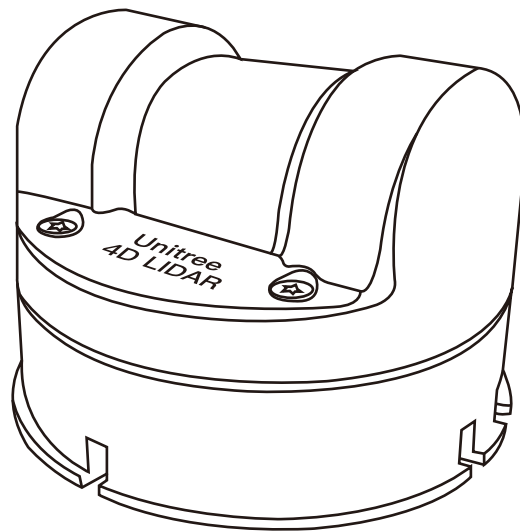# Unitree 4D LiDAR-L1

User Manual v 1.0

2023.04

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https://github.com/unitreerobotics/unilidar_sdk

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Product Overview

Introduction

Unitree 4D LiDAR-L1 is a cost-effective, safe, and reliable 4D LiDAR (3D position + 1D grayscale) that can achieve high-speed laser ranging sampling at 21,600 times per second. It can be widely used in robotics, smart cities, smart toys, logistics, and other fields, supporting functions such as mapping, positioning, recognition, obstacle avoidance, environment scanning, and 3D reconstruction.

The L1 radar can detect objects as close as 0.05 meters and as far as 30 meters away (90% reflectivity).

The L1 unit is compact and lightweight, weighing only 230 grams, making it suitable for general robot environment scanning, positioning, mapping, navigation, and obstacle avoidance.

The L1 has outstanding ultra-wide-angle scanning capabilities, with a field of view (FOV) expanding to 360° horizontally and 90° vertically, enabling three-dimensional space detection of a hemispherical field of view. Its application range can be expanded to more commercial scenarios.

The L1 has an IMU module with built-in 3-axis acceleration and 3-axis gyroscope, supporting a push frequency of 250Hz.

The L1's azimuthal scanning frequency is 11Hz, and its vertical scanning frequency is 180Hz, with an effective sampling frequency of 21,600 points/second. The L1 not only has excellent performance but also has high reliability, meeting the working environment temperature range of -10℃~60℃ and IEC-60825 Class 1 eye safety level.

Working Principle

The L1 radar mainly consists of the laser emission and ranging core, reflector, high-speed rotating motor, and low-speed rotating motor. In the working state, as shown in the diagram, the rotating directions of the high-speed and low-speed rotating motors are as shown in the figure.
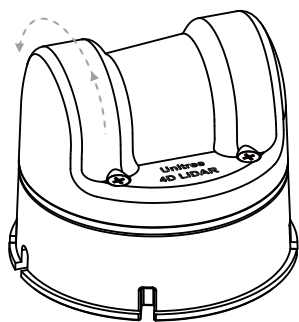

Direction of High-Speed Motor Rotation
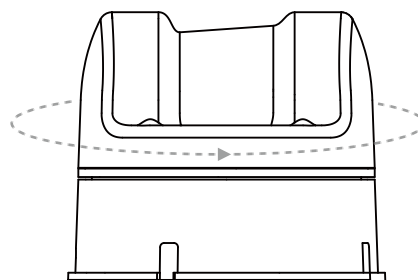
Direction of Low-Speed Motor Rotation

The communication and power supply interfaces of the L1 are connected through a conversion module, which includes a power supply port and a Type-C port. Users can supply power through a power adapter and obtain scanning ranging data through the Type-C port. The L1 is equipped with a conversion module, power adapter, and data cable for users, eliminating the need for a complex power supply system and debugging cables, reducing usage costs.

