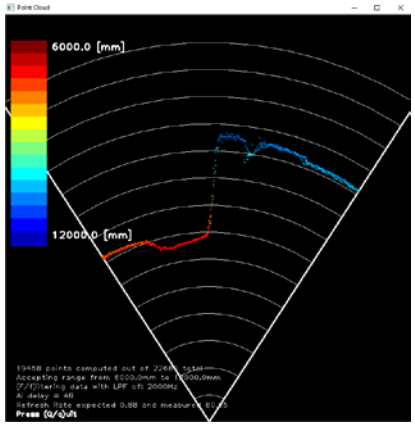
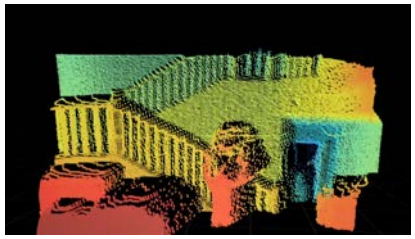
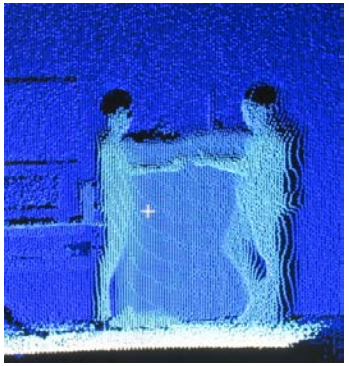
The products discussed in this User Guide are intended for development and prototyping purposes as **OEM** subsystems for incorporation into customer's prototypes and end products. Therefore, they do not comply with the appropriate requirements of FDA 21 CFR, section 1040.10 and 1040.11 for complete laser products.







SYMPL MEMS MIRROR 3D LIDAR DEMONSTRATOR KIT (DEMO-07)

mirrorcle TECHNOLOGIES, INC.

Last Revised: August 2020

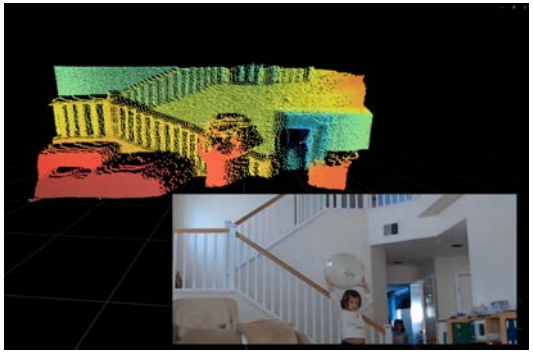
Mirrorcle Technologies, Inc.

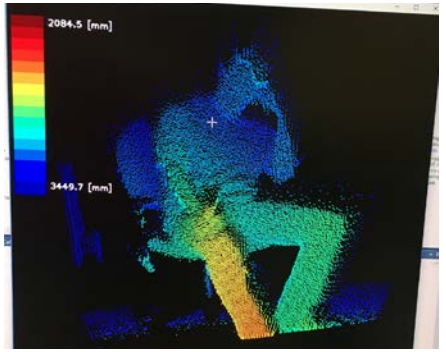
Introduction

- The **SyMPL MEMS Mirror 3D LiDAR** demonstrator kit includes a plug-and-play **3D LiDAR system** with **software applications** that demonstrate its capabilities.
  - Part Number: **DEMO-07**

- The kit is designed to demonstrate the capabilities of Mirrorcle's Synchronized MEMS Pair LiDAR ("SyMPL") architecture and to experience the aspect of **programmable scanning** for LiDAR applications.

SyMPL MEMS Mirror 3D Lidar Demonstrator Kit





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What does the DEMO-07 Kit do?

SyMPL 3D LiDAR Specifications

- Programmable Region of Interest
  - Horizontal (azimuth) Scan up to -15° to +15°
  - Vertical (elevation) Scan up to -9° to +9°
- Aspect ratio (horizontal to vertical) is fully programmable
- Weight <0.25kg
- Power consumption approx. 1.25 W
- Power and serial communication by a USB cable (PC)
- Software Package built for Windows
- At least 12m for 10% targets, 25m for typical targets
- Based on scanning 905nm laser, ~1-2mW average power

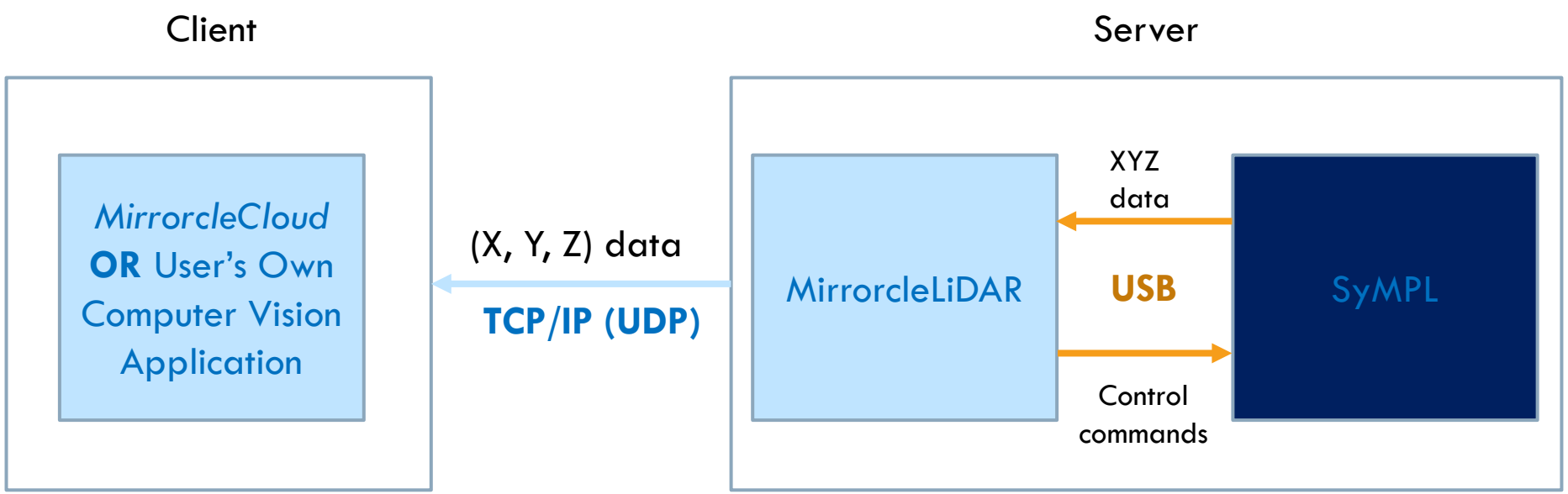
Programmable Scanning

- SyMPL 3D LiDAR allows for programmable scanning and custom scan patterns for advanced users.
- Customizable parameters include:
  - Scan Size
  - Scan Speed
  - Scan Rotation
  - Scan Position/Offset
  - Number of Lines
  - Waveform filters, data filters
- Using the provided Applications, the user is able to select the scan that is best suited for their purpose, via simple **User Interface**, or ***.ini** file
- For full programmability – users may purchase Mirrorcle Software Suite SDKs and software support hours or work with Mirrorcle's engineering team on product customization.

Software Overview

- DEMO-07 Software package consists of two Windows applications and their supporting libraries and files
- Additionally there is an ***.ini** text file where user can define some parameters of scanning (more later).
- Application MirrorcleLiDAR.exe utilizes Mirrorcle Software Suite API to communicate with the MEMS Controller, set all the scanning parameters, and receive sensor data over the USB link. This data is then presented at a TCP/IP socket for client applications to receive and process.
- Application MirrorcleCloud.exe is a Mirrorcle-developed example client for visualizing point cloud data provided by the SyMPL LiDAR. Users may develop their own client applications to receive and process the point cloud data.

