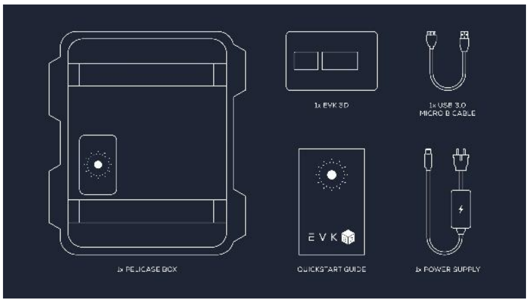
PROPHESEE
METAVISION FOR MACHINES

EVK3D



Metavision® EVK3D is your perfect entry point to Structured Light depth sensing with Event-based Vision, by the inventors of the world's most advanced neuromorphic vision systems. This platform is compatible with Metavision® SDK software Suite. This evaluation kit features at its core the revolutionary SONY IMX636 TS HD Event-based Vision sensor, realized in collaboration between SONY and PROPHESEE as well as an addressable VCSEL array designed and manufactured by LUMENTUM. Available in three different versions for short, middle and long range applications, it enables users to evaluate fast depth measurement from a camera – structured light projector pair.

Welcome to our global inventors community, we can't wait to see what frontiers you will be pushing.

REVISION HISTORY

Version 1.1

Product: EVK3D

Release date: 29/02/2024

Revision: 1.1

Description of changes: Ranges definitions

Event Based Sensor	Model		Sony IMX636TS jointly designed by Sony and Prophesee
	Resolution (H x V Pixels)		HD: 1280 x 720
	Sensor format		1 / 2.5”
	Pixel size		4.86um x 4.86um
Optics on Sensor	Reference		ACTM124IR5MP
	Manufacturer		Aico Electronics Limited
	Filter		940nm bandpass filter Center : 940nm, FWHM : 40nm
	Field of View with IMX636TS	Horizontal	94.4°
		Vertical	65.8°
		Diagonal	135.7°
Light Projector	Manufacturer		Lumentum
	Technology		VCSEL (Vertical Cavity Surface Emitting Laser)
	Wavelength		940nm
	Number of channels		8
	Number of Laser emitter per channel		16
	Diffractive optical element (DOE) pattern		3x3 non overlapping tiles
	Overall number of laser dots		1152 (= 8x16x3x3)
	Field of Illumination (FOI)		80°x 45°
	Angular resolution	Horizontal (edge)	1.7°
		Horizontal (center)	1.4°
		Vertical (edge)	2.0°
		Vertical (center)	1.3°
	Maximum electrical Power per channel	Peak	6W
		Mean	19mW
		Duty cycle	0.31%
	Laser Class		Class 1
Ranges	Minimum distance without disambiguation error	Baseline S variant	0.25m
		Baseline M variant	0.45m
		Baseline L variant	0.80m
	Maximum distance at RMSE 1.5%	Baseline S variant	0.65m
		Baseline M variant	1.0m
		Baseline L variant	2.0m
Power supply	Manufacturer		GlobTek, Inc
	Manufacturer Reference		TR9CE5000LCP-N(R6B)
	Digi-Key Part Number		1939-1237-ND

	Voltage		12V
	Maximum Power		60W
	Power Consumption	**At rest (FPGA)**	6.5W
		In operation, at maximum laser power	7.7W
Mechanical	**Casing Material**		Aluminum
	Baseline S variant		30mm
	Baseline M variant		50mm
	Baseline L variant		100mm
	Dimensions (WxHxD) S & M variants		108mm x 70mm x 72mm
	Dimensions (WxHxD) L variant		158mm x 70mm x 72mm
	Weight S & M variants		555g
	Weight L variant		707g
	Attachment		Standard tripod screw
Software	Custom Application development Solution		Prophesee Metavision® SDK (v4.4.0 onward)
	First Hands on experience		Prophesee EVK3D Explorer App
	Supported OS		Linux Ubuntu 20.04 and 22.04 Windows 10 64-bits.

CONTENTS

OVERVIEW

PROPHESEE EVK3D - SL Demo kit is an embedded 3D camera that enables evaluation of the SONY IMX636 TS HD stacked Event Based Vision sensor, co-developed with PROPHESEE in the context of Structured Light depth measurement. Combined with a modulated Vertical Cavity Self Emitting Laser (VCSEL) projector source manufactured by LUMENTUM, it can generate point clouds at unprecedented speeds.

The LUMENTUM 8 channels addressable VCSEL array emits a highly efficient 940nm infrared dot pattern onto the scene at sub-millisecond periods, combined with the high speed capabilities of the IMX636 sensor, this match allows to capture depth information in highly dynamic scenes and challenging ambient light conditions.

This platform is compatible with Metavision SDK(v4.4 onward) see here to allow users to develop their application requiring fast point clouds. In addition to this SDK, we allow users to get a first experience of streaming the demo kit with EVK3DExplorer.

The embedded Xilinx Zynq Ultrascale+ 6EG platform processes the data sent by the sensor and encodes it into a point cloud format sent to the host via a SuperSpeed USB connection.

Trigger features allow both slave and master mode to permit multiple systems to operate in the same environment and help dealing with application-level control and cross talk mitigation.

The combination of the EB sensor and the projector allows depth measurement thanks to the principle of triangulation as depicted in the Figure 1.

The main components of the EVK3D-SL are described in the Figure 2, along with external interfaces and simplified internal connections.

1. Triangulation Principle

As depicted in Figure 1, the principle of triangulation present in a variety of depth measuring techniques, is also used in the EVK3D. One laser dot projected by the illuminator will be seen at a different pixel location on the sensor depending on the depth of the object it encounters, This simple principle is illustrated in Figure 3. In our case the knowledge of mapping that allows to convert the pixel coordinate into depth for a given laser dot is obtained through calibration.