The L1 uses laser flight time ranging technology, combined with a high-speed laser acquisition and processing system, to achieve a ranging action of 21,600 times per second. In each ranging action, the L1 emits ns-level narrow-pulse infrared laser signals. The reflected light from the target object is received by the radar's laser acquisition system, and after analysis and processing by the processor, the distance value and current angle information between the illuminated target object and the L1 are output from the communication interface.
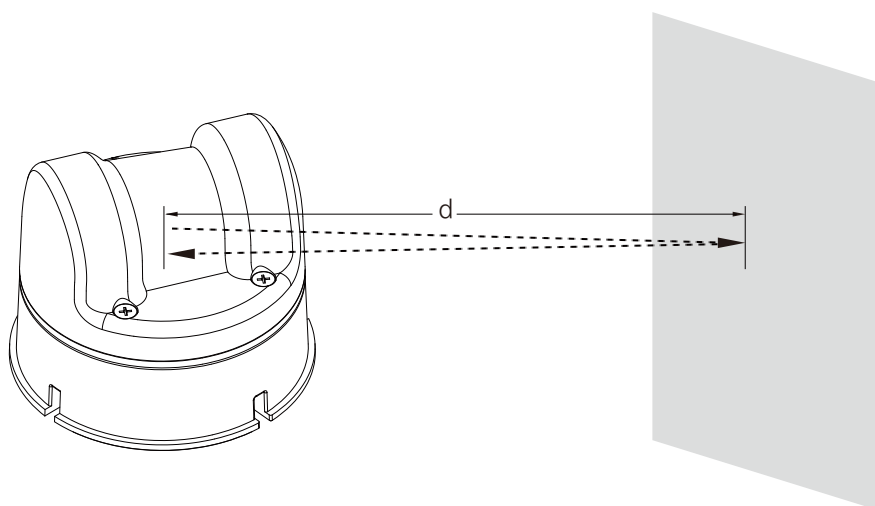
Schematic Diagram of Working Principle

Component Description
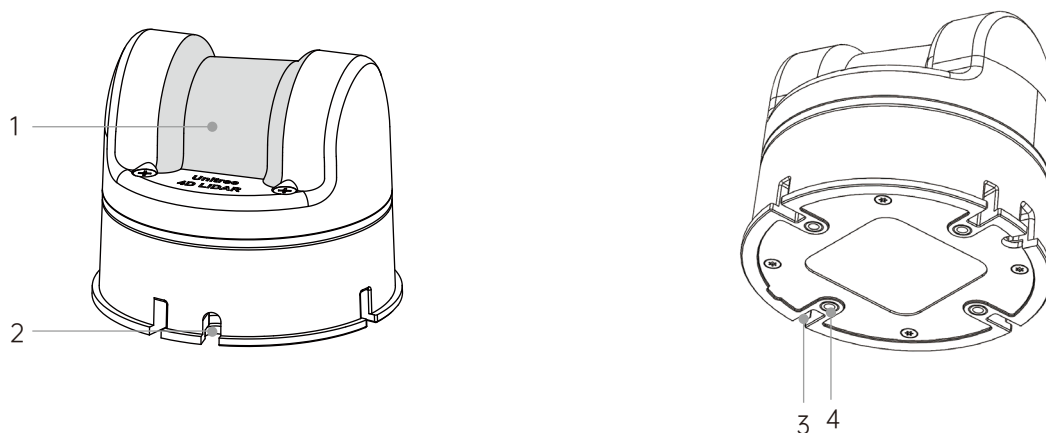
1. **Optical Window**

   The laser beam emits outward through the window, scanning objects within the FOV range.

2. **Outlet**

   The end of the cable is a 4-pin connector that, when combined with the conversion module, can quickly test the performance of the laser detection and ranging instrument. It is recommended that users customize and use cables suitable for their scene requirements based on the plug wire sequence to improve the system's protection capabilities (such as dust and water resistance). Please refer to the Interface Definition section for the pin sequence of the 4-pin connector.

3. **Locator slot**

   When designing a fixed bracket, the positioning point can be used to improve the overall positioning accuracy. Please refer to the Installation Dimensions section for specific dimensions.

4. **M3 Mounting Hole**

   The L1 can be fixed to a suitable position using M3 screws through this mounting hole.

Interface Definition

4-Pin Connector

The L1 output cable is a 4-pin serial port, which can be connected to the L1 using the included conversion module, power adapter, and data cable to realize power connection, control signal transmission, and data transmission. Users can also replace the conversion module with other cables according to their own needs to improve the system's protection capabilities (such as water and dust resistance).The specification of the serial port socket is GH1.25mm 4PIN.
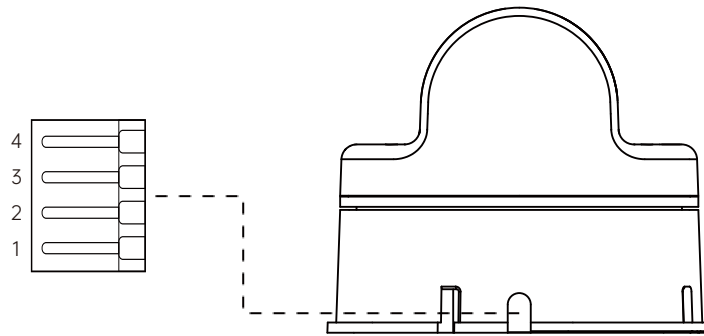
4-Pin Serial Port Diagram and Pin Numbering Diagram