SyMPL System-Software Communication



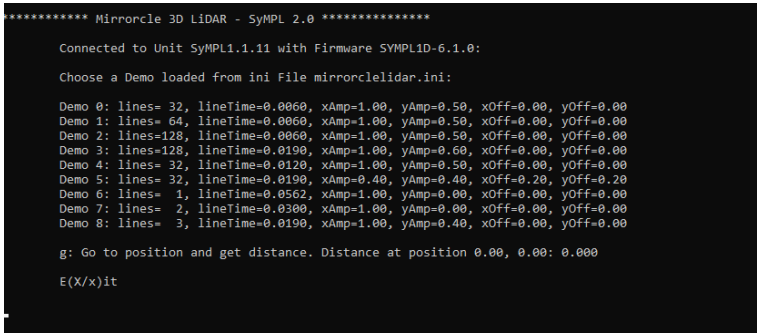
IP Address: 127.0.0.1
Listening Port: 48012
Sending Port: 48013

IP Address: 127.0.0.1
Listening Port: 48013
Sending Port: 48012

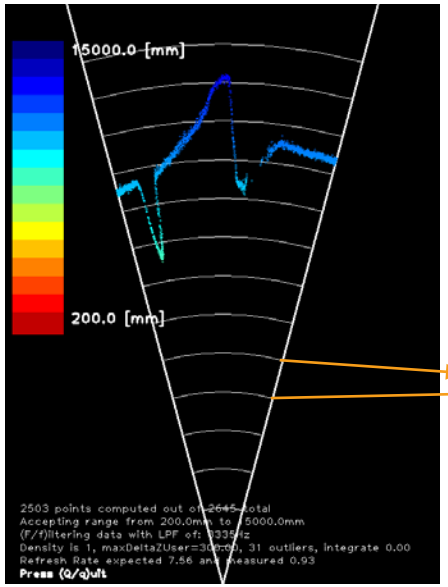
Please ensure that these ports are not being used by other applications before using MirrorcleLiDAR/MirrorcleCloud

MirrorcleLiDAR – Overview

- Command-prompt based application to control the SyMPL unit
- MirrorcleLiDAR comes with a number of pre-programmed scan patterns that are individually set to the SyMPL unit.
- The application serves as a TCP/IP server that broadcasts the point cloud for other applications (e.g. MirrorcleCloud), streaming with minimized latency to the socket as the sensor data is received and processed.
- Application shows point cloud data in a polar plot window, with distances plotted with respect to azimuth scan angles.

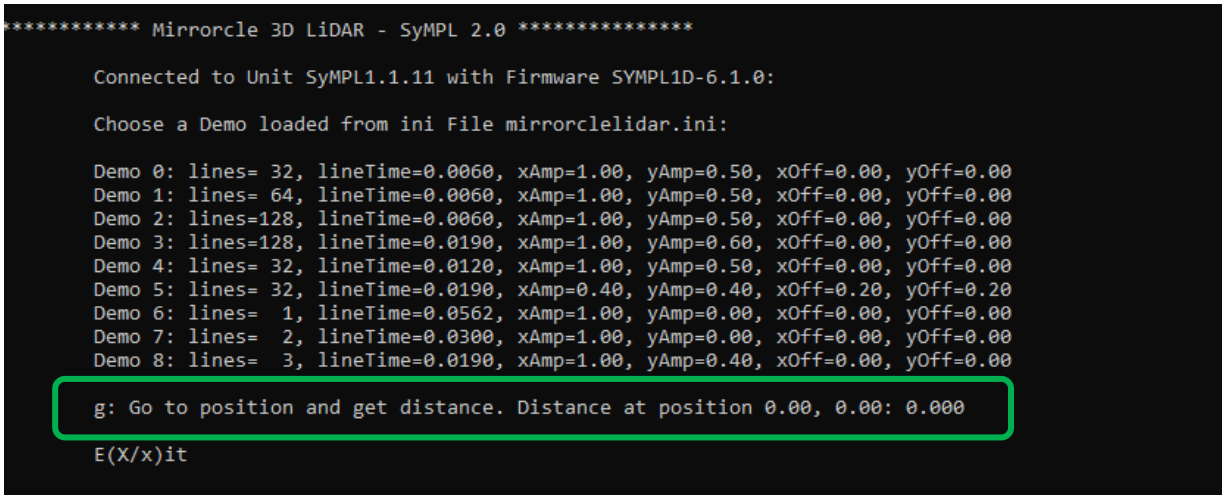


MirrorcleLiDAR comes with a number of examples



The "polar plot" window

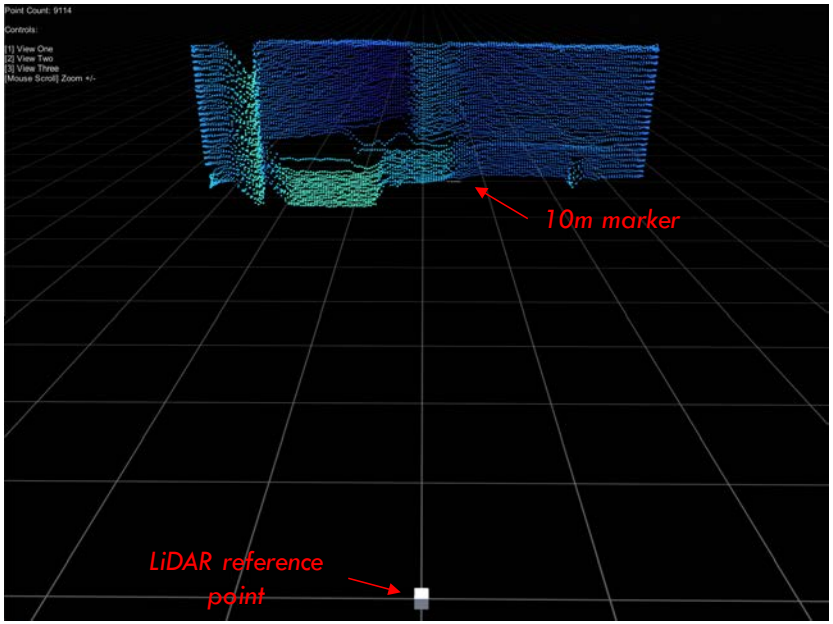
MirrorcleLiDAR – Point and Range

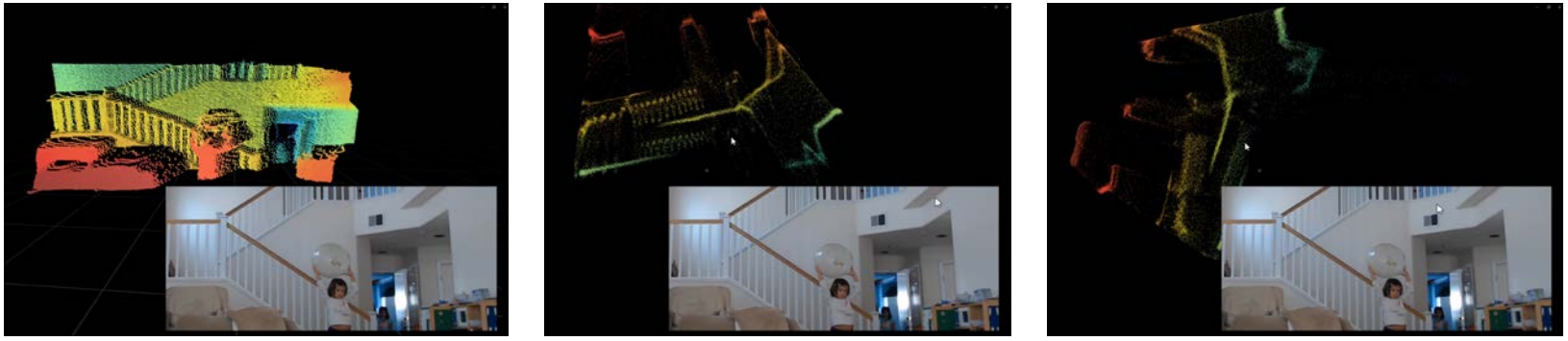


- MirrorcleLiDAR supports point-and-range functionality that allows users to input an X,Y position and receive a range
- X, Y positions are in normalized ±1 coordinates
  - These positions are effectively xOff and yOff as described in **Scan Angle and Normalized Parameters Definitions, pg. 16**
- Returned range is in millimeters

MirrorcleCloud – Overview

- MirrorcleCloud is a 3D display application used to render and visualize point clouds returned by SyMPL
- MirrorcleCloud receives point cloud data from a TCP/IP socket, where it is shared by the MirrorcleLiDAR
- Users have control of viewing angle's, position, field of view (zoom), etc.





Example of MirrorcleCloud 3D data views from different orientations shown alongside a camera view from an accessory webcam.

