INDUSTRIAL SUMMIT 2024
POWERING YOUR SUSTAINABLE INNOVATION

Imaging 3D Sensing And IoT Solutions

Sebastian Tu

Agenda

1. ST IMG Introduction And Roadmap
2. SPD And Gesture
3. Cup Detection
4. 2.3k d-ToF L9 Module
5. Global Shutter
6. 3D-ITOF

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25 Years Of Optical Sensing

1986 — **The University of Edinburgh** Initiates work in CMOS sensor early paper on CMOS imaging

1990 — **Creation of VISION** startup from The University of Edinburgh

1999 — **ST acquires VISION**

2002 — 1M camera module & ISP shipped for mobile

2003 — Large volume camera proliferation in Nokia camera phones

2009 — 500 million ISP shipped

2012 — Start customer & application diversification

2014 — **Time-of-Flight** Ranging sensor ramp-up

2015 — FlightSense pervasion in smartphones

2017 — High volume **global shutter** production

2018 — ST 1st ALS product launched

2019 — 1Bu FlightSense Shipped\

FlightSense Proliferation in PC & Mass Market

2020 — **Open-Market** global shutter

ODIFF technology ramp-up

2021 — **High volume ALS** production

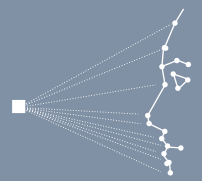
2022 — **Automotive** global shutter

Multizone ToF market acceleration

Worlds 1st metasurface in MP

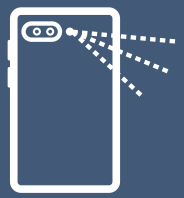
Optical Sensing Solutions

Core applications



Smartphone front facing

- Face authentication
- Biometrics
- Ambient Light sensing



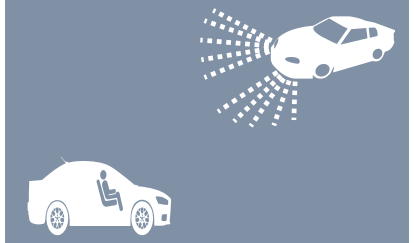
Smartphone world facing

- Camera assist (bokeh, laser autofocus..)
- Ambient Light sensing

PC / laptops

- Low power presence detection
- Face authentication
- Security

High growth areas



Automotive

- Driver monitoring
- Occupancy monitoring
- Exterior camera

Industrial

- Robotics
- People counting
- Touchless operation
- Smart home
- Payment terminals
- Edge AI sensor

Emerging applications

- AR / VR / MR
- Consumer lidar
- Gesture control
- AI computer vision

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ST Imaging | Track Record

dToF module
Direct ToF

Single point to multizone

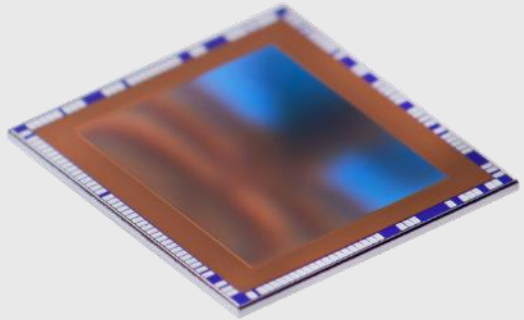
All-in-one module

SPAD 40 nm process

>2 Bu
ToF sensors sold

n°1

3D ToF sensor
Indirect ToF

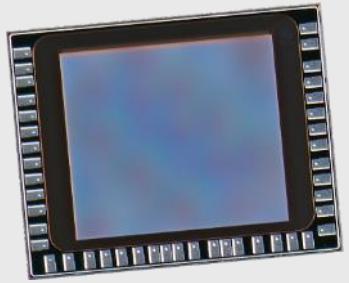


High resolution

Indirect & direct ToF

3D stacked BSI 40 nm

Global shutter
2D camera sensor



High sensitivity

Smallest size

Ultralow power

>1 Bu
Global shutter sensors sold

n°1

ALS & combo
Ambient light sensing

ALS & proximity sensor

High sensitivity

Under OLED operation

>500 Mu
ALS sensors sold

FlightSense Industrial & Mass Market Portfolio

Multizone

- 256 — High resolution (up to 256 zones) Histogram mode
- Up to 64 zones (8x8) AI enabler CNH data
- 64 — Up to 64 zones (8x8) Histogram mode Autonomous mode

Single zone

- Histo — Distance up to 8 m Histogram mode High ambient immunity
- 400cm — Ranging up to 4 m Autonomous mode
- Proximity up to 1.3 m Short distance linearity Ultralow power

LONGEVITY 7 YEARS COMMITMENT

VL53L8UX
65° FoV
256 zones (16x16)
300 cm dark
Low power consumption

VL53L7CH
90° FoV
64 zones (8x8)
350 cm dark

VL53L8CH
65° FoV
64 zones (8x8)
400 cm dark/285cm amb
Low power consumption

Compact normalized histogram

STGesture™ recognition

VL53L5CX
65° FoV
64 zones (8x8)
400 cm dark/170cm amb

VL53L7CX
90° FoV
64 zones (8x8)
350 cm dark

VL53L8CX
65° FoV
64 zones (8x8)
400 cm dark/285cm amb
Low power consumption

VL53L3CX
25° FoV
500 cm dark/140cm amb
ULP mode

VL53L4CX
18° FoV
600 cm dark/180cm amb
10 mm linearity

VL53L1CB
27° FoV configurable
800 cm dark/160cm amb
Sequential 2x2 zones

VL53L0CX
25° FoV
200 cm dark

VL53L1CX
27° FoV configurable
400 cm dark/130cm amb
ULP mode

VL6180V1
25° FoV
60 cm dark
10 mm linearity

VL6180X
Integrated ambient light sensor

VL53L4CD
18° FoV
130 cm dark
1 mm linearity
ULP mode

VL53L4ED
18° FoV
130 cm dark
1 mm linearity
40°C to 105°C
Extended temperature range

Ultralow power mode

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Legend: Legacy product | New product | Recent product | Tentative

SPD and Gesture

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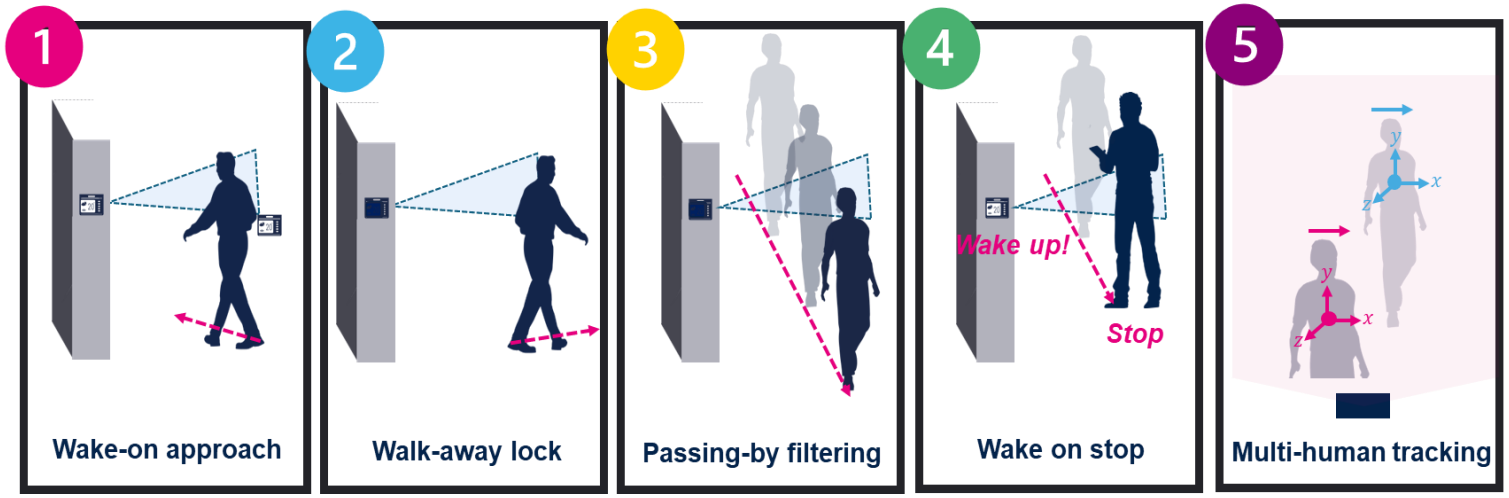
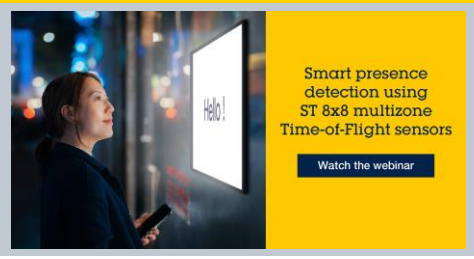
Smart Presence Detection



Access the on-demand webinar



FlightSense for presence detection

- 100% privacy, no image
- Real and accurate distance measurement
- Works even in the dark
- All-in-one module easy to integrate

