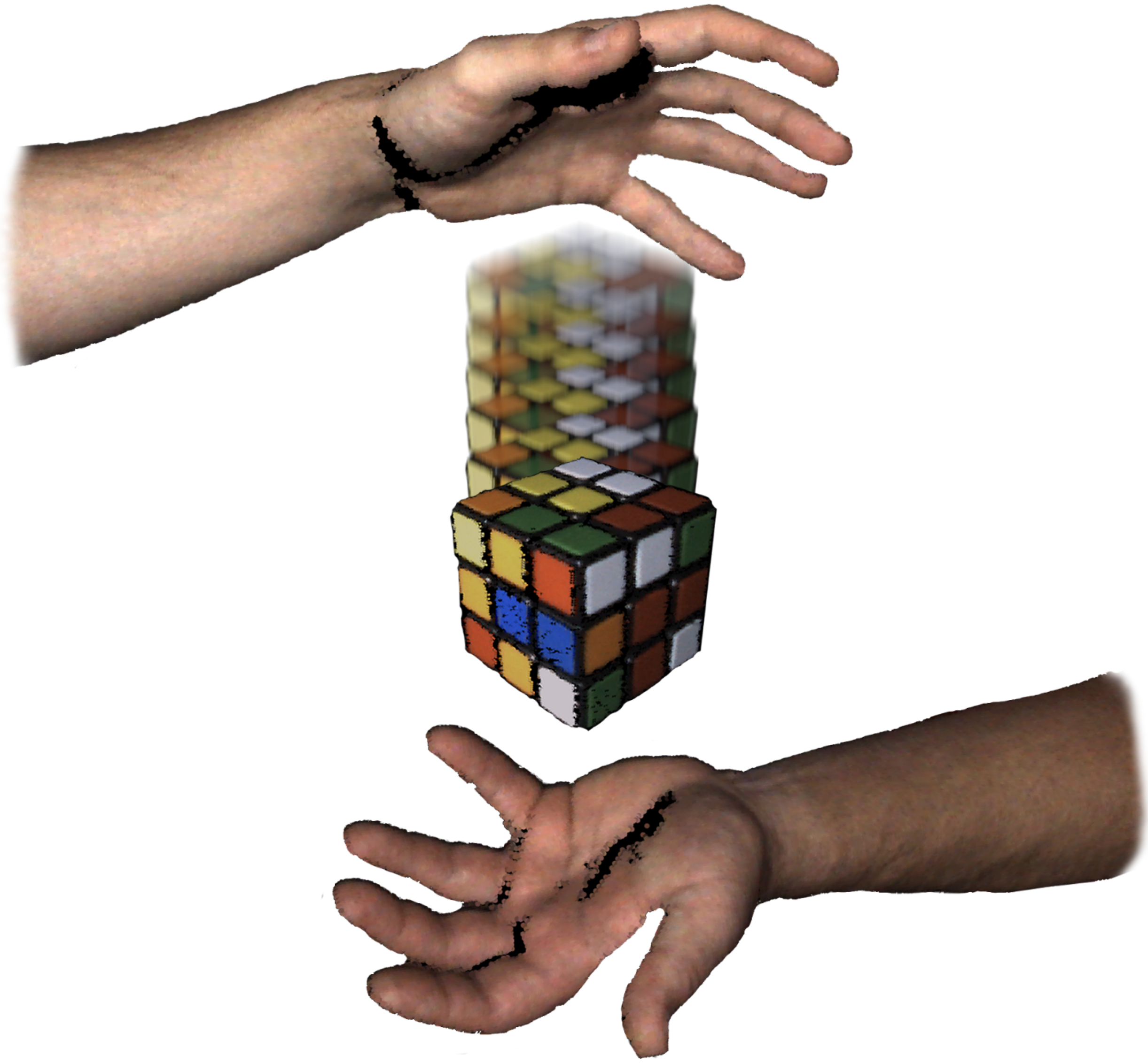
Photoneo | Focused on 3D



PhoXi® Control 1.12

User Manual

User Manual for PhoXi Control version 1.12.

About This User Manual

This manual is intended for users who want to familiarize themselves with PhoXi Control software for MotionCam-3Ds (Color), PhoXi 3D Scanners, and Alpha 3D Scanners. PhoXi Control provides both a graphical user interface (GUI) and an application programming interface (API).

The MotionCam-3D (Color) is a high-resolution and high-accuracy 3D camera that uses a patented CMOS sensor and Parallel Structured Light technology developed by Photoneo. It provides the scanning quality of structured light devices with the ability to scan dynamic scenes at the speed of Time of Flight devices. Additionally, output from the RGB camera unit on the color models is mapped on the point cloud, adding an important layer of information for further processing.

PhoXi 3D Scanner is a compact yet powerful 3D scanner with state-of-the-art performance in terms of precision, noise, and overall efficiency. It can be used for scanning a wide variety of objects, making it a universal tool for all kinds of industrial applications, mainly automated object manipulation and inspection.

Alpha 3D Scanner takes advantage of the structured light technology, providing high-quality 3D point clouds for a great variety of machine vision tasks, making it a perfect choice for scanning large objects with a simple shape such as boxes or containers in measurement, inspection, and similar applications.

This manual is based on the Photoneo 3D Sensors on firmware version 1.12. Using a Photoneo 3D Sensor on a different version may result in slight differences. It is recommended to use the newest firmware version available at Firmware Updater Consult the Versioning Guide to see the newest firmware version for your device.

Visit www.photoneo.com for the most up-to-date information and documents.

Please read the **PhoXi Control User Manual** before using the software, and the **Photoneo 3D Sensor User Manual** to become familiar with the safety and assembly instructions before using the devices.

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Technical support

Contact us at the Help Center.

See the Troubleshooting section at the end of this manual.

Visit Photoneo support pages at www.photoneo.com/support.

Orders and inquiries:
sales@photoneo.com

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Introduction

This user manual will first guide you through the use of PhoXi Control Graphical user interface (GUI) and the API, and then provide a quick scanning guide with references to further resources. Additionally, alternative ways of operating Photoneo 3D Sensors are referenced or described.

Photoneo sensors can be operated via:

- PhoXi Control
    - GUI
    - API
    - GenICam
- GigE Vision protocol

PhoXi Control application enables users to control Photoneo 3D Sensors manually via a GUI or by a computer program using the provided API or GenICam interface. Alternatively, Photoneo sensors can run in GigE Vision compatible mode in which PhoXi Control cannot be used.

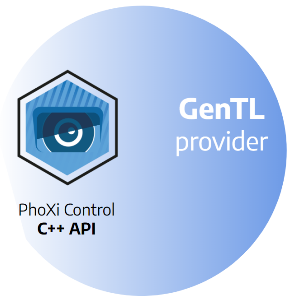
PhoXi Control

The GUI is primarily used to set up the scanning environment, configure the device parameters, and test the output. In addition, the GUI can also be used as a powerful debugging tool for development with the API since the calls to the API trigger the same response in the GUI as the user inputs. After triggering the scan by calling the API method, the application will execute the scan, send it as an output of the call, and display it simultaneously on the GUI.

The API has been designed to serve as a central platform for the development of custom applications. To facilitate the development process as well as to reduce computing demands, all 3D data computations are performed on the device itself. The postprocessing of the data (e.g. Localization of object) happens on the user's computer.

GenICam interface

The Generic Interface for Cameras standard is the base for plug-and-play handling of cameras and devices. It was developed by the European Machine Vision Association (EMVA)



GenICam support is provided via the GenTL library that works as a wrapper around PhoXi Control C++ API. PhoXi Control has to be running in order to use the GenICam interface.

The available examples for Python and Halcon support can be found in the installation directory:

- On Windows OS, the path to the GenTL directory is usually:
    - `Program Files/Photoneo/PhoXiControl-1.12.x/API/GenTL`
- On Linux OS, the path to the GenTL directory is usually:
    - `/opt/Photoneo/PhoXiControl-1.12.x/API/GenTL`

User guides for GenICam integrations contain more detailed information and requirements for running the examples.

GigE Vision

GigE Vision is a high-speed communication protocol and interface standard that is designed for transmitting data over Ethernet networks. Third-party software with GigE support can be used to operate Photoneo 3D Sensors without a running instance of PhoXi Control.
User guides for GigE integrations contain more detailed information and requirements for running the examples.

Common Terms

Clarification of several terms used in this document.

Photoneo 3D Sensor	General term for PhoXi 3D Scanner or MotionCam-3D (Color).
device	General term for PhoXi 3D Scanner or MotionCam-3D (Color).
MotionCam-3D	General term for MotionCam-3D devices including the MotionCam-3D Color if not stated otherwise
2D camera	Refers to the 2D camera unit inside PhoXi 3D Scanners.
image sensor	The devices are composed of three main units: projection unit, 2D camera unit, and computation unit. ‘Image sensor’ refers to the CMOS sensor inside the 2D camera unit.
RGB camera	Refers to the 2D RGB camera unit inside the MotionCam-3D Color.

Getting Started

Computer Requirements

Please ensure that your computer meets the minimum recommended requirements in order to run PhoXi Control smoothly.

Processor	Intel Core i7 or higher, x64 architecture (Processor performance affects the responsiveness of the application)
Operating system:	Only 64-bit platform Windows 10 / 11 Ubuntu 18 / 20 / 22
RAM:	Recommended 16 GB (minimum 2 GB for the application connected to 1 device)
SSD:	128 GB (Minimum 4 GB free disk space)
GPU:	GeForce GTX 1060 3 GB or similar external graphics card with OpenGL v 3.0 support.

Note: *Photoneo 3D Sensors have a very high-resolution mode producing up to 3 million 3D points, therefore the requirements made on the graphical performance of your graphics cards are higher. Old or slow graphics cards can reduce the performance of the 3D viewer.*

Supported compilers

To use the API, the following compilers are supported:

- Windows OS:
  - Visual Studio 12 2013 Win64
  - Visual Studio 14 2015 Win64 (compatible with Visual Studio 2017 & Visual Studio 2019)
  - Visual Studio 17 2022 Win64
- Ubuntu 18:
  - g++ 7.4.0
- Ubuntu 20:
  - g++ 9.3.0
- Ubuntu 22
  - g++11.3.0

Installation

Download the latest version of PhoXi Control: www.photoneo.com/downloads/phoxi-control

The installer will prompt you to uninstall any existing version of PhoXi Control. Several versions of PhoXi Control can be installed on one computer, but only one instance can run at a time.

Windows

To install PhoXi Control on Windows, proceed as follows:

1. Double-click the downloaded *.exe installation file.
2. Follow the setup wizard and restart the computer if this is your first installation of PhoXi Control.
3. Run PhoXi Control as a standard Windows application. The application automatically starts after the computer starts.

Note**:** The user is able to install PhoXi Control with or without the included file camera examples or the API. This can be changed during the *Choose Components* part of the installation process.

Default installation paths:

- Shortcut folder:
  `C:\ProgramData\Microsoft\Windows\Start Menu\Programs\Photoneo PhoXi Control`
- Installation folder:
  `C:\Program Files\Photoneo\PhoXiControl-<version>`
- Application data folder:
  `%AppData%/PhotoneoPhoXiControl/`

Linux

To install PhoXi Control on Ubuntu, proceed as follows:

1. Unpack the downloaded .tar file.

```
$ tar -xvf PhotoneoPhoXiControlInstaller-<version>-Ubuntu[22 20 18]-STABLE.tar.gz
```

2. Make the file executable and then execute with sudo. The installation requires the user to accept EULA, to do this automatically, pass the `--accept` flag to the installer script.

```
$ chmod +x PhotoneoPhoXiControlInstaller-<version>-Ubuntu[22 20 18]-STABLE.run
$ sudo ./PhotoneoPhoXiControlInstaller-<version>-Ubuntu[22 20 18]-STABLE.run
$ sudo ./PhotoneoPhoXiControlInstaller-Ubuntu-<version>.run --accept
/opt/Photoneo/PhoXiControl-<version>
```

3. Successful installation output will show you the installation path and will ask you to reboot.

4. Restart your computer.

```
$ sudo reboot
```

5. Run PhoXi Control from a command line or from a launcher.

```
$ PhoXiControl
```

Default installation paths:

- Installation folder:
  `/opt/Photoneo/PhoXiControl-<version>`
- Application data folder:
  `/home/<username>/.PhotoneoPhoXiControl`

Multiple Versions of PhoXi Control

Multiple versions of PhoXi Control can be installed on one computer. This is achieved by choosing different installation directories during the installation. The process is as follows:

Windows

On Windows, the installer asks for a path where the application should be installed. By default, this path is

`C:\Program Files\Photoneo\PhoXiControl-<version>`

When another version of PhoXi Control is installed, a different path should be specified, for example,

`C:\Program Files\Photoneo\PhoXiControl-custom`

Linux

Ubuntu installer automatically installs PhoXi Control in the following folder:

`/opt/Photoneo/PhoXiControl-1.12.x`

To install PhoXi Control to a different folder, pass it as an argument to the install script:

```
$ sudo ./PhotoneoPhoXiControlInstaller-1.12.x-Ubuntu.run /your/custom/path
```

To match the old behavior of the Ubuntu installer use the original location:

```
$ sudo ./PhotoneoPhoXiControlInstaller-1.12.x-Ubuntu.run /opt/Photoneo/PhoXiControl
```

Running the Application

By default, PhoXi Control starts automatically after the operating system is started. Users can change the default application behavior by setting up specific environment variables or by command line parameters.

Disabling GUI or 3D Viewer

Disabling GUI or the 3D Viewer is used mainly in the following situations:

- Need to save computer resources or when the computer has insufficient performance (3D Viewer)
- Applications with their own GUI using only the API

Desired behavior	Action needed
Permanently disable GUI	Set environment variable: `PHOXI_WITHOUT_DISPLAY=ON`
Permanently disable the 3D Viewer only	Set environment variable: `PhoXi3DViewer=0`
Temporarily disable GUI	Run script: - Windows: `%PHOXI_CONTROL_PATH%\bin\support\PhoXi_Control_as_background_process.bat` - Linux: `/opt/PhotoneoPhoXiControl/bin/support/RunPhoXiControlOnBackground.sh`
Temporarily enable GUI (when permanently disabled by the environment variable)	Run script: - Windows: `%PHOXI_CONTROL_PATH%\bin\support\PhoXi_Control_enable_gui.bat`

Command Line Parameters

PhoXi Control can be started with the following command line parameters:

```
-minimized
```

- PhoXi Control will be started minimized.

```
-lock
```

- Used to lock the application against unauthorized use. The application will ask you to set up a password and then to restart. Users are prompted to enter a password every time they start the application. The API can connect to the device only after the password is entered.

```
-unlock
```

- Removing the authorization request after the application startup. The application prompts you to enter the password and then restarts. This means PhoXi Control can be used without authorization.

```
-kill
```

- Any instance of PhoXi Control will be switched off.

```
-forceRun
```

- Used together with -kill. While -kill alone stops all running instances of PhoXi Control, additional argument `-forceRun` ensures that a new instance of PhoXi Control will be started as next.

Example command:

```
PhoXiControl -kill -forceRun
```

Graphical User Interface

Overview

The initial window of the application is called Network Discovery. It displays a list of all the devices available on the network. A new connection to the device opens a new Device window. Device windows can be organized by dragging the window title. The application minimizes itself into the system tray. To close the application, use the Menu or right-click on the system tray icon and select the option to **Turn off PhoXi Control**.
The version of the PhoXi Control is displayed in the title bar of the GUI window.

Drop-down menus

This chapter explains the use of drop-down menu items.

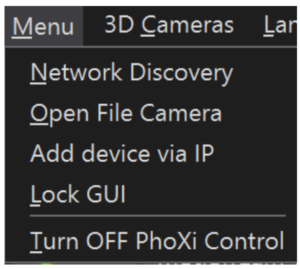
Menu Items

Network Discovery

- Opens the Network Discovery window. After a successful connection to the device, the Network Discovery window is usually hidden in the background.

Open File Camera

- Loads 3D scans in *.praw format into a new File Camera, which remains available until the application is shut down.



Add device via IP

- Allows adding Photoneo 3D Sensor into PhoXi Control via its IP address

Lock GUI

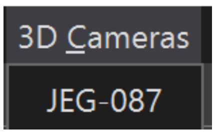
- Option to protect GUI against unauthorized use.

Turn Off PhoXi Control

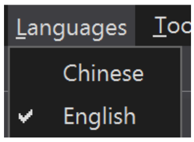
- Shuts down the application. (Using the standard close window button will only hide the application in the system tray).

3D Cameras

- A List of active devices allows switching between windows of the connected devices or virtual File Cameras.



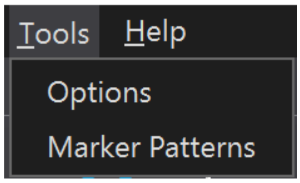
Languages



- Switch between supported languages.

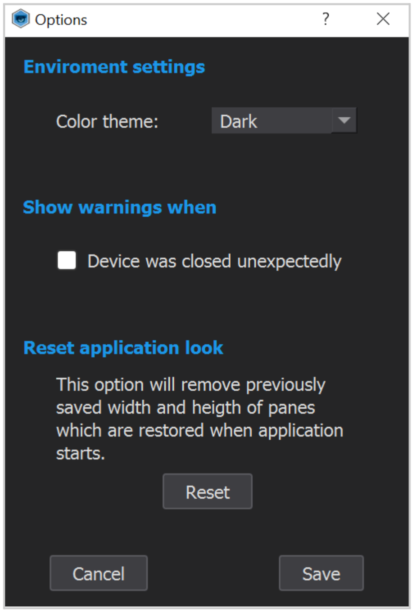
Tools

Marker Patterns



- This option opens a directory containing folders with marker patterns and their metadata.
- Marker patterns are used for changing the coordinate space and device calibration (multiple devices together, hand-eye calibration, calibration with an external 2D camera)
- Marker patterns come in 4 sizes that are intended for different scanning distances. The applicable scanning distances for each pattern are stated in the name of the corresponding pdf file.

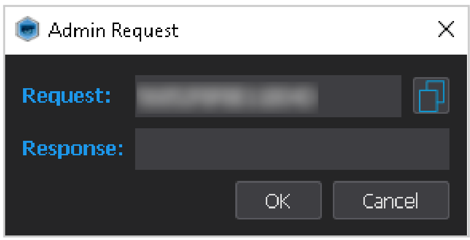
Options



- Switching between different color themes.
- Disabling default warning behavior.
- Reset application look
  - The application remembers your preferences for showing UI components. Use this function to reset PhoXi Control to the default layout. Useful mainly when switching between monitors with different DPI and resolutions.

Help

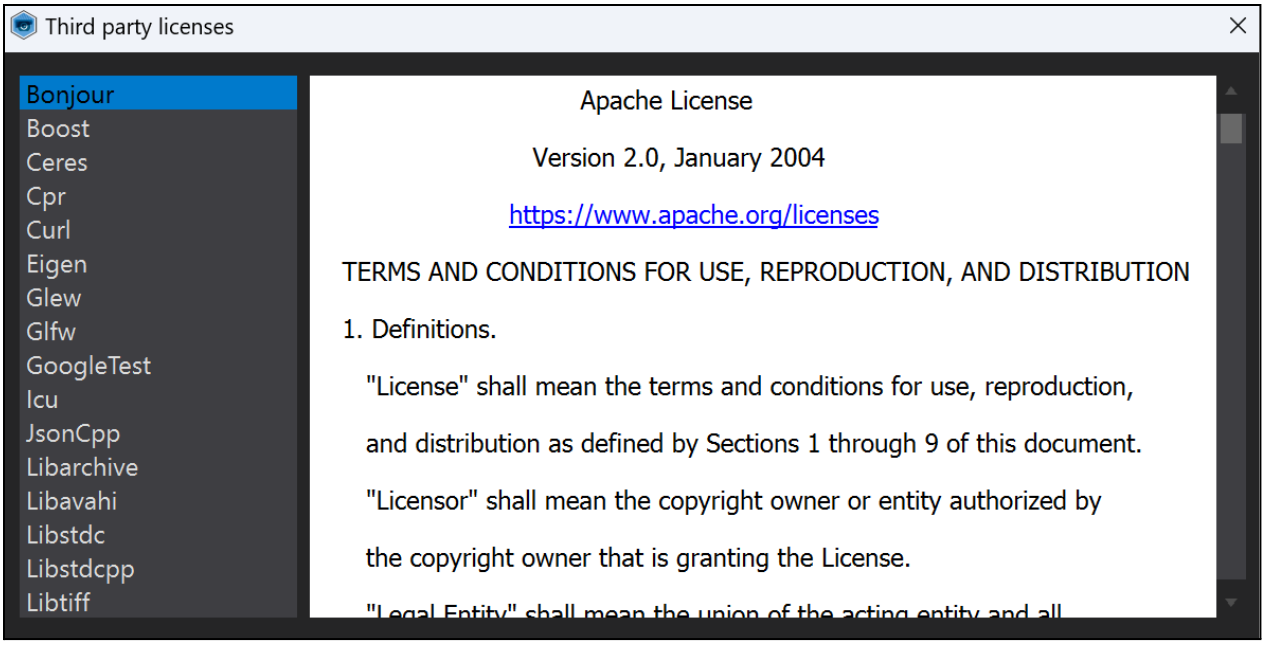
Switch to Admin



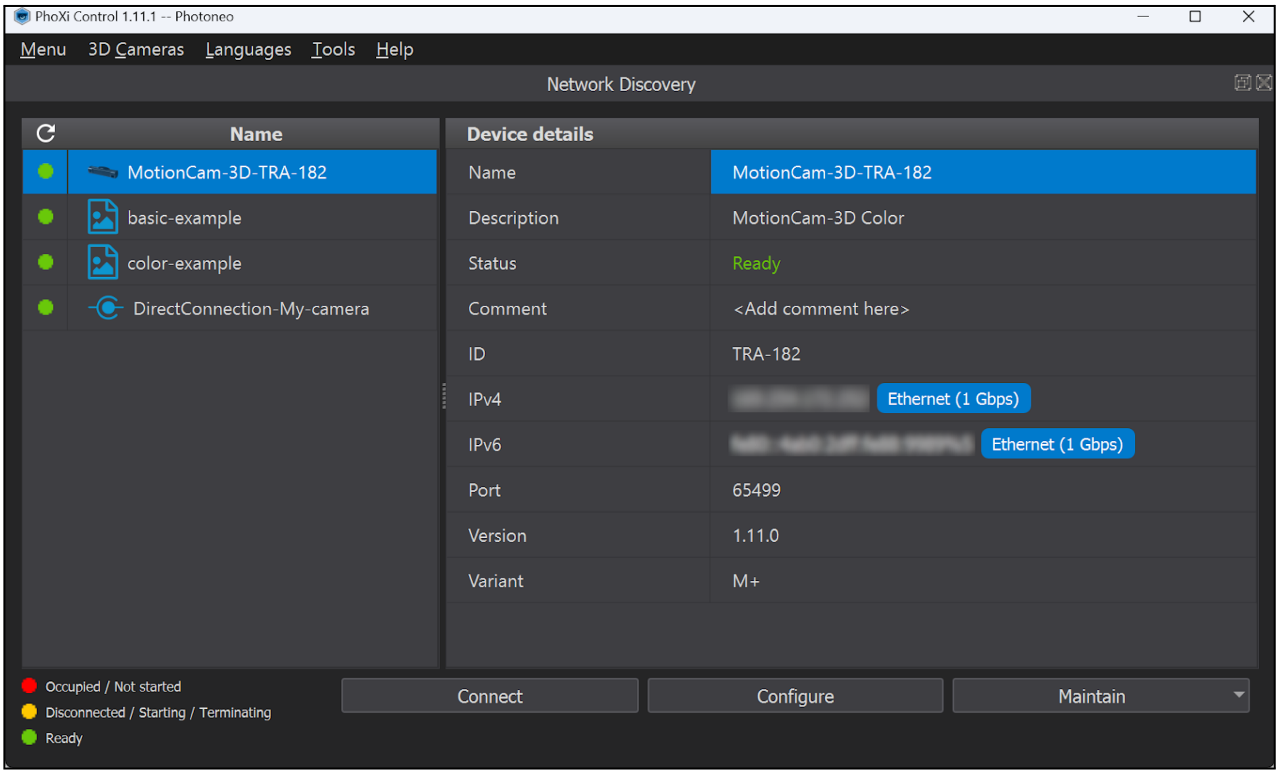
- This function is only used by Photoneo staff during remote sessions to temporarily set admin privileges.

About

- Displays the current PhoXi Control application version and links to the Photoneo web page.
- Third Party Licenses button displays a comprehensive overview of the 3rd party licenses.



Network Discovery



The Network Discovery window lists all available devices on the network. After the application starts, please wait a moment until all devices are found or click on the refresh button in the upper left corner above the displayed devices.

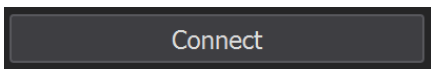
If your device is not listed, please make sure that it is turned on and connected to the network. After a short time, the device will appear on the list. The time required to discover a newly powered device should be under 3 minutes. The time required to discover the device after it was disconnected or the connection was lost should be under 45 seconds.

If no device is shown on your list, please check your network configuration. See the chapter Configuring Device Network Settings for more information.

Selecting a device will display its details such as name, description, status, model, and ID, as well as its network settings and firmware version. Not all information is available for File Cameras or for devices with an older firmware version. For example, a *comment* field in the network discovery allows the user to describe the device with a custom message (up to 1024 characters). This is possible only for devices with firmware versions higher than 1.9.0. A comment can be added by right-clicking the *Comment* section which can be found in the *Device details* in the *Network Discovery* section.

IPv4 and IPv6 address rows contain dynamic interface labels. The labels dynamically change color: red for non-routable addresses, orange for sub-1Gbps interface speed, and blue for normal operation (1Gbps).

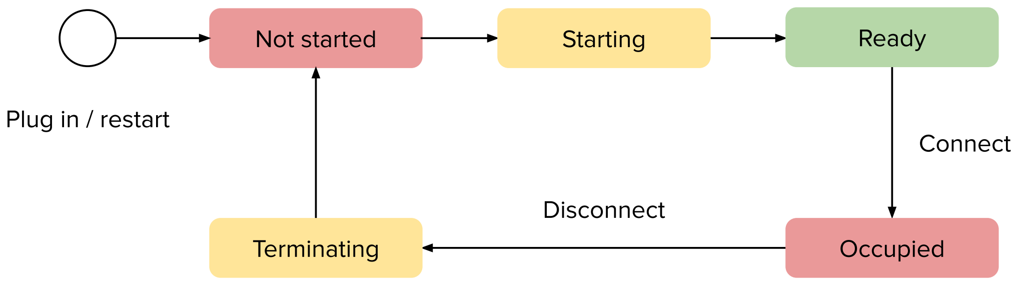
Connecting to the device



To connect to a device, simply double-click on the device name or select it and click **Connect**. It usually takes about 2-5 seconds for the device to connect; however, based on the internal state of the device, it can take up to 1 minute. It is only possible to connect to a device in a Ready state. Once the device is connected, a new [Device window](#) will open and its status in Network Discovery will change from Ready to Occupied. Therefore, if you share a device with other users, make sure you disconnect from it after you finish using it. The following list represents all the possible device states.