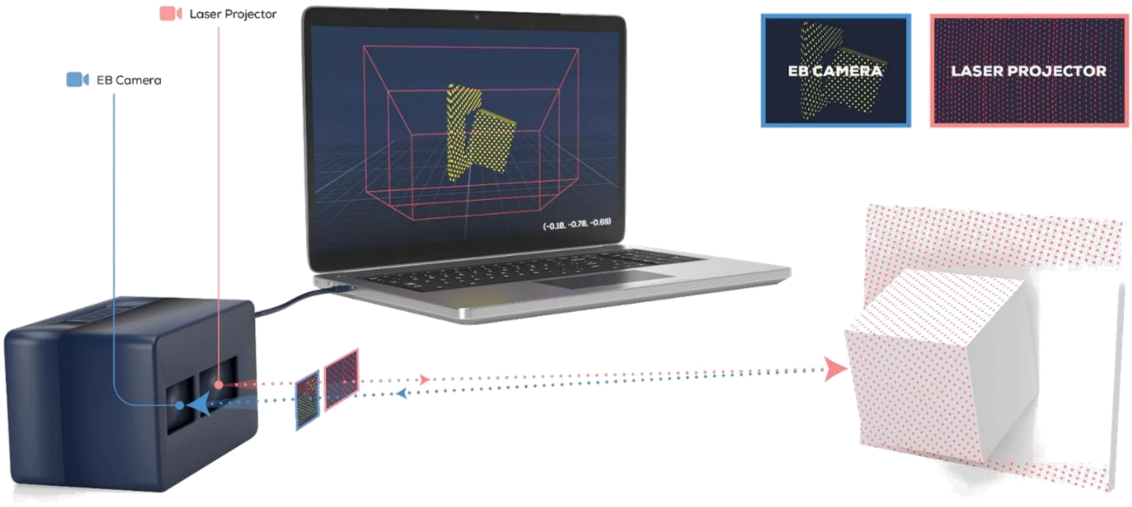


Figure 1 : EVK3D SL Triangulation Principle

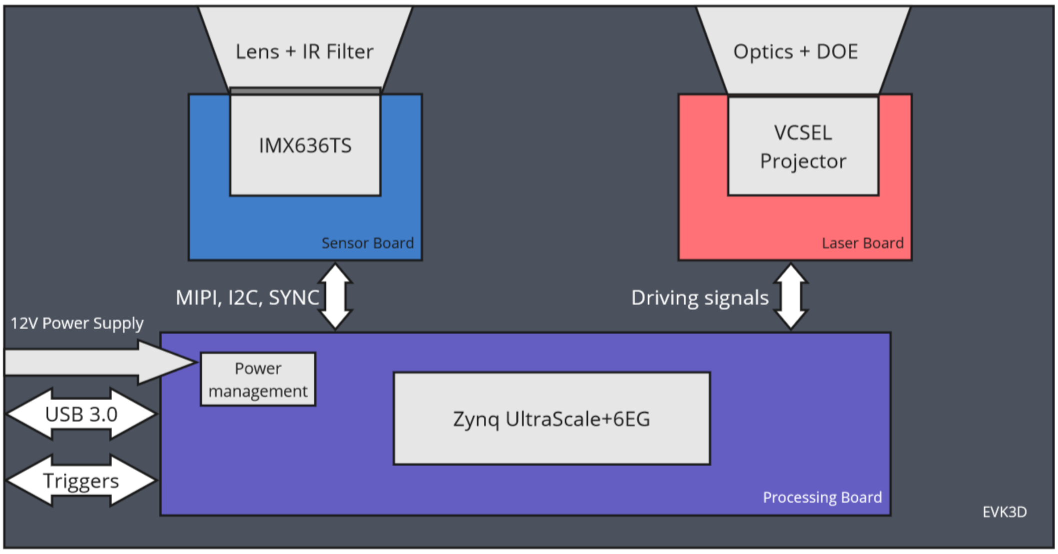


Figure 2 : EVK3D Simplified block Diagram

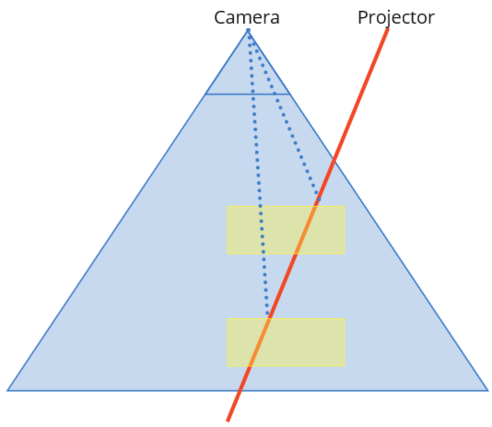


Figure 3 : Simplified view of triangulation principle: a laser dot coming from the laser hitting an object at different depths is seen at different pixels coordinates

SPECIFICATIONS

Electrical Specifications

The Main power supply (12V 60W) is provided with the kit.

		Min	Typ.	Max
Slave Mode	**Input Low Voltage TRIG_IN**			1.35V
	Input High Voltage TRIG_IN	2.8V@1.3mA	3.3V	9.0V
	Input Current TRIG_IN			10mA
Master Mode	**IOutput Low Voltage TRIG_OUT**			0.55V
	Output High Voltage TRIG_OUT	2.3V	3.3V	
	Output Current TRIG_OUT		24mA	

Mechanical specifications

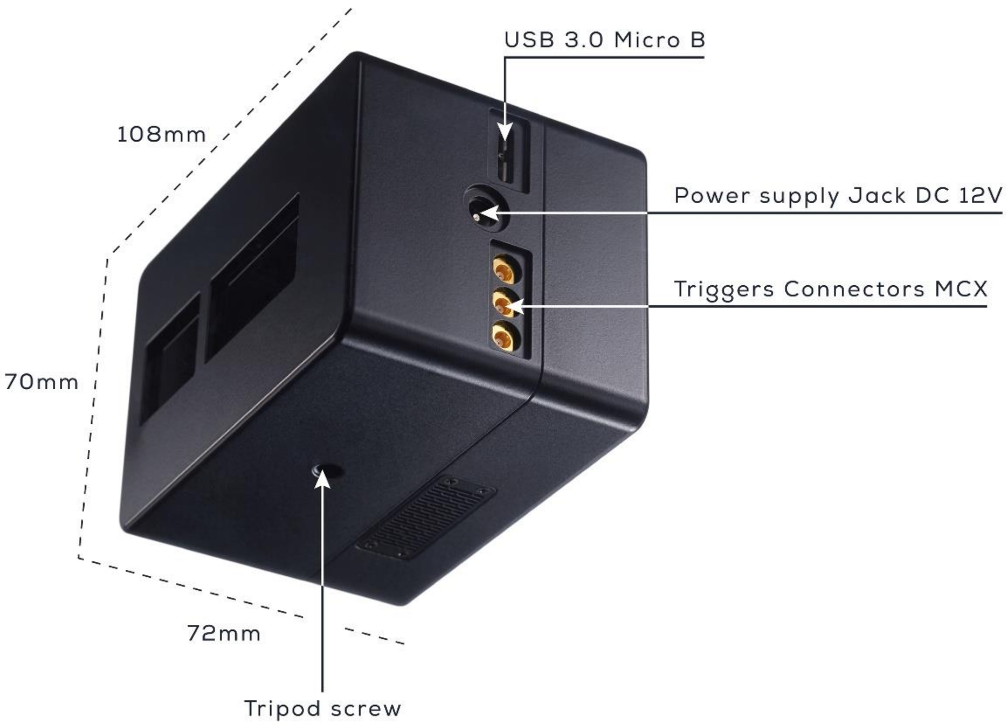


Figure 4 EVK3D Dimensions and Connection features

Prophesee EVK3D demo kit can be fixed via a tripod screw on the bottom face. All electrical interfaces are available on the lateral side. Three air vents ensure cooling of the device, it is recommended to let them unblocked. They are located on the top, bottom and back sides. In addition to air vents, an internal fan is located on the back side.

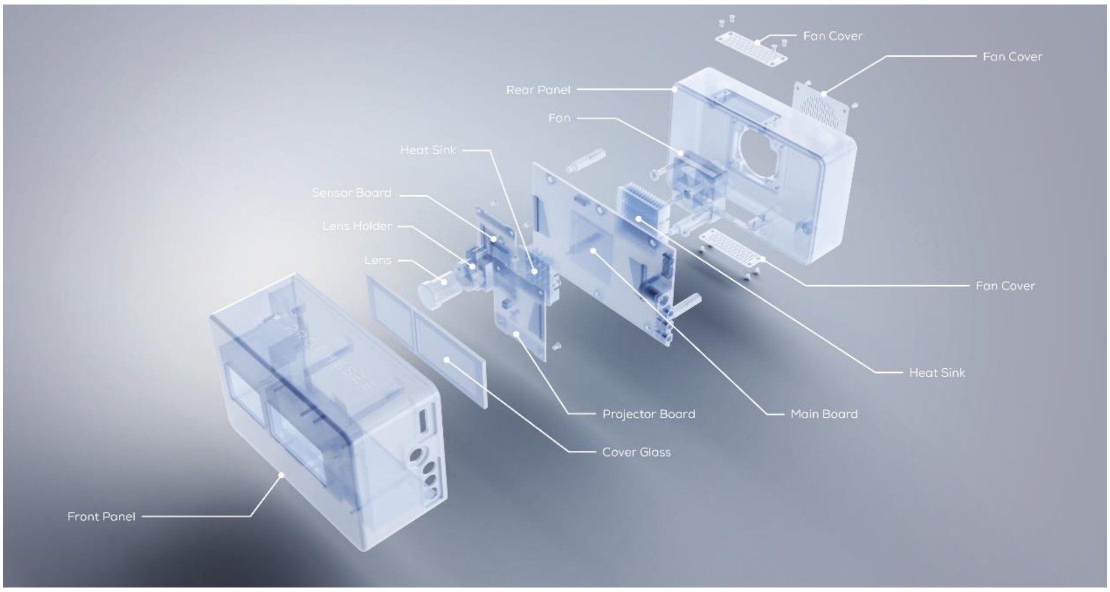


Figure 5 : Internal components of the EVK3D

REQUIREMENTS

Electrical requirements

The EVK4 is electrically powered with the 12V power supply provided.