2 Multizone Time-of-Flight

VL53L7CX

- **90° wide FoV**
- Up to 350 cm ranging

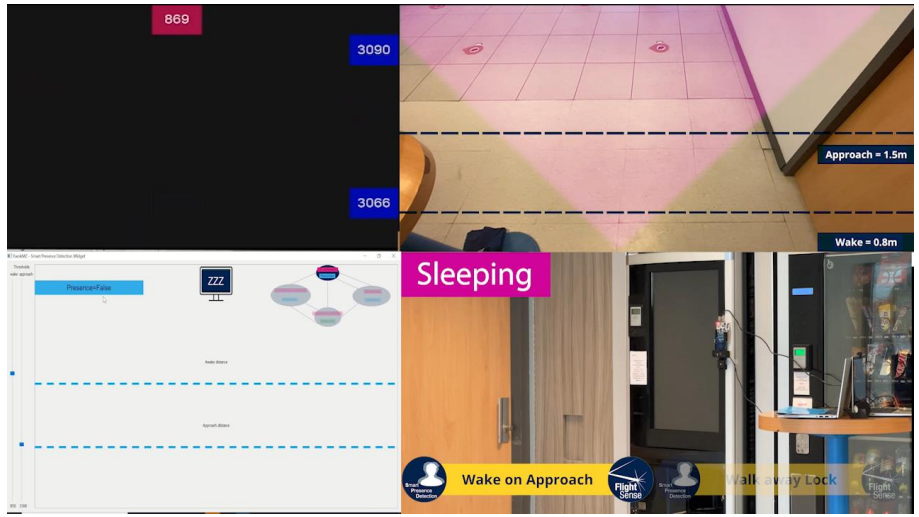
VL53L8CX

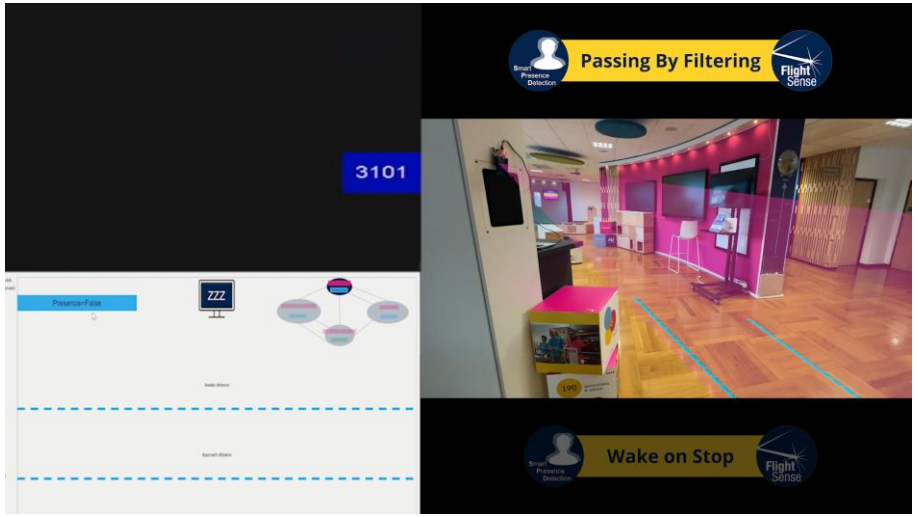
- **Ambient light immunity**
- **Low power**
- 65° wide FoV
- Up to 400 cm ranging

3 Solution outputs

1. **Presence flag**
2. User x, y, z positions
3. User speed

Live demo using the VL53L8CX





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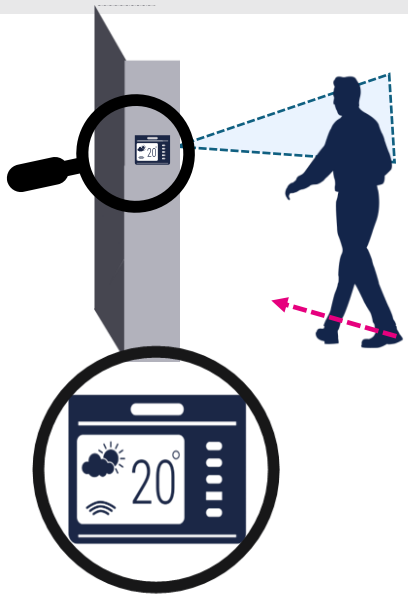
Wake-on Approach / Walk-Away Lock

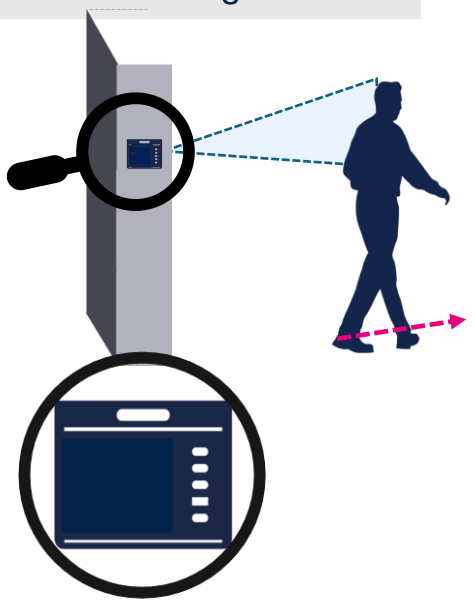
Wake-on approach

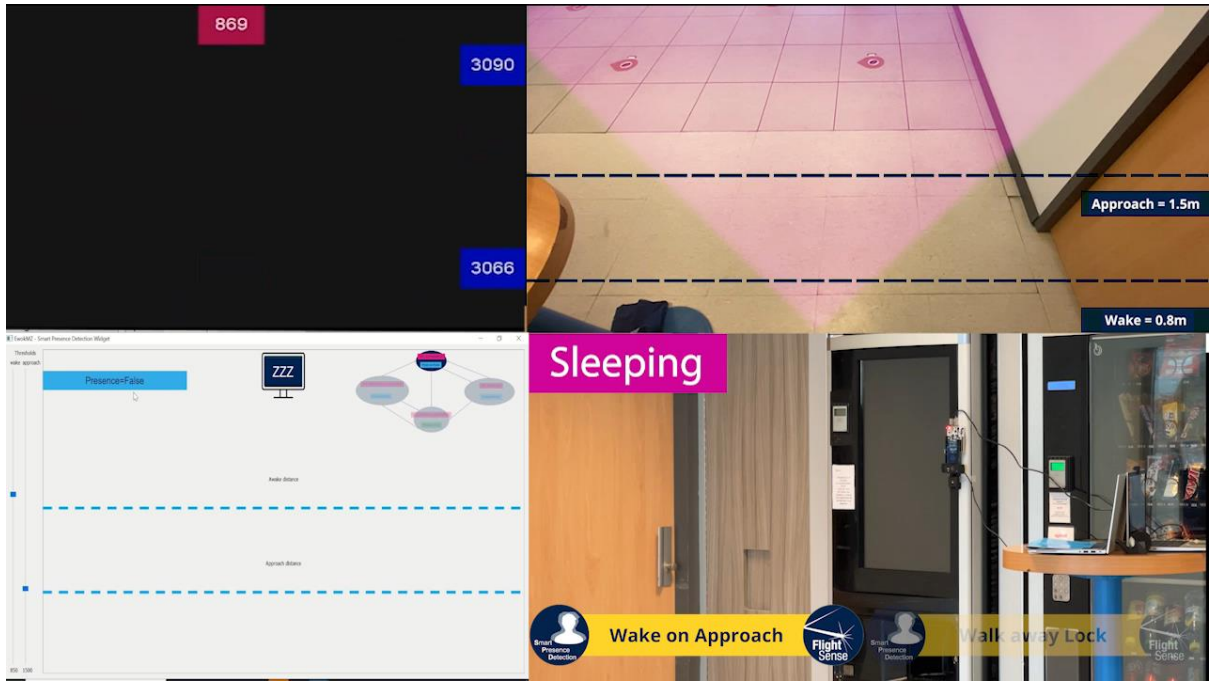
Analyze scene changes and allows to wake a system up



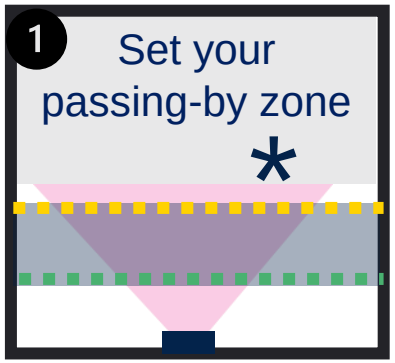
Walk-away lock

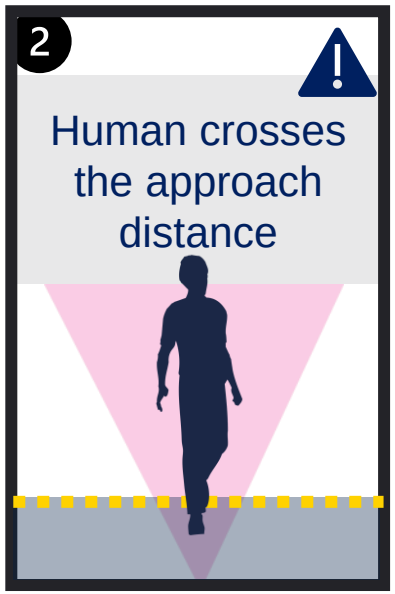
Allow to turn a system off automatically when the user is leaving.

