MOB-THANOSV3 demonstration system

Introduction

This document describes the MOB-THANOSV3 demonstration system and serves as an operational user manual.

The MOB-THANOSV3 is a demonstration system from STMicroelectronics based on an iToF (indirect Time-of-Flight) fast photodiode image sensor, and producing high-resolution depth maps. It embeds a sensor and illuminator hardware in its interface board, both of which are controlled by software running on a computer. Software also controls 3D reconstruction of grabbed images. The system can operate over short (for example, Face ID mode) and long distances (for example, AR/VR mode).

Laser safety is embedded and guaranteed in this system. Refer to Section 4 Laser safety.

1 Acronyms and abbreviations

Acronym	Definition
AR	augmented reality
EVK	evaluation kit
GPU	graphics processing unit
GUI	graphical user interface
HW	hardware
iToF	indirect Time-of-Flight
MPD	monitoring photodiode
PFM	portable floatmap
PGM	portable gray map
PLY	polygon file format
SW	software
ToF	Time-of-Flight
VR	virtual reality

2 MOB-THANOSV3 demonstration system overview

The MOB-THANOSV3 includes a physical component, and a GUI software.

2.1 Evaluation kit content

The MOB-THANOSV3 demonstration system kit includes the following components:

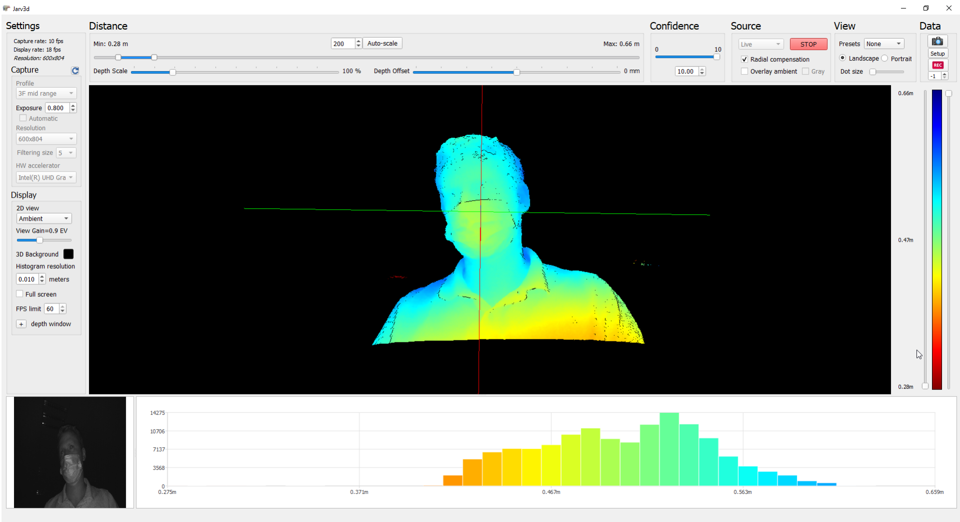
- MOB-THANOSV3 demonstrator system
- USB 3.0 cable
- Tripod to hold demonstrator
- Power supply for demonstrator and its main adaptators

Figure 1. MOB-THANOSV3 EVK parts

2.2 Evaluation kit GUI software

The MOB-THANOSV3 EVK software is a graphical user interface (GUI) used to operate the VD55H1 sensor, demonstrate functional performance, and allow the user to adjust the parameters that control the ranging capabilities and 3D video performances.

Figure 2. MOB-THANOSV3 demonstration GUI



Note: This document is linked to jarv3d 1.6.0 software delivery.

Note: The MOB-THANOSV3 demonstration system interface is Windows® compliant.

In order to ensure correct frame rate performance levels, the following minimum computer hardware / software configuration is recommended:

	Minimum specification
OS	Windows® 10
Processor	Intel® Core™ I5
Graphic card	Intel® GPU and NVIDIA(R) GPU
Memory	16 GBytes (TBC)
Connectivity	USB3.0

Caution: If a laptop is used, it should remain connected on the main to allow full performance capability to keep maximum frame rate displayed.

Note: The graphic card driver should be up-to-date.

Note: It is recommended to connect only the MOB-THANOSV3 on its USB controller, in order to dedicate the maximum bandwidth to the device.

Note: It is recommended to not run any other CPU and/or GPU intensive programs in parallel.

3 EVK start up

In order to use MOB-THANOSV3 EVK, you must first follow the hardware startup procedure as follows:

1. Connect USB 3.0 cable between MOB-THANOSV3 EVK and an USB 3.0 port of your computer.
2. Make sure the SD card is plugged in the connector slot of the demo casing.
3. Plug the power supply on your local electrical system (use adaptators if needed) and plug the male jack into the female jack on the EVK. You may hear the fan of the grabbing board starting to run.
4. Click on the power button, you should see a red light appear (as illustrated in Start button). Wait until the light turns blue (approximately 20 seconds).
5. Install the MOB-THANOSV3 EVK GUI software, as described in Section 8 GUI software installation.
6. Click on the MOB-THANOSV3 EVK GUI sofware icon on the desktop.
7. Click on START button to start the streaming.

Figure 3. MOB-THANOSV3 EVK setup

For more information on the MOB-THANOSV3 GUI, refer to Section 9 MOB-THANOSV3 EVK GUI user guide.

4 Laser safety

During normal operations, the MOB-THANOSV3 demonstration system meets Class 1 laser classification requirements under EN/IEC60825-1:2014. However, users must take the following safety precautions when using the system.

- Examine the casing for any damage before powering on the board.
- Check that the Tx cover glass is not removed or broken.
- Check that the demonstration system casing is not broken.
- If there is any damage, stop operating immediately by removing power from the system.

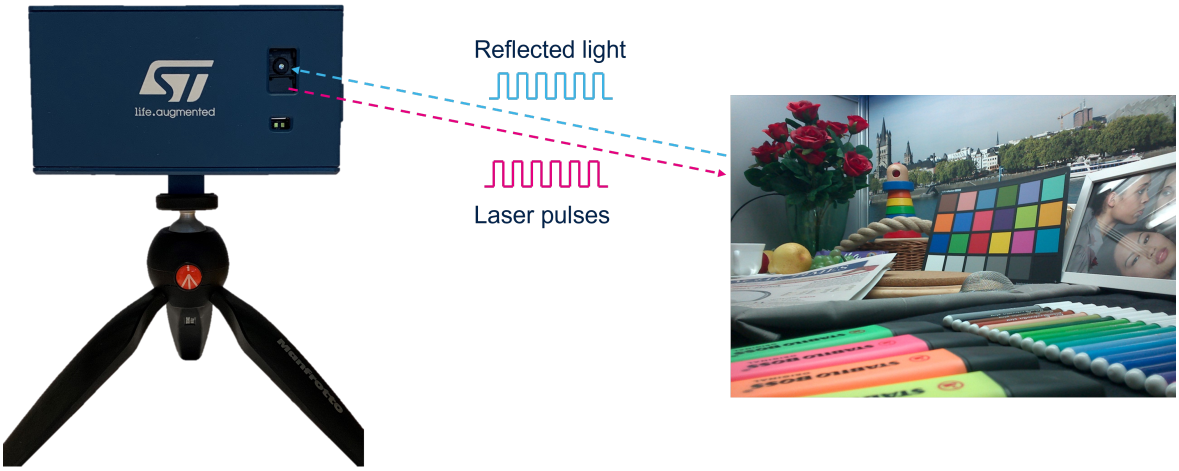
Opening the casing or removing the laser cover glass or diffuser may lead to hazardous radiation exposure. Any circuit modification to the board other than the recommended user guidelines provided by STMicroelectronics for the MOB-THANOSV3 demonstration system may lead to violation of Class 1 safety limits. It is forbidden to modify the laser beam characteristics by modifying the laser cover glass or adding optical elements.

There is no scheduled maintenance required for the MOB-THANOSV3 demonstration system. Any servicing and maintenance of this system must be performed by trained STMicroelectronics personnel. Any modification or significant damage to the demonstration system could potentially cause the system to operate outside the EN/IEC60825-1:2014 Class 1 classification limits.

