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Time-of-Flight sensors with greater data throughput

IMAGING division

October 26th, 2023

FlightSense™ making light work

Time-of-Flight Principle

- ST proprietary FlightSense™ technology
- True distance measurement
- Fast and low power
- Truly invisible 940nm illumination

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ST pioneer and leader in Time-of-Flight (ToF)

ST is #1 Worldwide Time-of-Flight sensor supplier

4 Generations

of all-in-one ToF solution deployed since 2014

>500 devices

Over 200 phones with ST's Time of Flight technology
Several hundreds of non wireless end products on the market
Unlimited variety of use-cases beyond smartphones

>80,000

Evaluation kits deployed

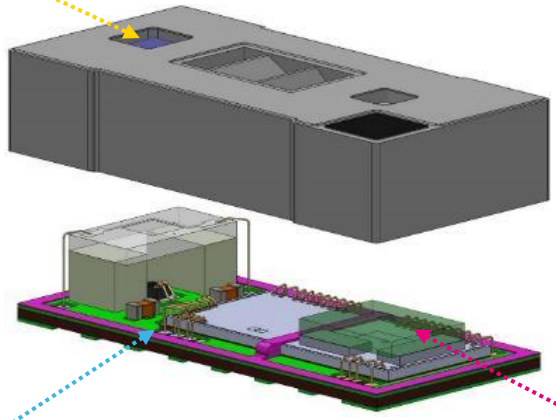
>2 Billions

ToF units shipped. Mastering end-to-end supply chain

All-in-One (illumination & sensor) Time-of-Flight system

Advanced optics with integrated IR filters

State-of-art assembly & testing ST manufacturing line in Shenzhen



Monolithic ToF SoC, SPAD Array, high safety Class1 VCSEL driver

Full Class 1 safety high efficiency VCSEL

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FlightSense industrial & mass market portfolio

LONGEVITY 7 YEARS COMMITMENT

Multizone

Up to 64 zones (8x8)
Artificial intelligence enabler
CNH data

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

Up to 64 zones (8x8)
Histogram mode
Autonomous mode

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

Single zone

Histogram mode
Long distance up to 8 m
High ambient immunity

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

Ranging up to 4 m
Autonomous mode

VL53L0CX
25° FoV
200 cm dark

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

Proximity up to 1.3 m
Short distance linearity
Low power consumption

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

Ultralow power mode

Legend:
- Legacy product
- Recent product
- New product

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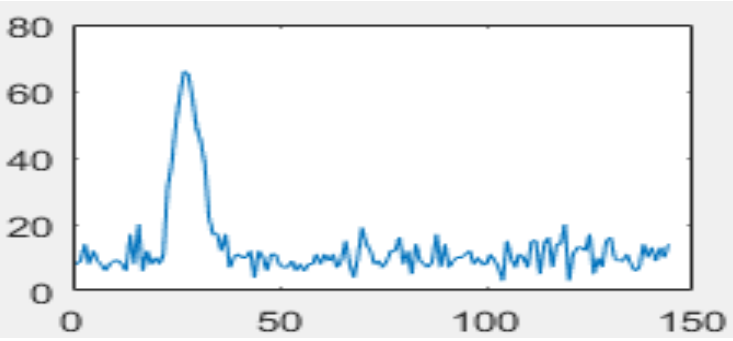
What are CNH?

From standard data to CNH

Giving system host access to original sensor power to enable AI

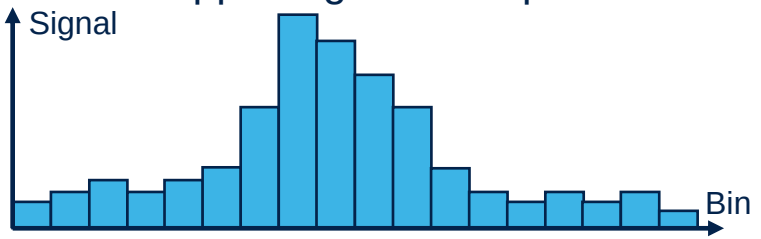
Raw histogram

- Provides histogram for each zone on 128 bins
- Bin size is exactly 37.5 mm
- Data are raw sensor output, but not accessible as is



Compact Normalized Histogram

- Up to 18 programmable bins output per zone in 8x8 mode (64 zones)
  - Up to 72 bins for 16 zones
  - Up to 128 bins for 8 zones
- The product firmware is computing raw histogram data to output CNH
- Only new LxCH sensor products are supporting CNH output data



Standard data

- Up to 5 standard data (distance, signal, ambient) output per zone, in addition to CNH data output
- The product firmware is computing raw histogram data to output standard data
- All sensor products, including new LxCH are supporting standard data output

Output data	Value
Distance	357 mm
Peak signal rate	66 kcps/spad
…	…

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Standard Time-of-Flight data output

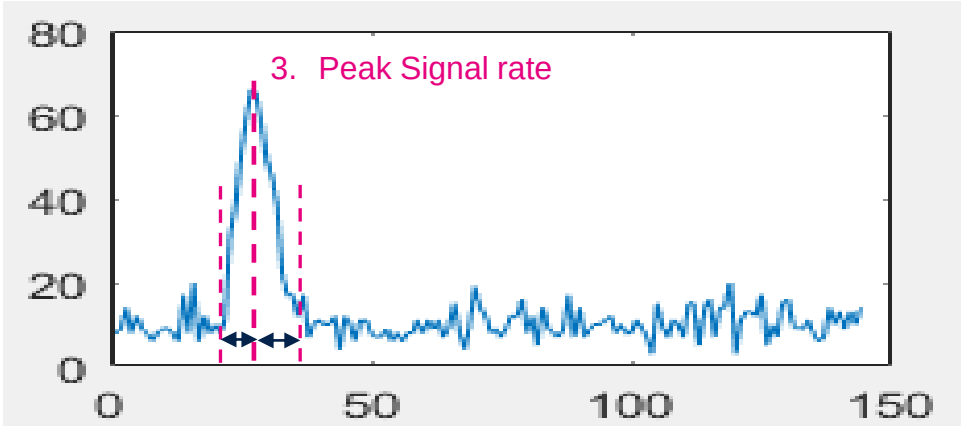
For each multizone-sensor zone, the sensor pre-processes histogram data into 5 information output

5 pre-processed histogram data

- **Distance related**
  - Distance (mm)
  - Distance sigma (mm)
- **Signal related**
  - Peak signal rate (kcps/spad)
- **Other**
  - Infrared ambient level (kcps/spad)
  - Reflectance (%)

From the raw histogram, extract standard data

- Computed directly in the firmware, the standard are output via I²C or SPI to the system host



1. Distance
2. Distance Sigma

Additional output data:

4. Infrared ambient level
5. Reflectance

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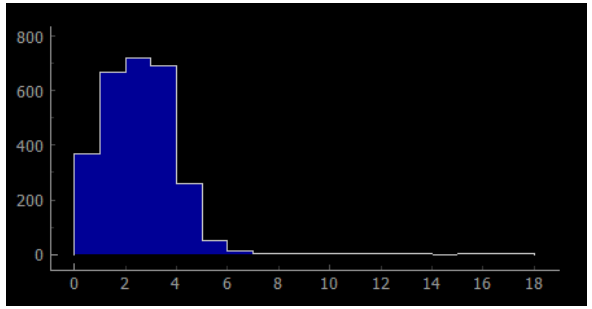
Compact Normalized Histogram

CNH resolution and data-set contains way more information than ranging distances

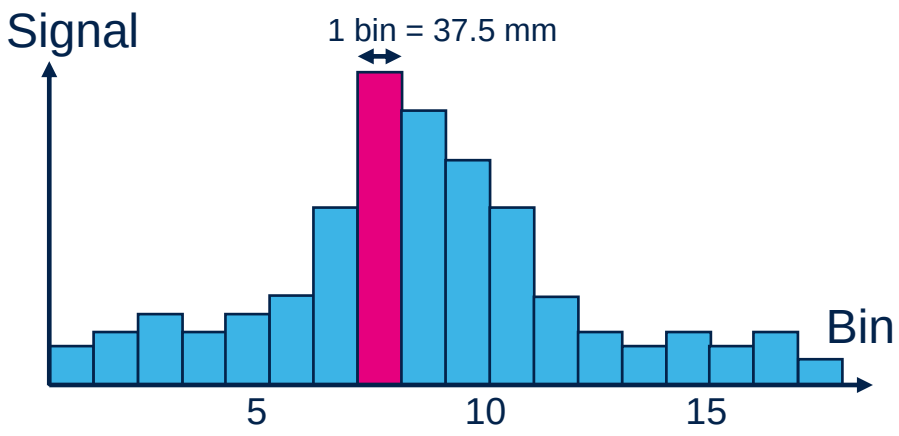
New data

- For each zone, the sensor provides CNH, with signal count on each bin



  - X unit is bin number
  - Y unit is signal count

- 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 available

* VL53L8CH only

High data quantity

- 1 histogram bin = 1 data
- Up to 18 bins per zone (8x8)
  - Total of 1152 data

What means CNH?

C: Compact → Options are available to reduce the amount of data compared to the native “raw” histogram data

N: Normalized → Raw data are adjusted to compensate variations caused by frame-to-frame adjustments

H: Histogram → Primary data is in the form of histograms recording return-signal-strength vs range

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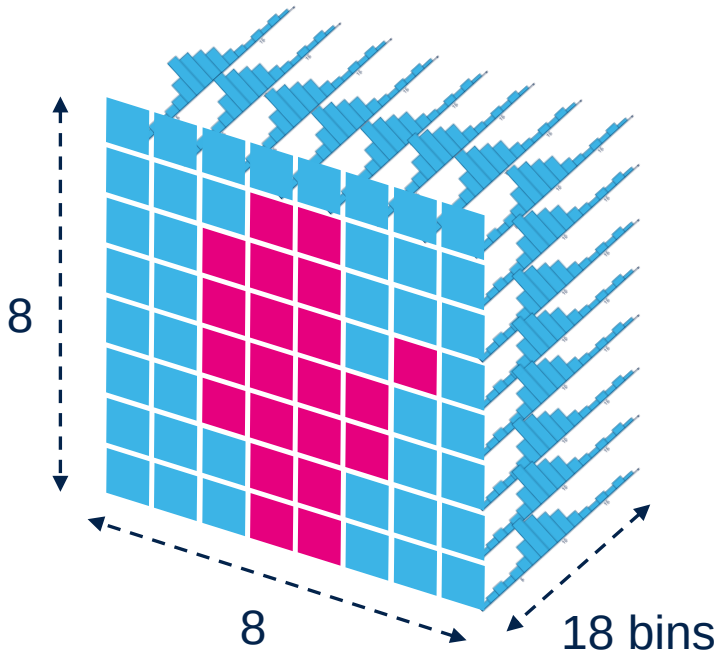
Multi-zone CNH

