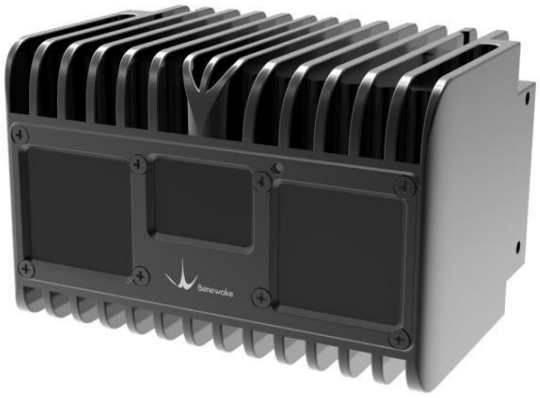
CE30-D Solid-State Array LiDAR
Operation Manual



www.benewake.com
Benewake (Beijing) Co., Ltd.

Product

Product model: CE30-D
Product name: Solid-state LiDAR

Manufacture

Company name: Benewake(Beijing)Co., Ltd
Address: No.28,Xinxi Road Haidian district, Beijing, China

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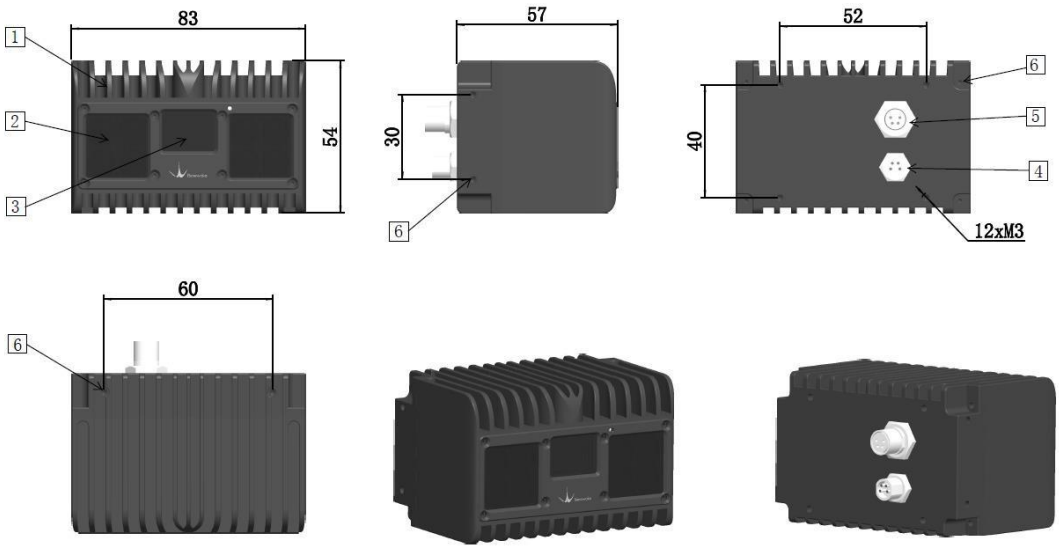
Table of Contents

1. CE30-D introduction

CE30-D is a solid-state array LiDAR developed based on the TOF theory. Compared with single-channel scanning LiDARs, there is no any mechanical rotating component, so it can run steadily and reliably for a long time, able to get a wider range of vertical detection.

At the top, bottom, left, right and back, CE30-D has mounting location holes provided, through which it can be fixed with peripheral devices reliably. See Figure 1 for the positions and spacing of the mounting holes subject to the size of M3.



1. Enclosure
2. Emitting panel (working area , cannot be covered)
3. Reception panel (working area , cannot be covered)
4. Power
5. Ethernet interface (M8 aerial plug)
6. Equipment installation hole (M3)

Figure 1 DELIADAR CE30-D outer dimensions

2. Operation of Display Program

CE30-D has provided a complete SDK based on Linux and Windows systems for customers' fast development and use. Please log on to our GitHub open source community to get the SDK source code and the corresponding documentation.