Figure 4. Class 1 laser product label

5 Indirect Time-of-Flight principles

Figure 5. **IToF presentation**



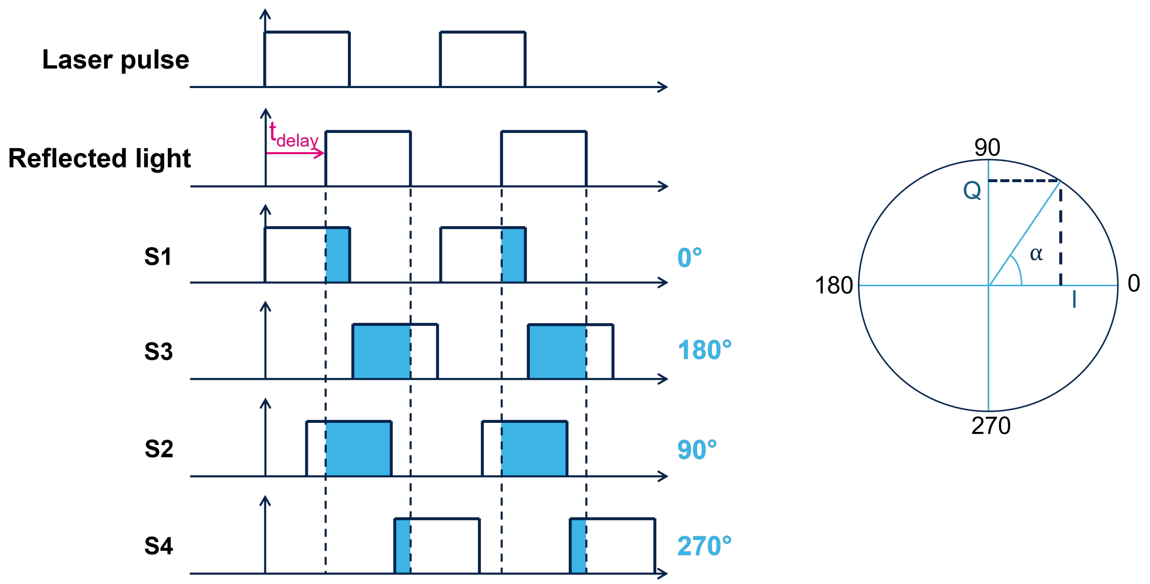
Indirect Time-of-Flight (iToF) principle is based on delay measurement between scene illumination and scene received reflected light using IQ technique.

The scene illumination is done using a high frequency modulated light at 940 nm wavelength.

Each pixel of the sensor converts the reflected light of the scene using a photo sensitive element in two memory (Taps) using fast switches, synchronized on illumination high frequency signal.

In the following figure, the description is based on 4 Taps method that requires two sequential integrations, with two sensor integration phase shifts (0 and 90°) as shown in Figure 8. IToF exposure functioning.

Figure 6. **IToF overall principle illustrated**



The following calculations transform the 4-bin information into distance, amplitude, and offset information, for each pixel.

Figure 7. Processing calculations

$$Z_{meas} = \frac{c_{light}}{4\pi.f}.\arctan\left(\frac{S_2 - S_4}{S_1 - S_3}\right)$$

$$Amplitude \propto \sqrt{(S_1 - S_3)^2 + (S_2 - S_4)^2}$$

$$Offset_{meas} \propto S_1 + S_2 + S_3 + S_4$$

Distance information is recomputed in 3D coordinates with the origin at the optical center of the 3D iToF imager.
Amplitude corresponds to received signal amplitude.
Offset image corresponds to a 2D gray image of the scene.

Figure 8. IToF exposure functioning

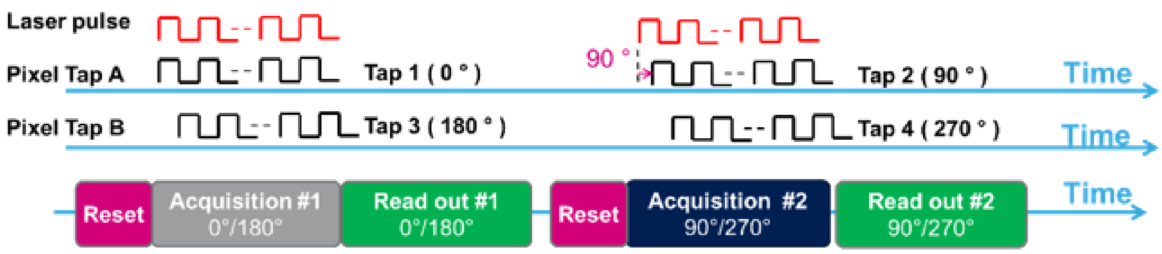
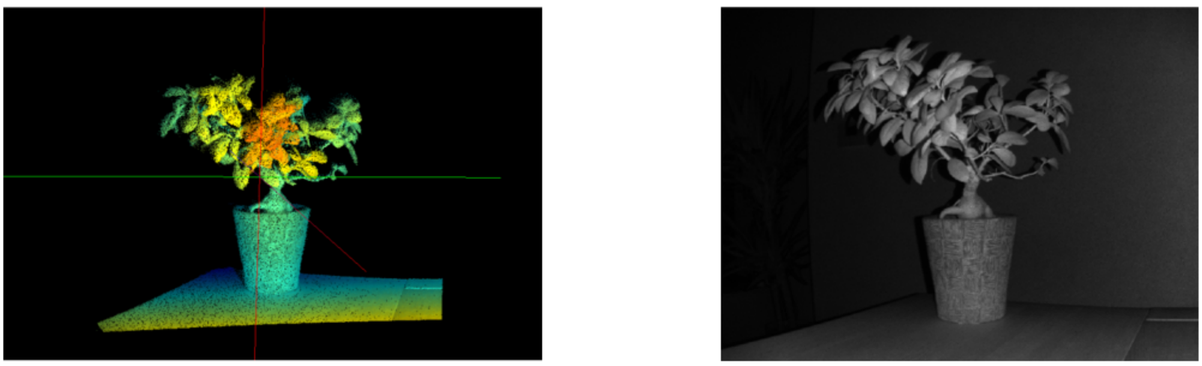


Figure 9. Depth and offset image examples



Notice that maximum measurement range is directly linked to demodulation frequency used. When the ToF of a light pulse reflecting off a target becomes higher than its own time pulse period, the system cannot differentiate if the object is at d or d + modulo distance of the period. For example, with a frequency of 50 Mhz, the range is limited to 3 m. Therefore, in order to measure higher distances with good accuracy trade-off, the system uses at least two frequencies and a disambiguation algorithm to reconstruct the whole scene. Depth reconstruction uses noise metrics per pixel to assess each pixel's confidence level, before making a final decision to display it.

6 Hardware overview and design specification

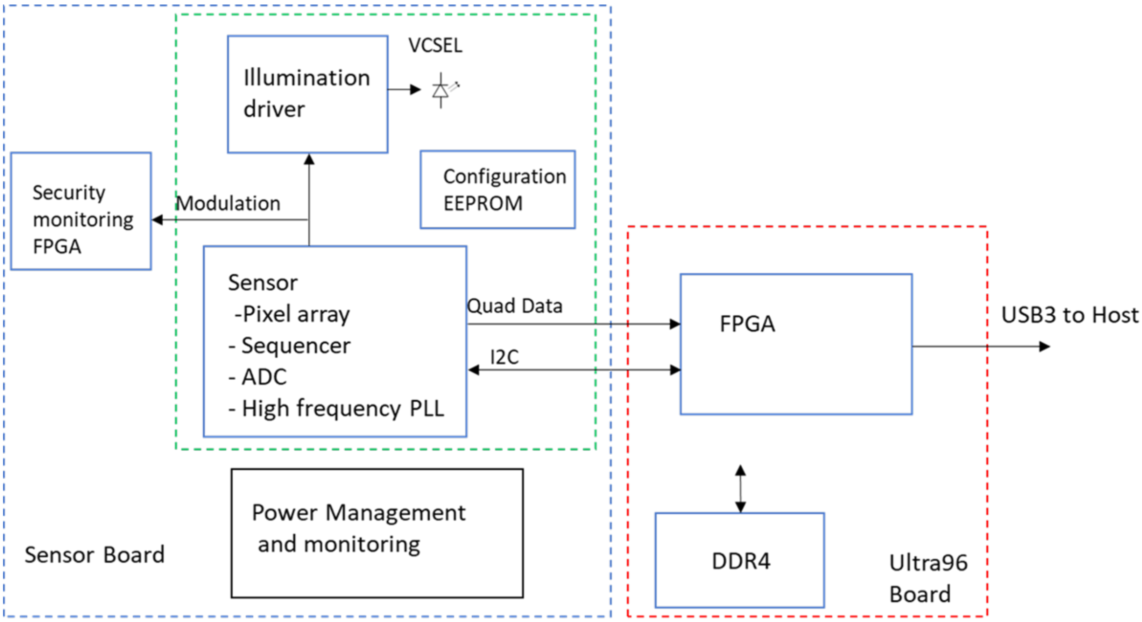
6.1 Block diagram

The VD55H1 sensor provides the modulation signal for the internal pixel array, as well as for the external illumination drivers. The illumination drivers in turn drive the laser illumination.