The data transfer is handled by USB through the USB 3.0 microB connector to the host PC. The user must ensure the USB port of the host PC is USB 3.0 SuperSpeed compatible to provide the necessary communication bandwidth.

Environmental requirements

The camera has been designed to endure IEC certifications (T° / Heat / Shocks / Electrostatic discharge). The following table summarizes the certifications and operational ranges :

Environmental Specifications			
Safety/Quality standard		CE EMC 2014/30/EU	
Complied standard Emission		EN61000-6-4:2007+A1:2011	
Immunity:		EN61000-6-2:2019	
RoHS		RoHS 2011/65/EU (EU)2015/863	
Eye-Safety		Class 1 Laser Certification : IEC 60825-1:2014; EN 60825-1:2014	
Durability	Vibration	Acceleration	: $98m/s^2$ (10G)
		Frequency	: 20 ~ 200Hz
		Direction	: X, Y, and Z 3 directions
		Testing time	: 120min for each direction
	Shock	No malfunction with $980m/s^2$(100)G for ±X, ±Y, and ±Z 6 directions without packaging.	
Operational Conditions	Temperature	0 ～ +40°C	
	Humidity	20 ~ 80%RH with no condensation.	
Storage Conditions Storage	Temperature	-25 ～ +60°C	
	Humidity	20 ~ 80%RH with no condensation.	

Figure 6 EVK3D is a certified Class 1 Laser Product

Software installation requirements:

- For Linux, Administrator rights (sudo account)
- Internet access (to install dependencies)

The EVK3D can be operated via Prophesee Metavision® SDK. The software can be downloaded following the instructions at [https://www.prophesee.ai/metavision-intelligence-sdk-download/.](https://www.prophesee.ai/metavision-intelligence-sdk-download/)

Active Illumination system and Crosstalk.

The EVK3D is an active illumination system. It operates under the assumption that the only light source present in the 940nm wavelength is the VCSEL projector present on the EVK3D. Another light source emitting in this domain could interfer with a correct operation of the EVK3D. We recommend not exposing the device to another light source in this spectrum. If for functional reasons such constraint is impossible, there is a possibility to synchronize several devices to avoid interference.

ACTIVE LIGHTING SYSTEM

Projector spatial structure

The Lumentum projector used in the EVK3D is comprised of 8 channels driven separately, each channel covers a different portion of the field of illumination.

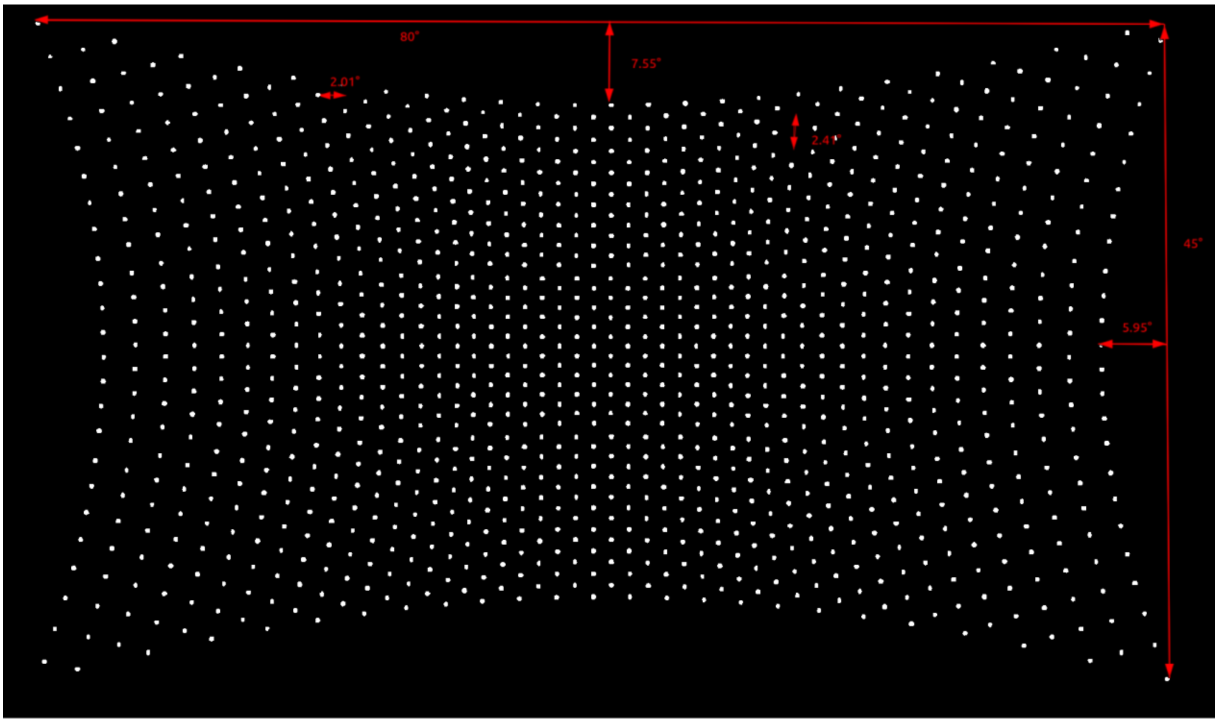


Figure 7 : Full Dot pattern : 1152 dots distributed on 48 columns of 24 dots. Projection on a flat plane.

The channels are distributed into 3 horizontal repetitions (or doublets) of 2 columns. One channel, when turned on, lights up 3 x 2 x 44 = 144 dots.