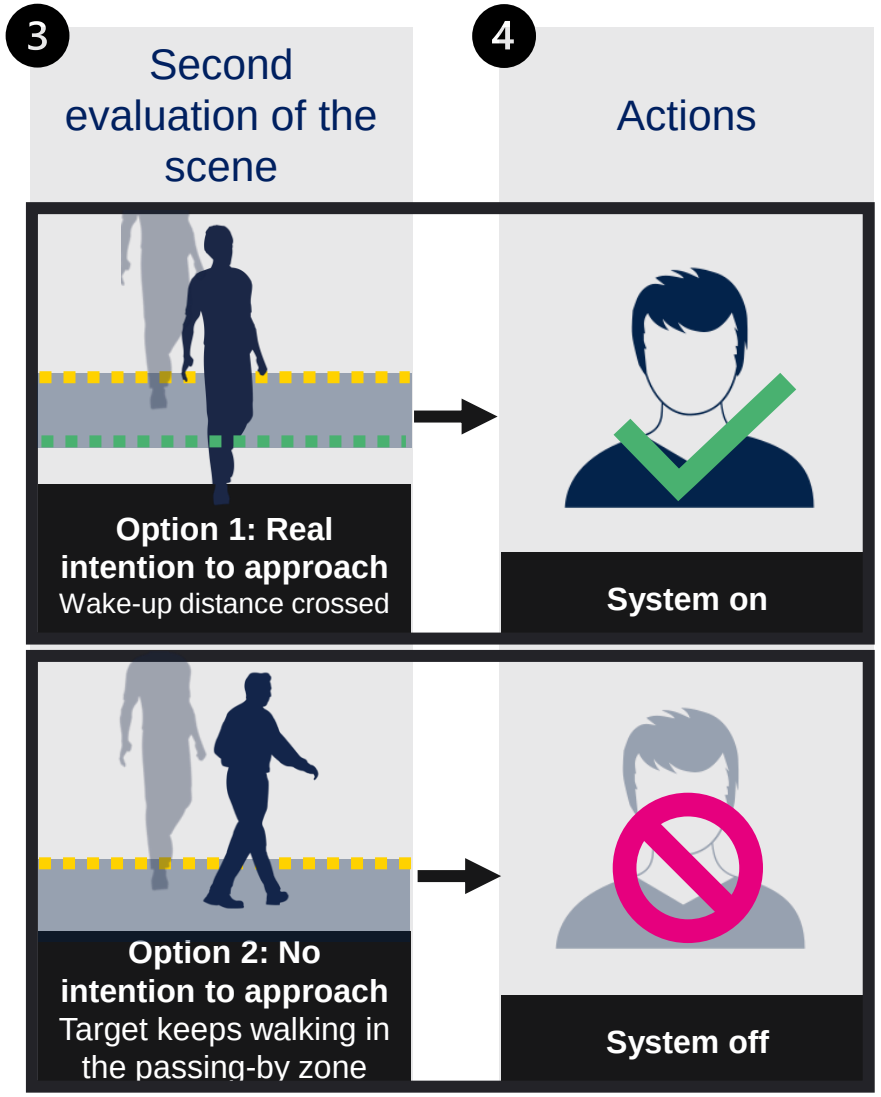


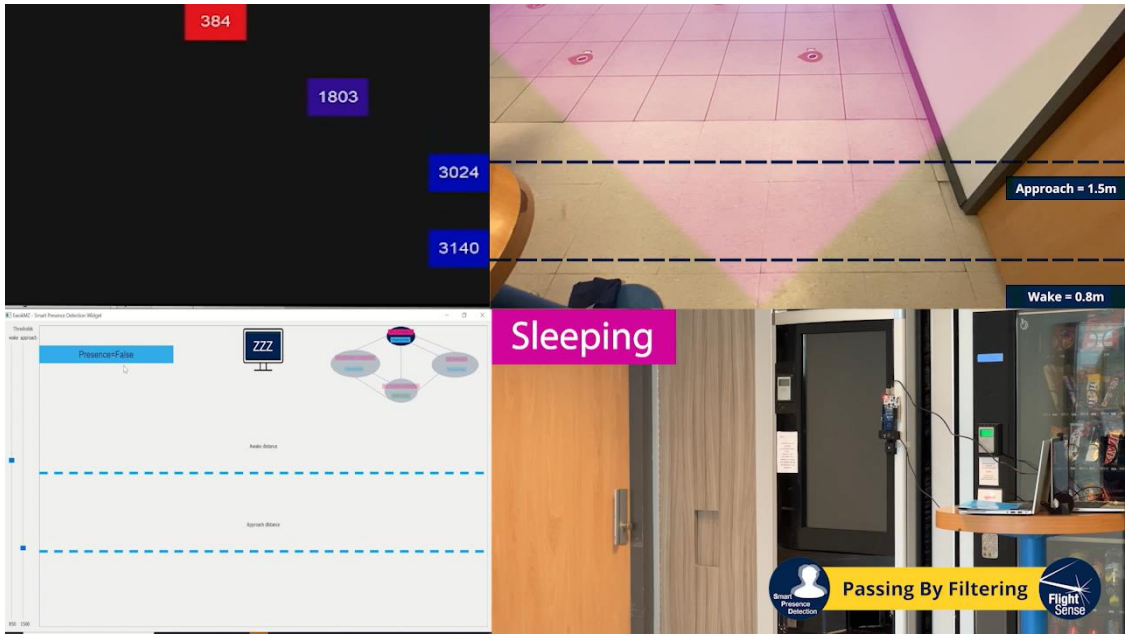


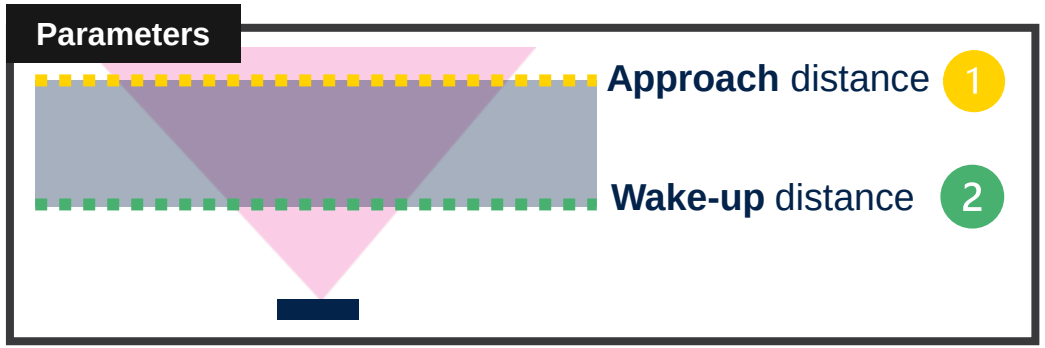
Passing-by Filtering
Avoids Unnecessary Activation











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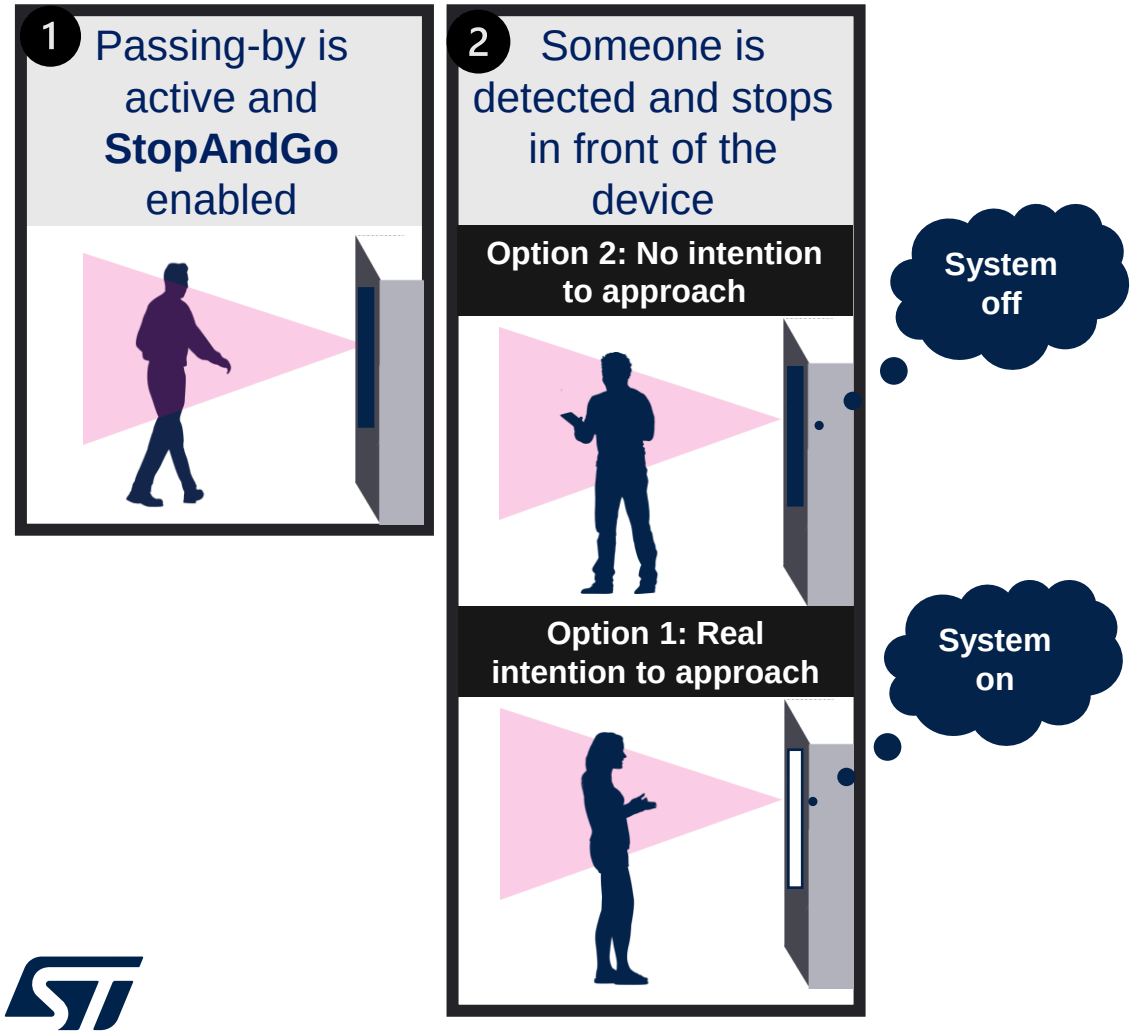
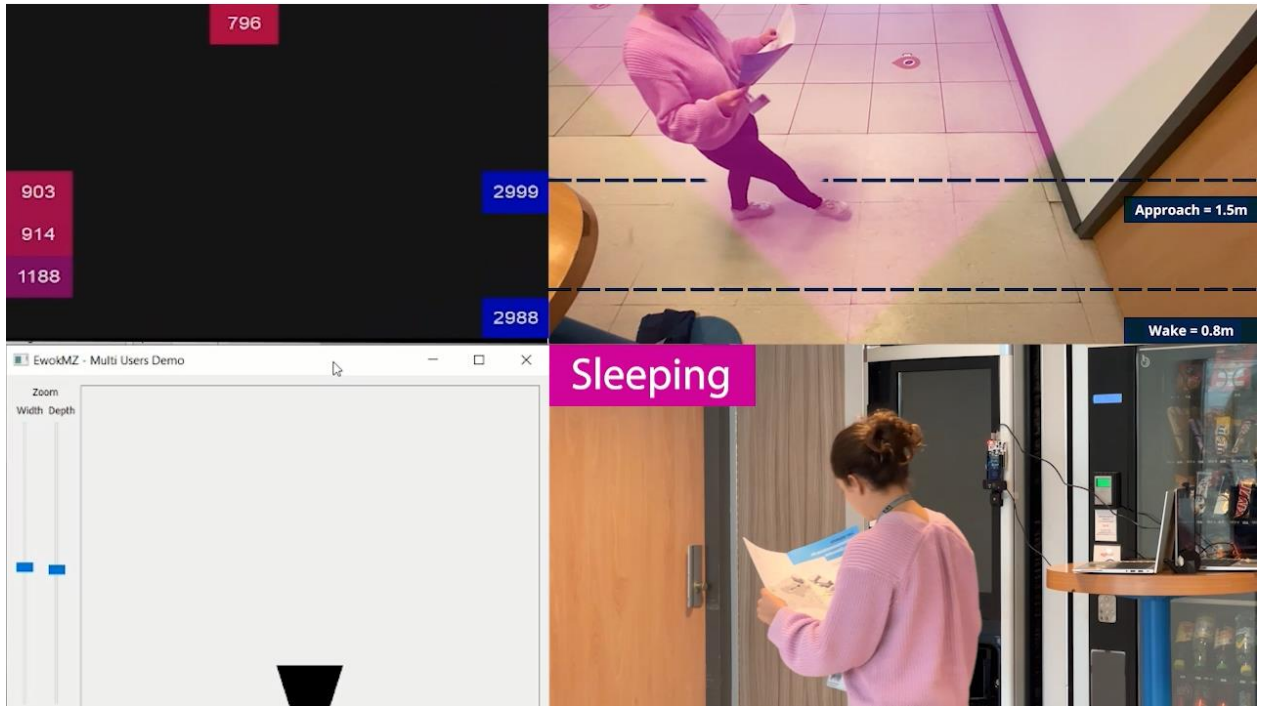
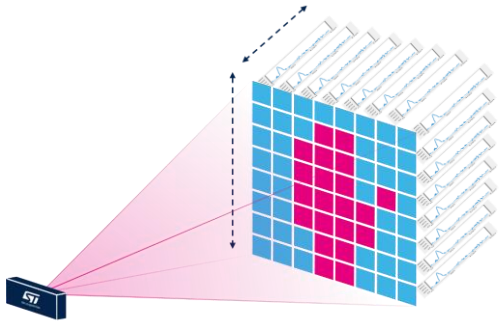
StopAndGo Enhances Detection Of Real Vs False Approaches



