S Series: dToF-Based RGBD Cameras

Technical Reference & Application Handbook

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Prepared by: MRDVS Technology

Content

Revision History

Rev. Date	Ver.	Edit by	Audit By	Revision Description
13-Jan-25	V1.0	Liping Wang	Ling Shi	Initial released
4-Apr-26	V2.0	Liping Wang	Ling Shi	Added New model S10 Ultra
24-Apr-26	V2.1	Liping Wang	Ling Shi	Added S10 Ultra MIPI and S11 MIPI related
2-May-26	V2.2	Liping Wang	Ling Shi	Added Appendix A: Installation Guide, Appendix D: Application Notes
5-May-26	V2.3	Liping Wang	Ling Shi	Added Appendix E (Use Cases) and restructured Appendix D

1. Product Overview

1.1 Introduction

The S Series is a family of compact, industrial-grade RGBD cameras built on dToF (direct Time-of-Flight) technology, providing synchronized RGB and depth data for mobile robot perception and depth sensing in demanding environments.

The series currently includes four models:

- **S10**: A compact industrial-grade RGBD camera providing synchronized depth and RGB data over a range of 0.3~8 meters. It features internal spatial and temporal alignment between depth maps and color images, supports multiple data streams (depth, intensity, RGB, point clouds, and processed obstacle avoidance results), and operates reliably indoors and outdoors under up to 100 KLUX ambient light. With low power consumption and frame rates up to 20 fps, the S10 is ideal for real-time responsive sensing and obstacle avoidance.
- **S10 Ultra**: A small-form-factor, wide-field-of-view, cost-effective industrial-grade RGBD camera that extends the sensing range up to 42 meters (0.2m~42m). In addition to core dToF capabilities, the S10 Ultra features RGB-D-IMU fusion with a built-in IMU (output at 200Hz), effectively supporting mainstream SLAM algorithms such as Fast-LIO, and LIVO (LiDAR-Inertial-Visual Odometry). It delivers spatially and temporally aligned RGB and depth data, supports software trigger, and is available in an MIPI module version for volume demand. The fully solid-state design (no moving parts) ensures enhanced vibration resistance and stability.
- **S11:** A high-cost-effectiveness, compact RGBD camera with an ultra-wide 140° HFOV, designed for obstacle avoidance at ranges up to 6 meters with ≤10 mm full-range accuracy. It supports USB, Ethernet, and MIPI (MIPI available for volume orders only), offering flexible connectivity for various integration needs. Compared to the S10, the S11 offers more flexible

interface options, slightly better accuracy, and a larger horizontal field of view (HFOV). However, its vertical field of view (VFOV) is smaller than that of the S10. The S11 provides higher cost-effectiveness. Therefore, if the VFOV meets the application requirements, the S11 is the primary recommendation.

- **MIPI Module:** To meet the lightweight, cost-effective, and easier integration demands for drones, lawn mower robotics, service robots, and consumer electronics, the S10 Ultra-MIPI and S11-MIPI modules are designed for direct connection to host processors via a compact MIPI CSI-2 interface (supporting NVIDIA Jetson, Qualcomm, NXP, Rockchip, and other platforms), eliminating the need for an external Ethernet controller. The modules deliver raw data output - including depth, IR amplitude, and optional RGB streams, making it ideal for high-volume embedded vision systems.

1.2 Product Status

1.2.1 S10

- Status: Launched in Q3 2025
- Certification: CE, Laser Safety Class 1, RoHS, REACH
- Availability: Available for immediate order

1.2.2 S10 Ultra

- Status: Pre-order
- Certification: In preparation; planned to be completed in Q3 2026
- Availability: Accepting pre-orders. First testing unit available in Q2 2026. Larger volumes require confirmation.

1.2.3 S11

- Status: Final retuning
- Certification: In preparation; planned to be completed in Q3 2026

- Availability: Accepting pre-orders. First testing unit available in Q2 2026. Larger volumes require confirmation.

2. Specifications

Parameter	**S10**	**S10 Ultra**	**S11**
Laser Wavelength	940nm	940nm	940nm
Output Format	Depth/RGB/IR Amplitude Map	Depth/RGB/IR Amplitude Map	Depth/RGB/IR Amplitude Map
Depth Resolution & Frame Rate[①]	240 × 160 @Max 20fps (typ. 15fps)	240 × 160 @Max 10fps (typ. 10fps)	240 × 96 @Max. 15fps (typ. 10fps)
TOF FOV (H×V)	120° × 80°	120° × 80°	140° × 56°
RGB Resolution & Frame Rate[①]	1632 × 1224 @ Max. 20fps (typ. 15fps)	1280 × 1080 @ Max 20fps (typ. 10fps)	1280 × 1080 @ Max 20fps (typ. 10fps)
RGB FOV (H×V)	120° × 80°	120° × 110°	120° × 110°
Range	0.3~8m (90% reflectivity); 0.3~3m (5% reflectivity)	0.2~42m (90% reflectivity); 0.2~30m (5% reflectivity)	0.1~6m (10%-90% reflectivity), 100kLux
Accuracy[②]	≤3 cm	≤4 cm	±1 cm @ 2m; ±2 cm @ 6m
Average Power Consumption	≤4W	< 9W	Typ. <4W Max. 13W
Dimensions (L×W×H)	80 × 37 × 25 mm	106 × 69 × 43 mm	90 × 25 × 25 mm
Weight	190 g	440 g	130 g
Power Supply	12–28V DC	12–27V DC	12~28V DC 5V USB 3.0
Interface	Ethernet	Ethernet	Ethernet/USB*
MIPI CSI-2 Available	No	Yes	Yes

Parameter	S10	S10 Ultra	S11
IP Rating	IP54	IP67	IP54
Operating Temperature	-20°C~60°C	-20°C~75°C	-20°C~60°C
Storage Temperature	-40°C~85°C	-40°C~85°C	-40°C~70°C
Time Synchronization	PTP	PTP	PTP
SDK Support	C/C++/ROS1/ROS2	C/C++/ROS1/ROS2	C/C++/ROS1/ROS2
OS Compatibility	Windows 7/8/10/11, Linux, Arm Linux	Windows 7/8/10/11, Linux, Arm Linux	Windows 7/8/10/11, Linux, Arm Linux
Ambient Light Resistance	100 KLUX	100 KLUX	100 KLUX

Table 1 Product Specification Parameters

Note:

①*The typical (typ.) frame rate represents the recommended operating condition for optimal thermal and power performance. The maximum (max.) frame rate is technically achievable but may lead to increased power consumption and higher temperature rise. Operation at max. frame rate is not recommended for general use. If higher frame rates are required for a specific application, please contact MRDVS technical support for further evaluation.*

②*Accuracy may degrade with distance and depends on object reflectivity and surface roughness.*

3. Technology Overview: dToF vs. Stereo

3.1 How They Work & Accuracy Comparison

- dToF Camera: Measures distance by emitting light pulses and directly timing their round-trip flight. Every pixel returns a valid depth value regardless of surface texture or color. Provides consistent absolute accuracy throughout the specified working distance range. Near-field depth resolution is lower due to SPAD array density.

- Stereo Camera: Computes depth by triangulating corresponding features from two image sensors. Performance depends heavily on surface texture, lighting, and pattern richness. Achieves sub-millimeter accuracy at very close range (<0.5 m), but accuracy degrades beyond ~3 meters due to disparity error.

3.2 Application Scenarios

- dToF Camera: Reliable obstacle avoidance for a wide range of mobile robots, including AGV, AMR, cleaning robots, outdoor low-speed vehicles, and UAVs, as well as operator-assisted blind-spot detection on manned vehicles (e.g., forklifts). Performs reliably on low-reflective objects, uniform surfaces, and under outdoor lighting.
- Stereo Camera: 3D scanning, facial recognition, industrial inspection – best when scene texture is controllable.

A comprehensive comparison, including additional test scenarios, in-depth analysis, full reference data, and application-specific recommendations, is available in Appendix D: Application Notes - RGB-D Camera Comparison: MRDVS S11 vs. Intel RealSense D435.

4. Hardware Description

4.1 S10 Camera

4.1.1 Camera Interfaces

There are two interfaces on the S10 camera end: DC24V power interface, 100M Ethernet interface.