Please ensure that you are using a wired network connection to the device. WIFI connections are not recommended due to lower speed and reliability.

Device States Overview



Not started	The device has just been plugged in or was restarted. After a few seconds, the status will change to Starting.
Starting	The device is starting its operating application. After a few moments, the status will change to Ready.
Ready	The device is ready for a new connection.
Occupied	The device appears as occupied after the connection is established. Only one connection at a time is permitted. It is not possible to connect to an occupied device.
Terminating	The device is being terminated after the user disconnects from the device. After a few moments, the status will change to Starting and Ready.

Relationship Between GUI and API

Connection to the device via API causes the GUI to open the Device window similar to when connecting via the GUI. When you connect to the device through the GUI, it is possible to work with the device through API.

File Cameras

Every 3D scan captured by PhoXi 3D Scanner or MotionCam-3D can be saved into a Photoneo RAW (*.praw) file. The main advantage of this native format is that it contains all the information about the scanning configuration and additional information about the device. All other formats can be exported from *.praw files.

Additionally, dynamic scans taken by MotionCam-3D can be saved into a Photoneo MotionCam-3D RAW (*.pmraw) file. This format is capable of creating a file camera consisting of a single file but containing many scans.

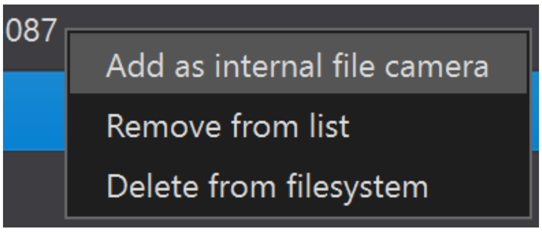
Single or multiple *.praw files can be loaded into PhoXi Control either by using the menu or by dragging & dropping the files anywhere on the GUI. Opening N *.praw files will create a new virtual device called File Camera. This virtual device behaves in a very similar way to a regular device. In case of drag-and-dropping multiple *.praw files or opening a *pmraw file, triggering a scan opens the next scan.

PhoXi Control already contains 2 example file cameras, which contain 1 or more captured frames and can be used for testing purposes.

Note: *The scanning parameters for File Camera are read-only, as these scans have already been taken and processed.*

Network Discovery window offers specific options for File Cameras when **right-click** is used or by using a keyboard shortcut:

- **Add as internal file camera**
  - Internal File Camera remains in Network Discovery even after you restart the PhoXi Control application. Otherwise, the File Camera is present only until the end of the application.
- **Remove from list** (Delete key)
  - This option will remove the File Camera from the list of devices, but keep underlying files on disk.
- **Delete from the filesystem** (Shift + Delete keys)
  - This option will remove the File Camera from the list of devices and also delete underlying files from the disk.



Setting the order of scans in an internal file camera

After creating an internal file camera using a group of scans, it is possible to define the order of the loaded scans using an *order.cache* file in the directory of the internal file camera which can be found at::

```
%AppData%/PhotoneoPhoXiControl/File3DCameras/<file camera name>
```

Create a file *order.cache* and open it in a text editor. The order of the scans being loaded in the internal file camera can be defined as follows:

- Defining the order by name (alphabetical order)
  - Line 1: “order_by_name”
- Defining the order by the last modified date/time
  - Line 1: ”order_by_modified_time” custom
- Defining a custom order (files not mentioned will be skipped)
  - Line 1: “scan_1.praw”

- Line 2: “scan_14.praw”

Note: The file camera needs to be set to an Internal File Camera in order to *order.cache* config file to affect the order. Scans loaded to PhoXi Control by *Menu → Open File Camera* or by dragging the scans will be normally loaded in the order they were selected in their original directory.

Scanning Settings and *.praw Files Compatibility

The scanning settings are applicable to the device depending on its FW version. A PRAW file contains complete data about the scan, including scanning settings. It needs to be noted that older versions of PhoXi Control might not display all parameters of devices with newer FW.

Configuring Device Network Settings

To ensure the smooth operation of the device with your computer, make sure you follow the guidelines for hardware setup and network connection described in the next sections. Before you connect your device to any network, make sure you know how the network is set up or have the administrator of your network do it for you.

Connect the network cable to the device first, then connect the power cable.

Network Media

Always use cables of a Cat5e category or higher that support Gigabit Ethernet or 10 Gigabit Ethernet standards. Do not use cables of the Cat5 category as their speed is usually 10 - 100 Mbps, which is too low to obtain a good scanning performance. To distinguish these two types of cables you can try

- reading the labeling on the PVC jacket,
- using the Test speed tool,
- and looking at the IPv4 and IPv6 address rows in the *Networks Discovery* tab which contain dynamic interface labels based on the connection speed.

WiFi connections are not recommended and may result in random disconnection.

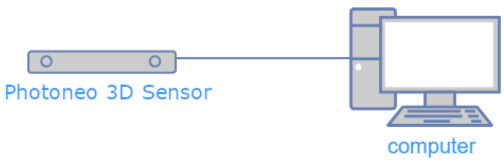
If you are connecting your device to a switch, make sure it is able to run at 1 Gbps or more.

Network Topology

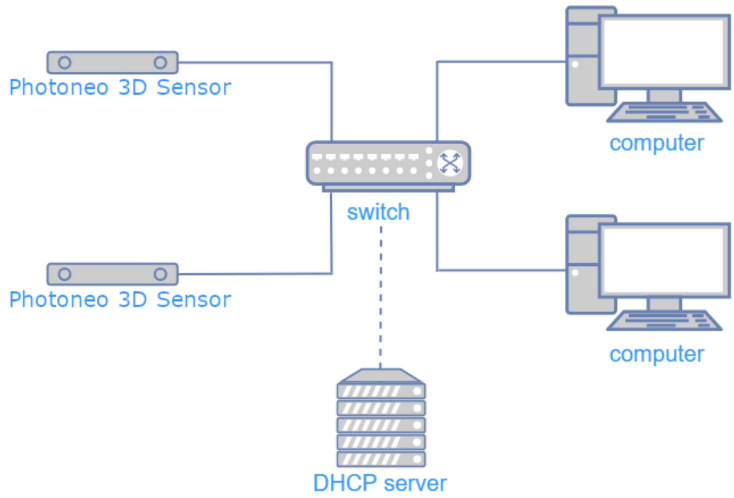
We recommend connecting Photoneo devices directly to a computer or a local network, ideally keeping them air-gapped.

Photoneo devices use Zeroconf technology for service discovery. However, this technology is generally not routable outside of local sub-networks. Therefore, the supported network topologies are

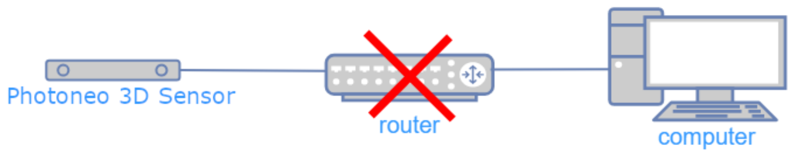
- Direct connection between the user's PC and Photoneo 3D Sensor.



- Star topology with one or more user PCs and one or more Photoneo 3D Sensors connected to a switch, all on a single local subnet. The switch has to be able to run at 1 Gbps or more.



If you connect your device to your network via a router, it will not be accessible since routers usually connect two different subnets. Zeroconf technology is routable only in the same subnet.



Network Configuration

If you are not sure how your network works or how to set up an IP address assignment, contact your network administrator.

Photoneo 3D sensors are network devices, therefore, they need a unique IP address so that any other computer on the same network can identify them, and communicate with them. IPv4 addresses usually serve this purpose.

There are three ways the device can obtain an IPv4, and how it can be discovered in the network:

- **Dynamic IP assignment via DHCP** (Dynamic Host Configuration Protocol). Ask your network administrator if you have a DHCP server available on your network.
- **Dynamic IP assignment via Zeroconf technology** (for networks without DHCP). Thanks to Zeroconf technology the device is assigned an IPv4 address automatically and can be discovered on the network with no further input from the user. IPv4 addresses assigned by Zeroconf come from the 169.254.0.0/16 network as described in RFC 3927. Some Ubuntu systems require a Link-Local connection for the correct Zeroconf IP address assignment.
- **Static IP address assignment.** A static IP address has to be set up manually. Ask your network administrator for a valid and available IPv4 address before configuring it. Be careful not to set an IP address outside of the network you are currently in, as this would make the device in the network undiscoverable. Once you set a static IP address for your device, write it down and store it in case you need to use the device in a different network or want to change your network parameters in the future.

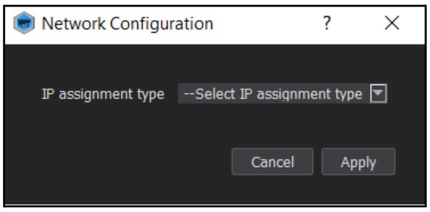
Note: Zeroconf network discovery works with Link-Local connections on Ubuntu OS. Using Zeroconf without a Link-Local connection may result in IPv4 addresses not being assigned correctly. Symptoms include missing IPv4 address in the corresponding field in PhoXi Control and command

```
ip addr show <INTERFACE-NAME>
```

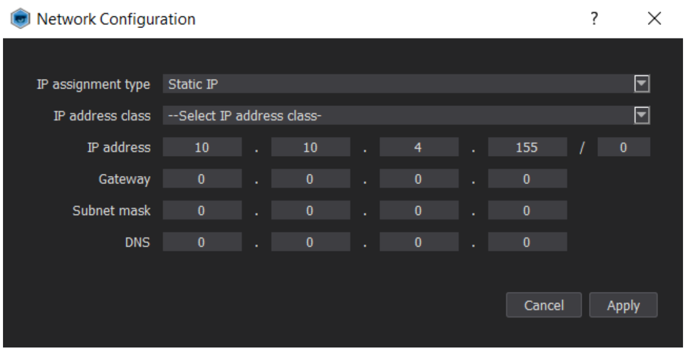
not showing 169.254.x.x IPv4 address. Read instructions on how to create a Link Local connection in the section Troubleshooting.

Note: A fixed IPv6 link-local address is assigned to each device. The address starts with fe80:: and can also be used to connect to the device. IPv6 connection is preferred over IPv4.

The three different IP assignment types are reflected in the PhoXi Control setup. The configuration can be done by clicking the Configure button in the lower part of the Network Discovery window. You can select between DHCP and Static IP. The device restarts after every change in network configuration.



Choosing Static IP opens a new window where IP address class, IP address, Gateway, Subnet mask, and DNS can be set up. Please note that setting an invalid IP address will make the device undiscoverable on the network, so make sure the IP address is valid and not outside the subnet you are on.



By default, the devices use DHCP for IP assignment. On networks with no DHCP, the IP will be assigned by Zeroconf.

Using Zeroconf technology for service discovery does not rely on any specific PhoXi Control configuration - the IP assignment type can be left blank or set to DHCP. After the device is connected to a network without a DHCP server, it should already be available in PhoXi Control. The only requirement for Zeroconf to work correctly is to have Avahi installed on Linux systems and Bonjour service on Windows systems.

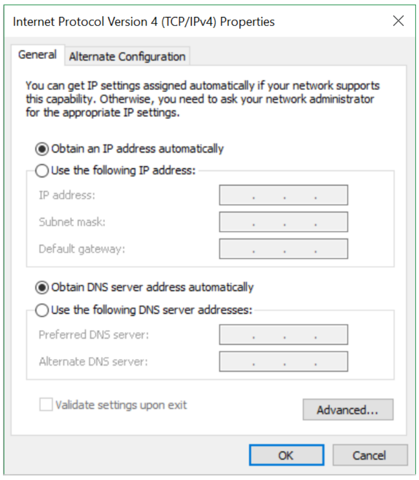
If a device is moved from a network with a static IP address assignment to a network with a dynamic IP address assignment, before the device is disconnected, its IP assignment type should be changed to DHCP.

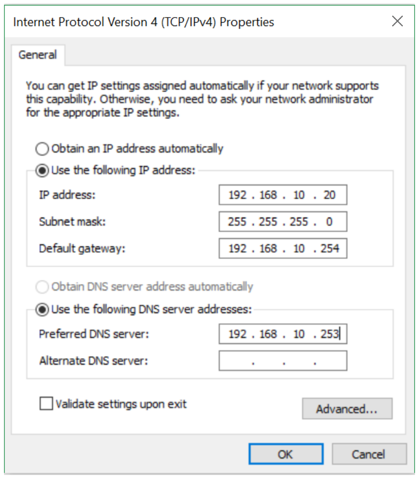
Checking Computer Network Configuration

Note that the IPv4 addresses used in the following pictures are just for illustrative purposes and may not work on your network.

Windows

Automatic DHCP method	Static IP

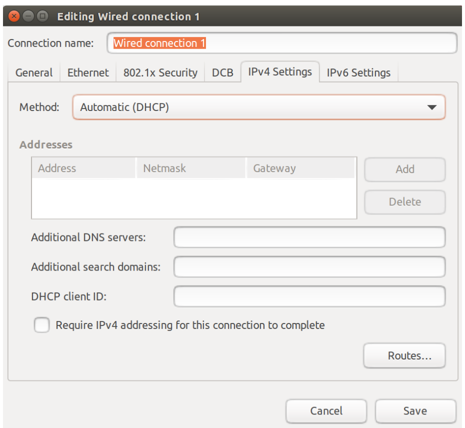


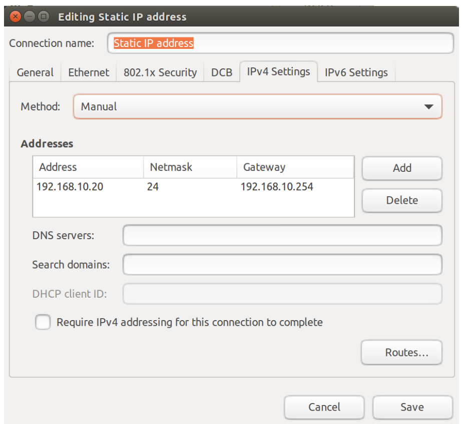


1. Network and Internet Sharing Center → Change Adapter Options
2. Right-click on the Ethernet adapter, and select Properties.
3. Open Internet Protocol Version 4 (TCP/IPv4).
4. For the automatic DHCP method select Obtain IP automatically.
5. For the static IP setting select Use the following IP address. Then the IP address, Subnet mask, and Default gateway should be filled in.

Ubuntu

Automatic DHCP method	Static IP





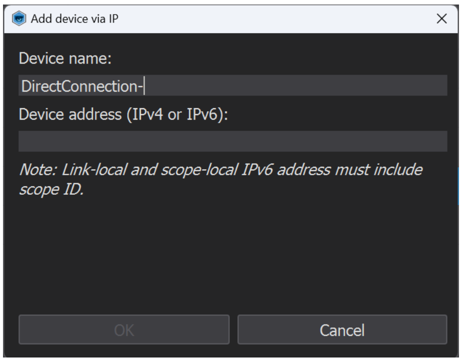
1. Network Connections → Ethernet
2. Add or edit connection
3. In the new window select the IPv4 Settings tab
4. Check which Method is selected. For DHCP or Zeroconf it should be Automatic (DHCP) or Link-Local Only
5. For a static IP - the Method should be set to Manual, and the Address, Network, and Gateway should be filled in

Network Environment Variable for IPv4 Preference

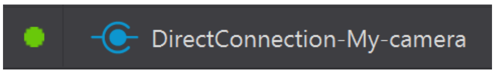
If it is possible, the scanner always establishes a connection via IPv6. To prefer an IPv4 connection before an IPv6 connection, set the environment variable:

```
PHO_PREFER_IPV4 == ON
```

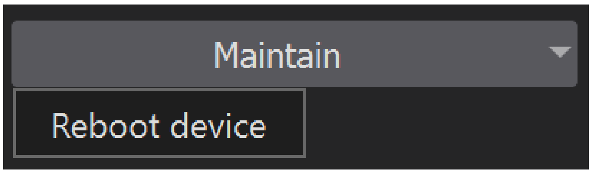
Adding device via IP address



A device can be added using its IP address in the **Menu** -> **Add device via IP** which displays the following dialog. A device added in such a way will carry a different icon and user-defined name “DirectConnection-<User-defined>”



Maintain

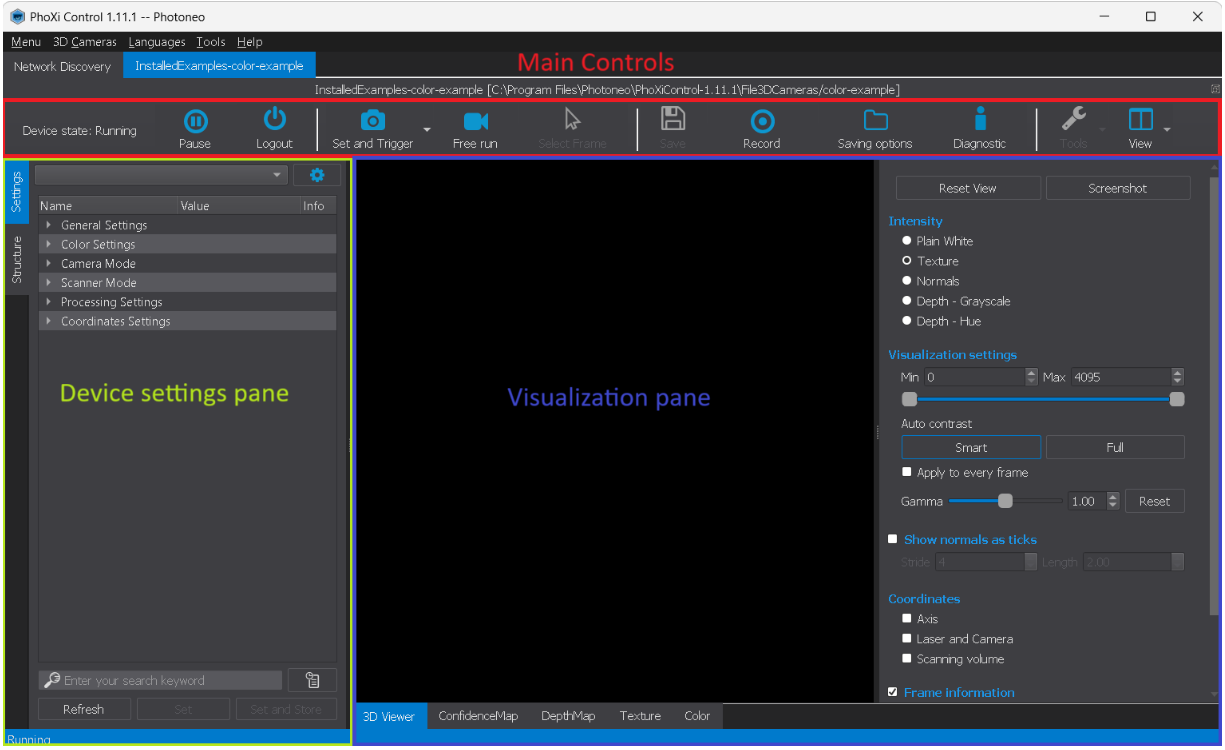


The Maintain button located and the very right-bottom corner of the Network Discovery tab and allows the user to Reboot the device.

Device Window

The Device Window is the main screen used to control the device. It is divided into 3 sections:

- Main controls (red)
- Device settings pane (green)
- Visualisation pane (purple)



Tip:

Once the window is open, hit F5 or the **Trigger scan** button to trigger a scan.

Main Controls

This pane provides the basic functions and advanced tools for triggering and saving scans and for safe disconnection from the device.

Acquisition Modes - Triggering Scan

- Single scan mode (default)
  - The device waits for the trigger command to capture a 3D scan.
  - Use the **Trigger scan** or **Set and Trigger button**
    - The Set and Trigger button automatically temporarily saves changes made in the Device Settings or Structure tabs and triggers a scan.
- Free run mode
  - The device performs consecutive scans at maximum speed (if not slowed down by the Maximum FPS setting).
  - To turn the free run mode on or off, use the button **Free run**.
  - When the device is in Free-run mode, you can pause and restart the acquisition with the **Pause / Start** button.

Photoneo 3D Sensors can also use a hardware trigger to acquire scans. In hardware trigger mode, the scan is triggered by a signal change on a specific GPIO pin. More information can be found in the section Hardware trigger.

You may prevent the device from taking a scan by using the Pause button at any time. Using this function is more intuitive in the API, where a secondary application may prevent another application from triggering the scan.

Saving 3D Scans

PhoXi Control allows you to save scans both manually and automatically. The automatic saving mode is called recording.

The output can contain:

- Point cloud: an organized set of 3D points.
- Normals: for each captured 3D point, the normal vector expresses the orientation of the captured surface.
- Texture: grayscale intensity or RGB values for each 3D point.
- Depth map: the depth data for each pixel.
- ColorCameraImage: 2D RGB texture captured by the color camera unit in MotionCam-3D Color
- Confidence data: the data expressing the estimated noise of the acquired point.
- Information about the device, such as the ID number or calibration data of the image sensor
- Information about the 3D scan, e.g. duration, scanning parameters, coordinate system

All these data can be stored only in the native Photoneo RAW formats (*.praw or *.pmraw). They can be opened later in PhoXi Control as a File Camera and converted to any other supported file format.

Other scan formats (PLY, PTX, TIF) are capable of storing only partial information, usually only point cloud, normals, and texture. The saving options dialog enables the user to choose from output structures saved in each file format.

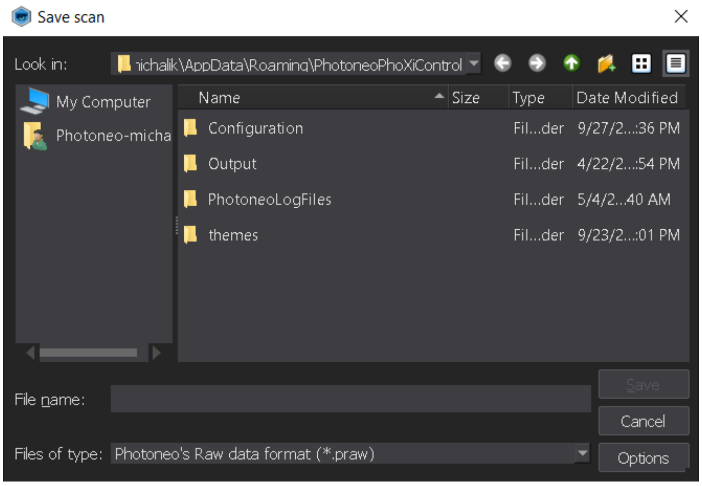
List of Supported Formats

- Photoneo RAW data format (*.praw)
- MotionCam-3D RAW data format (*.pmraw)
- Stanford's PLY (*.ply)
- Leica's PTX (*.ptx)
- Text file (*.txt)
- Raw images in tif (*.tif)

For each format, you can choose which data to store (point cloud, normals, texture...). For further information, see the Saving Options section below.

Saving Single Scan Manually

After triggering a scan, use the **Save** button to open the saving dialog. Choose one of the supported formats and saving directory.



Saving Scans Automatically - Recording

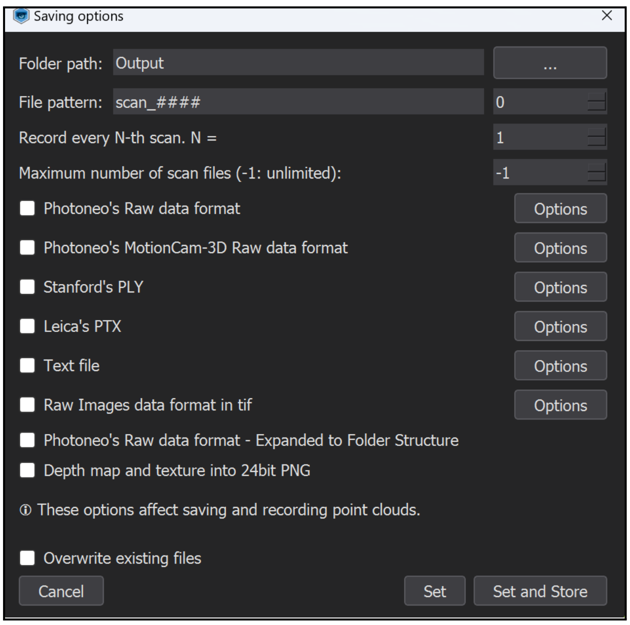
Click the **Record** button to start or stop automatic recording. Before using this functionality, use the saving options dialog to define the destination and file formats in which the acquired scan should be stored. Using *.txt format to save data during recording is not recommended.

When recording is used in free run mode, the disk writing speed may limit the number of stored frames and some frames might be skipped and not stored. This usually happens when multiple file formats are being saved at once or when compression is used to save *.praw files. If this occurs, the status bar in PhoXi Control displays the message “Scans cannot be saved, they are generated faster than the computer can process them. Consider changing saving options.”.

Saving Options

Use the button **Saving Options** to configure how the 3D scans and corresponding data are saved.

The Folder path and File pattern fields are used by automatic recording. The folder path defines the destination where the scans will be saved. The file pattern defines the name of the files, hash signs will be replaced by a counter starting at the defined value. The image on the right depicts the settings that will save the scan with the name *scan_0000*. Users can define the frequency of saved scans by changing the *N* parameter. Additionally, the number of scans can be limited by the *Maximum number of scans* parameter. Use the checkboxes on the left to select all the formats in which the scan should be saved during automatic recording. Use the **Options** buttons on the right to define which data should be saved when using the selected file format.



Tip: *Any scan in a *.praw / *.pmraw format can be converted into any other format by loading it into PhoXi Control and choosing a different file format in the saving dialog.*

Specifics of File Formats

- An Explanation of the Confidence map can be found in the 2D Image Tabs section
- Using a text file to save data may result in longer saving time, depending on the speed of your SSD or HDD. The same is true when the binary format is not used in the PLY format.
- TIF file is one-dimensional, therefore it creates multiple files for each stored component.

Understanding Scanner Outputs - Topology of the 3D Scan

The point cloud acquired by PhoXi 3D Scanners is topologically organized according to the image sensor. An image from the image sensor is called texture. There is one computed 3D point for each pixel in the texture. If any point from the scene is not illuminated by projection (usually because of shadows) the corresponding pixel has no 3D value (its coordinates are [0, 0, 0]) and is called a “zero 3D point”.