The pin sequence definition of the L1's 4-pin serial port is as follows:

PIN NO.	Signal	Attribute	Description	Cable Color	Function
1	VCC	Power Supply	DC 12V power supply	Red	Power cable
2	GND	Ground	Ground	White	Power cable
3	RX	Input 3.3V	Ranging core serial port input	Green	Functional cable
4	TX	Output 3.3V	Ranging core serial port output	Black	Functional cable

Installation

Effective Field of View (FOV) Range

The L1 includes a high-speed motor and a low-speed motor. The high-speed motor drives the reflector to rotate, realizing vertical measurement within a 180 ° range. The low-speed motor then drives the measuring core to rotate 360 ° , thus achieving a hemispherical super-wide-angle sc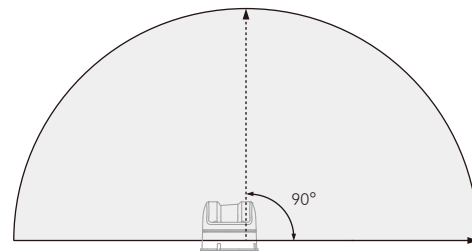an of 360*90° . It can measure the three-dimensional space above the radar in a 360° range, as shown in the figure below. When installing, please pay attention to the effective range of the FOV to avoid obstructing the FOV area.
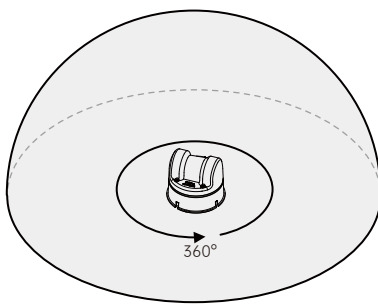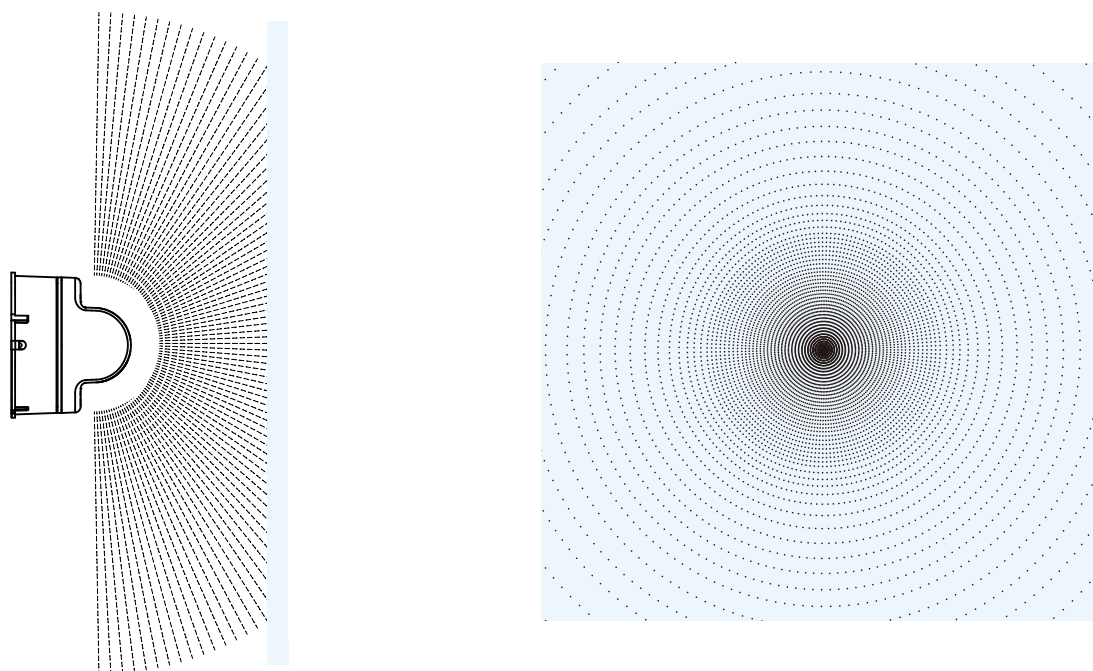

Horizontal Direction

Vertical Direction

Effective FOV Range of L1

Please note that the point cloud density of the L1 varies in different FOV areas, with higher density near the center. Please refer to the figure below for details.


