AWRL6432 2-Row Child Presence Detection (CPD) Use Cases

Dec. 2022

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Overview

CPD Testing shows that AWRL6432 enables the detection of baby inside the car to enable customers to meet base NCAP requirements.

Information in the following slides:

- Test setup details
- 2 ROW CPD Performance and Test Results
- Processing Chain Overview

EURO NCAP Direct sensing requirements:

- ✓ Full Cabin/row coverage
- ✓ Detection delay no more than 10sec
- ✓ Continuous Cabin monitoring
- • Optional - 2 Level Classification (Adult vs Child)

Key performance metric:

Parameter	EURO NCAP Requirement	AWRL6432 Demo Results
Coverage	Full 2 row coverage	Full 2 row + footwell coverage
Child detection accuracy	>95%	100%
Detection delay	<10s	4s
Avg power	-	59.02mW

AWRL6432

1st Row Seat
2md Row Seat
1st Row Footwell
2nd Row Footwell

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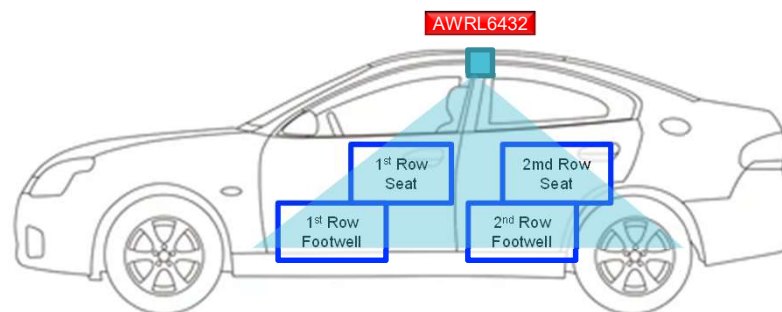
Test Setup Details

- The data is collected with the TiREX demo – AWRL6432 Life Presence Detection Demo
  - Data collection duration: 200 frames
  - Frame rate: 200ms
  - Detailed Chirp configuration discussed in the next slide
  - For performance evaluation, the initial 4ms of data is used for settling and the detection after 4ms is used to calculate the detection rate in the performance report.

- Point Cloud Data was collected with baby doll (Aston Drake) placed in different seats and footwell

- Overhead Mounting position details –
  - For all the test data, the sensor is mounted at (x = 0, y = 1.2m, z = 1.2m) and rotated 90 degrees to face the floor. In addition 90-degree anti-clockwise rotation in the x-y plane to use the better FOV in azimuth to cover the depth of the car.

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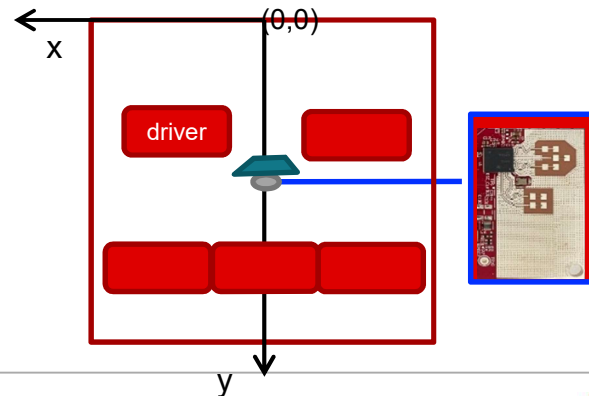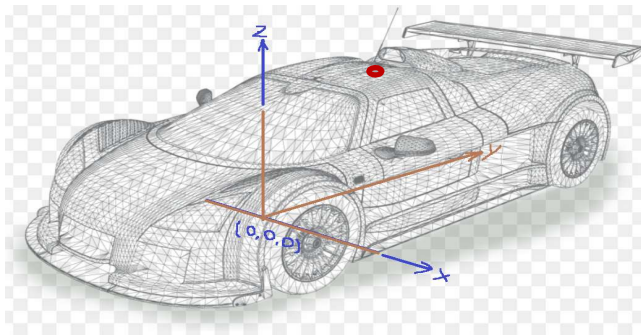
Chirp Configuration Details