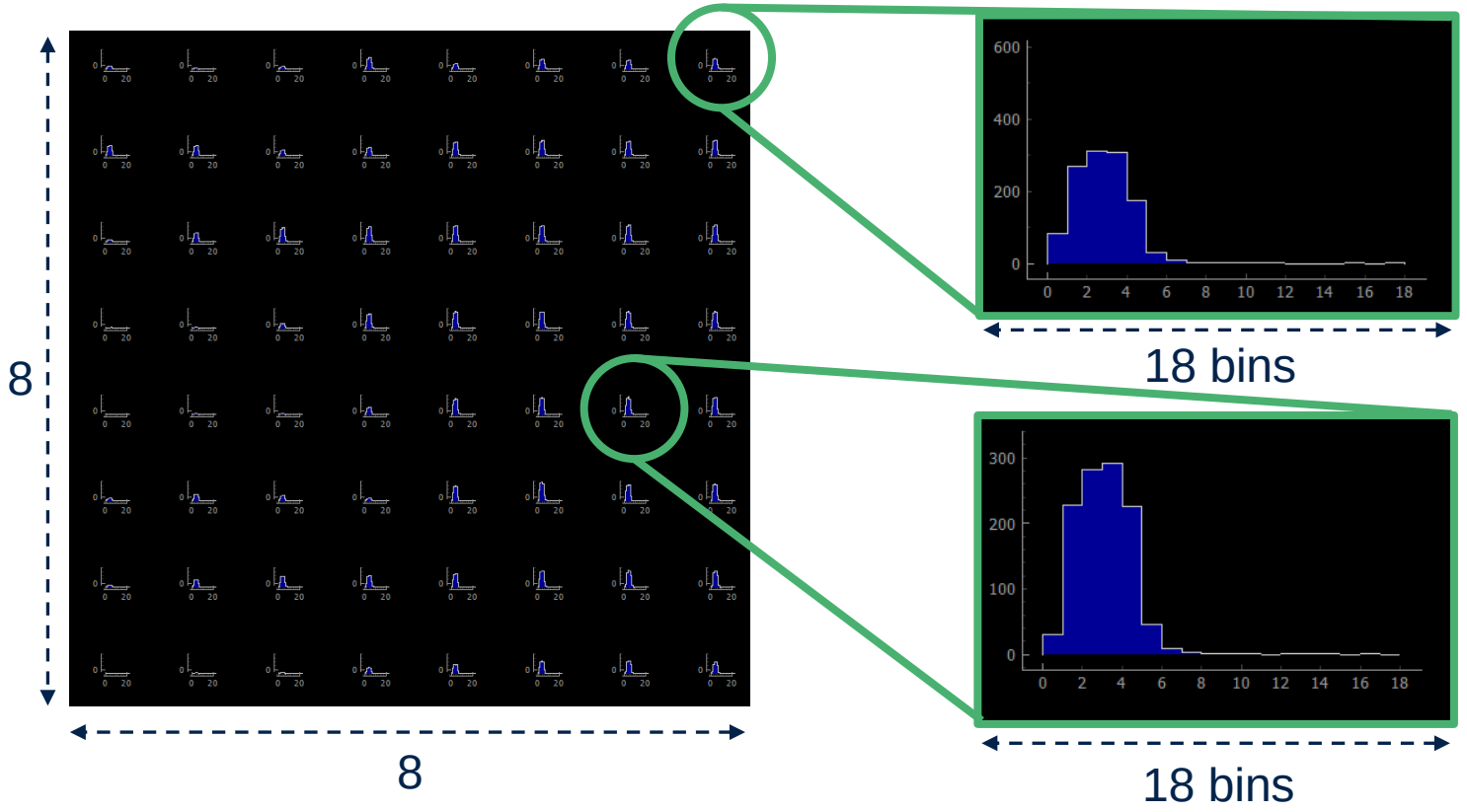
CNH resolution and data-set contains way more information than ranging distances

Theory

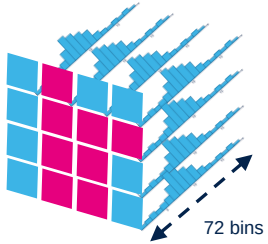
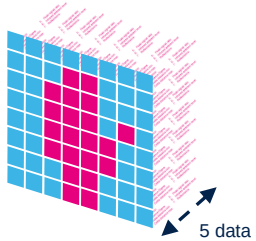
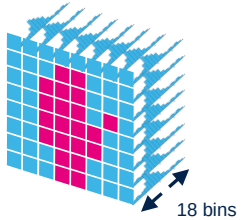


"Visible" X,Y resolution: 8x8 zones

"Hidden" Z resolution : 18 bins



15x more data per frame in 4x4 mode

Resolution	Standard data only	CNH only	Standard data + CNH
4x4	• Up to 5 data per zone • 16 zones  • **Up to 80 data per frame**	• Up to 72 CNH bins per zone* • 16 zones  • **Up to 1152 data per frame**	• 5 standard data per zone • Up to 72 CNH bins per zone* • Total of 77 data per zone* • 16 zones • **Up to 1232 data per frame**
8x8	• Up to 5 data per zone • 64 zones  • **Up to 320 data per frame**	• Up to 18 CNH bins per zone** • 64 zones  • **Up to 1152 data per frame**	• 5 standard data per zone • Up to 18 CNH bins per zone** • Total of 23 data per zone** • 64 zones • **Up to 1472 data per frame**

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CNH products

Two products, one solution

Two products

- **VL53L7CH**

  - Up to 350 cm ranging
  - 60° x 60° FoV (90° diagonal)
  - I²C interface

- **VL53L8CH**

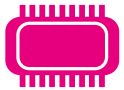
  - Up to 400 cm ranging
  - 45° x 45° FoV (65° diagonal)
  - High ambient light immunity
  - Low power consumption
  - I²C and SPI interface
  - External synchronization pin

- **Common features**
  - Autonomous low power mode
  - Motion Indicator

100% compatible

Single STM32 project

Single driver (ULD)

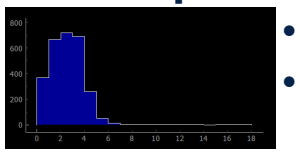


Single FW

Single GUI

Output data

- **Compact Normalized Histogram**

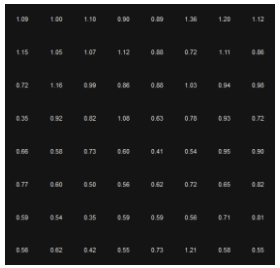


  - Up to 18 bins in 8x8 at 15Hz
  - Up to 72 bins in 4x4 at 15Hz

- **Standard data**

  - 2 for distance (distance, sigma)
  - 1 for signal (signal peak)
  - 2 additional data (ambient level and reflectance)

- **Ambient map**



  - IR ambient light level data generated

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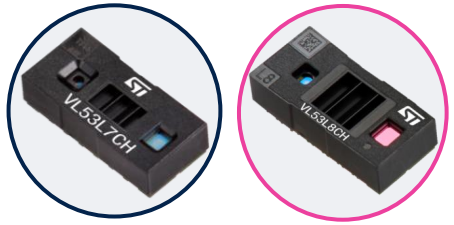
VL53L7CH and VL53L8CH selection guide



VL53L7CH

VL53L8CH

Field of view		**60° x 60° (90° diagonal)**	45° x 45° (65° diagonal)
Resolution		Up to 8x8 (64 zones)	
Common features		Autonomous low power mode	
Additional features			**External synchronization pin**
Driver		100% compatible	
Interfaces		I²C (1 MHz)	I²C (1 MHz) and **SPI** (3 MHz)
Distance ranging	Dark condition	350 cm	**400 cm**
	Under ambient light*	65 cm	**285 cm**
Power consumption**		4.5mW	**1.6mW**
Module size		6.4 x 3.0 x **1.6 mm**	6.4 x 3.0 x 1.75 mm

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* Best conditions using white target (88% reflectance)
** Power consumption measured at 1hz frequency and with 3.3 V analog and VCSEL supply

VL53L7CH overview

An Artificial Intelligence enabler, 90° FoV 8x8 multizone Time-of-Flight sensor

Multi-zone (8x8)

Package size :

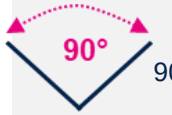
6.4 x 3.0 x 1.6 mm

FoV : 90° diagonal

Maximum ranging distance: 3.5 meters

Ranging under ambient light (5 klux): 65 cm

Close distance linearity: >2cm



90° FoV

64 zones

CNH

Compact Normalized Histogram (CNH)

Typical use-cases

- AI applications
- Floor sensing
- Glass detection
- Gesture recognition

Applications

Vacuum cleaners

Smart speaker

Home automation

White goods

Industrial

Highlights

Parallel multizone ranging output:

- **Up to 8x8 zone** separate regions of interest

Ultra-wide field of view: 60° x 60° (**90° diagonal**)

Distance ranging performances:

- Up to **350 cm ranging** in **dark condition**
- Up to **65 cm ranging** under **ambient light**

Multi-target detection and distance measurement in each zone

Motion indicator indicating if the target has moved

30 Hz frame rate capability

Immunity to cover glass cross-talk beyond 60cm

Pin-to-pin compatible with VL53L5CX and VL53L7CX

Software driver compatible with VL53L8CH

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VL53L8CH overview

An Artificial Intelligence enabler, high performance 8x8 multizone Time-of-Flight sensor

Multi-zone (8x8)

Package size :
6.4 x 3.0 x 1.75mm

FoV : 65° diagonal

Maximum ranging distance: 4 meters

Ranging under ambient light (5 klux): 285 cm

Close distance linearity: >2cm

65° FoV

8 x 8 — 64 zones

Perf. Under Ambient (>200cm)

CNH — Compact Normalized Histogram (CNH)

Typical use-cases

- AI applications
- Rim detection
- Floor sensing
- Glass detection
- People counting
- Gesture recognition
- Air quality monitoring

Applications

Vacuum cleaners | Smart speaker | Home Appliances | Air purifier | Industrial

Highlights

Parallel multizone ranging output:

- **Up to 8x8 zones** separate regions of interest

Wide field of view: 45° x 45° (**65° diagonal**)

Distance ranging performances:

- Up to **400 cm ranging** in **dark condition**
- Up to **285 cm ranging** under **ambient light**

