LiDAR output stream data format and scaling

Raw output format

The MicroVision LiDAR sensor acquires two measurements for each optical pulse:

- **Depth** based on the return time of the reflected pulse
- **Intensity** based on the amplitude of the reflected pulse

These values are acquired concurrently and remain paired per pulse within each scan line.
The acquired scan lines therefore contain interleaved depth and intensity values.

Figure 1 shows one line of the LiDAR data frame with N points of interleaved depth and intensity data. Each value is unsigned 16-bit (UINT16) and transmitted as little-endian (MSB first).

A frame of LiDAR data is composed of a series of lines in this format. Each line represents a horizontal scan, and the lines are in the same sequence as the laser scan. The scan direction is top to bottom, and the LiDAR device streams the lines out in that top-to-bottom sequence. (Note: Windows USB Video Class drivers flip the line sequence).

Point 0		Point 1		Point 2		...	Point N	
UINT16 Depth	UINT16 Intensity	UINT16 Depth	UINT16 Intensity	UINT16 Depth	UINT16 Intensity		UINT16 Depth	UINT16 Intensity

Figure 1 *- Raw scan line format with interleaved depth and intensity*

For host image processing purposes, it is desirable to de-interleave the depth and intensity data into separate buffers. The MicroVision LiDAR SDK includes code to unpack the data and the API provides a pointer to each of the separated depth and intensity buffers.

Figure 2 shows an extracted depth buffer, with depth values labeled as d[h,v] where h is a horizontal index within a scan line and v is a vertical index to the scan line. The data maps to the scanned field of view with d[0,0] at the top left corner when viewed from the sensor's perspective and d[M,N] at the lower right corner. The extracted intensity frame has the same arrangement.

Line 0	Point 0	Point 1	Point 2	...	Point N
	d[0,0]	d[0,1]	d[0,2]	...	d[0,N]
Line 1	d[1,0]	d[1,1]	d[1,2]	...	d[1,N]
...				...	
Line M	d[M,0]	d[M,1]	d[M,2]	...	d[M,N]

Figure 2 *- Extracted Depth Frame*

Data value scaling

The depth value is radial distance in millimeter units.
The intensity value is unitless. It indicates the reflected intensity.

3D positional scaling of data points

A frame of the MicroVision LiDAR data is acquired by pulsing through the scan field at equal angles. The resulting depth data is naturally in a spherical coordinate system with the radius captured by depth values and the horizontal and vertical angles implied by the pulse position within the depth array.

For each depth value d[h,v], the horizontal index h is directly proportional to the horizontal scan angle, and the vertical index v is directly proportional to the vertical scan angle.

A spherical coordinate (r, θ, φ) representation for depth array elements d[h,v] is:

- $r = d$
- $\theta = (\theta FOV / Htot) * (h - Htot/2)$
- $\varphi = (\varphi FOV / Vtot) * (v - Vtot/2)$

Using this notation:

- 'd': depth as radial distance from sensor (in mm).
- 'θ': horizontal scan angle.
- 'φ': vertical scan angle.
- 'θFOV': horizontal field of view, i.e. horizontal range of scan angle.
- 'φFOV': vertical field of view, i.e. vertical range of scan angle.
- 'h': horizontal index within data frame.
- 'v': vertical index within data frame, i.e. scan line index.
- Htot: horizontal range of data, i.e. number of points within a scan line.
- Vtot: vertical range of data, i.e. number of scan lines per frame.

For image processing or display of the LiDAR depth data in a (x,y,z) point cloud format, a spherical to Cartesian conversion step is necessary.

Cartesian conversion

For depth array d[h,v] and other symbols described earlier:

- $x = d[h,v] * \cos(\theta) * \sin(\varphi)$
- $y = d[h,v] * \sin(\theta) * \sin(\varphi)$
- $z = d[h,v] * \cos(\varphi)$

The dimensional scaling constants for MicroVision Consumer LiDAR for frame resolution 720x360 are:

- θFOV = 64 degrees horizontal FOV
- φFOV = 36 degrees vertical FOV
- Htot = 720
- Vtot = 360