For example, the pixel at position [x= 2010, y =350] in the texture is the (2064*350 + 2010) = 724410-th point in the point cloud.

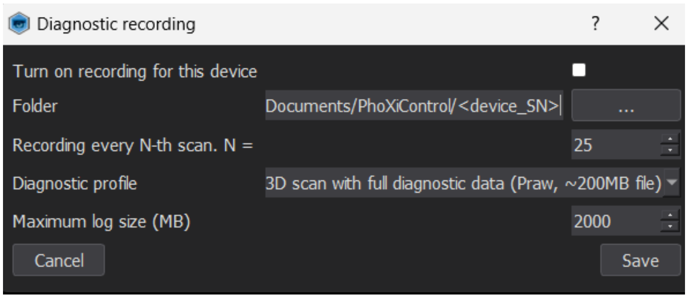
PhoXi Control also allows unorganized point clouds to be saved. In **unorganized point clouds**, the "zero 3D points" are omitted and not saved; therefore, the topology is lost. If you have an unorganized point cloud and would like to restore its organization, you will need to iterate over the point cloud and find a corresponding pixel in the depth map by comparing the Z value.

Understanding MotionCam-3D Output - Topology of the 3D Scan

On MotionCam-3D the relationship between the number of pixels on the image sensor and the number of points in the point cloud is not 1:1. The ratio depends on the Sampling and Output Topologies.

Diagnostic recording

This tool serves to save scans for diagnostic purposes independently from the client application. The setup allows choosing how often and where the scans are saved, and what information is contained within them. This is selected via the diagnostic profile dropdown menu. When the maximum log file size is surpassed, deletion of *.praw files will commence, beginning with the oldest *.praw file. This tool can save:

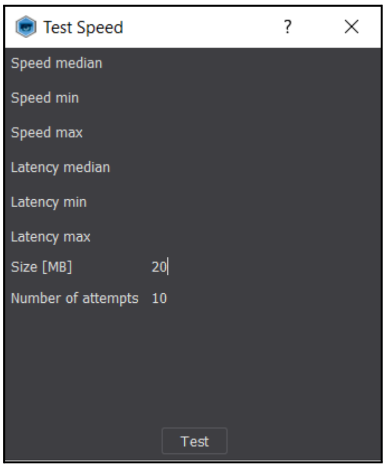


- 3D scans
- 3D scans with diagnostic data
- 3D scans with full diagnostic data (default, recommended)
- 2D outputs
- 2D outputs with diagnostic data

Note: Different diagnostic profiles have different performance impact resulting in higher processing or transfer time.

Tools

Test Speed



This tool can be used to measure the transfer speed between the device and the computer running PhoXi Control. Use the default settings for “Size [MB]” and “Number of attempts” in case you don’t suspect any connection issue.

If you suspect there is a slow connection speed, change the parameters “Size [MB]” and “Number of attempts” to lower values.

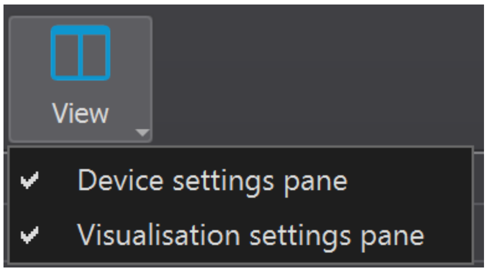
The result of the test is shown as Speed and Latency with their minimal, maximal, and median values. On 1 Gbps networks, the expected speed should be around **100 MB/s** with a latency below **6 ms**.

Low speeds significantly prolong the overall scanning time. Check if the network cables are of a Cat5e category or higher. Lower-category cables have a speed of around 10 MB/s.

Tip: Besides the ability to use the Test Speed, IPv4, and IPv6 address rows in the *Networks Discovery* tab contain dynamic interface labels. The labels dynamically change color: red for non-routable addresses, orange for sub-1Gbps interface speed, and blue for normal operation (1Gbps and higher).

View

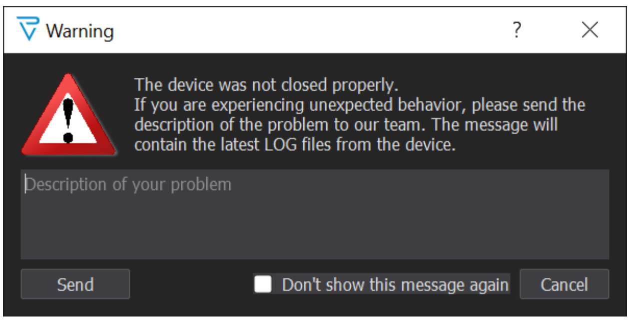
Toggling the visibility of GUI components:



- Device settings pane:
  - The pane on the left side contains device settings.
- Visualisation settings pane:
  - The pane on the right-hand side contains options to change the visualization of the point cloud.

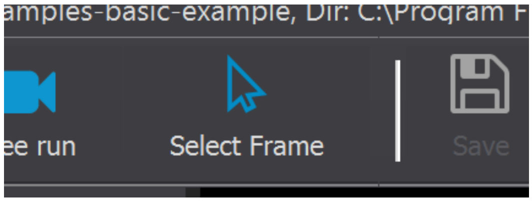
Device Logout

Clicking the **Logout** button disconnects PhoXi Control from the currently selected device. Closing PhoXi Control without disconnecting from the scanner may produce a warning when the next connection is established.



Select Frame

This setting is only available for viewing File Cameras. It opens a new window where you can select the index of the *.praw or a specific scan in a *.pmraw file that will be displayed after the next scan is triggered. The file is selected based on the order of the files in the directory (index starts with 0).



Device Settings Pane

- Contains the scanning profiles selector and scanning parameters (tab Settings).
- Allows control of the output data received from the device (tab Structure).

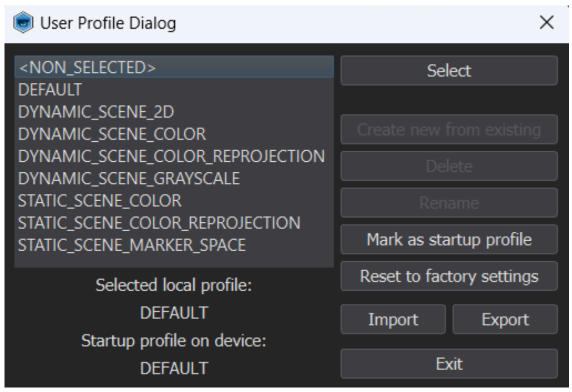
The set of scanning parameters and profiles depends on the firmware version of your device. This User Manual is based on FW version 1.12.

Scanning Profiles

Scanning profiles allow users to easily change multiple scanning parameters at once. There are several profiles pre-configured with different scanning parameters for different uses. Factory profiles are not editable, and cannot be deleted or renamed, however, it is possible to clone them and edit the cloned profile. A different set of factory profiles is available for MotionCam-3D and PhoXi 3D Scanner. It is also possible to define custom profiles.

Use the cog button to enter the advanced configuration.

- **Select** - switch to the chosen profile.
- **Create a new from existing** - this creates a new duplicate profile from your selected profile. The newly created profile can be modified in the Properties tab and stored on the device.
- **Delete** - deletes user-created profile.
- **Rename** - renames the user-created profile.
- **Mark as startup profile** - the device will be started with this user profile.
- **Reset to factory settings** - resets settings to factory default.
- **Import** - imports a user profile from a *.phop file.
- **Export** - saves a user profile into the *.phop file.



Using a Custom Profile

- Use the button and create a new profile from the existing one, which is closest to your use case. You might want to mark it as a startup profile as well.
- Modify the desired parameters to your needs.

- Use the **Set and Store** button below to store the settings in your custom-made profile permanently.

Scanning Parameters

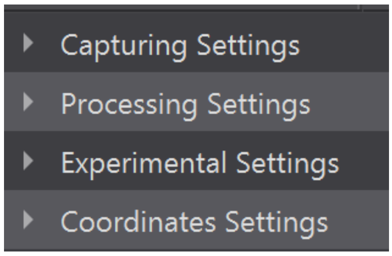
The set of scanning parameters available depends on the version of the firmware installed on the device. This manual is based on firmware version 1.12.0.

The scanning process consists of three phases: capturing (or acquisition), processing (computation), and transfer.

Scanning parameters are divided into several logical groups. These groups differ for the PhoXi 3D Scanner and MotionCam-3D and MotionCam-3D Color.

PhoXi 3D Scanner

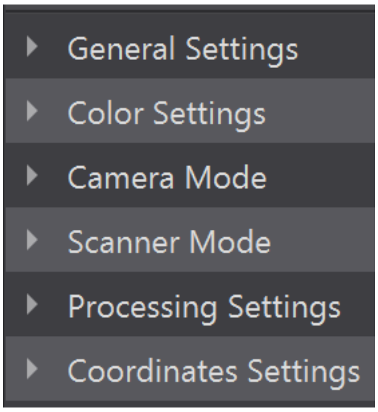
- Capturing settings - these options change exposure times and methods of projecting light patterns.
- Processing settings - these options affect the computation of the point cloud and allow the setting of filtering criteria such as the region of interest.
- Coordinate settings - defines the coordinate space for the point cloud.



MotionCam-3D

- General settings - settings that control the operating mode of MotionCam-3D (camera or scanner mode)
- *Color Settings - settings for 2D RGB camera unit
- Camera Mode - settings for acquisition in camera mode
- Scanner mode - settings for acquisition in scanner mode
- Processing settings - point cloud computation and filtering (ROI)
- Coordinate settings - define the coordinate space for the point cloud

*only with the MotionCam-3D Color



The total scanning time is the sum of the time required for acquisition (defined by capturing settings), computation (defined by processing settings) and transfer (defined by [Output structure](#)).

The use of scanning parameters is described in the [Scanning Guide - Parameters](#) at the end of this User Manual.

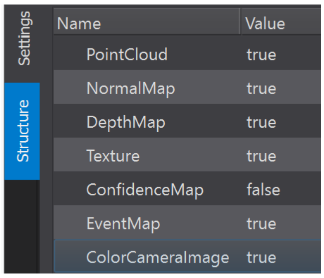
Controls

- **Search box** (Ctrl+F)
  - Search setting by name.
- **Set button** (Ctrl+S)
  - Sets scanning parameters for the current session only. Settings are discarded after the Scanner is disconnected.
- **Set and store button** (Ctrl+Shift+S)
  - Stores scanning parameters permanently to the Scanner memory (applies to the current profile).
- **Refresh button** (Ctrl+R)

- Retrieves current settings for the selected profile from the Scanner memory.

Structure

Output structure lets you choose what kind of data will be retrieved from the device. Any changes to the output structure will affect the transfer stage. The read-out time can be sped up by selecting only the data which you need for your application.

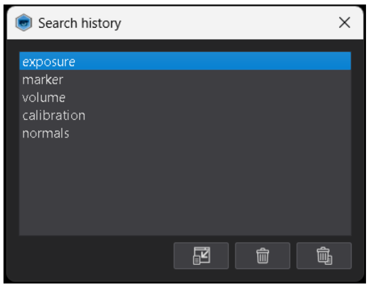


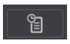
PointCloud	The point cloud is a set of measured 3D points. Each 3D point has the coordinates X, Y, and Z in the point cloud coordinate space (see Coordinate settings). The point cloud has a topology that depends on the device in use. On PhoXi 3D Scanners each point in the point cloud corresponds to the pixel on the image sensor. On MotionCam-3D the points are organized in superpixel topology - 2 or 4 3D points per one superpixel in irregular patterns or can be interpolated into a grid topology that resembles that of the scanner. Unmeasured points (pixels) caused by shadows are given the default coordinates [0, 0, 0]. Based on the saving options, these unmeasured points might or might not be saved. The point cloud can be examined in the 3D Viewer tab.
NormalMap	The normal vector for each 3D point can also be calculated. The normal vector is perpendicular to the area surrounding the point (see Normal estimation radius). Normals can be inspected in the 3D Viewer tab after selecting the display parameter in the right pane.
DepthMap	The “depth” of a point is the absolute 3D distance from the image sensor to the measured point (the ray of light that hits the surface of the object). The DepthMap is, therefore, always in the camera coordinate system and corresponds to the Z coordinate value in the point cloud. Note: Even when you change the point cloud coordinate space, the DepthMap always shows the distance (depth) in the camera coordinate system.
Texture	Texture is the 2D photo of the scene. The texture is either in grayscale (in the red spectrum - the source of the illumination is either LED diode or laser projection) or Color captured by the RGB camera unit on MotionCam-3D Color (source of the illumination is either ambient light or internal white LED). The texture is also used to color the 3D point cloud.
ConfidenceMap	For each measured 3D point, the “confidence” value expresses certainty about the accuracy of the point measurements. For example, a confidence value of 0.12 means that the estimated error for a point measurement is 0.12 mm. This value is based on a heuristic method that considers the light conditions for each pixel.

EventMap	EvenMap is a 2D output available only on MotionCam-3D. For each measured point, it shows the time when it was captured. The time is in milliseconds and is measured from the beginning of exposure - each point can have a value from 0 up to the total duration of exposure - ie 10 ms.
ColorCameraImage	This output is only accessible on the MotionCam-3D Color. When set to true, it outputs an image from the RGB camera unit in the resolution specified in the Color Settings in the settings tab.

Note: Adjusting the resolution of the ColorCameraImage can affect the performance of the MotionCam-3D Color.

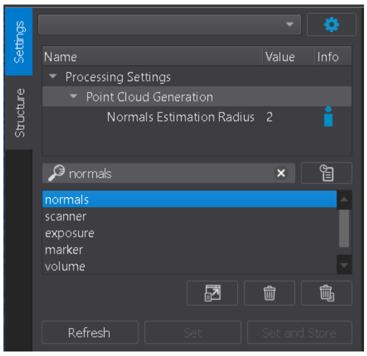
Search history



 icon situated next to the search bar at the bottom of the Device Settings Pane allows the user to open the Search history window. This window contains the recent search inputs and can be very helpful when reusing a specific parameter repeatedly. In the bottom right corner of the window, 3 buttons are available:

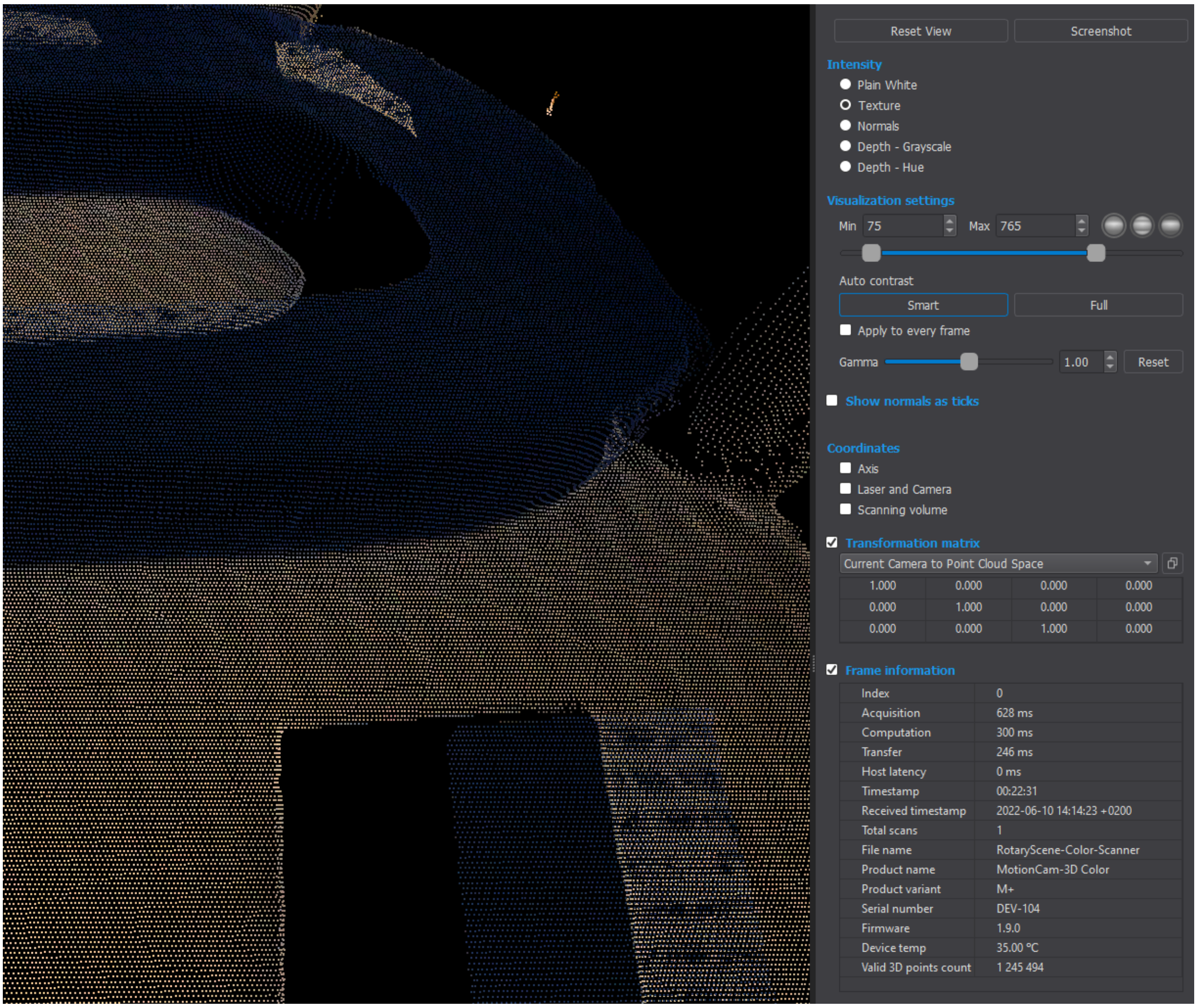
-  - Dock the Search history window
-  - Delete selected history (DEL key)
-  - Clear search history

Docking the Search history window will result in the search history being available under the search bar.



Visualization pane

This pane displays the output from the Scanner in various views. After the Device window is opened, hit F5 or press the **Trigger scan** button in the main controls to trigger the scan. The output is provided as a 3D point cloud (3D Viewer tab) and a set of corresponding data as 2D images (all other tabs). The view can be switched using the tabs at the bottom. Each view has its own display settings on the right. These settings do not change the data themselves, just their visualization.

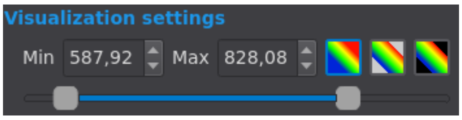


3D Viewer

Use this tab to inspect the point cloud and obtain a general overview of the scanned scene.

Changing the Visualisation

Reset view	Resets the camera to the default position.
Screenshot	Allows the user to save a *.png screenshot of the 3D Viewer window.
Intensity	Select the data source for coloring the point cloud: ▪ Plain White - all points are white, no shader is applied ▪ Texture - points have color from the photo (Texture) of the scene ▪ Normals - the color is based on point orientation (direction of the normal vector) ▪ Depth - Grayscale - the color of the point is based on its distance from the device. The furthest points are white, the closest points are black. If the coordinate space is set to *Marker space* and objects are below the marker pattern, negative depth may occur.

	■ Depth - Hue - the color of the point is based on its distance from the device. The farthest points are red, green, and the nearest points are blue. If the coordinate space is set to *Marker space* and objects are below the marker pattern, negative depth may occur.
Visualization settings	Adjusting the brightness and contrast of the scene. ■ Contrast - Manually set **Min** and **Max** values or use **Smart** or **Full** presets to adjust the contrast of the scene. This setting can be used only for the current frame or all frames by checking the box **Apply to every frame.** Additionally, when using the *Depth - Hue* intensity visualization, a trio of icons can be used for flexible range display options, enabling clamping, graying out, or hiding values beyond the selected range.  ■ The brightness of the scene can be adjusted by applying gamma correction. This is useful for viewing dark objects. It can be adjusted using a slider or setting the value manually. Clicking on **Reset** resets the value of Gamma to 1.
Show normals as ticks	This checkbox allows the rendering of normal vectors for selected 3D points. The selection of 3D points can be adjusted using the Stride setting and the length of the vectors by the Length setting.
Coordinates	Displaying the coordinate system: ■ Axis - Renders the axis of the coordinate system. ■ Laser and Camera checkbox - Renders the positions and fields of view of the camera and laser unit of the Scanner. ■ Scanning volume - Renders the scanning volume of the respective device

Tranformation matrix

Transformation matrix	Show the transformation matrix from “Point Cloud Space” to the currently chosen “Camera space” (or vice versa). Point Cloud Space is a general term used for the currently chosen Coordinate Space (CameraSpace, MarkerSpace, RobotSpace, CustomSpace or PrimaryCameraSpace). ■ Primary Camera to Point Cloud Space. ■ Current Camera to Point Cloud Space. See the Coordinate settings section to understand the essential terms (ColorCamera, PrimaryCamera, CameraSpace, Marker space).

Frame Information

Frame information section	Shows information about the current frame, such as ▪ Index - serial number of scanned frames in a current session. ▪ Acquisition - duration of the acquisition phase (projection of patterns). ▪ Computation - duration of the computation on the device. ▪ Transfer - duration of the data transfer from the device to the computer. ▪ Timestamp - timestamp of the scanned frame in the current session. ▪ FileName - the name of the file opened in File Camera. ▪ Received timestamp - timestamp when the frame was received by PhoXi Control ▪ Total scans - number of scans made by the scanner or number of .praw / *.pmraw files in the file camera. ▪ Product name - Photoneo 3D Sensor type. ▪ Product variant - a model of the device. ▪ Serial number - serial number of the device. ▪ Firmware - firmware version of the scanner. ▪ Device temp - current device temperature. ▪ Valid 3D points count - number of the valid 3D points.

Note: The displayed frame information also depends on the FW version of the device.

3D Viewer Controls

Left mouse button drag	Rotates the point cloud around the selected point of focus. By default, the selected point of focus is the camera position.
Mouse wheel or Vertical right mouse button drag or Keys: [ ]	Zooms in/out.
Mouse wheel drag or Hold SHIFT + left mouse drag	Moves the point cloud.
Hold CTRL + left mouse drag	Tilts the point cloud.
F	Sets the point of focus to the point under the mouse cursor. This is the point around which the scene is rotated.
R	Resets the view to default. Used to center the view on the point cloud.
Key: +	Increases the size of the points.
Key: -	Decreases the size of the points.

File Camera Controls

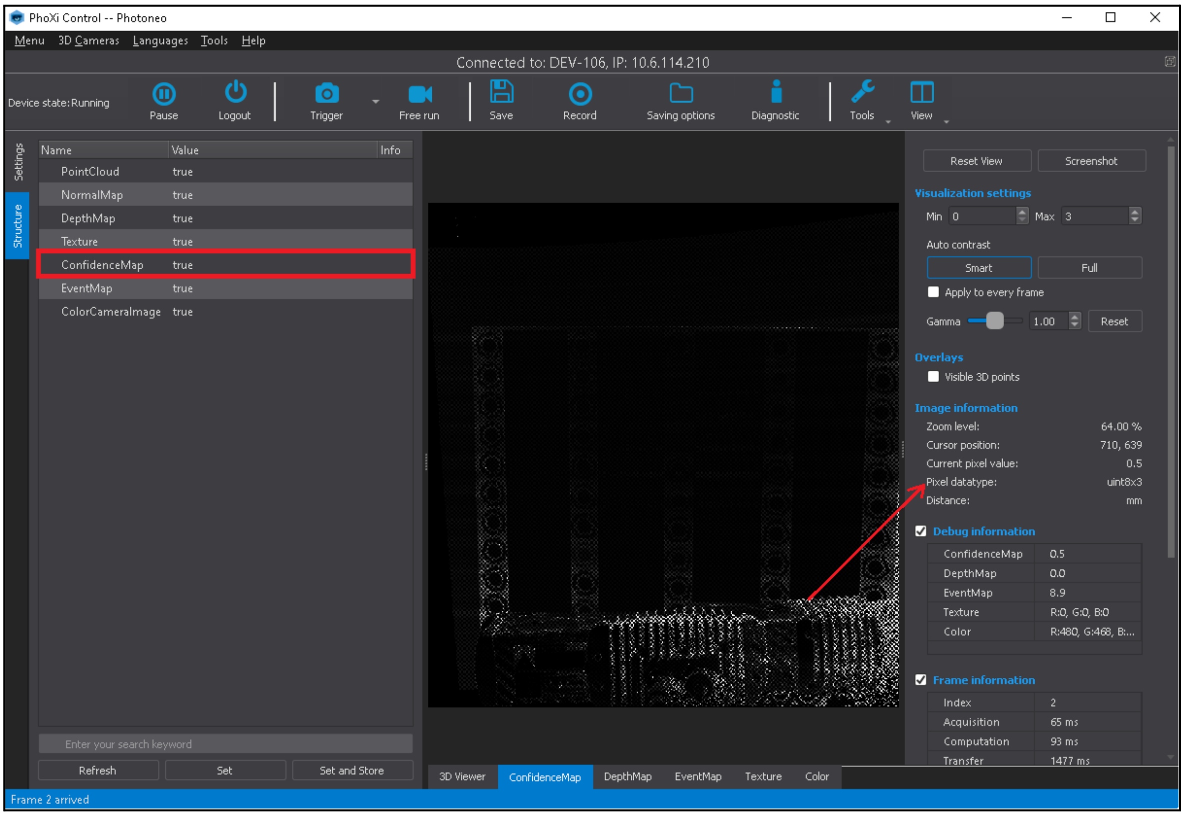
Left arrow	Previous frame
Right arrow	Next frame
Shift + left arrow	Go 10 frames back
Shift + right arrow	Go 10 frames forward
Home	Go to the first scan of the file camera
End	Go to the last frame of the file camera

2D Image Tabs

Confidence Map

This tab displays the predicted error of depth measurement for each pixel (corresponding 3D point). Darker areas on this map show parts of the scene that have been scanned with lower error rates, while brighter areas show parts of the scene where errors may have occurred, suggesting that these sections of the scene may be problematic. Confidence Map serves as a tool for estimating inaccuracy in millimeters. It can be used to find places where the inaccuracy is high and then trim them away using the Max Inaccuracy (mm) setting.

To see the confidence map, it is necessary to turn on the Confidence Map checkbox in the output structure and then trigger a new scan. Setting the Maximum value threshold in the right pane to a reasonably small number, e.g. 0.5. Then hover the mouse cursor over the image to see the value of the specific pixel (its corresponding 3D point).



Depth Map

This view shows the scene as a gray-scaled image in which the intensity of every pixel represents the distance of the measured point from the camera. The depth value of the pixel under the cursor is shown on the right side pane as the current pixel value. The image can be made more readable by adjusting the settings on the right side of the window, as explained below. This view can also be used to measure the distance between 3D points by dragging a line between corresponding pixels with the right mouse button.