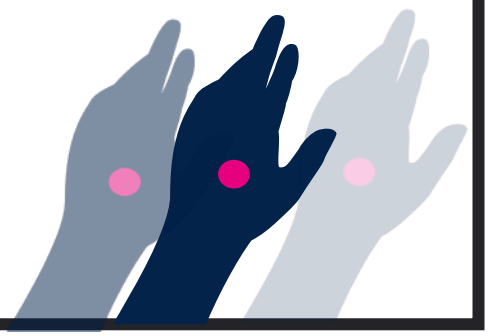


Gesture Recognition
Enabling Natural Human Interaction

1 Sensor data extraction



2 Hand tracking



3 Associating motion with gesture

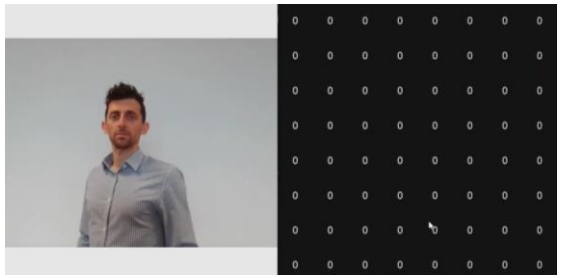
“Left”

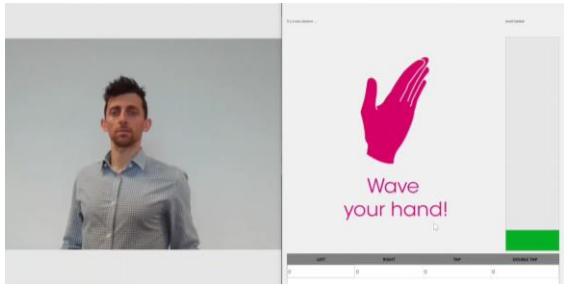
4 Application control

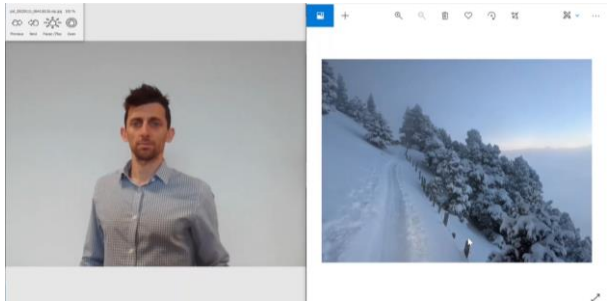
“Next picture”

Using multizone Time-of-Flight sensor data:

- Distances for each zones
- Signal (quantity of photons)







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Cup Detection

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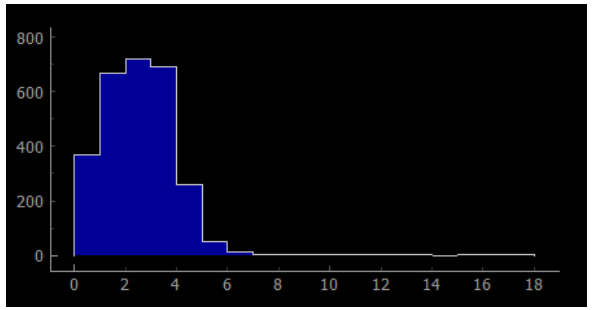
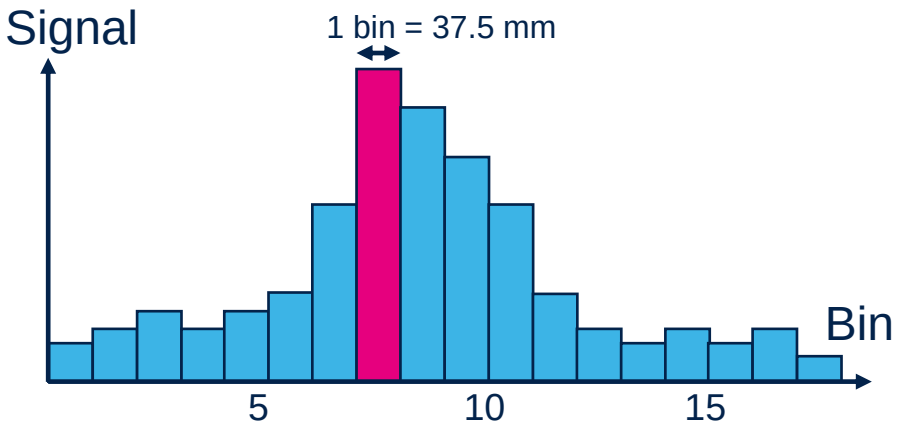
Compact Normalized Histogram Contains Far More Information Than Ranging Distances

New data

- For each zone, the sensor provides CNH, including count on each bin
  - Y unit is signal count

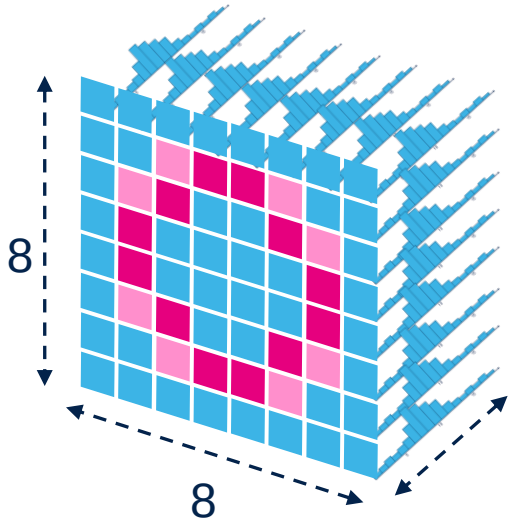


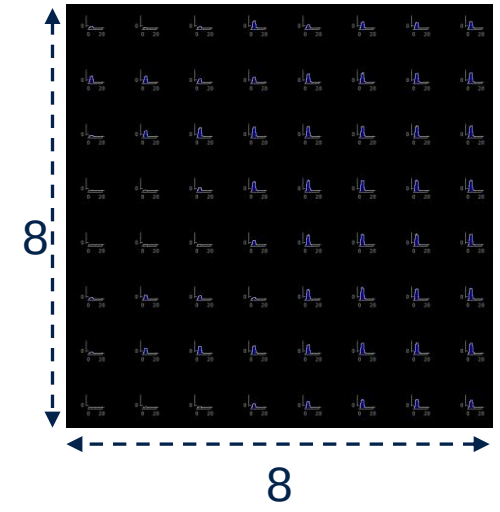
  - X unit is bin number
- The measured ambient level is removed from the CNH data



Additional features

- Both standard and CNH data
- Ambient map information
- Autonomous mode available
- Both I²C and SPI* communication modes are available





* VL53L8CH only

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ST patent pending

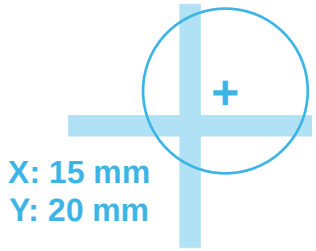
Ready-to-use Cup Detection Solution

Four functions

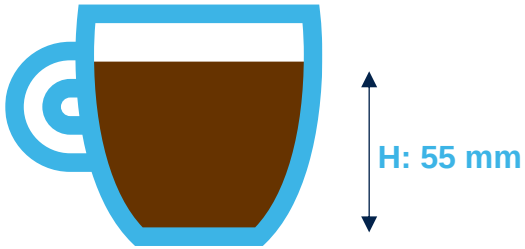
- **Cup detection**
  - Cup presence
  - Cup identification vs another object
  - Cup upside down detection