Multi-target detection and distance measurement in each zone

Low power consumption

Motion indicator indicating if the target has moved

30 Hz frame rate capability

Immunity to cover glass cross-talk beyond 60cm

Pin-to-pin compatible with VL53L8CX

Software driver compatible with VL53L7CH

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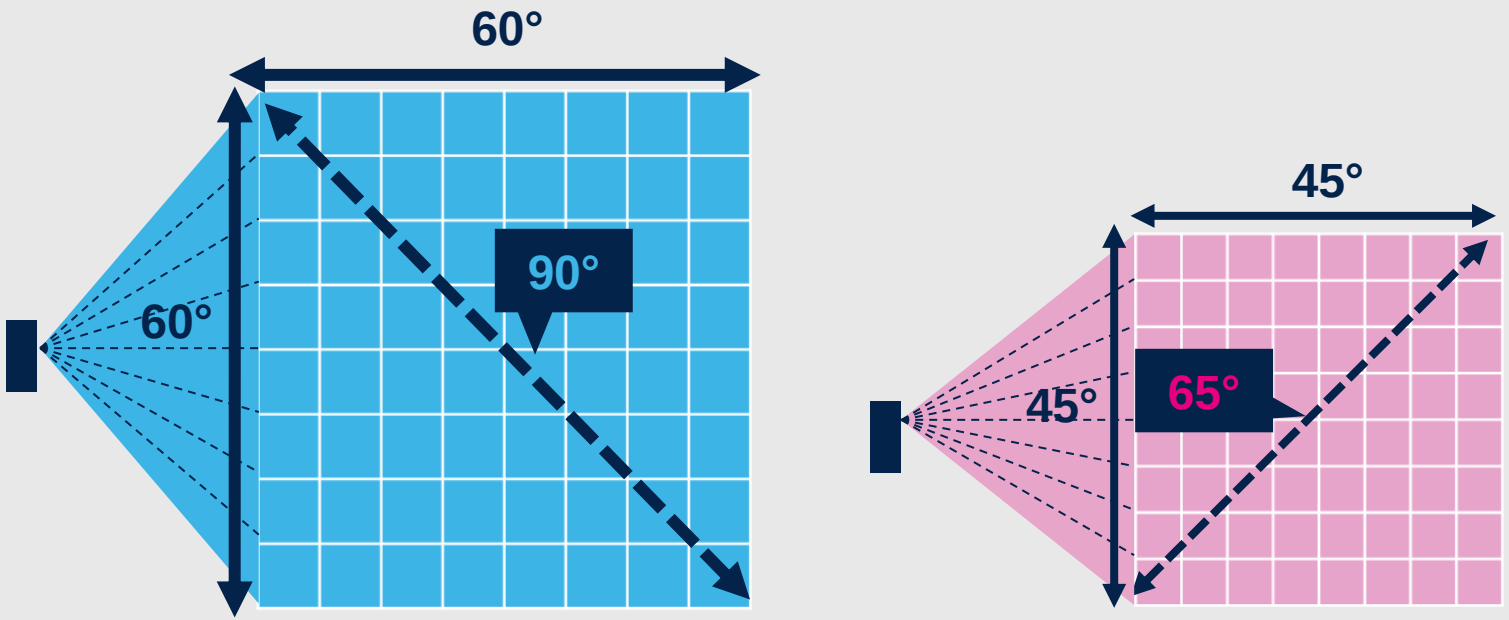
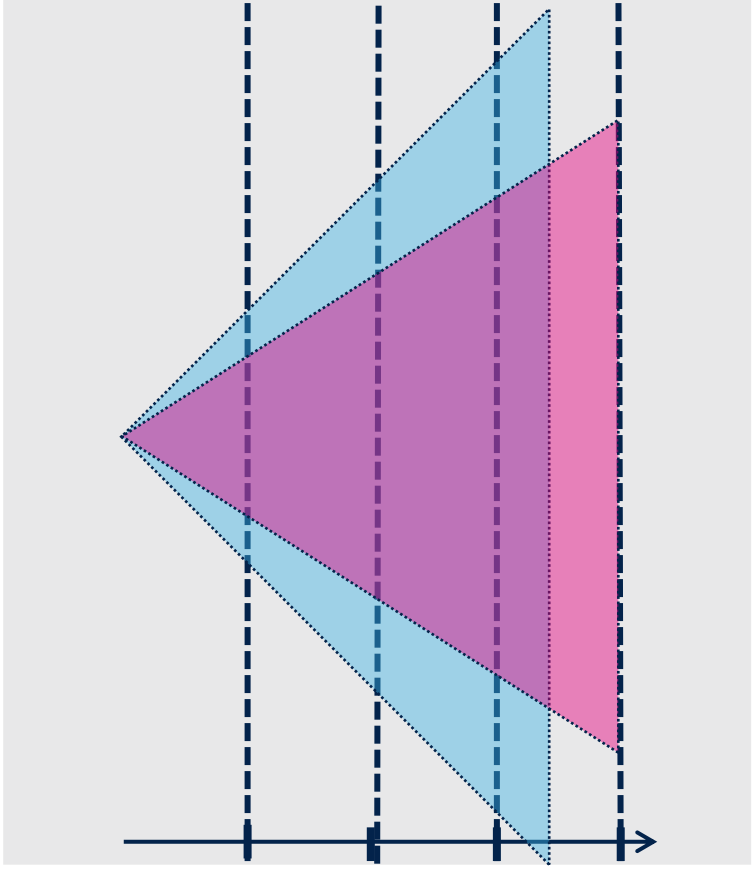
Field of view and ranging comparison

The VL53L7CH has a wider optical field of view, the VL53L8CH ranges further

Coverage zone



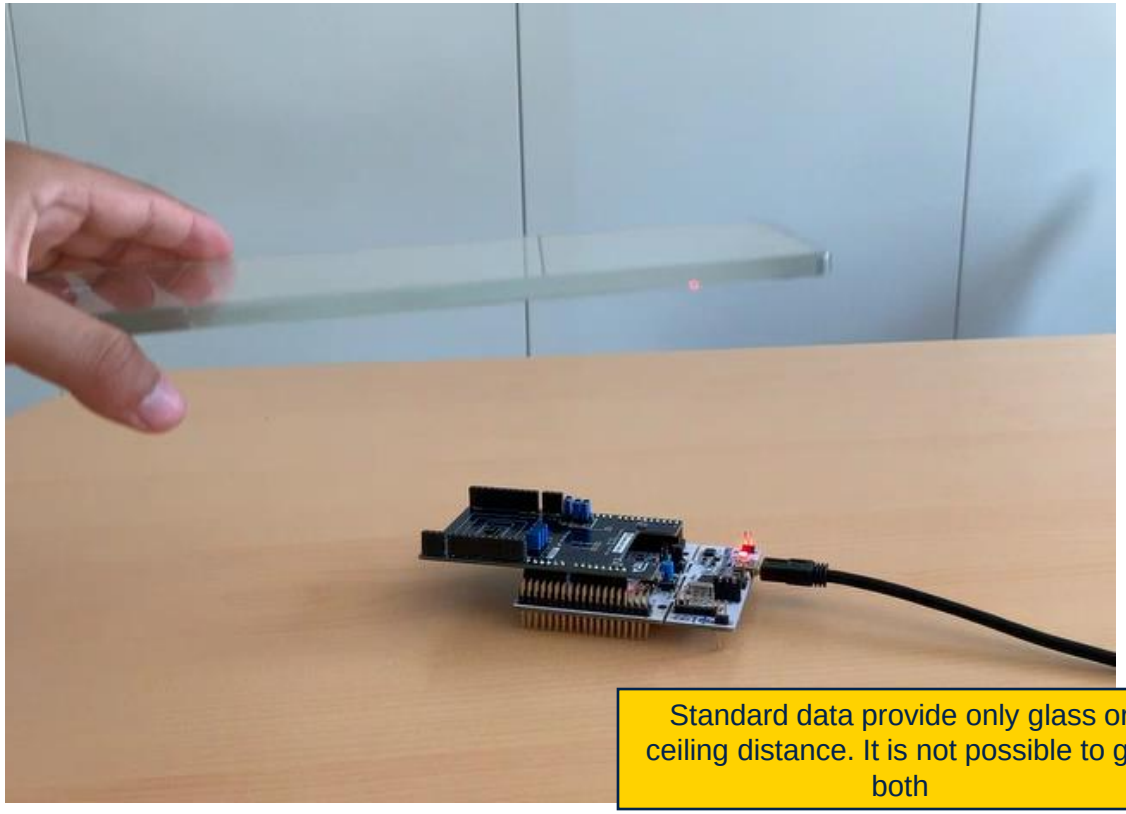
Maximum ranging distance
(drawing at scale)



CNH demos and applications

CNH allows Ceiling and glass detection

Live scene



Standard data provide only glass or ceiling distance. It is not possible to get both