GitHub open source community: https://codincodee.github.io/ce30_driver

This display program is used to process and display the output data of CE30-D LiDAR under the Windows operating system. Before using this display program, please confirm that the local folder of the display program

contains complete documents necessary for operation:

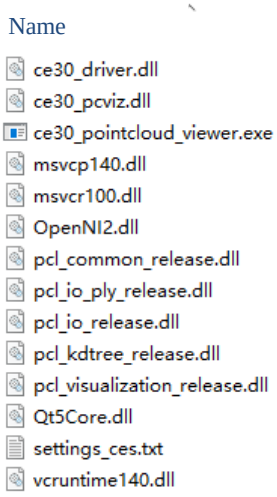


Figure 2 Display program and documents necessary for its operation

2.1 Connection

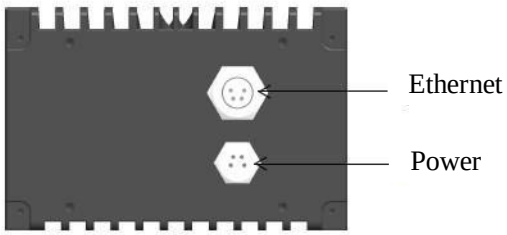


Figure 3 CE30-D aerial plug wiring instructions

a. Use the two aerial plug cables attached in the package (including one power supply plug cable and one network port plug cable) to connect the LiDAR with the aerial plug cables as illustrated in Figure 3; connect the power interface to the adapter DC 12V (≥3A), DC 5.5*2.5mm; connect the aerial plug network port (RJ45) to the computer.

b. Set the Ethernet IP address and subnet mask in the directory "*Control panel*\Network and Internet*Network Connections*" as shown in Figure 5.

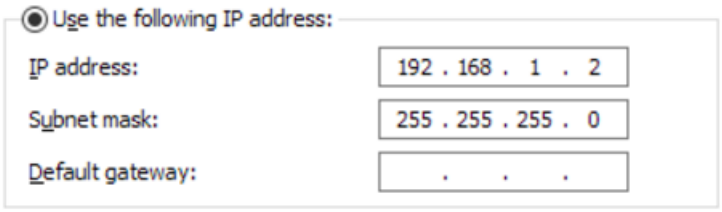


Figure 4 Network Settings

c. Open the CMD command interface in the Windows running window; enter and execute the command to

check whether the data connection is available:

ping 192.168.1.80 -t

If it prompts as shown in Figure 6, it indicates that the LiDAR is working normally with the data connection available. If no, it indicates that the data link suffers from ping failures. Please check as follows:

a) Check whether the indicators light up on the front panel of the LiDAR and whether the red lamp keeps normally on and flashing after startup;
b) Check whether the power supply is available and whether the voltage is 12V with the rated current ≥ 3A;
c) Check whether the computer network port is normally connected and whether the local Ethernet is identified;
d) Disconnect the power supply and wait for 5 seconds before reconnecting it.

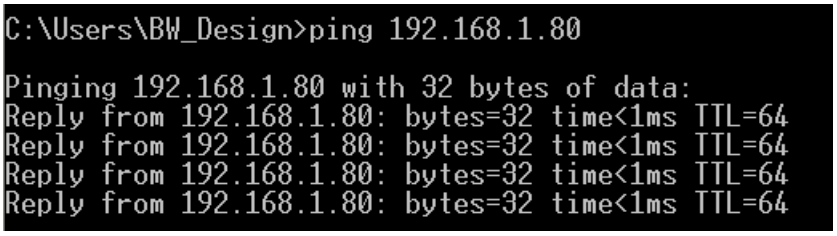


Figure 5 Data connection check

2.2 Display program window

Double click the program *ce30_pointcloud_viewer.exe* to open the display program and the prompt and point cloud image windows will appear as illustrated in Figure 6 for LiDAR version and operation shortcuts.

The prompt window is used to display the LiDAR connection, shortcut prompts and other running information.

The point cloud image window displays the point cloud images in the LiDAR field of view calculated based on the depth map and projection relation. In this window, hold down the left mouse button and move the mouse to change the direction for viewing the point cloud images; use the mouse wheel and you can zoom in/out the point cloud image; hold down the mouse wheel and move the mouse to move the point cloud image horizontally.