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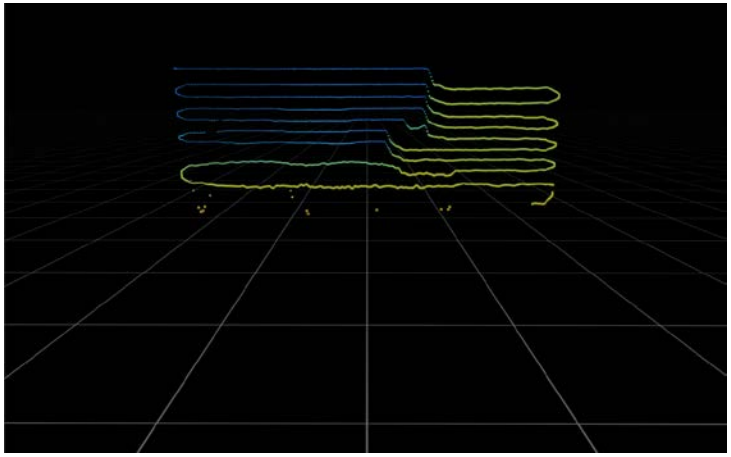
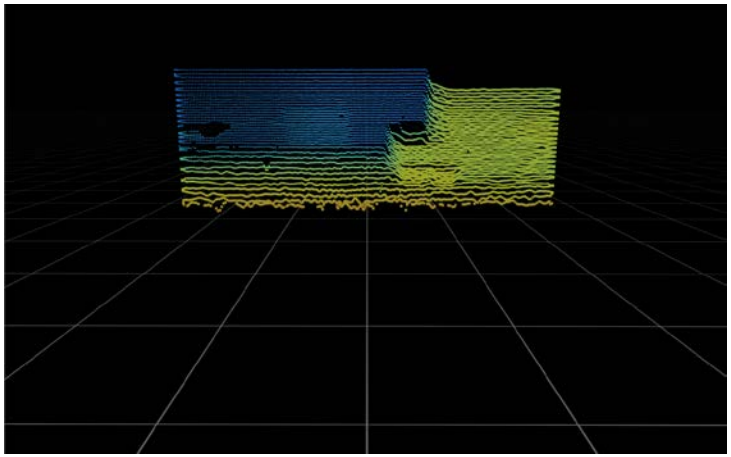
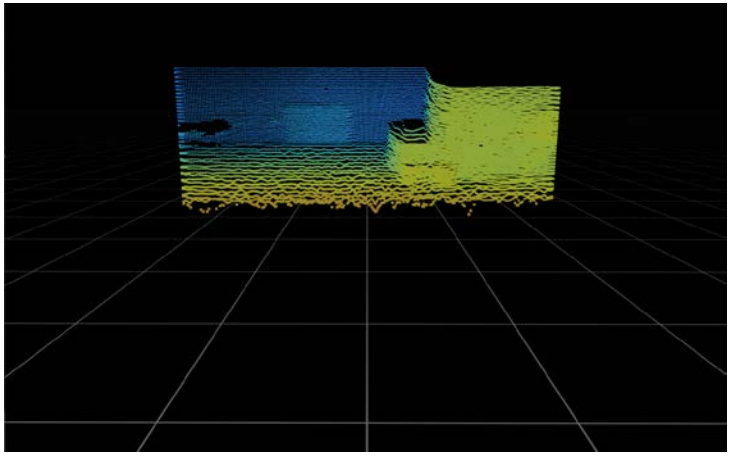
Programmable Scanning with DEMO-07



10 lines, 8 Hz

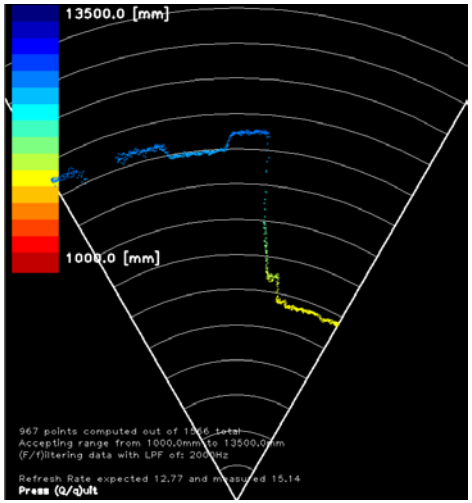


40 lines, 2 Hz



60 lines, 1.5 Hz

4 lines,
13 Hz



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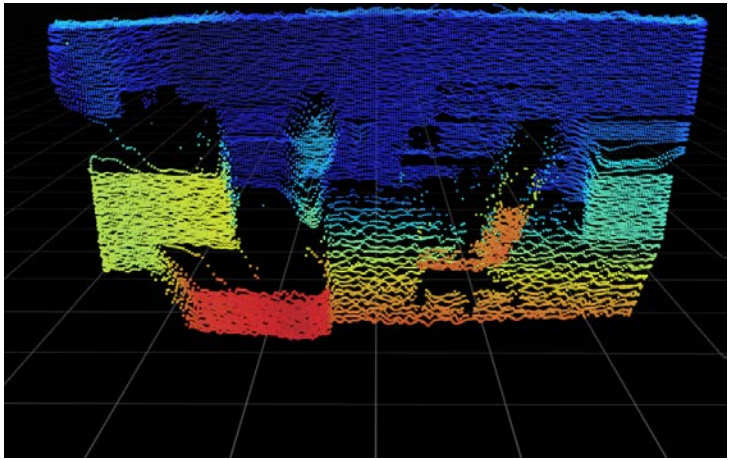
What does DEMO-07 include?

Demonstrator Kit - Contents

- **SyMPL 3D LiDAR system**
- Software Applications (Windows)
  - **MirrorcleLiDAR**
  - **MirrorcleCloud**
- Accessories
  - 1x **USB Micro Cable** for power and data
- See next page for optional SDK Add-Ons

Software on USB

SyMPL system + USB Micro Cable



Optional Software Development Kits

Mirrorcle offers a comprehensive Application Programming Interface (APIs) for generation of content (rasters, point-to-point) and streaming of 3D data from the sensor.

Mirrorcle's LiDAR API is available in C++ and on various platforms:

- **Available Add-On: C++ SDK** (Windows, x86 and x64)

- **Available Add-On: C++ SDK** (Linux, Ubuntu x64)

Extensive documentation and references are provided at https://mirrorcletech.com/documentation/

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Platforms and SDKs

- **SyMPL 3D LiDAR system**
- Software Applications (Windows)
  - **MirrorcleLiDAR**
  - **MirrorcleCloud**
- Accessories
  - 1x **USB Micro Cable** for power and data

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Pricing and Availability

Pricing and Availability

- Contact sales@mirrorcletech.com for a formal quotation with most up to date pricing and lead time
- Typical lead time is 2-3 Weeks

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Quickstart Guide

WARNING AND CAUTION

Danger due to improper use

Any improper use can result in dangerous situations. Therefore, observe the following information:

- Device should be used only in accordance with its intended use.
- All information in these operating instructions must be strictly observed.

Optical radiation: Laser class up to IIIR

The accessible radiation **may pose a danger when viewed directly from <2m distance**. It may pose a danger to eyes and skin if incorrectly used.

- Do not open the housing. Opening the housing may increase the level of risk.
- Current national regulations regarding laser protection Must be observed.

Hazardous radiation

If any operating or adjusting other than those specified here are used or other methods are employed, this can lead to dangerous exposure to radiation. Damage to the eyes is possible.

- If the product is operated in conjunction with external illumination systems, the risk described here may be exceeded. This must be taken into consideration by the users on a case-by-case basis.
- Do not look into the light source when it is switched on.
- Comply with the latest version of the applicable regulations on photobiological safety of lamps and lamp systems as well as on laser protection.

Electrical voltage

Electrical voltage can cause severe injury or death.

- Work on electrical systems must only be performed by qualified electricians.
- The power supply must be disconnected when attaching and detaching electrical connections.
- The product must only be connected to a voltage supply as set out in the requirements in the operating instructions.
- National and regional regulations must be complied with.
- Safety requirements relating to work on electrical systems must be complied with.

NOTICE

Modifications and conversions to the device may result in unforeseeable dangers.

Interrupting or modifying the device or Mirrorcle software will invalidate any warranty claims against Mirrorcle Technologies, Inc. This applies in particular to opening the housing, even as part of mounting and electrical installation.