Standard data

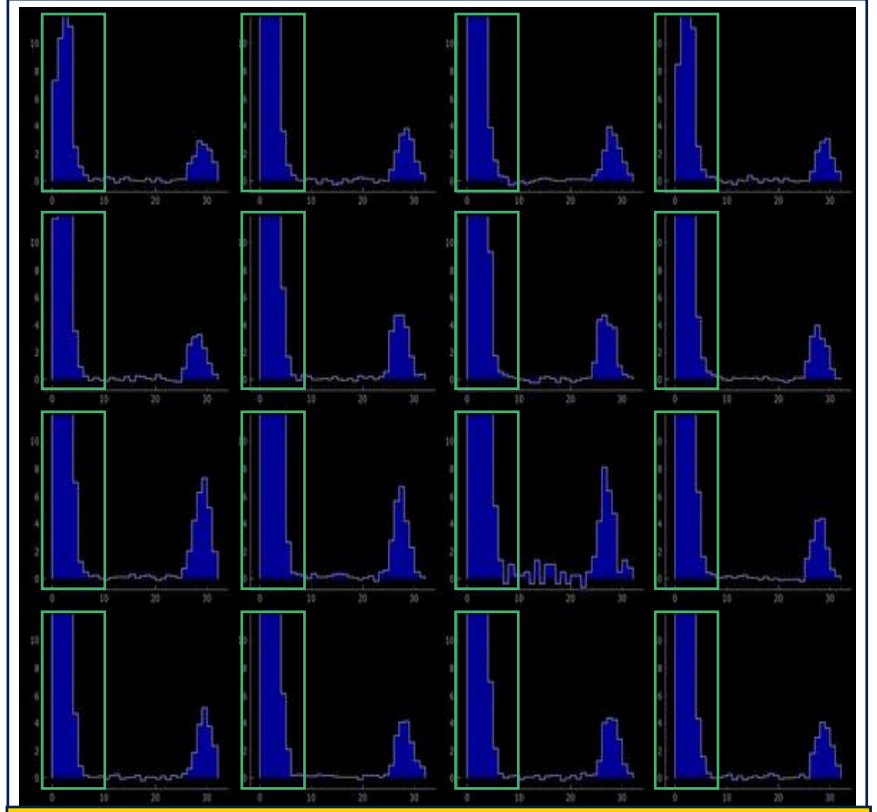
Distance

1910	1918	1925	1938
1918	71	72	1946
1958	66	74	1938
1926	1925	1935	1925

Signal

29	33	32	28
34	873	835	29
52	7485	1374	35
31	37	37	32

CNH

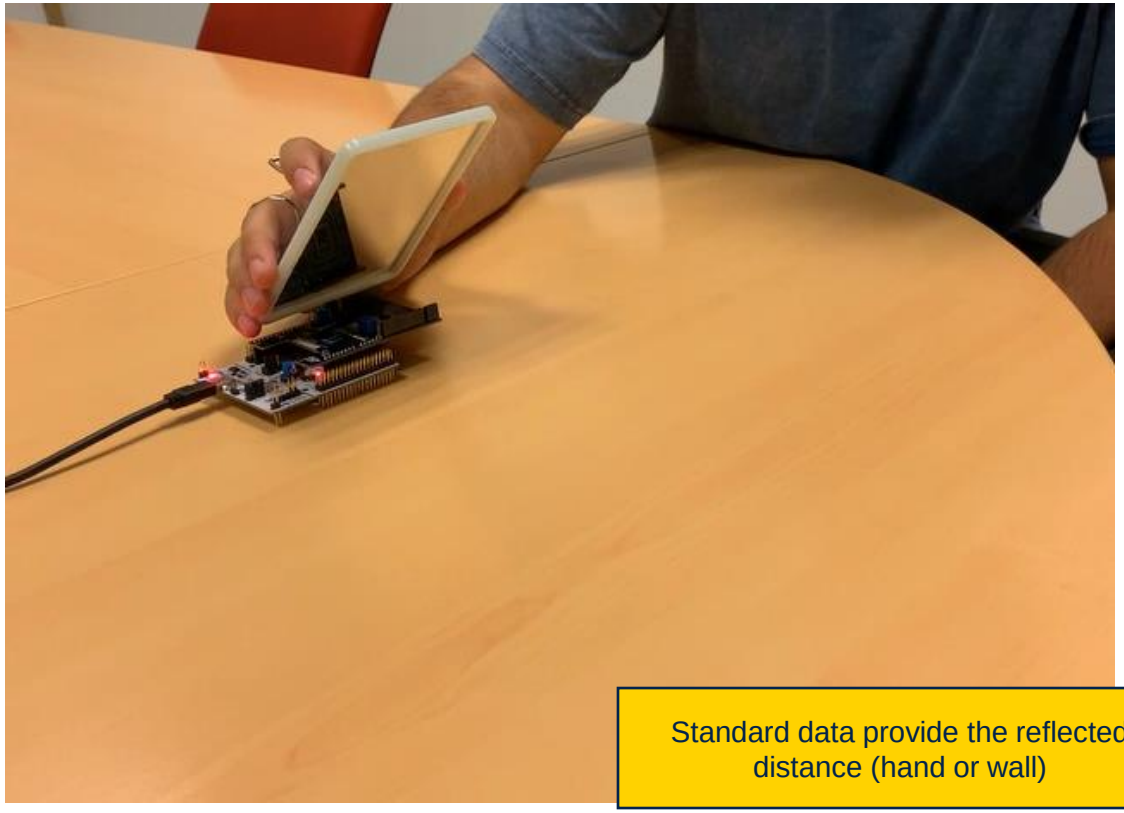


CNH provides two peaks. The first peak identifies the glass presence. The second one illustrates the distance to ceiling

4x4 mode is used for better visibility and readability

CNH allows Detecting mirror and reflecting distance

Live scene



Standard data provide the reflected distance (hand or wall)

Standard data

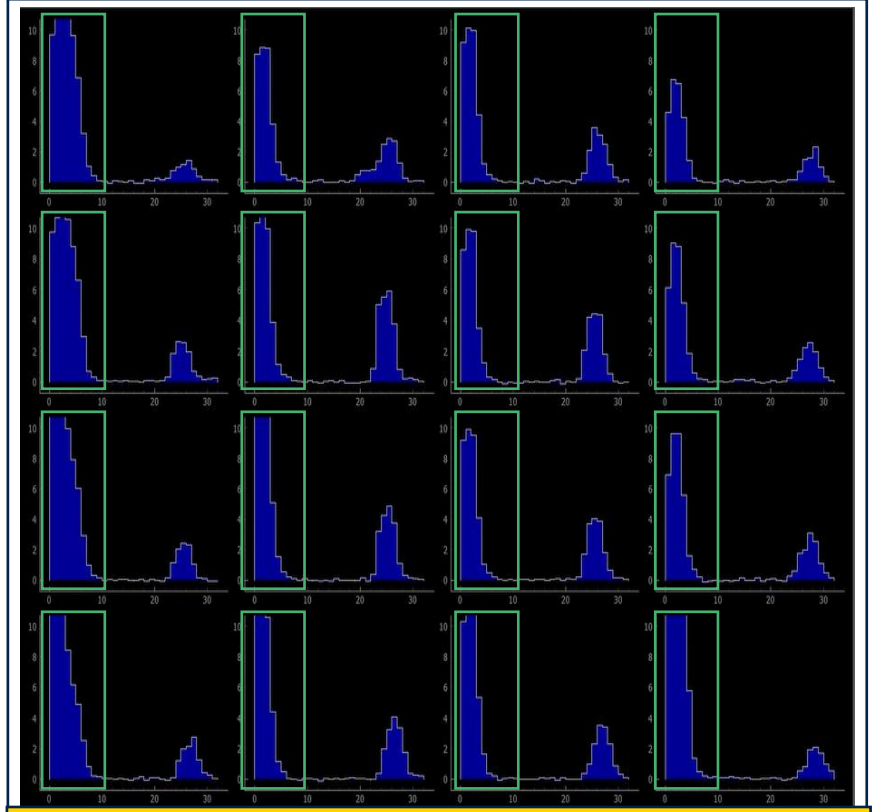
Distance

1695	1734	1804	1860
1706	1780	1836	1872
1730	1796	1856	1895
1736	1811	1876	1896

Signal

13	25	29	21
19	42	31	20
18	33	28	23
21	27	30	21

CNH



CNH provides signal peaks on the first histogram bins, identifying the distance to mirror, rather than reflected image

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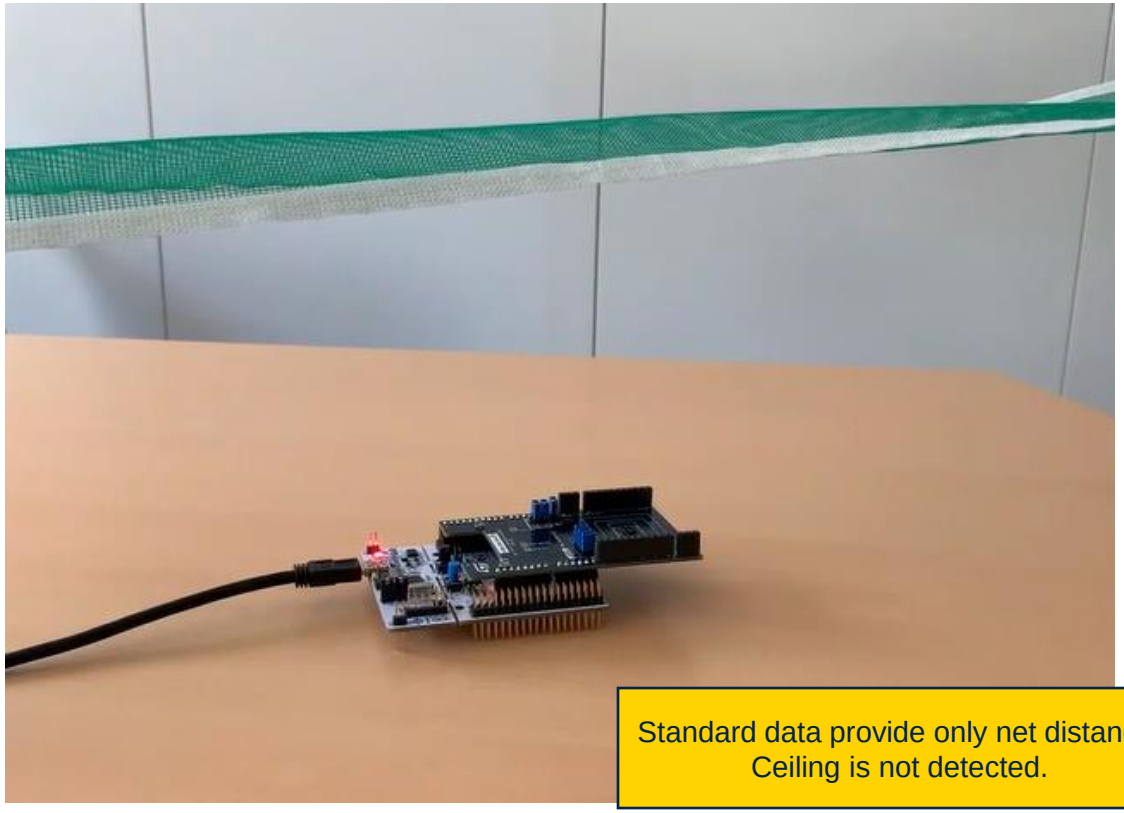
4x4 mode is used for better visibility and readability

CNH allows Seeing through a net

Live scene



Standard data provide only net distance.
Ceiling is not detected.

Standard data

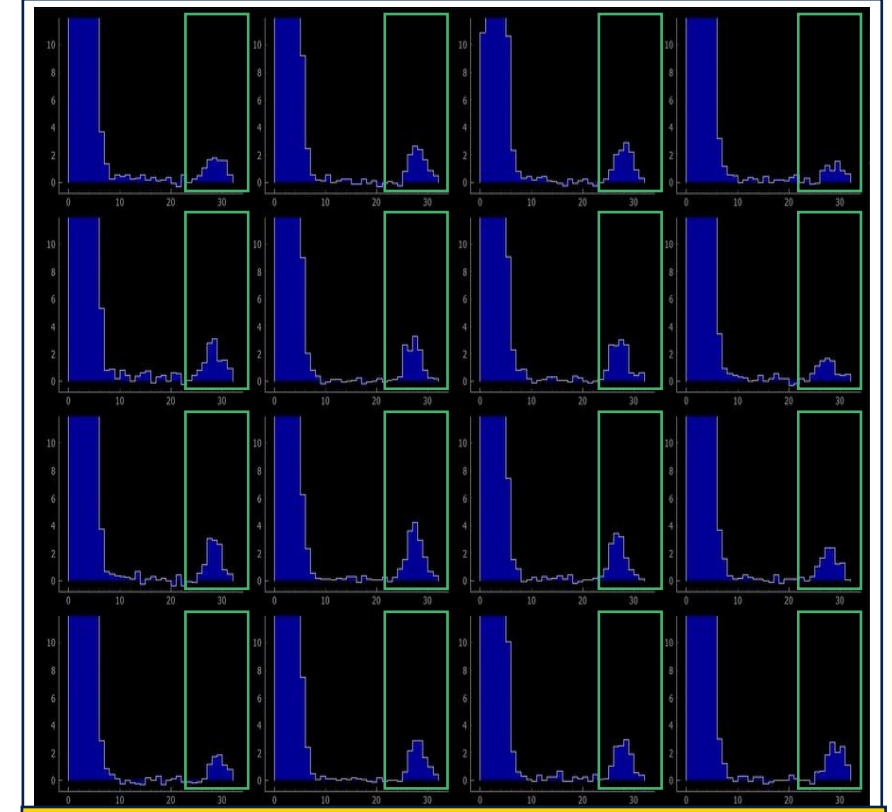
Distance

132	142	155	145
134	146	156	150
137	148	157	150
135	146	157	150

Signal

1789	669	686	1360
1596	750	721	1452
1245	667	625	1288
1225	615	633	1133

CNH



Standard data provides only net distance when CNH provide also the ceiling distance thanks to the second (small) peak

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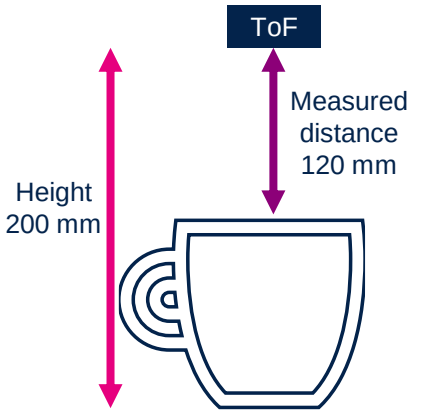
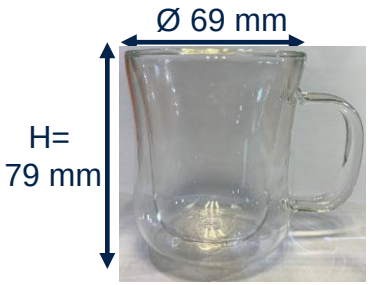
4x4 mode is used for better visibility and readability