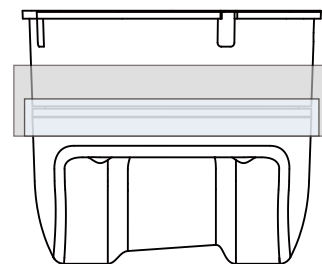Point Cloud Density in Different FOV Areas of L1

Installation Precautions

Before installing the L1, please read the following precautions:

1. Dust or dirt on the optical window may affect the performance of the laser detection and ranging instrument. We recommend using alcohol or a cleaning cloth to clean it according to the maintenance section of this document. After cleaning, proceed to installation.

2. The FOV of the laser detection and ranging instrument should not be obstructed during installation, even if transparent glass is installed in front of the window, it may still affect the performance of the laser detection and ranging instrument.

3. The installation direction of the laser detection and ranging instrument is not limited and can be installed using its lower surface.

4. The installation structure of the laser detection and ranging instrument can only ensure its own reliability, and the body of the laser detection and ranging instrument cannot bear additional loads.

5. The laser detection and ranging instrument requires airspace design on all sides during installation to prevent poor air flow from affecting heat dissipation. It is recommended that the airspace size around the laser detection and ranging instrument is not less than 10mm.

6. When waterproofing is required for the usage scenario, the laser detection and ranging instrument needs an additional waterproof protective bracket. The schematic diagram of waterproof protection for both upright and inverted installation is as follows:
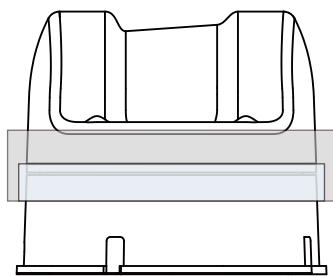
Upright Installation   Inverted Installation
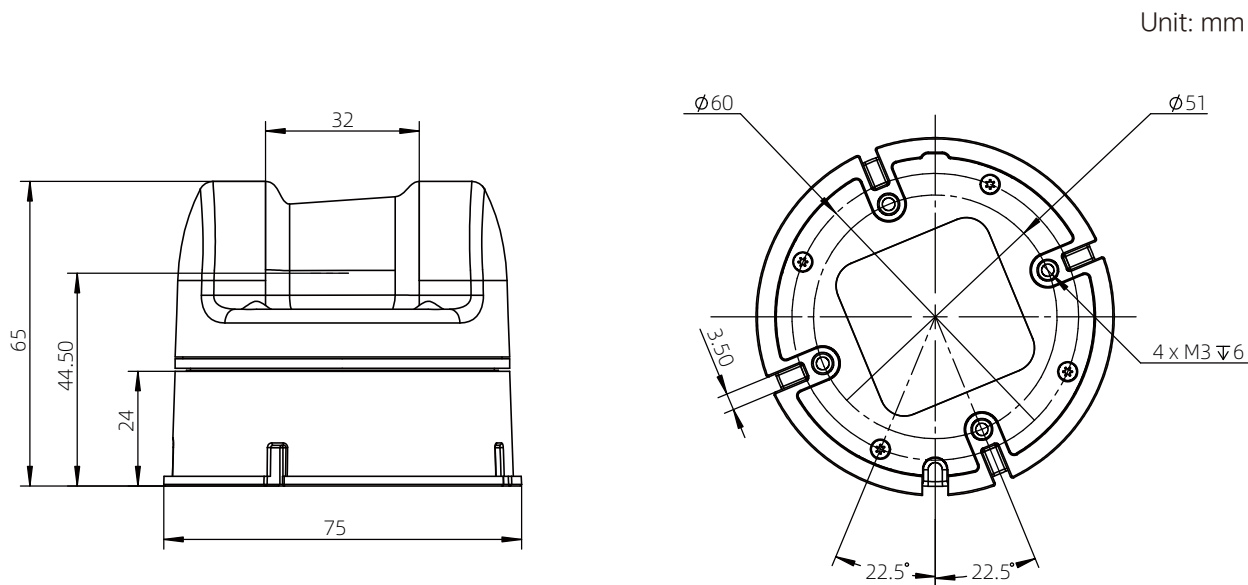
Waterproof Protection Schematic Diagram

Installation Dimensions

The bottom of the L1 has four M3 mounting holes with a depth of 6mm. Please refer to the following L1 size and mounting hole size diagram to install the L1 in the appropriate position.