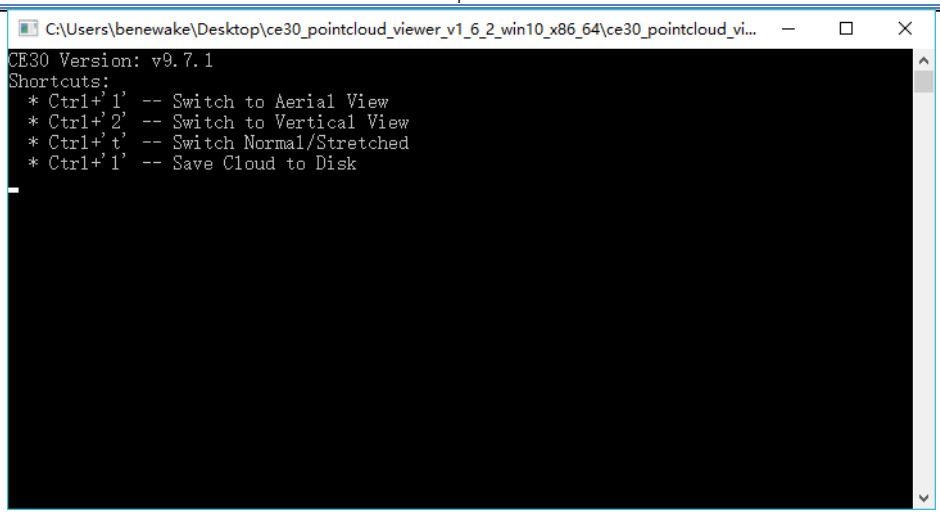


Figure 6 Information prompt window

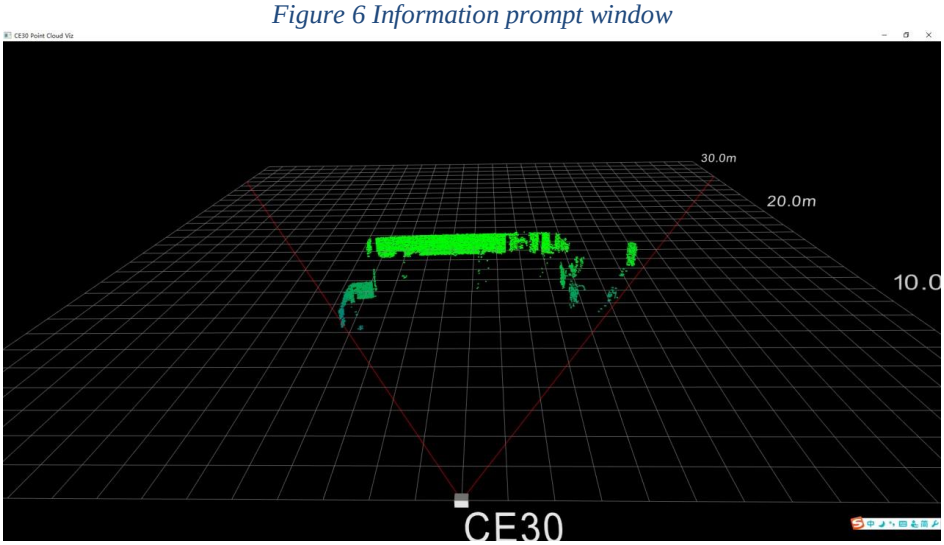


Figure 7 Point cloud image window

When the program runs, it will display the following window for shortcut keys.

a) CTRL+1 Switch to Aerial View (default);
b) CTRL+2 Switch to Vertical View;
c) CTRL+T Switch to Normal/Stretched;
d) CTRL+L Save the current frame data and press it again to stop.

Note: The shortcut keys are effective only in the point cloud window. Click the point cloud information window to activate it on the Windows interface.

3. Coordinate transformation

The CE30-D outputs distance and angle by polar coordinates. In order to facilitate the reconstruction and application of 3D point cloud image, they can be transformed into rectangular coordinate system by the following formula. X, Y and Z represent the coordinates of rectangular coordinate system, respectively.

$$X = Dist \times \sin(90 - V) \times \cos(H - 30)$$
$$Y = Dist \times \sin(90 - V) \times \sin(H - 30)$$
$$Z = Dist \times \sin(90 - V)$$

Declaration:

Dist: the distance output by photoreceptor cell;

V: Vertical, which is the vertical angle of photoreceptor cell, has the angle range from -1.9 °to +1.9 °