Cup size estimation

Use-case

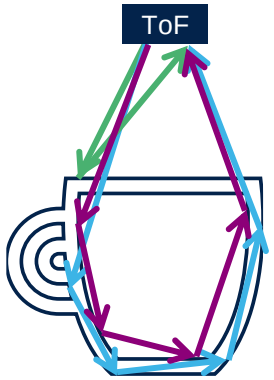
- Measure the height of a glass coffee cup





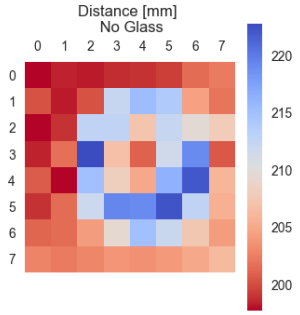
Known limitations

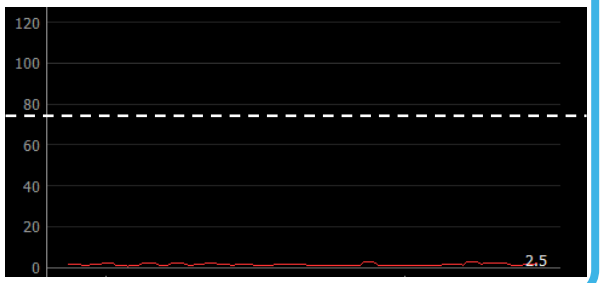
- Due to the light path passing through the glass cup, wrong distances are provided
- Photons reflect everywhere creating many light path impacting distance accuracy



- Some reflect inside the cup
- Some reflect through the glass cup
- Few reflect on the edge

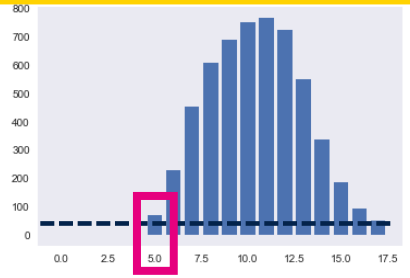
- Using standard data provide 2.5 mm cup height which is totally wrong



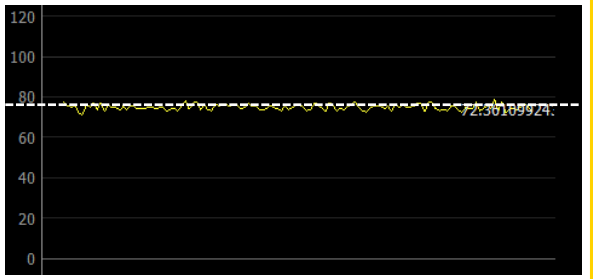


CNH solution

- Thanks to the CNH and histogram shape, we can deduct all light path
- Using the FSB method (First Significant Bin), we easily extract the distance from the sensor to the cup rim

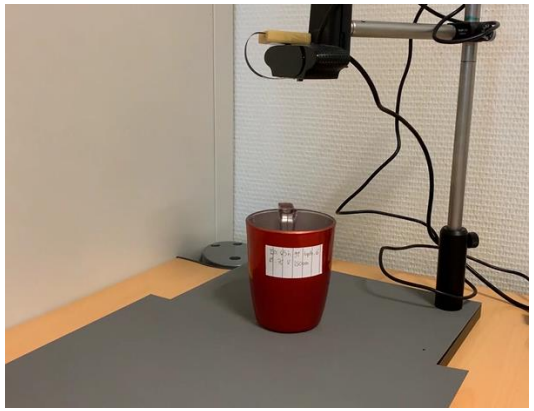


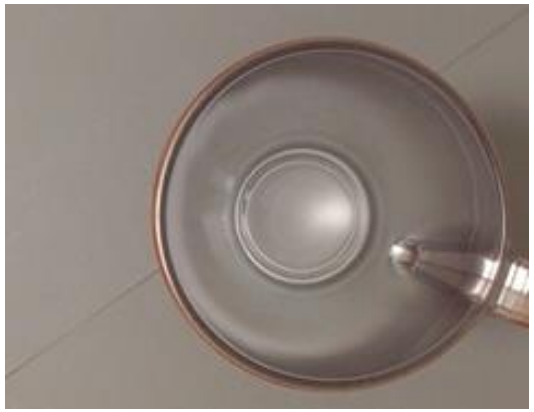
- Subtract the measured distance by the height to obtain the cup height
- Using CNH data and FSB method, we extract 72 mm and higher accuracy



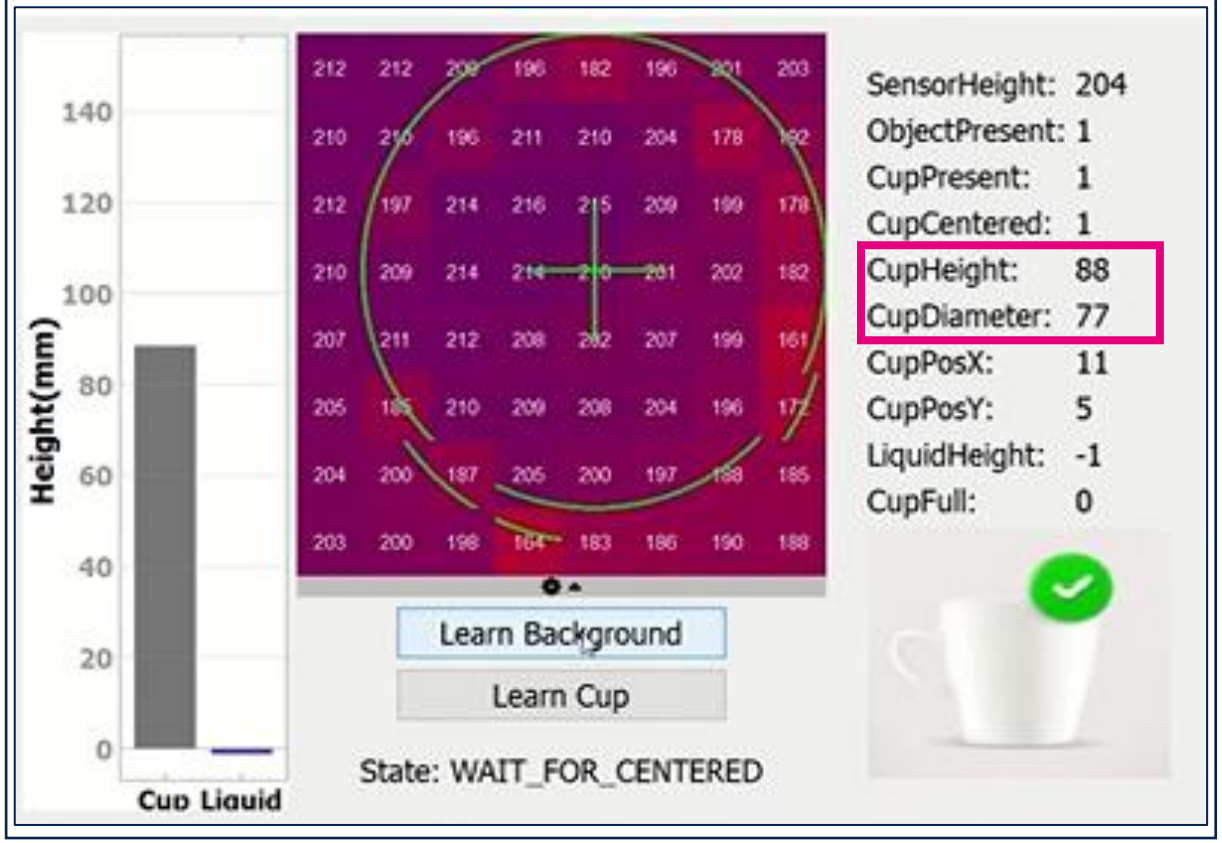
CNH allows Measuring cup size, regardless of material

