user manual

pco.cpp

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pco.

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Excelitas PCO GmbH asks you to carefully read and follow the instructions in this document.
For any questions or comments, please feel free to contact us at any time.

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Contents

1 General

The **pco.cpp** package is powerful and easy to use high level C++ Software Development Kit (SDK) for working with PCO cameras. It contains everything needed for camera setup, image acquistion, readout and color conversion.

The high-level C++ class architecture makes it very easy to integrate PCO cameras into your own software, while still having access to the underlying **pco.sdk** and **pco.recorder** interface for a detailed control of all possible functionalities.

1.1 Installation

Windows Download the Windows installer, unzip it and execute it. Simply follow the steps in the installer.

In your install directory (default: C:\Program Files\PCO Digital Camera Toolbox\pco.cpp) you will find:

- A visual studio (2019) solution file with all provided examples
- A **samples** directory containing all example projects
- The **pco.camera** directory containing the actual sources of this class-interface sdk
  Projects need to cover these source files for compilation.
- The **include** directory containing all necessary headers of pco.sdk and pco.recorder
- The **bin** directory with the compiled example programs and runtime dll.
- The **lib** directory with pco.sdk libraries for implicit linking.

Linux Download the *.deb package file. Install it by using dpkg, e.g. in the command line with this command: [1]

```
$ sudo dpkg -i pco.cpp_*.*.*_amd64.deb
```

This will install **pco.cpp** into **/opt/pco/pco.cpp**

In your install directory (default: /opt/pco/pco.cpp) you will find

- A Makefile for compiling all provided examples
- A **samples** folder containing all example projects
- The **pco.camera** folder containing the actual sources of this sdk
  Projects need to cover these source files for compilation.
- The **include** directory containing all necessary headers of pco.sdk and pco.recorder
- The **bin** directory with the compiled example programs.
- The **lib** directory with linux pco.sdk libraries.

To work with the code you might need to copy the content to a directory where you have full read/write access rights.

[1] The dpkg package needs to be installed for this, this can be done by *sudo apt-get install dpkg*

1.2 Basic Usage

```
#include "../../pco.camera/stdafx.h"
#include "../../pco.camera/camera.h"
#include "../../pco.camera/cameraexception.h"

int main()
{
    try
    {
        pco::Camera cam;
        pco::Image img;

        cam.setExposureTime(0.01);

        cam.record(10, pco::RecordMode::sequence);
        cam.image(img, 1, pco::DataFormat::BGR8)
    }
    catch (pco::CameraException& err)
    {
        std::cout << "Error Code: " << err.error_code() << std::endl;
        std::cout << err.what() << std::endl;
    }
    return 0;
}
```

This snippet shows the basic usage.

As soon as a `Camera` object is created, a camera is searched, opened and initialized. There are several functions to adjust the camera settings. Here we set the exposure time to 10 ms using `cam.setExposureTime`. Calling `record()` will start the recording. Depending on the recorder mode, the function either waits until record is finished (like for sequence mode which is selected here) or directly returns (see 1.3 for the full list of available modes).

The `Image` class handles the image data, i.e. it enables you to easily get the data either as 16 bit raw image or in various color and monochrome formats (see 1.4 for the full list of available formats). With the `image` / `images` / `imageAverage` functions you can get the recorded images in several different formats. [2]

Here we want to have the image with **index** 1 in the *BGR8* format.

1.3 Recorder Modes

Depending on your workflow you can choose between different recording modes.

In blocking modes the `record` function waits until the specified number of images is reached. In non-blocking modes the caller must ensure that either recording is finished or the process is waiting for the next acquired image (`waitForFirstImage` / `waitForNewImage`), e.g. for live view.

Memory modes are holding image data in RAM, while file modes save images directly to file(s) on the disk. However, images acquired with file mode can also be accessed from memory via `image` functions after recording is done.

[2] Depending on the camera

CamRam modes are using the camera's internal RAM memory for high-speed acquisition. Images can be acquired by reading from a segment or on the fly.