Unit: mm

Mechanical Dimensions of L1

Weight and Size of L1:

| Weight	230g
Size	75 (W) x 75 (D) x 65 (H) mm

Usage

Wiring

The 4-pin connector of the L1 provides external power and data transmission. Please refer to the Interface Definition section for the specific pinouts. To temporarily test or use the L1, we recommend using the included adapter module, power adapter, and data cable for connection and usage as follows:

a. Insert the 4-pin serial port of the L1 into the adapter module.

b. Insert the power adapter into the power port of the adapter module for power supply.

c. Insert the Type-C interface of the data cable into the data communication port of the adapter module and connect the other end to a personal computer.

Unitree4D LiDAR-L1   USB to Type-C Cable   Unitree   Adapter Module   Connecting to an External Power Source
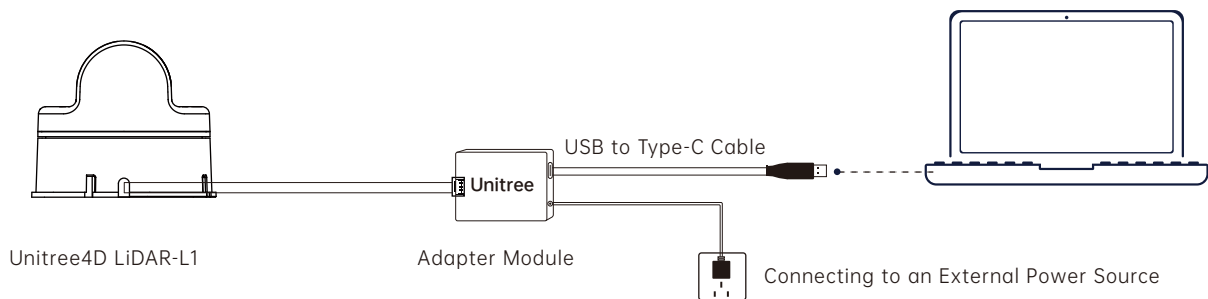
The adapter module, power adapter, and data cable are included in the package and can be used for power supply, control signal transmission, and data transmission. Alternatively, you can use other cables according to your needs to improve usability and system protection (such as dust and waterproofing).

When debugging, be sure to place the L1 radar on the included rubber pad and place the rubber pad on a flat surface to ensure stable operation and prevent collisions and falls.

Coordinate System

The Cartesian coordinate system of L1, denoted as 0–XYZ, is defined as shown in the diagram below. O is the origin of the point cloud coordinate system, located at the bottom center position, with the +X axis pointing in the opposite direction of the outlet, and the +Y axis pointing counterclockwise 90 ° from the +X axis. O–XYZ is the point cloud coordinate system of L1(The origin and XYZ coordinate system of the IMU can be found in the L1 3D model, and its XYZ axes are parallel to the point cloud coordinate system.)

Unitree 4D LiDAR-L1 Coordinate Definition
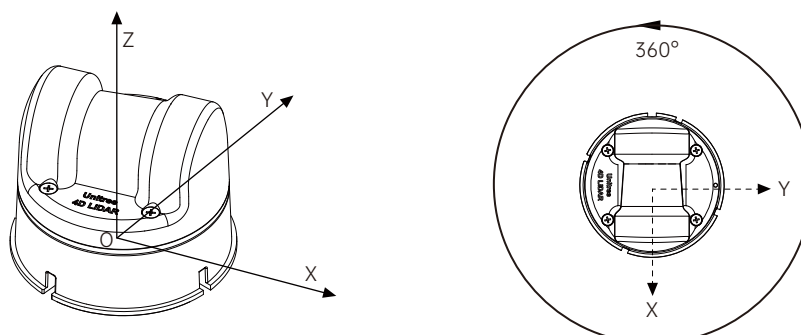
Point Cloud Data

By default, the L1 starts outputting point cloud data as soon as it is powered on. The point cloud data includes distance values, angles, reflectivity, IMU data, and working status data.