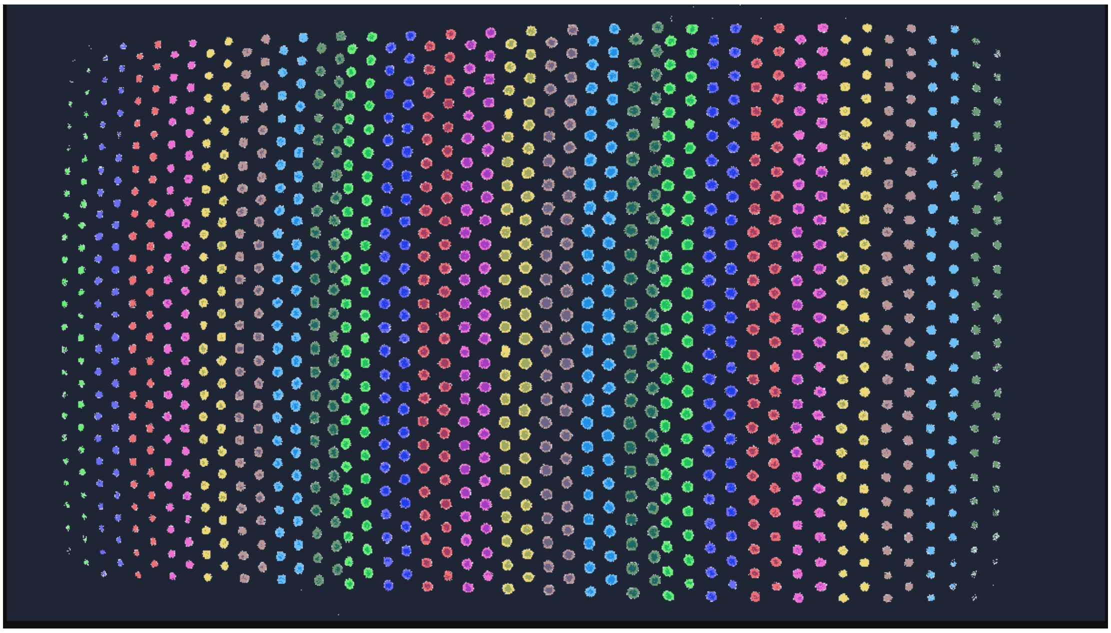


Figure 8 Pattern hitting a flat plane, seen by the IMX636 sensor for an EVK3D 30mm. Each color corresponds to a different projector channel.

Projector temporal modulation

Each Channel is modulated in time, once a channel modulation is transmitted, the next channel transmission begins and so on. A full point cloud is generated after all the 8 channels have cycled.

The frequency f_{PC} which a point cloud is generated (in Master Mode) is directly linked to the channel period T_c parameter:

$$f_{PC} = \frac{1}{2 * 8 * T_c}$$

The user can choose the point cloud frequency (indirectly the channel period) as well as the peak power of each channel.

It was chosen to maintain a constant channel duty cycle when the point cloud frequency changes. This allows to have a constant mean power consumption. In other words, when the point cloud is faster, the laser will be on less time, thus less energy will be sent for each channel at iso-peak power. It results in an increased probability for a pixel to detect the laser with slower point clouds.

RANGES AND PRECISION

X and Y density

Along the X (horizontal) and Y (vertical) directions, the resolution is dictated by the laser points pattern density : the 80° wide horizontal field of illumination is actually 68.1° wide in the center due to distortion. This field of illumination is covered by 48 columns thus divided into 47 portions of 1.44°, on the edges (top and bottom part of the FOI) this number becomes 1.7°. The same reasoning gives the Y (vertical) numbers provided in the main characteristics table.

Maximum Visible Range.

In order to generate a point in the 3D point cloud, the laser light hitting the surface on the scene must be detected by the camera.

The main physical parameters involved in the power budget considerations are :

- The laser power and modulation
- The distance to the object
- The object reflectance.
- The ambient light level

The higher the power, the closer the distance, the more reflective the target object is and the lower the ambient light level, the better will be the event detection. When the combination of all these factors becomes too unfavorable, the event detection drops and eventually the sensor does not see the laser anymore.

With the EVK3D, we set the laser power to its maximum value, and measure the distance at which the laser completely disappears. We obtain from experimental measurements, the graphs on Figure 9 and Figure 10. The reason why the point cloud rate has an impact on the range is because it was chosen that the duty cycle remains constant. With a constant duty cycle, reducing the point cloud rate increases the period, thus the ON time of the laser and in turn, the energy in each pulse. All the working domain is contained within approximately 1% of the AEL (Admissible Emission Level) for class 1 laser device according to the EN 60825-1:2014 norm.

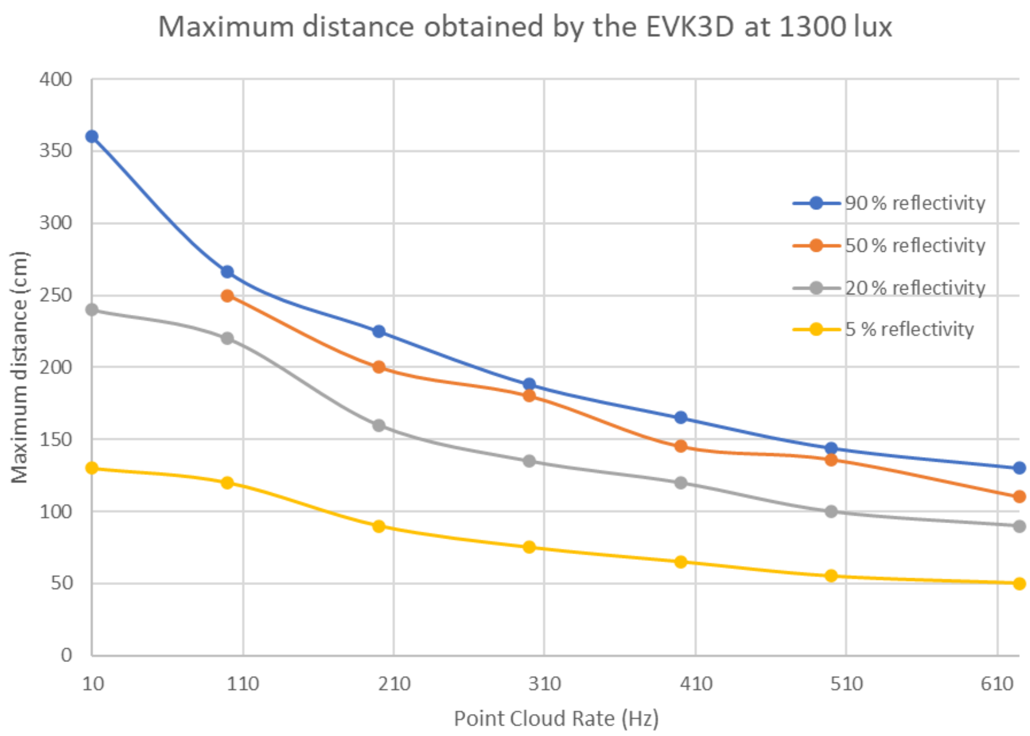


Figure 9 : Maximum visible distances at 1.3klux as a function of the point cloud rate for multiple reflectance objects.