Mode	Storage	Blocking	Description
`sequence`	Memory	yes	Record a sequence of images
`sequence_non_blocking`	Memory	no	Record a sequence of images, do not wait until record is finished
`ring_buffer`	Memory	no	Continuously record images in a ringbuffer, once the buffer is full, old images are overwritten
`fifo`	Memory	no	Record images in fifo mode, i.e. you will always read images sequentially and once the buffer is full, recording will pause until older images have been read
`sequence_dpcore`	Memory	yes	Same as `sequence`, but with DotPhoton preparation enabled
`sequence_non_blocking_dpcore`	Memory	no	Same as `sequence_non_blocking`, but with DotPhoton preparation enabled
`ring_buffer_dpcore`	Memory	no	Same as `ring_buffer`, but with DotPhoton preparation enabled
`fifo_dpcore`	Memory	no	Same as `fifo`, but with DotPhoton preparation enabled
`tif`	File	no	Record images directly as tif files
`multitif`	File	no	Record images directly as one or more multitiff file()s
`pcoraw`	File	no	Record images directly as one pcoraw file
`dicom`	File	no	Record images directly as dicom files
`multidicom`	File	no	Record images directly as one or more multi-dicom file(s)
`camram_segement`	Camera RAM	no	Record images to camera memory. Stops when segment is full

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Mode	Storage	Blocking	Description
`camram_ring`	Camera RAM	no	Record images to camera memory. Ram segment is used as ring buffer

In the code the recorder mode is represented as an enum type:

```
enum class RecordMode {
    sequence, sequence_non_blocking, ring_buffer, fifo,
    sequence_dpcore, sequence_non_blocking_dpcore,
    ring_buffer_dpcore, fifo_dpcore,
    tif, multitif, pcoraw, b16, dicom, multidicom,
    camram_segment, camram_ring
};
```

Note For more information on the DotPhoton preparation and image compression, please visit DotPhoton or feel free to contact us.

1.4 Image Formats

In addition to the standard 16 bit raw image data you can also get images in different formats, shown in the table below.

The format is selected when calling the `image` / `images` / `imageAverage` functions (see 2.1.24, 2.1.25, 2.1.26) of the `Camera` class. The image data is stored in an `Image` object, which enables you to access both the raw data and the image data in the selected format.

Format	Description
`Mono8`	Get image as 8 bit grayscale data
`Mono16`	Get image as 16 bit grayscale/raw data
`BGR8`	Get image as 24 bit color data in bgr format
`BGRA8`	Get image as 32 bit color data (with alpha channel) in bgra format
`BGR16`	Get image as 48 bit color data in bgr format (only possible for color cameras)

In the code the data format is represented as an enum type:

```
enum class DataFormat {
    Undefined,
    Mono8, // 8 bit camera, compressed images
    Mono16,
    BGR8,
    BGRA8,
    BGR16,
    CompressedMono8 //
};
```

Note For monochrome cameras, the `BGR16` format is not available and the colors in the `BGR8`/ `BGRA8` depend on the selected lut, which is a standard grayscale mapping by default. For selecting different lut files you can use the functions `setConvertControl` (see 2.1.21) or `loadlut` (see 2.1.22) from the camera class.

1.5 Error Handling

In the example in 1.2, the code is surrounded by a try-catch block.

Error handling works this way:

- The underlying SDKs (**pco.sdk, pco.recorder, pco.convert**) have a C-API which provides error codes as return values of the exported functions
- The `Camera` and `Image` classes in this package use the `CameraException` class to transform those error codes into an exception
- This exception is then thrown by the class in case something goes wrong

For robust programs we recommend to always surround code, where `Camera` and `Image` class functions are used, with a try-catch and react on the error in the catch block.

Additionally you can also enable the logging of the underlying SDK's. For more information on that please visit our pco.logging page.

2 API Documentation

The pco.cpp package consists of 3 different classes:

- `pco::Camera` is the main class for controlling the camera, acquiring and reading images
- `pco::Image` is the class for handling the image data. Images can have various formats, but the raw data is also available
- `pco::CameraException` is an exception class for mapping PCO error codes to std::exception objects

2.1 pco::Camera

This section describes the functions of the `Camera` class. The following list provides a short overview of the most important functions:

- **Constructor** Open and initialize a camera with its default configuration
- **Destructor** Close the camera and clean up everything
- **defaultConfiguration()** Set default configuration to the camera
- **getConfiguration()** Get current camera configuration
- **setConfiguration()** Set a new configuration to the camera
- **getExposureTime()** Get current exposure time
- **setExposureTime()** Set new exposure time to the camera
- **record()** Initialize and start the recording of images
- **stop()** Stop the current recording
- **waitForFirstImage()** Wait until the first image has been recorded
- **waitForNewImage()** Wait until a new image has been recorded
- **getConvertControl()** Get current color convert settings
- **setConvertControl()** Set new color convert settings
- **image()** Read a recorded image
- **images()** Read a series of recorded images
- **imageAverage()** Read an averaged image (averaged over all recorded images)
- **hasRam()** Check if camera has internal memory for recording with camram
- **switchToCamRam()** Set the camram segment where the images should be written to/read from
- **getCamRamSegment()** Get segment number of the active segment
- **getCamRamMaxImages()** Get number of images that can be stored in the active segment
- **getCamRamNumImages()** Get number of images that are available in the active segment
- **setCamRamAllocation()** Set allocation distribution of camram segments

2.1.1 Constructor

Description Initialize the camera.