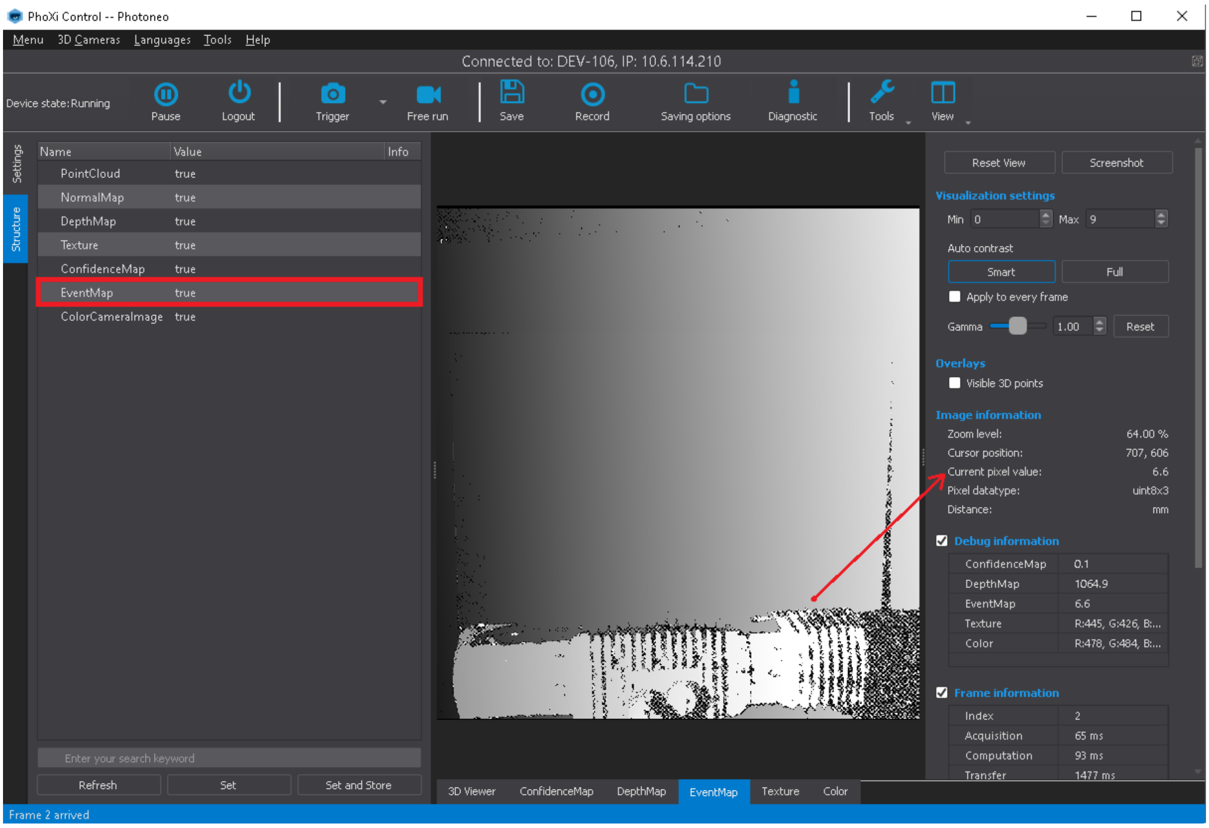
Texture

The texture is a 2D photo of the scene. Intensities from the texture are used to color the point cloud.

EventMap

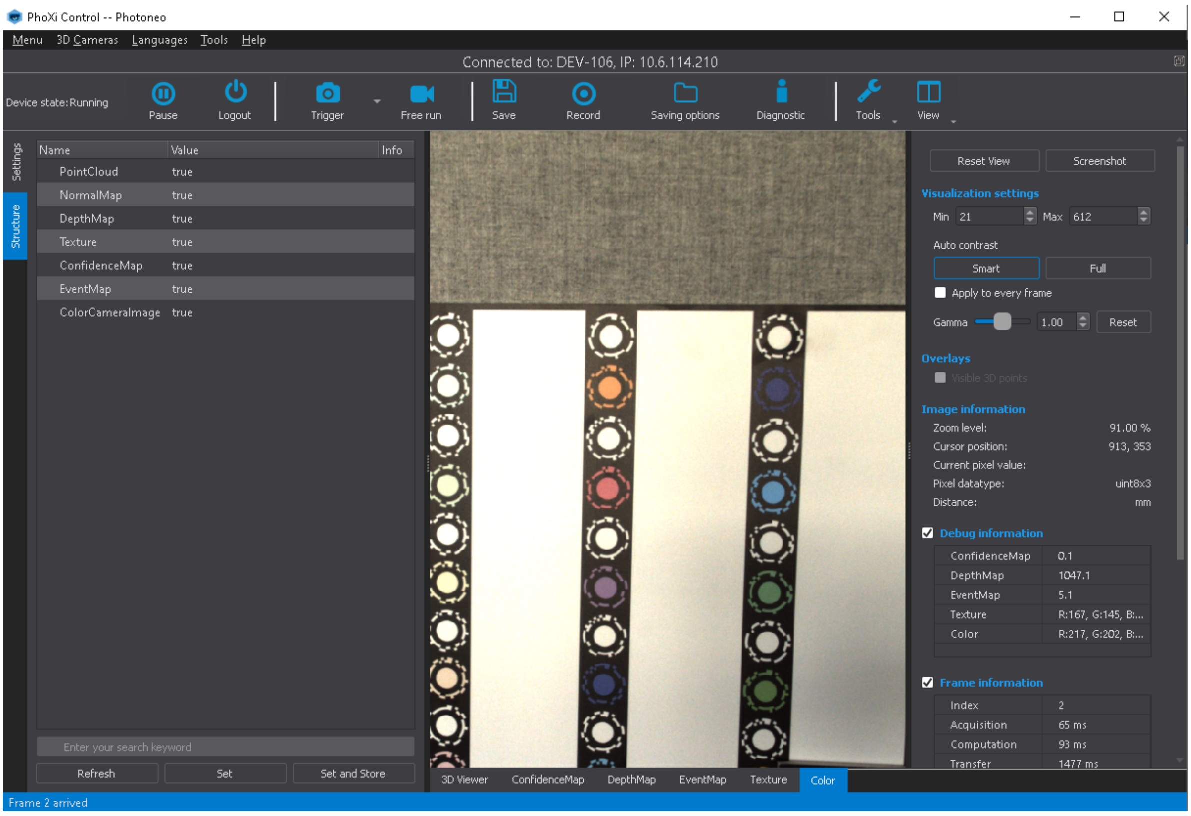
Event Map displays time information about when each 3D point was acquired. The measurement starts and ends together with the acquisition of 3D data which is achieved by sweeping a laser line over the object and modulating pixels in the camera sensor. Each point in EventMap can only have values ranging from 0 to Exposure time (ie 0 - 10 ms).

The time information is useful for applications where movement plays a role. MotionCam-3D can scan objects moving at high speeds, however, depending on the speed and direction of the movement, the resulting point cloud can be distorted. Combining the information from the EventMap with information about the speed and direction of the object is necessary to undistort the point cloud.



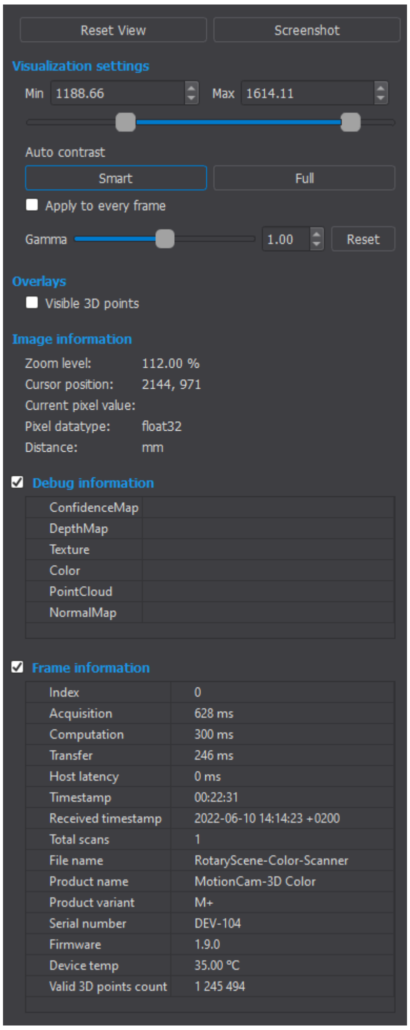
ColorCameraImage

After setting ColorCameraImage to true, a *Color* 2D image tab will appear at the bottom of the Visualisation pane. It is the native RGB image from the RGB camera unit in the MotionCam-3D Color. Its resolution can be altered in Color Settings.



2D Image Tabs Visualisation Controls

The top part of the 2D image tabs visualization controls and the Frame Information are the same as in the 3D viewer visualization controls.



Overlays

Visible 3D points	Creates an overlay of visible 3D points on the currently opened 2D image tab

Image Information

Zoom level	Current zoom level of the image.
Cursor position	Position of the pixel under the cursor.
Current pixel value	Value of the pixel under the cursor.
Pixel datatype	Represents the data type of the image.
Distance	The distance between two points. You can measure the distance between two points by dragging a line between them with the right mouse button.

Debug Information

When hovering over a specific pixel with a mouse cursor, the debug information pane displays values of all of the available output maps for the current pixel.

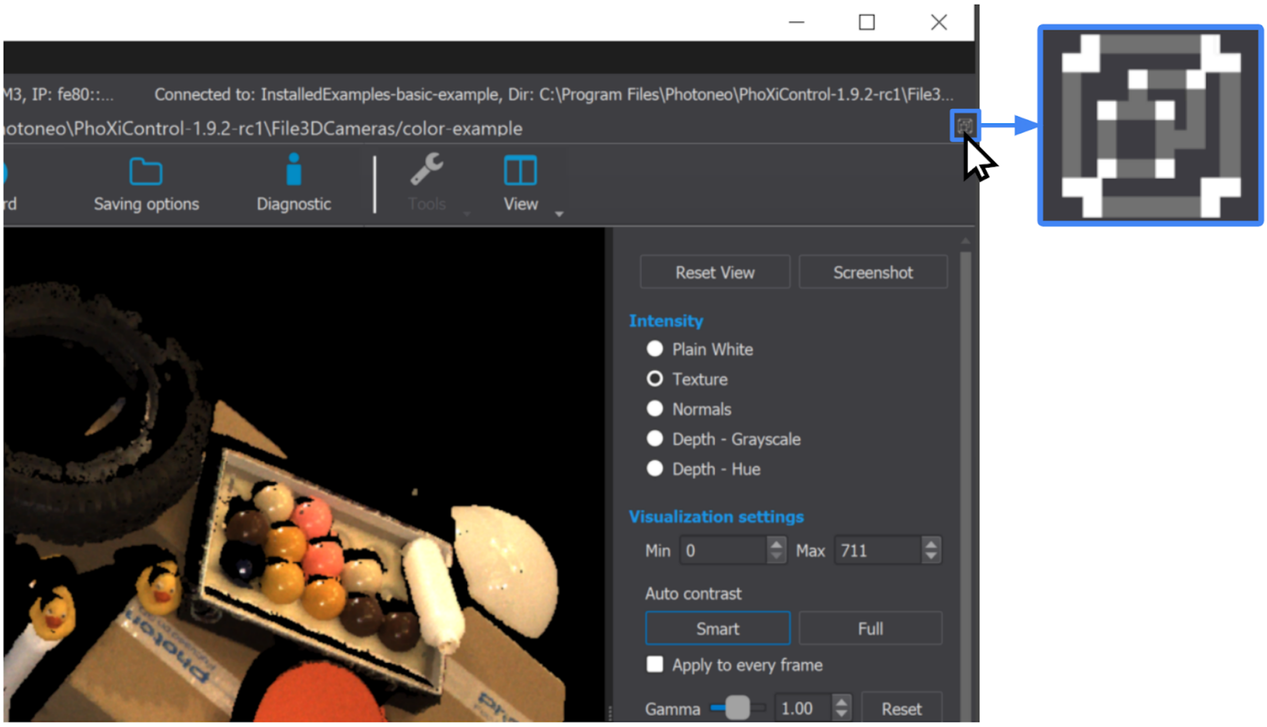
Controls

Button: Set default view	Resets the image position and zoom to default values.
Button: Restore default settings	Restores the default settings for Intensity settings.
Left mouse button drag	Moves the scene.
Mouse wheel	Zooms in/out.
Right mouse button drag	Draws a line between two pixels and computes the distance between the two corresponding 3D points.

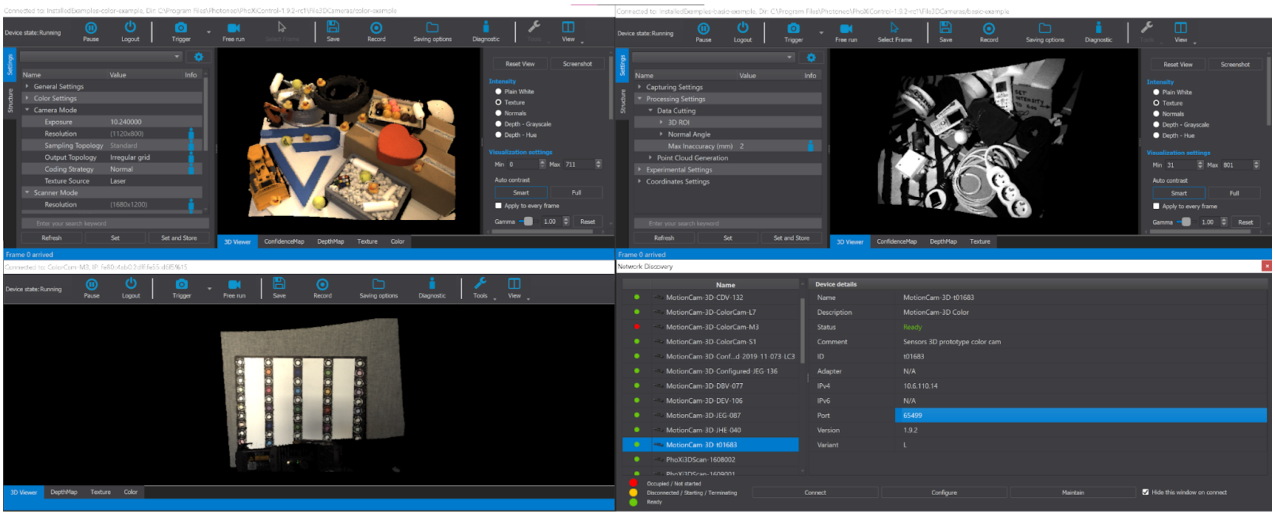
Undock Device Tabs

This feature allows the user to observe more device windows while working with multiple devices and/or file cameras by opening more undocked tabs side by side.

The Undock Device Tabs feature can be activated after clicking the Undock Device Tabs icon at the right top corner of the PhoXi Control GUI.

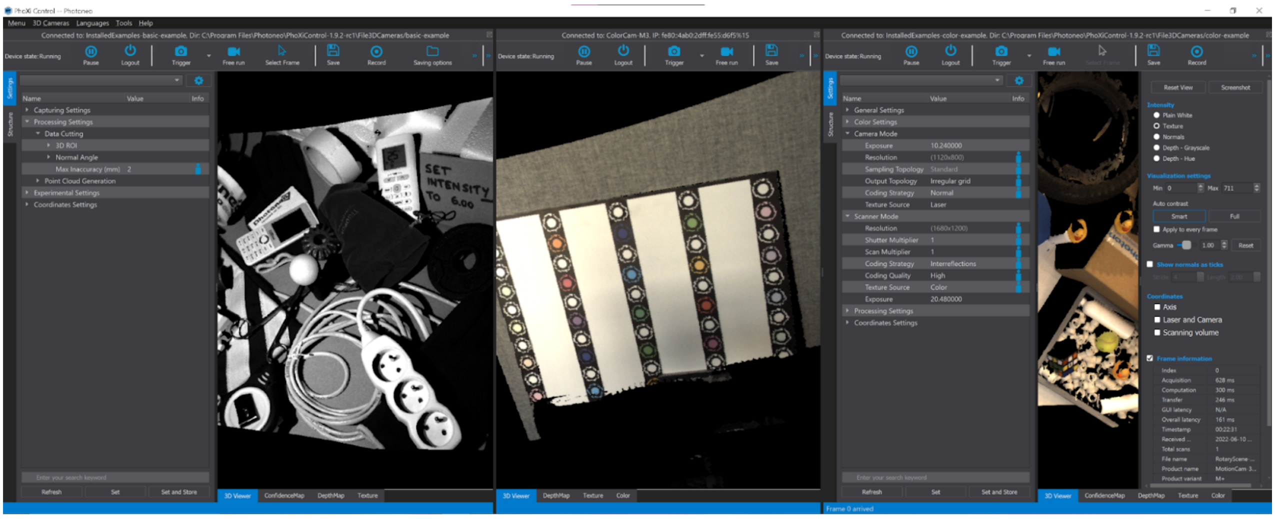


This feature allows the user to undock a device tab from the main PhoXi Control base tab and position it anywhere on the screen. In this case, all 4 tabs can be moved separately and the user can adjust both the width and height of the window.



Example of 4 simultaneously observed undocked tabs.

Additionally, the user can also dock the individual tabs in the PhoXi Control base tab and use it in a split-screen view. In this case, all 3 tabs are docked and the user can adjust the width of the individual windows.



Example of 3-way split-view within PhoXi Control

API

Introduction

PhoXi API provides the building blocks necessary for developing your custom C++ or C# application for working with Photoneo devices. All API functionalities are provided directly by the PhoXi Control application, therefore, PhoXi Control has to be always running for your custom application to work with the device.

This manual shows how to use the API in several examples. You may start your development based on one of the examples and modify it to suit your specific needs. Microsoft Visual Studio 2015 and CMake are used to demonstrate how to run the API examples.

The technical documentation is located in the file `API/API_Manual.html` inside the application installation directory.

On Windows OS, the path to the API directory is usually:

```
Program Files/Photoneo/PhoXiControl-1.12.x/API
```

On Linux OS, the path to the API directory is usually:

```
/opt/Photoneo/PhoXiControl-1.12.x/API
```

Prerequisites

CMake version 3.10 or above. You can download CMake from the following link: www.cmake.org/download/

API Examples

API examples contain source codes together with build instructions (CMake) to bootstrap the development of your custom application based on PhoXi API.

The most extensive source code is the **Full API example** which contains all functionalities provided by the API for the PhoXi 3D Scanner. Settings that are specific for MotionCam-3D are showcased in the **MotionCamChangeSettings**. For better readability, specific functionalities are provided in the form of additional examples. All examples are located in corresponding folders in the application installation directory in `API/examples/CPP` or `API/examples/C_Sharp`. The overview of all examples is laid out in the following table.

Example name	C++	C#	You will learn how to
Apply Custom Projection	✓	-	■ Apply transformation from camera space to custom space of the scanner. ■ Reproject the depth map into this custom space. ■ Save the reprojected depth map.
ChangeColorSettings	✓	✓	■ Retrieve and set color camera settings. ■ Best practice to disconnect from the device.
Change Settings	✓	✓	■ Retrieve and set capturing, processing and coordinates settings.

			■ Best practice to disconnect from the device. Note: *For MotionCam-3D - use MotionCamChangeSettings*
Change Profile	-	✓	■ Retrieve currently used profile. ■ Set profile that is to be used. ■ Best practices to disconnect from the device.
Connect and Grab	✓	✓	■ Check if PhoXi Control is running. ■ Obtain a list of devices connected to the network. ■ Connect to a device attached to PhoXi Control if there is one or to the last device on the list if there is not. ■ Different ways to capture scans.
Daisy Chain	✓	-	■ Check if appropriate devices are available. ■ Set up devices for the daisy chain. Note: *For more information about Hardware Trigger and daisy chain see the Hardware trigger section.*
External Camera	✓	-	■ Calibrate the Scanner to work with an external 2D camera. ■ Obtain a depth map aligned from the point of view of the external camera. ■ Align a color texture from an external camera with the point cloud.
Get Image Sensor Calibration Parameters	✓	-	■ Obtain image sensor calibration parameters.
Get Profiles	✓	-	■ Use profiles. ■ Get the profile that is currently used. ■ Set the profile that is to be used. ■ Import and export profiles.
Get Temperatures	✓	-	■ Get temperatures of the projection unit control board and of the laser diode.
Maintenance commands	✓	✓	■ Find scanners available on the network. ■ Use maintenance functionality of the PhoXiFactory such as reboot, shutdown, and factory reset of the device.
Minimal OpenCV	✓	-	■ Use the OpenCV library in your project. ■ Convert the scan into OpenCV format.
Minimal PCL	✓	-	■ Use PointCloud Library in your project. ■ Convert the scan into PCL format.
MotionCamChangeSettings	✓	✓	■ Retrieve and set settings for MotionCam-3D. ■ Best practice to disconnect from the device.
Movement Compensation	✓	-	■ How to compensate the motion distortion of the point cloud if the frame was acquired by a

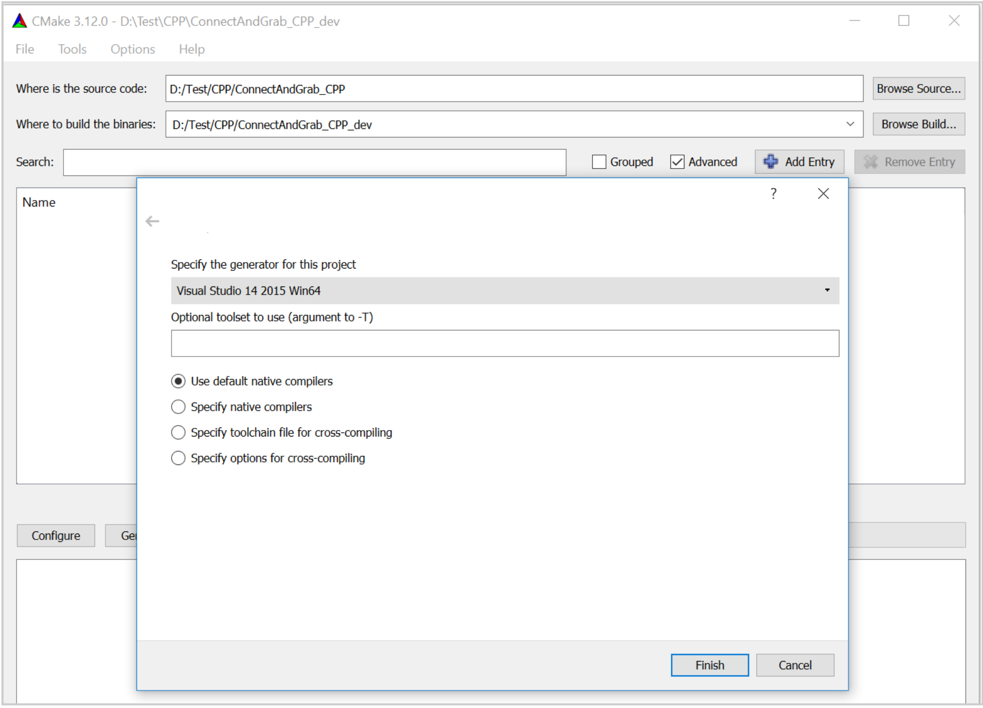
			MotionCam-3D in the Camera mode, and the velocity vector of the object is known.
Point Cloud Calculation	✓	✓	■ Calculate the point cloud using a Reprojection map.
Read Point Cloud	✓	-	■ Connect to a device from a list of devices connected to the network by requesting its ID. ■ Work with the acquired data and save it to a specific data structure. ■ Save scans into different file formats.
Rotated Calibration	✓	-	■ Obtain transformation from marker space to camera space. ■ Apply a custom transformation matrix before triggering a scan.
Two Scanners	✓	-	■ Connect to multiple scanners and trigger scans.
Two Scanners Multithread	✓	✓	■ Connect to multiple scanners and trigger scans using multiple threads.
WinForms	-	✓	■ Set up your C# project independent from CMake, ■ use WinForms in your project.
Full API Example	✓	✓	■ Find scanners available on the network. ■ Various methods to connect to the device. ■ Obtain details about the current state of the device and its capabilities. ■ Capture the scene using free run and manual mode, and obtain all available output formats. ■ Change the scanning settings and specify desired output formats. ■ Handle and store the received data. ■ Correctly disconnect from the device.

Running the Examples

Windows OS

To run the examples on the Windows operating system you will need CMake and Microsoft Visual Studio:

- Copy the content of any of the directories, e.g. `API/examples/CPP/ConnectAndGrab_CPP` to your custom directory (This is only necessary when you want to edit the source code. Originally, the source code is located inside the Program Files directory, so you will need admin rights to change the file).
- Launch CMake:
  - Choose the source and destination directory.
  - Click the **Configure** button, specify **Visual Studio 14 2015 Win64** or newer as the generator for the project, and confirm with the Finish button. Supported toolsets are v120 and v140 (also compatible with v141 and v142).



- Wait until the configuration is completed, then click the Generate button.
- In the destination directory, open the file `ConnectAndGrab.sln`.
- Set the project `ConnectAndGrab` as a StartUp Project (in the right context menu).
- Rebuild the solution in Visual Studio (Menu → Build → Rebuild Solution).
- Make sure that the PhoXi Control application is running.
- In Visual Studio, hit **F5** to run the example (Menu → Debug → Start Debugging)
- While the example is running, switch back to the PhoXi Control application - every frame captured by the camera is displayed in the Viewer pane.

Linux OS

- Copy the folder with the example to your home directory.

```
cd ~
cp -r /opt/Photoneo/PhoXiControl-1.12.x/API/examples/CPP/FullAPI/ ./FullAPI
```

- Create a new directory for the build.

```
mkdir dev
cd dev
```

- Prepare your project with CMake. The build type can also be Debug.

```
cmake ../FullAPI . -DCMAKE_BUILD_TYPE=Release
```

- Compile the program.

```
make
```

- Run the program.

```
./FullAPIExample_Release
```

API and Multiple Versions of PhoXi Control

When multiple versions of PhoXi Control are installed on one computer, the exact path to the PhoXi Control installation directory has to be specified in the find_package(PhoXi) command in the project's `CMakeList.txt` file, e.g.:

```
find_package(PhoXi REQUIRED CONFIG PATHS "C:/Program Files/PhotoneoPhoXiControl-second")
```

Logs

PhoXi API creates a `PhotoneoLogFiles` folder in the current project directory. To change the directory where this folder should be created please use the environment variable `PHO_LOG_FILES_DIR`.