Point cloud data is the comprehensive result of all the point clouds detected by the laser ranging instrument on the surface of the measured object in the field of view. Each point cloud data mainly includes the following information:

Distance value: the actual distance between the sampling points, in millimeters.

Angle: the angle between the sampling point and the L1's own orientation, in degrees.

Reflectivity: the reflectivity of the object detected.

IMU data: 3-axis accelerometer and 3-axis gyroscope data.

Working status data: current speed, voltage, temperature, and other data of the laser ranging instrument.

Working Status and Working Modes

The working status of the L1 refers to the current state of the laser ranging instrument, while the working mode refers to the target working mode set by the user.

Working Status Description

The working status of the L1 includes sampling status, standby status, and interference status, as detailed in the table below.

Working state	Description
Sampling status	The laser ranging instrument has been powered on and is functioning normally (emitting laser beams).
Standby status	After setting the standby mode, the laser ranging instrument enters the standby status with a power consumption of less than 1W. The LED light is turned off, the high-speed motor stops rotating, the low-speed motor stops rotating, and only IMU data is output.
Interference status	If the laser ranging instrument is forcefully stopped due to external forces, the point cloud cannot be used. However, when the external forces are released, the L1 will automatically resume rotation and point cloud data output.

Working Mode Description

The working mode of the L1 refers to the target working mode set by the user. The L1 has two working modes that users can set: normal mode and standby mode. Users can set different working modes through Unilidar or Unilidar SDK. The default mode for L1 when first used is the normal mode. If L1 loses power and is turned on again, it will revert back to the default normal mode.

LED Modes

The L1's LED light ring has eight modes to choose from, including command mode, slow forward rotation, fast forward rotation, slow reverse rotation, fast reverse rotation, three-segment flip, three-segment breathing, and six-segment breathing. Users can set different LED modes through Unilidar or Unilidar SDK.

The default LED mode is six-segment breathing, and when using Unilidar point cloud software, it will automatically switch to command mode. After the L1 is powered off and on again, it will maintain the last used LED mode.

When using command mode, users can customize the state of each LED light bead. For detailed configuration methods, please refer to the relevant chapters of the "Unilidar User Manual" and Unilidar SDK documentation.

Unilidar

Unilidar is an operating software that can display and parse 3D point clouds in real-time, and supports advanced functions such as product settings and external parameter adjustments. By using Unilidar software, users can perform simple graphical debugging. Before using Unilidar, it is necessary to install the driver, which can be downloaded from www.unitree.com to view point cloud images. Unilidar currently supports Windows® (64-bit).

For Windows users: unzip the file, open the unzipped folder, double-click on the program named "CP210xVCPInstaller_x64" to install the driver, and run the Unilidar.exe program as an administrator.

For more detailed instructions on how to use Unilidar, please visit the official website at www.unitree.com and download the "Unilidar User Manual" for more information.

Unilidar SDK

In addition to using Unilidar to view real-time point cloud data, users can also use the Unilidar SDK software development kit to apply the point cloud data obtained through the laser ranging instrument to their own custom scenarios. This can achieve the following functions:

· Configure the laser ranging instrument: configure and query the laser ranging instrument parameters and status information;

· Obtain point cloud data: point cloud coordinate data generated by the laser ranging instrument.

Visit https://www.unitree.com/en/download for more detailed information about the Unilidar SDK documentation.

Storage, Transportation, and Maintenance

Storage

The storage temperature range for the L1 is -20℃~60℃. Please store it in a dry and dust-free environment, and pay attention to the following:

· Do not expose the product to toxic, harmful, or corrosive environments.

· Handle the product with care when storing, and avoid dropping it.

· For devices stored for more than three months, regularly check the appearance and interfaces to avoid abnormal conditions when using.

Transportation

Before transportation, please carefully check whether the product is securely installed and then pack it in the packaging box. It is necessary to put buffer foam in the packaging box, and ensure that the packaging box is dry and clean, without moisture. During transportation, handle the product with care, avoid collision, impact, or dropping.