Prototype

```
Camera(CameraInterface cam_interface = CameraInterface::Any);
```

Parameter

Datatype	Name	Description
CameraInterface	cam_interface	Specific interface to search for cameras. If undefined, search on all interfaces.

Note

```
enum class CameraInterface : WORD {
  FireWire            = PCO_INTERFACE_FW      ,
  CameraLinkMTX       = PCO_INTERFACE_CL_MTX ,
  GenICam             = PCO_INTERFACE_GENICAM,
  CameraLinkNAT       = PCO_INTERFACE_CL_NAT ,
  GigE                = PCO_INTERFACE_GIGE    ,
  USB                 = PCO_INTERFACE_USB     ,
  CameraLinkME4       = PCO_INTERFACE_CL_ME4 ,
  USB3                = PCO_INTERFACE_USB3    ,
  WLAN                = PCO_INTERFACE_WLAN    ,
  CLHS                = PCO_INTERFACE_CLHS    ,
  Any                 = UNDEF_W
};
```

2.1.2 Destructor

Description Close the activated camera and release the blocked resources.

Prototype

```
~Camera();
```

2.1.3 getName

Description Return the name of the camera.

Prototype

```
std::string getName() const;
```

Return value

Datatype	Name	Description
std::string	name	Camera name

2.1.4 getSerial

Description Return the serial number of the camera.

Prototype

```
DWORD getSerial() const;
```

Return value

Datatype	Name	Description
DWORD	serial_number	Camera serial number

2.1.5 isRecording

Description Return the flag if a recording is currently active.

Prototype

```
bool isRecording() noexcept;
```

Return value

Datatype	Name	Description
bool	recording	Flag if a recording is currently active

2.1.6 isColored

Description Return the flag if camera is a color camera.

Prototype

```
bool isColored() const;
```

Return value

Datatype	Name	Description
bool	colored	Flag if camera is colored

2.1.7 getDescription

Description Return the description parameters of the camera.

Prototype

```
Description getDescription() const;
```

Return value

Datatype	Name	Description
`Description`	`description`	Structure containing the description of the camera (see 2.4.4)

2.1.8 defaultConfiguration

Description (Re)set the camera to its default configuration.

Prototype

```
void defaultConfiguration();
```

2.1.9 getConfiguration

Description Get the current camera configuration.

Prototype

```
Configuration getConfiguration() const;
```

Return value

Datatype	Name	Description
`Configuration`	`configuration`	Structure containing the current configuration of the camera (see 2.4.3)

2.1.10 setConfiguration

Description Set a configuration to the camera.

Prototype

```
void setConfiguration(Configuration config);
```

Parameter

Datatype	Name	Description
`Configuration`	`config`	Configuration that should be set (see 2.4.3).

2.1.11 getExposureTime

Description Get the current exposure time of the camera.

Prototype

```
double getExposureTime();
```

Return value

Datatype	Name	Description
double	exposure_time_s	Exposure time of the camera [s]

2.1.12 setExposureTime

Description Set a new exposure time to the camera.

Prototype

```
void setExposureTime(double exposure_time_s);
```

Parameter

Datatype	Name	Description
double	exposure_time_s	Exposure time [s] that should be set

2.1.13 getDelayTime

Description Get the current delay time of the camera.

Prototype

```
double getDelayTime();
```

Return value

Datatype	Name	Description
double	delay_time_s	Delay time of the camera [s]

2.1.14 setDelayTime

Description Set a new delay time to the camera.

Prototype

```
void setDelayTime(double delay_time_s);
```

Parameter

Datatype	Name	Description
double	delay_time_s	Delay time [s] that should be set

2.1.15 record

Description Create, configure, and start a new recorder instance. The entire camera configuration must be set before calling `record()`. The commands for getting and setting delay/exposure time are the only exception. These can be called up during the recording.