Live scene



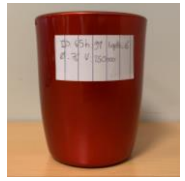


Cup detection demo



Metal red cup

H: 91mm
Ø: 76mm



Double wall glass cup

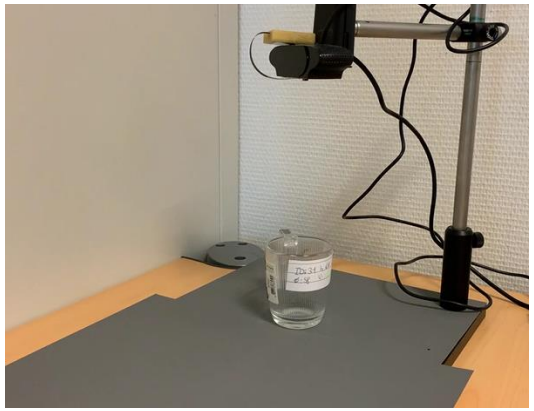
H: 66 mm
Ø: 61 mm

Single wall glass cup

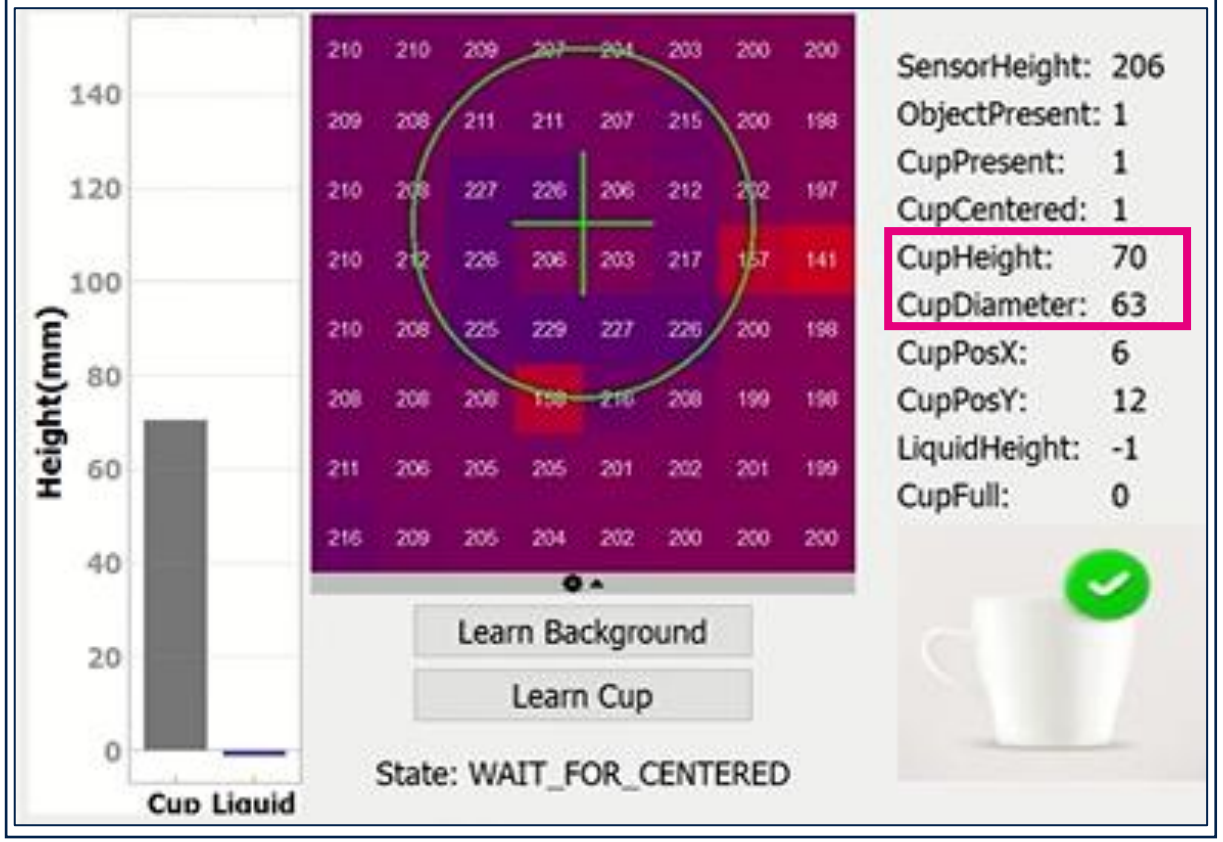
H: 68 mm
Ø: 58 mm

CNH allows Measuring cup size, regardless of material

Live scene



Cup detection demo



Metal red cup

H: 91mm
Ø: 76mm

Double wall glass cup

H: 66 mm
Ø: 61 mm

Single wall glass cup

H: 68 mm
Ø: 58 mm

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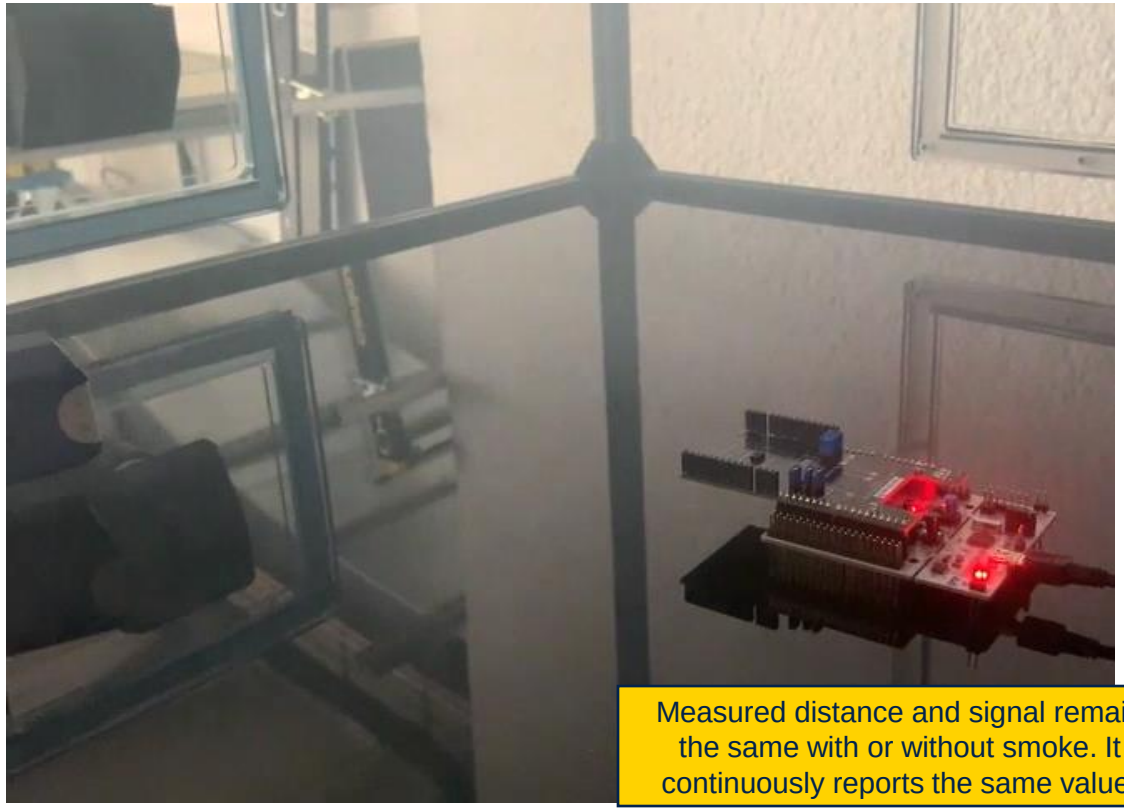
CNH allows Detecting smoke intensity

Live scene



Measured distance and signal remain the same with or without smoke. It continuously reports the same value.

Standard data

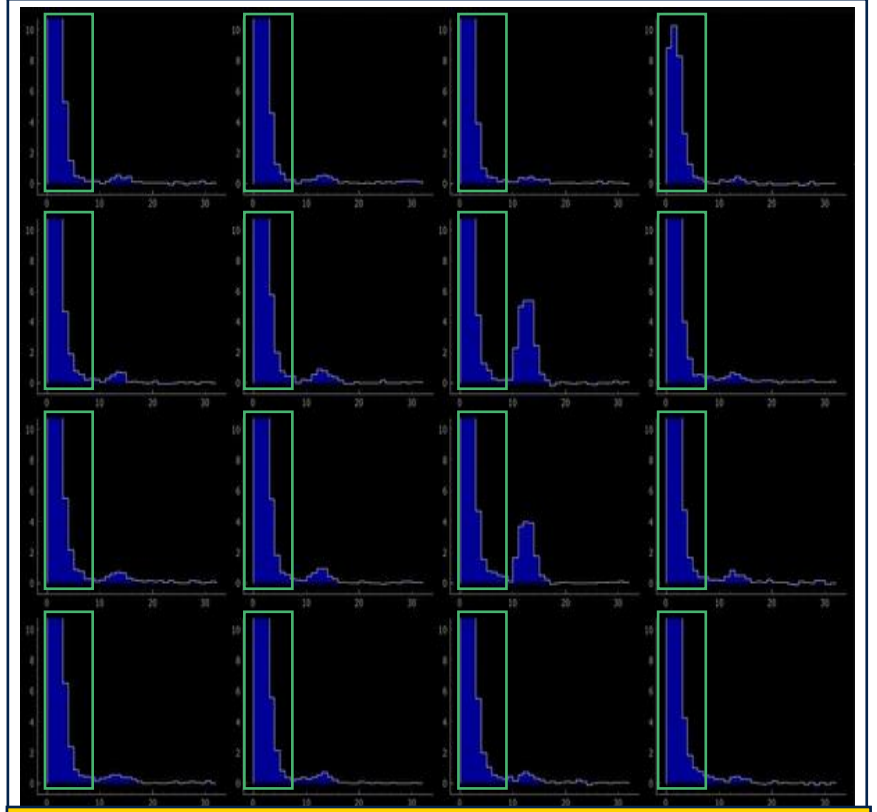
Distance

834	912	827	913
843	879	877	922
889	886	884	858
907	891	880	851

Signal

5	6	4	4
5	6	41	5
6	8	30	6
4	4	5	4

CNH



CNH provides a bin information appearing at the start representing smoke presence detection

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4x4 mode is used for better visibility and readability

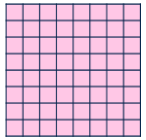
CNH technically

CNH data are widely parameterizable

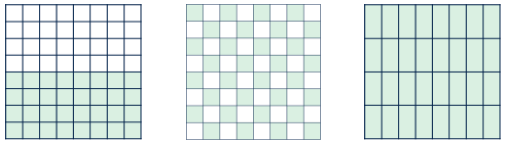
Resolution

- Set the resolution up to 64 zones
- Merge close zones into one bigger
- Reduce resolution to allow for increased number of bins and frequency

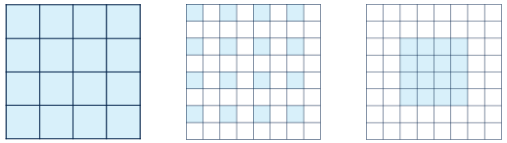
- 64 zones



- 32 zones

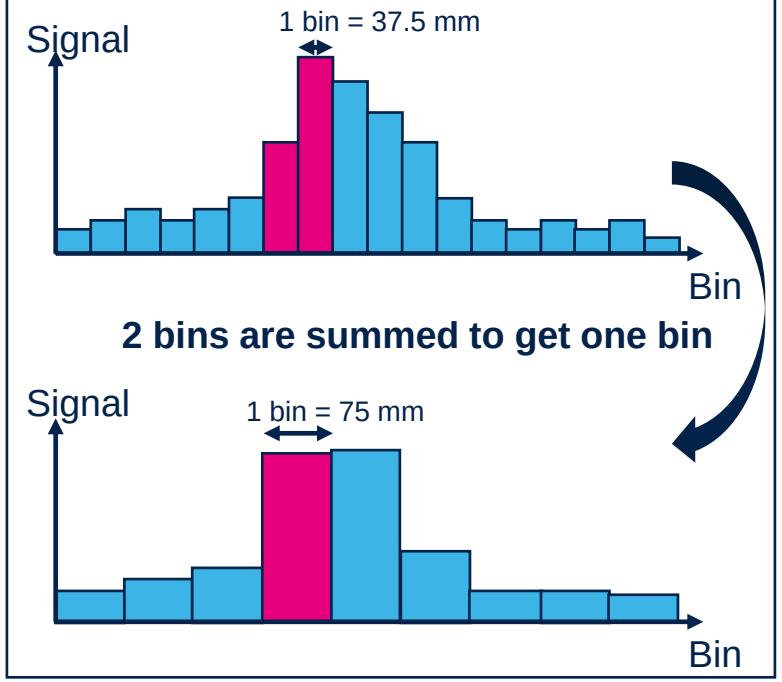


- 16 zones



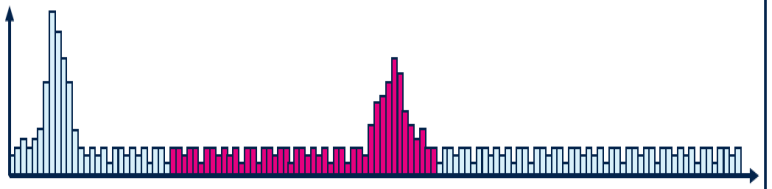
Histogram binning

- Increase the depth of the histogram by summing adjacent bins
- Bin your histogram up to 8 bins in 1



CNH parameters

- Bin start = bin26
- Number of selected bins = 48



Configuration examples

Res.	Histo	CNH size*	Transfer time	Frame rate
8 zones	80 bins	3268 bytes	32 ms	30 fps
8 zones	128 bins	5188 bytes	48 ms	20 fps
16 zones	48 bins	3948 bytes	36 ms	25 fps
16 zones	72 bins	5868 bytes	54 ms	18 fps
32 zones	36 bins	6108 bytes	56 ms	15 fps
64 zones	18 bins	6108 bytes	56 ms	15fps