The receiver light is focused using a lens on to the VD55H1 sensor. The depth correlation data obtained by the VD55H1 sensor is digitized, and sent to Ultra 96 grabbing board using the MIPI quad lane interface. Ultra 96 grabbing board embeds an FPGA and a DDR4 memory to convert and transfer frames over USB3.

On computer subframes, data are processed and provide the distance output for each pixel.

Figure 10. Block diagram



6.2 Module OZT-376

OZT-376 OFilm module embeds:

- VD55H1 A0 sensor, IR filter and lens
- laser driver
- VCSEL, diffuser and monitoring photodiode (MPD)
- EEPROM for configuration and calibration storage

Figure 11. OZT-376 OFilm module

6.3 Design specification

The overall specifications of the MOB-THANOSV3 demonstration system EVK are listed in the following table.

Table 1. MOB-THANOSV3 specifications

Item		Specification
Time-of-Flight sensor		VD55H1 A0
Sensor resolution		804 x 600 (SVGA)
Field of view		77° diagonal
Frame rate (1)	1 frequency - short range	30 fps
	2 frequencies - mid range	15 fps
	2 frequencies - mid range - high fps	30 fps
	3 frequencies - mid range	10 fps
	3 frequencies - mid range - high fps	23 fps
	3 frequencies - long range	10 fps
Modulation frequency		50 to 200 MHz square wave at 50% duty cycle
Distance range	1 frequency - short range	Up to 0.75 m
	2 frequencies - mid range	Up to 4.5 m
	3 frequencies - mid range	Up to 6.75 m
	3 frequencies - long range	Up to 10.5 m
Illumination source wavelength		940 nm
Laser beam shape		Rectangular
Max peak optical output power		2.5 W
Lens F number		1.3
Connectivity		USB 3.0 micro connector
Operating conditions		0°C to 40°C (ambient)
Power supply operation voltage		12 volts
Maximum exposure time		0.8 ms
Laser compliancy		Class 1

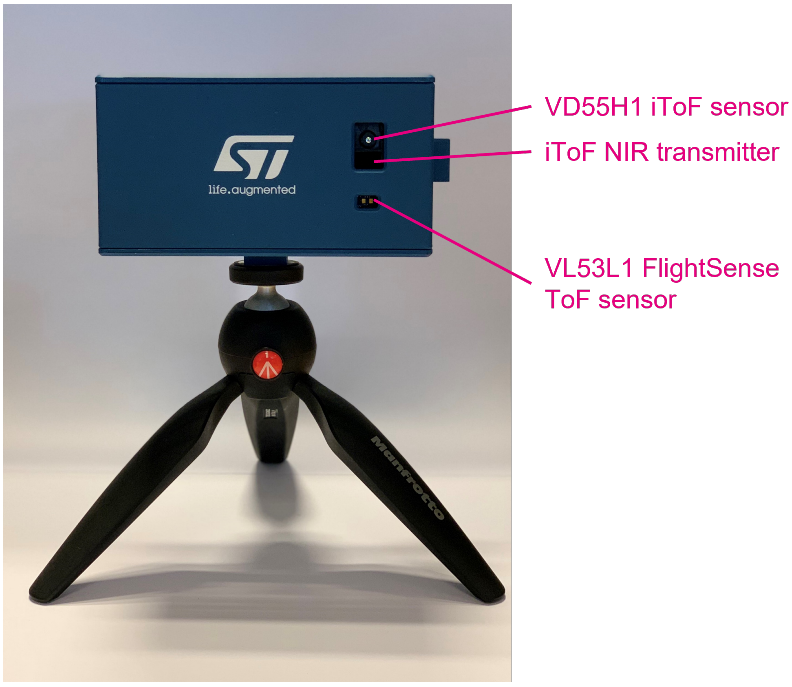
1. *The frame rate value in this table is the frame rate set to the sensor. Effective frame rate seen in the application may be lower, depending on the capability of the computer to retrieve and process all the frames. Overall, demo performances are heavily linked to the computer hardware performance.*

7 Demonstrator description

MOB-THANOSV3 demonstration system front side shows:

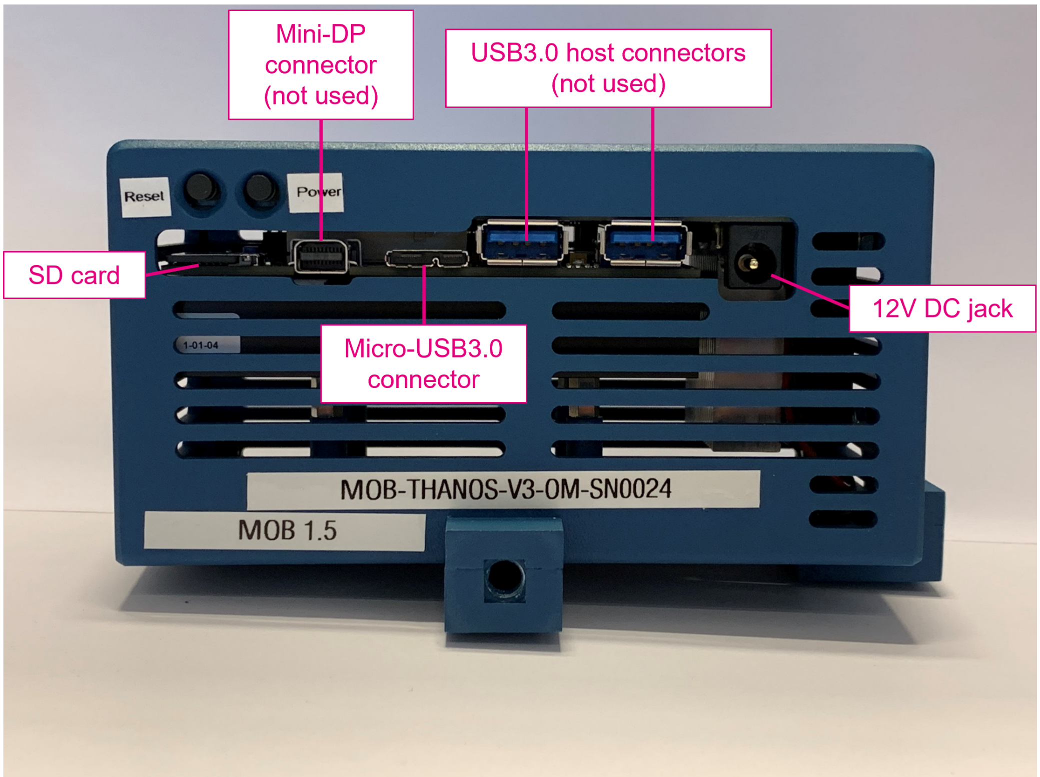
- VD55H1 3D ToF sensor with lens above
- VL53L1: EwokPlus ToF rangefinder, mainly used for demo system development and calibration procedure
- OZT-376 module aperture
- Laser cover glass

Figure 12. **Demonstration system front view**



The 12V power supply jack, micro-USB 3.0 connector and start/reset push buttons are located on the bottom side.