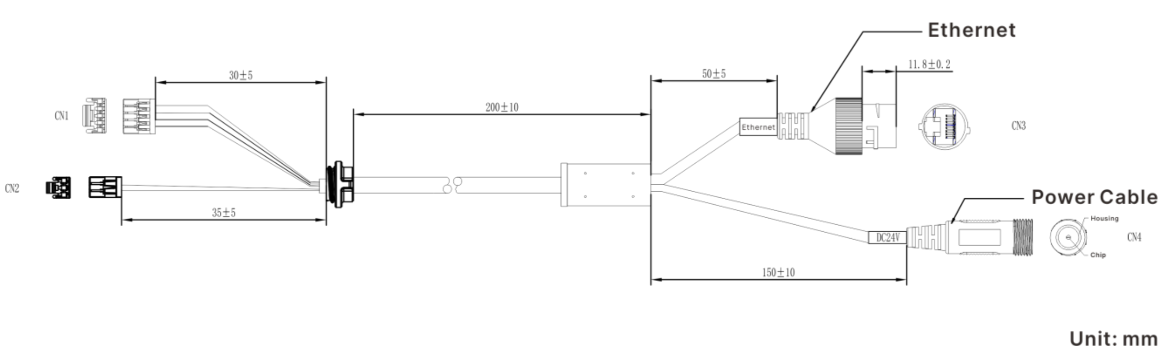


Figure 1 - S10 Camera Interface Diagram

4.1.2 Component Overview

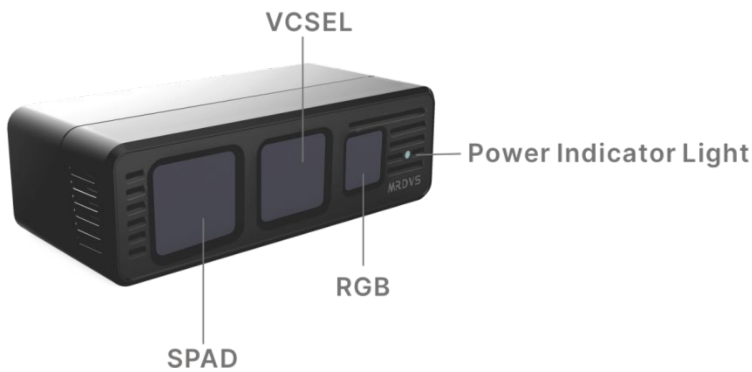


Figure 2 - Overview of S10 Camera

4.1.3 Mechanical Dimensions

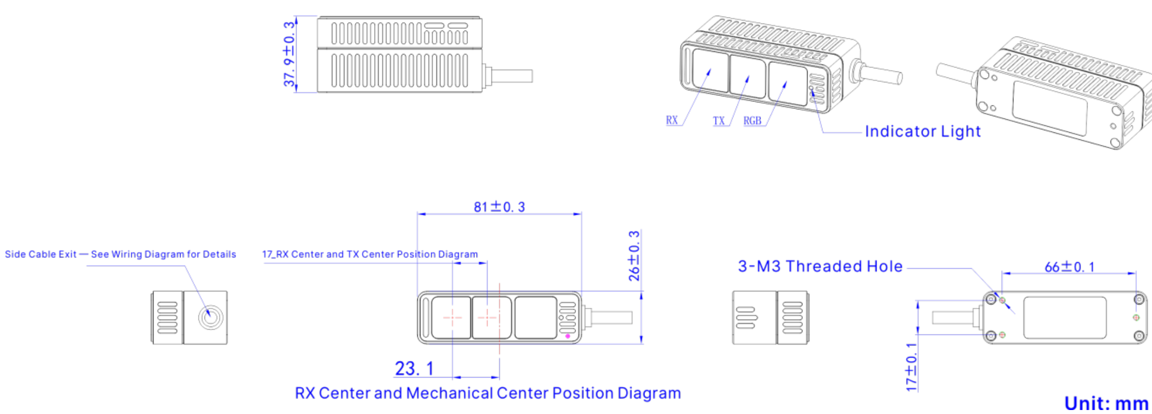


Figure 3 - S10 Camera Dimensions Diagram

4.1.4 Photo of the physical product

Figure 4 - S10 Photography

4.2 S10 Ultra Camera

4.2.1 Camera Interfaces

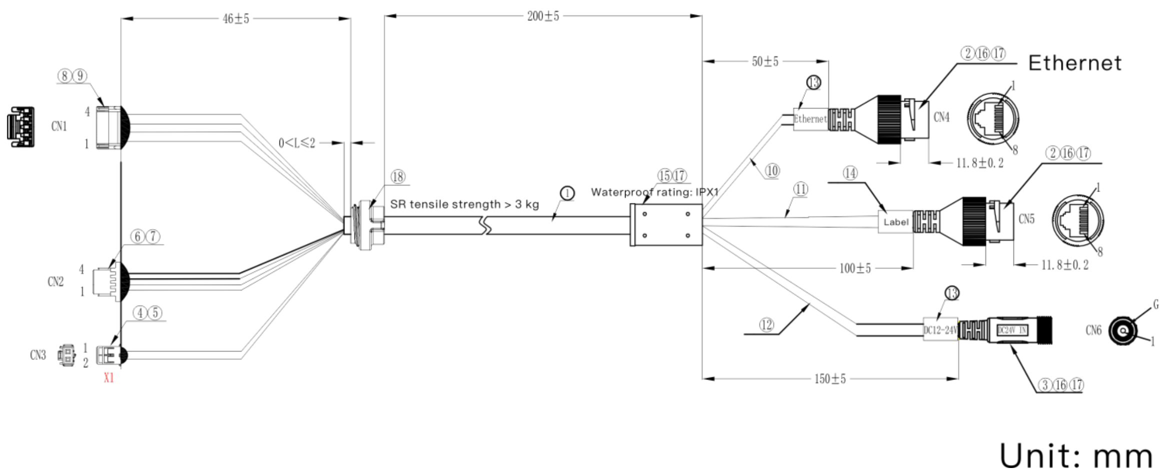


Figure 5 - S10 Ultra Camera Interface Diagram

4.2.2 Component Overview

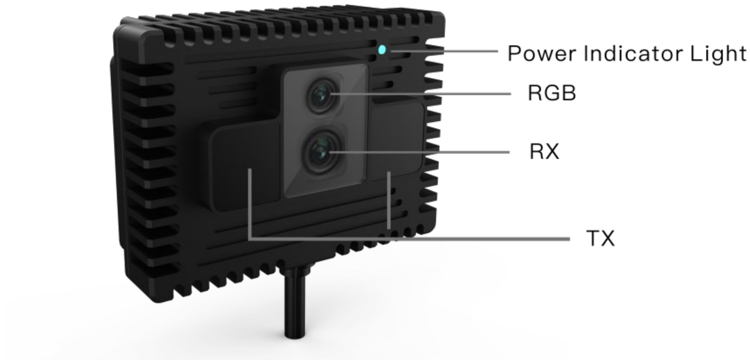


Figure 6 - Overview of S10 Ultra Camera

4.2.3 Mechanical Dimensions

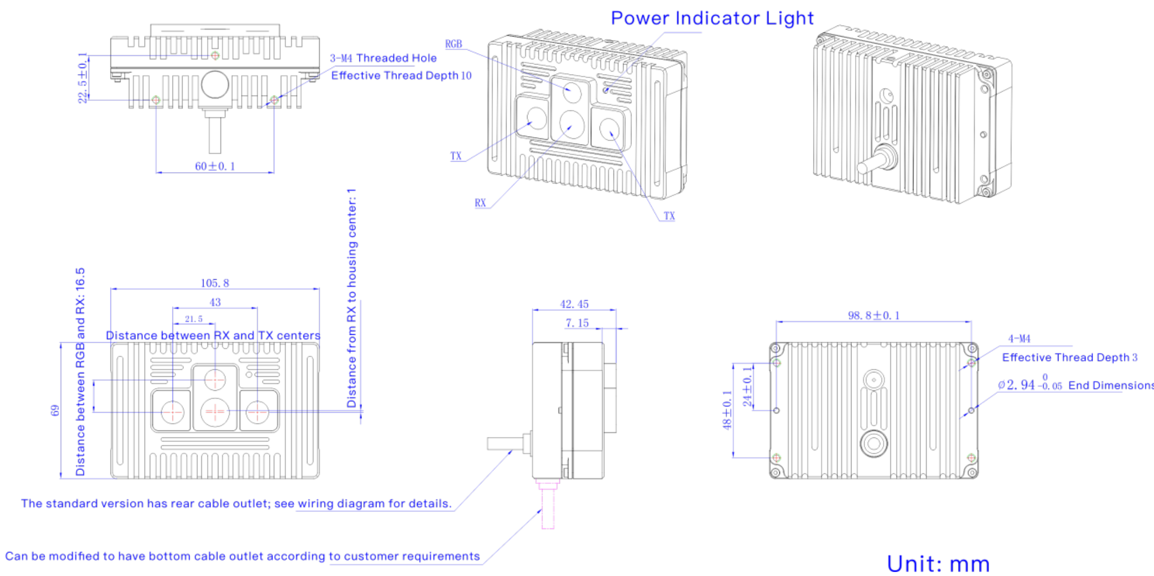


Figure 7 - S10 Ultra Camera Dimensions Diagram

4.2.4 Photo of the physical product

Figure 8 - S10 Ultra Photography

Figure 9 - S10 Ultra MIPI Photography

4.3 S11 Camera

4.3.1 Camera Interfaces

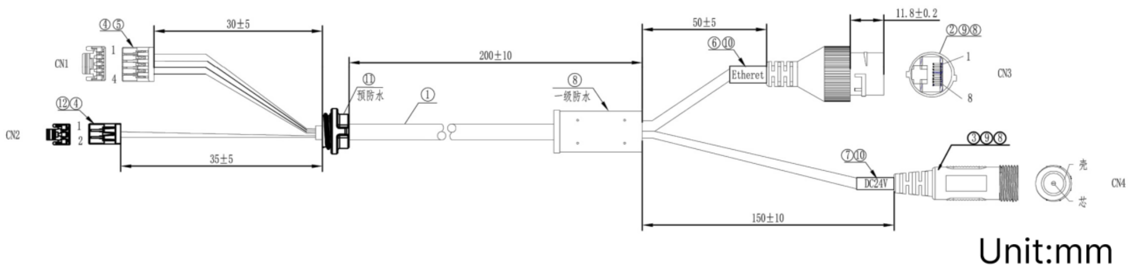


Figure 10 - S11 Camera Interface Diagram

4.3.2 Component Overview

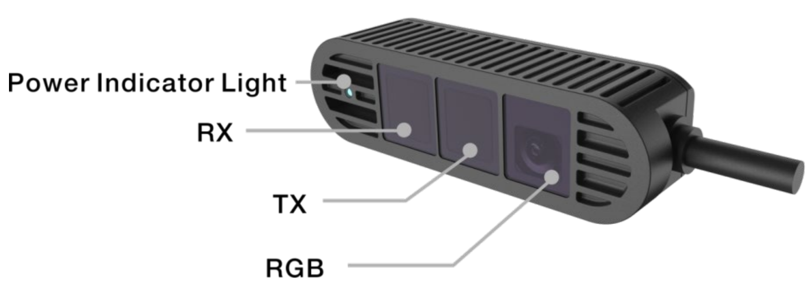


Figure 11 - Overview of S11 Camera （Ethernet，USB also provided）

4.3.3 Mechanical Dimensions

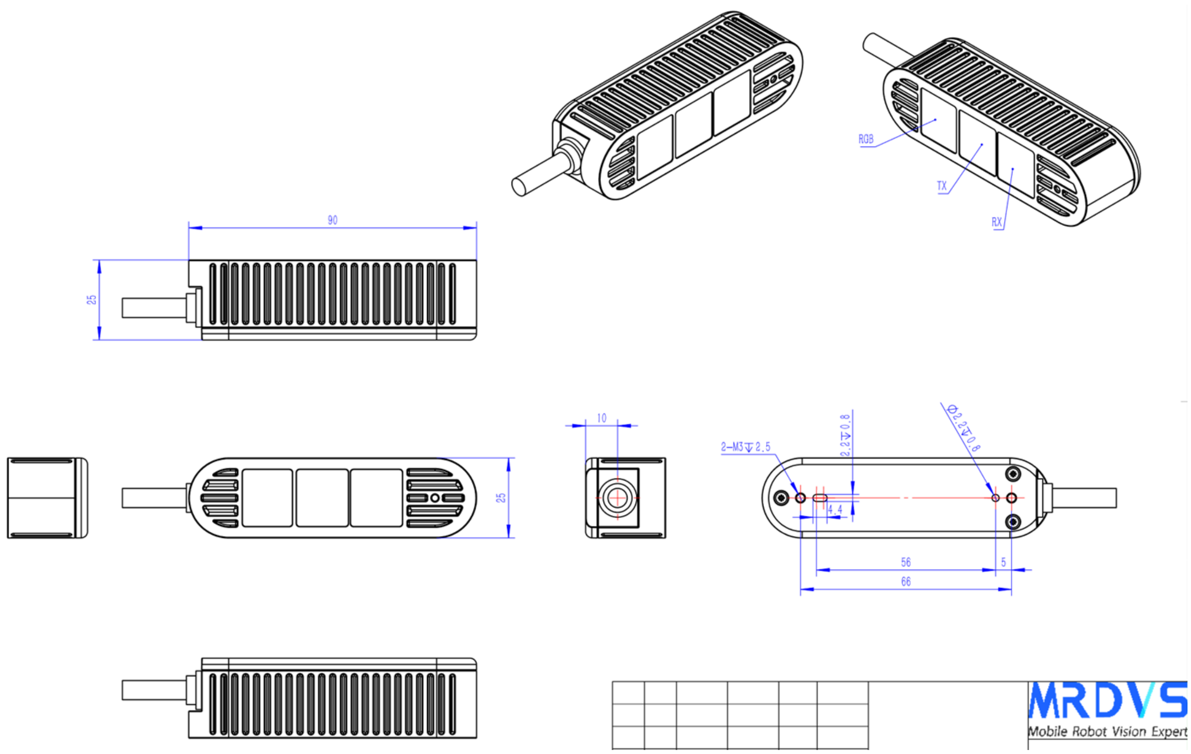


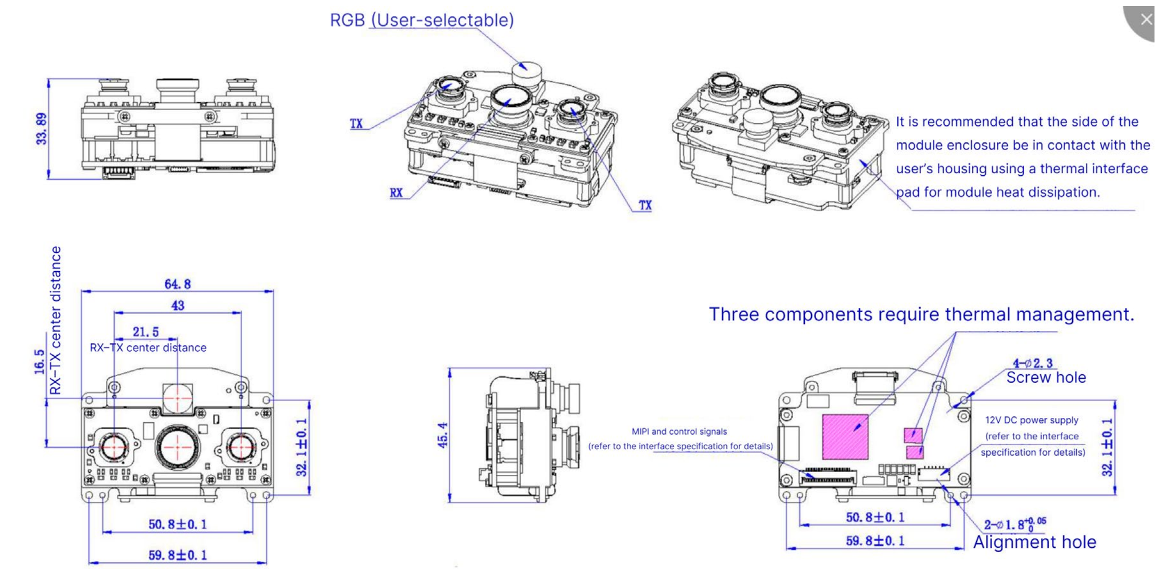
Figure 12 - S11 Camera Dimensions Diagram

4.3.4 Photo of the physical product

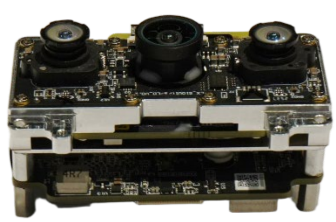
Figure 13 - S11 Photography

4.4 S10 Ultra MIPI Module

4.4.1 Mechanical Dimensions



4.4.2 Photo of the physical product

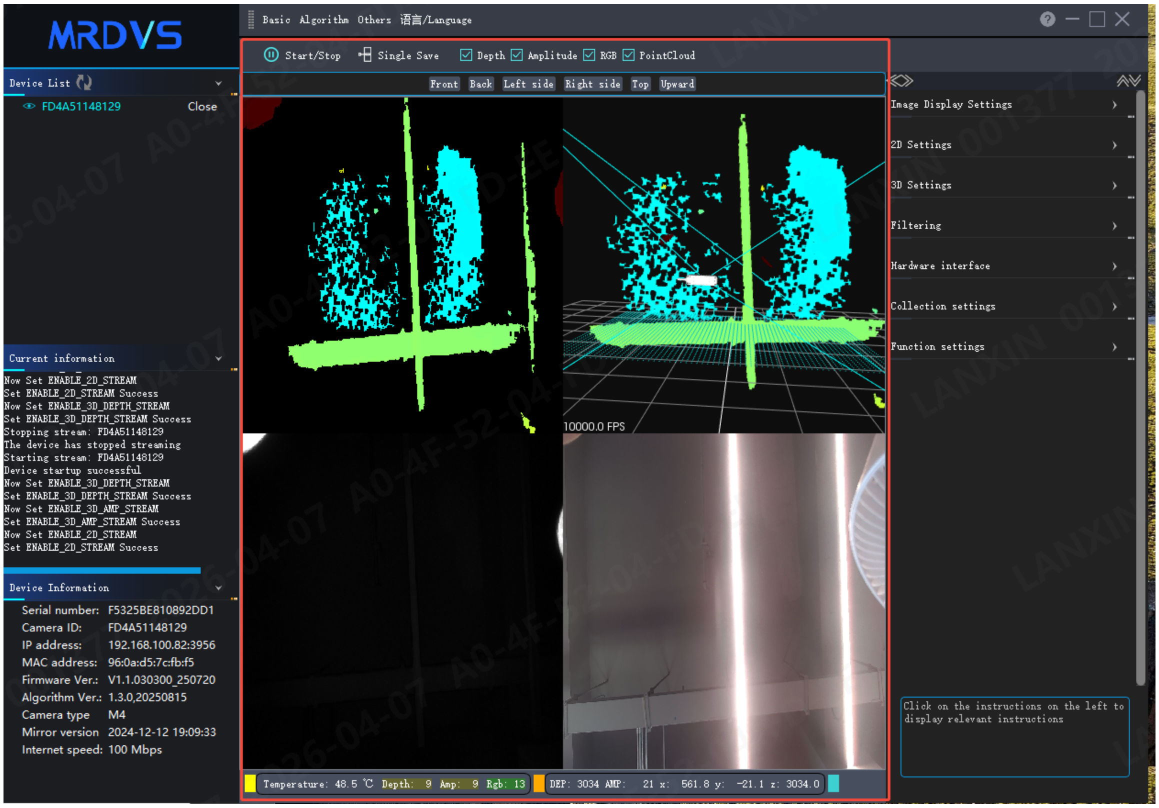


5. Output Data Formats and Visualization

This chapter details the data formats output by the S Series cameras and provides guidance on how to visualize them using common third-party software.

5.1 MRDVS GUI Software: LxCameraViewer

LxCameraViewer is the official GUI software for all MRDVS cameras. It supports displaying depth maps, intensity maps, point clouds, and RGB images, and allows users to read and configure basic camera settings as well as algorithm parameters. The software also provides camera temperature monitoring, frame rate display, pixel value readout, and real-time status feedback. Users can view and save image data, camera configurations, detailed algorithm data, and device information such as serial number, firmware version, and IP address.



After connecting a camera, a function panel appears on the right side, organized under three menus: "Basic Tools" (image display, 2D/3D settings, filtering, hardware interface, collection and function settings), "Apply Algorithms" (working mode, algorithm settings and version), and "Others" (point cloud loading, IP configuration, capture, and communication tools).