Examples:

Absolute path:

```
PHO_LOG_FILES_DIR=C:\my_logs
```

All logs from the client application will be saved in `C:\my_logs\PhotoneoLogFiles`

Relative path:

```
PHO_LOG_FILES_DIR=my_app_logs
```

Client application that runs from folder `C:\my_app` will create logs in `C:\my_app\my_app_logs\PhotoneoLogFiles`

Scanning Guide

How to Scan

1) Arrange the scene for optimal scanning quality. See Factors Affecting the Quality of Scan.
2) Put the device into optimal scanning distance. Consult the datasheets which can be found on the Photoneo website for further details.
3) Adjust scanning parameters for optimal results. See Scanning parameters.

Factors Affecting the Quality of Scan

The quality of the scan depends on a number of different factors. The devices provide a variety of settings that help to perform an optimal scan. Before you decide to change the scanning settings, try to rearrange the scene to ensure the best conditions for scanning. Changing the position of the device with regard to the scene can also make the results of the scan better.

Distance: Closer objects have a better spatial resolution and generally have less noise.

Material albedo (reflectivity): Material with a higher albedo provides a better signal-to-noise ratio. Albedo is defined as a measure of the material's reflectivity or the degree to which the material will reflect the incoming radiation. The higher the albedo, the more radiation the material reflects from its surface. Generally, brightly colored materials have a higher albedo than darker colored ones, but color alone is not the most reliable indicator of albedo, because radiation has many components outside the visible spectrum.

Strong ambient light: Indoor ambient light generally does not influence the scan very much. However, very strong light such as direct sunlight might be a problem, especially when scanning outdoors. Try to remove all direct sunlight, e.g. by closing window blinds or by moving the installation to a different place. Additionally, Ambient Light Suppresion can be used with specific Photoneo 3D Sensors.

Reflections: Non-glossy, matte materials are typically scanned with high-quality results. Even semi-glossy objects are scanned with almost optimal quality. However, glossy, shiny, smooth-sanded, or polished objects often produce specular (mirror-like) reflections - the projected light is reflected out of the sight of the camera. These reflections can significantly lower the scan quality in the corresponding parts of the scan. Additionally, this reflected light can also be reflected onto other parts of the scene. In such cases when the parts are illuminated by reflections from other parts, these secondary "interreflections" can interfere with regular reflections and produce "ghost artifacts". Metal parts with a high-gloss (or mirror-like) finish are particularly difficult to scan.

Note:

A rule of thumb - Take a flat piece of the material you wish to scan and try to look into it as you would into a mirror. If you are able to recognize the shape of your head in the reflection, the material is glossy. In scenes containing such objects, some of them may not be scanned optimally.

When scanning glossy objects, find a position where the light from the projection unit does not illuminate other objects in the scene as this causes interreflections.

Transparent objects: Transparent materials such as glass, ice, or water cannot be scanned. Remove such materials from the scene to avoid artifacts. It is possible to scan objects wrapped in a thin layer of plastic, however, there is a risk they will increase the glossiness of the object and generate more noise in the scan (see the previous paragraph). Scanning through a flat glass is possible as long as the glass does not cause reflection - the angle between the projection unit and the glass plate should be close to a right angle.

Translucent objects: It is possible to scan semi-translucent objects to a certain extent, however, the scattering of light inside the material may reduce the accuracy of the scan of the object's surface. Materials with a high degree of translucency (near transparent) cannot be scanned.

Assessing the Quality of the Scan

First, do a quick visual check of the scan in the PhoXi Control application. Switch to the 3D Viewer tab. Do you see all parts of the object? Use the mouse to rotate the scene or the mouse wheel to zoom in or out.

For a more advanced assessment, switch to the Confidence Map. This tab displays the estimated deviation of the measured distance. Darker map areas have been scanned with lower error rates, while brighter areas show parts of the scene in which the error rate might be higher, indicating that these sections may be problematic.

Scanning Parameters

Before using any of the devices, it is useful to become familiar with the basics of structured light projection. Please ask your sales representative for more detailed materials and webinars on this topic.

The scanning process consists of three phases:

- Capturing (or acquisition)
- Processing (computation)
- Transfer

Scanning parameters cover the first two phases: capturing and processing. The transfer is affected by the amount of selected data as defined in the Output structure. In addition, scanning parameters also contain settings for changing the coordinate system of the point cloud.

Capturing parameters (MotionCam-3D)

General Settings		
Operation mode	Camera mode Scanner mode 2D	MotionCam-3D can operate in 3 modes controlled by this setting. ▪ **Camera mode** - intended for dynamic scenes and moving objects. ▪ **Scanner mode** - intended to capture static scenes at high quality. ▪ **2D** - intended to capture textures only.
Laser Power	1000 - 4095	Controls the intensity of the projected light. By default, it is set to the highest possible value. Decrease the value in case of overexposure.
LED Power	0 - 4095	Enables to decrease the LED light intensity used to capture texture. Useful for cases when the texture is used for extracting additional information and is experiencing overexposure.
Maximum FPS	0 - unlimited	Useful for limiting FPS in freerun mode. If you want to allow scan every 10 seconds, set Maximum FPS to 0.1.
Hardware Trigger	- off/on	Usually used when two or more devices need to be synchronized. When MotionCam-3D is in hardware trigger mode and a scan is triggered, the acquisition will start after a specified edge of the signal is detected on the trigger input pin. MotionCam-3D can also signalize to other devices that it is acquiring by keeping the trigger output signal in the high state.
Hardware Trigger Signal	- Falling - Rising - Both	Specifies what type of signal is used to trigger MotionCam-3D.
Color Settings (MotionCam-3D Color)		
White Balance (Color Settings)		Allows users to adjust individual red, green, and blue channels' presence in the RGB texture and ColorCameraImage. It also contains different custom presets to choose from and can be turned off completely.
Exposure (Color Settings)	0.32 - 100 ms	This setting allows the user to adjust the exposure of the RGB camera unit in the MotionCam-3D Color independently from the 3D data acquisition.
ISO (Color Settings)	50 - 12800	This value can be adjusted to increase the RGB sensor’s sensitivity to light. Higher ISO means, the image will be brighter, however, high ISO values introduce noise which can affect the quality of the RGB data.

Gamma (Color Settings)	0 - 1000	The brightness of the RGB data can be adjusted by applying gamma correction. It will be applied after hitting **Set** or **Set and Store** By altering these settings, data are changed also in the API, while the gamma correction in the Visualisation setting pane only affects the way the data is displayed in the GUI.
Resolution (Color Settings)	1288 x 730 1932 x 1096 3864 x 2192	This setting will not affect the resolution of the 3D data. It only changes the resolution of the ColorCameraImage (*Color* in the 2D image tab). If the Camera Space is set to ColorCamera (MotionCam-3D Color only), the depth map resolution is determined by the ColorCameraImage resolution (supported resolutions: 1288x730 or 1932x1096) and it is used as Texture.
Remove False Colors	true/false	Solution to address falsely colored points caused by occlusions in the perspective of the color camera unit
Camera Mode (MotionCam-3D)		
Exposure	10 - 100 ms	Data acquisition time: In the camera mode, the duration of the laser line sweep across the scanned area.

Resolution
(Read-only)
	1120 x 800	Resolution of the depth map. It is a read-only parameter:
		▪ In Camera Mode, determined by the selected Output Topology
		  ▫ **Raw**: 560 x 800
		  ▫ **Irregular**: 1120 x 800
		  ▫ **Regular**: 1120 x 800
		▪ Or if the Camera Space is set to ColorCamera (MotionCam-3D Color only), the depth map resolution is determined by the ColorCameraImage (Settings → Color Setting → Resolution) resolution (supported resolutions: 1288x730 or 1932x1096).

Sampling Topology (Read-only)	Standard	Defines the topology of sensor pixel modulations used for 3D data computation. Currently, only "Standard" sampling topology is supported.
Output Topology	Regular grid Irregular grid Raw	Defines the structure of the point cloud. ▪ **Raw** - points are organized into a checkerboard grid. ▪ **Irregular Grid** - complements the missing checkerboard grid through interpolation in PhoXi Control. ▪ **Regular Grid** - shares the same sampling locations as Irregular grid, however, all 3D points of this topology are properly estimated (i.e. no interpolation is involved). This option requires longer transfer time. ▪ **Full grid** - Computes 3D points on the native sensor resolution (2 Mpix), as in the Scanner mode. Transfer and computation time are

		impacted. Acquisition is identical to using other *Output Topologies* in the *Camera mode* - therefore suitable for scenes in motion. (to find out about possibility to upgrade of devices without this option - manufactured before Nov 2023 - contact our Help Center)
Texture Source	Laser Color LED	Determines the way the Texture is acquired. ■ **Color** - will capture an additional image illuminated with the white LED flash that offers a speckle-free 2D RGB image (MotionCam-3D Color only) ■ **Laser** - is a texture computed from the structured patterns - no additional image is required. Images have speckles (laser noise). ■ **LED** - will capture an additional image illuminated with the LED flash that offers a speckle-free 2D image.
Scanner Mode (MotionCam-3D)		
Resolution Read-only	1680 x 800	Resolution of the depth map. It is a read-only parameter: ■ In Scanner Mode: 1680 x 1200 ■ Or if the Camera Space is set to ColorCamera (MotionCam-3D Color only), the depth map resolution is determined by the ColorCameraImage (Settings → Color Setting → Resolution) resolution (supported resolutions: 1288x730 or 1932x1096).
Shutter Multiplier	1 - 50	Increases scanning time and amount of used light by repeating the projection of each pattern. Shutter Multiplier helps with ■ Scanning dark objects. ■ Sharp scanning angle. ■ Any other condition when the pattern is reflected back only partially. ■ Setting high values of the Shutter Multiplier can lead to overexposure and cause missing points in the point cloud.
Scan Multiplier	1 - 10	Increases scanning time by repetition and averaging the scanning sequence. Scan Multiplier helps to increase the signal-to-noise ratio and brings higher contrast in situations where a high dynamic range is required and a shutter multiplier leads to overexposure.

Coding Strategy	Normal Interreflections	Coding strategy changes the shape of the patterns modulated by the camera sensor (MotionCam 3D) with the aim of lowering interreflections in the scene. The coding strategy optimized for Interreflections uses advanced digital coding that enables the repression of some diffuse interreflections. Interreflections Coding strategy makes the projected light stripes very similar in width, while Normal makes the stripes go from very thick to very thin across the projected patterns. MotionCam-3D - uses a Normal strategy by default. Interreflections Coding Strategy has a lower effect than the Phoxi 3D Scanner.
Coding Quality	Fast High Ultra	Determines the number of used patterns and the subpixel accuracy: ▪ **Fast** - no sub-pixel accuracy. ▪ **High** - sub-pixel accuracy (default). ▪ **Ultra** - enhanced sub-pixel accuracy. This parameter also influences both scanning and processing time. Selection between Ultra and High should be made based on specific scenes. Ultra is usually useful for long-distance scanning with the L or L+ models.
Texture Source	LED Computed Laser Focus Color	Determines the way the Texture is acquired. ▪ **LED** - will capture an additional image illuminated with the LED flash that offers a speckle-free 2D image. ▪ **Computed** - is a texture computed from the structured patterns - no additional image is required. Images have speckles (laser noise). ▪ **Laser** - will trigger an additional image using a laser flash. Use this setting to investigate light conditions in the scene. Images have speckles. ▪ **Focus** - will set the scanned structured light pattern as a texture. This setting is useful for analyzing problems with signal contrast and for finding optimal scanning time. Explore the dark and white areas and compare their values. The higher the contrast value, the higher the scanning quality. But avoid overexposure (value above 4095). ▪ **Color** - will capture an additional image illuminated with the white LED flash that offers a speckle-free 2D RGB image (MotionCam-3D Color only)
Exposure	10 - 40 ms	In scanner mode, the length of exposure of one pattern. (16 patterns + texture by default).

Capturing parameters (PhoXi 3D Scanner, Alpha 3D Scanner)

Capturing Settings (PhoXi 3D Scanner, Alpha 3D Scanner)

Basic / Shutter Multiplier	1 - 50	Increases scanning time and amount of used light by repeating the projection of each pattern. Shutter Multiplier helps with ■ Scanning dark objects. ■ Sharp scanning angle. ■ Any other condition when the pattern is reflected back only partially. Setting high values of the Shutter Multiplier can lead to overexposure and cause missing points in the point cloud.
Basic / Scan Multiplier	1 - 50	Increases scanning time by repetition and averaging the scanning sequence. Scan Multiplier helps to increase the signal-to-noise ratio and brings higher contrast in situations where a high dynamic range is required and a shutter multiplier leads to overexposure.
Basic / Resolution	PhoXi 3D Scanner 2064 x 1544 1032 x 772 Alpha 3D Scanner 1440 x 1080	This parameter adjusts the resolution of the depth map. PhoXi 3D Scanner supports high (2064 x 1544) and half (1032 x 772) resolution. Half resolution is achieved by binning pixels. Benefits of lower resolution: ■ Significantly shorter acquisition time is needed (with the same scan accuracy as at full resolution. ■ Faster transfer time due to fewer data.
Basic / Camera Only Mode	true/false	In this mode, the internal camera is used to capture 2D images of the scene. This setting is useful when it is necessary to navigate the Scanner around the scene or to take a quick snapshot to look for changes in the scene. The captured images can be read as Texture. The setting does not perform any computations necessary for 3D scanning and therefore has low latency.

Advanced / Ambient Light Suppression	true/false	Special acquisition method which limits the effect of ambient light. When Ambient Light Suppression is set to True, increase Shutter Multiplier and Single Pattern Exposure. It is recommended to set LED Shutter Multiplier to non-zero value PhoXi 3D Scanner Gen 1 - ALS Gen 1 Alpha 3D Scanner - ALS Gen 2 PhoXi 3D Scanner Gen 2 (FW 1.2.37 and lower) - ALS Gen 2 PhoXi 3D Scanner Gen 2 (FW 1.10.0 and higher) - ALS Gen 3
Advanced / Coding Strategy	Normal Interreflections	Coding strategy changes the shape of the projected light patterns (Phoxi 3D Scanner). The coding strategy optimized for Interreflections uses advanced digital coding that enables the repression of some diffuse interreflections. Interreflections Coding strategy makes the projected light stripes very similar in width, while Normal makes the stripes go from very thick to very thin across the projected patterns. Phoxi 3D Scanner - for most scenes, choosing the interreflections strategy will provide better output, but in some specific situations, the Normal strategy might be useful.
Advanced / Coding Quality	Fast High Ultra	Determines the number of used patterns and the subpixel accuracy: ▪ **Fast** - no sub-pixel accuracy. ▪ **High** - sub-pixel accuracy (default). ▪ **Ultra** - enhanced sub-pixel accuracy. This parameter also influences both scanning and processing time. Selection between Ultra and High should be made based on specific scenes. Ultra is usually useful for long-distance scanning with the XL model.
Advanced / Single Pattern Exposure	10 - 100 ms	Increases acquisition time by prolonging the projection of each pattern. The longer the time the more light is projected on the scene. Has the same effect as Shutter Multiplier, but offers more variability in choosing the right value. In combination with Ambient Light Suppression, use values above 40 ms.
Advanced / Texture Source	LED Computed Laser Focus	Determines the way the Texture is acquired. ▪ **LED** - will capture an additional image illuminated with the LED flash that offers a speckle-free 2D image. ▪ **Computed** - is a texture computed from the structured patterns - no additional image is required. Images have speckles (laser noise).

		▪ **Laser** - will trigger an additional image using a laser flash. Use this setting to investigate light conditions in the scene. Images have speckles. ▪ **Focus** - will set the scanned structured light pattern as a texture. This setting is useful for analyzing problems with signal contrast and for finding optimal scanning time. Explore the dark and white areas and compare their values. The higher the contrast value, the higher the scanning quality. But avoid overexposure (value above 1023).
Advanced / Maximum FPS	0 - inf	Useful for limiting FPS in freerun mode. If you want to allow a scan every 10 seconds, set Maximum FPS to 0.1.
Advanced / Laser Power	0 - 4095	Controls the intensity of the projected light. By default, it is set to the highest possible value. Decrease the value in case of overexposure.
Advanced / Projection Offset (Left/Right)	0 - 512	This parameter narrows the area covered by the projection, shortens the shutter window, and thus limits the ROI of the device. It determines the number of projection columns that are cut off from the left/right side of the projection. The total width of the projection is 512 columns. It is useful for cases where the surroundings of the scanned object interfere with the scan or are unnecessary for further use of the point cloud. Additionally, the sensor's shutter window length is adjusted to match the narrowed projection, allowing less ambient light to enter the sensor. This parameter can help in scenes with extreme ambient light levels.
Advanced / LED Power	0 - 4095	Enables to decrease the LED light intensity used to capture texture. Useful for cases when the texture is used for extracting additional information and is experiencing overexposure.
Advanced / LED Shutter Multiplier	0 - 20	Increases scanning time and amount of used light to capture texture.

Experimental Settings (PhoXi 3D Scanner, Alpha 3D Scanner)

Use Extended Logging	true/false	Determines whether extended logging is enabled in PhoXi Control. Please use this option only when instructed to do so by a Photoneo employee. When enabled, much more data is logged on the Scanner and this can lead to the Scanner's memory becoming full. The Scanner must be restarted after changing this setting.

Processing Settings (Photoneo 3D Sensor)

Data Cutting / 3D ROI	Camera Space Min.-Max. X, Y, Z Point Cloud Space Min.-Max. X, Y, Z	Defines data cutting volumes (ROI- Range of Interest) in either the Camera or the Point Cloud coordinate space. The cutting will be applied only if min. X is smaller than max. X, min. Y smaller than max. Y, etc. Setting any value to 0 disables data cutting in that direction. If cutting close to 0 is necessary, a small decimal value can be used instead. Cutting is processed after the point cloud is computed, therefore, this setting cannot speed up the transfer time. ROI cutting applied in camera space is always based on the original coordinate system. ROI cutting in point cloud space is applied only when the coordinate system of the point cloud is different from the camera space. Tip: use this setting in combination with Marker Space to remove the background and this will make scan alignment easier.
Data Cutting / Normal Angle	Max Camera Angle 0 - 90°	Maximal angle accepted between the camera-to-3Dpoint straight line and the measured normal vector at this point. (can be understood as “how much the scanned surface is rotated away from the camera”).
	Max Projection Angle 0 - 90°	Maximal angle accepted between the projector-to-3Dpoint straight line and the measured normal vector at this point. (=“how much the scanned surface is rotated away from the laser projector”) 3D points with normals rotated away above these thresholds will be filtered out. Useful for scanning objects where edges are causing problems.
	Min Halfway Angle 0 - 90°	Minimal angle accepted between the “halfway line” to a 3D point and the normal vector in this point. The halfway line is the center line between the camera-to-3D point line and the projector-to-3D point line.
	Max Halfway Angle 0 - 90°	Maximal angle accepted between the “halfway line” to a 3D point and the normal vector from this point.

Data Cutting / Max Inaccuracy	0 - 5 (mm)	Threshold for filtering the 3D points based on the point measurement reliability. Enables prefiltering of the output data according to the specific needs of your application. Some applications require a more complete scanner output at the expense of lower precision. Other applications are intended to work with precise data only and need to filter out regions where the precision does not meet a specific criterion. Max Inaccuracy can be set based on data from the Confidence Map. The corresponding parameter in the API is named Confidence.
Data Cutting / Calibration Volume Only	- on / off	By default, only the points scanned in the recommended scanning volume are displayed. It is possible to see all the data acquired in the scene by setting the Calibration Volume Only to false. Data outside of the recommended scanning range are not guaranteed to be measured with the same accuracy. Recommended scanning volume is defined by the minimal and maximal scanning distance, which differs by the Scanner model and can be found in the Scanner datasheet.
Point Cloud Generation / Surface Smoothness	- Sharp - Normal - Smooth	Determines the setting of the smoothness of the point cloud generation algorithm. ▪ **Sharp** - optimized for small feature retrieval. Higher noise on surfaces. ▪ **Normal** - standard sensor setting suitable for most scans. ▪ **Smooth** - an edge-preserving algorithm that smooths the surface, lowering noise at the expense of small features.
Point Cloud Generation / Normals Estimation Radius	0 - 4	Determines the size of the area (in sensor pixels) around the point that serves for the computation of the normal vector of each 3D point. A higher radius leads to smooth normal vectors and a small radius to noisy normals. With the radius set to 0 normals are not calculated.
Interreflections Filter (PhoXi 3D Scanner, Alpha 3D Scanner only)	true/false	Special filter used to remove incorrectly calculated points due to the presence of interreflections. Switching the filter on changes the Coding Strategy to Interreflections. Interreflections occur when the laser light pattern is reflected from a diffuse surface and illuminates nearby objects. If the reflection interferes with the primary light pattern reflected from the scene, the depth calculation is affected causing the existence of discrete patches of points isolated from the rest of the point cloud, and they do not represent reality.

Interreflection Filter Strength (PhoXi 3D Scanner only)	0.01 -0.99	Allows the user to adjust the strength of the Interreflection Filter.
Pattern Decomposition Reach	Local Small Medium Large	This parameter is mostly used to scan objects that are harder to scan due to challenging scanning angles, dark color, or higher shine. It helps to correct or eliminate points that have higher computation errors. To correctly decode the series of light patterns for each pixel, the values of surrounding pixels are taken into account. If the difference between them is larger than expected, the value of the candidate pixel is adjusted. This way some errors that are identified during computation are corrected. If the difference between neighboring pixels is too large, the candidate pixel is filtered out.
Signal Contrast Threshold (PhoXi 3D Scanner, Alpha 3D Scanner only)	0 - 4095	Serves as a filter that helps to eliminate parts of the scan with low contrast and low quality. Lowering the value of the Signal contrast threshold can help in situations where strong ambient light or worse scanning properties produce insufficient contrast between the light and dark stripes of the pattern. Higher values can serve to eliminate some noise from the scan. Each pattern is composed of light and dark stripes. The difference in intensity between them is called contrast. Two neighboring pixels belong to differently illuminated stripes (one is light and one is dark) if the contrast between them is higher than the threshold set by this parameter. To assess the contrast between light and dark stripes, set the “Focus” texture option within the Texture source setting and examine the resulting contrast in the Texture image.

Coordinate Settings (Photoneo 3D Sensor)

Robot / Custom Transformation	Rotation Matrix	Defines the rotation matrix to transform from the camera space to the robot or custom space. Clicking the Edit button opens a new window with a 3x3 editable matrix.
	Translation Vector	Defines the translation vector from the camera space to the robot or custom space. Clicking the Edit button opens a new window where the X, Y, and Z coordinates of the vector can be set.

Marker Scale	X 0 - inf Y 0 - inf	Enables the setting of the X and Y scale of the marker pattern. Use X or Y larger than 1 for upscaled marker patterns and smaller than 1 for downscaled marker patterns. The correct scale is when the origin of the coordinate system is placed in the center of the white circle in one of the corners of the marker pattern.
Camera Space	PrimaryCamera CurrentCamera	Defines the origin of the depth map if the "Coordinate Space" is set to "CameraSpace". ■ **PrimaryCamera**: The origin of the depthmap is in the primary camera of the device - the 3D sensor. ■ **ColorCamera**: The origin of the depth map is in the color camera of the device (MotionCam-3D Color only). Note: The resolution of the depth map is determined by the resolution of the ColorCameraImage (Color Settings -> Resolution) at either resolution of 1288x730 or 1932x1096 (interpolated). Resolution 3864x2192 is not supported.
Coordinate Space	CameraSpace MarkerSpace RobotSpace CustomSpace PrimaryCameraSpace	■ **CameraSpace:** Coordinate space with the origin in the primary camera or color camera (MotionCam-3D Color only) of the device. The X-Y plane is defined by the camera sensor and Z is the perpendicular distance from the sensor to the scene/object. ■ **MarkerSpace**: To align multiple scans in PhoXi Control, it is useful to use marker patterns. Marker patterns are available in Tools/Marker patterns. If you place a marker pattern below an object and set the marker space as your coordinate space, you can now move the sensor to different locations with the point cloud automatically returning to the same coordinate system defined by the marker plate. See Appendix 1 - Marker Space for more information. ■ **RobotSpace**: Coordinate space with the origin of the robot. Automatically set by Robot-Camera Calibration Tool. See the Photoneo website for more information. ■ **CustomSpace**: Your custom-defined coordinate space. ■ **PrimaryCameraSpace:** Coordinate space with the origin in the primary camera of the device.
Recognize Markers	true/false	When true, the algorithm will look for markers in the scene. Then you need to place a marker pattern in the scanning scene, otherwise, the resulting frame will be corrupted.
Save Transformations	true/false	When true, the new transformation from CameraSpace to any other Coordinate Space will be automatically saved to the device. The same can be done manually with the Set and Store function.

Primary Camera to Point Cloud Space transformations

Coordinate Space	Camera Space	Transformation matrix
CameraSpace	PrimaryCamera	Match (identity matrix)
CameraSpace	ColorCamera	Transformation between primary camera and color camera
MarkerSpace	PrimaryCamera	Transformation between the primary camera and the marker space
MarkerSpace	ColorCamera	Transformation between the primary camera and the marker space
PrimaryCameraSpace	PrimaryCamera	Match (identity matrix)
PrimaryCameraSpace	ColorCamera	Match (identity matrix)
Robot/CustomSpace	PrimaryCamera	Transformation between the primary camera and the robot/custom space
Robot/CustomSpace	ColorCamera	Transformation between the primary camera and the robot/custom space

Current Camera to Point Cloud Space transformations

Coordinate Space	Camera Space	Transformation matrix
CameraSpace	PrimaryCamera	Match (identity matrix)
CameraSpace	ColorCamera	Match (identity matrix)
MarkerSpace	PrimaryCamera	Transformation between the primary camera and the marker space
MarkerSpace	ColorCamera	Transformation between the color camera and the marker space
PrimaryCameraSpace	PrimaryCamera	Match (identity matrix)
PrimaryCameraSpace	ColorCamera	Transformation between primary camera and the color camera
Robot/CustomSpace	PrimaryCamera	Transformation between the primary camera and the robot/custom space
Robot/CustomSpace	ColorCamera	Transformation between the color camera and the robot/custom space

Hardware trigger

The hardware trigger provides the user with means of triggering devices by external means - outside of the software environment. To get further hardware specifications about the hardware trigger, see the Photoneo 3D Sensor User Manual. This functionality is mostly used for synchronization purposes:

- With external events, such as an object arriving inside the field of view of Photoneo 3D Sensor (i.e. triggered by an optical gate)
- With other devices, such as 2D cameras, PLCs, etc.
- With multiple Photoneo 3D Sensors

Software Configuration

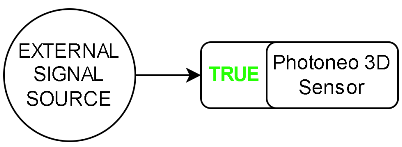
The supported uses cases are:

- Single device triggered by HW trigger
  - Example: A MotionCam-3D Color triggered by an optical sensor to capture a moving object on a conveyor belt
- A device sending an output signal to a PLC
  - Example: A MotionCam-3D sends an output signal to a robotic controller after the acquisition to start a solution. Locator Studio picking from a moving conveyor belt.
- Multiple devices triggered by HW trigger independently from each other
  - 2 Photoneo 3D Sensors triggered by a PLC with a specific delay
- Two or more devices triggered sequentially in a chain → Daisy chain
  - PhoXi Instant Meshing model creation
- Two or more devices triggered sequentially in a loop → daisy chain in a loop

Simple configurations

Single device triggered by HW trigger (SEXT)

The device can be triggered with a software (default) or a hardware trigger. There is a dedicated parameter in PhoXi Control / PhoXi API to control device trigger mode. To trigger the device via hardware trigger:



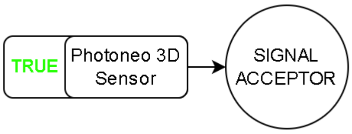
- Set `Hardware Trigger = TRUE`
- Put the device into freerun

- Send the signal to trigger input

With hardware trigger mode enabled, the device will capture a new scan each time an input signal is detected. If the trigger input signal arrives during an active device acquisition, it will be ignored. To stop the device from listening to the hardware trigger signal, turn the freerun OFF. To disable hardware trigger mode, set the `Hardware Trigger = FALSE`. The response to the trigger signal is around 3 ± 2 milliseconds.