Chirp parameters and system performance	Values	Units
Starting frequency	58.1	GHz
Ramp slope	60.0	MHz/us
Number of samples per chirp	128	#
Number of burst	16	#
Sampling frequency	2.50	MHz
Idle time	7	us
ADC valid start time	10	us
Ramp end time	63.0	us
Chirp accumulation *	4	#
Burst period	800	us
Valid sweep bandwidth	3072.11	MHz
Frame duration	200	ms
Maximum range, Rmax	2.8	m
Range resolution	4.9	cm

* New feature in AWRL6432

4

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2-Row CPD Performance

- Results based on 200 frames

|	Test Case	Detection Rate	MaxAvgSNRIndB	maxNumDetectPoint
Seats	No occupancy	0%	12.7	2
	Baby in 2nd row driver side, facing forward	100%	28.2	6
	Baby in 2nd row middle seat, facing forward	100%	29.9	8
	Baby in 2nd row passenger side, facing forward	100%	25.3	7
	Baby in 1st row passenger seat, facing backward	100%	20.9	7
	Baby in 2nd row driver side, facing backward	100%	14.1	10
	Baby in 2nd row passenger side, facing backward	100%	16.5	8
Footwell	Baby lay in 1st row driver side footwell	100%	19.2	5
	Baby lay in 1st row passenger side footwell	100%	15.2	4
	Baby lay in 2nd row driver side footwell	100%	26.3	6
	Baby lay in 2nd row middle footwell	100%	34.5	8
	Baby lay in 2nd row passenger side footwell	100%	18.9	7

Definitions

- **Detection Rate**: detected frame divided by the total number of frame

- **MaxAvgSNRIndB**: maximum of average SNR of the detected points cross frames

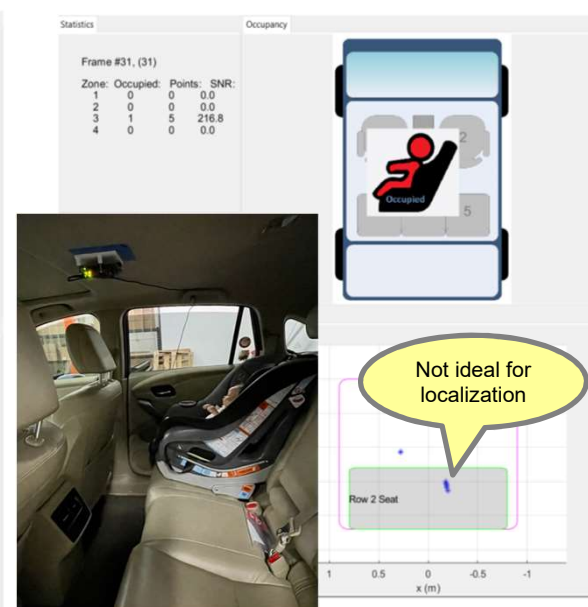- **maxNumDetectPoint**: maximum number of the detected points across all frames