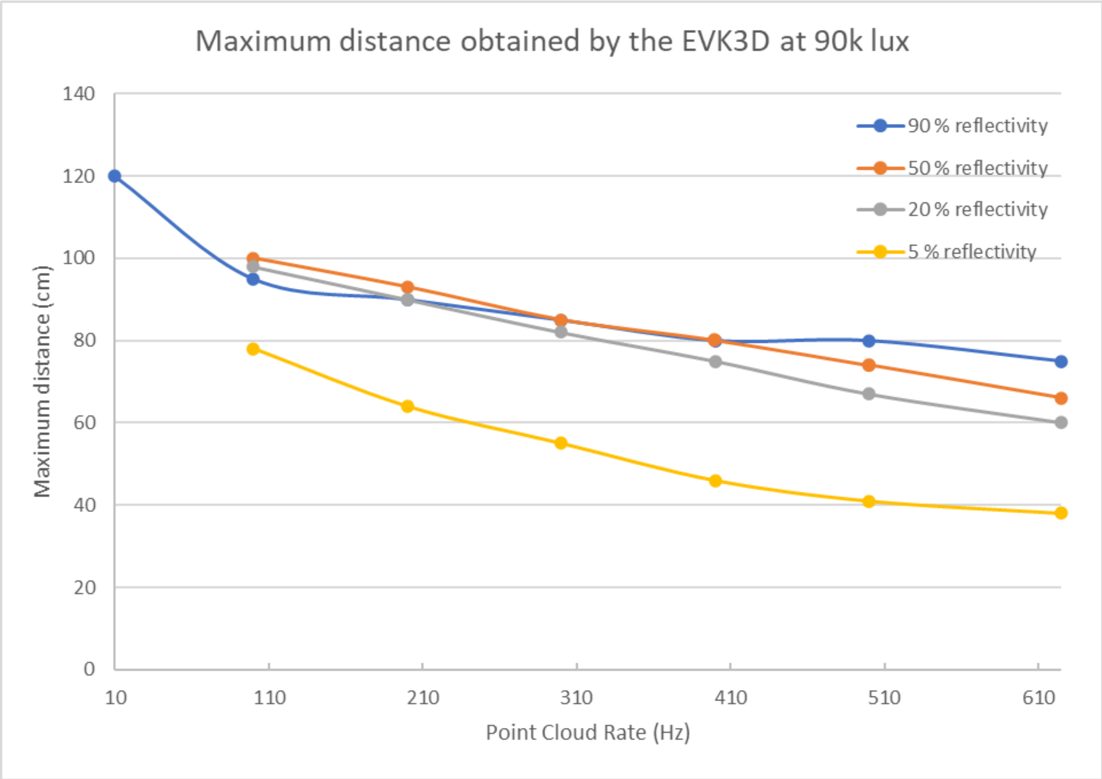


Figure 10: Maximum visible distances at 90klux as a function of the point cloud rate for multiple reflectance objects.

Minimum Distance.

There are several physical phenomena that determine a minimum distance:

- The horizontal size of the FOV/FOI intersection. It grows linearly from zero at the closest intersection point and depends on the baseline variant. It is equal to 18mm, 30mm and 60mm respectively for short, medium and long-range variants.
- The minimum coarse disambiguation distance (detailed below) gives theoretical minimum distance of approximately 60mm, 100mm and 200mm respectively for each baseline value.

- The minimum fine disambiguation distance (detailed below) gives experimental minimum distance of approximately 25cm, 45cm and 80cm. This constraint is the most limiting one, this is the distance we report.

The notion of disambiguation corresponds to the ability to distinguish each column of laser points of a given channel. For each channel there are three groups of two laser columns. Separating the three groups is considered as the coarse part. Within a group of two columns separating left or right is considered the fine part of the disambiguation. The Figure 11 illustrates the full disambiguation principle.

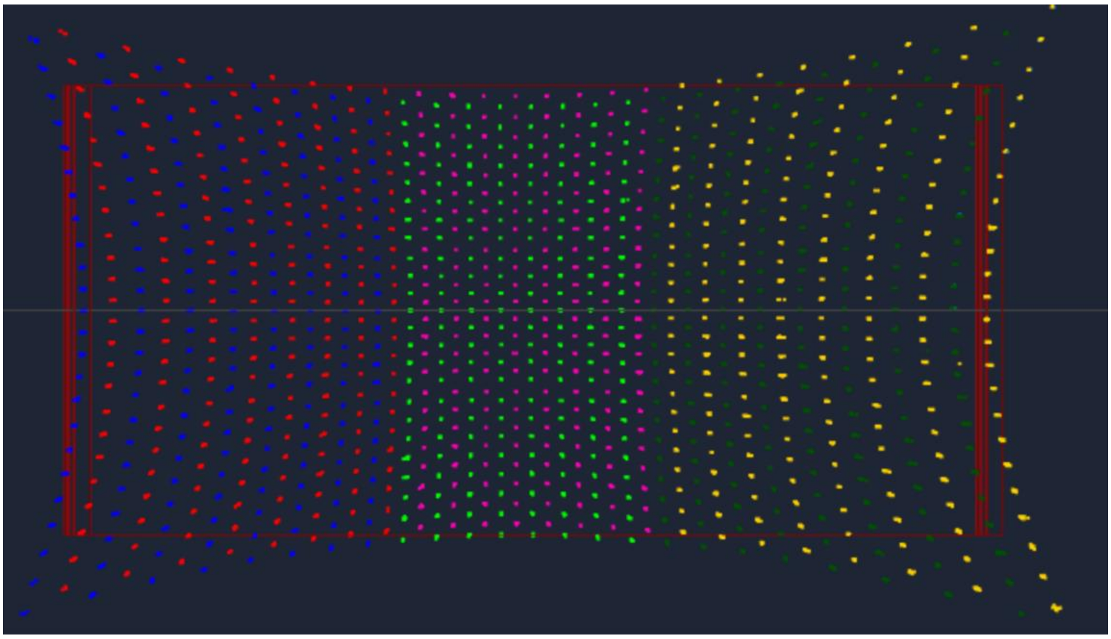


*Figure 11: Illustration of complete disambiguation: each color codes for a column ID in [0,5]. The ID is equal to 2 * coarse_id + fine_id*

The coarse disambiguation is based on the fitted position of lines at infinity, this is explained in Figure 12. The tangent of the repetition angle is equal to the baseline divided by the minimum distance, this is how we obtain the minimum distance for coarse disambiguation theoretical values.

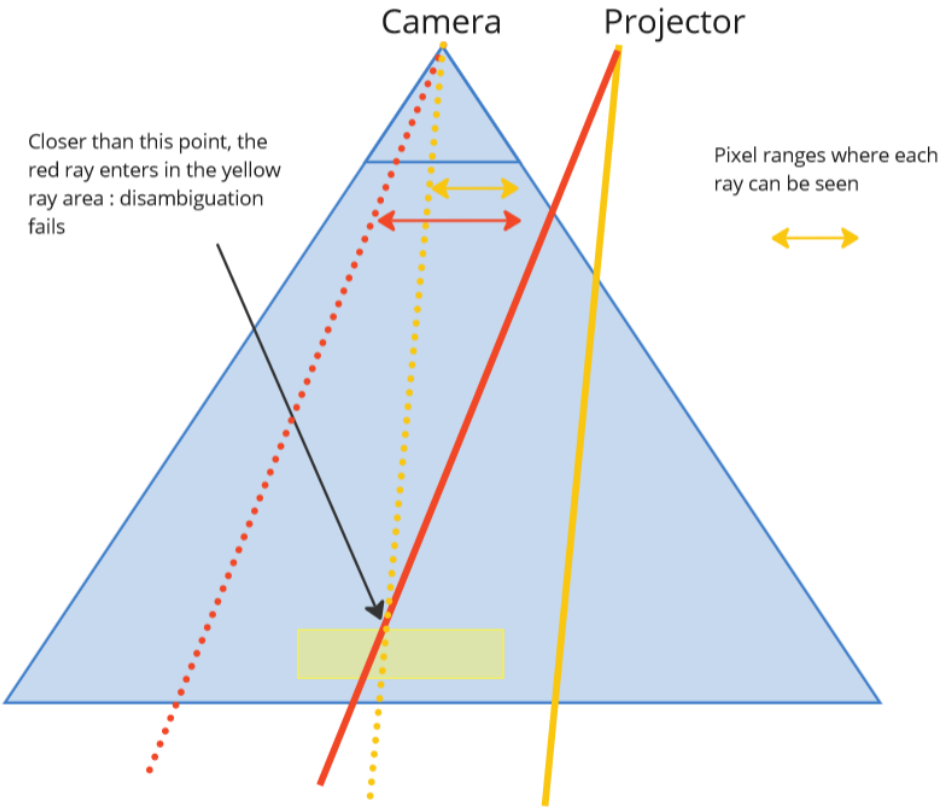


Figure 12 Coarse disambiguation illustration: Red and yellow rays correspond to different dots of the same channel. Their parallel counter parts in dotted lines represent the direction from which the camera would see the ray at infinity (disparity = 0). The arrows ranges represent the pixel areas where it is physically possible for the camera to see either of the two laser rays. When moving closer starting at infinity, there is a distance where the red ray enters the yellow range. The object is placed at this position, it is the minimum distance for coarse disambiguation.