- **Cup size measurement**
  - Cup height
  - Cup diameter

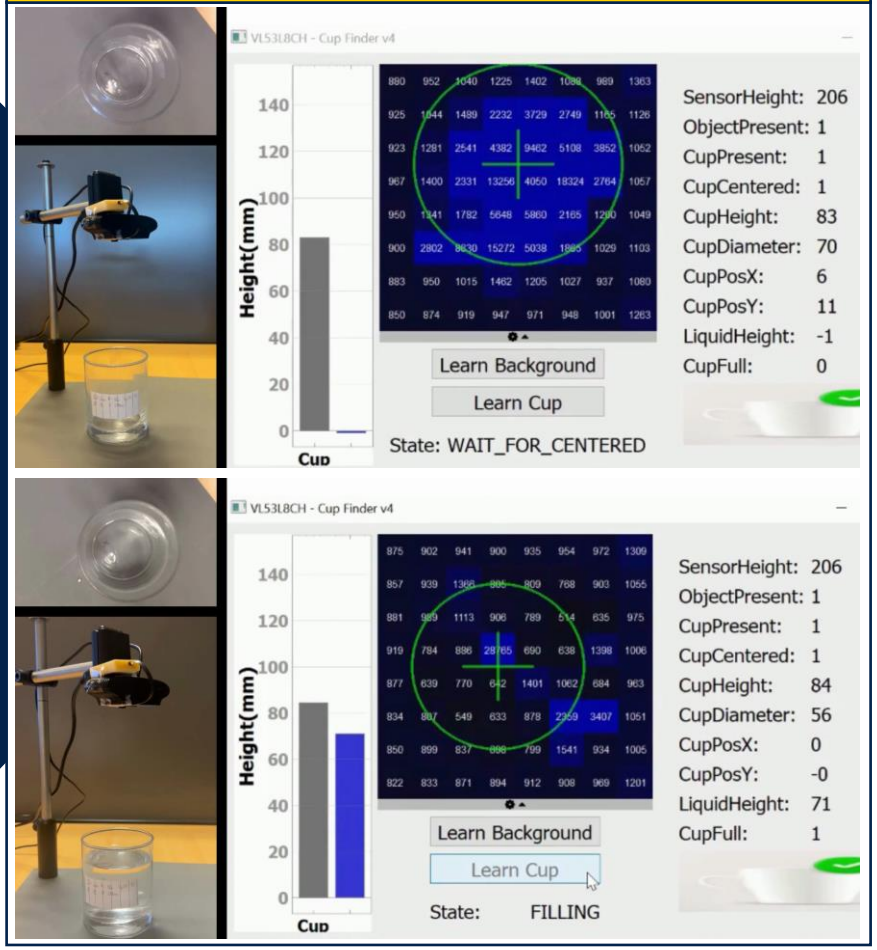
- **Cup positioning**
  - XY position



- **Liquid level monitoring**
  - Measuring liquid as the cup is filled



All-in-one solution



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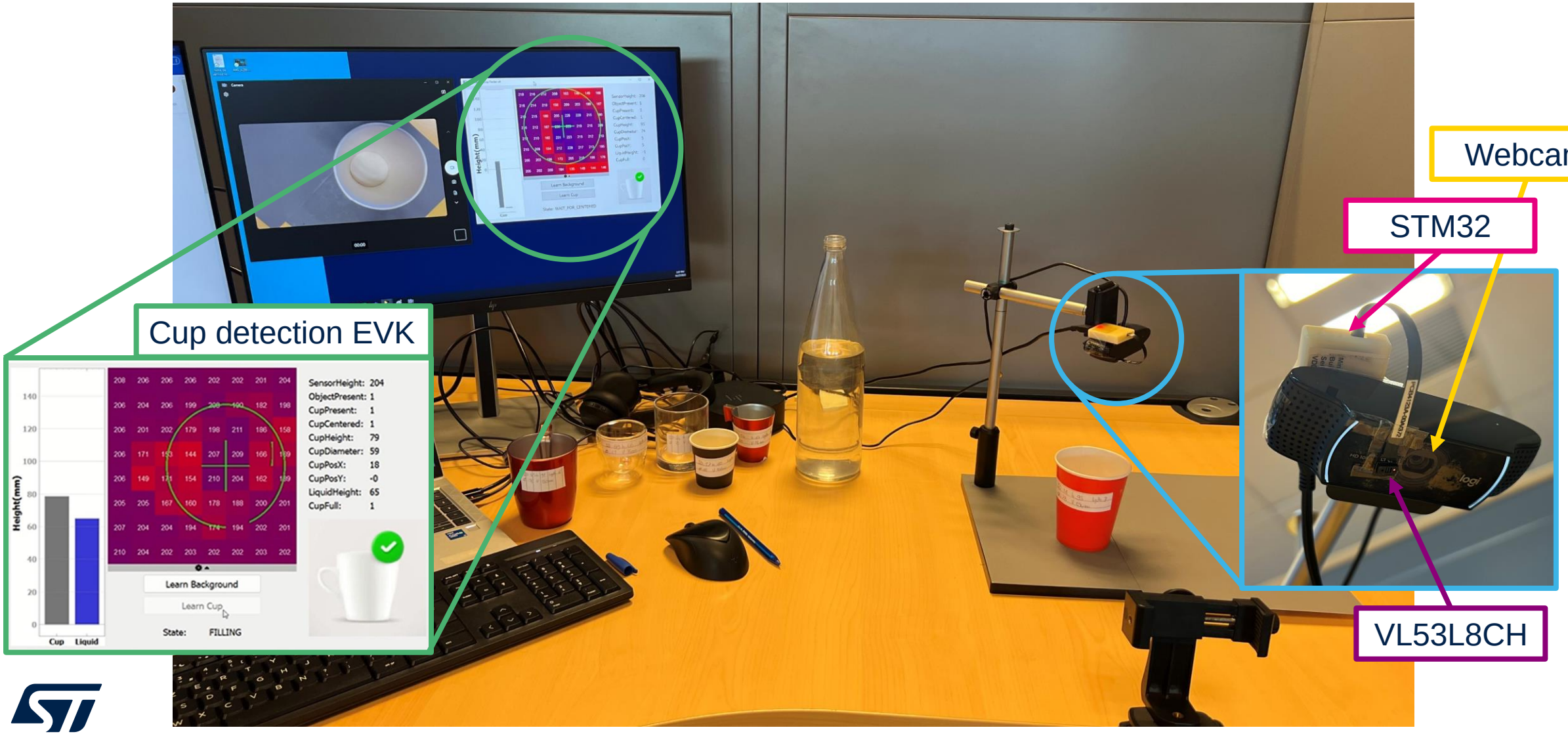
ST Demo Setup



2.3k d-ToF L9 Module

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Cam assist | AR/VR | LAF & T2F | Obj detect | Gesture | User intent

1k ES/EVK: Now | **2.3 K demo:** Now
CS: Nov ’24 | **MP:** Q1 ’25

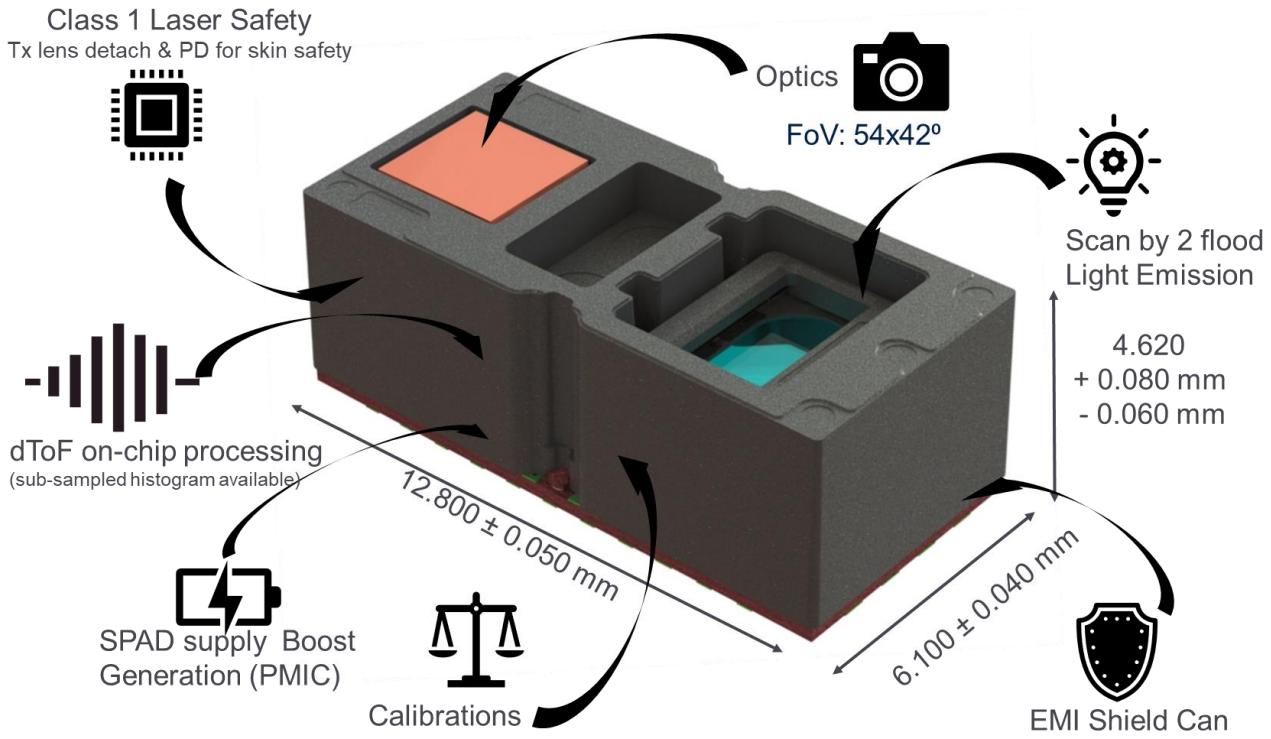
VL53L9 3D-Max

dToF all-in-one lidar module

2.3k & 0.5k 2D IR & depth | *5 cm* to >9 m ranging | dToF processing & PMIC for SPAD supply

Cutting edge dToF lidar system in a fully integrated, ready-to-use module

True all-in-one lidar module | no extra component & system cost



ToF receiver

- 3DSPAD based | BSI stacked on C40
- Full Res: 54x42 = 2,268 zones @ 60 fps
- 0.5k & 0.25k outputs supported by binning
- On-chip dToF processing | subsampled raw histogram option
- FoV: 54x42º, with crop support to reduce SPAD PWR
- I/F data: MIPI or I^3C | control: I^3C or I^2C | 1.2V I/O support
- Internal SPAD VHV generation – no external components

Key performance item

- 150 mW typical system power at full Resolution

(700 mW max power when temporarily required – full FoV/AMB)

- 2.3k: 54x42: >9 m at 0Lux, 88% target
- 2.3k: 54x42: >4 m at 40klux, 20% target
- Close distance: capable to range <7 cm with excellent linearity
- Calibration free device

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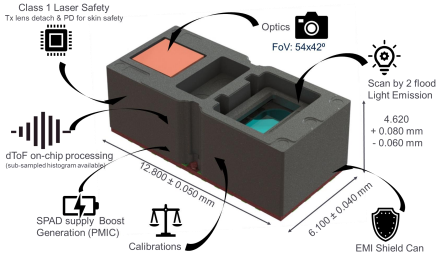
VL53L9 (2.3 K) | KPI & Use Cases



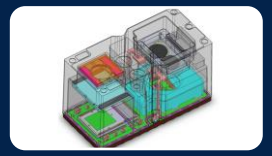
Ultimate camera-assist lidar

- 520 zones | 60 fps | <100 mW inc processing
- 2.3k resolution, with crop support, for telephoto cam bokeh
- <5 cm ranging for wide Angle macro LAF support