Prototype

```
void record(
    DWORD num_images = 1,
    RecordMode record_mode = RecordMode::sequence,
    std::filesystem::path file_path = ""
);
```

Parameter

Datatype	Name	Description
`DWORD`	`num_images`	Sets the number of images allocated in the driver. The RAM, disk (of the PC) or camera RAM (depending on the mode) limits the maximum value.
`RecordMode`	`record_mode`	Defines the recording mode for this record (see 1.3).
`std::filesystem::path`	`file_path`	Path where the image file(s) should be stored (only for modes who directly save to file, see 1.3).

2.1.16 stop

Description Stop the current recording.

For blocking recorder modes (see 1.3), the recording is automatically stopped when the required number of images is reached. In this case `stop()` is not needed.

Prototype

```
void stop();
```

2.1.17 waitForFirstImage

Description Wait until the first image has been recorded and is available.

Prototype

```
void waitForFirstImage(
    bool delay = true,
    double timeout_s = NAN
);
```

Parameter

Datatype	Name	Description
`bool`	`delay`	Flag if a small delay should be used in the waiting loop (typically recommended to reduce CPU load)
`double`	`timeout_s`	If defined, the waiting loop will be aborted if no image was recorded during `timeout_s` seconds.

2.1.18 waitForNewImage

Description Wait until a new image has been recorded and is available (i.e. an image that has not been read yet).

Prototype

```
void waitForNewImage(
    bool delay = true,
    double timeout_s = NAN
);
```

Parameter

Datatype	Name	Description
`bool`	`delay`	Flag if a small delay should be used in the waiting loop (typically recommended to reduce CPU load)
`double`	`timeout_s`	If defined, the waiting loop will be aborted if no new image was recorded during `timeout_s` seconds.

2.1.19 getRecordedImageCount

Description Get the number of currently recorded images.

Note For recorder modes `fifo` and `fifo_dpcore` (see 1.3) this represents the current fill level of the fifo buffer, not the overall number of recorded images.
In these cases, check for `if(cam.getRecordedImageCount()> 0)` to see if a new image is available.

Prototype

```
size_t getRecordedImageCount() const;
```

Return value

Datatype	Name	Description
`size_t`	`recorded_image_count`	Number of currently recorded images

2.1.20 getConvertControl

Description Get the current convert control settings for the specified data format.

Prototype

```
ConvertControl getConvertControl(DataFormat data_format);
```

Parameter

Datatype	Name	Description
DataFormat	data_format	Data format for which the convert settings should be queried.

Return value

Datatype	Name	Description
ConvertControl	convert_control	Structure containing the current convert settings for the specified data format (see 2.4.5)

Example

```
pco::ConvertControlPseudoColor cc = std::get<pco::↩
    ConvertControlPseudoColor>(cam.getConvertControl(pco::DataFormat↩
    ::BGR8));
cc.lut_file = lut_file;
cam.setConvertControl(pco::DataFormat::BGR8, cc);
```

2.1.21 setConvertControl

Description Set convert control settings for the specified data format.

Prototype

```
void setConvertControl(
    DataFormat data_format,
    ConvertControl convert_control
);
```

Parameter

Datatype	Name	Description
DataFormat	data_format	Data format for which the convert settings should be set.
ConvertControl	convert_control	Convert control settings that should be set.

Example

```
pco::ConvertControlPseudoColor cc = std::get<pco::↩
    ConvertControlPseudoColor>(cam.getConvertControl(pco::DataFormat↩
    ::BGR8));
cc.lut_file = lut_file;
cam.setConvertControl(pco::DataFormat::BGR8, cc);
```

2.1.22 loadLut

Description Set the lut file for the convert control settings.

This is just a convenience function, the lut file could also be set using `setConvertControl` (see: 2.1.21).

Prototype

```
void loadLut(
    DataFormat data_format,
    std::filesystem::path lut_file
);
```

Parameter

Datatype	Name	Description
`DataFormat`	`data_format`	Data format for which the lut file should be set.
`std::filesystem::path`	`lut_file`	Actual lut file path to be set.

2.1.23 adaptWhiteBalance

Description Do a white-balance using a transferred image.

Prototype

```
void adaptWhiteBalance(Image& image);
void adaptWhiteBalance(Image& image, Roi roi);
```

Parameter

Datatype	Name	Description
`Image&`	`image`	Image that should be used for white-balance computation
`Roi`	`roi`	Use only the specified ROI for white-balance computation

2.1.24 image

Description Get a recorded image in the given format. The type of the image is an `Image` object (see 2.2).

The `Image` object has to be created by the caller and transferred to the function via reference. Internally, it automatically checks the allocated buffer size and adapts it according to the format and ROI. There is no special pre-allocation needed.