Figure 13. Demonstrator connectors (side view)



7.1 Laser cover glass

In order to protect the laser illumination, there is a cover glass on top of the laser. If the laser cover glass is broken or missing it is mandatory to stop using the EVK and to contact an STMicroelectronics representative.

7.2 Power button

The power button starts up Ultra 96 grabbing board to allow communication with the computer but does not start the sensor and illuminator, which are controlled by the software in a second step. Ultra 96 boot takes approximately 20 seconds, during which time the led is red, becoming blue when boot is complete (as shown, in Figure 14. Platform boot on going and Figure 15. Platform boot complete).

Note: There is no means to stop the Ultra 96 board except by unplugging the main power supply.

Figure 14. Platform boot on going

Figure 15. **Platform boot complete**

7.3 Reset button

The reset button resets the entire Ultra 96 board without the need to power-cycle the board. As part of the reset process, the reset triggers a USB connect and disconnect on the USB, and output data streaming stops.

7.4 Cooling

MOB-THANOSV3 EVK Ultra 96 grabbing board generates a certain amount of heat, which warms the overall solution due to its FPGA.

There is an integrated fan to cool down the grabbing board, and avoid overheating the OZT-376 module.

Therefore, you should ensure that the air vents are not blocked on all sides of the EVK.

7.5 Power supply

The image of the power supply recommended for use with the MOB-THANOSV3 demonstration system along with all the blade options is shown in the following.

Within the kits, UK/ US / Europe blades are provided as shown below.

Figure 16. **Power supply**

The power supply specifications are shown in the following table:

Item	Specification
Output voltage	12 V
Output current	Up to 3 A
Input voltage	90 ≈ 264 VAC
Frequency	50 / 60 Hz
Blade options	US, UK, Europe

7.6 Orientation capabilities

It is possible to use the demonstrator on the tripod in portrait or landscape positions as illustrated below.

Figure 17. **Landscapte mounted**

Figure 18. Portrait mounted

8 GUI software installation

8.1 Compatibility and limitations

In terms of compatibility, the MOB-THANOSV3 EVK GUI software requires a computer running Windows® 10, and equipped with a USB3 port, to which the HW can be connected.

Concerning the limitations related to your computer and operating system, consider that:

- The current MOB-THANOSV3 EVK GUI software relies on GPU acceleration for the rendering and the processing of the frames. Currently it supports only computers equipped with Intel® and NVIDIA(R) GPUs.
- As for the installation of every application on Windows®, the privilege escalation might be required depending on your company policy. The tool itself does not require privilege escalation.

8.2 GUI software installation steps

This section describes the procedure to install the MOB-THANOSV3 EVK GUI software and its dependencies. It requires three steps. Step 1 and 3 are covered in detail in the later sections, as it is STMicroelectronics specific, while step 2 is Microsoft® specific.

The first two steps are prerequisites. This means that you need to do them only once. If you get an upgrade of the MOB-THANOSV3 EVK GUI software, only the third step will be required.

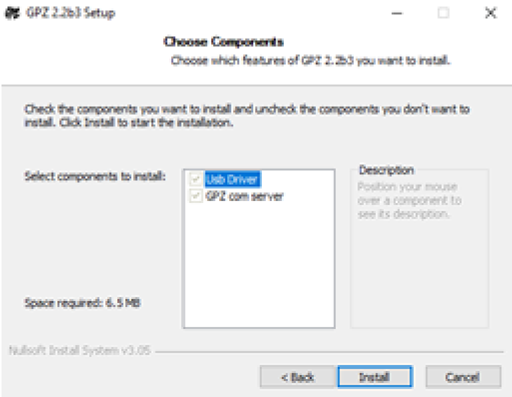
1. Install the SW that is used by the VD55H1 application to communicate with the MOB-THANOSV3 HW demonstrator system. This will be done using the "GPZ_Installer.exe" file that is provided along with the delivered package. Refer to Section 8.2.1 GPZ installer for more details.
2. Ensure that you have installed on your computer the following Microsoft Visual C++ Redistributable package: Microsoft Visual C++ 2015-2019 Redistributable (x64)
   – You can check this by looking in your Windows® settings in : Control_Panel > All Control Panel Items > Programs and Features
   – If those packages are not installed, you can find them on the web with the following link: https://support.microsoft.com/en-us/help/2977003/the-latest-supported-visual-c-downloads
3. Install the MOB-THANOSV3 EVK GUI software using the installer: "jarv3d-x.x.x-win64.exe" that is included in the delivered package.

8.2.1 GPZ installer

This section describes the steps to install GPZ.

Once you execute the “GPZ_installer.exe”, you will navigate through the different steps below.

1. On the Welcome pop up, click Next.
2. The following window shows the two components that will be installed:
   – The driver handles the HW board through the USB interface
   – A communication server that handles the communication between the application and the HW again through USB

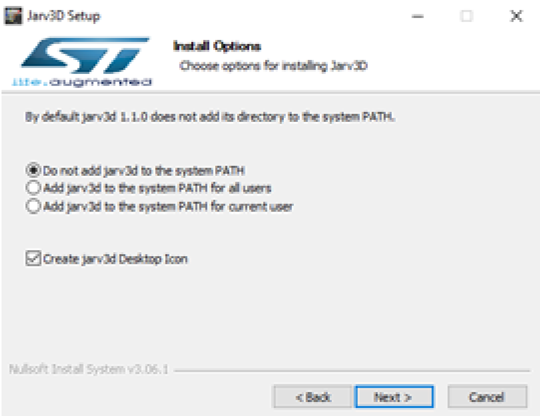


3. Click on Install.
4. Another window will pop up once the drive is installed. Click Next to continue.
5. You should see a Installation Complete window. Click Close.

8.2.2 GUI software installer

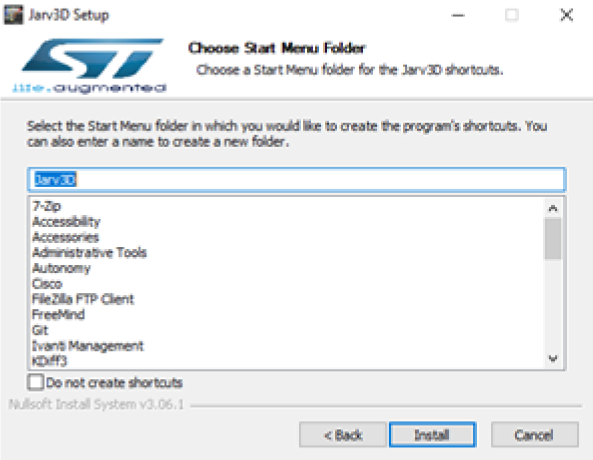
This section describes the procedure for installing the GUI software.

1. First, execute “jarv3d-x.x.x-win64.exe”
2. On the Welcome popup, click Next.
3. Once you have read and you agree with the terms of the license, you can continue the installation by clicking “I Agree”.
4. On the following window (see figure below), select the installation option. You can install the application for one or several users in the system path if they are on the machine. By default, we advise you to select the first option as shown in the following figure. You also have the option to create an icon on the desktop that will allow you to run the application.

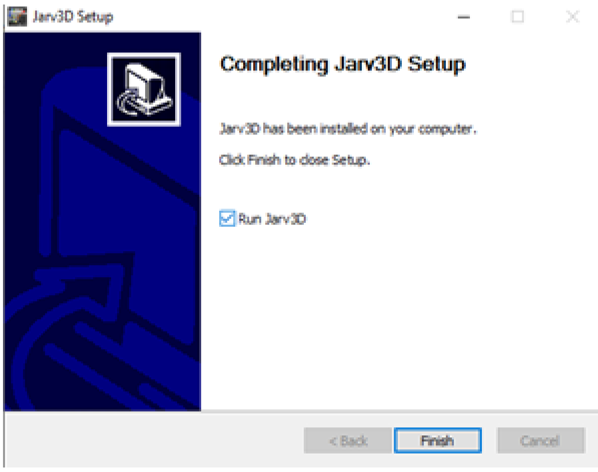


   Click Next.
5. Chose the directory where the application will be installed. Click Next to continue.