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2-Row CPD Test Snapshot
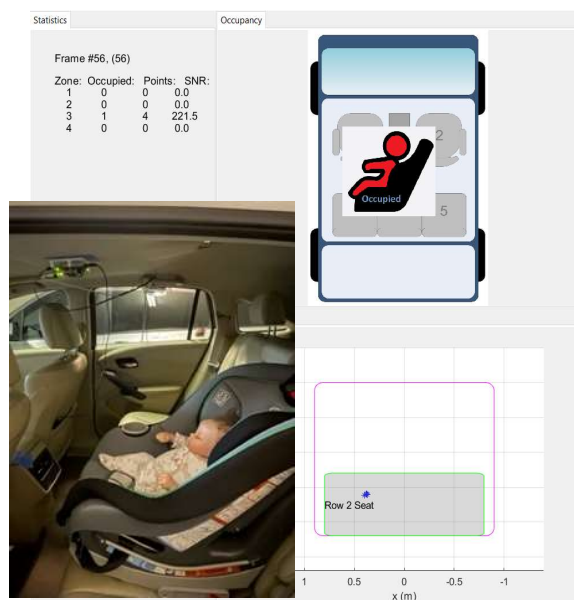
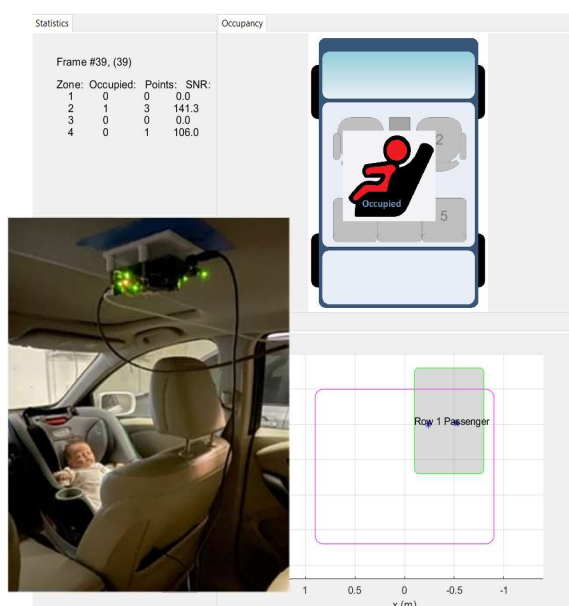Baby in 2nd-row driver side facing forward
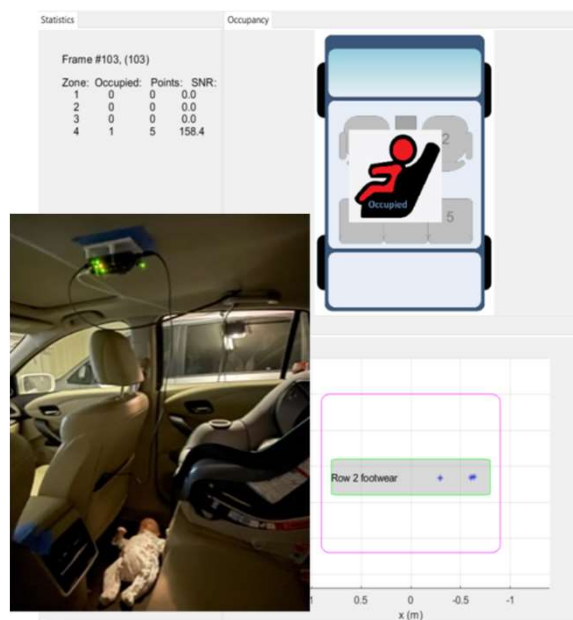
Baby in 2nd-row footwell
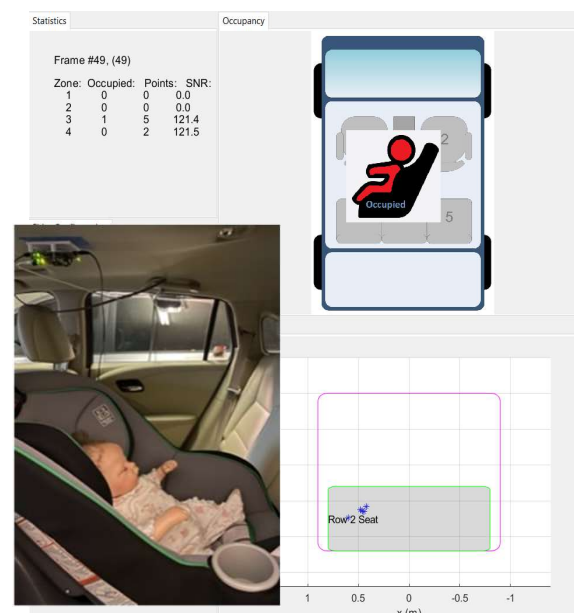

Baby in 2nd-row passenger side facing forward

2-Row CPD Test Snapshot (Cont…)

Baby in 1st-row driver side footwell

Baby in 1st-row passenger side rear-facing

Baby in 2nd-row driver side rear-facing

Performance Summary and Analysis

- Running AWRL6432 Life presence detection demo with minor chain
  - ✓ Using 4 chirp accumulation (accum = 4)
  - ✓ After chirp accumulation, use 16 chirps per frame and 64 chirps cross 4 frames for further process.