The fine disambiguation is limited by the current algorithm implemented in the FPGA pipeline, when getting too close, an increasing number of laser dots will be wrongly disambiguated (a left point will be considered right or vice versa). The Figure 13, Figure 14 and Figure 15 give the plots of the amount of correctly fine-disambiguated points as measured from experiment. It can be seen that the minimum distance reported is the one for which the first point starts to be wrongly disambiguated, in other words, it does not mean that the entire 3D point cloud is wrong, it means it is the distance point closer from which there starts to be a degradation due to disambiguation errors

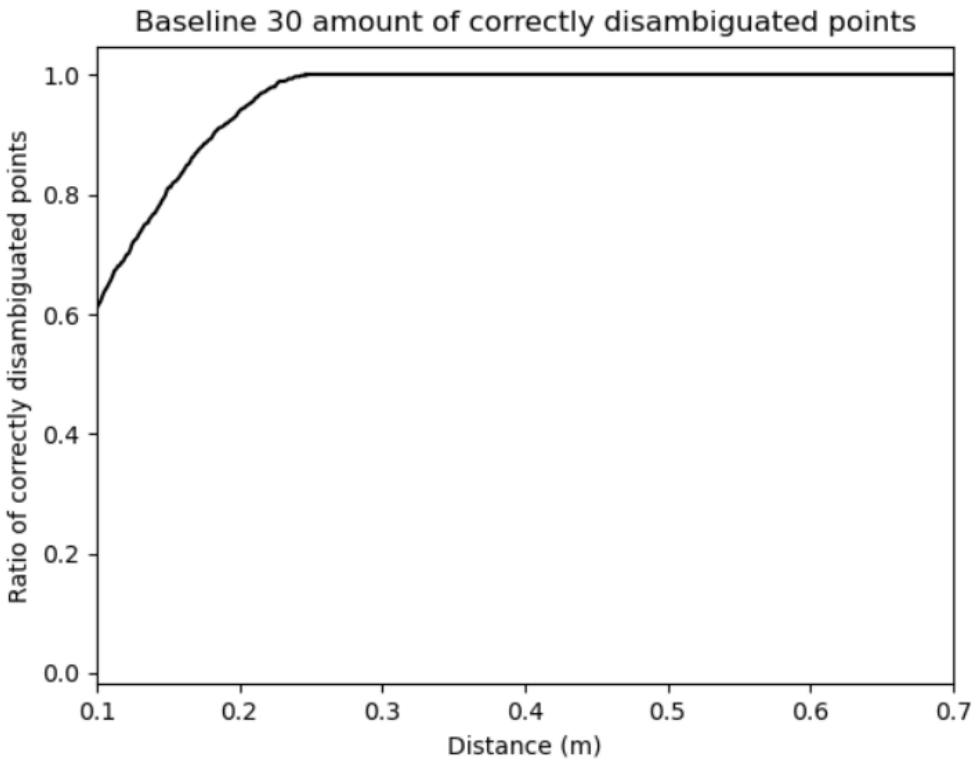


Figure 13 : Amount of correctly fine-disambiguated points as a function of the distance for short range variant.

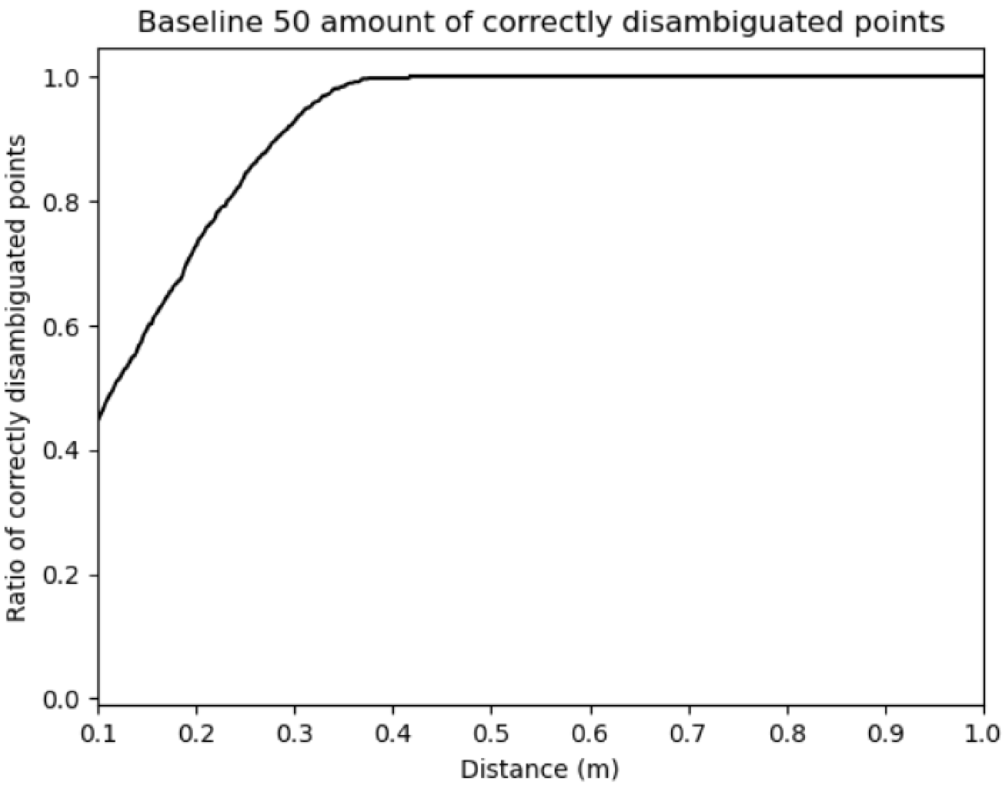


Figure 14 : Amount of correctly fine-disambiguated points as a function of the distance for middle range variant.

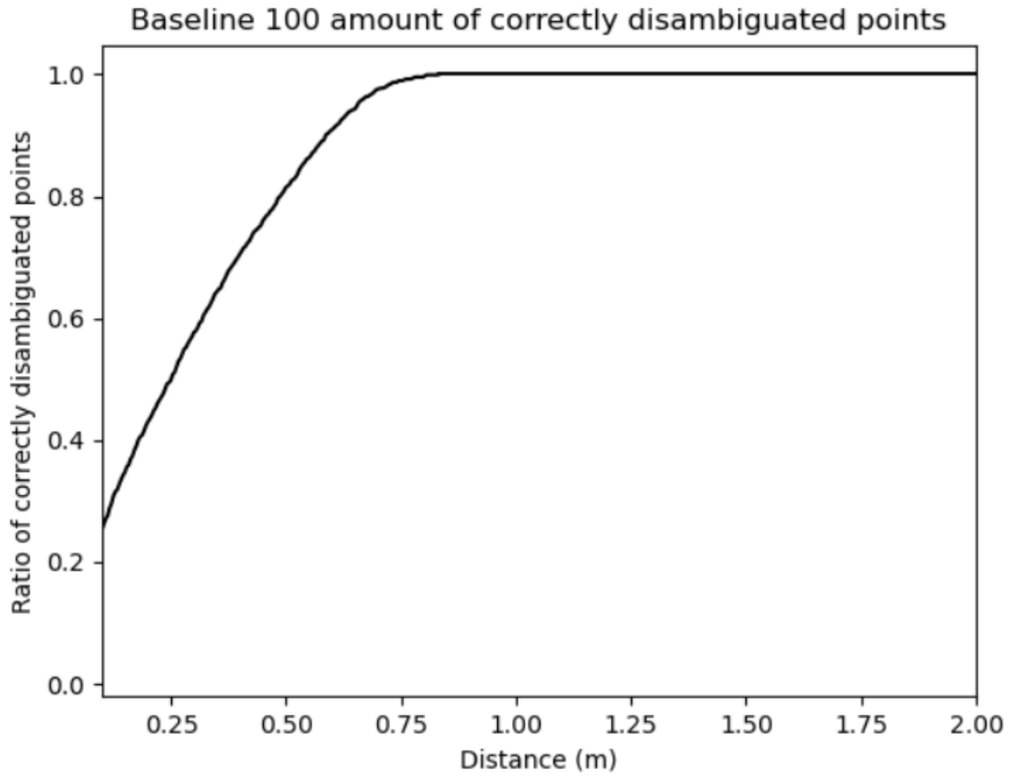


Figure 15 : Amount of correctly fine-disambiguated points as a function of the distance for long range variant.