6. The following window (see figure below), allows you to select the name of the folder in which the application will be located in your Windows® Start Menu Folder. Click Install to get to the final stage.



7. Once the installation is complete, the following window appears. You can choose to start the application by default, as shown in the figure below; however, make sure that the HW is properly connected and recognized.



9 MOB-THANOSV3 EVK GUI user guide

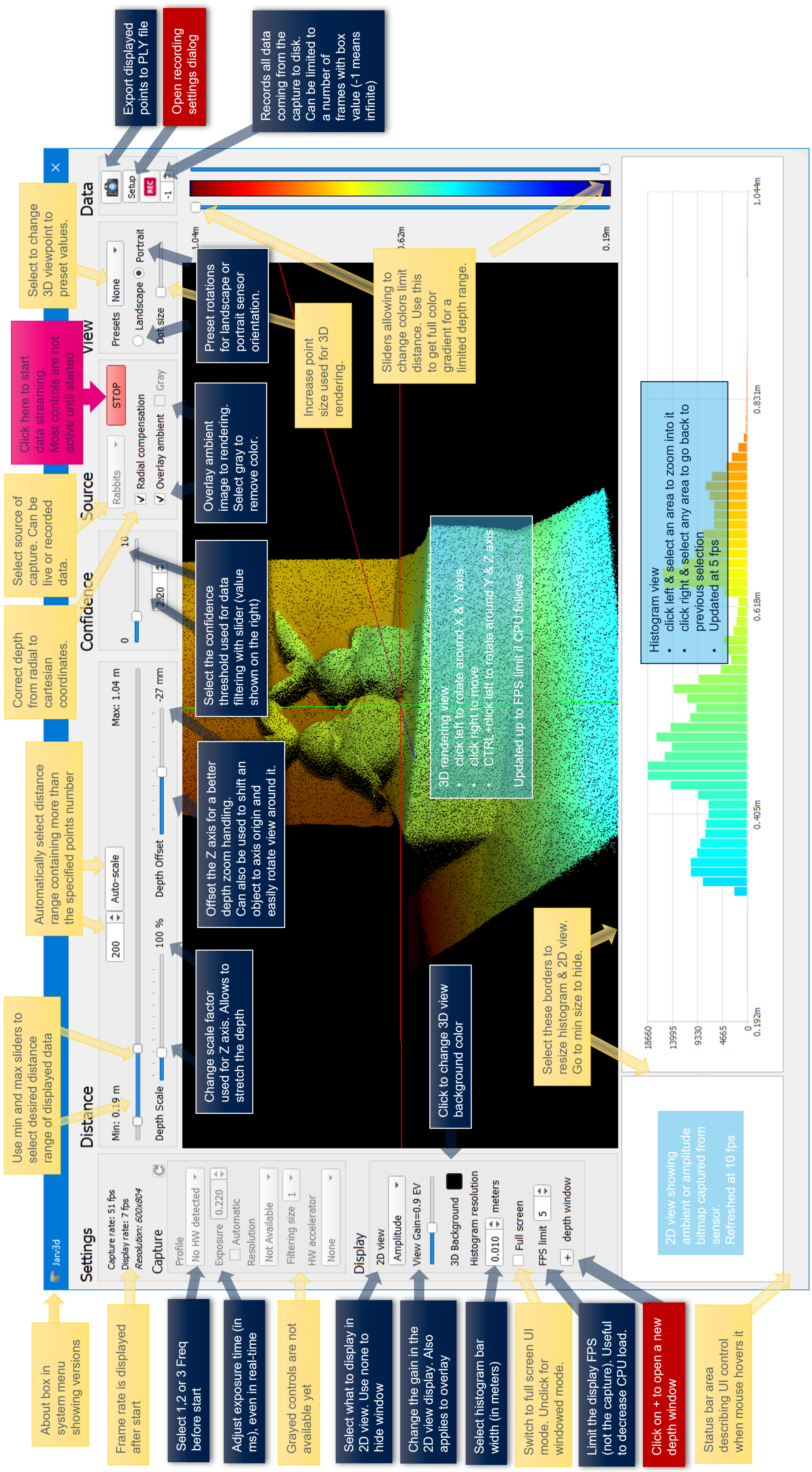
9.1 Startup

Once the EVK HW is successfully setup, the MOB-THANOSV3 EVK GUI software can be started by clicking the desktop icon shown below.

Figure 19. GUI desktop icon

The following is a screen capture of the interface with some explanations on its use.

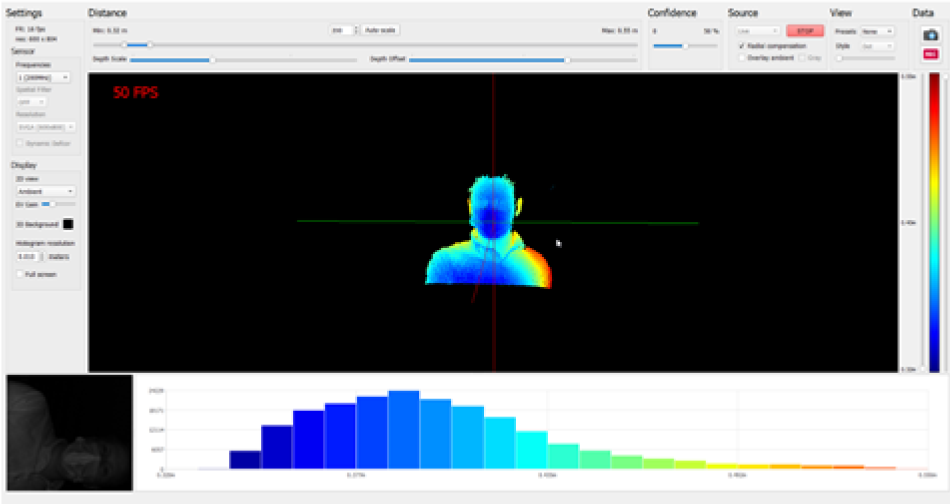
Figure 20. GUI interface summary



9.2 Successful connection

Once you have launched the GUI software and clicked on the Start button, the following 3D image should be displayed.

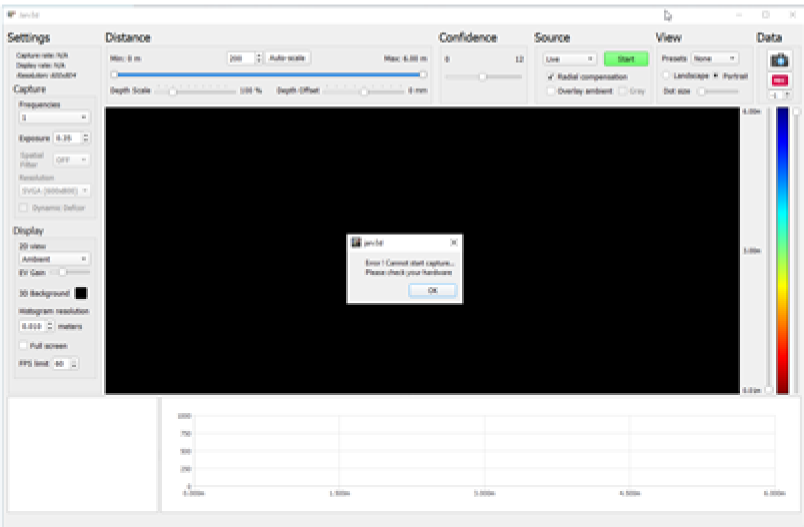
Figure 21. GUI connected



9.3 Connection issue

Once you have launched the GUI software and clicked on the Start button, if there is an issue connecting with the MOB-THANOSV3 EVK, an error message is displayed as in the figure below.

Figure 22. Connection issue



From the command prompt, it is possible to get information regarding the connection issue.

The connection issue can be caused by any of the following:

- MOB-THANOSV3 EVK USB3 is not connected
- MOB-THANOSV3 EVK has no power supply
- The host PC does not have the correct MOB-THANOSV3 EVK drivers installed
- The COM port is used by another process

9.4 Troubleshooting

If the MOB-THANOSV3 sensor is not detected, it may be for one of the reasons explained below, along with some troubeshooting steps.