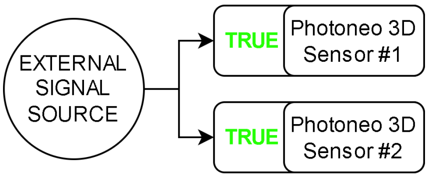
Photoneo 3D Sensor output signal to PLC or other device (OUT)

Photoneo 3D Sensor sends a signal to trigger a secondary device, which can be a PLC or other signal acceptor.



Multiple devices triggered by HW trigger independently from each other (MEXT)

In this case, an external trigger would be triggering 2 or more devices independently. The devices need to be set up the same way as in the previous use case with a single device. If the devices' FOVs (fields of view) overlap, make sure the input signals are timed adequately in order to acquire 3D data without any distortions caused by the projection interference.



Daisy Chain and Daisy Chain in a Loop

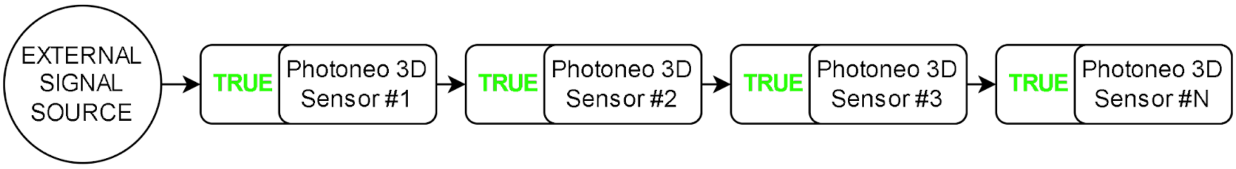
Daisy chain and daisy chain in a loop are special setups in which two or more Photoneo 3D Sensors are interconnected and are triggered consecutively by each other. They are mostly used to prevent interference between two projections if the devices have overlapping fields of view. In a daisy chain, the trigger sequence is always triggered by external means. In a daisy chain in a loop, once the acquisition has started it will continue until the loop is broken.

Two or more devices triggered sequentially in a daisy chain (EXTSEQ, INTSEQ)

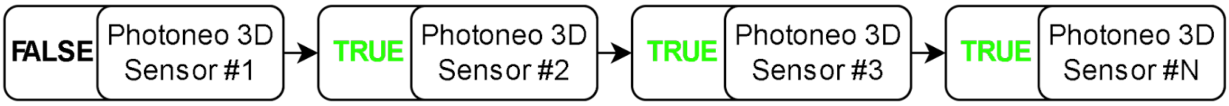
In a daisy chain consisting of, for example, 4 devices, the output pin of the first device is connected to the trigger input of the second device. The output of the second device is connected to the input on the third device and so on. The output on the last (fourth device) is not connected to any Photoneo 3D Sensor (but can be connected to a different device).

There are two options on how to set up the chain:

- Sequential triggering with external signal source - EXTSEQ
    - Set `Hardware Trigger = TRUE` on all devices.
    - Start freerun on all devices. In this scenario nothing will happen unless
        - Hardware trigger from an external source is sent to the trigger input of the first device in the chain



- Sequential internal triggering - INTSEQ
  - Set `Hardware Trigger = TRUE` on the last three devices and put them into freerun.
  - Trigger the first device by software trigger/ freerun. This will start the chain and trigger all consecutive devices.
  - In case the freerun is used, to stop the acquisition of all devices, it is necessary to disable freerun on the first device

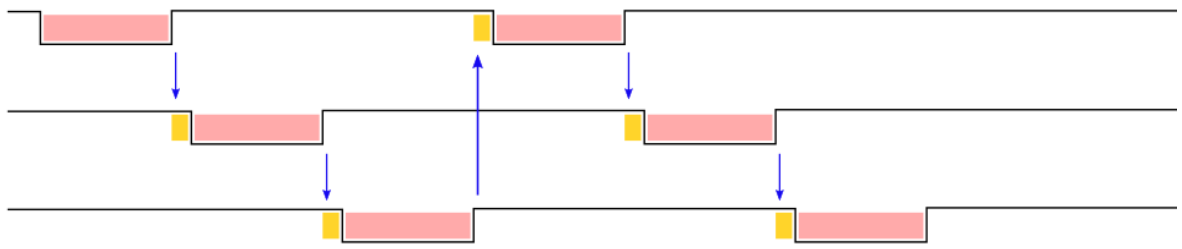


Limiting the FPS in some applications might be necessary to achieve stable results. For example, we can have 4 MotionCam-3Ds with overlapping FoVs of which one is primary and it is running on freerun (via PhoXi Control or API) which triggers the other 3 secondary devices via the hardware trigger (connected in series). If, theoretically, the acquisition takes 15 ms for each MotionCam-3D and the Maximum FPS is set to 20 (frame every 50 ms), there is enough time to trigger only 2 secondary devices and part of the acquisition of the last device would be overlapping with the following frame on the primary device. If we limit the FPS of the primary device to 15 (frame every 66 ms), there is enough time to trigger all secondary devices to avoid overlapping. The acquisition windows of the secondary device and tertiary device need to fit in the window between the frames of the first device.

Two or more devices triggered sequentially in a loop - daisy chain in a loop (EXTDCL)

This case is very similar to the basic daisy chain explained above. We can have 4 devices, where the output pin of the first device is connected to the trigger input of the second device. The output of the second device is connected to the input on the third device and so on. However, in this case, the output signal from the last device is connected to the input of the first device, creating a loop.

The picture below illustrates the daisy chain loop with three devices. The red rectangle represents the time period in which the device is in acquisition (the laser is sweeping the scene). During this time period the signal, which is represented by the black line, is opposite to what it was before the acquisition. Once the acquisition on the first device is finished, the signal changes back and thus produces a trigger signal (blue arrow) for the second device that is connected to the first one. A few milliseconds later the acquisition on the second device is started. The yellow rectangle represents the delay between when the trigger signal is received and when the acquisition starts. This delay is typically around 3 milliseconds.



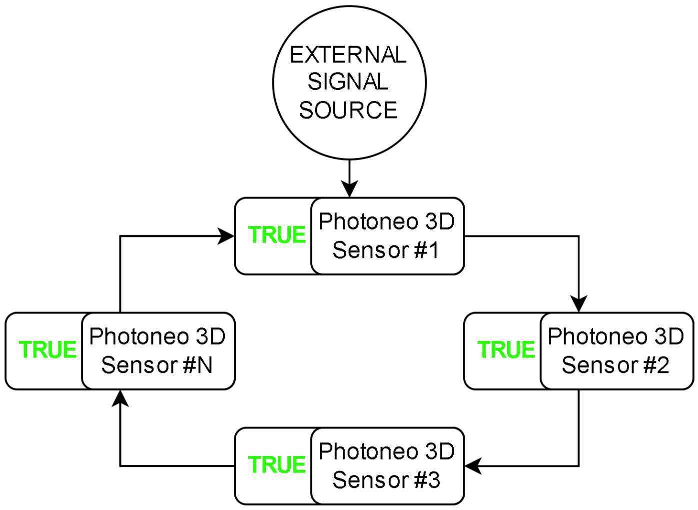
Simplified signal representation for 3 devices in a daisy chain in a loop

In these setups, the end of acquisition on MotionCam-3D #1 produces a falling edge on its output pin which triggers acquisition on MotionCam-3D #2. This is followed by the acquisition on the MotionCam-3D #3.

To set up Photoneo 3D Sensors in a daisy chain in a loop configuration:

- Set `Hardware Trigger = TRUE` on all devices.
- Enable free run on all devices
- Send a signal from an external signal source to initialize the acquisition

To stop the acquisition, disable freerun on one of the devices.



See our API example for the daisy chain to learn how to control the devices via hardware trigger.

Troubleshooting

If the following section does not help in solving the difficulty you are experiencing, contact our support team at the Help Center.

The more information that you provide, the faster and more accurate the answer can be. The following section explains how to collect the log files that you are kindly asked to attach to your support requests.

Additionally, please describe what you have been trying to do, what the result was, and what you expected. Depending on the nature of the problem, please also report the version of the operating system being used, your PC configuration, and other additional information that would be helpful in replicating the problem and identifying its root cause.

Collecting Log Files

There are several types of diagnostic information to collect and attach to your support request:

1) Logs from the device
2) Logs from PhoXi Control
3) Crash dump of PhoXi Control (in case PhoXi Control crashes)
4) Logs from your API application
5) Crash dump of API application

Downloading Logs From Device

Log Downloader is a stand-alone utility for downloading logs from device

> It is recommended to set up your error handling process to run Log Downloader immediately after experiencing any issue with the device.

Windows 10

1) Download the utility from https://www.photoneo.com/dl/logdl-win
2) The downloader has two modes
    a) Interactive mode
        i) Double click the phoxi-log-downloader application
        ii) Input device ID or IPv4/IPv6 address upon request
    b) Direct mode

i) Call the application in command prompt or by your application and supply the ID or IP address of the device

```
<name_of_the_chosen_log_downloader> <IPv6>
```

3) Once the application finishes (Result: OK), all the logs are stored in file log.txt in the folder with the application.

4) Send the file log.txt to Photoneo Support.

Ubuntu

1. Download the utility from https://www.photoneo.com/dl/logdl-lin
2. Open a new terminal in the folder with the application
3. Give the application executable rights:

```
chmod +x <name_of_the_chosen_log_downloader>
```

4. Execute the application with its ID or IPv4 or IPv6 as an argument

```
./<name_of_the_chosen_log_downloader> <IPv6>
```

5. Once the application finishes (Result: OK), the logs are stored in the file log.txt which was created in the folder with the application.

Device Log Level

By default, the logging level on the device is optimized for performance. To extend the logging level to contain extensive information on PhoXi 3D Scanners, turn on Extended logging in PhoXi Control and reconnect to the device (the logging level is determined at the time of connection to the device.) Extended log level on MotionCam-3D needs to be enabled by our support during the remote sessions.

PhoXi Control Log Files

PhoXi Control log files are located in the application folder:

Windows 10

- `C:\Users\<user>\AppData\Roaming\PhotoneoPhoXiControl\PhotoneoLogFiles`

Ubuntu

- `~/.PhotoneoPhoXiControl/PhotoneoLogFiles`

PhoXi Control Log Level

PhoXi Control always creates basic log files. If you experience any problem with Phoxi Control please collect the logs from the folders mentioned above. If you are able to recreate the problem, please set up Extended Logs:

- Open LogConfig.txt in the PhotoneoLogFiles folder
- On the first line, change 0 to 10 to enable extended logs
- Restart PhoXi Control
- Once you have replicated the issue and collected logs, change the first number in LogConfig.txt back to 0.

PhoXi Control Core Dumps

If you have experienced a crash of PhoXi Control, please collect the core dump located in the ProgramData folder on Windows and in the /tmp folder on Ubuntu. The core dumps are available for all PhoXi Controls with version above 1.2.22:

Windows 10

- Location: C:\ProgramData\PhotoneoPhoXiControl\CrashDumps
- The dump file looks like this: %ProgramData%\PhotoneoPhoXiControl\CrashDumps\PhoXiControl.exe.6548.dmp

Ubuntu

- Location: /tmp
- The dump file looks like this: /tmp/core.PhoXiControl.1000.5503.1602775821.dmp

API Log Files

Client API application does not create logs by default.

To set up API logging (generating a lot of data):

- Navigate to your application folder and open PhotoneoLogFiles folder
- Open LogConfig.txt and change the value on the first row to 10
- Restart your application
- Once you have replicated the issue, you can turn off the logs by changing the first-row value back to 0

The API log files directory can be changed by setting up the environment variable PHO_API_LOG_FILES_DIR or PHO_LOG_FILES_DIR. If PHO_API_LOG_FILES_DIR environment variable is defined, logs will be saved in the direction it points to. If it is not defined, logs are saved in the directory pointed by the PHO_LOG_FILES_DIR. If none of these is defined, the logs will be saved directly on the desktop. In case both of the variables are defined, PHO_API_LOG_FILES_DIR is prioritized.

API Core Dumps

If you are experiencing crashes of your application, you can set up creating crash dumps.

Windows 10

Crash dumps for your application need to be activated in the Windows registry.

- Download the following file crashdump.reg
- Open it in the text editor
- Overwrite UserAPiApp.exe with the name of your application and save the changes. The .exe is a necessary part of the name.
- Double click on the crashdump.reg and allow it to become part of the Windows registers
- The crash dumps should be generated in the same folder as the PhoXi Control crash dump %PROGRAMDATA%\PhotoneoPhoXiControl\CrashDumps

Ubuntu

Type the following command into the terminal:

```
ulimit -c unlimited
sudo sysctl -w kernel.core_pattern=/tmp/core.%e.%u.%p.%t.dmp
```

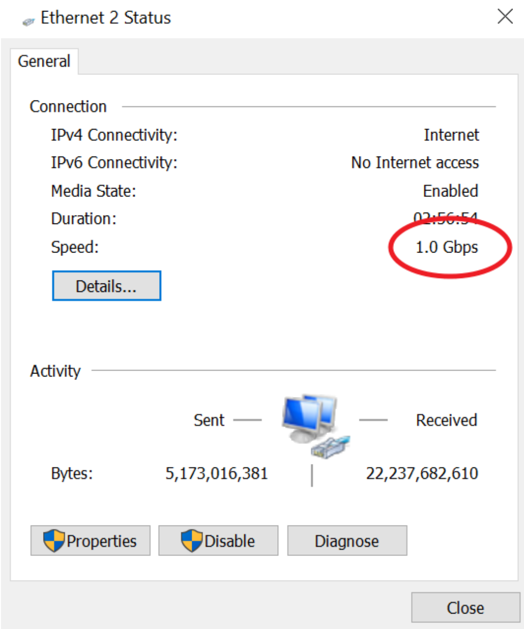
The crash dumps are generated in the /tmp folder. Here's an example core dump file::
/tmp/core.my_app_name.1000.5503.1602775821.dmp

Troubleshooting Network Connection

Cannot connect to the device or scanning time is too long

The device is listed in the PhoXi Control application, but after trying to connect to it, it disconnects:

- Check your ethernet connection speed; the minimum speed should be 1 Gbps.



- If your connection is very slow (10 Mbps), the connection will most likely time out.
- If your connection is slow (100 Mbps), data transfer will take more time.
- Use the [Speed test] to verify the right connection speed

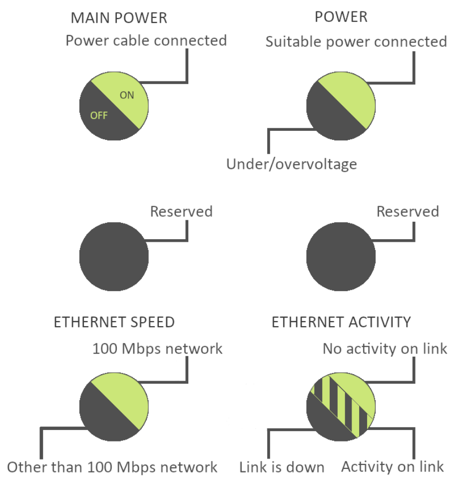
The device is not visible in PhoXi Control on a network with a dynamic IP assignment

Make sure your device is connected correctly - you are using network media supporting Gigabit Ethernet or higher and your network topology is either star or direct (see sections Network media and Network topology).

Reboot the device.

Check the LED lights on the backside of the device. The last two indicate the status of the Ethernet connection. Please note that the PoE devices have a different set of LEDs than the 12 V devices.

12 V devices

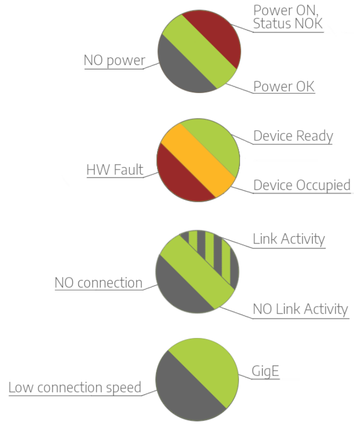


- The left diode indicates speed:
  - ON - 100 Mbps
  - OFF - other than 100 Mbps, usually 1 Gbps
- The right diode indicates Ethernet activity:
  - OFF - link is down
  - Flashing - link is up with activity
  - Steady - link is up without activity

PoE devices:

- 3rd LED from top:
  - OFF - link is down
  - Flashing - link is up with activity
  - Steady - link is up without activity
- 4th LED from top:

- ON - Gigabit connection
- OFF - slower than gigabit connection



Check the network configuration of your computer:

- Your firewall is blocking communication with the device.
- Zeroconf implementations (Avahi or Bonjour service) are not running or are running incorrectly.

To resolve the problems listed above:

- Check your Network Connection status in system settings. If networking is disabled, enable it.
- Check if your firewall is not blocking Bonjour Service: www.digitalcitizen.life/how-change-windows-firewalls-list-allowed-blocked-apps
- Check the settings of your firewall. The device communicates with the computer on ports - 5353 and 5354 on the computer side and ports - 65499 and 65534 on the device side.
    - Allow incoming UDP traffic on ports 5353 (mDNS), 5354 (mDNS responder).
    - Allow outgoing TCP traffic on ports 65499 and 65534.

- **On Ubuntu (16.04):**
    - Check if avahi-daemon is running.

```
systemctl status avahi-daemon.service
systemctl status dbus-org.freedesktop.Avahi.service
systemctl status dbus.service
```

- **On Windows:**
    - Is Bonjour service installed and running?
    - Open Windows Task Manager (Ctrl + Shift + Esc) → Services.
    - Find Bonjour service and check its status.
    - If it is not running, try to start it.
    - If starting it fails, open the Event Viewer application.
    - Go to Windows Logs → Application in the left pane and look for Errors (Event Level column) reported by Bonjour Service (event Source column).
    - Reinstall Bonjour Service if needed.

Bonjour Service cannot be started on Windows

If you try to start Bonjour Service and it fails due to exception 1067, download the 32-bit version of Bonjour Service from Apple. The name of the 32-bit version is ‘Bonjour Print Services for Windows v2.0.2’ and can be found in the following link: support.apple.com/kb/dl999?locale=en_US.

Ubuntu does not show IPv4 address - creating a Link-Local connection

When the PhoXi 3D Scanner or MotionCam-3D is connected to Ubuntu and you want to use dynamic IP address assignment relying on Zeroconf, the network discovery usually requires a Link-Local connection. It is necessary to create Link Local connection when:

- PhoXi Control does not display IPv4 address in the corresponding field
- Running the following command does not show 169.254.x.x IPv4 address

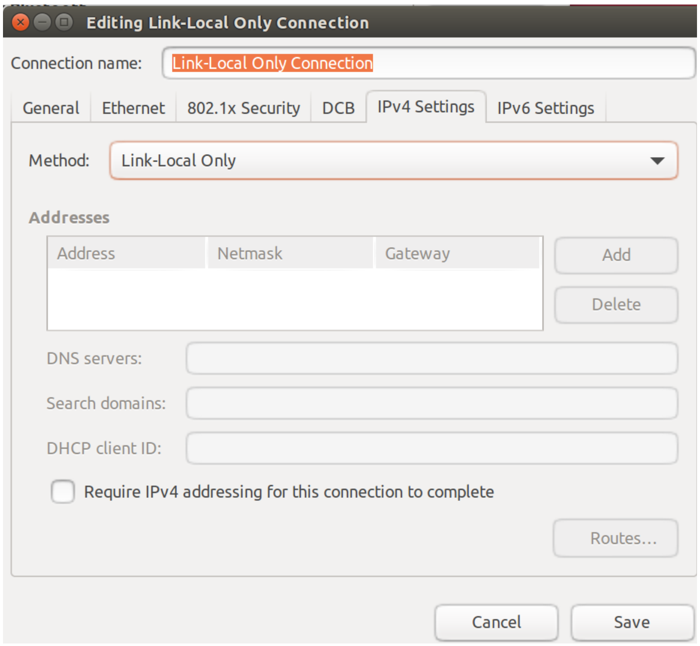
  ```
  ip addr show <INTERFACE-NAME>
  ```

To create Link-Local connection:

1. Connect the device to your computer.
2. Find out the system name of the network interface you have used. It is usually **ethN** or **enpNs0** where N is some small number, e.g. eth0 or enp2s0. You can find out the list of network interfaces by typing `ip -br -c link shown` into a terminal window. Your device will be shown as UP. Note that if you use more than one Ethernet interface you'll see more than one device UP. In that case, disconnect the network cable from the Photoneo device, run the `ip -br -c link show` command again to see which one went DOWN, and plug the network cable back again. Note the hardware (MAC) address of the device. In our example, the device is `enp2s0` and its hardware address is `7c:67:a2:9e:57:c3`.

   ```
   peterko@peterko-dell:~$ ip -br -c link show
   lo               UNKNOWN        00:00:00:00:00:00 <LOOPBACK,UP,LOWER_UP>
   enp2s0           UP             7c:67:a2:9e:57:c3 <BROADCAST,MULTICAST,UP,LOWER_UP>
   wlp3s0           DOWN           50:9a:4c:b5:0f:93 <NO-CARRIER,BROADCAST,MULTICAST,UP>
   tap0             UNKNOWN        ea:cd:74:7a:4d:04 <BROADCAST,MULTICAST,UP,LOWER_UP>
   ```

3. Create a new network connection using NetworkManager. In the *Ethernet,* tab choose the right device (the field is under *the Identity* tab and called *MAC address* on some versions of Ubuntu). In the *IPv4 Settings* choose ***Link-Local Only*** as the connection method.



4. Name the connection for example as “Link-Local Only Connection” and save its configuration.
5. Activate the connection by clicking on its name in the network connections list in the top right corner of your screen.

In case of other issues

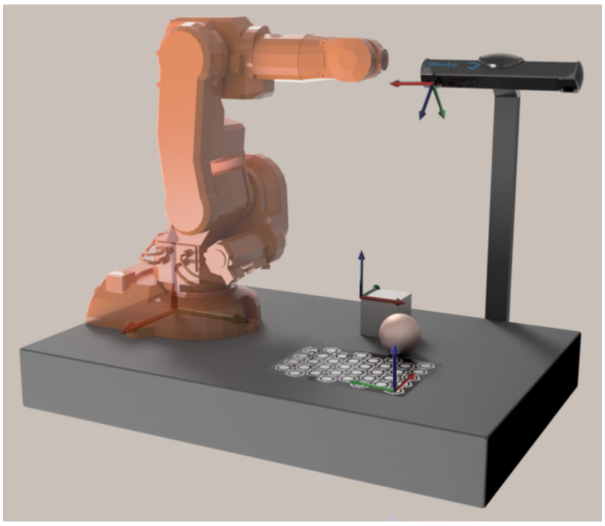
Please report any issues to Help Center.

Please describe what you have been trying to do, what the result was, and what you expected. Depending on the nature of the problem, please also report the version of the operating system being used, your PC configuration, and other additional information that would be helpful in replicating the problem and identifying its root cause. Thank you!

Appendix 1 - Marker Space

Introduction

Every point in a point cloud is identified by three numbers - its XYZ coordinates. Coordinates give the precise position of each 3D point relative to the point of origin of the specific coordinate system.

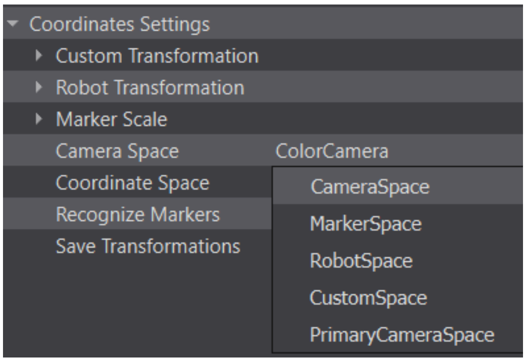


Different coordinate systems.

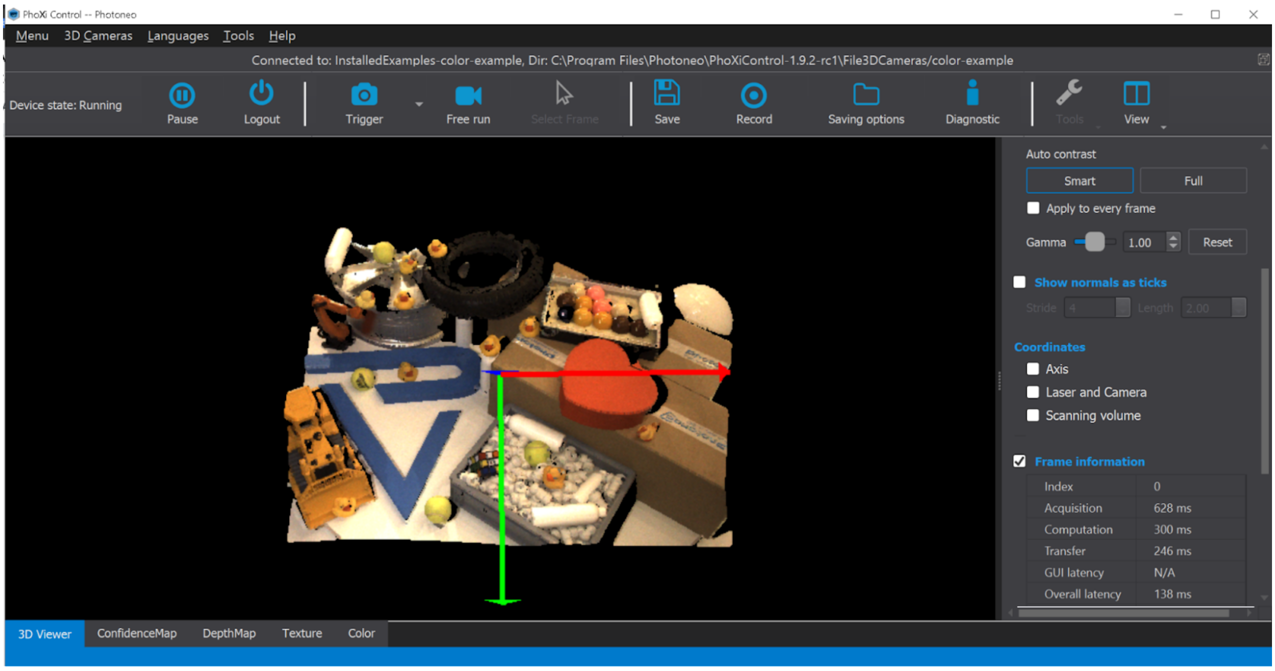
By default, all Photoneo 3D Sensors are set to generate point clouds in the camera coordinate space (the point of origin is located in the center of the camera sensor). Additionally, they provide the internal capability to real-time transform the point cloud to any arbitrary coordinate space. Once the transformation parameters are known the device generates the point cloud (using 3D rotation and translation) in the selected coordinate system. .