Quick controls include:

【Start/Stop】 - start or stop image streaming

【Single Save】 - save the current image from all active streams

【Depth】/【Amplitude】/【RGB】/【PointCloud】 - enable the desired output formats

For detailed instructions, refer to the LxCameraViewer User Manual:

CameraSDK/Document/LxCameraViewer_User_Manual.md at master · Lanxin-MRDVS/CameraSDK · GitHub

5.2 Data Output Formats and Samples

The S Series cameras can output multiple synchronized data streams shown as below.

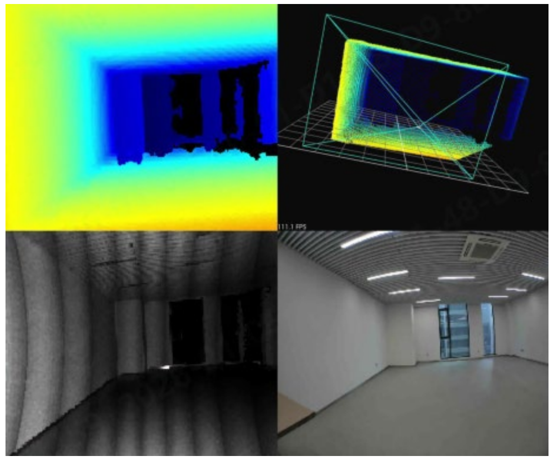


Figure 10 - Example GUI Visualization: Camera Multimodal Data

(Top Left: Depth Map | Bottom Left: Intensity Map | Top Right: Point Cloud Map | Bottom Right: RGB Map)

20240407_191957513_a.pgm	2024/4/7 19:19	PGM 文件	2,401 KB
20240407_191957513_d.pgm	2024/4/7 19:19	PGM 文件	2,401 KB
20240407_191957513_r.png	2024/4/7 19:19	PNG 文件	1,825 KB
20240407_191957513_t.pcd	2024/4/7 19:19	PCD 文件	19,201 KB

Figure 11 - Example Saved Output Data Files

(From top to bottom: Intensity Map (_a.pgm), Depth Map (_d.pgm) , RGB Image (_r.png), Point Cloud (_t.pcd))

Output Data Type	**Description**	**Format**
Depth Map	A pseudocolor image where each pixel's color corresponds to the distance from the camera. Warmer colors (e.g., red/yellow) represent closer objects, cooler colors (e.g., blue/purple) represent farther objects.	.pgm

Intensity (Amplitude) Map	A grayscale image representing the strength of the reflected infrared signal. Higher values indicate stronger reflection. Please note the vertical striping appears due to the dToF SPAD sensor's region-based exposure architecture and parallax. This is an inherent characteristic of dToF technology and does not affect depth accuracy.	.pgm
Point Cloud	A 3D point cloud file (PCD format) containing XYZ coordinates for each pixel, derived from the depth map and camera intrinsics.	.pcd
RGB Image	A standard color image from the onboard RGB camera, spatially aligned with the depth map.	.png

Table 2 Output Data Type and Description

5.3 Recommended Third-Party Software

We recommend the following free, open-source software to inspect the exported data files:

- For Point Cloud (*.pcd files):
    - Recommended Software: CloudCompare
    - Download Link: CloudCompare - Open Source project
    - Usage: Open the .pcd file directly to visualize, rotate, measure, and analyze the 3D point cloud.
- For Depth and Intensity Maps (*.pgm files):
    - Recommended Software: ImageJ
    - Download Link: ImageJ

  - Usage: Open the .pgm file. You can use the analysis tools to check pixel values, profiles, and histograms. Note that depth maps are typically encoded in millimeters.