INTERFACES

USB interface

The EVK3D is equipped with a USB Type-3.0 - microB connector. It is compliant with USB 3.0 specification 1.0.

Synchronization signals

The EVK3D provides dedicated interfaces for multi-sensor synchronization with compatible hardware. Two synchronization modes are available to synchronize the EVK3D with other devices.

Master Mode

In master mode, the EVK3D generates point clouds according to the settings it is configured in and outputs a pulse on the TRIG_OUT connector at the beginning of each new point cloud. The width of the pulse can be set.

Slave Mode

In Slave Mode, the EVK3D will generate a new point cloud when it receives a pulse on the TRIG_IN input. As soon as a pulse is received, the light pattern starts.

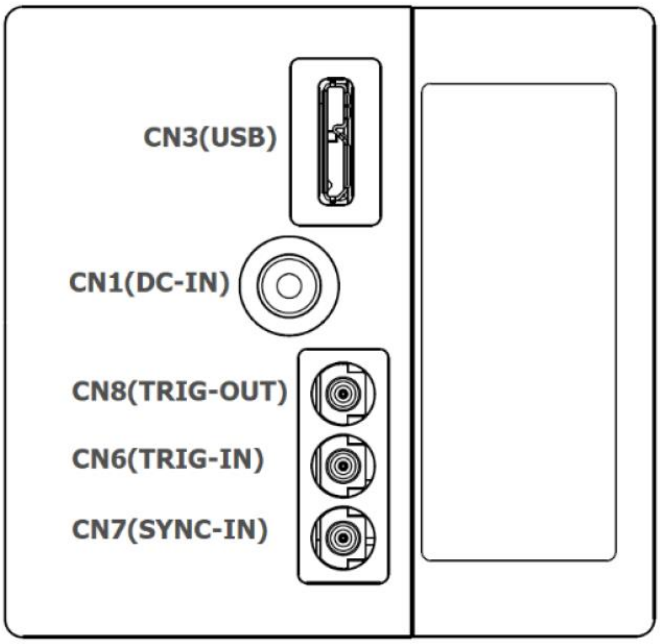


Figure 16 : External Connectors Pin Assignment

SETUP

Connection procedure

First connect potential trigger connectors in case the EVK3D is used in a Synchronized mode (Slave or Master).

Then connect the power supply provided.

Finally connect the USB cable to the host. We strongly recommend connecting the A side first, then the microB side. This will reduce risks of enumerating the device in USB2.0 instead of USB3.0.

Software Setup

There are two solutions to have a first experience with the EVK3D Demo kit : with the EVK3D Explorer App available on the Knowledge Center : https://support.prophesee.ai/portal/en/kb/articles/evk3d-assets. Or with the *metavision_evk3d_viewer* sample available in Metavision SDK (v4.4.0 onward) described here : https://docs.prophesee.ai/stable/samples/modules/driver/evk3d_viewer.html

EVK3D Explorer

After having downloaded the zip, unzip it, open a terminal in its location and execute the following command:

On Linux (Ubuntu 20 or 22):

```
$./launch.sh -b resources/sl.bias –calib path/to/calibration_file.json
```

On Windows (with Power Shell):

```
> .\launch.bat -b resources\sl.bias --calib path\to\calibration_file.json
```

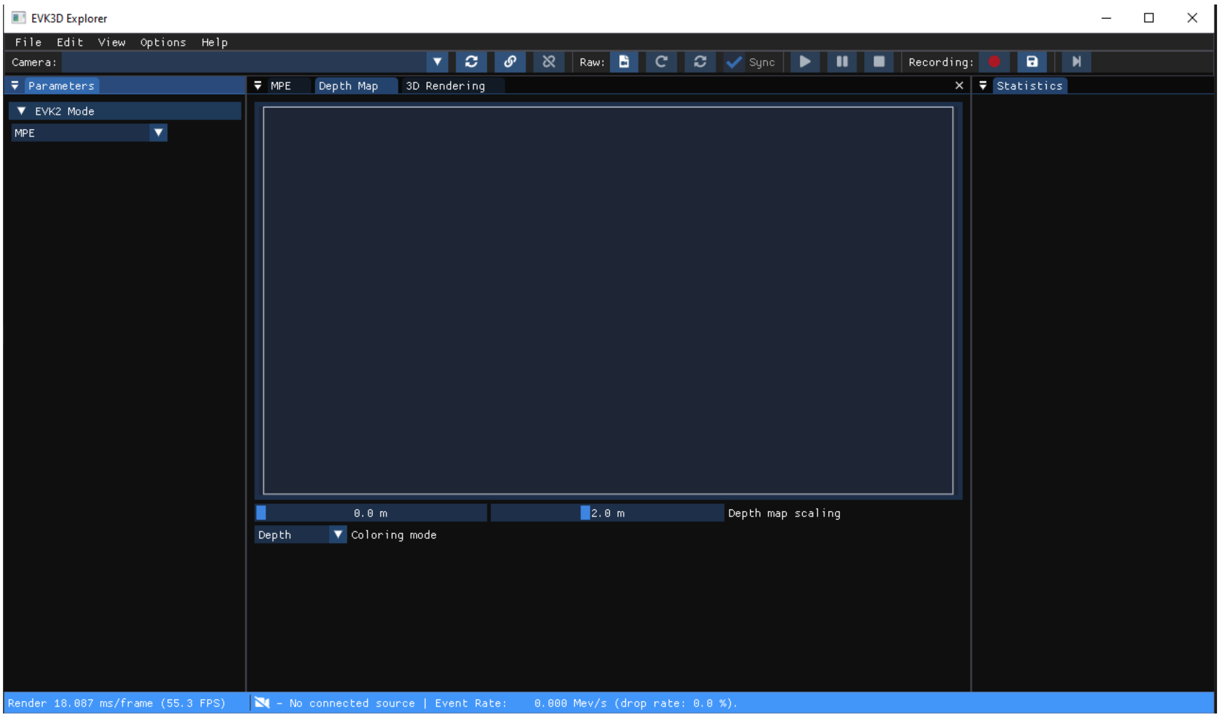


Figure 17 EVK3D Explorer Appearance at start

In order to enable connection with the plugged EVK3D, check that the camera is detected, it is when the full device name appears in the Camera name bar.