Quickstart

1. Connect the SyMPL's USB cable to your computer
2. Copy the files from the provided USB flash drive or download link to your computer.
    1. Suggested install folder in Windows, C:\MirrorcleTech\(Mirrorcle LiDAR Software Suite\)
    2. Suggested install folder in Linux, ~\MirrorcleTech\(Mirrorcle LiDAR Software Suite\)

Quickstart (Linux only)

- For Linux users only:

1. Verify that you can access the device from Linux
    1. Run the command `dmesg | grep FTDI` and you should see “FTDI USB Serial Device converter now attached to ttyUSB0”. This means that the device is accessible at `/dev/ttyUSB0`.

       (You can also run the command `ls -l /dev/serial/by-id` to get the ttyUSB number.)
    2. Check permissions on the device, for example `ls -l /dev/ttyUSB0`. If the permissions are `rw-rw-rw-`, then it means all users have access and you can skip to the installation steps.
    3. If you do not have access to the device, there are two ways you can gain access to it.
        1. **(Permanent, requires reboot)** You can add yourself to the group that does have access (typically 'dialout') by running the following. This will persist across reboots.
            1. `sudo usermod -a -G dialout $USER`
            2. `sudo reboot`
        2. **(One-time)** You can give permissions to all users for this session. This will reset to default on reboot.
            1. `sudo chmod 666 /dev/ttyUSB0`
2. Install OpenCV (OpenCV is needed for LiDAR Software Suite applications windowing)
    1. `sudo apt-get install libopencv-dev`
3. For users of the SDK, Install CMake (CMake is needed for building the demo applications)
    1. `sudo apt-get install cmake`

Quickstart (Linux only)

- For Linux users only:
- MirrorcleLiDAR must be run with a path to the library files that are included in the same directory. There are two methods of setting the path to the libraries:

1. Adjust library search path at runtime:

   From the ./MirrorcleLiDAR/ directory, execute:

   LD_LIBRARY_PATH=. ./MirrorcleLiDAR

   This will set the LD_LIBRARY_PATH to the current directory **and execute the MirrorcleLiDAR application**

2. Add the library path to system library search path

   sudo gedit /etc/ld.so.conf.d/mirrorclelibs.conf

   In this file, add the complete path to the MirrorcleLiDAR directory where the .so files are located

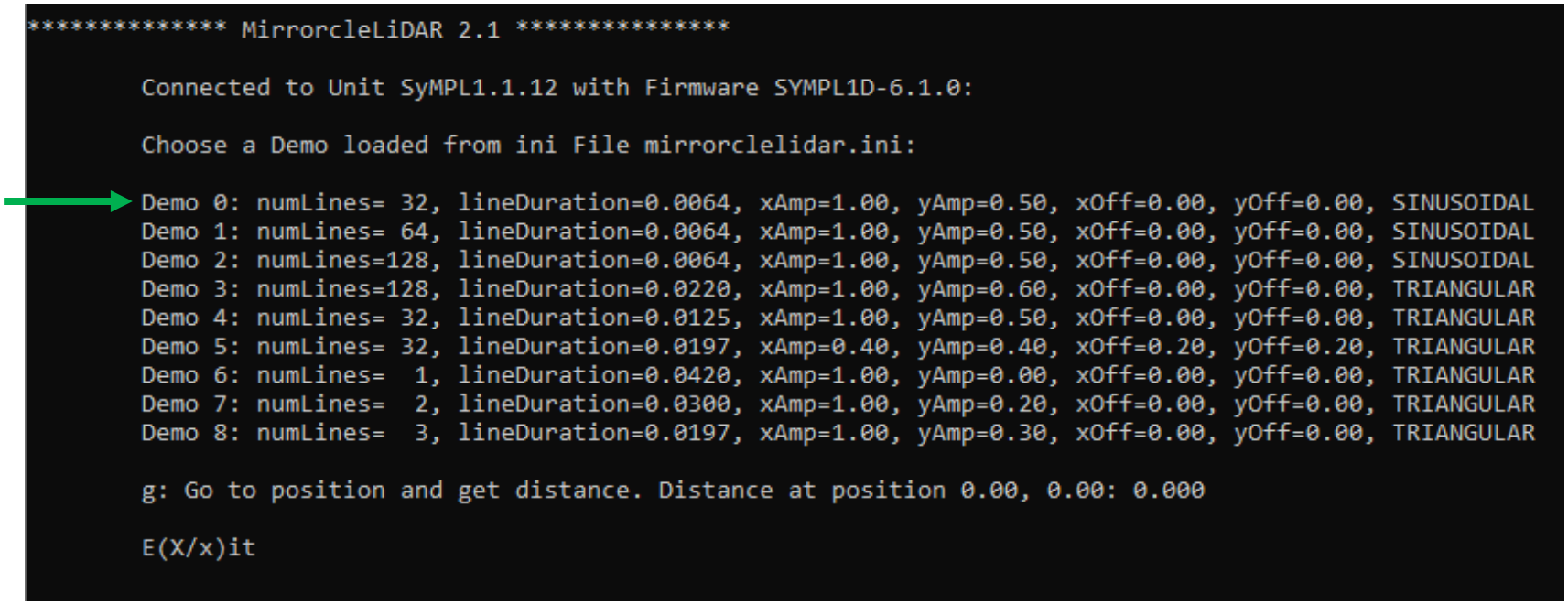
   For example: */home/username/MirrorcleTech/Mirrorcle LiDAR Software Suite/MirrorcleLiDAR*

   Save and run *sudo ldconfig* to update the system

   Once this is set, the MirrorcleLiDAR application can be run by executing *./MirrorcleLiDAR* from its directory

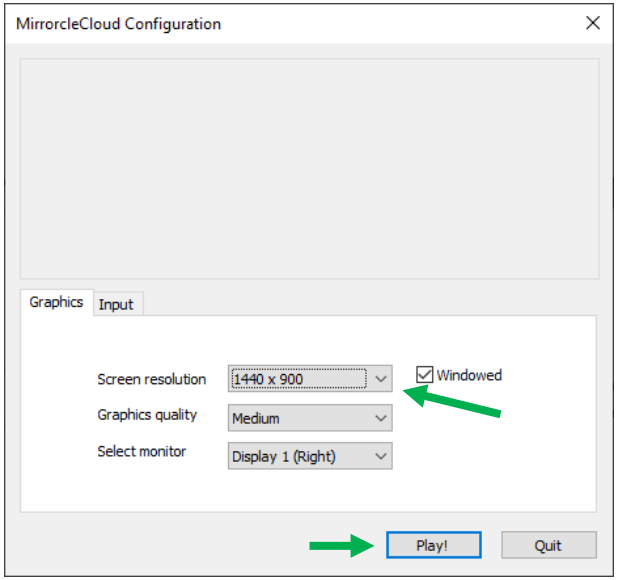
Quickstart

3. From the .*MirrorcleLiDAR*\ directory, **start MirrorcleLiDAR.exe**
4. Choose demo [0] from the list of available demos



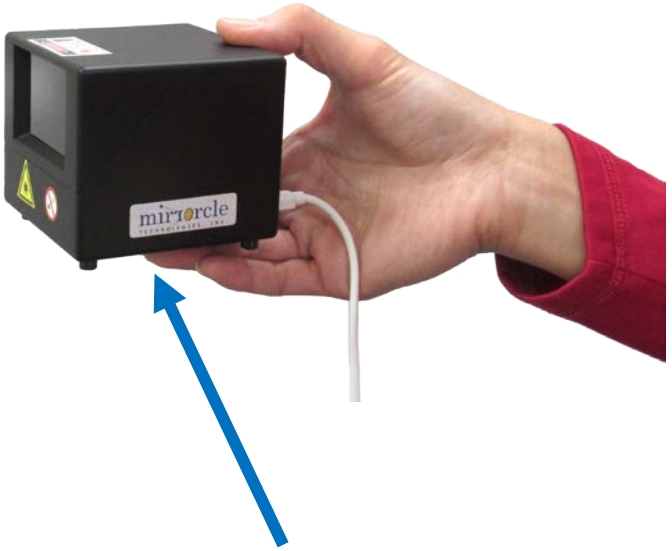
Quickstart

5. From the .*MirrorcleCloud*\ directory, **start MirrorcleCloud.exe**
6. Choose a resolution that fits your screen and press **[Play!]**



SyMPL Mounting Using Threaded Hole

- SyMPL units include a ¼”-20 threaded hole on the bottom for convenient mounting purposes
- When mounting the SyMPL device using the ¼”-20 threaded hole, **DO NOT EXCEED 5mm depth into the housing** as there is an increased risk of damage.