H: Horizontal, which is the horizontal angle of photoreceptor cell, has the angle range from 0 °to 60 °

4. Indicator Instruction

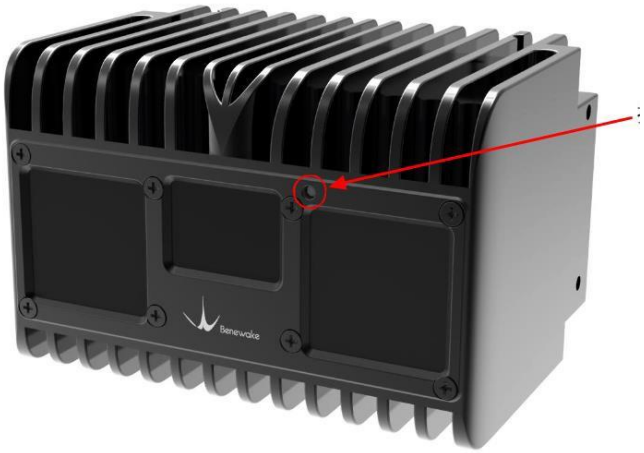


Figure 8 Indicator position

1) Blue normally on: In the “Ready” state, it can be connected to work.
2) Blue flashing: It is working.
3) Red flashing: The relevant run files are missing.
4) Red normally on: Fatal error (abnormal signal, abnormal interface communication, abnormal I2C, etc.)

5. Line sequence descriptions

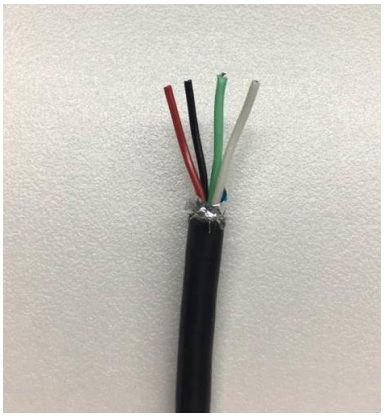


Figure 9 Line sequence at the power supply port: red - power positive, black - power negative

Note:

1. The current should be more than 3A for the power adapter;
2. When the LiDAR is powered on, it may be rarely possible to suffer from longer startup delay; if it doesn't start in 2 minutes, cut off the power and restart as recommended;
3. To have it stop working, first disconnect its power supply and then disconnect other connecting lines.

6. Installation diagram

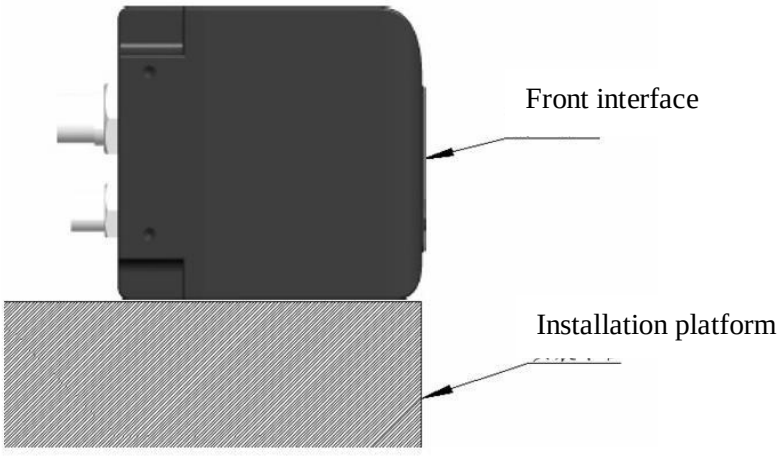


Figure 10: Recommendation for LiDAR installation. The LiDAR front interface must extrude from (at least be aligned to) the front plane of the installation platform; otherwise, the data accuracy will be lower due to interference.

7. Test Instruction and Description

7.1 Detecting Range Description

7.1.1 Blind Zone

When detecting objects with high reflectivity, a blind zone as shown in Figure 11 would appear. This is caused by the overexposure when objects' reflected light is excessive. LiDAR will filter the data from this overexposure zone. When the detected object's reflectivity is lower, the blind zone can become smaller. The blind zone is 20 cm long when detect objects with 10% reflectivity

.