Lidar for xR & room/object mapping

- 2.3k zones | 60 fps | >9 m | 1 deg per zone angular resolution
- 2D IR + depth output for segmentation & hand gesture
- 150 mW total system power, with on-chip depth processing

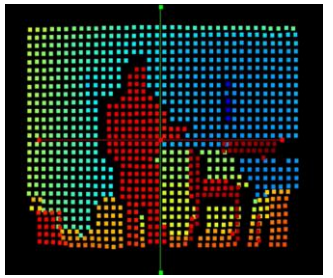
True all-in-one lidar dToF module



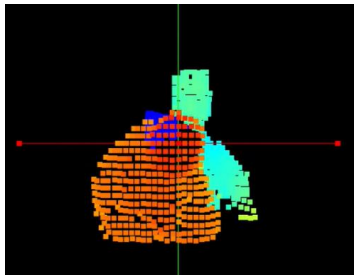
- Calibration free, low EMI reflowable module
- On-chip dToF processing
- Embedded PMIC for SPAD & VCSEL driver

Flood and low x-talk dToF

- Detect small objects & fine edges
  (vs. sparse info with competition dToF dot)
- Range at <5 cm
  (not possible with competition dToF dot)



Chair legs & edge detect



<5 cm ranging

WFoV POC recently launched

- 70°x53° (92° diag vs 71° diag) ➔ Cam assist gen2
- 120°x55° (130° diag) ➔ Best for AR/VR & robot
- 108°x92° (125° diag) ➔ Best for VR w/ hand gesture

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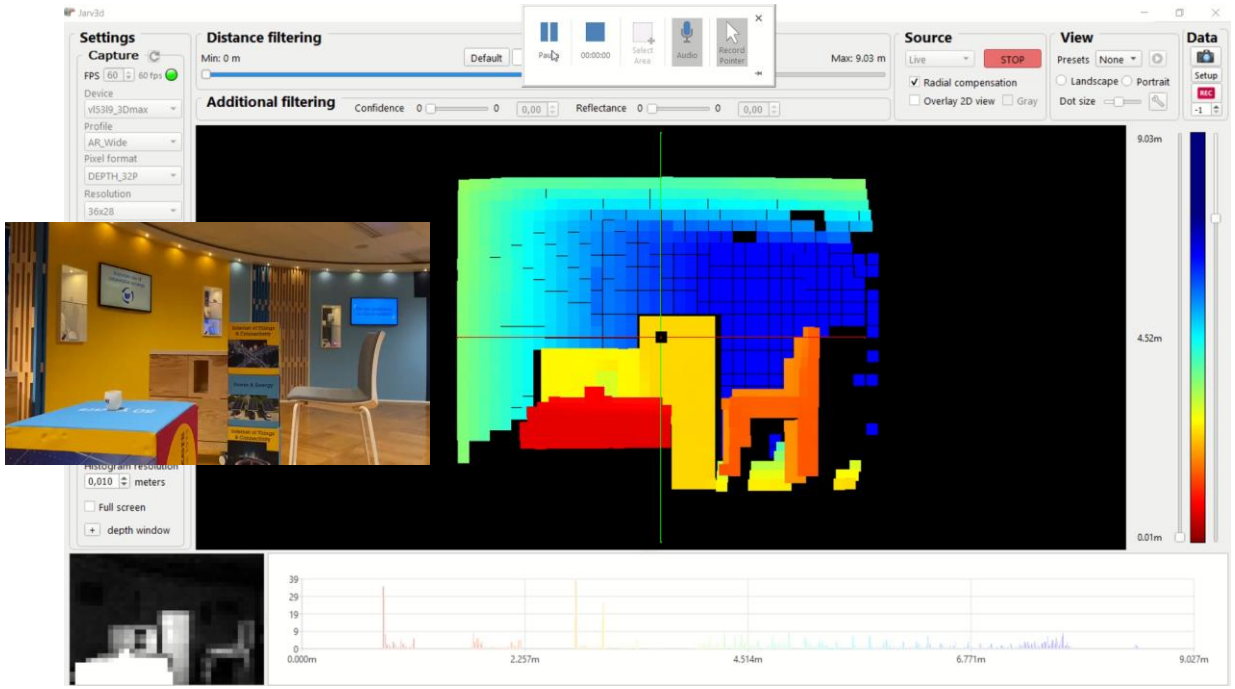
3DMax Videos

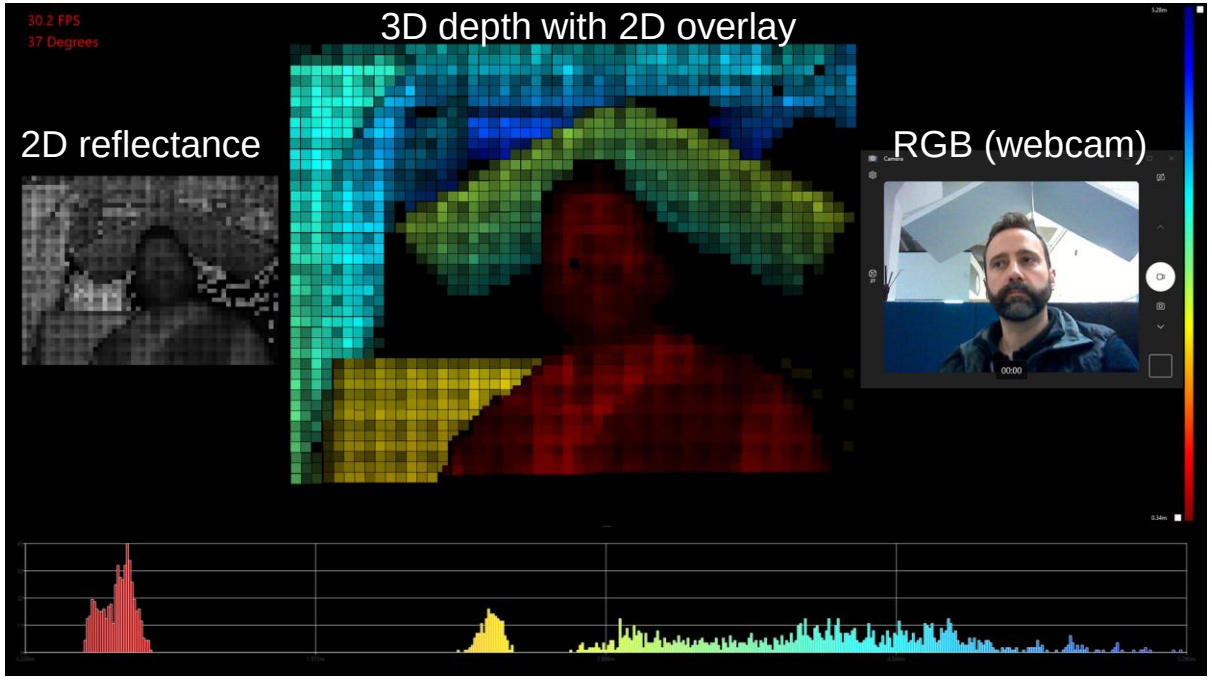
1k: 36 x 38 zones, 60 fps
Large scene dynamic | able to detect small objects



Note:

- Raw 2D IR & depth map, temporal noise filters being added

2.3k: 54 x 42 zones POC
Excellent resolution | keep scene dynamic



Note:

- SPAD apertures currently optimized for 6x6 MacroPix (bin by 3).
- Aperture pattern visible in bin by 2 (4x4 macro pixel)
  ➔ Fixed on final product (CS/MP)

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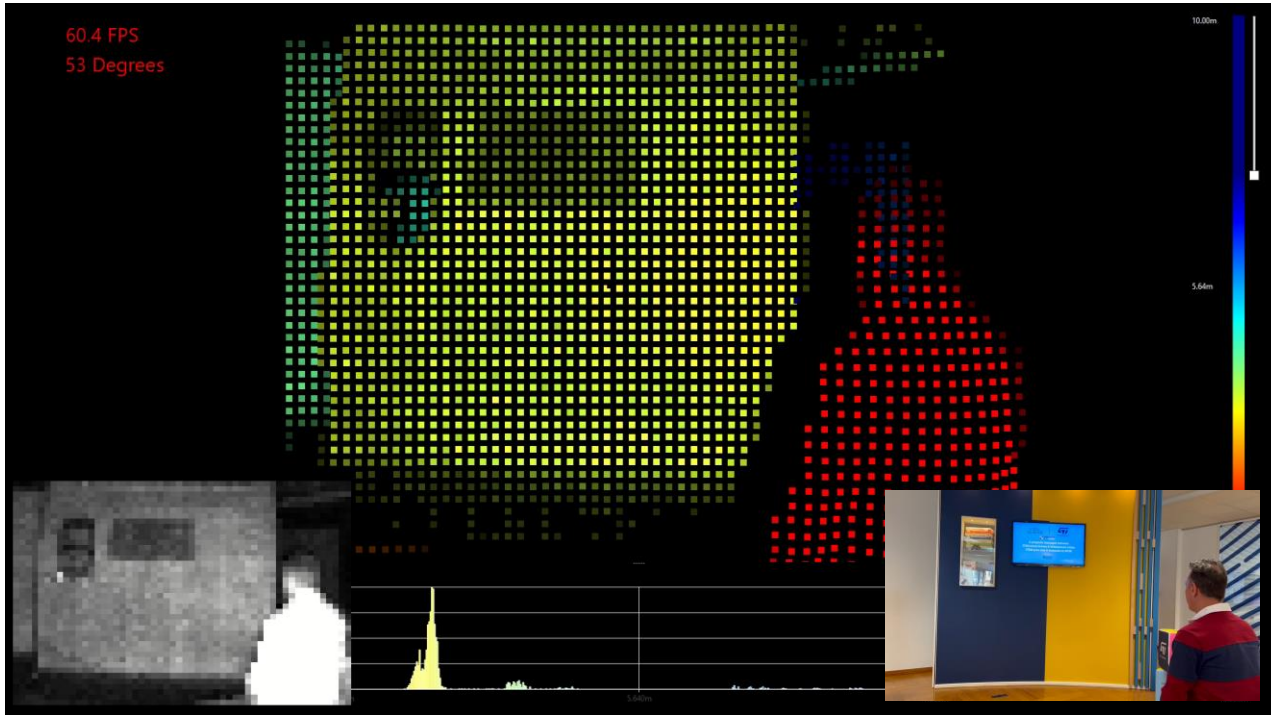
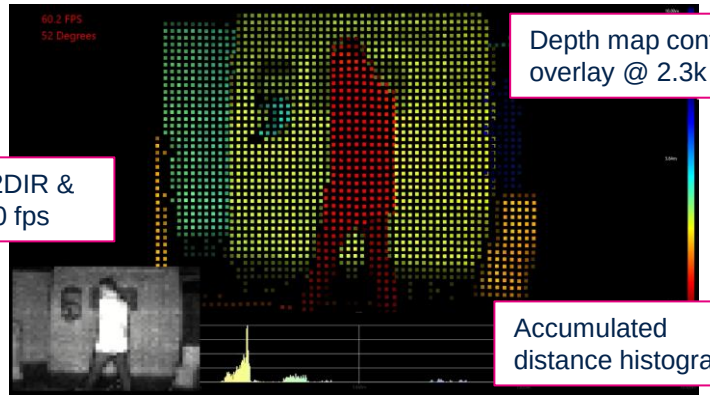
VL53L9 | 2.3k Lidar For VR Room Mapping