In PhoXi Control there are five coordinate spaces to choose from

- Camera space
- Marker space
- Robot space
- Custom space
- PrimaryCameraSpace



The default setting for all Photoneo 3D Sensors is to use CameraSpace. This coordinate system has a point of origin in the center of the camera sensor.
In PhoXi Control, use the checkbox Axis under the Coordinates box in the right pane to visualise the axis defining the default coordinate system. (XYZ axes follow the RGB color convention).



Camera space in PhoXi Control.

Z-axis (blue) lines up perfectly with the direction of the view, so it is not visible.

- In the camera space, X-axis aims to the right side of the device, and Y-axis aims downwards. . The sensor is mounted at a specific angle relative to the sensor body. This angle varies for different scanner models, so the XY-plane is not parallel with the outer casing of the scanner (see Table 1 for details).
- Z-axis aims at the scene and defines the “depth” at which the object is observed by the scanner. It’s the perpendicular distance of every single point on the scene to the XY-plane defined by the camera sensor.

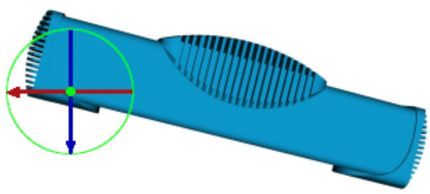


Figure 3: Orientation of camera space coordinate system in relation to the device.

The X-axis is red, the Y-axis is green and the Z-axis is blue.

Table 1: Angles at which the camera sensor is mounted in different models of PhoXi 3D Scanner.

Device	XS	S	M	L	XL
Angle	0°	15.45°	11.75°	9.45°	7.50°

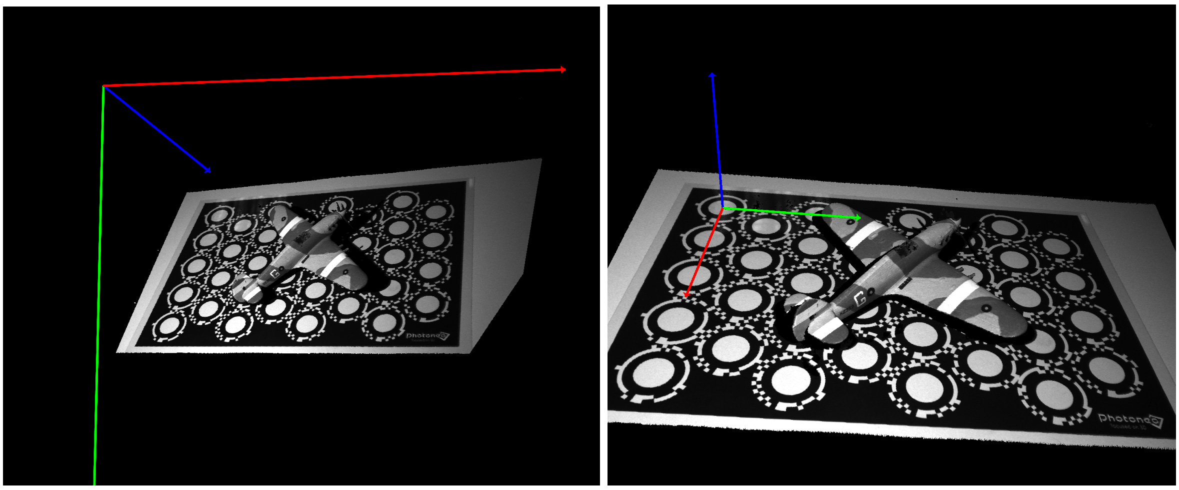
Table 2: Angles at which the camera sensor is mounted in different models of PhoXi 3D Scanner.

Device	L	XL
Angle	7.50°	7.50 °

Table 3: Angles at which the camera sensor is mounted in different models of MotionCam-3D (Color).

Device	S	S+	M	M+	L	*L+
Angle	0°	0°	0°	0°	0°	0°

* Only available as MotionCam-3D Color



Camera space and marker space in PhoXi Control.

Marker Space

Marker space provides you with a practical tool for many different real-world applications. Marker space transformation is useful in situations like: calibration of a coordinate system with a specific plane, multiple scan alignment (one moving scanner), multiple device calibration (scanning scene from different directions), or calibration of a device mounted on a moving robot arm.

Marker space has the point of origin and its axes defined by marker pattern:

- The origin point lies in the middle of one of the corner circles - for the exact position please refer to Figure 5.
- The XY-plane is aligned with the plane of the marker pattern. The X-axis aims through the center of outer circles on the shorter side of the pattern, Y-axis is aiming through the center of outer circles on the longer side. (see Figure 5.)
- The Z-axis points upwards from the marker pattern perpendicular to the XY plane.

Marker Pattern

Marker pattern is a specially developed printed pattern recognized by Photoneo 3D sensors used to transform the coordinate system from default camera space to marker space. It contains N uniquely recognizable white circles on black background with encoded coordinates. Marker patterns are available in different sizes - in the PhoXi Control installation folder or for downloading from our website www.photoneo.com/downloads/device-resources/.

Use PhoXi Control Menu → Tools → Marker Patterns to open a folder containing two subfolders. In the subfolder `Patterns`, you can find PDF versions of all available marker pattern sizes. Since different scanner models are able to scan different volumes from different distances, they also need different sizes of marker pattern.

Table 3: Recommended sizes of marker patterns for PhoXi 3D Scanner models.

	XS	S	M	L	XL Scanning distance [mm]: < 1900	XL Scanning distance [mm]: > 1900
A5	✓	-	-	-	-	-
A4	-	✓	✓	-	-	-
A3	-	-	✓	✓	✓	-
A2	-	-	-	-	✓	✓

Table 4: Recommended sizes of marker patterns for MotionCam-3D models.

	S	S+	M	M+	L	L+ < 1900	L+ > 1900
A5	✓	✓	-		-	-	-
A4	✓	✓	✓	✓	✓	-	-
A3	✓	✓	✓	✓	✓	✓	✓
A2	-	-	-		✓	✓	✓

Table 5: Recommended sizes of marker patterns for Alpha 3D Scanner models.

	L	XL
A5	-	-
A4	✓	-
A3	✓	✓
A2	✓	✓

For complete information about minimal/maximal distances and maximal angles from which marker pattern is recognizable by Photoneo 3D Sensors please refer to Table 6, 7, and 8..

Table 6: Sizes, distances, and angles at which the marker pattern is still recognizable by PhoXi 3D Scanner devices

XS	A5	A4	A3	A2
Minimal distance	150	230	230	-

Maximal distance	250	250	250	-
Maximal angle (~180 mm)	30	-	-	-
S				
Minimal distance	380	380	380	-
Maximal distance	580	580	580	-
Maximal angle (~440 mm)	80	80	80	-
M				
Minimal distance	460	460	460	-
Maximal distance	620	1160	1160	-
Maximal angle (~650 mm)	80	80	80	-
L				
Minimal distance	-	870	870	1300
Maximal distance	-	1950	1950	2200
Maximal angle (~1240 mm)	-	80	80	80
XL				
Minimal distance	-	1680	1680	1680
Maximal distance	-	1950	1950	3950
Maximal angle (~2300 mm)	-	80	80	80

Table 7: Sizes, distances, and angles at which the marker pattern is still recognizable by different models of MotionCam-3D.

S	A5	A4	A3	A2
Minimal distance	380	380	380	-
Maximal distance	580	580	580	-
S+				
Minimal distance	640	640	640	-
Maximal distance	1000	1500	1540	-
M				
Minimal distance	-	500	500	-
Maximal distance	-	935	935	-
M+				
Minimal distance	-	640	635	-

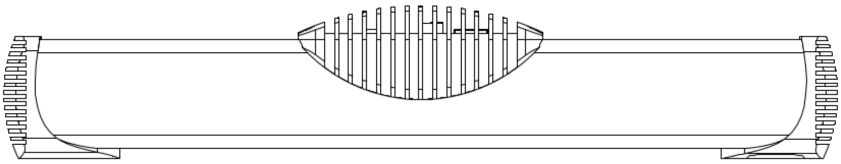
Maximal distance	-	1500	1540	-
L				
Minimal distance	-	780	780	780
Maximal distance	-	1400	2350	3030
L+				
Minimal distance	-	-	1300	1300
Maximal distance	-	-	2950	3780

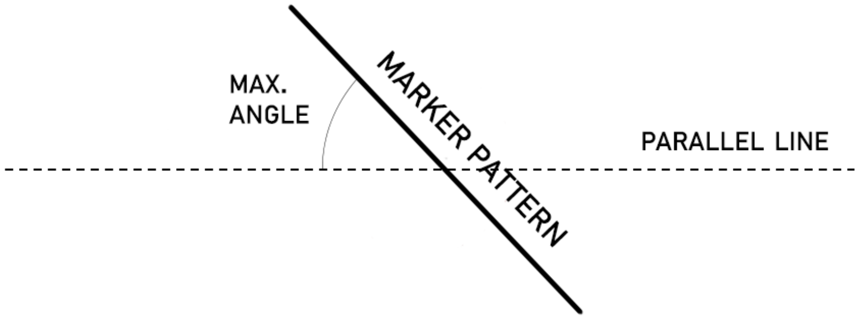
Table 8: Sizes, distances, and angles at which the marker pattern is still recognizable by different models of Alpha 3D Scanner.

L	A5	A4	A3	A2
Minimal distance	-	870	870	870
Maximal distance	-	1630	2150	2150
XL				
Minimal distance	-	-	1680	1680
Maximal distance	-	-	2840	3780

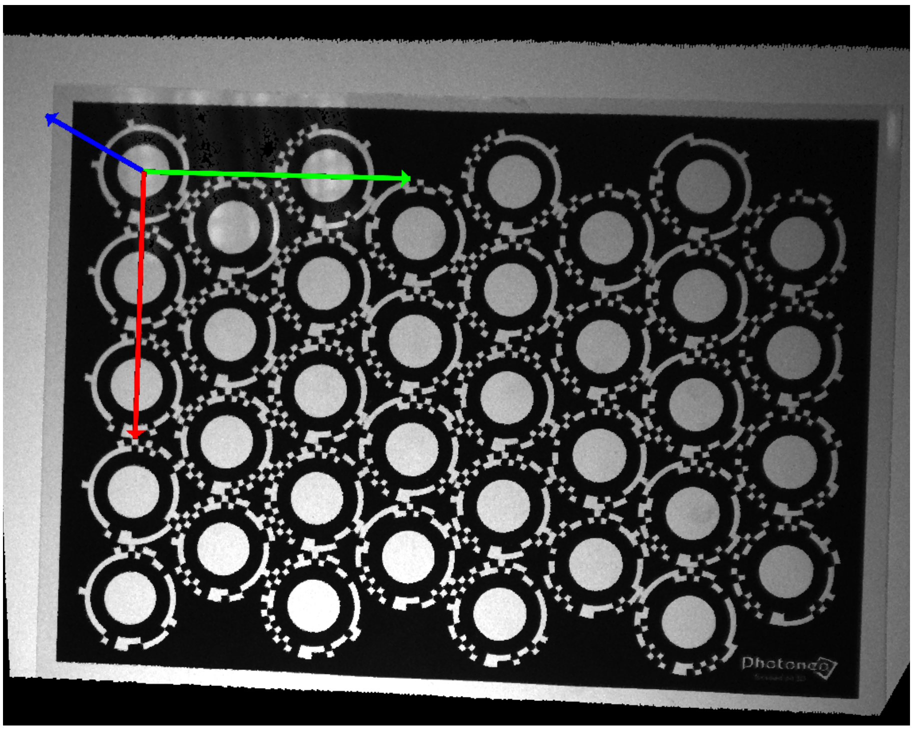
Table 6, 7, 8 explanations:

- Minimal distance - minimal distance at which the device can still recognize the marker pattern.
- Maximal distance - the maximal distance at which the device can still recognize the marker pattern.
- Maximal angle - maximal angle to which the marker device can be rotated away from the position parallel with the device as can be seen in the following figure.





Maximal angle to which the marker pattern can be rotated away from position parallel with the device for the pattern to be still recognizable. For maximal angles for different sizes of scanners and marker patterns refer to Tables 3 and 4.



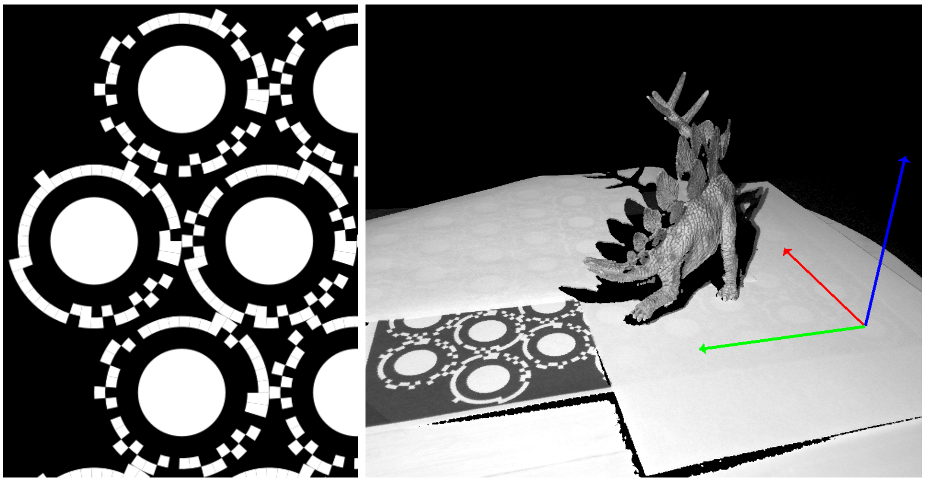
Marker pattern with the point of origin and X (red), Y (green), and Z (blue) axes depicted.

The origin of marker space always lies in one specific circle (see Figure 5). Even if this circle is not visible in the initial scan, the design of the pattern ensures that the point of origin can be calculated based on which circles are visible in the scan. If the marker pattern is printed scaled and the corresponding scale is not set in PhoXi Control, the marker pattern will not be recognized correctly (i.e. the point of origin will be on the edge of the circle instead of in the middle.

For applications where the highest accuracy is necessary, the marker pattern can also be ordered as a metal plate. Paper marker patterns usually are not perfectly flat, which can cause small deviations in the setting of the XY plane. Even though this error is small, for objects that are larger or further away this initial error multiplies and can cause millimeter deviations in measurements far from the pattern. Marker patterns on metal plates have better flatness and eliminate these types of errors.

For applications where scaled versions of the above-mentioned marker patterns are used, the scale of the pattern has to be reflected by setting up the Marker Scale in PhoXi Control. The marker Scale is part of the Coordinate Settings menu. For lower versions of PhoXi Control, this utility is used to change the scale of the marker pattern.

In most cases at least an area of 2 columns *x* 3 rows of the marker pattern has to be visible to the scanner. The circles on the marker pattern visible to the scanner cannot be collinear or the scanner will not be able to recognize them.



Minimal part of the marker pattern that has to be visible for the scanner to correctly recognize it and set marker space. It does not matter which part of the marker pattern is visible to the scanner.

Marker Space Set Up

Marker space set up is a two-step process:

1. Calibration
2. Usage

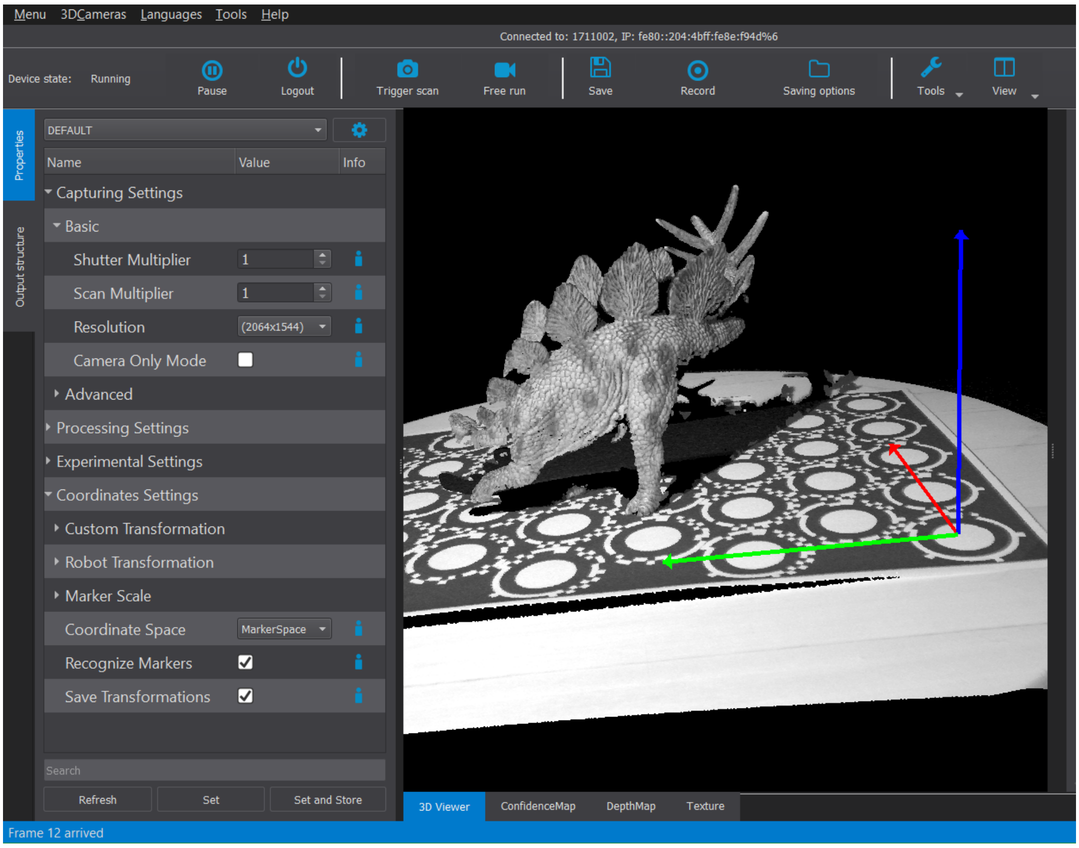
Calibration

"Calibration" is the process of recognizing the position of the marker pattern and setting up the marker space coordinate system. It can be done one time, e.g. to calibrate the coordinate system with the table or the floor, or every time the scan is taken, e.g. to be used on rotary tables.

To calibrate the scanner for marker space:

- Connect to Photoneo 3D Sensor as usual. See section Connecting to the device in this manual

- If using a MotionCam-3D, for the **Camera mode**, markers should be 1.5x larger than in the Scanner mode to accommodate the reduced resolution and the Topology needs to be set to **Regular**.
- In the **Coordinates Settings** menu set **Coordinate Space** to **Marker Space**.
- Check **Recognize Markers**.
- Check **Save Transformations**.
- Hit the **Set** button.
- You can also save this marker space transformation into your current profile, and hit the **Set and Store** button.
- Place the marker pattern in the scene, and trigger the scan.
  - If any object is in the scene, make sure the minimal part of the marker pattern is visible (Figure 5).



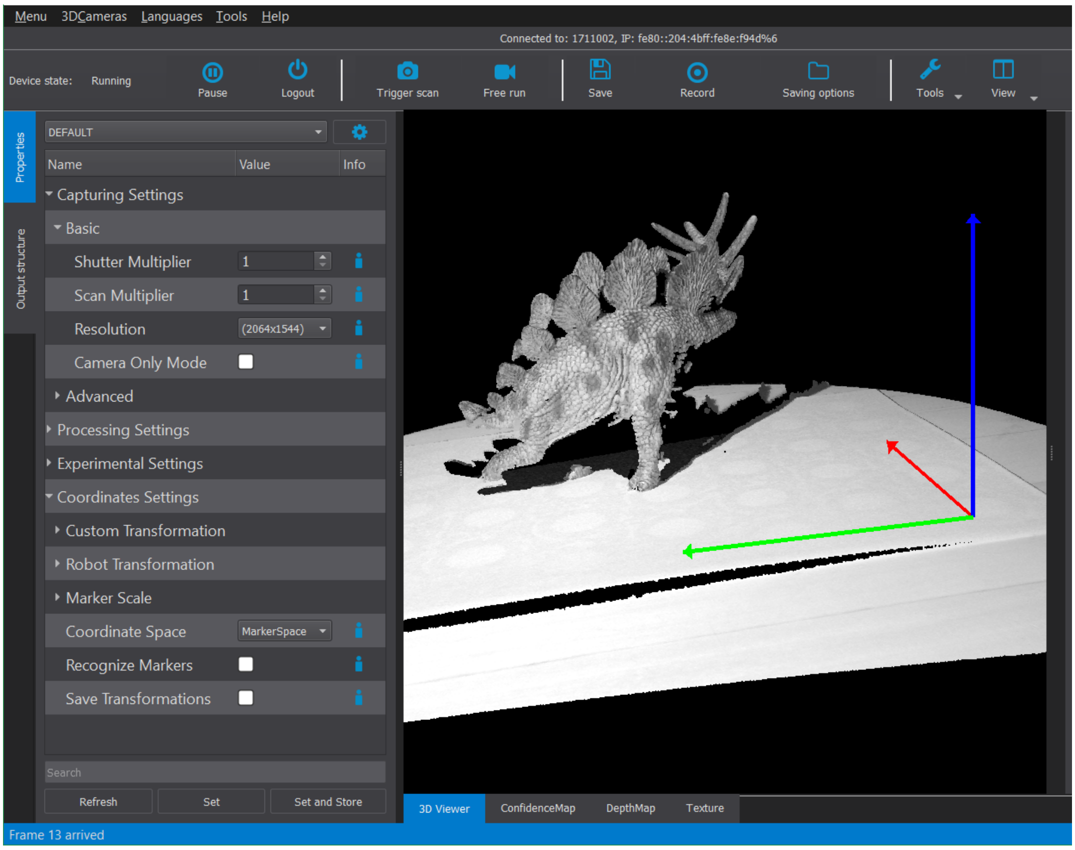
Calibration of marker space.

Usage

Once the calibration is completed, the marker coordinate system is stored in the device, so the marker pattern can be removed from the scene.

For the following scans:

- Set Coordinate Space to Marker Space.
- Set Recognize Markers to off.
- Set Save Transformations to off.
- If using a MotionCam-3D, after the calibration is complete, **Operation Mode** can be either set to **Camera** or **Scanner** while preserving the **Marker Space**



Usage of marker space.

Recognize Markers parameter is used to tell the scanner to look for the marker pattern in the scene:

- When this option is checked and the marker pattern is in the scene, transformation to marker space occurs.
- When this option is checked and the marker pattern is not in the scene, no point cloud is generated and PhoXi Control shows the status **Error: Marker pattern was not recognized (3D-Based)!**.
- It is only necessary for Recognize Markers to be checked during marker space calibration. Once the transformation is known it is saved on the scanner by the Save Transformations parameter.
- Moving the scanner between sessions or making other adjustments to the scene in terms of distances and/or angles between the scanner and plane defined by the marker pattern makes the transformation incorrect.

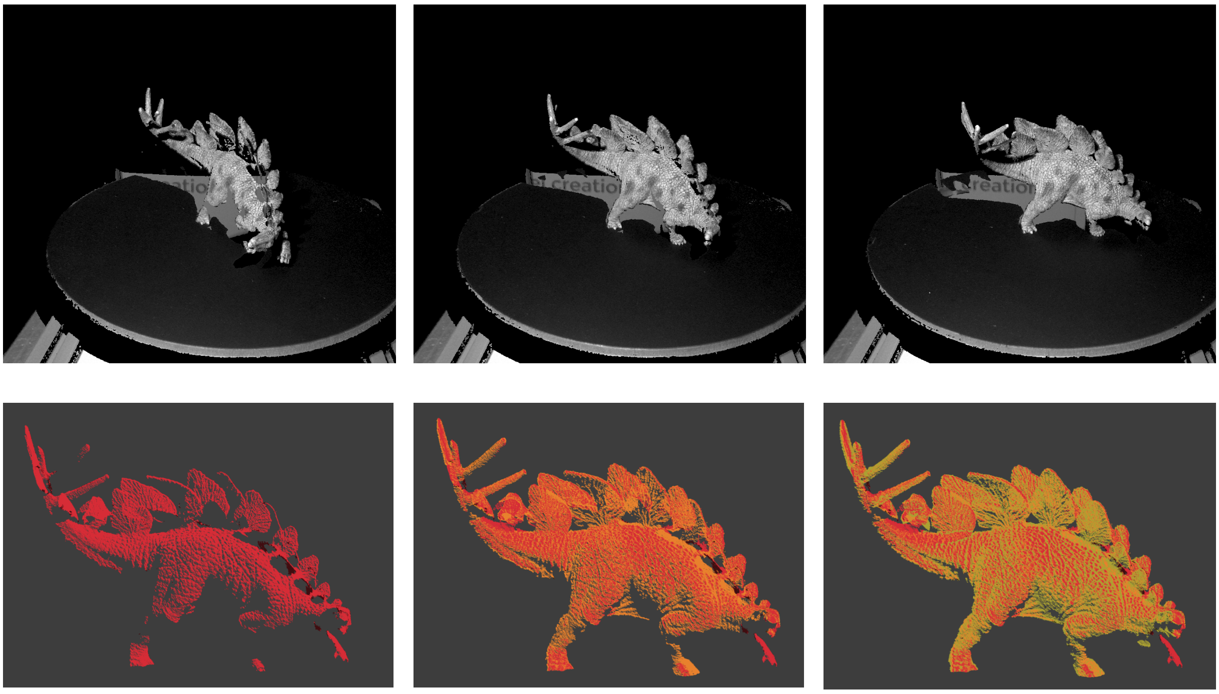
Save Transformations parameter is used to permanently save transformations from camera space to other coordinate spaces (marker space, custom, or robot space) to the scanner. This means that even when marker space is selected in the following session (after the device restart) and the pattern is not set to be recognized again, the transformation is applied to the point cloud.

