required spatial resolution
Gesture control & behavioural prediction		✓	✓		High resolution it is usually not necessary
Robotics mapping and navigation (SLAM)			✓		Cost sensitive application
People counting (shops ,public transportation)			✓	✓	
Smart lighting			✓	✓	High spatial resolution and depth accuracy to carry-out accurate object classification

iTOF sensor – Automotive Use Cases



	range	Gen 1 QVGA chipset MLX75023+75123	Gen 2 QVGA chipset MLX75024+75123	Gen 3 VGA Single chip MLX75027	
Indoor / Interior		850 nm	850 nm or 940 nm		
Gesture recognition		✓	✓	✓	Gen1 has 850nm integrated IR BP filter
In cabin monitoring – Front seat			✓	✓	940nm IR illumination, not visible to human eye
Full in-cabin monitoring				✓	VGA to cover wide area with enough spatial resolution
Head pose, hands on wheel			✓	✓	940 nm IR illumination, not visible to human eye
Object detection & tracking		✓	✓	✓	Depending on Field of View and required spatial resolution
Outdoor / Exterior			940 nm		
Gesture recognition			✓	✓	
Object detection & tracking			✓	✓	Depending on Field of View, depth accuracy (Fmod) and minimum object size
Object classification & tracking				✓	High spatial resolution and depth accuracy to carry-out accurate object classification

Automotive : comparison 2D vs 3D sensor



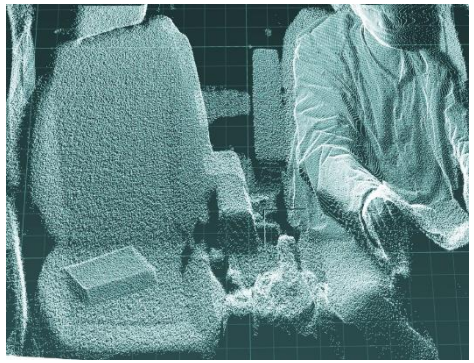
	2D	TOF 3D	Key differentiator or reason
Gesture recognition	✗	✓	Reliable detection in volume of interest and dynamic light/shadow conditions
Head pose & tracking – small angles & movements	✓	✓	
Head pose & tracking – nodding, large angles & movements	✗	✓	Salient points can be tracked in 3D
Face recognition	✓	✓	
Face recognition for authentication	✗	✓	Anti-spoof thanks to depth data
Eye opening & blinking	✓	✓	
Eye gaze	✓	✓	
Hands-on-wheel	✓	✓	Resolve occlusions thanks to depth information
Hands-on-wheel – approaching & leaving	?	✓	Absolute hand position thanks to depth data
Occupancy detection – front & rear seats	✓	✓	
Passenger classification (adult, a front/rear-faced child seat..)	?	✓	Body volume & height
Passenger position – for control of airbag deployment	?	✓	Real time absolute body position thanks to depth data
Arm & body tracking	✗	✓	Reliable detection in volume of interest and dynamic light/shadow conditions
Seat position & orientation	✗	✓	Absolute position & angle thanks to depth data
Object position & orientation (e.g. smartphone)	✗	✓	Absolute position & angle thanks to depth data

ToF sensor evaluation kit

Evaluation Kit

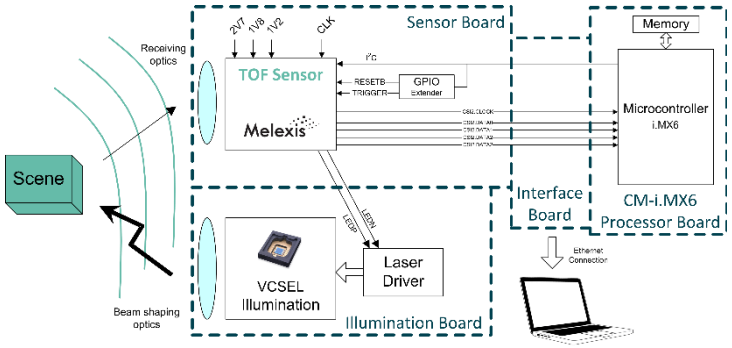
Key Features

- Exchangeable sensor optics (standard S mount)
- Distance & confidence data at max. 60 FPS
- Raw data mode(s)
- Visualizer, C API & Matlab SDK
- Dimensions: 80 x 50 x 35mm (full module)



Modular concept

- four stacked PCBs (from top to bottom)
  - illumination board
  - ToF sensor board
  - interface board
  - processor board.



It is possible to detach the top two PCBs from the bottom two PCBs by bypassing the board to board connection with an external cable suitable for FPD-Link III communication

Evaluation Kit – available versions

Feature	Part number	FOV	Wavelenght	Illlumination
Gen 1 QVGA	EVK75123-110-850-1	110°	850nm	VCSEL
	EVK75123-60-850-1	60°	850nm	VCSEL
Gen 2 QVGA	EVK75024-80-940-1	80°	940nm	LED
	EVK75024-110-940-1	110°	940nm	VCSEL
Gen 3 VGA	EVK75027-110-940-1	110°	940nm	VCSEL

Thank you

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