Performance can be increased through the definition of roi and data format or reusing the `Image` object.

Prototype

```
void image(
  Image& image_ref,
  DWORD image_index = 0,
  DataFormat data_format = DataFormat::Mono16,
  PCO_Recorder_CompressionParams* comp_params = nullptr
);

void image(
  Image& image_ref,
  Roi roi,
  DWORD image_index = 0,
  DataFormat data_format = DataFormat::Mono16,
  PCO_Recorder_CompressionParams* comp_params = nullptr
);
```

Parameter

Datatype	Name	Description
`Image&`	`image_ref`	Reference to the `Image` object for storing the image
`Roi`	`roi`	Soft ROI to be applied, i.e. get only the ROI portion of the image (see 2.4.2 for the `Roi` structure)
`DWORD`	`image_index`	Index of the image that should be queried, use `PCO_RECORDER_LATEST_IMAGE` for latest image (for recorder modes `fifo`/`fifo_dpcore` always use 0 (see 1.3))
`DataFormat`	`data_format`	Data format the image should have (see 1.4)
`PCO_Recorder_CompressionParams*`	`comp_params`	Pointer to compression parameters, not implemented yet

2.1.25 images

Description Get a series of images in the given format as `std::vector`. The type of the images is an `Image` object (see 2.2).

The position of the images in the recorder to query are defined by a start index and the length of the transferred vector that should hold the images (i.e. there is no additional length parameter).

The `Image` vector has to be created by the caller and transferred to the function via reference. Internally, the function automatically checks the allocated buffer sizes and adapts them according to the format and ROI. There is no special pre-allocation needed. Performance can be increased through the definition of ROI and data format of the vector's `Image` objects.

Prototype

```
void images(
  std::vector<Image>& images,
  DataFormat data_format = DataFormat::Mono16,
  size_t start_index = 0,
  PCO_Recorder_CompressionParams* comp_params = nullptr
);

void images(
  std::vector<Image>& images,
  Roi roi,
  DataFormat data_format = DataFormat::Mono16,
  size_t start_index = 0,
  PCO_Recorder_CompressionParams* comp_params = nullptr
);
```

Parameter

Datatype	Name	Description
`std::vector<Image>&`	`images`	Reference to a vector of `Image` objects for storing the images
`Roi`	`roi`	Soft ROI to be applied, i.e. get only the ROI portion of the images (see 2.4.2 for the `Roi` structure)
`DataFormat`	`data_format`	Data format the images should have (see 1.4)
`size_t`	`start_index`	Index of the first image that should be queried (the number of images is defined by the length of the image vector)
`PCO_Recorder_CompressionParams*`	`comp_params`	Pointer to compression parameters, not implemented yet

2.1.26 imageAverage

Description Get an averaged image, averaged over all recorded images in the given format. The type of the image is a `Image` object (see 2.2).

The `Image` object has to be created by the caller and transferred to the function via reference. Internally it automatically checks the allocated buffer size and adapts it according to the format and ROI. There is no special pre-allocation needed.

Note We recommend that you not use this function while recording is active, as it may give unexpected results (especially in `ring_buffer` mode, see 1.3).
Record the number of images you want to average as a sequence, then after all images have been recorded, use this function to calculate the average.

Prototype

```
void imageAverage(
   Image& image_ref,
   DataFormat data_format = DataFormat::Mono16,
);

void imageAverage(
   Image& image_ref,
   Roi roi,
   DataFormat data_format = DataFormat::Mono16,
);
```

Parameter

Datatype	Name	Description
`Image&`	`image_ref`	Reference to the `Image` object for storing the averaged image
`Roi`	`roi`	Soft ROI to be applied, i.e. get only the ROI portion of the image (see 2.4.2 for the `Roi` structure).
`DataFormat`	`data_format`	Data format the averaged image should have (see 1.4)

2.1.27 hasRam

Description Flag indicating whether camera-internal memory for recording with camram is available

Prototype

```
bool hasRam();
```

Return value

Datatype	Name	Description
`bool`	`has_camram`	Boolean indicating whether cam ram is available

2.1.28 switchToCamRam

Description Sets camram segment and prepare internal recorder for reading images from camera-internal memory.

Prototype

```
void switchToCamRam();

void switchToCamRam(WORD segment);
```

Parameter

Datatype	Name	Description
`WORD`	`segment`	Segment number for image readout. Optional parameter.