- ***Able to cover two-row and footwell CPD with 100% of detection***

- Point cloud precision summary: Second-row passenger-side baby localization is not precise compared to other locations tested. Antenna design can further be optimized to improve performance (more details in next slide)

- The current signal chain is optimized for low power. For higher performance, tradeoffs can be made between system power vs accuracy, using a different signal chain design

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xWRL6432 Antenna Radiation Pattern
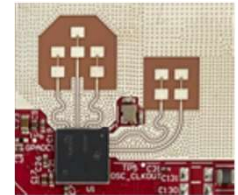
- Lower cost PCB material (FR4) results in lower antenna gain
  - PCB materials like Rogers can improve the performance further
- 2 patch antenna design results in narrower FOV for elevation.
- TX1 FOV is impacted by the crystal oscillator metal case (highlighted in the red cycle)

Antenna Design can be improved for in-cabin sensing applications compared to the reference design

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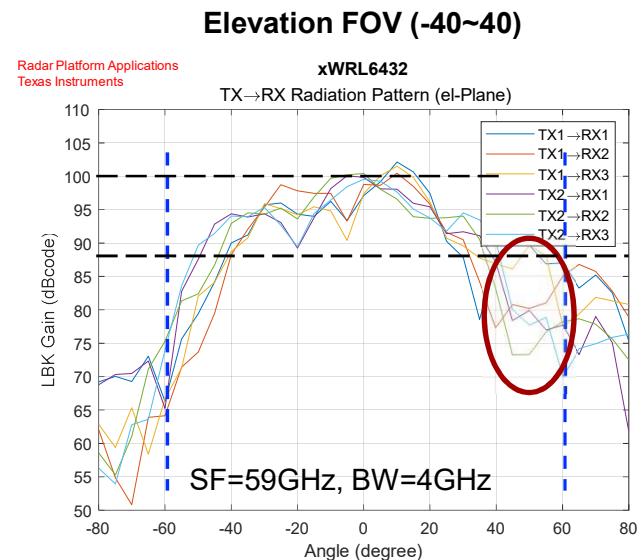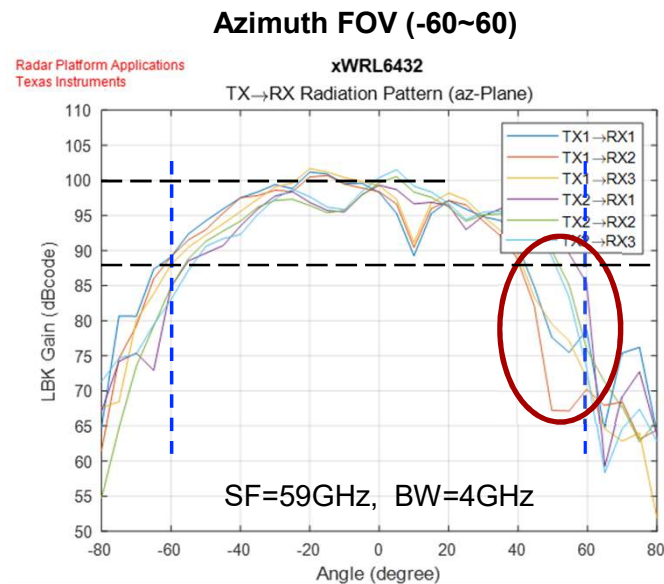
AWRL6432 Life Presence Detection
Processing Chain Details

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Signal Chain Overview

- Frame processing is controlled by the ARM core, using HWA.