- For RGB Images (*.png files):
  - These can be opened with any standard image viewer (e.g., Windows Photos, Preview on macOS).

5.4 Software Download and Development Support

Different packages of the SDK (for C/C++, Python, ROS 1, ROS 2) and the GUI viewer binaries (for Windows and Ubuntu), along with their corresponding user manuals, can be downloaded via the MRDVS GitHub channel:

https://github.com/Lanxin-MRDVS/CameraSDK/releases

6. Environment and Reliability

Item		S10	S10 Ultra	S11
Operating Environment	**Operating Temperature**	-20℃ to 60℃	-20℃ to 75℃	-20℃ to 60℃
	Humidity	Max 90%RH	Max 90%RH	Max 90%RH
	Illuminance	0 ~ 100KLUX	0 ~ 100KLUX	0 ~ 100KLUX
Storage Environment	**Temperature**	-40℃ to 85℃	-40℃ to 85℃	-40℃ to 70℃
	Humidity	Max 90%RH	Max 90%RH	Max 90%RH

Table 3 Product Integration Guide

7. Certification Statement

Note: The certifications listed in this chapter have been completed for the S10. For the S10 Ultra and S11, these certificates have not yet been obtained and are planned to be acquired in Q3 2026.

7.1 Laser Security Level

	Laser Safety Guidelines
	This product emits invisible laser radiation during operation. Avoid exposure to the eyes to prevent injury. The laser emitted by this product complies with Class 1 safety requirements. According to EN 60825, it poses no hazard to humans during normal use.

CLASS 1 LASER PRODUCT

This product is classified as a Class 1 laser product under IEC 60825-1:2014. It is safe for normal use under reasonably foreseeable conditions and does not pose a hazard to the eyes.

7.2 European Directives

This product complies with EU CE conformity assessment requirements and meets the specifications of harmonized standards EN IEC 61000-6-2:2019 and EN IEC 61000-6-4:2019.

7.3 European Union RoHS Statement

This product meets RoHS Directive (2011/65/EU Annex II & amendment (EU) 2015/863) requirements. Restricted substances (Cadmium, Lead, etc., including phthalates) passed testing per applicable RoHS standards.

7.4 European Union Regulation

This product complies with the requirements of Regulation (EC) No 1907/2006 of the European Parliament and of the Council on the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH).

Appendix A: Installation Guidance

Proper installation is critical to ensure optimal sensor performance.

FOV Clearance

Ensure no structural components (housing edges, ribs, brackets) intrude into the sensor's nominal FOV; mount the sensor centered within the opening. *Otherwise, FOV truncation may cause fixed blind areas, false close-range readings, and obstacle avoidance failures.*

Particularly during initial testing, it is recommended to place the sensor on a support 20~30 cm above the ground with no obstructions in its field of view, as the image shown above.

Optical Path

Keep the sensor at least 10 cm away from highly reflective surfaces (polished metal, mirrors, glossy plastics). *Otherwise, near-field IR crosstalk or multi-path interference may cause distance distortion, data corruption, or receiver saturation.*

Mechanical Mounting

Apply moderate and even torque; avoid over-tightening. Use soft gaskets or spacers if needed. *Otherwise, mounting stress may cause lens deformation or optical axis shift, resulting in distance offset.*

Thermal Management

Provide adequate ventilation, especially in enclosed spaces; avoid heat sources. *Otherwise, temperature rise may cause distance drift and long-term performance degradation.*

Window Maintenance

Implement a regular cleaning schedule for dusty or humid environments. *Otherwise, contamination or fogging will degrade signal-to-noise ratio.*

Appendix B: Quick Start & Diagnostic Guide

1. Power Connection

Connect the camera to an appropriate power source according to its interface type: for models with a DC input, use a DC power supply within the specified voltage range (e.g., 12–24V DC, 3A); for models supporting 5V USB power, ensure the source provides stable 5V power with sufficient current (e.g., 5V, 2A). Once properly connected, the blue power indicator will flash slowly, indicating normal power-on. Please refer to the product specifications for the exact voltage, current, and interface requirements of your specific model.

2. Network Connection

Connect the camera to the computer via the required cable (Ethernet or USB).

3. Computer Network Configuration

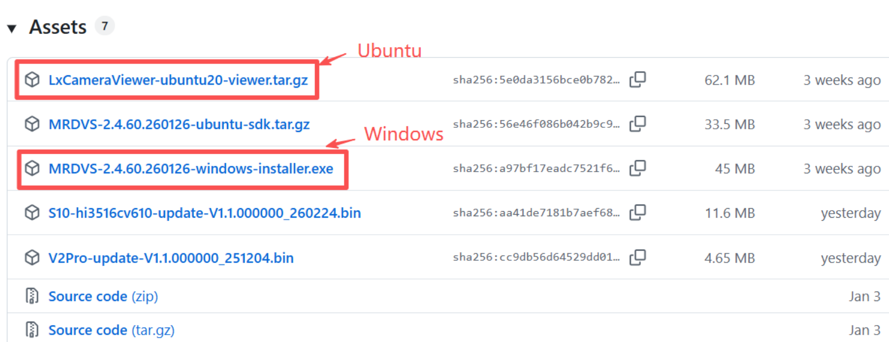
Set your computer's IP address to the same subnet as the camera (default camera IP: 192.168.100.82) and disable the computer's firewall.

4. Install GUI Tool

Note: The GUI is required for device status checking, firmware update, image testing, parameter setting, IP changing, etc.

Download the GUI Tool:

https://github.com/Lanxin-MRDVS/CameraSDK/releases



Note:

- The Windows version is recommended as it offers greater stability.

- It is recommended to install the software to a non-system drive (e.g., D: drive) or to run the program as an administrator, as installing to the default C: drive may cause permission issues.

5. Check and Update the Embedded Firmware to the Latest

5.1 Check Current Firmware Version

Launch the installed `LxCameraViewer.exe` software, locate your device in the **Device List**, and check the **Device Information** to see the current firmware version.

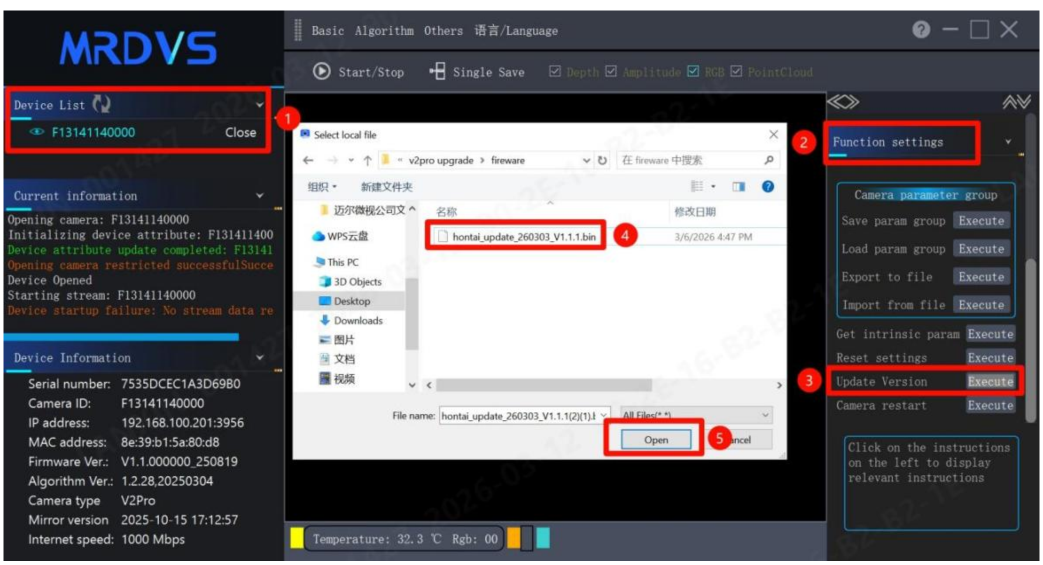
Compare it with the latest firmware version shown in the GitHub Release. If the current firmware version does NOT match the latest version in GitHub Release, an update is required. Please follow steps 5.2 and 5.3 below.