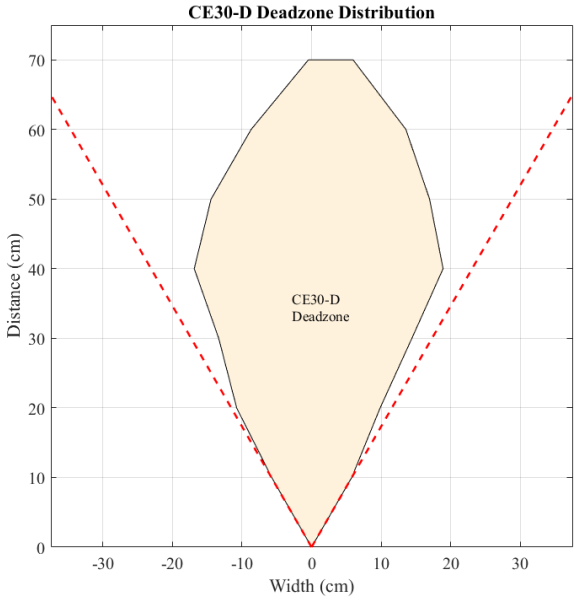


Figure 11 Blind zone distribution (test with 90% reflectivity objects)

7.1.2 Detecting Range

The maximum detectable range is different in different area of field of view. The detectable area of a

90% reflectivity object is shown in Figure 12.

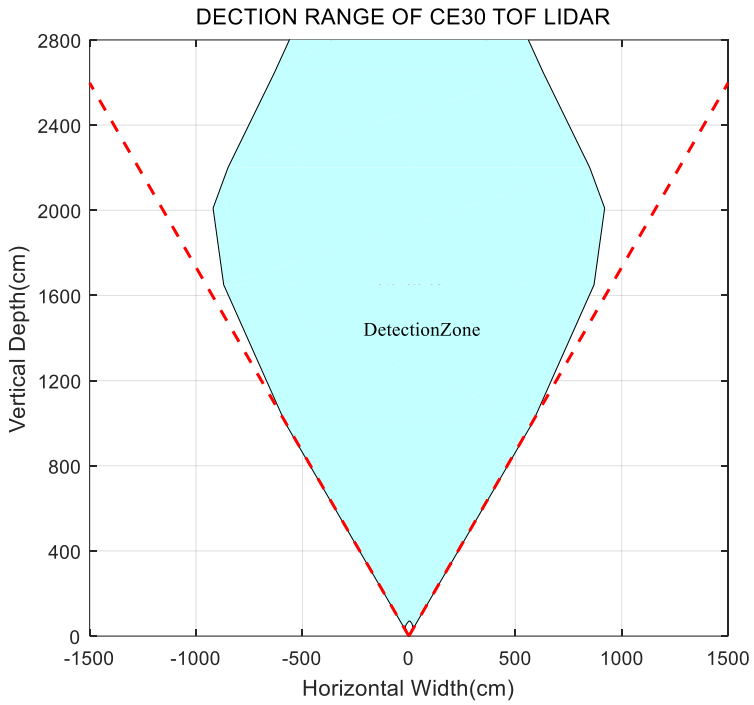


Figure 12 CE30-D's detecting area

7.2 Vertical Angle Resolution

CE30-D has 20 lines in vertical direction, and the vertical angle resolution is 0.2 degree, so that CE30-D has more precise resolution capacity. The detection angle in vertical direction is presented in

Table 1.

Table 1 Detecting angle in vertical direction

Vertical Line	Vertical Angle (°)
1	1.9
2	1.7
3	1.5
4	1.3
5	1.1
6	0.9
7	0.7
8	0.5
9	0.3
10	0.1
11	-0.1
12	-0.3
13	-0.5
14	-0.7
15	-0.9

16	-1.1
17	-1.3
18	-1.5
19	-1.7
20	-1.9

7.3 Interference of Ambient light

LiDAR can work at ambient light with 60klux intensity, but the error increases compared with indoor situation. The error in different testing conditions is presented in the following.