9.4.1 MOB-THANOSV3 board not connected

Ensure that the EVK is connected to the PC on an active USB port.

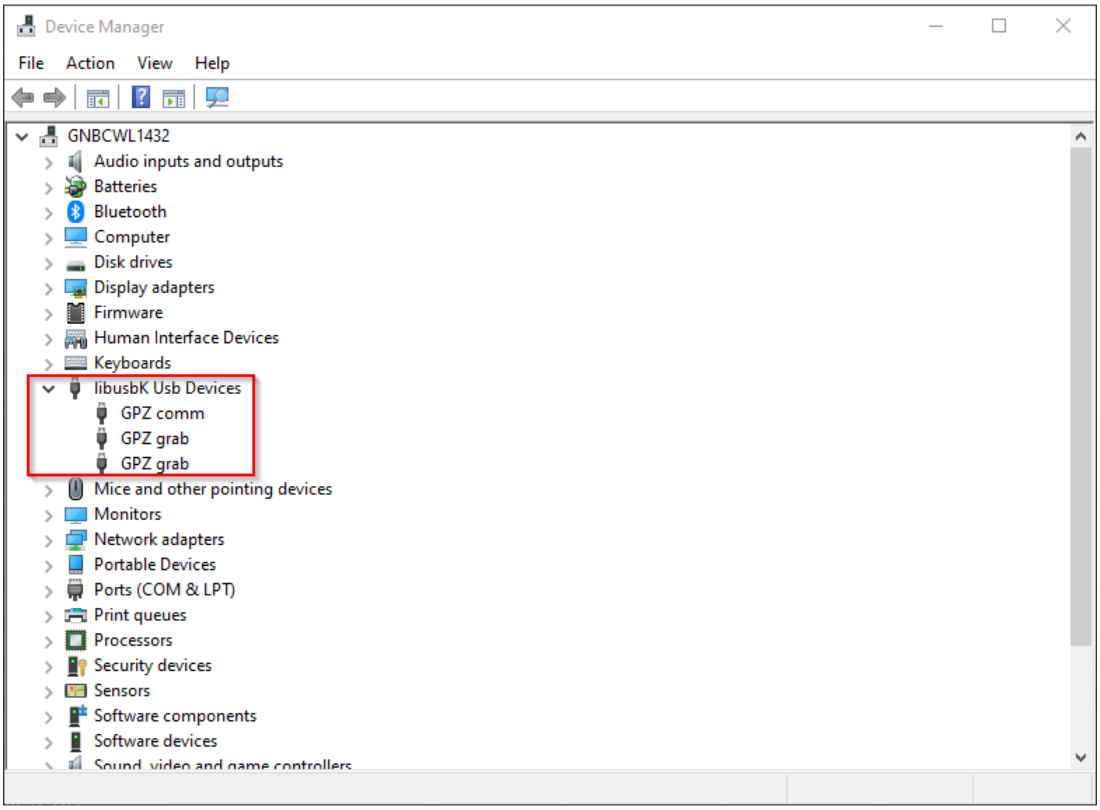
9.4.2 Drivers not installed

The MOB-THANOSV3 will be visible to the host PC as a removable device the first time the board is connected to the PC.

In order to check if the drivers have been successfully installed and the board is correctly detected, open the "Device Manager".

The detected board should appear under "libusbK Usb Devices" with the name "GPZ grab" and "GPZ comm" as shown below.

Figure 23. USB device list



9.5 Output image file format

9.5.1 PGM file format

A PGM file is a grayscale image file saved in the portable gray map (PGM) format and encoded with one or two bytes (8 or 16 bits) per pixel. The PGM format is one of several image formats defined by the Netpbm project, which is an open-source package of graphics programs. Other formats include the portable bitmap (.PBM) format and portable pixmap (.PPM) format.

It contains header information and a grid of numbers that represent different shades of gray from black (0) to white (up to 65 535). The header defines the PGM format type ("P2" for text or "P5" for binary), image width and height, and the maximum number of shades.

If the maximum number of shades is below 256, each pixel is encoded on 8 bits. If it is between 256 and 65535, each pixel is encoded on 16 bits.

Figure 24. **PGM file example**

Example :

This example shows the beginning of a .pgm file.

```
P5
#METADATA BEGIN
#__data_type__,3,Mono
# Recorded from Jarv3d, Tue Sep 21 12:14:52 2021
# InsertionTime=1735586359
# DurationInMs=16
# ExposureInMs=0.350
# Confidence=2.8
# MinDistance=0.000
# MaxDistance=32768.000
# Metadata width=-1
# Metadata height=-1
# Metadata orientation=0
# Metadata temperature=32
# Metadata isZCompensated=1
# Metadata dmax_mm=6745.330
# Metadata xCenter=303.260
# Metadata yCenter=408.120
# Metadata focal=637.360
# Metadata alpha=-1.73e-07
# Metadata xScale=1.000
# Metadata yScale=1.000
#METADATA END
600 804
8191
STRQNOOQRRQOPNNNO..................
```

Magic number for PGM binary format

Header metadata to be easily parsed or skipped thanks to the '#' character at the beginning of each line.
This part is customizable. Each program or user can put anything in this section.

Image size (width and height)

Maximum value

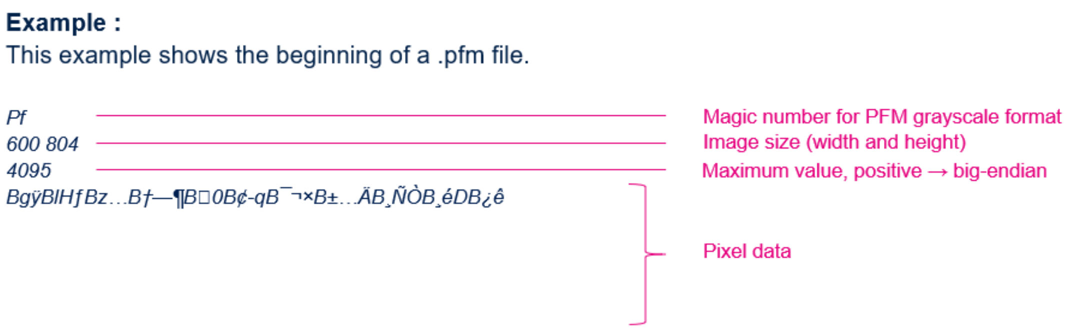
Pixel data

9.5.2 PFM file format

The PFM (portable floatmap) format is similar to the PGM format. It is the unofficial four bytes IEEE 754 single precision floating point extension.

A color file is identified with the ASCII text "PF" in the first line of the header and a grayscale with "Pf". The next ASCII text line contains the width and height, separated by the space character. The third ASCII text line holds a nonzero decimal number that indicates little endian floats for the pixel data when negative and big-endian floats when positive. The absolute value of the number indicates the range. So, the third line containing -1.0 indicates little-endian format, in the range zero to one. After the header, the file proceeds with floating point numbers for each pixel, specified from left to right, bottom to top.

Figure 25. **PFM file example**



9.5.3 PLY file format

PLY is a computer file format known as the Polygon File Format. It was principally designed to store three-dimensional data from 3D scanners. The data storage format supports a relatively simple description of a single object as a list of nominally flat polygons and/or vertices. A variety of properties can be stored, including color and transparency for example. There are two versions of the file format, one in ASCII, the other in binary.

From this point, the description of the PLY file will be focused on the one output by Jarv3d SW which uses the ASCII format and only stores a list of vertices and their associated color.

The header always starts with a magic number, a line containing “ply”, which identifies the file as a PLY file. The second line indicates which variation of the PLY format this is (in Jarv3d SW it is “format ascii 1.0”). Comments may be placed in the header by using the word “comment” at the start of the line. Everything from there until the end of the line should then be ignored. The "element" keyword introduces a description of how some particular data element is stored and how many there are. Therefore, in a file where there are 12 vertices, each represented as a floating point (X,Y,Z) triple, one would expect to see:

element vertex 12

property float x

property float y

property float z

Other property lines can indicate that colors or other data items are stored at each vertex and indicate the data type of that information.