* CNH size must be <6180 bytes

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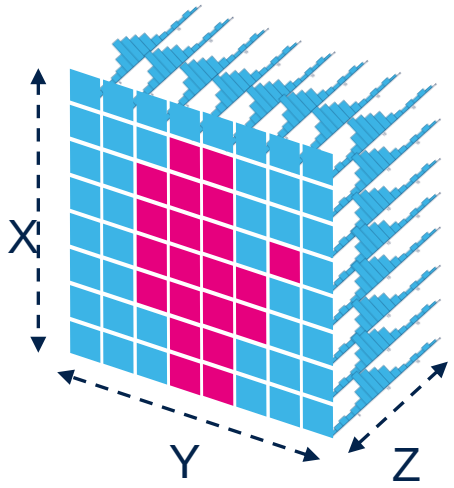
XY resolution vs Z resolution

Lower XY resolution allows higher Z resolution

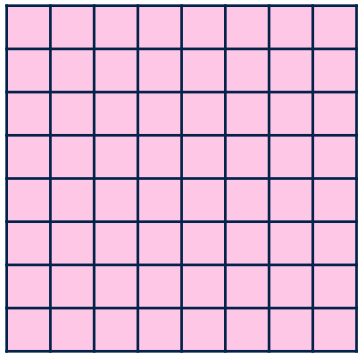
XYZ resolution

- X and Y represents the numbers of zone you can range
- Z resolution represents the number of bins



64 zones

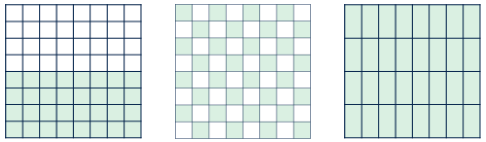
- Outputting the 64 zones means to get the full 8x8 resolution



- Bins/Max frequency:
  - 18 bins = 15Hz
  - 12 bins = 15Hz
  - 8 bins = 15Hz

32 zones

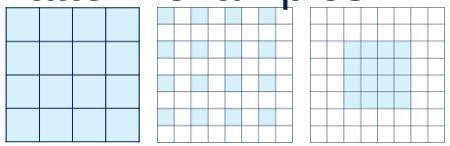
- Choose the 32 zones
  - By selecting only few zones on an 8x8 matrix
  - By merging two close zones into one from an 8x8 matrix
- Pattern examples*:



- Bins/Max frequency:
  - 36 bins = 15Hz
  - 18 bins = 15Hz
  - 12 bins = 15Hz

16 zones

- Choose the 16 zones
  - By aggreging an 8x8 matrix in 4x4
  - By selecting only few zones on an 8x8 matrix
- Pattern examples*:



- Bins/Max frequency:
  - 72 bins = 18Hz
  - 48 bins = 25Hz
  - 28 bins = 30Hz

* Product supports all type of aggregate patterns, but the EVK only accepts the first of the three examples

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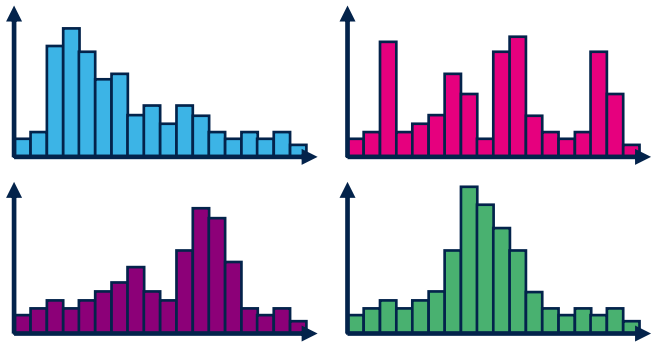
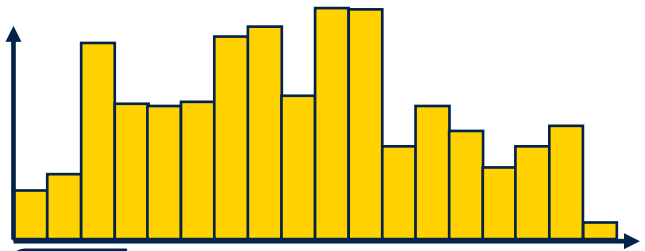
Bin aggregation

Bin aggregation allows deriving a single CNH

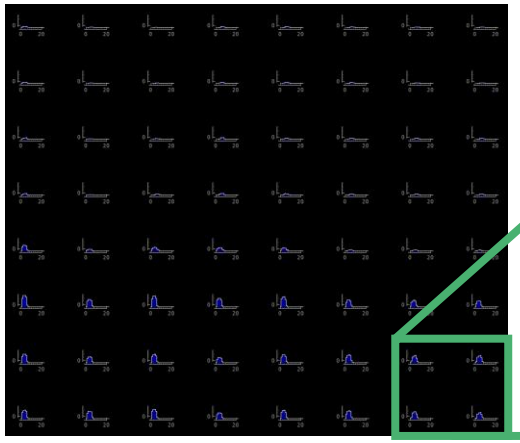
Theory

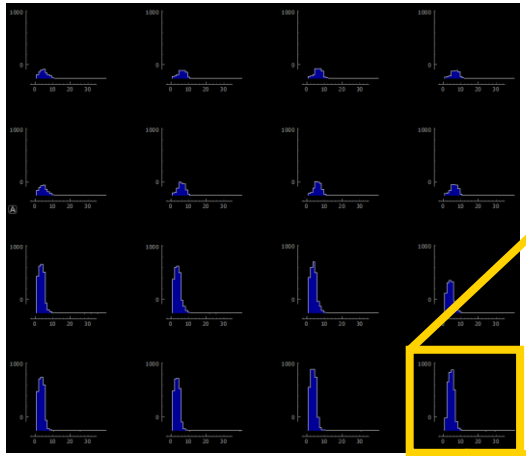


4 histogram are aggregated to get only one

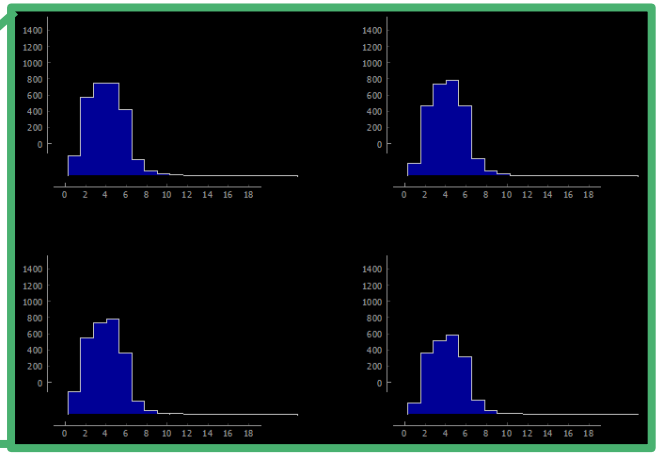


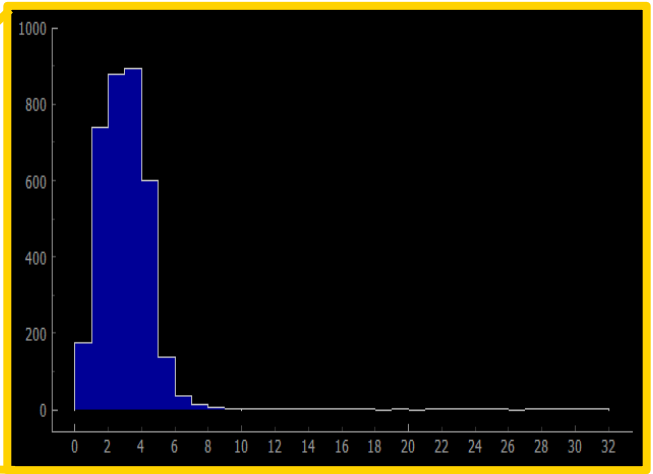
Full resolution





Focus





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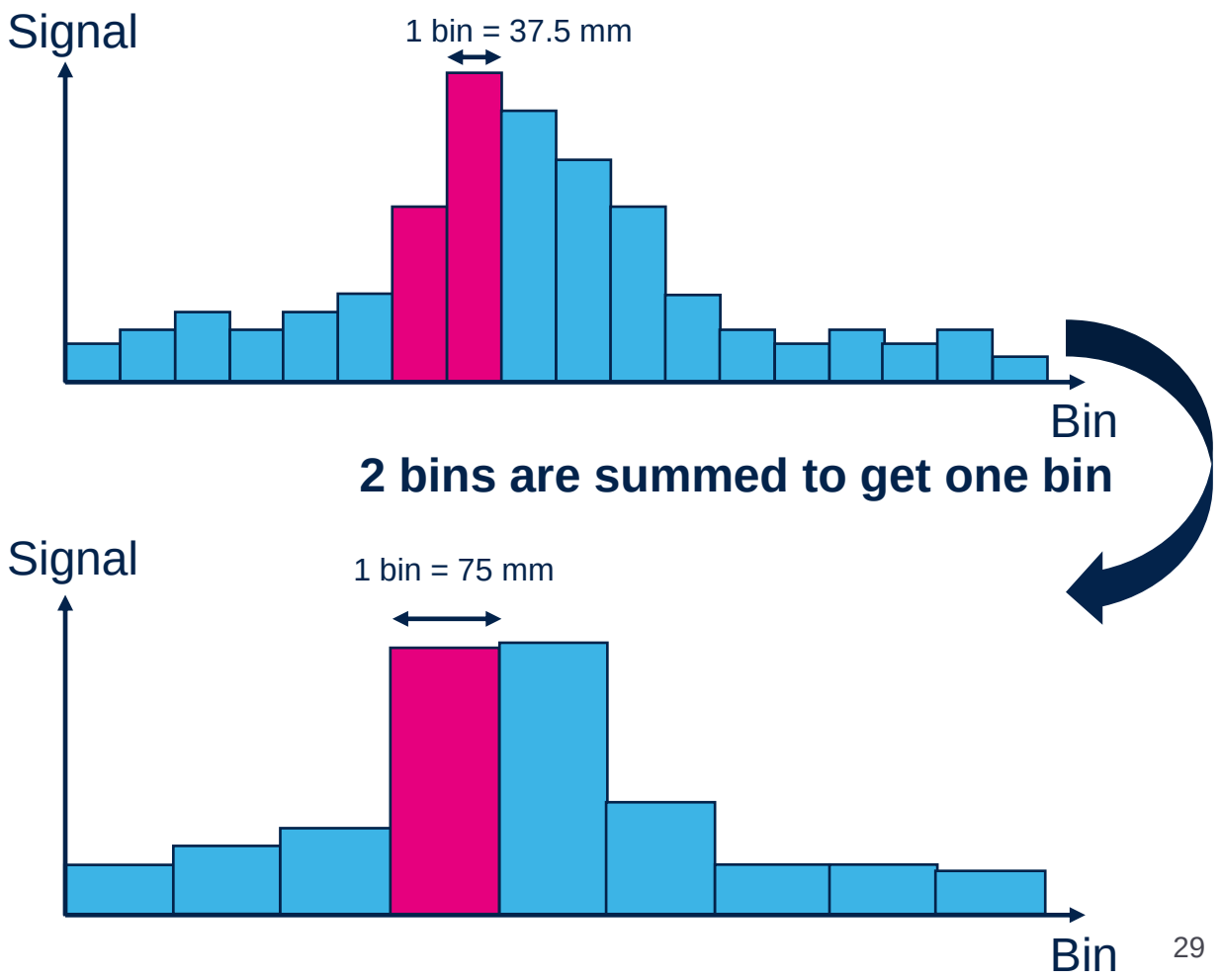
Histogram binning