2.1.29 setCamRamAllocation

Description Set allocation distribution of camram segments.

Maximum number of segments is 4. Accumulated sum of parameter values must not be greater than 100.

Prototype

```
void setCamRamAllocation(std::vector<DWORD> percents);
```

Parameter

Datatype	Name	Description
`std::vector<DWORD>`	`percents`	Vector that holds percentages of segment distribution. Length: 1 <= size() <= 4

2.1.30 getCamRamSegment

Description Get segment number of active camram segment.

Prototype

```
WORD getCamRamSegment();
```

Return value

Datatype	Name	Description
WORD	segment_num	Number of active camram segment

2.1.31 getCamRamMaxImages

Description Get number of images that can be stored in the active camram segment.

Prototype

```
DWORD getCamRamMaxImages();
```

Return value

Datatype	Name	Description
DWORD	max_image_count	Maximal images for recording to active segment

2.1.32 getCamRamNumImages

Description Get number of images that are available in the active camram segment.

Prototype

```
DWORD getCamRamNumImages();
```

Return value

Datatype	Name	Description
DWORD	image_count	Number of images available for readout from active segment

2.1.33 sdk

Description Get the internal handle to the pco.sdk API. This is needed whenever you need to call special pco.sdk functions directly.

Prototype

```
HANDLE sdk() const;
```

Return value

Datatype	Name	Description
HANDLE	sdk	Handle to the pco.sdk library functions

2.1.34 rec

Description Get the internal handle to the pco.recorder API. This is needed whenever you need to call special pco.recorder functions directly.

Prototype

```
HANDLE rec() const;
```

Return value

Datatype	Name	Description
HANDLE	rec	Handle to the pco.recorder library functions

2.1.35 conv

Description Get the internal handle to the pco.convert API for a specific image format. This is needed whenever you need to call special pco.convert functions directly.

Prototype

```
HANDLE conv(DataFormat data_format) const;
```

Parameter

Datatype	Name	Description
DataFormat	data_format	Data format for which the convert handle should be queried.

Return value

Datatype	Name	Description
HANDLE	conv	Handle to the pco.convert library functions

2.2 pco::Image

The `Image` class stores the data of an image. With convenient methods you can access the raw image data, and if available, additional information such as metadata and timestamp.

The following list provides an overview of the functions:

- **Constructor** Can be called with and without camera or image-size information. If called with image-size and data format information, the image buffer is pre-allocated according to data format and ROI
- **isColored()** Get flag if the stored image is a color image
- **getDataFormat()** Get the format of the stored image
- **width()** Get width of the stored image
- **height()** Get height of the stored image
- **validAllocation()** Check pre-allocation of image buffer according the parameter data format and ROI
- **resize()** Adapt allocation of the image buffer according to the parameter data format and ROI
- **setRecorderImageNumber()** Set number of the stored image (used in `Camera` class internally)
- **getRecorderImageNumber()** Get number of the stored image
- **setMetaData()** Set metadata of the stored image (used in `Camera` class internally)
- **getMetaDataPtr()** Get pointer to the metadata of the stored image
- **getMetaData()** Get metadata of the stored image
- **setTimestamp()** Set timestamp of the stored image (used in `Camera` class internally)
- **getTimestampPtr()** Get timestamp of the stored image
- **raw_data()** Get `void` pointer to the raw image data and size in bytes
- **data()** Get `void` pointer to the image data and size in bytes
- **size()** Get image size in pixel
- **vector_8bit()** Get image data as `std::vector` of 8 Bit values (for 8-Bit image formats)
- **vector_16bit()** Get image data as `std::vector` of 16 Bit values (for 16-Bit image formats)
- **raw_vector_16bit()** Get raw image data as `std::vector` of 16 Bit values

2.3 pco::CameraException

The `CameraException` class is derived from `std::exception` and transforms PCO error codes into exception objects which are thrown by the `Camera` class in case of an error. With this workflow you can catch camera errors with a try-catch block just like any other `std::exception`.

The following list provides a short overview of the class functions:

- **Constructor()** Get exception message according to the transferred error code
- **what()** Get the error text as char pointer
- **error_code()** Get the error code
- **error_text()** Get the error text

2.4 Structs

In the following sections you will find all structures used in the `Camera` class.

2.4.1 Binning

Description Structure holding the binning information.