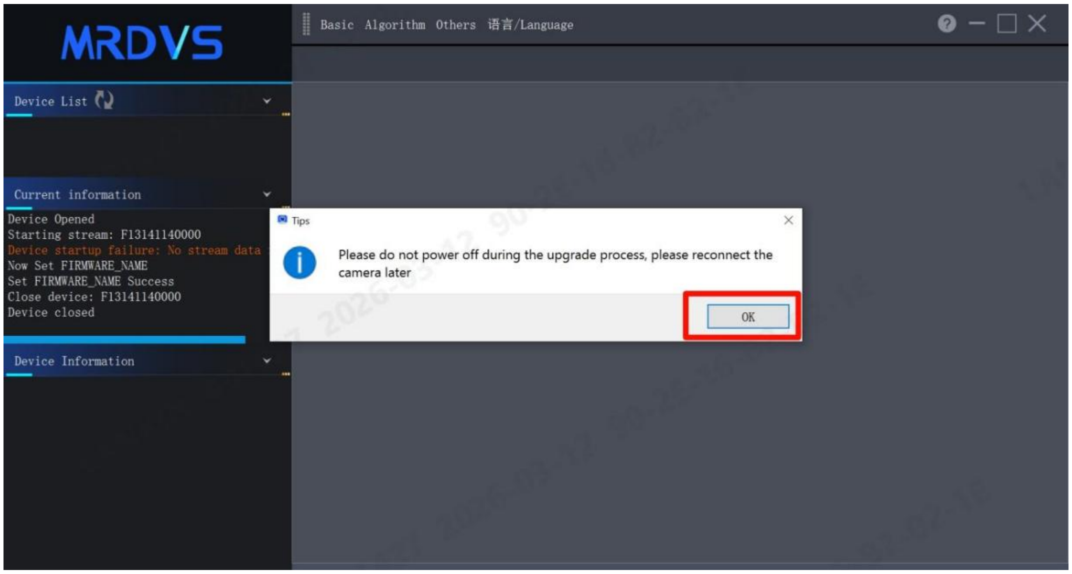
5.2 Download the latest Firmware

https://github.com/Lanxin-MRDVS/CameraSDK/releases

Firmware Name: S10-xxxxupdate_Vxxx_xxxxxx.bin

5.3 Follow the instructions shown below to upgrade the firmware;

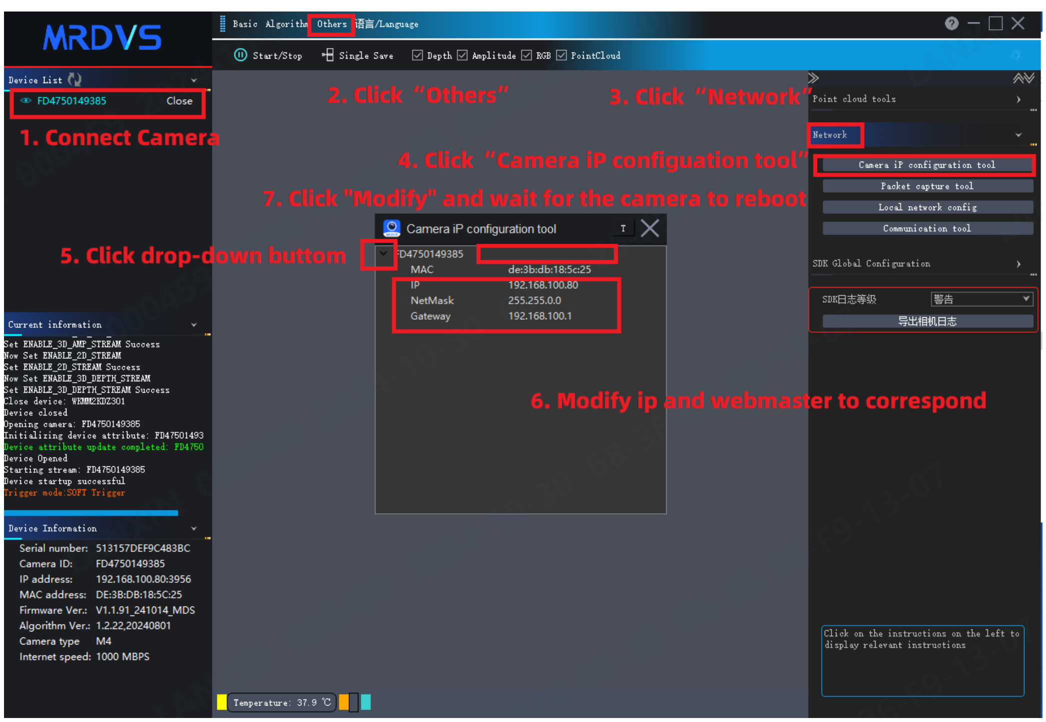




The upgrade process takes approximately one minute. Once complete, reopen the device in the **Device List** and check **Device Information** to verify the firmware version has been successfully updated.

5.4 Modify Device IP Address (if needed)

If the target device requires a different IP address, it can also be modified using the GUI tool (see screenshot below).



6. Installation and FOV Clearance

After completing the software and firmware setup, ensure proper physical installation of the camera. Particularly during initial testing, it is recommended to place the sensor on a support 20~30 cm above the ground with no obstructions in its field of view, as shown in the image below.

7. Diagnostic Guide

7.1 No Data After Opening the Camera

If no data appears after opening the camera with the host computer software, follow the diagnostic steps below

- Firewall - Ensure the firewall is turned off or that the camera software is permitted to pass through.
- IP Configuration - Set the camera and host computer to the same network segment.
- Multiple IP Addresses - If the host computer has obtained multiple IP addresses and the camera has detected the same IP within the local network, select the desired IP address to activate it.

- Network Hardware - Check whether the network switch or cables are malfunctioning.
- Computer - Try replacing the host computer to isolate the issue.
- Network Segments - Configure multiple network segments if required by the environment.
- GUI Version - If the GUI cannot display images or the image is abnormal, refresh the GUI viewer to the latest version.
- Application Permissions - If the error "failed to exclusively acquire application permissions" appears, ensure that only one user is connected to the camera at the same time.

7.2 Image Quality Issues

Issue	Recommended Action
Edges of nearby white objects are less precise	The glare algorithm has been optimized, but detection of black objects may still be incomplete.
Reflective pillar location is overexposed	Turn on the glare suppression algorithm.
Imaging of detected object is sparse or missing	Check high exposure parameters (typically 600–1200). Check low signal threshold (typically 10–30).

Appendix C: S10 Ultra MIPI Module Hardware Interface & Technical FAQ

1. Pin Definition

No.	Signal Name	Signal Direction	Signal Type	Signal Level	Description
1	MOD_PWR_EN	Input	LVCMOS	1.8v	Power Enable: 1: Enable module power (amplitude ≥ 1.8V). 0: Disable module power
2	RSV	-	LVCMOS	-	Reserved: Suspended
3	RSV	-	LVCMOS	-	Reserved: Suspended
4	MOD_SYNC_IN	Input	LVCMOS	1.8v	Graphic frame synchronization model: PWM, duty cycle 30% - 70%
5	RSV	-	LVCMOS	-	Reserved: Suspended
6	RSV	-	LVCMOS	-	Reserved: Suspended
7	MOD_SYNC_OUT	Output	LVCMOS	1.8v	Reserved: Suspended
8	GND	-	GND	-	Power ground
9	FPGA_GPIO_1	Input/Output	LVCMOS	1.8v	GPIO: Reserved
10	FPGA_GPIO_2	Input/Output	LVCMOS	1.8v	GPIO: Reserved
11	FPGA_GPIO_3	Input/Output	LVCMOS	1.8v	GPIO: Reserved
12	FPGA_GPIO_4	Input/Output	LVCMOS	1.8v	GPIO: Reserved
13	GND	-	GND	-	Power ground
14	MIPI_CSI_CK_N	Output	Differential clock pair	MIPI D-PHY	MIPI clock signal
15	MIPI_CSI_CK_P	Output	Differential clock pair	MIPI D-PHY	

16	GND	-	GND	-	Power ground
17	MIPI_CSI_D0_N	Output	Differential data pair	MIPI D-PHY	MIPI data signal D0
18	MIPI_CSI_D0_P	Output	Differential data pair	MIPI D-PHY	
19	GND	-	GND	-	Power ground
20	MIPI_CSI_D1_N	Output	Differential data pair	MIPI D-PHY	MIPI data signal D1
21	MIPI_CSI_D1_P	Output	Differential data pair	MIPI D-PHY	
22	GND	-	GND	-	Power ground
23	MIPI_CSI_D2_N	Output	Differential data pair	MIPI D-PHY	MIPI data signal D2
24	MIPI_CS_D2_P	Output	Differential data pair	MIPI D-PHY	
25	GND	-	GND	-	Power ground
26	MIPI_CSI_D3_N	Output	Differential data pair	MIPI D-PHY	MIPI data signal D3
27	MIPI_CSI_D3_P	Output	Differential data pair	MIPI D-PHY	
28	GND	-	GND	-	Power ground
29	REV_I2C_SCL	Input	LVCMOS	1.8v	I2C clock: Supports 100K to 400KHz, 1.8V level
30	REV_I2C_SDA	Bidirection	LVCMOS	1.8v	I2C data: 1.8V level

2. Technical Notes

2.1 Trigger & Synchronization

The device supports the following synchronization features:

- Trigger input (Pin 4, MOD_SYNC_IN): The device synchronizes at the rising edge. The high level should be maintained for 1~10 ms to trigger successfully.
- Duty cycle: Changing the duty cycle does not affect triggering. The device supports trigger control across the full 30~70% duty cycle range.
- Maximum triggering frequency: 10 fps
- Sync output (Pin 7, MOD_SYNC_OUT): Outputs a 25 ms high-pulse signal. The module begins exposure a few hundred microseconds after the signal goes high.

2.2 I2C Communication

- Voltage Level: The I2C interface is 1.8V only (as specified in the pin table). If 3.3V level is required, an external level shifter must be added between the device and the host.
- Data Format: I2C communication allows configuration of certain camera functions and reading of camera operational information. The format consists of a 16-bit register address corresponding to 8-bit data.
- Register Manual: A Register Configuration Reference Manual is available, documenting all I2C-configurable registers. Please contact MRDVS technical support to request this manual.

Appendix D: Application Notes

RGB-D Camera Comparison: MRDVS dToF Camera S11 vs. RealSense D435

Update: 4th May. 2026

This document provides a technical comparison between the S11 depth sensor and the Intel RealSense D435. The analysis covers key aspects including depth sensing technology, specifications, ranging capability, accuracy, ambient light adaptability, real-time performance, hardware complexity, and typical application scenarios. The goal is to present an objective, balanced assessment of both solutions, including their respective advantages and limitations.

1. Key Specification Differences

Aspect	MRDVS S11	RealSense D435
Product Image		
Depth Technology	dToF (Direct Time-of-Flight)	Stereoscopic (Active Stereo)
Illumination Wavelength	940nm	~850nm
Detection Range	0.1 ~ 6m	0.3 ~ 3m (ideal)
Minimum Distance	~10cm	~28cm
Accuracy*	±1 cm @ 2m; ±2 cm @ 6m	<2% at 2m (~4cm)
Depth FoV	140° × 56°	87° × 58°
Depth Frame Rate	Up to 20fps (typ. 10fps)	Up to 30 fps @ 1280×720; 90 fps @ 480×270

Depth Resolution	240 × 96	Up to 1280 × 720
RGB FoV	120° × 110°	69° × 42°
RGB Resolution	1280 × 1080	1920 × 1080
RGB Sensor	Rolling Shutter	Global Shutter
Interface	Ethernet / USB	USB-C 3.1
Dimension	90 × 25 × 25 mm	90 × 25 × 25 mm
Operating Temp	-20°C ~ 60°C (Industrial)	0°C ~ 35°C (Consumer / Non-industrial)
IP Rating	IP54	None
Typical Power Consumption	≈ 2.5 W	≈ 2.5~3 W (varies with resolution)

*For the MRDVS dToF camera S11, the full-range accuracy degrades gradually with distance and depends on object reflectivity and surface roughness. However, it remains largely unaffected by indoor or outdoor lighting conditions.

Regarding latency comparison: Direct time-of-flight measurement enables per-frame depth calculation with minimal processing overhead. Theoretical end-to-end latency is therefore expected to be lower than that of stereo solutions, though actual performance will depend on the host system configuration. For the S11, the typical end-to-end latency is approximately 70~100 ms under standard operating conditions.