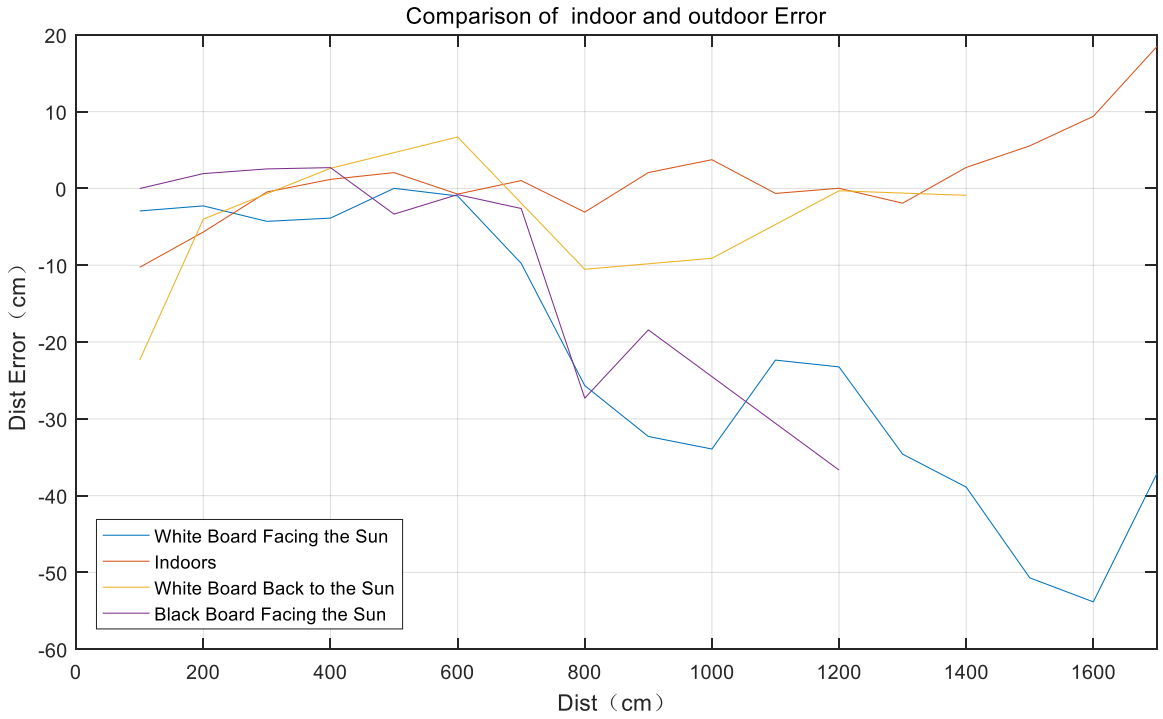


Figure 13 Comparison of indoor and outdoor Error

Note:

1. The figure only show the error within 17m. The evaluated sample is 4x4 pixels in the central of field. The performance of different machines differ from each other.
2. The outdoor and indoor accuracy within 7m are at the same level. The detecting performance with different reflectivities are within expectation. The outdoor accuracy at long range is slightly poor, as shown in the above figure.
3. The standard deviation of a whole frame of pixels are within 10cm. The difference range can be up to 40cm.
4. The abnormal performance outdoors: when the sunlight emmits straight into the optical window of the LiDAR, 15% of the measuring data is unrealiable.

7.4 Influence of Temperature

The LiDAR is tested in different ambient temperature to obtain the detecting repeatability when temperature changed. The Figure 14 presents an example of data from a single LiDAR. The evaluated example is 4x4 pixels in the central of field.