Datatype	Name	Description
WORD	vert	Vertical binning
WORD	horz	Horizontal binning

2.4.2 Roi

Description Structure holding the ROI information

Datatype	Name	Description
size_t	x0	Left position of ROI (starting from 1)
size_t	y0	Top position of ROI (starting from 1)
size_t	x1	Right position of ROI (up to full width)
size_t	y1	Bottom position of ROI (up to full height)

Additionally the following convenience function are available.

Datatype	Name	Description
size_t	width()	Get width of the ROI
size_t	height()	Get height of the ROI
size_t	size()	Get overall size in pixel
size_t	evenPaddedWidth()	Get padded width
size_t	paddedSize()	Get padded overall size

2.4.3 Configuration

Description Structure holding a camera configuration.

Datatype	Name	Description
double	exposure_time_s	Exposure time [s]
double	delay_time_s	Delay time [s]
Roi	roi	Hardware ROI structure (see 2.4.2)
WORD	timestamp_mode	Timestamp mode
DWORD	pixelrate	Pixelrate
WORD	trigger_mode	Trigger mode
WORD	acquire_mode	Acquire mode

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Datatype	Name	Description
WORD	metadata_mode	Metadata mode
WORD	noise_filter_mode	Noise filter mode
Binning	binning	Binning structure (see 2.4.1)

2.4.4 Description

Description Structure holding the camera description information.

Datatype	Name	Description
DWORD	serial	Serial number of the camera
WORD	type	Sensor type
WORD	sub_type	Sensor sub type
CameraInterface	interface_type	Interface type
double	min_exposure_time_s	Minimal possible exposure time
double	max_exposure_time_s	Maximal possible exposure time
double	min_exposure_step_s	Minimal possible exposure step
double	min_delay_time_s	Minimal possible delay time
double	max_delay_time_s	Maximal possible delay time
double	min_delay_step_s	Minimal possible delay step
size_t	min_width	Minimal possible image width (hardware ROI)
size_t	min_height	Minimal possible image height (hardware ROI)
size_t	max_width	Maximal possible image width (hardware ROI)
size_t	max_height	Maximal possible image height (hardware ROI)
size_t	roi_step_horz	Horizontal ROI stepping (hardware ROI)
size_t	roi_step_vert	Vertical ROI stepping (hardware ROI)
bool	roi_symmetric_horz	Flag if hardware ROI has to be horizontally symmetric (i.e. if x0 is increased, x1 has to be decreased by the same value)

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Datatype	Name	Description
bool	roi_symmetric_vert	Flag if hardware ROI has to be vertically symmetric (i.e. if y0 is increased, y1 has to be decreased by the same value)
WORD	bit_resolution	Bit-resolution of the sensor
bool	has_timestamp_mode	Flag if camera supports the timestamp setting
bool	has_timestamp_mode_ascii_only	Flag if camera supports setting the timestamp to ascii-only
std::vector<DWORD>	pixelrate_vec	Vector containing all possible pixelrate frequencies (index 0 is default)
bool	has_acquire_mode	Flag if camera supports the acquire mode setting
bool	has_ext_acquire_mode	Flag if camera supports the external acquire setting
bool	has_metadata_mode	Flag if metadata can be activated for the camera
bool	has_ram	Flag if camera has internal memory
std::vector<WORD>	binning_horz_vec	Vector containing all possible horizontal binning values
std::vector<WORD>	binning_vert_vec	Vector containing all possible vertical binning values

2.4.5 ConvertControl

Description Structure containing (color) convert information.

Depending on the image format (see 1.4) a different structure will be used.

Mono8 format `ConvertControlMono`

Datatype	Name	Description
bool	sharpen	Flag if the image should be sharpened
bool	adaptive_sharpen	Flag if adaptive sharpening should be enabled
bool	flip_vertical	Flag if the image should be vertically flipped
bool	auto_minmax	Flag if auto scale should be enabled
WORD	min_limit	Minimum scaling value (will be ignored if auto scale is enabled)

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Datatype	Name	Description
WORD	max_limit	Maximum scaling value (will be ignored if auto scale is enabled)
double	gamma	Gamma of the image (default is 1.0)
int	contrast	Contrast of the image (default is 0)

Color camera and color format

ConvertControlColor

Datatype	Name	Description
bool	sharpen	Flag if the image should be sharpened
bool	adaptive_sharpen	Flag if adaptive sharpening should be enabled
bool	flip_vertical	Flag if the image should be vertically flipped
bool	auto_minmax	Flag if auto scale should be enabled
WORD	min_limit	Minimum scaling value (will be ignored if auto scale is enabled)
WORD	max_limit	Maximum scaling value (will be ignored if auto scale is enabled)
double	gamma	Gamma of the image (default is 1.0)
int	contrast	Contrast of the image (default is 0)
bool	pco_debayer_algorithm	Flag if PCO debayering should be used
int	color_temperature	Color temperature of the image
int	color_saturation	Color saturation of the image
int	color_vibrance	Color vibrance of the image
int	color_tint	Color tint of the image