2. Depth Technology

S11: Uses Direct Time-of-Flight (dToF). It emits pulsed infrared light (940nm) and measures the time each pulse takes to return to the sensor, directly converting this into distance. Every pixel within the Field of View returns a depth value.

D435: Uses active stereo vision. It employs two global shutter infrared cameras to capture images and calculates depth by triangulating disparities between them. An infrared projector is integrated to project a pseudo-random speckle pattern onto the scene, enhancing feature matching in low-texture environments such as white walls.

3. Measurement Distance

S11: Specified for an operating range of 0.1 to 6 meters. Since its depth calculation does not depend on a physical baseline, accuracy degrades gradually with increasing distance. Near-field detection works down to ~10 cm.

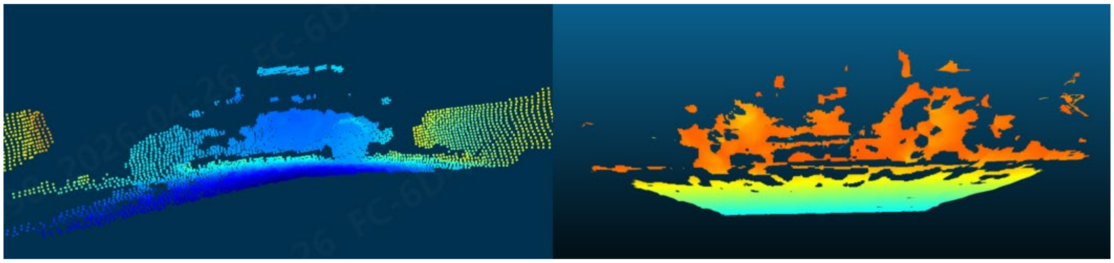
D435: Performs optimally between approximately 0.3 and 3 meters. Beyond this range, the disparity between the two stereo images becomes smaller, leading to a more noticeable increase in depth error due to its fixed baseline.

4. Environmental Light Adaptability

S11: Demonstrates strong resistance to ambient light, including sunlight and artificial lighting. The 940nm wavelength experiences less solar interference, and the sensor is specified for operation up to 100kLux, providing consistent performance across varied lighting conditions including direct sunlight.

D435: Can experience degraded performance under strong ambient light, particularly direct sunlight, as intense infrared components may overwhelm its ~850nm projected pattern. In overcast, shaded, or controlled indoor lighting environments, its performance remains stable.

Outdoor test scenario – Black vehicle detection



In this extreme outdoor scenario, neither sensor captures a fully complete point cloud on the vehicle body. However, the S11(the left) retains significantly more point cloud data compared to the D435(the right), which shows extensive data loss and higher noise levels.

5. Accuracy and Resolution

S11: Provides consistent absolute accuracy of approximately 1 centimeter across its specified range (0.1-6m). Its depth resolution in the near field is comparatively lower due to limitations of SPAD array density.

D435: Achieves sub-millimeter accuracy at very close distances (e.g., <0.5 m), making it well-suited for fine-detail capture. At longer distances (beyond 3m), disparity error grows and absolute depth accuracy degrades. It offers higher RGB lateral resolution (1920×1080) compared to the S11 (1280×1080).

Aspect	MRDVS S11	RealSense D435
Pixel Validity	Every pixel returns a depth value	Invalid points (holes) occur on textureless, reflective, or black surfaces
Resolution Concept	Lower effective pixel count but 100% valid	Higher potential resolution but valid percentage varies with scene texture
Near-Field Detail	Lower resolution at very close range	Sub-millimeter accuracy achievable at close range

Depth Data Validity Comparison

6. Typical Application Scenarios & Suitability Summary

6.1 Typical Application Scenarios

S11: Commonly selected for mobile robot obstacle avoidance (including AGV and AMR), cleaning robots, and service robot navigation, where consistent performance over varying distances, surface types (including black objects), and lighting conditions (including outdoor) is beneficial.

D435: Often used in applications requiring close-range, high-detail depth sensing, such as 3D scanning, facial recognition development, and bin-picking, particularly when scene texture is controllable, and where higher RGB resolution and high frame rate are beneficial.

6.2 Application Suitability Summary

The table below highlights preferred sensors for specific requirements, acknowledging that both have strengths.

Priority / Requirement	Better Suited	Notes
Outdoor / direct sunlight operation	**S11**	D435 may degrade under strong IR light
High-speed motion capture (>30 fps)	**D435**	Up to 90 fps (at reduced resolution)
Close-range sub-mm detail (<0.5 m)	**D435**	Stereo excels with textured objects at close range
Minimum detection distance	**S11**	Works down to 10 cm (D435 has a 28 cm minimum distance)
Hole-free depth on uniform / black surfaces	**S11**	Active stereo often fails on textureless areas

Glass / transparent obstacles	**Neither**	Consider ultrasonic or LiDAR
Mirror surfaces	**Neither**	Consider mechanical bumper or floor-mounted LiDAR
Dusty / foggy environments	**Neither**	D435 slightly less affected
Highly reflective objects	**S11 (with tuning)**	D435 suffers from pattern washout
Multi-sensor operation (fleet)	**S11 (with hardware sync)**	D435 interference is severe
Industrial temperature (-20°C to 60°C)	**S11**	D435 is specified for 0–35°C
IP-rated protection (dust/water)	**S11**	IP54 vs. none
Ethernet interface (long cable, industrial bus)	**S11**	D435 is USB only
Development ecosystem / SDK & community	**D435**	Mature ROS, OpenCV, and Python support
Technical support & timely response	**S11**	Direct engineering support from MRDVS
Batch customization (OEM/ODM)	**S11**	S11 supports hardware/software customization for volume orders

6.3 Selection Guidelines

Consider S11 when you need:

- Stable operation outdoors or under direct sunlight

- Hole-free depth on uniform, textureless, or black surfaces
- Minimum detection distance down to 10 cm
- Industrial temperature range (-20°C to 60°C) and IP-rated protection
- Ethernet interface and batch customization support

Consider D435 when you need:

- High frame rate motion capture (>30 fps, up to 90 fps at reduced resolution)
- Sub-mm close-range detail (<0.5 m)
- Higher RGB and depth resolution (up to 1280×720 depth, 1920×1080 RGB)
- Mature development ecosystem (ROS, OpenCV, Python)

7. Multi-Sensor Interference (Multiple Cameras on Same Robot / Fleet)

When several depth sensors operate in close proximity, their emissions can interfere.

Aspect	MRDVS S11	RealSense D435
Interference mechanism	Interference occurs when pulses from another sensor overlap in time and wavelength.	projected speckle patterns from multiple cameras can corrupt each other's disparity maps.
Severity	Low to moderate Random pulse timing or pseudo-random coding reduces collisions. Still, two S11 units facing each other may cause erroneous depth readings.	High Patterns interfere even at short distances. Holes and false depth increase rapidly.
Mitigation strategies	Sync via hardware trigger (external clock) or separate	Use official anti-interference mode (alternating projection) or different

	operating time slots (time-division multiplexing). Keep sensors pointing away from each other.	pattern configurations (if SDK allows). Physical separation >1m or angled away.
Recommendation for multi-robot fleets	Acceptable with time-sharing.	Not recommended for dense fleets; consider switching some units to passive stereo (IR projector disabled) if ambient texture is sufficient.

8. Challenging Materials and Environmental Conditions

8.1 Sensor Performance Comparison

Condition / Material	MRDVS S11	RealSense D435
Glass (windows, transparent panels)	Partial detection dToF often sees glass as a weak return or range extension (signal penetrates then reflects). Depth may be erratic on clear glass.	Limited detection Stereo matching struggles on transparent surfaces due to lack of projected texture. Glass typically appears as a hole or distant object.
Highly reflective objects (metals, glossy plastics)	Over-saturation can cause early returns, resulting in measured distance shorter than actual. Mitigation: gain control and multi-echo processing (if supported).	Speckle pattern becomes distorted or washed out, resulting in invalid depth holes. Performance varies significantly with angle and surface roughness.
Mirror surfaces	Direct reflection may cause range overestimation or ghost points,	Stereo treats the mirror image as a virtual scene behind the mirror,

	resulting in unreliable depth data on mirrors.	resulting in false depth readings at a distance. No valid object detection.
Dust & airborne particles	Moderate impact Dense dust clouds can attenuate the optical signal and reduce range. Static dust on the lens primarily reduces SNR.	Low impact on depth computation, as stereo works with edges rather than intensity. However, dust on lenses degrades image sharpness and pattern contrast, resulting in more depth holes.
Fog, rain, steam	Severe attenuation Water droplets scatter and diffuse the IR pulse, causing range to collapse rapidly in thick fog or heavy rain.	Less affected Stereo matching still works on visible edges, though fog reduces overall contrast. Rain droplets close to the lens may create false disparities.

8.2 Practical recommendations

For glass detection: neither sensor is reliable. Add ultrasonic or acoustic sensors, or use structured light with a wavelength that reflects from glass.

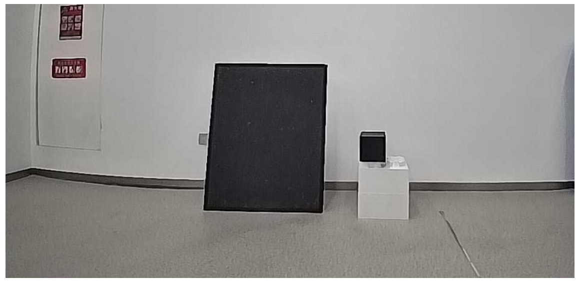
For mirrors / highly polished floors: avoid relying on either depth sensor. Use a mechanical bumper or 2D LiDAR at a low height.

For dusty or foggy environments (e.g. agricultural robots, outdoor emergency response): consider LiDAR (mechanical or solid-state) instead of either camera. Between the two, D435 has a slight edge in light fog, but neither is robust.

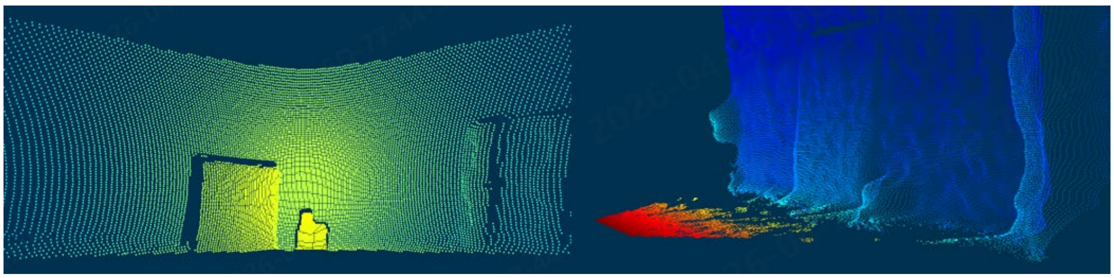
For reflective objects: S11 can be tuned with multi-frame averaging and exposure control; D435 may benefit from oblique camera angles.