Increase histogram depth by summing histogram

Binning for longer bin window

- Some applications could require covering a longer bin window
- Bin the histogram up to 8 bins in 1
  - In this case, bin now measures 37.5 mm x 8 = 300 mm
- Examples:

Binning factor	Bin size	Max window in 8x8 (18 bins @15Hz)
1	37.5 mm	675 mm
2	75 mm	1350 mm
4	150 mm	2700 mm
8	300 mm	5400 mm*



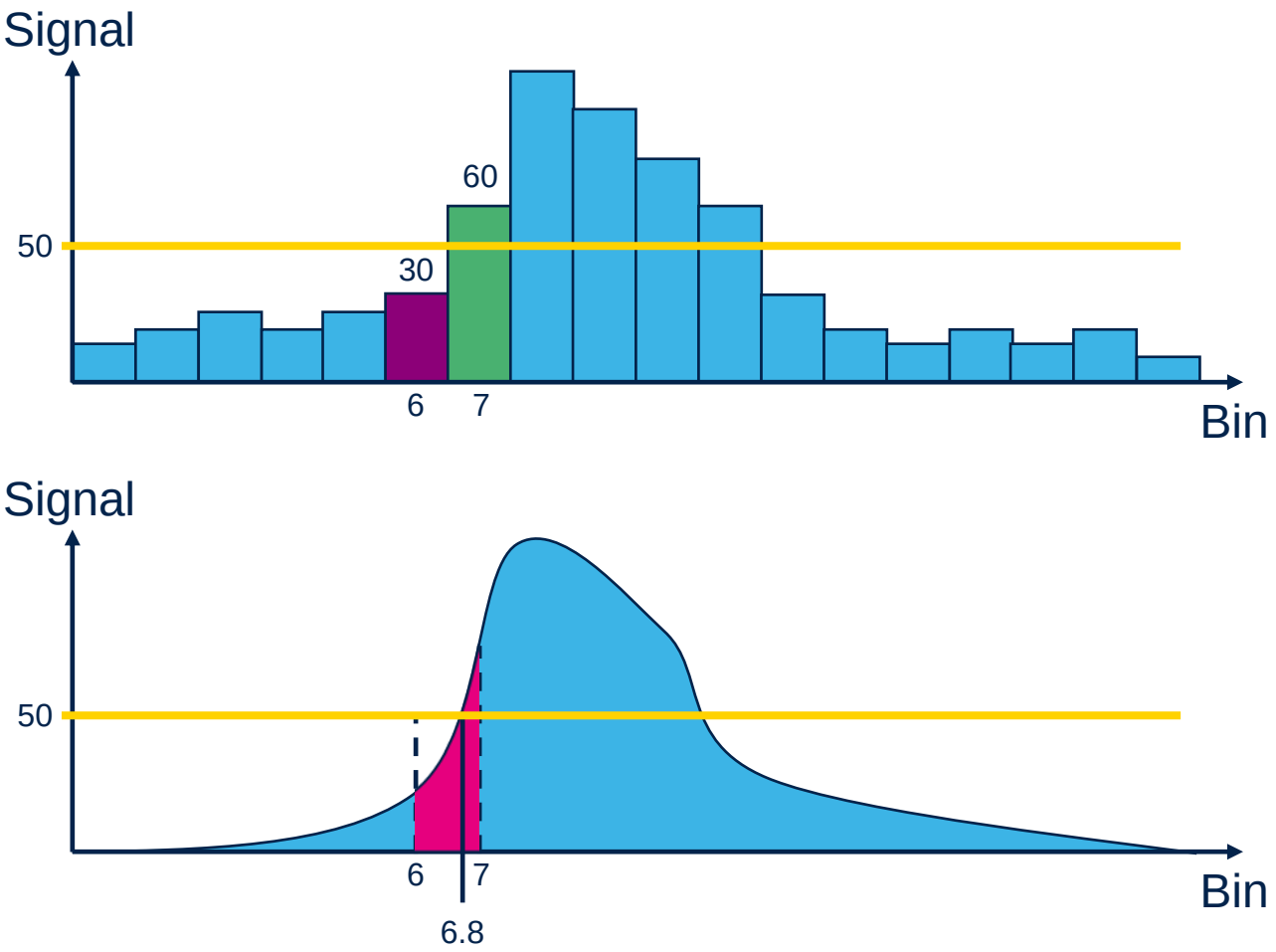
* All bins after 4,000 mm will report only noise due to wrap around limiting the max distance of the sensors at 4 m

First Significant Bin (FSB)

FSB is one of the major post-processing data

First bin above the ambient light level

- The **ambient light level data** is generated for each zone
- The logic would like to take the first bin reaching this value
  - In our example: it should be the **bin7**
- Because we don't know at which moment the signal has reached threshold, we do interpolation
  - In our example: between **bin6** and **bin7**
- Based on this interpolation, we can know more precisely the moment is has been reached
  - In our example: it has been reached at **bin6.8**
- To know the distance, we just multiply the bin found by the bin size (37.5 mm*)
  - In our example: 37.5 mm* x 6.8 = 25.5 cm



* In the case of the binning factor = 1

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Ordering codes

Technical documentation

Complete toolset to start evaluation and integration

	VL53L7CH 	VL53L8CH 
Datasheet	DS14309	DS14310
Software package	STSW-IMG043	
User Manual	UM3183	
GUI	Integrated to the SW zip file	
Evaluation boards	X-NUCLEO-53L7A1 P-NUCLEO-53L7A1 SATEL-VL53L7*	X-NUCLEO-53L8A1 P-NUCLEO-53L8A1 SATEL-VL53L8

* SATEL-VL53L7 boards are not yet on the market, SATEL-VL53L7CX can be used for the moment

Software package

www.st.com/en/embedded- software/stsw-img043

	Part Number	General Description	ECCN (EU)	ECCN (US)	Supplier	Download
+	STSW-IMG043_EVK	GUI for VL53L7CH and VL53L8CH	NEC	EAR99	ST	Get latest
+	STSW-IMG043_F401	STM32F401 project source code	NEC	EAR99	ST	Get latest
+	STSW-IMG043_LNX	Linux driver based on the ULD	NEC	EAR99	ST	Get latest
+	STSW-IMG043_PY	Python scripts examples	NEC	EAR99	ST	Get latest
+	STSW-IMG043_ULD	Ultra Lite Driver source code	NEC	EAR99	ST	Get latest

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FlightSense™
Multi-zone AI enablers ordering codes

Go to st.com/FlightSense contact your usual distributor

Item	Picture	Ordering Code	Comments	
VL53L7CH sensor		**VL53L7CHV0GC/1**	Tape & reel	MOQ= 3.6ku
			With liner	LT= 22weeks
VL53L7 Nucleo™ expansion board		**X-NUCLEO-53L7A1/**	• Cover-window holder • Cover-window sample • 3x spacers	
VL53L7 expansion pack		**P-NUCLEO-53L7A1/**	X-NUCLEO-53L7A1 + NUCLEO-F401RE	
VL53L7 Breakout boards		**SATEL-VL53L7CX** **SATEL-VL53L7** (Q1'24)	2x Breakout boards delivered	

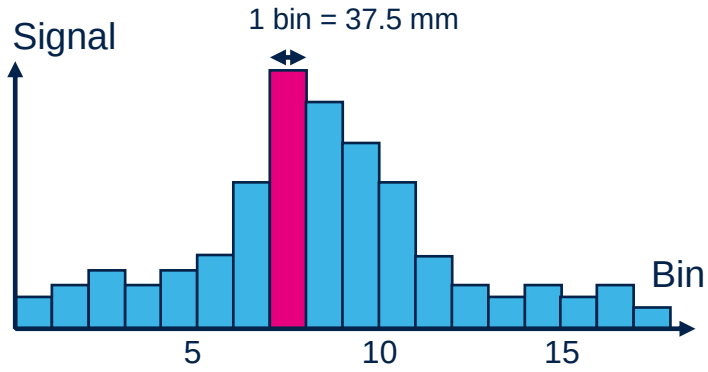
Item	Picture	Ordering Code	Comments	
VL53L8CH sensor		**VL53L8CHV0GC/1**	Tape & reel	MOQ= 3.6ku
			With liner	LT= 22weeks
VL53L8 Nucleo™ expansion board		**X-NUCLEO-53L8A1/**	• Cover-window holder • Cover-window sample • 3x spacers	
VL53L8 expansion pack		**P-NUCLEO-53L8A1/**	X-NUCLEO-53L8A1 + NUCLEO-F401RE	
VL53L8 Breakout boards		**SATEL-VL53L8**	2x Breakout boards delivered	

FlightSense™ Summary

Leader on Direct ToF

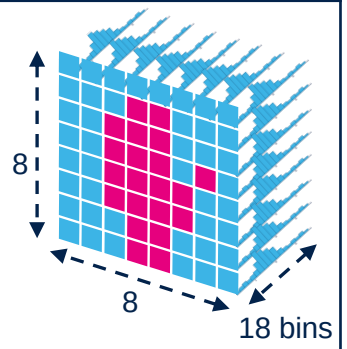
= 1st

Compact Normalized Histogram



Boost your data quantity

- Up to 1.5 K data per frame
- Both standard and CNH data

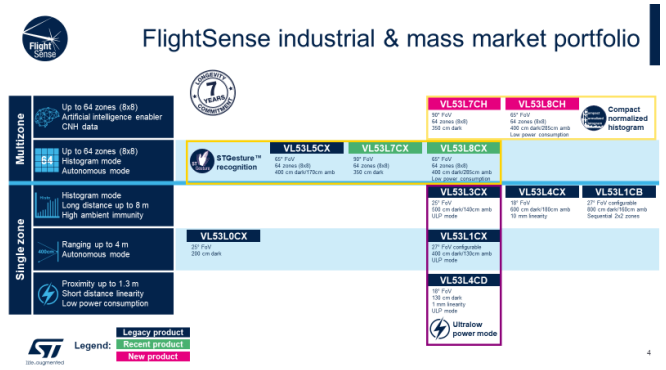


Two products

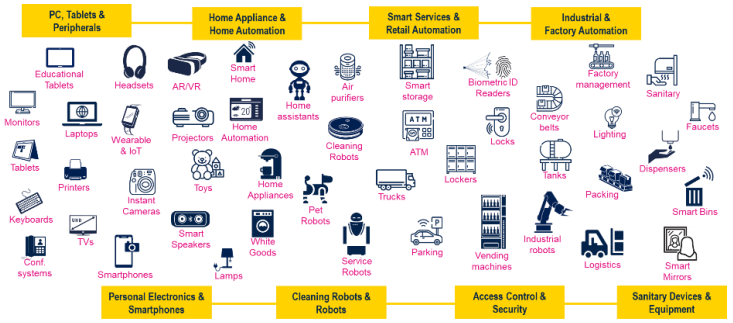
- **VL53L7CH**
  - 90° FoV
  - 350 cm max distance

- **VL53L8CH**
  - 65° FoV
  - 400 cm max distance

Continuous improvement



Unlimited markets & applications



Our technology starts with You

Find out more at www.st.com/FlightSense

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