BW camera and color format

ConvertControlPseudoColor

Datatype	Name	Description
bool	sharpen	Flag if the image should be sharpened
bool	adaptive_sharpen	Flag if adaptive sharpening should be enabled
bool	flip_vertical	Flag if the image should be vertically flipped
bool	auto_minmax	Flag if auto scale should be enabled
WORD	min_limit	Minimum scaling value (will be ignored if auto scale is enabled)
WORD	max_limit	Maximum scaling value (will be ignored if auto scale is enabled)
double	gamma	Gamma of the image (default is 1.0)
int	contrast	Contrast of the image (default is 0)
int	color_temperature	Color temperature of the image
int	color_saturation	Color saturation of the image
int	color_vibrance	Color vibrance of the image
int	color_tint	Color tint of the image

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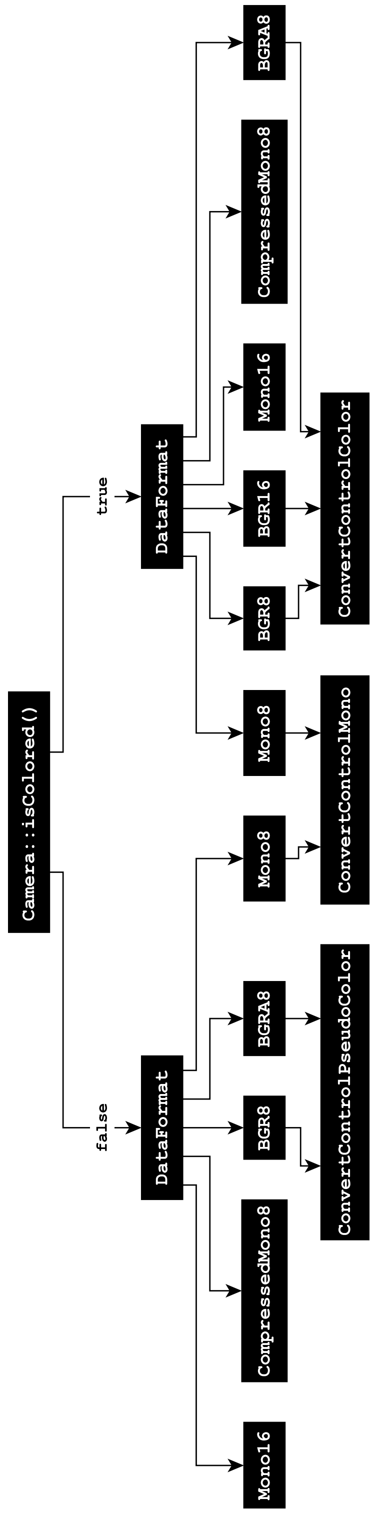
Datatype	Name	Description
std::filesystem::path	lut_file	Path of the lut file that should be used

Overview **Assignment of ConvertControl structs to DataFormat and BW/colored camera**



3 About Excelitas PCO

PCO, an Excelitas Technologies® Corp. brand, is a leading specialist and Pioneer in Cameras and Optoelectronics with more than 30 years of expert knowledge and experience of developing and manufacturing high-end imaging systems. The company's cutting edge sCMOS and high-speed cameras are used in scientific and industrial research, automotive testing, quality control, metrology and a large variety of other applications all over the world.

The PCO® advanced imaging concept was conceived in the early 1980s by imaging pioneer, Dr. Emil Ott, who was conducting research at the Technical University of Munich for the Chair of Technical Electrophysics. His work there led to the establishment of PCO AG in 1987 with the introduction of the first image-intensified camera followed by the development of its proprietary Advanced Core technologies which greatly surpassed the imaging performance standards of the day.

Today, PCO continues to innovate, offering a wide range of high-performance camera technologies covering scientific, high-speed, intensified and FLIM imaging applications across the scientific research, industrial and automotive sectors.

Acquired by Excelitas Technologies in 2021, PCO represents a world renowned brand of high-performance scientific CMOS, sCMOS, CCD and high-speed cameras that complement Excelitas' expansive range of illumination, optical and sensor technologies and extend the bounds of our end-to-end photonic solutions capabilities.

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