9. Mobile Robot Common Scenario Test Comparison

Test 1 - Black board near white wall



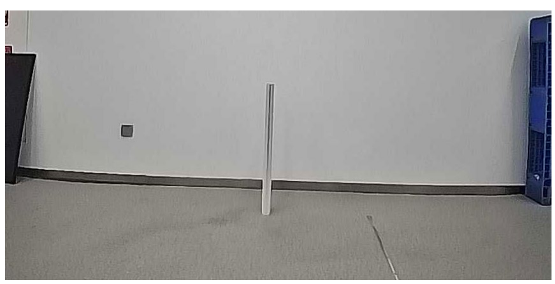
Indoor test scenario - Black board placed near a white wall



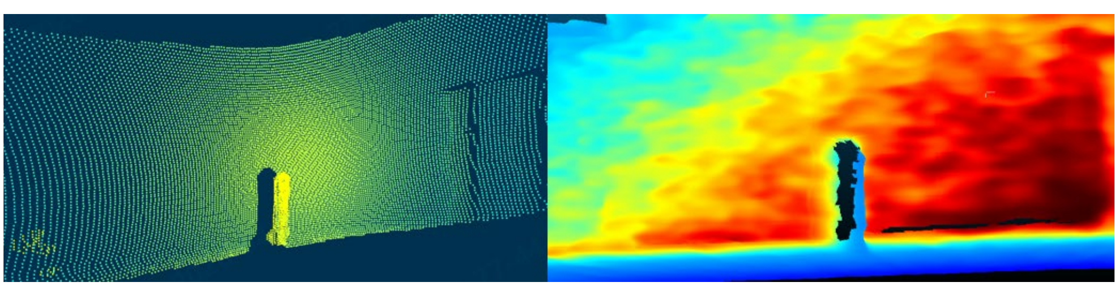
The S11(the left) captures a complete and clear depth image with well-defined edges separating the board from the wall.

The D435(the right) shows significant blending between the board and the wall, resulting in poor edge definition and unclear object separation.

Test 2 - Reflective column and surrounding environment



Reflective column and surrounding environment

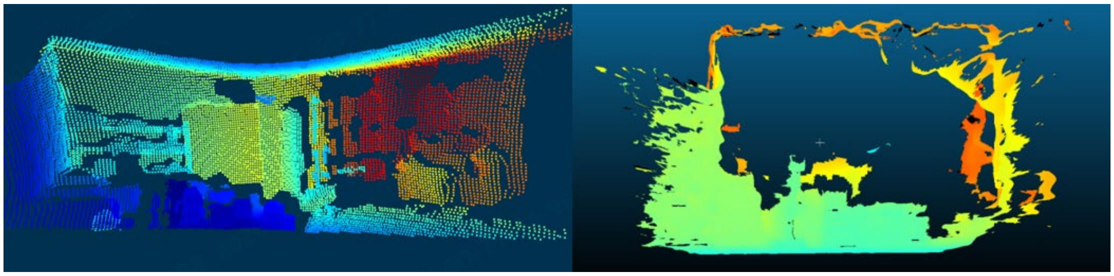


The S11(the left) produces a complete depth image with no missing or dispersed data at the column edges.

The D435(the right) shows minor edge loss with small missing portions around the reflective surface.

Test 3 - Indoor multiple objects

Indoor multiple objects with significant depth variation and stacking



The S11(the left) produces a clear point cloud with well-retained details throughout the scene.

The D435(the right) shows substantial point cloud loss and blank areas in the most complex regions where objects overlap and stack.

Appendix E: Use Cases

1. Autonomous Mobile Robotics (AMR)

Products: S10 / S11

Key advantages leveraged:

- Excellent detection of black and highly reflective obstacles
- Minimal impact from ambient light (indoor/outdoor operation)
- Wide FOV for enhanced scene coverage
- Ethernet interface for reliable industrial communication

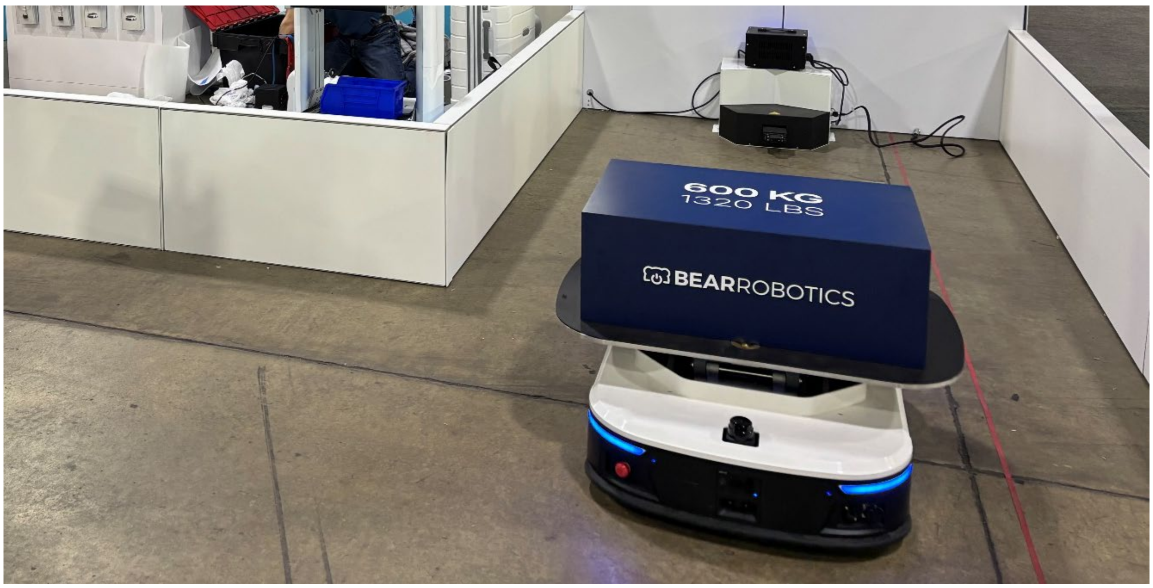
Applications:

- Humanoid robot chassis obstacle avoidance
- AGV forklift obstacle avoidance
- AMR (Autonomous Mobile Robot) chassis obstacle avoidance

Status: Shipping in volume to multiple well-known manufacturers and deployed in customer applications.



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BEARROBOTICS


2. Unmanned Aerial Vehicle (UAV)

Products: S10 Ultra MIPI module

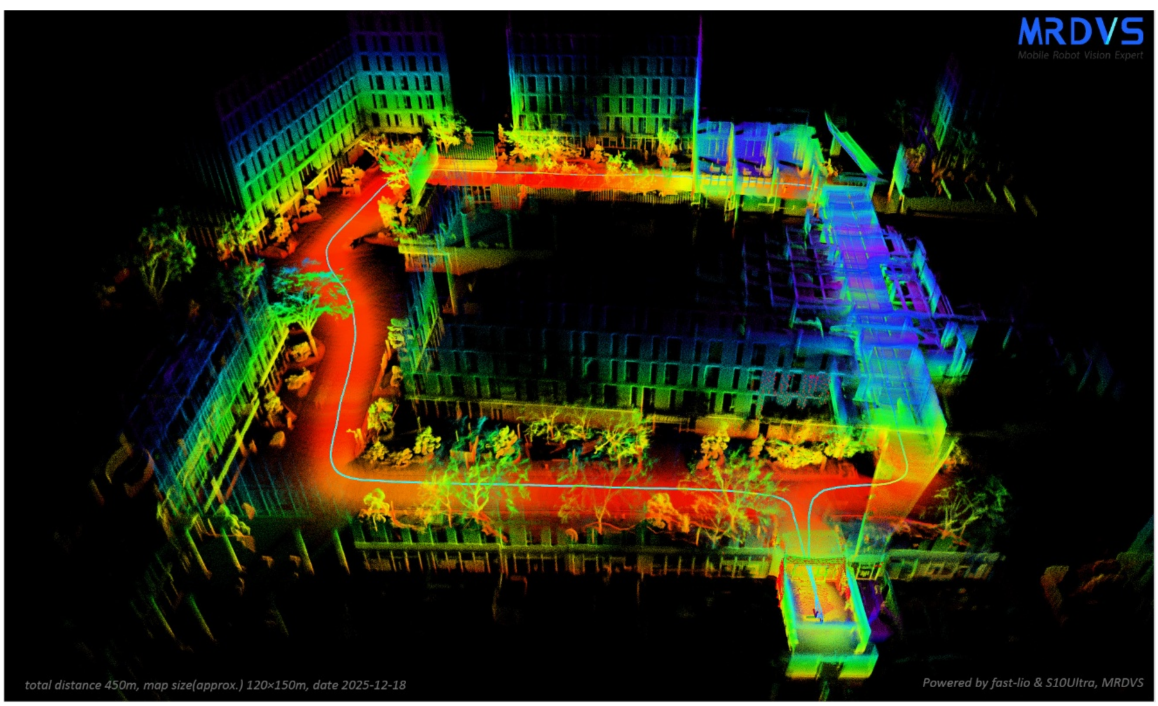
Key advantages leveraged:

- Lightweight and compact MIPI interface for drone integration
- Excellent detection of black and highly reflective obstacles
- Minimal impact from ambient light (outdoor operation)
- Wide FOV for enhanced scene coverage
- Long detection range for aerial applications

Applications:

- UAV SLAM & obstacle avoidance
- Autonomous flight path planning
- Low-altitude terrain following

Status: Joint development completed over 3 months; shipping to three leading UAV customers with production deliveries ongoing.



3. Commercial Cleaning Robot

Products: S11

Key advantages leveraged:

- Small near-field blind zone for close-range obstacle detection
- Ultra-wide FOV (one S11 replaces two sensors with smaller FOV)
- Minimal impact from ambient light, including direct sunlight and floor-to-ceiling windows
- Consistent full-range accuracy
- Edge following capability for wall and corner cleaning

Applications:

- Commercial floor cleaning robot obstacle avoidance
- Edge following and boundary detection

Status: Volume deliveries have commenced in alignment with two leading global cleaning robot manufacturers' new products launch.

4. Embodied Quadruped Robot

Products: S11

Key advantages leveraged:

- Ultra-wide FOV for comprehensive surrounding perception
- Stable detection of various obstacle types (black, reflective, textureless)
- Minimal impact from ambient light, enabling reliable indoor/outdoor operation

Applications:

- Quadruped robot obstacle avoidance
- Stair climbing and terrain perception
- Indoor/outdoor exploration

Status: Small-batch deliveries and validation are ongoing with one leading embodied quadruped robot manufacturer.