Marker Space Advantages and Use

There are several uses of Photoneo 3D Sensors where the Marker Space presents an advantage:

- **Calibration with a plane**: for applications that need to have a specific plane as their base, marker space provides an easy way to achieve this. The marker pattern can be removed after the initial calibration.

- **Multiple scan alignment**: for applications where multiple scans from different points of view are used to create a model of the scanned object. Point clouds that have coordinates in camera space can be aligned by complex algorithms or manually. However, when the point clouds are generated in marker space the scans can be automatically pre-aligned with each other.



Alignment of scans from multiple points of view.

- **Multiple devices calibration**: for applications where multiple devices are used to scan the scene from different points of view. If all the devices in the scene have coordinates set to marker space they generate point clouds with the same coordinates. This is very similar to scanning objects with one device from different points of view.

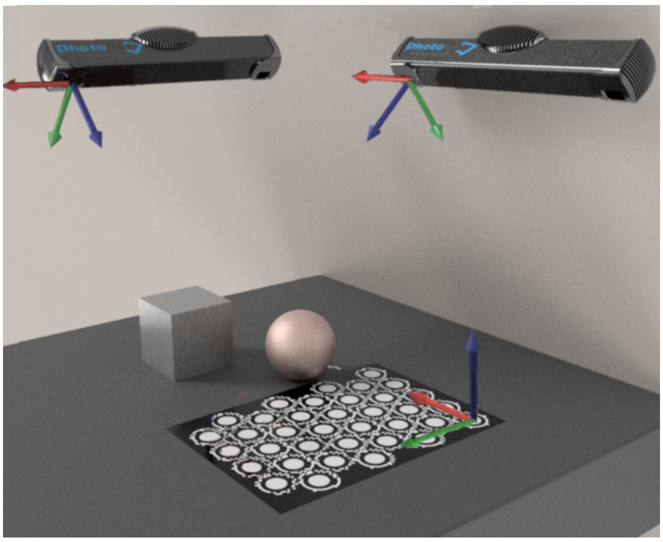
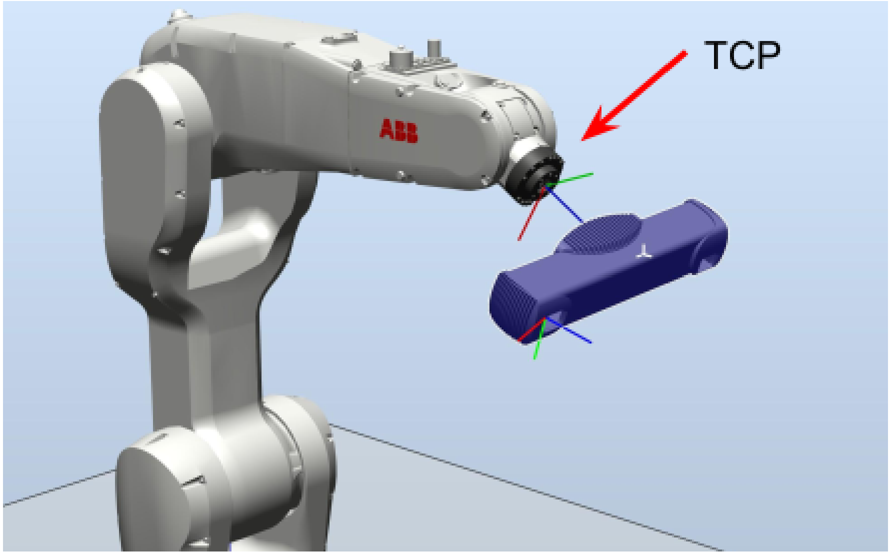


Figure 10: Multiple devices in one scene using marker space generated point clouds with the same coordinates.

- **Calibration of the device on a moving robot arm** allows determining the exact position of the device mounted on the moving robot arm with regards to the tool center point (TCP) of the robot. The calculation is done based on several scans of the marker pattern in different positions of the robot (its TCP). Knowledge of the exact position of the device on the robot is necessary to transform the position of the scanned object into the coordinate space of the robot.

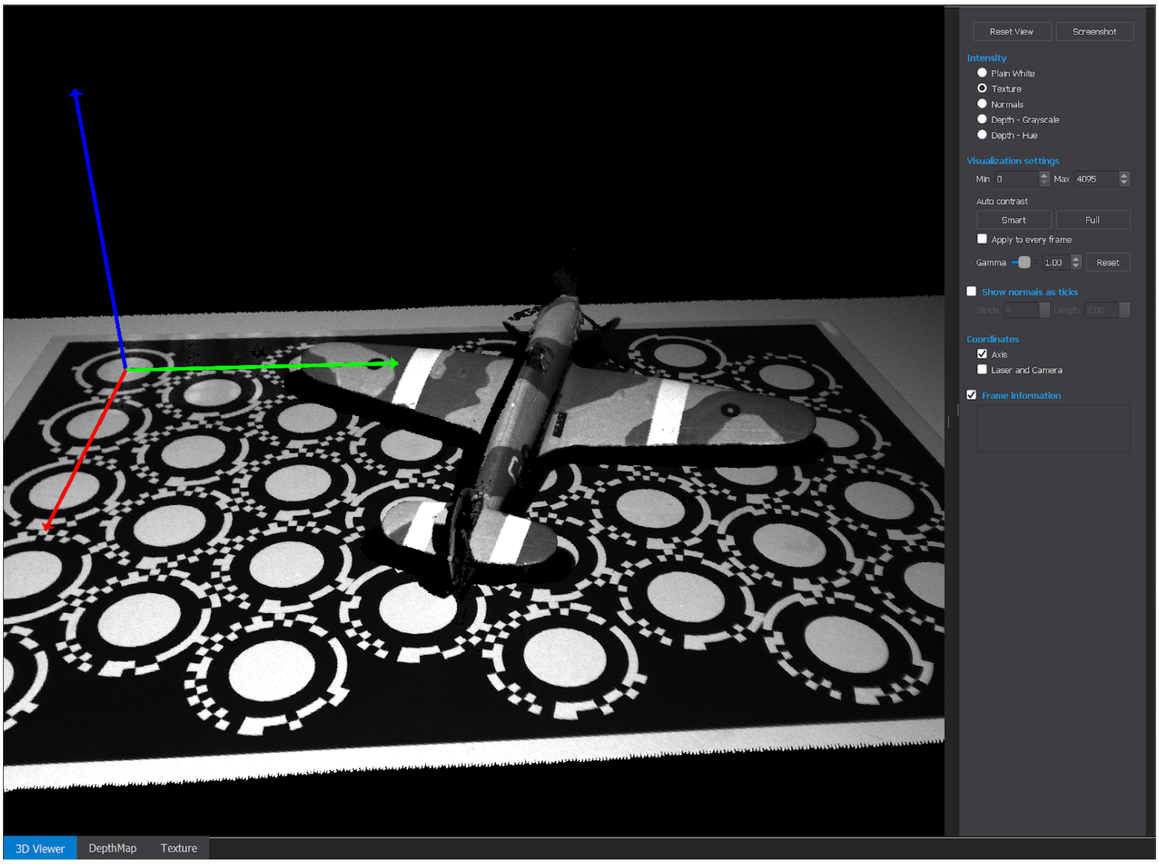


Marker space allows finding the transformation between the tool center point of the robot and the fixed position of the device on the robot arm.

Troubleshooting and FAQ

How do I find out if my point cloud is in the Marker space?

On the right side of the Viewer Pane in the Coordinates menu check the Axis box. This displays the axes of the point cloud coordinate system. Marker space axes can be easily visually checked in a 3D viewer to see if they are set correctly.



Scan in Marker space with displayed axes.

Point cloud is not generated, and the status bar shows Error: Marker pattern was not recognized (3D-Based)!.

The marker pattern is not detected correctly. Either:

- The visible portion of the marker pattern is too small
- There are only collinear circles in the visible portion of the marker pattern
- The angle between the marker pattern and the device is too big (please refer to Table 3, Table 4 and Figure 13),
- The point cloud is in half resolution.
- If using MotionCam-3D, the Operation mode is set to Camera

The point of origin of Marker Space is not in the center of the circle.

Check if the marker pattern is printed correctly without scaling or fitting it to paper. When the pattern is scaled the size of the circles is different, and the position of the point of origin is not calculated correctly.

Always use marker patterns available in PhoXi Control or downloaded from our website.

Does the origin point of Marker Space have to be visible to the scanner?

No. All the circles are unique so the origin point is calculated based on the circles that are visible.

Appendix 2 - External Camera Calibration

Introduction

Image sensors inside PhoXi 3D Scanners and MotionCam-3D (non-color) are capable of providing grayscale images only. Applications that require color information along with the 3D data can be performed using the MotionCam-3D Color or by a calibration (also referred to as alignment) of an additional color camera with the PhoXi 3D Scanners and MotionCam-3D (non-color).

The calibration is achieved via PhoXi C++ API by capturing multiple images of marker pattern both from the device and the external camera. The output of this calculation is a transformation from the default scanner coordinate space to the coordinate space of the external camera. As a result, the API can provide a depth map from the perspective of the external camera as well as a 3D point cloud with a mapped color texture.

This manual will guide you through the use of the API example ExternalCamera in the following steps:

1. Calibration of sample external camera with PhoXi 3D Scanner or MotionCam-3D.
2. Calculation of the depth map from the point of view of the external camera.
3. Application of color information on the 3D point cloud.

Provided example application has two modes of operation:

1. Batch mode controlled by command line arguments capable of calibration of the device with an external camera, depth map calculation, and color point cloud processing using saved files.
2. Interactive mode where each step is based on user input. This mode is capable of calibrating the external camera with the device, calculating the depth map, and processing the color point cloud while connected to the scanner.

Running the Example with Sample Data

Provided API application runs with sample data to demonstrate the process of calibration with an external camera, producing a depth map and colored point cloud. Implementation and use of your own external camera is described in later parts of this document.

The **ExternalCamera** API example can be found in

- Windows: `Program Files/PhotoneoPhoXiControl/API/examples/CPP/ExternalCamera`
- Linux: `/opt/PhotoneoPhoXiControl/API/examples/CPP/ExternalCamera`

It is recommended to copy the example folder into your user folder or other location where you have writing rights.

Download example data for calibration from the following link and copy the Data folder into your project folder:
http://photoneo.com/files/installer/PhoXi/api/external_camera_example_1.2.zip

Install OpenCV 3.1.0 on the following path:

- Windows: `C:/opencv`

- Linux: `home/OpenCV`

Calibration

The process of calibration serves to compute the transformation between the default coordinate space of the device and the coordinate space of the external camera which has origin in the external camera. The computation is achieved by processing:

- Ten pairs of images of marker pattern taken by the device and the external camera, each taken from a different point of view. For calibration purposes, the images from the external camera have to be in greyscale. The images are located in `<path>/Data` directory with the following naming convention:
  - Prefix **frame** for images captured by the internal camera of the scanner.
  - Prefix **image** for images captured by the external camera.

- Input parameters from files located in the `<path>/Settings` directory:
  - `FocalLength` → focal length of the external camera.
  - `PixelSize` → pixel size of the external camera.
  - `MarkerPositions` → positions of centers of circles on the marker pattern. Different sizes of marker patterns have different positions of the circles.

The calibration is handled by connecting to file camera `1.praw` located in the `<path>/Data` folder.

The result of calibration is file `calibration.txt` containing a set of estimates of intrinsic and extrinsic parameters of the external camera and transformation from the native Photoneo 3D Sensor coordinate space to the external camera coordinate space.

To calibrate the application with sample data, use the following command line argument:

```
./ExternalCameraExample --calibrate ExternalCamera/Data/1.praw Data/frame1.png
Data/frame2.png Data/frame3.png Data/frame4.png Data/frame5.png Data/frame6.png
Data/frame7.png Data/frame8.png Data/frame9.png Data/frame10.png Data/image1.png
Data/image2.png Data/image3.png Data/image4.png Data/image5.png Data/image6.png
Data/image7.png Data/image8.png Data/image9.png Data/image10.png
```

Note: At least 5 pairs of frames & images need to be processed for a successful calibration.

Aligned Depth Map Computation

During this step, the depth map aligned from the point of view of the external camera is calculated.

The aligned depth map is calculated based on the data loaded from `calibration.txt`. The application connects to a file camera `<folder>/Data/1.praw` and then computes the aligned depth map, which is saved as an image in `<folder>/fileCamera_1.jpg`. The following command line argument is used to calculate the depth map:

```
./ExternalCameraExample --depthmap
```

Colored Point Cloud Computation

This step serves to apply the color texture captured by the external camera to the point cloud.

The colored point cloud is calculated based on the data loaded from `calibration.txt`. The application connects to a file camera `<path>/Data/1.praw`, loads a color texture from `<path>/Data/1.bmp,` and applies it to the point cloud. The result is saved as `<path>/1.ply`. The following command line argument is used to calculate the colored point cloud:

```
./ExternalCameraExample --colorpc
```

Integration of External Camera

To use your own external camera with Photoneo 3D Sensor, the following steps are necessary:

- Preparation of the external camera and configuration of the input files.
- Implementation of the external camera into the API code.
- Preparation of marker pattern.

External Camera

For successful integration of the external camera with Photoneo 3D Sensor the following requirements have to be met:

- The external camera is C++ compatible and the user is able to trigger images via API calls.
- Its pixel size and focal length (both in millimeters) are known.
- The position of the external camera with regards to the device is fixed.
- The field of view of the external camera overlaps the field of view of the scanner camera as much as possible. It is recommended to mount the external camera very close to the camera unit of the device.

The following files have to be modified with the information about intrinsic parameters of the external camera:

- `<path>/Data/FocalLength.txt` - contains the focal length in millimeters.
- `<path>/Data/PixelSize.txt` - contains pixel size in millimeters.

Marker Pattern

The calibration of Photoneo 3D Sensor with an external camera requires a marker pattern and text file detailing the positions of circles on the pattern. A standard marker pattern bundled within PhoXi Control is used for this purpose. The folder containing marker patterns (Menu → Tools → Marker Patterns) also contains the subfolder `Patterns_with_Metadata` with text files where the position of each circle on the marker pattern is written. Each size of the pattern has different positions of the circles.

- Alternatively, download the [Marker Patterns with metadata]

- Please select the appropriate size of the marker pattern based on the scanner model and scanning distance and print it at 100 % scale.
- Copy the corresponding file with positions of the circles into
  - `<path>/Settings/MarkersPositions.txt`.
- When choosing the right size of the marker pattern, refer to Table 1 or Table 2.

External Camera Implementation

In order to gather images from the external camera, it is necessary that the user implements the following functions:

```
ExternalCamera:getCalibrationImage
ExternalCamera:getColorImage
```

Calibration

Frames and images of the marker pattern from which the transformation to the coordinate space of the external camera is calculated, are acquired during the calibration. The application prompts the user to trigger the frame, after which the method `ExternalCamera:getCalibrationImage` is called to capture the image from the external camera. **At least five pairs** of frames and images from different points of view have to be processed for the calibration to be successful. When the point of view is changed, the relative position of the external camera and the native camera of Photoneo 3D Sensor has to remain the same. The output of the calibration is saved into `<path>/calibration.txt`. The calibration is valid for all consecutive scans.

Using Already Saved Data

This mode allows for quick calibration of the external camera with the device with previously captured files.

```
--calibrate [full path to praw file] frames... cameraImages...
```

The full command for calibration with 10 pairs of frames and images would look like this:

```
./ExternalCameraExample --calibrate D:/ExternalCammera_CPP/Data/1.praw Data/frame1.png
Data/frame2.png Data/frame3.png Data/frame4.png Data/frame5.png Data/frame6.png
Data/frame7.png Data/frame8.png Data/frame9.png Data/frame10.png Data/image1.png
Data/image2.png Data/image3.png Data/image4.png Data/image5.png Data/image6.png
Data/image7.png Data/image8.png Data/image9.png Data/image10.png
```

Aligned Depth Map Computation

The application loads `calibration.txt`. The aligned depth map is calculated right after a new pair of frames and images is triggered and saved into `<folder>/device_1.jpg`. The number in the file name is increased every time a new scan is triggered and a new depth map is saved.

Using Already Saved Data

The calculation of the aligned depth map from previously captured data can be achieved with the following command line arguments:

```
--depthmap [full path to praw file] [output file]
```

The `calibration.txt` has to be present for this command to work, otherwise the application will exit with an error. The output file is where the resulting depth map is saved. The full command would look like this:

```
./ExternalCameraExample --depthmap D:/ExternalCamera_CPP/Data/scan.praw depthmap.jpg
```

Colored Point Cloud Computation

The application loads `calibration.txt`. After the new scan is triggered the application calls `ExternalCamera:getColorImage` method to capture color texture by the external camera. This texture is then applied to the native point cloud and saved into `<path>/device_1.ply`. The number in the file name is increased each time a new point cloud is saved.

Using Already Saved Data

The alignment of existing color texture over previously captured data can be handled by following command line arguments:

```
--colorpc [full path to praw file] [color image] [output file]
```

The `calibration.txt` has to be present for this command to work, otherwise, the application will exit with an error. The color image is the texture from the external camera that is going to be aligned with the point cloud and the output file is where the resulting point cloud is saved. The full command looks like this:

```
./ExternalCameraExample --colorpc D:/ExternalCamera_CPP/Data/scan.praw texture.bmp
pointcloud.ply
```

Appendix 3 - Intrinsic Parameters

Use Cases

Point Cloud Calculation from Depth Map

Depth map is a basic output calculated by Photoneo devices, transferred to PhoXi Control, and used for point cloud calculation. In some applications, the users might calculate the point cloud from the depth map by themselves and not rely on the calculation done by PhoXi Control. Some information about how the 2D camera "sees" the world is necessary for this procedure. This information is carried either by intrinsic camera matrix or by reprojection map.

In Photoneo scanning devices the texture and depth map have a direct relationship → each pixel in the texture has corresponding depth information in the depth map. Therefore operations like segmenting out the only object of interest in the texture and then calculating only the 3D points that were segmented are possible.

The point cloud can be calculated from depth map using these approaches:

- Using intrinsic camera matrix and triangle similarity described in pinhole camera model together with distortion coefficients to calculate point cloud for each pixel
- Using reprojection map to multiply the depth of given pixel by a reprojection vector corresponding to that pixel

Image Processing on Undistorted Data

Texture and a depth map from Photoneo devices are distorted. This means that straight lines at some parts of the picture appear bent or round-shaped objects appear to be oval-shaped in the texture. Therefore image processing for such geometric shapes is not possible on distorted data and we have to undistort them first.

To undistort we first apply the inverse of distortion function to each pixel, for example by using the OpenCV method. Once we have the undistorted texture, we can identify the feature points of our object. Then there are two possibilities:

- To undistort the depth map as well and use the intrinsic parameters to calculate a new, undistorted point cloud
- Distort the feature points back to see to which camera pixels they belong and then use this information to identify them in the point cloud

Intrinsic Parameters Provided by Photoneo Devices

All provided intrinsic parameters can be retrieved by PhoXi API. There are two different types of intrinsic parameters:

- Intrinsic camera matrix and distortion coefficients
- Reprojection map

Intrinsic Camera Matrix and Distortion Coefficients

Intrinsic camera matrix describes the transformation from 3D coordinates to 2D coordinates on an image plane using the pinhole camera model. It is a 3x3 matrix containing focal length - the distance between the pinhole and the image plane and principal point offset - the pixel offset from the principal point.

Distortion coefficients describe the properties of the camera lens and how it distorts the real shape of an object to the shape on the image. OpenCV compatible coefficients (k1, k2, p1, p2, k3) are used to describe the distortion introduced by the camera lens in Photoneo devices.

- Intrinsic camera matrix and distortion coefficient can be retrieved using PhoXi API by two different approaches:
- Global method: PhoXiDevice→CalibrationSettings:
  - provides the Camera Matrix and Distortion Coefficients at maximum device resolution:
    - PhoXi 3D Scanner → 2064x1544
    - MotionCam-3D → scanner mode 1680x1200
- PerFrame method: FrameInfo→Camera
  - provides the Camera Matrix and Distortion Coefficients for current device resolution
    - PhoXi 3D Scanner → 2064x1544 or 1032x772
    - MotionCam-3D → respects current Operation mode and Output topology. Empty for Raw and Irregular grid topologies

Global Method

See **GetISCalibParams** API example:

```
void printCalibParams(pho::api::PPhoXi &PhoXiDevice)
{
    pho::api::PhoXiCalibrationSettings CalibrationSettings = PhoXiDevice->CalibrationSettings;

    std::cout << "CalibrationSettings: " << std::endl;
    std::cout << "  FocusLength: " << CalibrationSettings.FocusLength << std::endl;
    std::cout << "  PixelSize: "
        << CalibrationSettings.PixelSize.Width << " x "
        << CalibrationSettings.PixelSize.Height
        << std::endl;
    printMatrix("CameraMatrix", CalibrationSettings.CameraMatrix);
    std::cout << "  DistortionCoefficients: " << std::endl;
    std::cout << "    Format is the following: " << std::endl;
    std::cout << "    (k1, k2, p1, p2[, k3[, k4, k5, k6[, s1, s2, s3, s4[, tx, ty]]]])" <<
std::endl;

    std::vector<double> distCoeffs = CalibrationSettings.DistortionCoefficients;
    std::stringstream currentDistCoeffsSS;
    std::size_t brackets = 0;
    currentDistCoeffsSS << "(";
    currentDistCoeffsSS << distCoeffs[0];
    for (std::size_t i = 1; i < distCoeffs.size(); ++i)
    {
        if (i == 4 || i == 5 || i == 8 || i == 12 || i == 14)
        {
```

```
            currentDistCoeffsSS << "[";
            ++brackets;
        }
        currentDistCoeffsSS << ", " << distCoeffs[i];
    }
    for (std::size_t j = 0; j < brackets; ++j)
    {
        currentDistCoeffsSS << "]";
    }
    currentDistCoeffsSS << ")";
    std::cout << "    " << currentDistCoeffsSS.str() << std::endl;
}
```

Per Frame Method

See **FullAPI** example:

```
void FullAPIExample::PrintFrameInfo(const pho::api::PFrame &Frame)
{
    const pho::api::FrameInfo &FrameInfo = Frame->Info;
    std::cout << "  Frame params: " << std::endl;
    std::cout << "    Frame Index: " << FrameInfo.FrameIndex << std::endl;
    std::cout << "    Frame Timestamp: " << FrameInfo.FrameTimestamp << " s" << std::endl;
    std::cout << "    Frame Acquisition duration: " << FrameInfo.FrameDuration << " ms" <<
std::endl;
    std::cout << "    Frame Computation duration: " << FrameInfo.FrameComputationDuration << "
ms" << std::endl;
    std::cout << "    Frame Transfer duration: " << FrameInfo.FrameTransferDuration << " ms"
<< std::endl;
    std::cout << "    Sensor Position: ["
        << FrameInfo.SensorPosition.x << "; "
        << FrameInfo.SensorPosition.y << "; "
        << FrameInfo.SensorPosition.z << "]"
        << std::endl;
    PrintMatrix("Camera calibration matrix", FrameInfo.CameraMatrix);
    PrintDistortionCoefficients("Frame Distortion Coefficients",
FrameInfo.DistortionCoefficients);
    std::cout << "     Camera binning height: " << FrameInfo.CameraBinning.Height <<
std::endl;
    std::cout << "     Camera binning width: " << FrameInfo.CameraBinning.Width << std::endl;
    std::cout << "    Total scan count: " << FrameInfo.TotalScanCount << std::endl;
}
```

Reprojection Map

Reprojection map is a field of vectors that describes the direction from which each pixel gathers data. Each pixel has its own vector, therefore when we multiply the depth information by the vector from the reprojection map we get a point cloud.

Reprojection map can only be retrieved by one method:

- Global method: PhoXiDevice→ReprojectionMap
  - Provides current reprojection map that respect current device settings
    - PhoXi 3D Scanner → both resolutions

- MotionCam-3D both operations modes and all output topologies

Global Method

See **PointCloudCalculation** API example:

```
bool calculatePointCloud(pho::api::PointCloud32f& pointCloud,
    pho::api::DepthMap32f depth,
    pho::api::PhoXiReprojectionMap reprojection) {
    if (pointCloud.Size != reprojection.Map.Size) {
        return false;
    }
    for (int row = 0; row < pointCloud.Size.Height; ++row) {
        for (int col = 0; col < pointCloud.Size.Width; ++col) {
            if (depth.At(row, col) > 0.0f) {
                pointCloud.At(row, col).x = depth.At(row, col) * reprojection.Map.At(row,
col).x;
                pointCloud.At(row, col).y = depth.At(row, col) * reprojection.Map.At(row,
col).y;
                pointCloud.At(row, col).z = depth.At(row, col) * reprojection.Map.At(row,
col).z;
            }
            else {
                pointCloud.At(row, col).x = 0.0f;
                pointCloud.At(row, col).y = 0.0f;
                pointCloud.At(row, col).z = 0.0f;
            }
        }
    }
    return true;
}
    pho::api::PhoXiReprojectionMap map = PhoXiDevice->ReprojectionMap;
    PhoXiDevice->StartAcquisition();
    if (!PhoXiDevice->isAcquiring())
    {
        std::cout << "Your device could not start acquisition!" << std::endl;
        return 0;
    }
    int id = PhoXiDevice->TriggerFrame();
    if (id < 0) {
        std::cout << "Trigger frame unsuccessful" << std::endl;
    }
    auto frame = PhoXiDevice->GetSpecificFrame(id);
    if (frame) {
        auto depth = frame->DepthMap;
        pho::api::PointCloud32f pointCloud;
        pointCloud.Resize(depth.Size);
        calculatePointCloud(pointCloud, depth, map);
        //pointCloud now contains your point cloud data
    }

    return 0;
```

Overview

	PhoXi 3D Scanner		MotionCam-3D	
How to retrieve when using:	Full resolution	Half resolution	Scanner mode	Camera mode
Camera Matrix and Distortion Coefficients	Global PerFrame when operating in full resolution	~~Global~~ PerFrame when operating in half resolution	Global PerFrame when operating in Scanner mode	~~Global~~ PerFrame when operating in Camera Mode Only applicable for Output Topology = Regular Grid
Reprojection Map	Global	Global	Global	Global

Focused on 3D

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