Example of a ¼”-20 mini ball head wall/ceiling mount that can be used to mount the SyMPL

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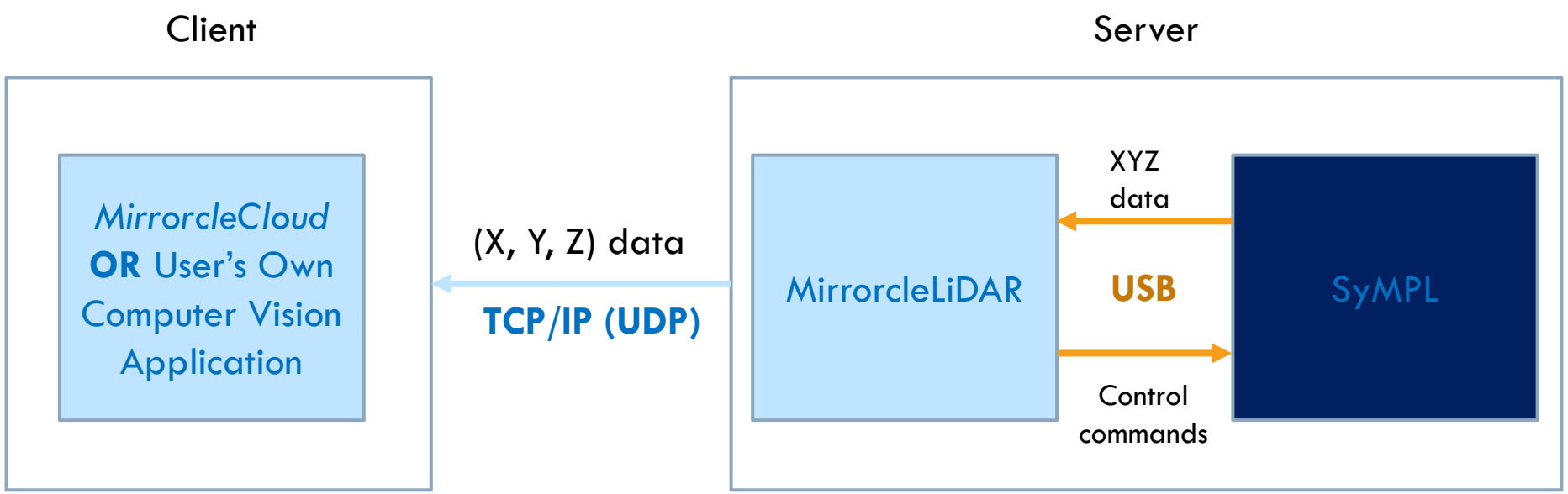
DEMO-07 Software

SyMPL System-Software Communication



IP Address: 127.0.0.1
Listening Port: 48012
Sending Port: 48013

IP Address: 127.0.0.1
Listening Port: 48013
Sending Port: 48012

Please ensure that these ports are not being used by other applications before using MirrorcleLiDAR/MirrorcleCloud

SyMPL Software Data Types

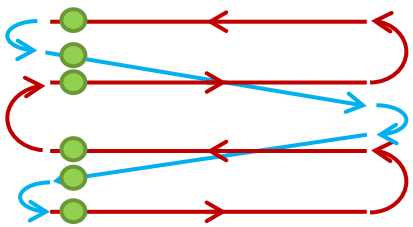
- **The Mirrorcle LiDAR Software Suite can present point cloud data with two data types:**
- PointXYZ
  - (x, y, z)
  - A point in 3D space, described in Cartesian coordinates
  - mtilidar::PointXYZ API reference
- PointSphere
  - (radius, azimuth, elevation) where θ is azimuth and ϕ is elevation
    - This ordering of terms resembles the mathematical conventional description of spherical coordinates rather than the ISO standard 80000-2:2009
  - A point in 3D space, described in a spherical coordinate system
  - More information on spherical coordinate system definition
  - mtilidar::PointSphere API reference

Raster Mode vs. Point and Range Mode

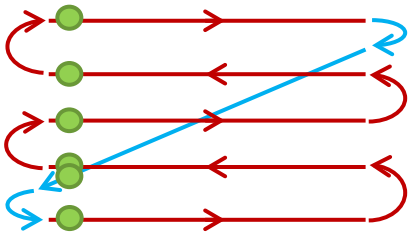
- The SyMPL architecture, based on Mirrorcle's gimbal-less dual-axis MEMS Mirrors can in general be programmed to scan any pattern.
- In the demonstration/development API, the control is restricted to two distinct operating Modes.
- **Raster Mode** – the sensor continuously and progressively scans horizontal lines over a region of interest, and acquires data along the whole scan, which is streamed to the software. Runs continuously until stopped by a software command.
- **Point and Range Mode** – the sensor holds for a command from software requesting a new pointing direction to range (measure distance). Upon receiving the command, sensor points to the specified direction, measures distance and replies to the software. Only one measurement is performed per software command.

Raster Mode – examples of rasters

- Raster frames are fully closed curves (waveforms) where the starting and ending point is identical.
  - When user specifies an odd number of lines to raster, an odd number of retrace lines is added to the scan to return the sensor to the starting point of each frame.
  - When user specifies an even number of lines to raster, an even number of retrace lines is added to the scan to return the sensor to the starting point of each frame.
- Sensor is continuously on, taking distance data at each and every sample during the raster frame.
- Two examples are shown below, including points sensed from a narrow vertical object in the Field of Regard of the LiDAR



A sample raster pattern where lines (or numLines) is defined as 4



A sample raster pattern where lines (or numLines) is defined as 5

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Scan Angle and Normalized Parameters Definitions

- The maximum scan angle ("LIDARMaxAngle") for DEMO-07 devices is based on the sensor's individual *.dat* file and is determined at calibration in manufacture. The value is 2x the mechanical angle from file, *XAxisMaxAngle*. Typical value for LIDARMaxAngle is 14°. This refers to the maximum scan angle amplitude for the azimuth (horizontal axis). Elevation scanning is up to 60% of that angle, giving typically 28° x 16.8° FoV specification.
- In the default Raster Mode, it rasters from –LIDARMaxAngle to +LIDARMaxAngle in azimuth. Azimuth and elevation scan angles can be adjusted with the xAmplitude, yAmplitude, xOffset and yOffset parameters as follows:
  - Azimuth scan angles
    - Min: LIDARMaxAngle * (-xAmplitude + xOffset)
    - Max: LIDARMaxAngle * (xAmplitude + xOffset)
    - Note that xAmp and xOff combined may not exceed -1.0 or 1.0
  - Elevation scan angles
    - Min: LIDARMaxAngle * (-yAmplitude + yOffset)
    - Max: LIDARMaxAngle * (yAmplitude + yOffset)
    - Note that yAmplitude and yOffset combined may not exceed -0.6 or 0.6

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SyMPL Software: MirrorcleLiDAR

MirrorcleLiDAR – Overview

- Command-prompt based application to control the SyMPL unit
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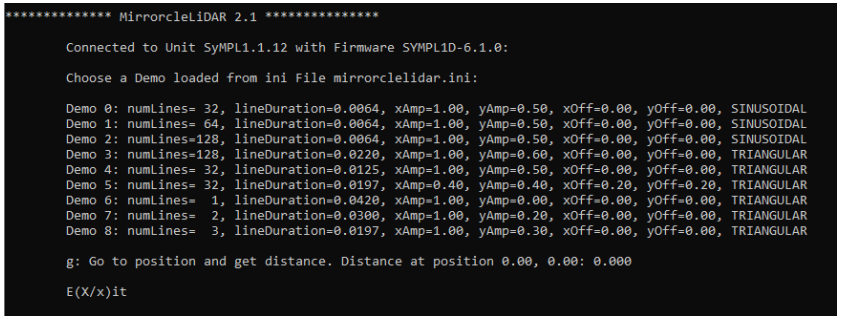
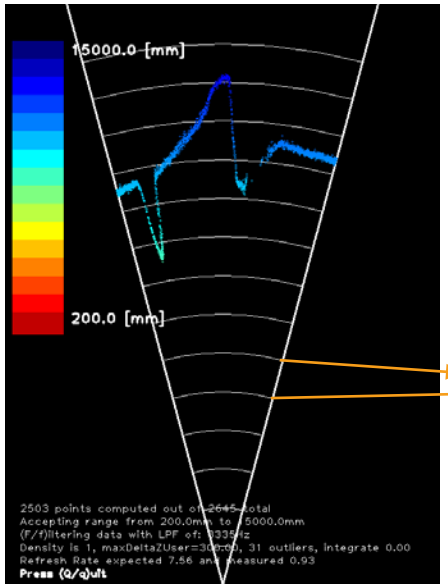
- The application serves as a TCP/IP server that broadcasts the point cloud for other applications (e.g. MirrorcleCloud), streaming with minimized latency to the socket as the sensor data is received and processed.
- Application shows point cloud data in a polar plot window, with distances plotted with respect to azimuth scan angles.