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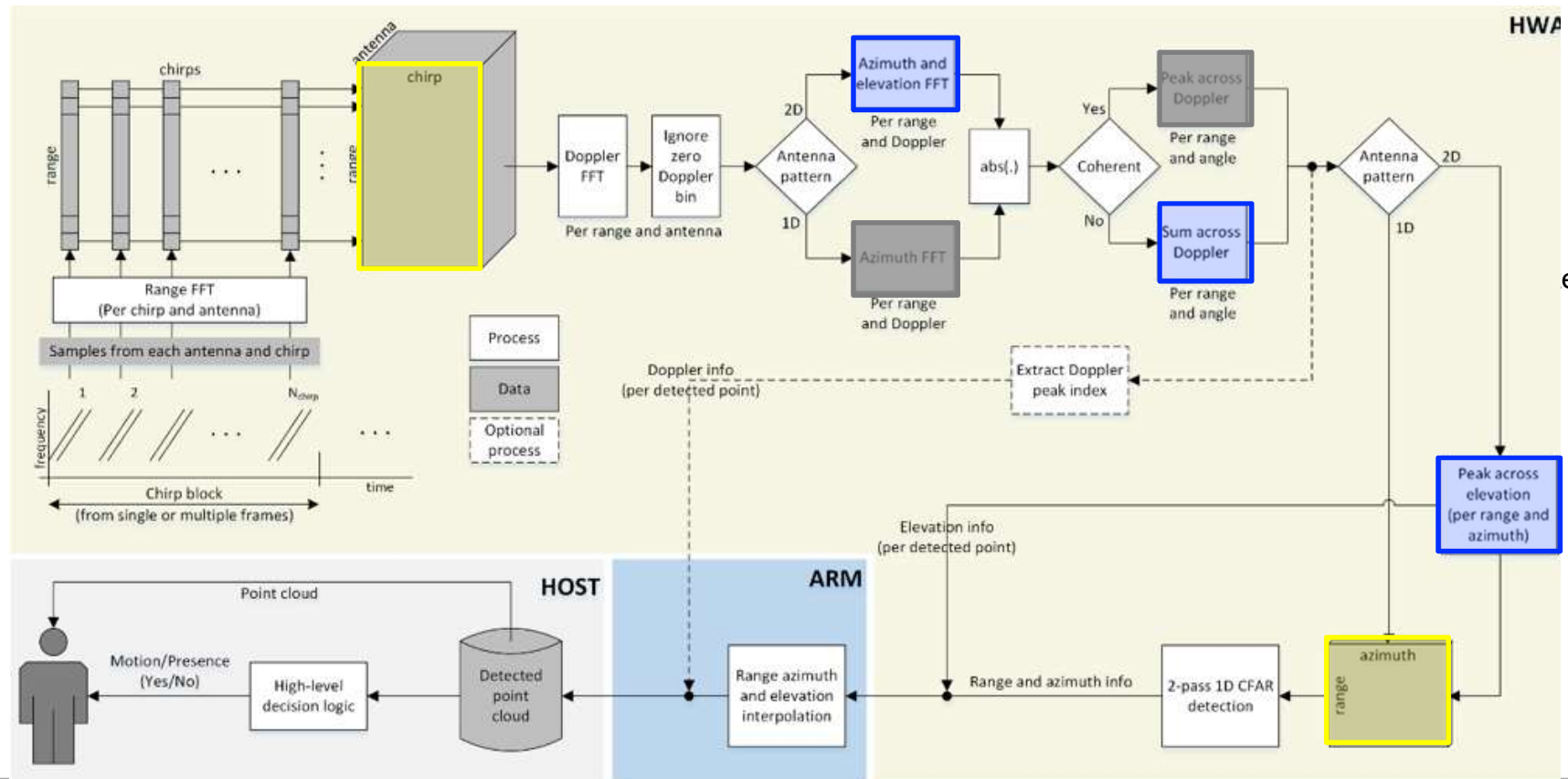
Motion Detection Chains

- Range FFT is saved in RadarCube in L3
  - Major chain: collect one frame of data
  - Minor chain: collect chirps across several frames (sliding window)

- For each range bin, Doppler FFT, azimuth FFT and elevation FFT are calculated
  - Have a memory limitation of 32KByte inside HWA for this Doppler-azimuth-elevation 3D FFT output
    - If numAzimBin = 16, numElevBin = 8; then numChirp for Doppler FFT can not exceed 64,
  - Zero Doppler is removed, rest of the Doppler bins are combined non-coherently ➔ Azimuth and Elevation heatmap per range bin
  - Record the peak elevation value per azimuth bin. Store elevation peak index and Doppler peak index
  - ➔ Create range-azimuth heatmap

- Run CFAR on Range-Azimuth heatmap

- Collect the point cloud (range, azimuth, elevation, Doppler and SNR info)
  - Peak interpolation in Range, azimuth

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High Level Decision Logic

- Transform the point cloud into the car-coordinate.

- Define zones in car-coordination

- Map the point cloud into zones.

- Run per zone-based state machine to make a decision on whether a zone is occupied or not.

- Declare presence detection if any zone is occupied.

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# Frame Processing: Point Cloud Transformation

- The detected point cloud is all relative to the sensor.
  - The sensor position can change, but the seating zone for a car is fixed given a car.
  - For simplicity, in the visualizer, we define the seating zone based on the car coordinates, and transform the point cloud from sensor coordinates to the car coordinates.