5. Robotic Lawn Mower

Products: S10 Ultra / S10 Ultra MIPI

Key advantages leveraged:

- 42m detection range for large-area mapping
- Outdoor ready - stable under direct sunlight
- 80° vertical FOV for better terrain and surrounding perception
- RGB vision fusion - supports FAST-LIVO and semantic recognition
- Built-in IMU (200Hz) for robust SLAM

Applications:

- Large-area lawn mapping and navigation
- Outdoor SLAM and semantic obstacle recognition
- Terrain perception (slopes, curbs, low obstacles)

Status: Completed joint testing (black-box & white-box) with a major manufacturer; volume shipments have commenced.

6. Outdoor Smart Wheelchair / Golf Cart

Products: S10 / S11

Key advantages leveraged:

- Outdoor ready - stable under direct sunlight
- Small near-field blind zone for close-range safety
- Wide FOV for comprehensive scene coverage
- Stable detection of black, reflective, and textureless obstacles

Applications:

- Smart wheelchair obstacle avoidance
- Golf cart collision prevention

Status: Joint testing and validation ongoing with multiple manufacturers with positive results. Small-batch deliveries have commenced with one manufacturer.

7. Outdoor Last-Mile Delivery Robot

Products: S10

Key advantages leveraged:

- Outdoor ready - stable under direct sunlight and varying weather
- Small near-field blind zone for low-speed safety
- Wide FOV for comprehensive scene coverage
- Stable detection of black, reflective, and textureless obstacles

Applications:

- Last-mile delivery robot obstacle detection
- Sidewalk and curb perception

Status: Joint testing and validation ongoing with multiple leading manufacturers with positive results. Small-batch deliveries have commenced with one manufacturer.

8. Passenger Flow Counting & Turnstile Anti-Ticket Evasion Detection

Products: S10 / S11

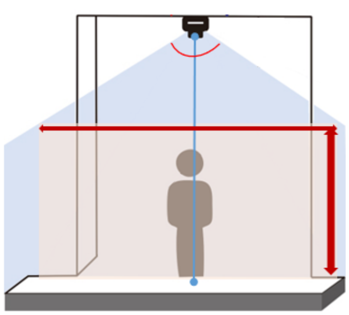
Key advantages leveraged:

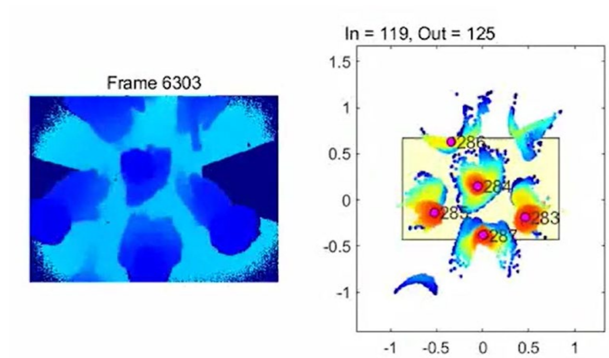
- Wide FOV covers multiple lanes with one sensor
- Minimal impact from ambient light (indoor/outdoor entrances)
- Reliable detection of dark hair
- Small near-field blind zone for close-range detection

Applications:

- Passenger flow counting
- Turnstile tailgating / anti-ticket evasion detection
- People counting for retail and public facilities

Status: Integrated by multiple customers with customer-developed algorithms. Volume deliveries completed to multiple customers.





9. Large Parcel Volumetric Measurement

Products: S10 (4 cameras, with MRDVS stitching & measurement algorithm)

Key advantages leveraged:

- Fast acquisition & low latency for real-time dimensioning
- Accurate black object detection
- ±3 cm per dimension accuracy
- Wide FOV
- Low multi-camera interference
- High cost-effectiveness

Applications:

- DWS system volume measurement
- Logistics and warehouse dimensioning

Status: Volume shipments and deployments ongoing across system integrators in Spain, South America, India, and other regions.

10. Warehouse Slot Occupancy Detection

The Challenge

In many AGV-equipped warehouses, manual stacking still exists, particularly in dynamic slotting areas (also known as "on-the-fly" slotting zones) or AGV-manual handover stations, preventing the WMS from knowing real-time slot occupancy, which can result in:

- Reduced operational efficiency
- Collisions between AGVs, goods, or equipment
- Potential safety risks to personnel and assets

Limitations of Other Sensors

Single-point LiDAR - Only one laser point per measurement; may miss gaps between cartons or pallets, leading to false occupancy detection.

RGB camera - Deep learning models may fail on objects outside the training set; no height information for stacking tasks.

MRDVS Solution

MRDVS uses the self-developed S series RGB-D camera to provide both 3D geometry and color information, enabling the system to automatically detect presence of goods, placement compliance, and abnormal occupancy. A complete hardware + software solution is provided, along with professional model training and deployment support.

Products: S10 Pro (customized, with on-camera compute power)

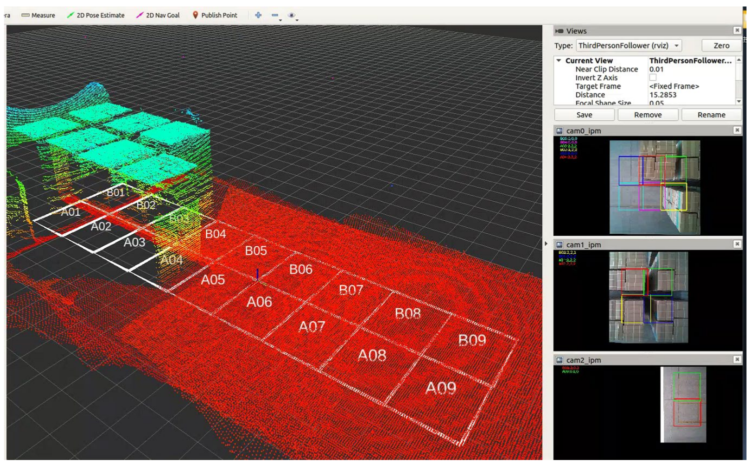
Key advantages leveraged:

- Built-in computing power - no external IPC required
- RGB-D data - 3D geometry + color information for accurate slot detection
- Flexible communication (TCP/IP, UDP, HTTP) with JSON data output

- Easy deployment with on-camera algorithms

Applications:

- Warehouse slot occupancy detection
- Automated inbound/outbound inventory control
- Abnormal occupancy and misplaced load detection
- Pallet presence verification for AGV task dispatch



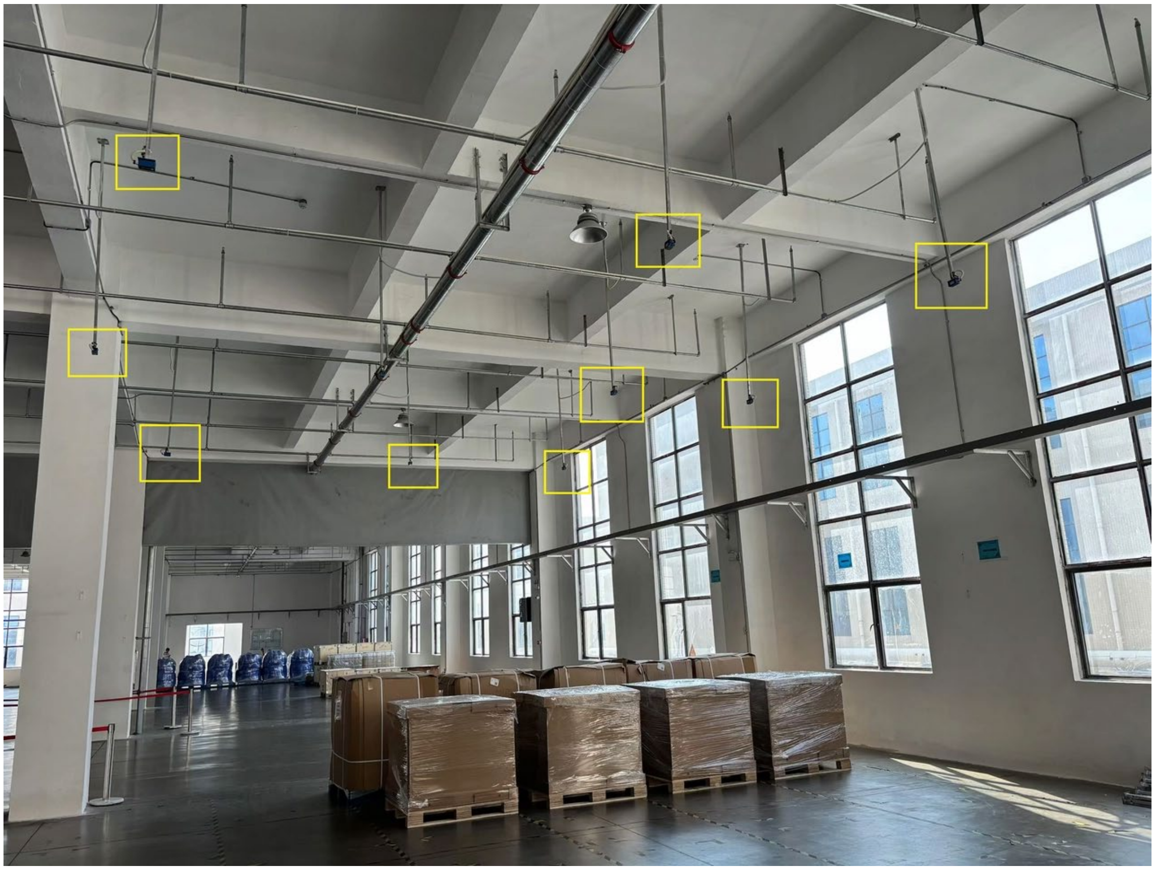
Workflow:

The upper-level control system sends a task request, triggering the camera to capture images and determine the status of the designated warehouse slots. The occupancy result is then reported to the upper system via JSON, enabling intelligent inbound/outbound management.

Communication protocols: TCP, UDP, HTTP

Installation recommendation: Mount the camera on a column or ceiling, directly above the target slot

Status: The solution has been deployed in dozens of warehouse sites, with over several hundred sensors installed.



11. Safety Protection - Personnel & Asset Collision Prevention

Products: S10 / S10 Pro

Key advantages leveraged:

- RGB-D data enables AI-powered person-object separation - accurately distinguishes between people and equipment
- Depth-based zone protection - leverages captured depth data for precise warning, buffer, and restricted zone definition with graduated responses

Applications:

- AGV/AMR personnel safety
- Industrial vehicle collision prevention
- Restricted zone enforcement

Status: Currently in joint development and validation with several customers.