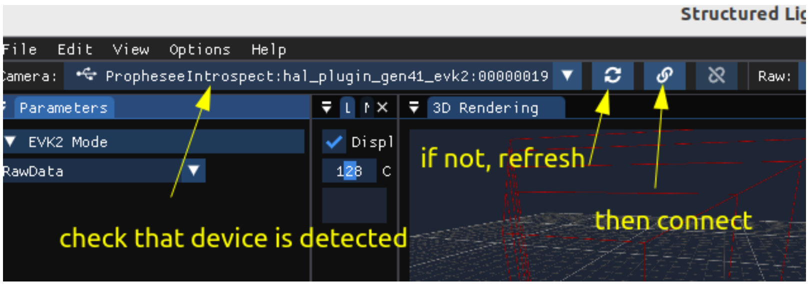


Figure 18 Connection procedure

Then select **MTRPixel** mode : 

And finally press the “**Open Selected Source**”  button.

After a few seconds (time needed to transfer calibration data to the camera), focus will be back to the main window.
Then in the **Projector Control** widget, you can set two parameters:

- **Point cloud rate (Hz)**
- **Laser Power**

Once the parameters are set, you can **Enable Projection.**
The laser power is expressed in an arbitrary unit which represents the portion of maximum peak power the laser drivers should deliver. When set to 1023, the drivers will operate at their maximum peak power.
It is allowed to change the Laser Power and Point cloud rate dynamically while projecting.
As soon as the **Enable Projection** checkbox is ticked, a Depth Map appears in the **Depth Map** tab and a Point Cloud appears in the **3D Rendering** tab.

Figure 19 shows an example of a point cloud rendered in the 3D view and Figure 20 shows a similar scene in the depth map view.

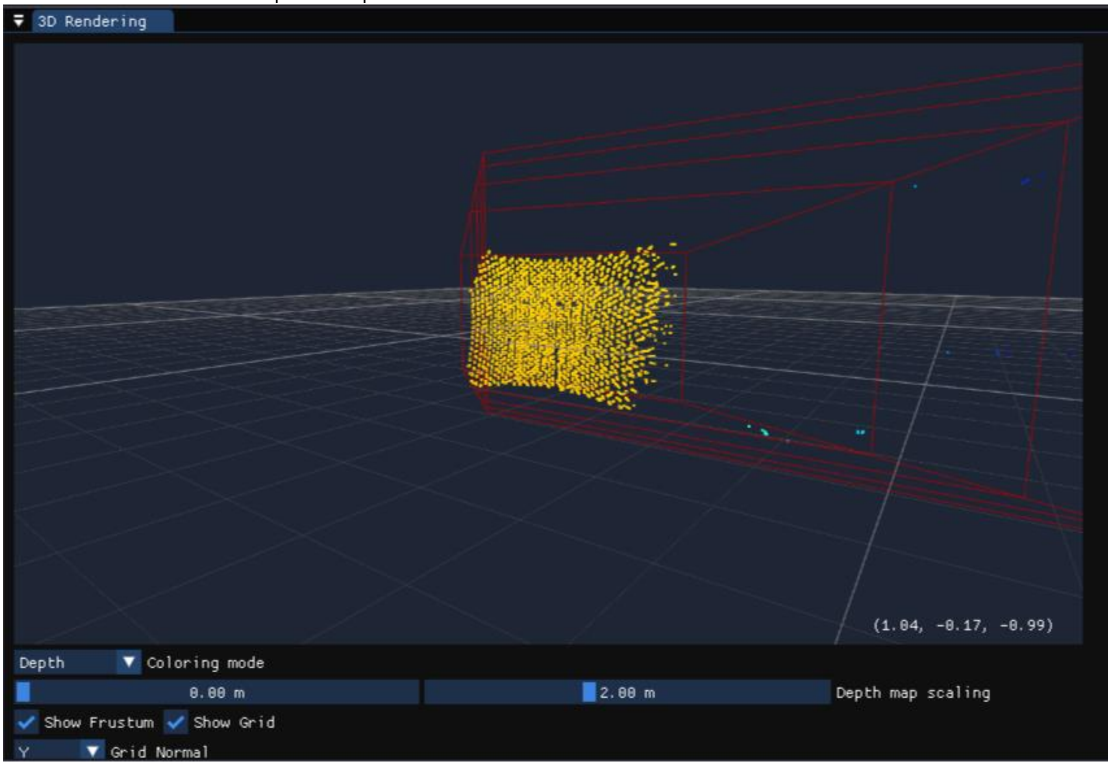


Figure 19 3D Rendering view example: a plane in front of the EVK3D

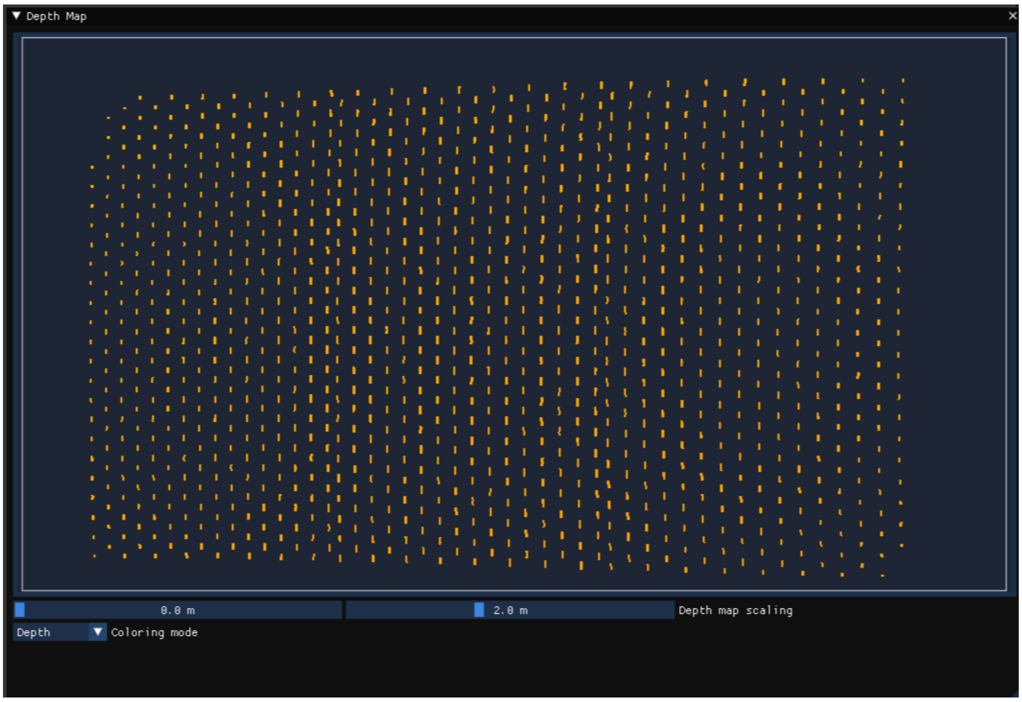


Figure 20 Depth Map rendering example: a plane in front of the EVK3D

Metavision SDK

The Metavision SDK (from v4.4.0) supports plugins for the EVK3D demo kit. It is ideal to develop a custom application using fast point clouds.

The sample evk3_viewer_sample provides a minimal example of a

CALIBRATION

Each EVK3D is calibrated at manufacturing. The calibration file must be retrieved by the user. Details on how to retrieve the calibration file are provided here: https://support.prophesee.ai/portal/en/kb/articles/evk3d-assets

LINKS AND RELATED INFORMATION

Knowledge Center space dedicated to EVK3D Demo kit : https://support.prophesee.ai/portal/en/kb/prophesee-1/metavision-sensing/evaluation-kits/evk3d

Metavision® SDK can be downloaded following the instructions at https://www.prophesee.ai/metavision-intelligence-sdk-download/ Metavision® documentation is available online at https://docs.prophesee.ai/stable/index.html

Product information and support is available at https://support.prophesee.ai/

Prophesee Development Center is community page where Engineers and Researchers can share EB projects, resources, news update and more: https://www.prophesee.ai/development-center/

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