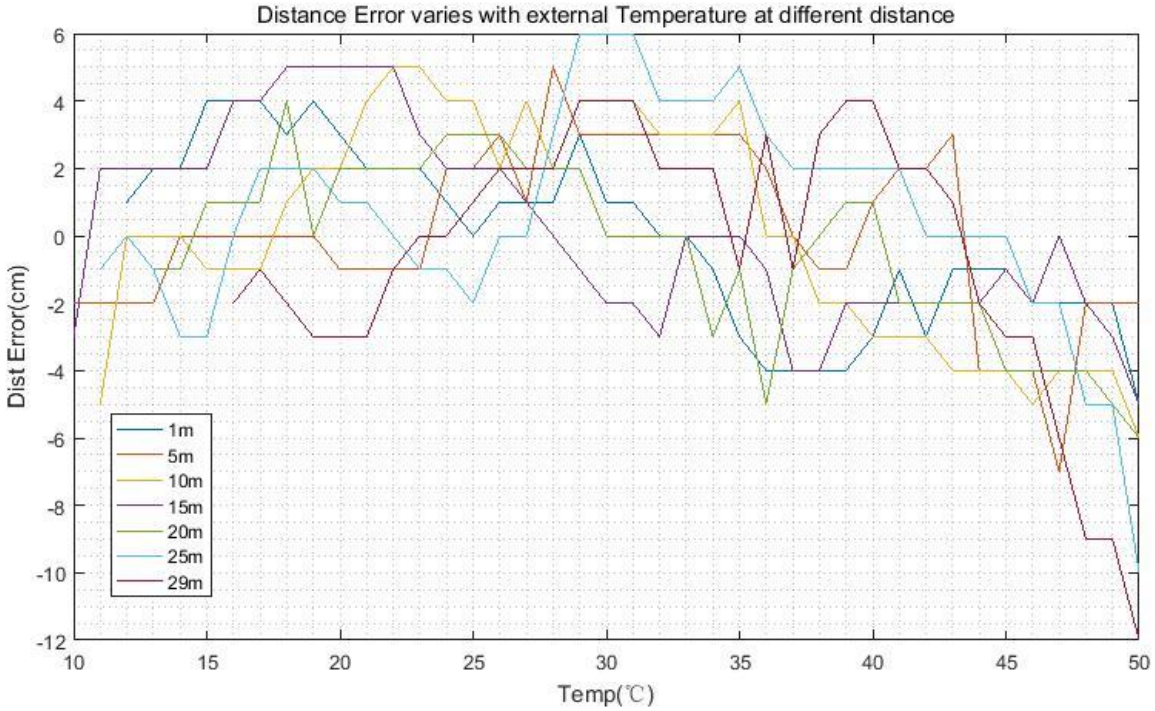


Figure 14 Dist Error varies with external Temp at different distance

8. Influence Factors of Measurement

8.1 Multi Optical Path

Based on ToF LiDAR principle, if there are multiple echo regions as shown in the figure below at the working height of the radar, the multi-path phenomenon will be triggered: the LiDAR receives the light returned by the path 1 and the path 2 at the same time, which may result in a larger measurement value.

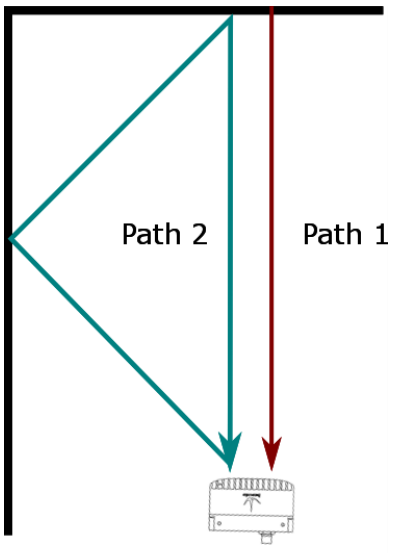


Figure 15 Multi optical path phenomenon

8.2 Stray Light

As shown below, when solid-state ToF LiDAR is working, in addition to the light reflected by the object 1, the light scattered by object 2 and object 3 that close to the LiDAR will enter the lens. Such stray light can lead to a deviation of the object 1's ranging.

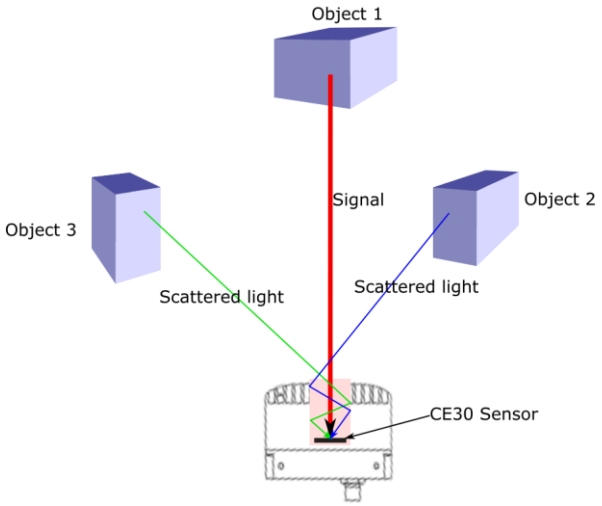


Figure 16 illustration of stray light

8.3 Multi Distance Objects

The light radiated by the LiDAR is reflected by the object onto the sensor of the LiDAR. If some pixels receive signals from both front and rear obstacles at the same time, the output distance of this pixel may be the value between the two obstacles. The degree of deviation is related to the distance between the two obstacles and the material.