Maintenance

The L1 has good reliability and stability, and under normal use, the probability of failure is small. It only requires cleaning of the optical window of the laser ranging instrument. If the output area of the radar is contaminated (such as dust, mud, etc.), it may affect the quality of the data generated after scanning objects. In this case, it is necessary to clean the radar. Please follow the following steps to clean it:

First, use a clean lens cleaning cloth to gently wipe the optical window. If there are still visible stains on the window, then use a small amount of alcohol on the cleaning cloth to gently wipe the window.

FAQ

If there is a problem during use, please refer to the following table for solutions. If the problem cannot be resolved, please contact an authorized dealer of Unitree or Unitree.

Problems	Solutions
Unable to detect the serial port connected to L1	· Confirm that all cables are correctly connected. · Confirm whether the adapter is suitable. The power supply requirement for the L1 is 12V, 1A. · Confirm whether the Unilidar driver program is installed. After the above confirmations, if the serial port connected to the L1 still cannot be detected, try restarting the L1 and Unilidar software.
Able to detect the serial port connected to L1, but unable to open the serial port or start sampling	· Confirm that all cables are correctly connected. · Confirm whether the adapter is suitable. The power supply requirement for the L1 is 12V, 1A. If the problem still exists, try restarting the L1 and Unilidar software.
L1 stopped rotating due to external interference	· Usually, when external force is released, the L1 will automatically resume rotation. · Try restarting the L1.

After-sales warranty information

Visit https://www.unitree.com/terms for more information on Unitree 4D Lidar-L1's warranty information.

Parameter Specifications

Unitree 4D LiDAR	
Model	L1 PM（Precision Measurement） L1 RM（Remote Measurement）
Laser Wavelength	905nm
Eye Safety Rating [1]	Class 1(IEC60825-1:2014) Eye Safety
Max Range [2]	20M（L1 PM @90% reflectity），30M（L1 RM @90% reflectity） 10M（L1 PM @10% reflectity），15M（L1 RM @10% reflectity）
Near Blind Zone [3]	0.05m
FOV	360°* 90°
Sampling Frequency	43200 points/s
Effective Frequency	21600 points/s
Scanning Method	Contactless Brushless Mirror Scanning
4D Information	3D Position + 1D Grayscale
Horizontal Scanning Frequency	11Hz
Vertical Scanning Frequency	180Hz
Communication Interface	TTL UART
Communication Baud Rate	2000000 bps
Measurement Accuracy [4]	±2.0cm
Measurement Resolution	8 mm
IMU Sampling Rate	1kHz
IMU Reporting Frequency	250Hz
Attitude Perception Dimension	3-axis Accelerometer + 3-axis Gyroscope
LED Ring Resolution	1°
LED Ring Refresh Rate	11Hz
Anti-Strong Light Ability	100Klux
Operating Environment Temperature [5]	-10℃-60℃

Storage Environment Temperature	-20℃-60℃
Protection Level [6]	IP54
Power [7]	6W（Environment Temperature25℃）
Operating Voltage	12V DC
Size	75 (width) x 75 (depth) x 65 (height) mm
Weight	230g

[1] The instantaneous peak power of the laser is 25W, but the actual average power used will be much lower than this value, and it is driven by a pulsed method, which only emits for a very short time to ensure the safety of humans and pets and meet the Class I level laser safety standard.

[2] The typical value of reflectivity is shown here, and the actual value depends on environmental conditions and target object characteristics.

[3] The laser ranging instrument can detect and output point cloud data when the distance to the target object is 0.05m. However, due to the inability to guarantee detection accuracy, this data is for reference only.

[4] To ensure the effective detection of objects with different reflectivities within the range, there may be a slight decrease in point cloud accuracy at some locations. The test conditions are as follows: environment temperature of 25℃, target object reflectivity of 90%, and test distance of 15m.

[5] The performance of L1 will slightly decline in high and low temperature environments, strong vibration, foggy weather, etc. In addition, long-term high-temperature operation may affect product performance or even cause product damage. It is recommended to increase cooling measures to ensure that the housing temperature does not exceed 60℃. When the temperature is too high, the over-temperature protection mechanism will be triggered, and L1 will issue an over-temperature warning. When the over-temperature is severe, L1 will stop working.

[6] The protective effect of L1 varies greatly under different installation angles. Please increase external protection according to the actual installation angle. Damage caused by improper installation or external protection is not covered by the warranty.

[7] The stable power and peak power under different environments are different.

This manual will not be notified separately if updated.

You can check the latest version of the "User Manual" on the official website of Unitree.

https://www.unitree.com/en/download