At the end of the header, there must always be the line “end_header”.

Figure 26. PLY file example

Example :

This example shows the beginning of a .ply file generated by Jarv3d software.

```
ply
format ascii 1.0
comment generated by Jarv3d
element vertex 145378
property float32 x
property float32 y
property float32 z
property uchar red
property uchar green
property uchar blue
end_header
-1.070393 1.041754 0.179030 0 194 255
-1.088092 1.051822 0.141945 0 166 255
-1.078836 1.046362 0.156781 0 178 255
-1.077639 1.048709 0.150405 0 174 255
-1.128878 1.087486 0.034815 0 88 255
-1.127553 1.089842 0.028389 0 84 255
-1.106137 1.072730 0.075047 0 119 255
-1.094833 1.065342 0.095192 0 135 255
-1.057631 1.032619 0.184415 0 202 255
-1.074346 1.052495 0.130221 0 162 255
-1.125248 1.080238 0.044350 0 96 255
-1.117892 1.076765 0.053851 0 104 255
```

Magic number for PLY format
ASCII data format
Comment
Number of vertices
Each line is composed by the x, y and z coordinates followed by the red, green and blue value
End of the header
Point cloud data

10 User mode reference setup

The use cases presented in this section are for reference only. The purpose of this section is to give some examples on how to set the demo, and are not the only settings that can be applied to have good results.

10.1 Short distance

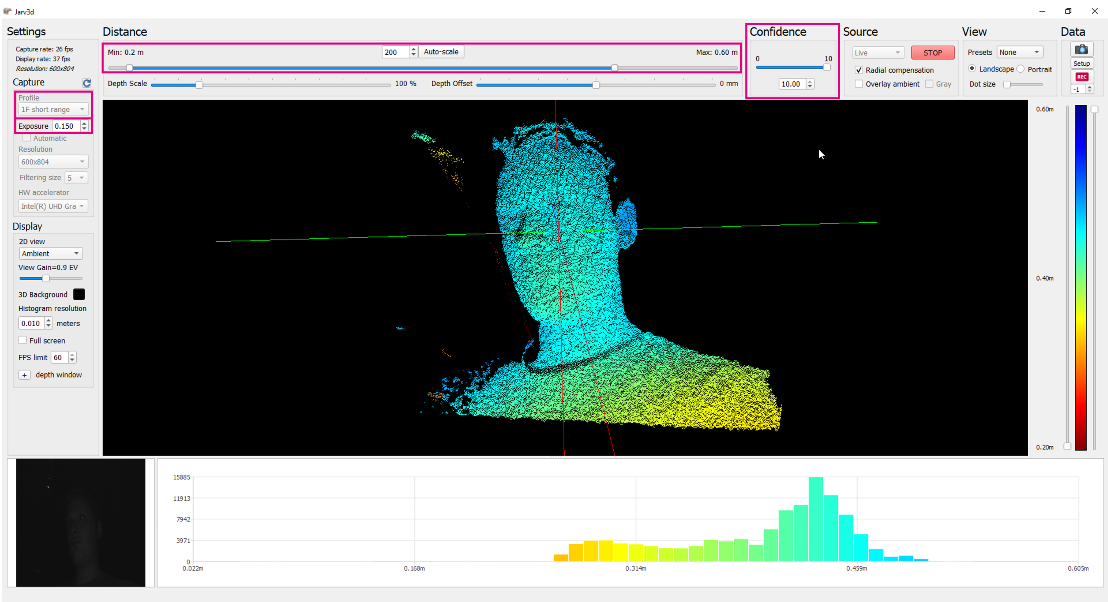
Used mainly for Face ID, working in mono frequency. Set the GUI as shown below using 1 frequency.

Note that this set up requires full FoV at maximum 75 cm to avoid longer distance false information as shown in the following image.

Table 2. **Main platform setup applied**

Profile	1F short range
Exposure	0.15 ms
Confidence threshold	10

Figure 27. **Calibration short distance**



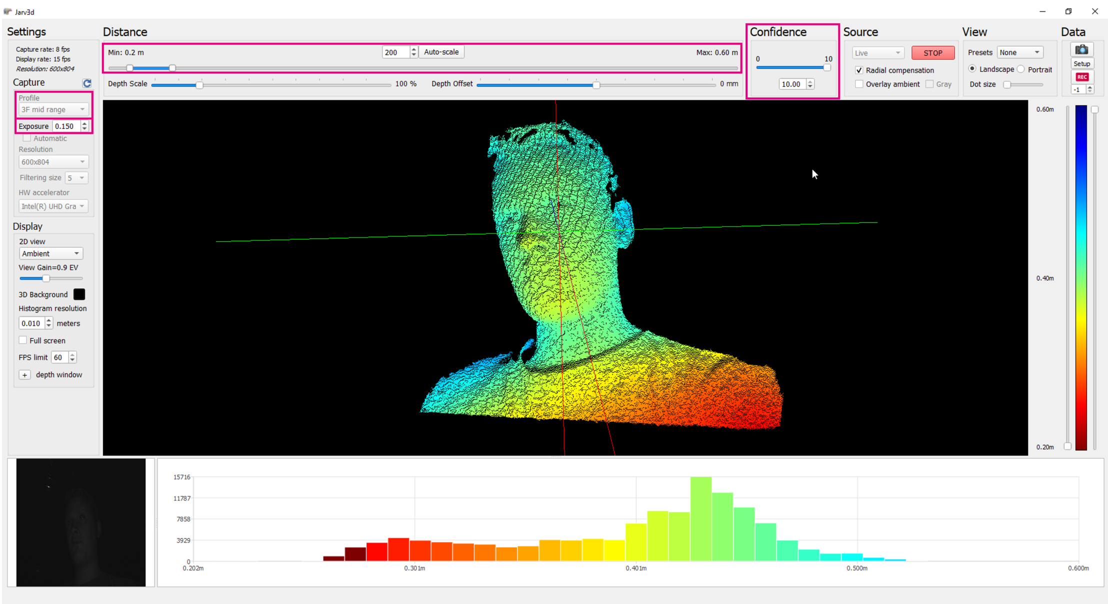
10.2 Short distance without long distance artefacts

Used mainly for Face ID and to avoid that long distance artefacts create false information. This set up works in multi frequency. Set the GUI as shown below:

Table 3. Main platform setup applied

Profile	3F mid range
Exposure	0.150 ms
Confidence threshold	10

Figure 28. Calibration, short distance without long distance artefacts



10.3 Mid range

Used mainly for world facing, working in multi frequency. Set the GUI as shown below:

Table 4. Main platform setup applied

Profile	3F mid range
Exposure	0.8 ms
Confidence threshold	0.2

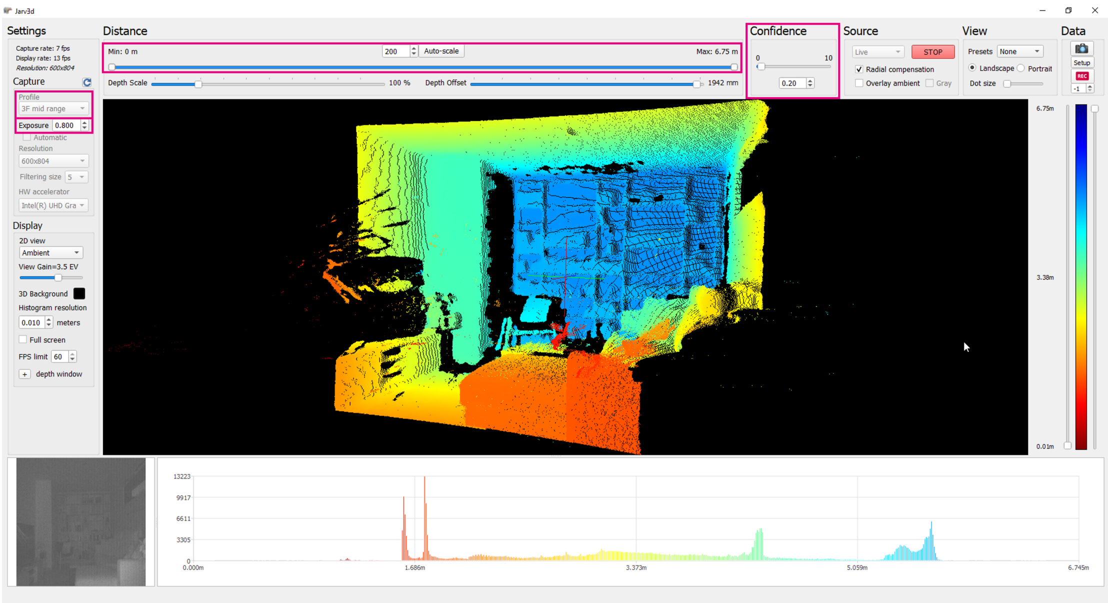


Figure 29. Calibration mid range

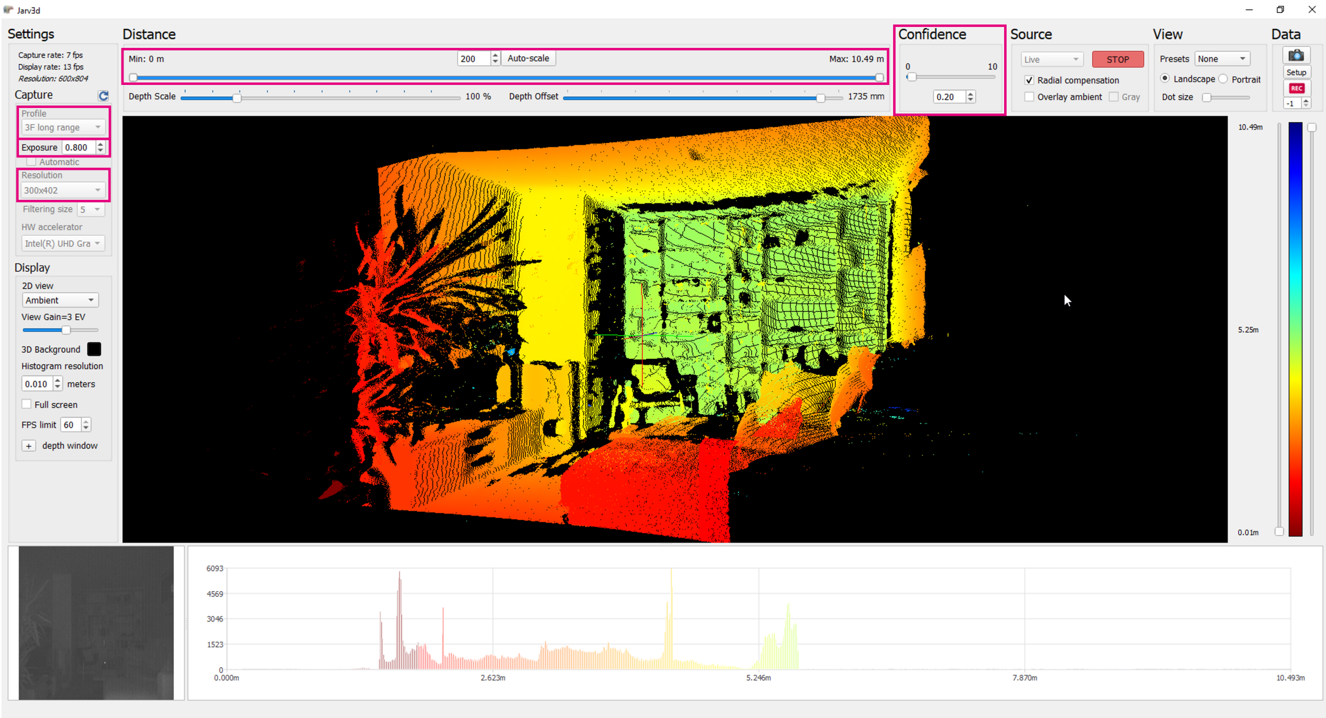
10.4 Long range

Used mainly for world facing, working in multi frequency and binning mode. Set the GUI as shown below.

Table 5. Main platform setup applied

Profile	3F long range binned
Exposure	0.8 ms
Resolution	300 x 402
Confidence threshold	0.2

Figure 30. Calibration long range



11 Calibration

The MOB-THANOSV3 is factory calibrated. The calibration is for demonstration purposes only and is not meant to be treated as the most accurate calibration possible.

All the factory calibration is done at ambient temperature.

11.1 Phase offset calibration

For all frequencies used in this demo, a test is performed to define the phase offset in order to compensate on sensor setting in normal functioning. This testing is done with a fix chart at 50 cm.

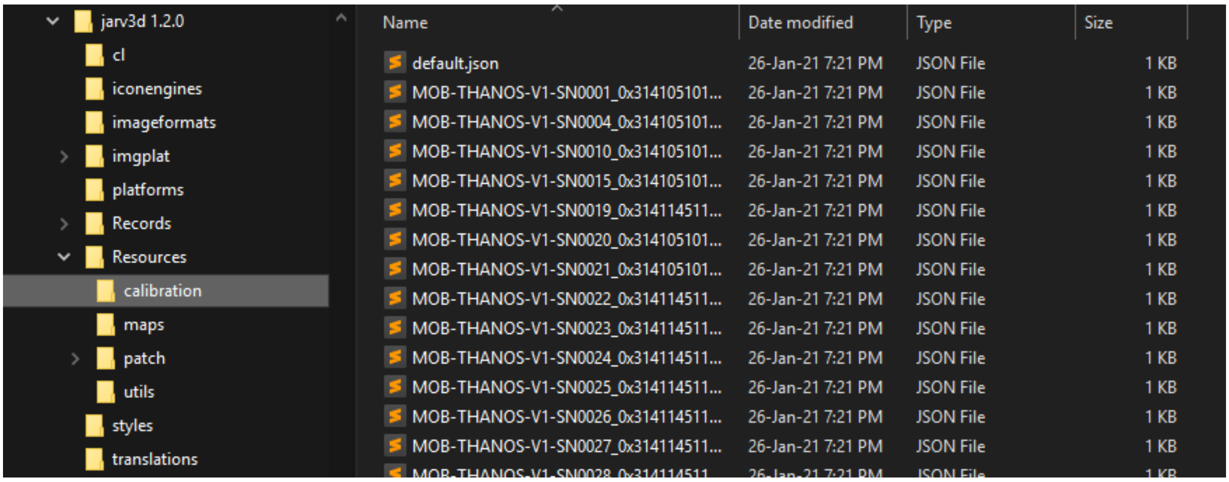
11.2 Tx driver optical power calibration

During Tx illuminator testing, a test is done to determine requested set up to reach a peak optical power of 2,5 W. This value is applied by default on each exposure.

11.3 Calibration file

Demo kits are calibrated. All calibration files are embedded in the demo software. At the startup of the demo, the software will automatically identify the hardware by its unique ID and load its dedicated calibration file to ensure best performance.

Figure 31. **Calibration file**



12 Functional limitations

12.1 Exposure

Currently, MOB-THANOSV3 EVK software does not support Auto Exposure mechanisms. The maximum exposure supported by the hardware is 0.8 ms.

12.2 Motion blur

MOB-THANOSV3 is configured in a way to optimize the performances in terms of motion blur artifacts. All the captures of the subframes are gathered at the beginning of the time frame.

12.3 Laser safety limitations

Internal laser safety limitations are hardware coded.

The maximum ratio between exposure time and frame overall content (exposure and blanking) for a 100 ms sliding window is set at 27%. If the laser safety limitations are exceeded, a fault is raised, and laser emission is stopped, leading to black screen.

Note: The maximum exposure length allowed by the laser safety compliance is 3 ms. The maximum exposure allowed by the application is 0.8 ms, which is laser safety compliant.

12.4 Thermal limitations

According to exposure ranges, the number of operating frequency and overall 3D frame rate, the average power into laser driver and sensor may exceed operational ranges.

The laser driver has its own minimum and maximum temperature monitoring. If its temperature goes out of this range (0-75°C), a fault occurs and laser emission is stopped, leading to black screen.

Revision history

Table 6. Document revision history

Date	Version	Changes
06-Jan-2022	1	Initial release

Contents