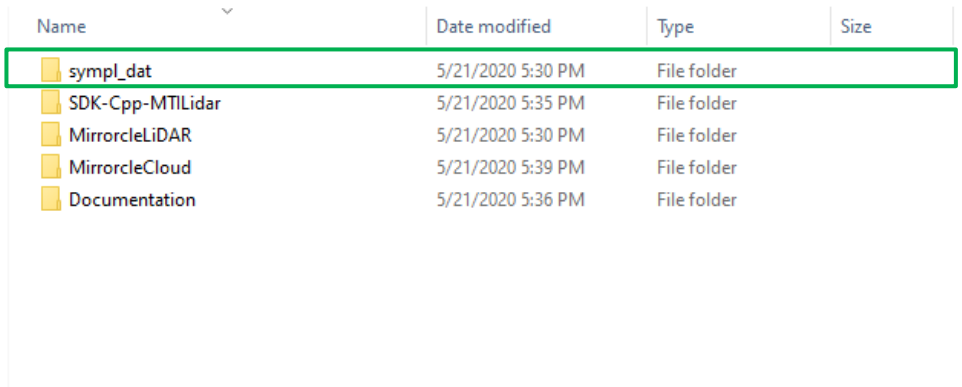


MirrorcleLiDAR comes with a number of examples



The "polar plot" window

MirrorcleLiDAR – SyMPL .dat File



- The SyMPL device will come with a folder of device-specific parameter file(s) called SyMPL .dat files – this includes data provided by the manufacturer and is **not for editing by users**
- SyMPL .dat files are provided as a folder called **sympl_dat**
- **The sympl_dat folder will only be read by the LiDAR Software Suite applications if:**
  - The sympl_dat folder is at the same directory or one/two/three levels above the executable.
- These are unit-specific settings that are pre-populated at manufacture-time at Mirrorcle
- **Users should not make any changes to the SyMPL .dat file, and any changes could result in voided warranty status.**
  - Please contact Mirrorcle support if you have any questions about device specifications/drive parameters

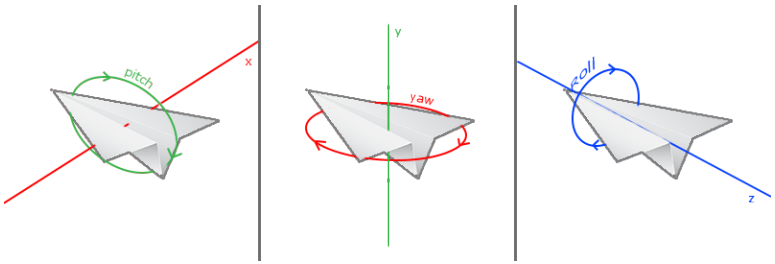
MirrorcleLiDAR – mirrorclelidar.ini File

- **AdvancedMenu** – enables the advanced menu for custom scan patterns at runtime
- **AngleMultiplier** – multiplier for the X component of points when displayed on the polar plot (widens plot)
- **PolarElevationLimitUpper/PolarElevationLimitLower** – the upper and lower limits of a point's Y angle (in degrees) it to be plotted on the polar plot
- **SensorPosition(X/Y/Z)** – The position of the sensor (in mm) in an X,Y,Z coordinate system. Used to offset the received points before outputting.
- **Sensor Pitch/Sensor Yaw** – The pitch and yaw of the sensor
- **RangeLimitUpper/RangeLimitLower** – the upper and lower limits (in mm) for a point to be accepted for display and output

mirrorclelidar.ini - Notepad

File Edit Format View Help

```
user*can*modify*below*parameters*after*consulting*Mirrorcle*support:
AdvancedMenu=1
AngleMultiplier=2.0
PolarElevationLimitUpper=-4
PolarElevationLimitLower=4
SensorPositionX=0
SensorPositionY=0
SensorPositionZ=0
SensorPitch=0
SensorYaw=0
RangeLimitUpper=13500
RangeLimitLower=200
```



Pitch/roll/yaw parameters

MirrorcleLiDAR – Customizing Scan Patterns

- Demos can be defined inside the mirrorclelidar.ini file in the section beginning with **
  - Demos defined here will be available at the MirrorcleLiDAR menu
  - Maximum of 9 demos may be defined
- **numLines** – defines the number of lines that will make up a scan
- **lineDuration** – defines the amount of time spent on each line. Approximately defines the refresh rate as 1/(lineDuration*numLines). This approximation does not account for the return path
  - *lineDuration that is entered via the .ini file or Advanced Menu may be modified/clamped per device recommendation*
- **xAmplitude/yAmplitude** – The amplitude of the scan in each axis
  - yAmplitude is restricted when the number of lines is <5 to reduce vertical steps between lines
- **xOffset/yOffset** – The offset of the scan
- **fastAxis** – The type of scan to be used for the fast axis of the scan (either SINUSOIDAL or TRIANGULAR)
- These parameters were detailed in **Scan Angle and Normalized Parameters Definitions, pg. 16**

```
user*can*modify*below*parameters:
AdvancedMenu=0
AngleMultiplier=1.5
RangeLimitUpper=15000
RangeLimitLower=200
PolarElevationLimitUpper=9.0
PolarElevationLimitLower=-9.0
SensorPositionX=0
SensorPositionY=0
SensorPositionZ=0
SensorPitch=0
SensorYaw=0
```

```
**    numLines    lineDuration    xAmplitude yAmplitude    xOffset yOffset fastAxis
Demo=    32,      0.0064,         1.0,            0.5,     0,      0,      SINUSOIDAL
Demo=    64,      0.0064,         1.0,            0.5,     0,      0,      SINUSOIDAL
Demo=    128,     0.0064,         1.0,            0.5,     0,      0,      SINUSOIDAL
Demo=    128,     0.022,          1.0,            0.6,     0,      0,      TRIANGULAR
Demo=    32,      0.012,          1.0,            0.5,     0,      0,      TRIANGULAR
Demo=    32,      0.019,          0.4,            0.4,     0.2,    0.2,    TRIANGULAR
Demo=    1,       0.042,          1.0,            0.0,     0,      0,      TRIANGULAR
Demo=    2,       0.030,          1.0,            0.2,     0,      0,      TRIANGULAR
Demo=    3,       0.019,          1.0,            0.3,     0,      0,      TRIANGULAR
```

After settings have been changed, press the [i] key at the MirrorcleLiDAR menu to reimport the settings and update demos

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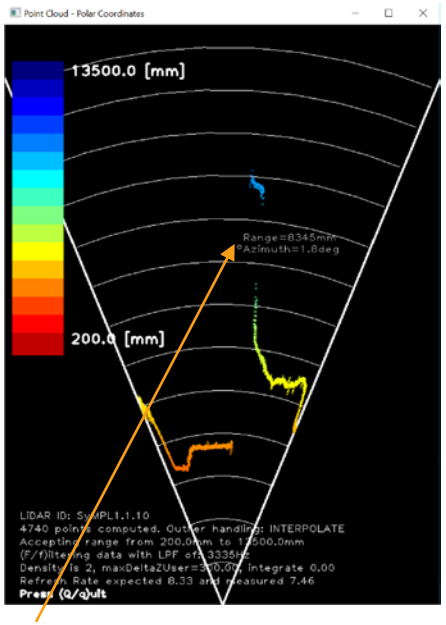
MirorcleLiDAR – Controls / Keybindings