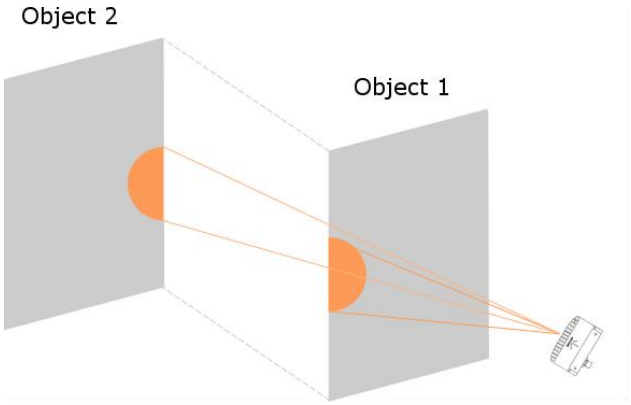


Figure 17 Multi distance objects

9. Frequently Asked Questions

Q1: After LiDAR is powered on, the display program of Windows crashes when opening, and present the interface as shown in the Figure 18

A1: Please make sure the indicator of radar is on. It will take about 30 seconds to start after radar is powered on, and the indicator is flashing.

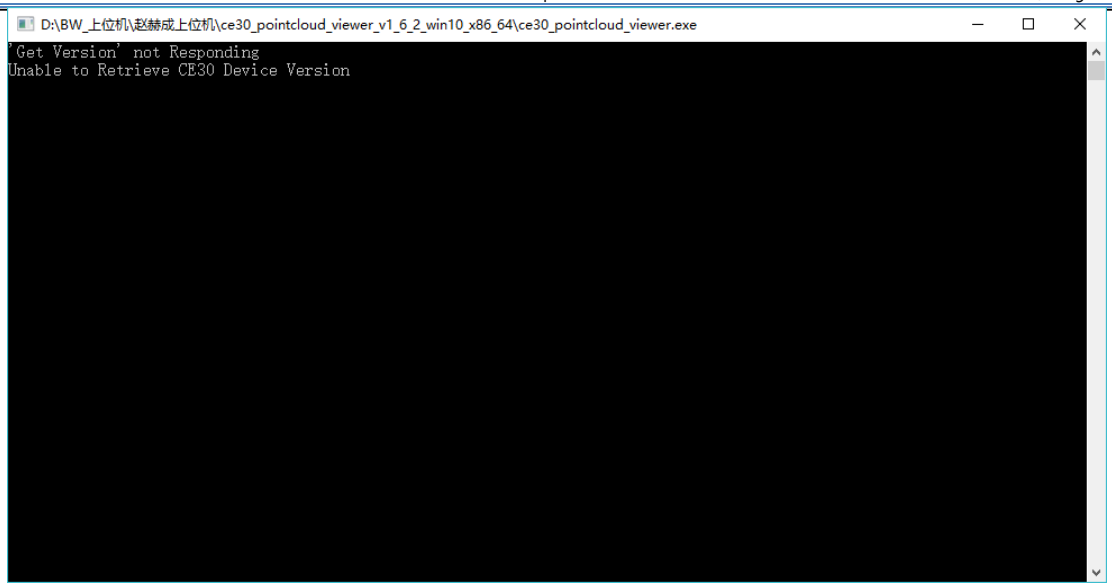


Figure 18 Viewer

Q2: From the manual, the power supply is DC 12V ± 0.5V （≥3A）,and power consumption is 8w. So how much is the working current?
A2: The normal working current is lower than 0.65A when radar working normally. There will be relatively high pulse current when radar is detecting distance, the peak of pulse current is lower than 3A.

Q3: Is CE30-D based on ROS?
A3: CE30-D will offer a SDK software to open source, which is based on Windows, Linux and ROS.
The address of open source community: https://codincodee.github.io/ce30_driver/