- To support different position and different mounting angle, "sensorPosition" CLI command is used
 - Indicates the mounting offset in (x, y, z) and mounting rotation angle in y-z plane, x-y plane and x-z plane
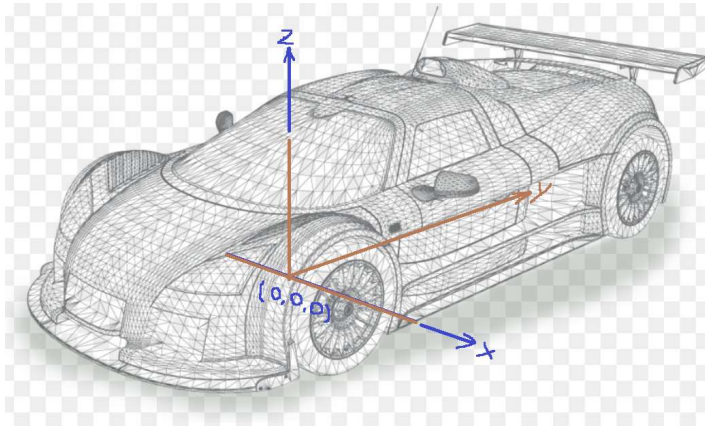
CLI command	Parameters (in command order)
sensorPosition	offset in x direction, in meter
	offset in y direction, in meter
	offset in z direction, in meter
	Clockwise rotation angle in y-z plane, in degree
	Clockwise rotation angle in x-y plane, in degree
	Clockwise rotation angle in x-z plane, in degree

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Frame Processing: Zone Definition and Assignment

- Zone definition through CLI commands to cover head, body and leg part:

  % zone 1 (driver)

  – cuboidDef 1 1   0.15 0.70   0.6 1.2   0.85 1.1
  – cuboidDef 1 2   0.2 0.70   0.3 1.1   0.4 0.85
  – cuboidDef 1 3   0.2 0.70   0.0 0.7   0.0 0.5

- Zone assignment occurs when a point cloud detection resides within at least one of the zone's cuboids.

- Cuboid rules:
  – Cuboids (for the same zone) may overlap or be disjoint.
  – Zones should not overlap, and usually perform better with some amount of space between them.
  – Some zones, such as intruder spaces and cargo areas can be represented with a single cuboid.

- Detections not matching any zone are discarded.

- The result is a list of point cloud detections mapping into each zone.

First row seats
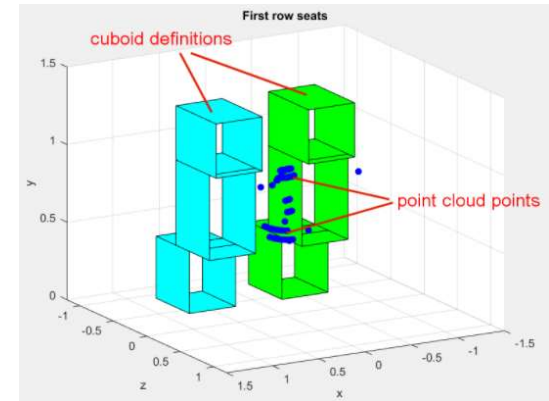
3D Zone Definition (side view)

15

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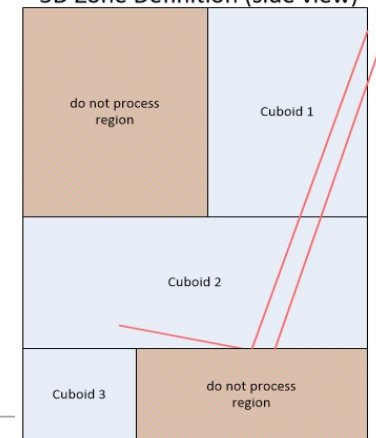
Frame Processing: Occupancy State Machine

- The Occupancy State Machine examines the detection to zone mapping and makes yes/no occupancy decisions each frame.

- Decisions can be further processed by application software.

- Entry conditions:
  - small number of detections with a high average SNR, *or*
  - larger number of detections with smaller average SNR.

- Stay condition:
  - num detections with thresholded SNR

- Forget condition:
  - exceeds number of frames failing the Stay condition

- Overload condition:
  - High energy level (vehicle entry, exit, or someone changing seats). This causes all zone states to be frozen until the overload subsides.

- All parameters are configurable via CLI commands.

Zone State Machine

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