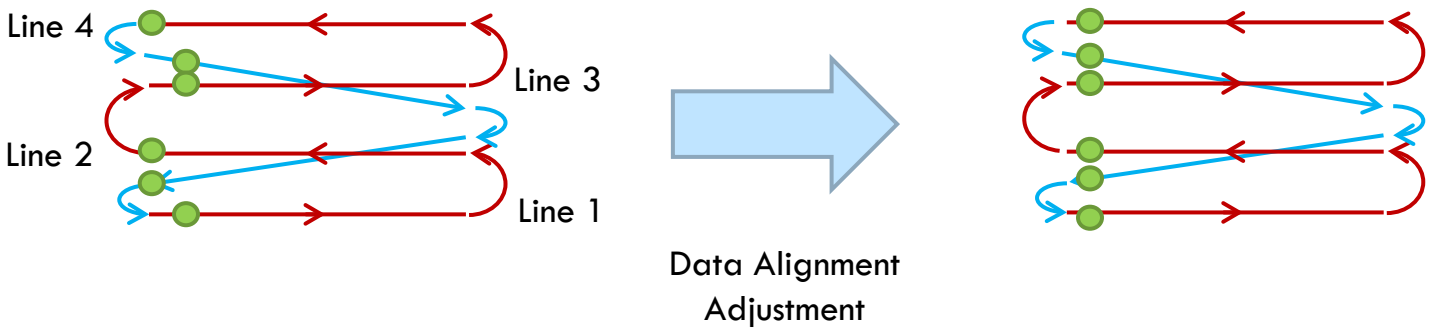
The polar plot window should be in focus when using keybindings

- Click into the polar plot to query distance (range) and azimuth.
- These controls are used when the SyMPL is actively scanning.

Keybindings	
M / Shift+M	Decrease/Increase RangeLimitLower
Z / Shift+Z	Decrease/Increase RangeLimitUpper
F / Shift + F	Decrease/Increase LPF cutoff frequency applied to incoming points
E	Export the current point cloud to a file
+/-	Increment/decrement data alignment adjustment
?	Disable the low-pass filter applied to incoming points

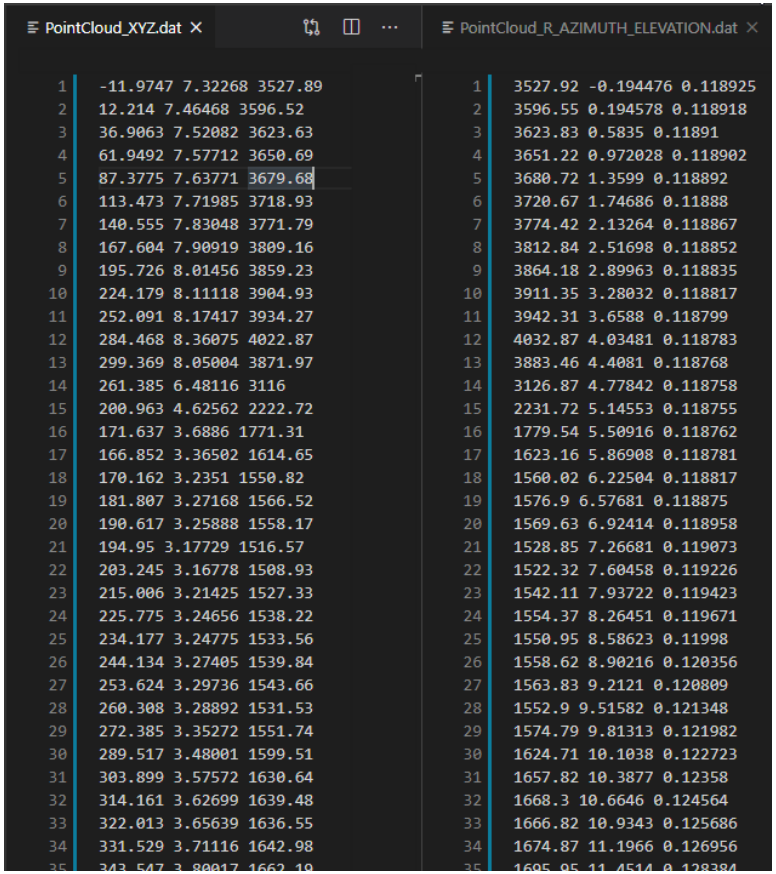
MirrorcleLiDAR – Data Alignment Adjustment

- Data Alignment Adjustment is a data processing parameter which corrects the correlation of XY MEMS positions and Z measurements.
- The system is setup to correctly assign distance data with respect to X,Y locations within the frame. However, a small delay between distance data measurement and scan position may still in some cases result in misalignment of data taken on left-to-right scanning lines with respect to right-to-left scanning lines.
- The applications and the software API provide a parameter for additional user-based adjustment of this data alignment, which behaves as illustrated below.



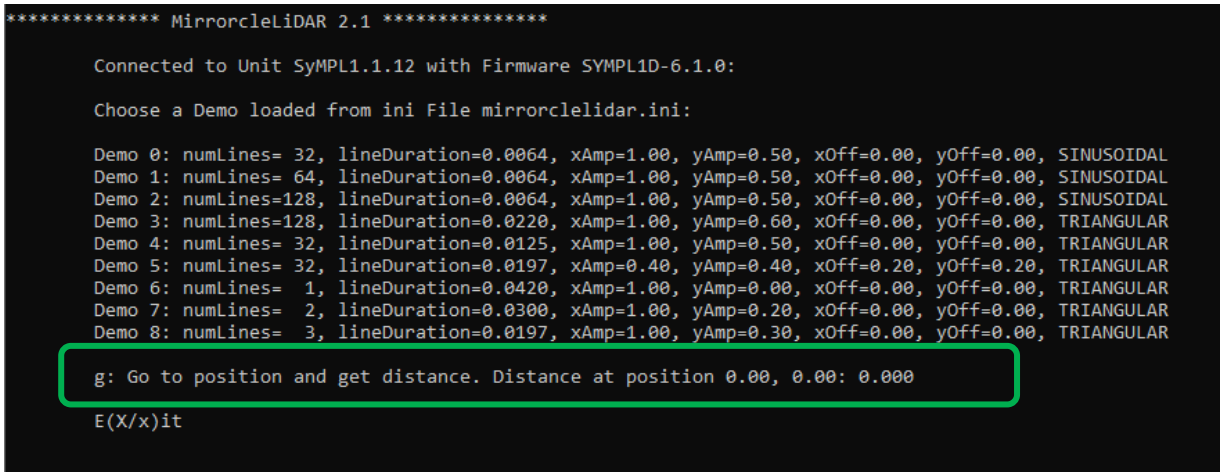
MirrorcleLiDAR – Exporting Data

- **Lidar device point cloud data may be exported directly from MirrorcleLiDAR**
- From the MirrorcleLiDAR polar plot window, hitting the [E/e] key will export the data to two space-delimited value files in the MirrorcleLiDAR application's directory
  - PointCloud_XYZ.dat contains the point cloud represented by the PointXYZ data type
  - PointCloud_R_AZIMUTH_ELEVATION.dat contains the point cloud represented by the PointSphere data type
  - More information on data types can be found in the page titled **SyMPL Software Data Types**



PointCloud_XYZ.dat and PointCloud_R_AZIMUTH_ELEVATION.dat after exporting from MirrorcleLiDAR