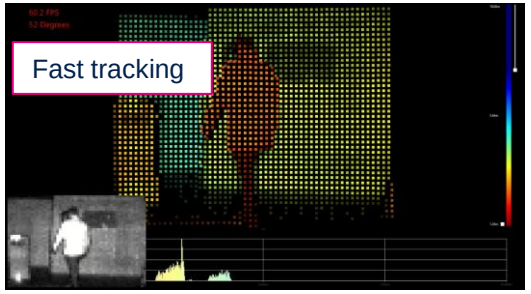


Depth map contrast overlay @ 2.3k / 60 fps

Contrast (based on 2DIR & distance) @ 2.3k / 60 fps

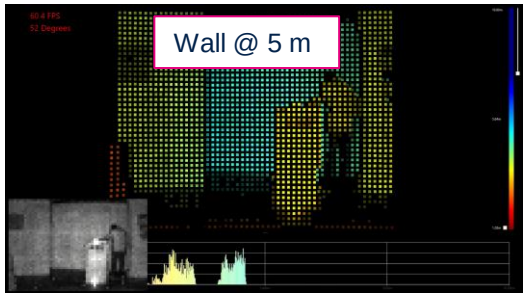
Accumulated distance histogram

VL53L9 ranging KPI



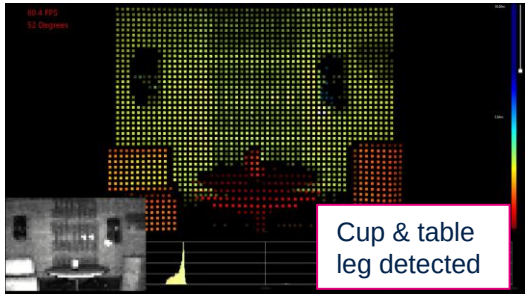
Fast tracking

Moving object: perfect tracking w/out tearing @ 60 fps



Wall @ 5 m

Excellent ranging dynamic: from <5 cm to 10 m



Cup & table leg detected

Able to detect small object/edge for VR application

TV display

Able to detect specular target such as TV display

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Global Shutter

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Under OLED face authentication

Robotic

AR/VR/MR

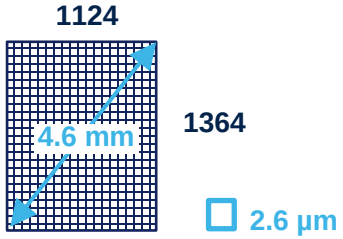
Smart home

Slam & tracking Obj detect

1.5 Megapixels

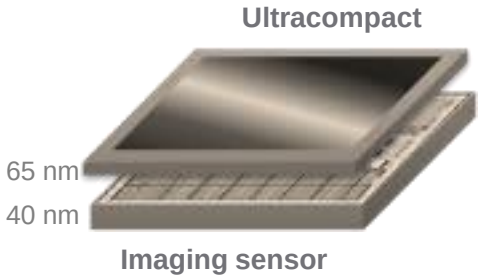
1124 x 1364, 2.61 µm BSI global shutter

- VD56G3 (Monochrome)
- VD66GY (Bayer RGB)
- VD16GZ(RGB-IR)



1.5Mpixels

FoV of +15%
1.5 MP vs 1.3 MP



Sensor characteristics

- 1.5 MP = 1124 x 1364 pixels array
- 2.61 µm BSI global shutter
- Full C-DTI with deep photodiode
- High sensitivity & sharpness, from visible to near-IR
- Autoexposure, defect correction, temperature sensor
- Only 4.3 x 3.6 mm die size
- 4 independent frame setups, linkable as flexible sequences
- Both Bayer RGB and monochrome (visible+NIR) versions

Development tools

- Evaluation kit (GUI and SDK)
- Linux driver & 96boards plugin
- Raspberry plugin
- STM32MCU adapter board & driver

Optical flow

- Embedded optical flow, fully hardware for best power/perf ratio
- Automatically detects points of interest, and track their position change
- Up to 2000 vectors of movement per frame at 60 fps (up to 300fps/512vectors)
- Fully autonomous, VD56G3 outputs the vector stream through CSI2 without the image or interlaced the image. No need for external computing.

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Under OLED face authentication

Robotic

AR/VR/MR

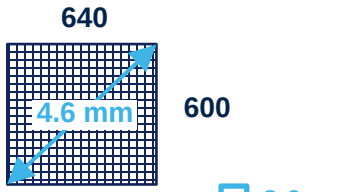
Smart home

Slam & tracking Obj detect

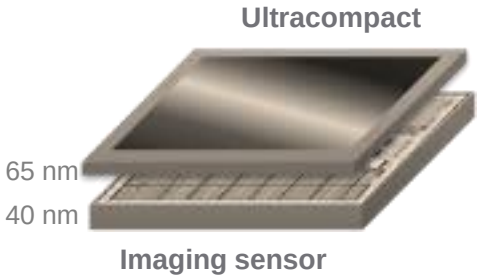
Laptop Tablet

VD55G0 0.4 Megapixels

644 x 604, 2.61 µm BSI global shutter



+25% V-FoV
vs VGA sensor



Sensor characteristics

- 0.4 MP = 644 x 604 pixels array
- 2.61 µm BSI global shutter
- Full C-DTI with deep photodiode
- High sensitivity & sharpness, from visible to near-IR
- Autoexposure, defect correction, temperature sensor
- Only 2.6 x 2.5 mm die size, requiring small footprint

Development tools

- Evaluation kit (GUI and SDK)
- Linux driver & 96boards plugin
- Raspberry plugin
- STM32MCU adapter board & driver

High integration & low power

- Larger pixel for higher sensitivity, more pixel than usual VGA but the smallest existing die size
- Unique single die global shutter, with no trade-offs on the pixel performance
- Low power, with 12 mW at 10 fps full resolution (55 mW at 60 fps)
- Power scaling with frame-rate and resolution

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Under OLED face authentication

Robotic

AR/VR/MR

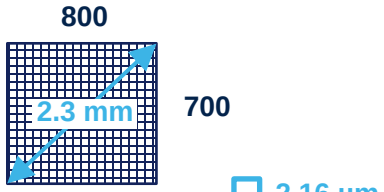
Smart home

Slam & tracking Obj detect

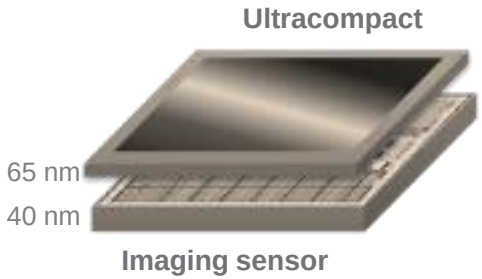
Laptop Tablet

VD55G1 0.6M Pixel

804 x 704, 2.61 µm BSI global shutter



+26% H-FoV
+47% V-FoV
vs VGA sensor



Sensor characteristics

- 0.6 MP = 804 x 704 pixels array
- 2.16 µm BSI global shutter
- Full C-DTI with deep photodiode
- High sensitivity & sharpness, from visible to near-IR
- Low noise GS pixel, combined with embedded smart denoising
- Autoexposure, defect correction, temperature sensor
- Only 2.7 x 2.2 mm die size, tiny footprint (& option for CSP)

Development tools

- Evaluation kit (GUI and SDK)
- Linux driver & 96boards plugin
- Raspberry plugin
- STM32MCU adapter board & driver

High integration & low power

- Smallest pixel, high performance & global shutter
- Smallest sensor size vs VGA, with +82% resolution vs 640x480
- Very low power, full IQ, all features ON, full resolution
  - 20 mW at 30 fps (39 mW at 60 fps)
  - 1 mW at 1 fps (5 mW at 10 fps VGA)

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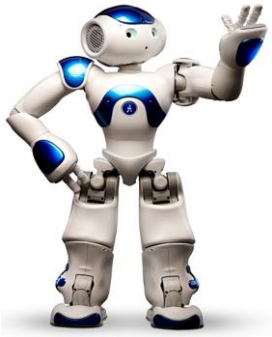
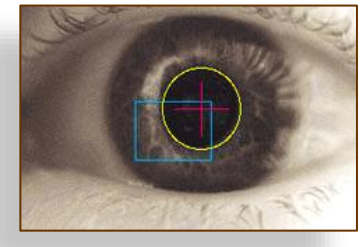
Applications





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3D I-ToF

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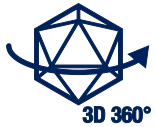
Secure face authentication