MirrorcleLiDAR – Point and Range

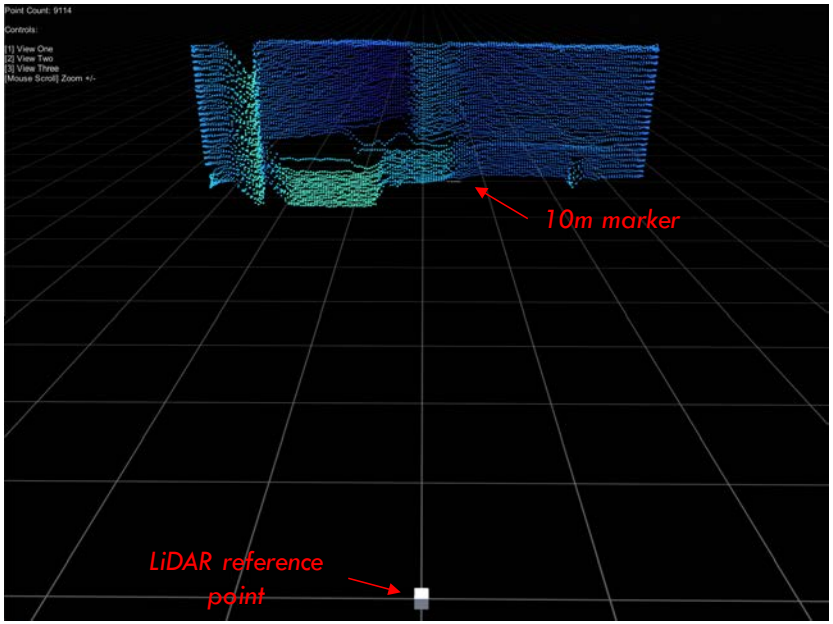


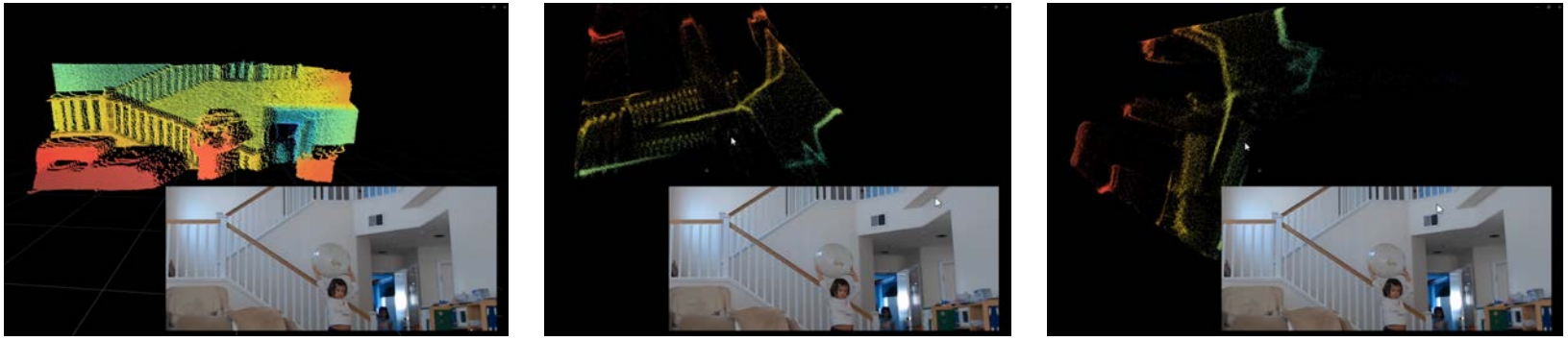
- MirrorcleLiDAR supports point-and-range functionality that allows users to input an X,Y position and receive a range
- X, Y positions are in normalized ±1 coordinates
  - These positions are effectively xOffset and yOffset as described in **Scan Angle and Normalized Parameters Definitions, pg. 16**
- Returned range is in millimeters

SyMPL Software: MirrorcleCloud

MirrorcleCloud – Overview

- MirrorcleCloud is a 3D display application used to render and visualize point clouds returned by SyMPL
- MirrorcleCloud receives point cloud data from a TCP/IP socket, where it is shared by the MirrorcleLiDAR
- Users have control of viewing angle's, position, field of view (zoom), etc.





Example of MirrorcleCloud 3D data views from different orientations shown alongside a camera view from an accessory webcam.

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MirrorcleCloud – Control & Navigation

Move view focus point	
W	Forward
A	Left
S	Right
D	Back
E	Up
Q	Down

Miscellaneous	
ESC	Open settings menu
I	Re-import settings file
C	Change color mapping direction (X, Y, or Z axes)

Mouse controls	
Left mouse button	Rotate the camera view
Right mouse button	Rotate the view about the view's origin

Snap to view points	
(1/2/3)	Snap to preset views
(4/5/6)	Snap to custom views
Shift+(4/5/6)	Save new custom view

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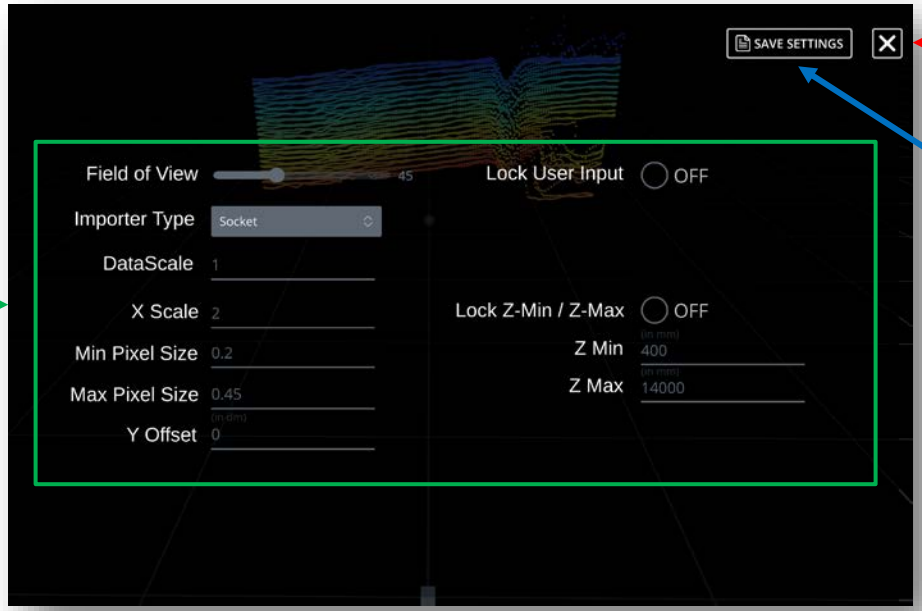
MirrorcleCloud – Changing Settings



Close MirrorcleCloud

Save settings to file

Modify Settings

- Pressing **[ESC]** will open a settings menu that overlays over the point cloud view.
  - Press [ESC] again will close the settings menu
- Users can modify settings that affect the view, how points are displayed, and how points are colored.
- Settings are automatically applied to the current session when modifying, but to write the settings to the settings file, click the "SAVE SETTINGS" button

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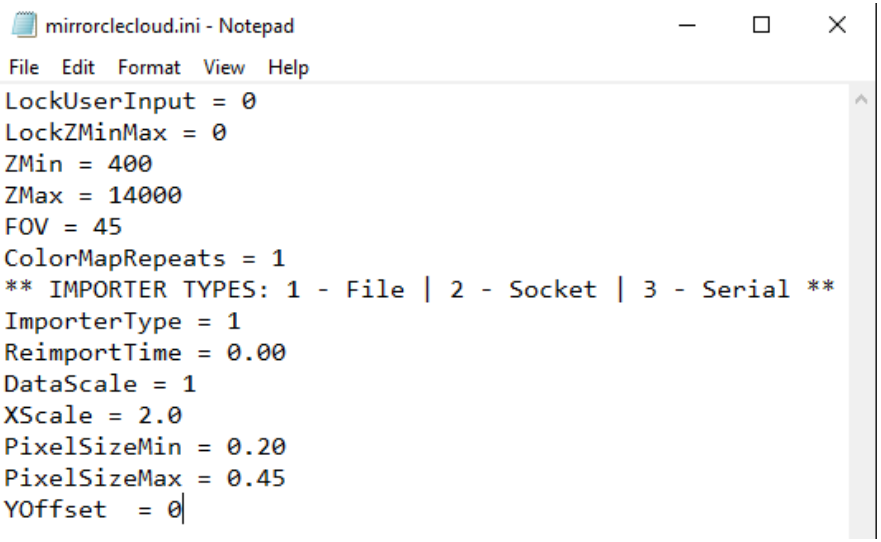
MirrorcleCloud – Changing Settings

- A settings file can be found at *MirrorcleCloud/MirrorcleCloud_Data/StreamingAssets/**mirrorclecloud.ini***
- This settings file is loaded by MirrorcleCloud on startup and when the **[i]** key is pressed
- This settings file is overwritten by MirrorcleCloud when the **"SAVE SETTINGS"** button is clicked in the settings menu.



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Thank You for Choosing

If you have any further questions regarding add-on software products, additional sensor units, or other suggestions please email sales@mirrorcletech.com

For technical support, please email support@mirrorcletech.com and provide serial numbers of your unit(s), software version info, and purchase info to allow us to initiate the support most efficiently.