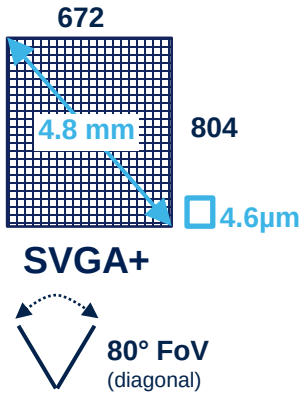
Object scanning

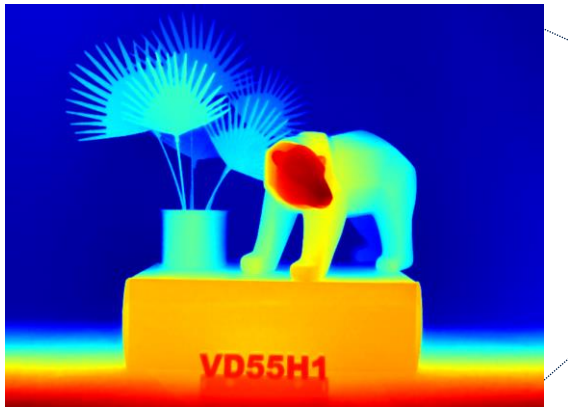
Bokeh

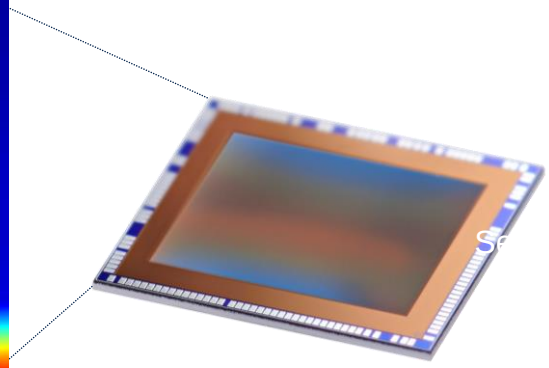
3D avatars

VD55H1 [Thanos] Flood Illumination Ref Design

Low noise 0.5 MP indirect ToF sensor die BSI stacked technology (65/40 nm)







VD55H1 sensor characteristics

- 672 x 804 iToF pixel array
- 4.6 µm BSI fast photo diode (charge domain)
- 200 MHz modulation frequency with DMC > 82%
- Die size: 4.5 x 4.9 mm
- Top wafer: 65 nm (imaging process)
  bottom wafer: 40 nm (logic)
- 12-bit RAW data over MIPI CSI2 @1.5 GHz (x2/4)
- Up to 60 fps depth images (full resolution)
  120 fps (analog binning 2x2)
- Sensor power consumption from 80 mW

Ref design, flood illumination (Thanos)

- 940 nm illumination, 2.5 W optical peak power (1 J VCSEL)
- 80° diagonal FoV
- Laser driver IC, 200 MHz operation
- SW depth reconstruction ISP
- 17.6 x 8.0 x 5.3 mm module
- Ranging: up to 5 m on 88% target (indoor)
  for 500 mW avg Rx+Tx power @ 30 fps

Unique features

- 0.5 MP into 22 mm² die
- Best-in-class depth noise (200 MHz operation)
- Optimized EMI / EMC, multiuser interference mitigation
- Smart iToF modulation, no wiggling error

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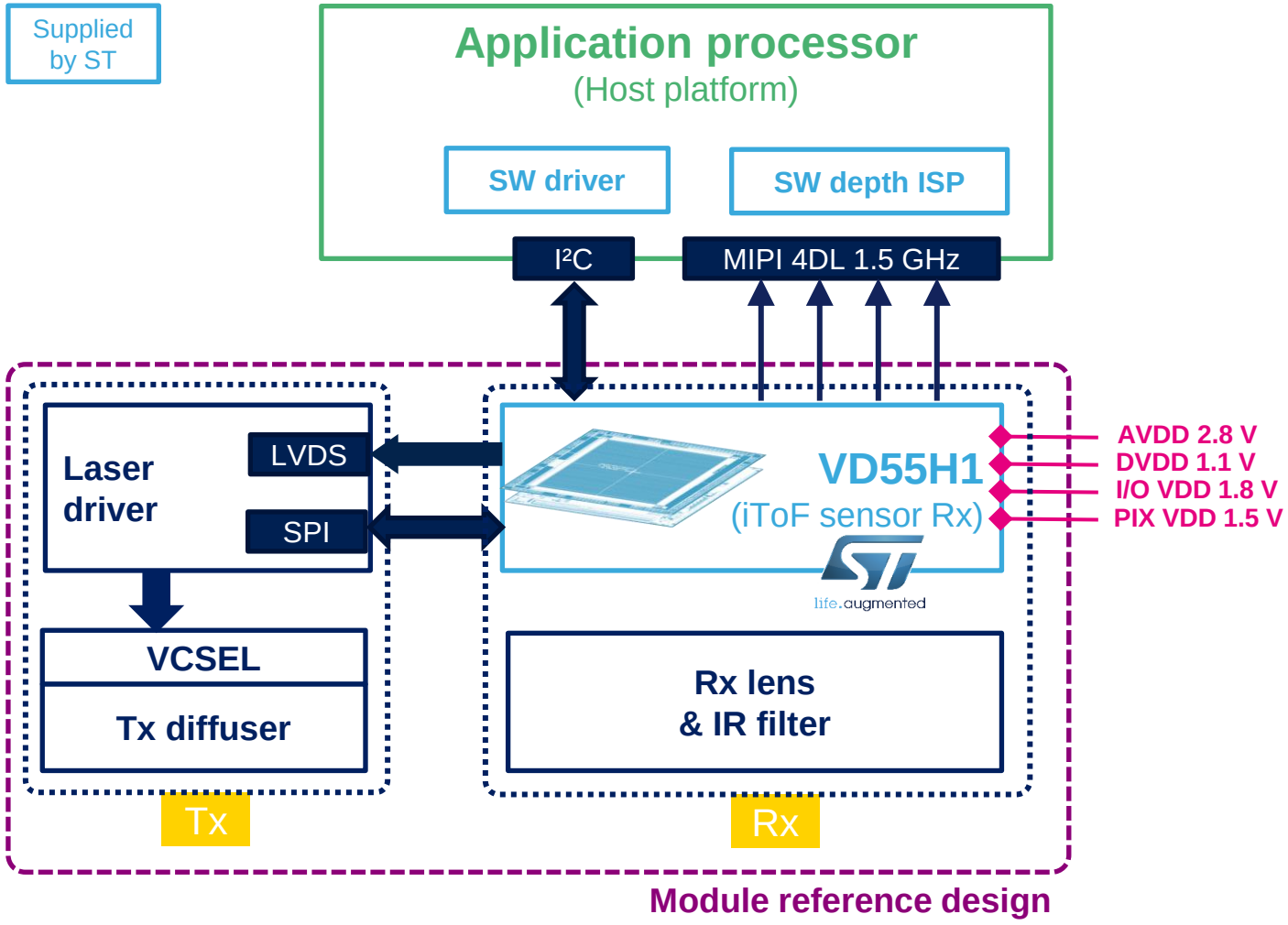
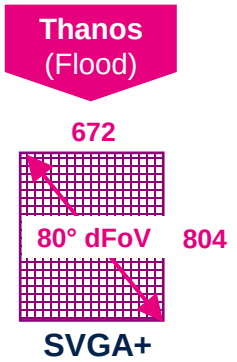
VD55H1 | Flood Illumination Ref Design [Thanos]



Reference module

17.6 x 8.0 x 5.3 mm

- Wireless compatible form factor
- Laser driver IC
- 200 MHz operation
- 2.5 W optical peak power



Software package

→ **SW sensor driver**

→ **SW depth ISP (Raw to depth processing library)**

- Depth map reconstruction from RAW iToF bins
- Binning
- Multifrequency management
- Noise reduction filters
- Flying pixel removal
- Auto exposure control

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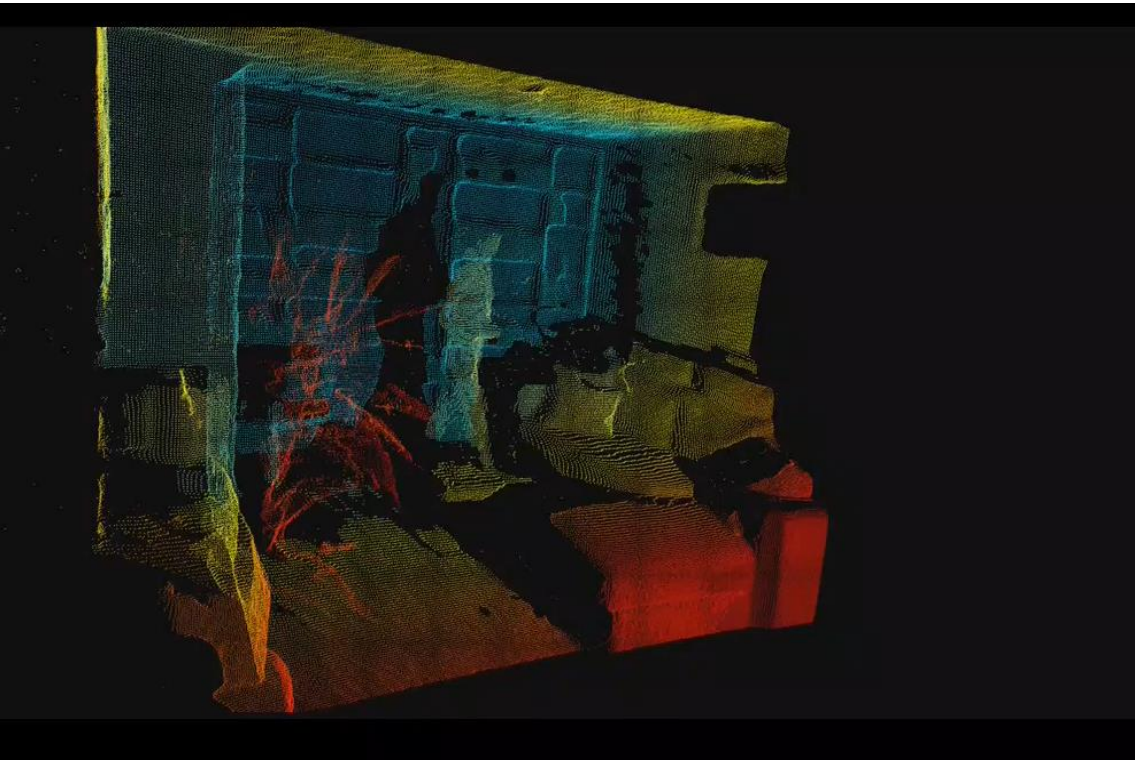
VD55H1 | 0.5 MP Depth Map
High Resolution, Low Noise 3D Sensing

World-facing

User-facing



Room mapping

AF assist

Secure face authentication

Object scanning

3D 360°

Bokeh segmentation

3D avatars

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Industrial Summit
download center

ST Power & SPIN
microsite (CN Only)

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