Fast VCR software for machine vision camera applications

User's Manual
v.0.1.0

Content

1 System requirements

1.1 Software requirements

Fast VCR requires a system with the following capabilities:

- Windows 10 (64-bit)

- NVIDIA GPU driver from https://nvidia.com/drivers

- To work with XIMEA cameras, you need to install drivers for such cameras (https://www.ximea.com/support/att

- When working with other machine vision cameras (Emergent Vision Technologies, IO Industries, Basler, Daheng Imaging, Mindvision) which are supported by the software, please install their respective drivers

1.2 Hardware platform requirements

Fast VCR is compatible with NVIDIA GPUs with compute capability 5.0 or higher. These are GeForce family starting from 1080 model and corresponding Quadro/Tesla GPUs. To run on a laptop, it should be connected to AC power to maximise the performance. If running on the built-in battery, performance may be noticeably degraded.

1.3 Recommended system configuration

- CPU: Intel Core-i7 9700K or better

- RAM: 8-16-32 GB RAM

- SSD: 500 GB

- GPU: NVIDIA GeForce RTX 2070, 2080Ti, 3070, 3080, 4090

- GPU memory 8-12-24 GB

- Motherboard with PCI-Express x16 Gen3/Gen4 support

There are other versions of this software that can run on Linux Ubuntu with NVIDIA GPU on laptops, PCs and servers. There are also a number of versions of this software that work with NVIDIA Jetson modules (TX2, NX, Xavier, Orin) where the L4T operating system is installed. The general properties of the software for all these cases are similar.

2 How to work with the software

2.1 Starting the application

The application does not require installation. To get started, unpack the archive and run the FastVCR.exe file using any method. Since image and video processing runs on NVIDIA GPU, please make sure that the latest NVIDIA driver is installed on your computer before running the application, which can be downloaded from https://nvidia.com/drivers. If you do not have an NVIDIA GPU or you haven't installed an updated driver, the software will not work.

2.2 Open Project dialogue

If the camera is not connected or if the user need to work not with a camera but with a series of RAW frames on the SSD, then at the start of the program, a window with a dialogue box appears, in which it is necessary to choose what type of files will be opened now. That mode is also called as «PGM virtual camera». There are two options:

1. PGM/TIFF file types   In this dialogue box you can choose to open a single file or a folder of files. Since PGM/TIFF formats have a header with the necessary information for working with images, you do not need to enter anything else.

2. RAW files   In this dialogue box you can also choose to open a separate RAW file or a folder with RAW files.

Since a RAW file usually contains only data for each pixel, it is necessary to set a number of additional parameters that are necessary for the software to work with RAW files correctly:

width - frame width
height - frame height
bits - image bit depth
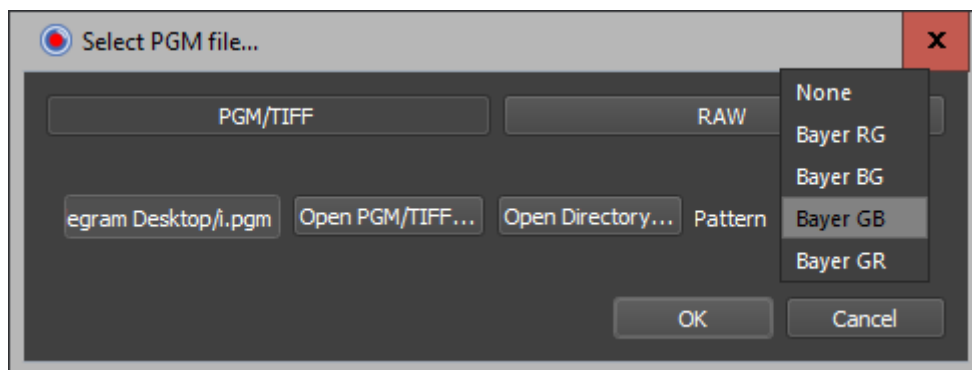byte order - BigEndian or LittleEndian
pattern - type of bayer pattern

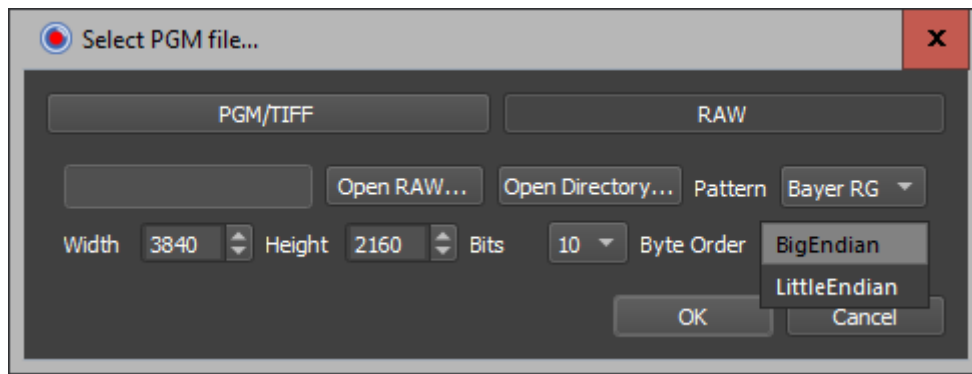Figure 2.1: Opening a PGM/TIFF image file or folder dialogue box

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Figure 2.2: Dialog box for opening a RAW image file or folder

2.3 Main window

After launching the application, the main application window will appear on the screen.
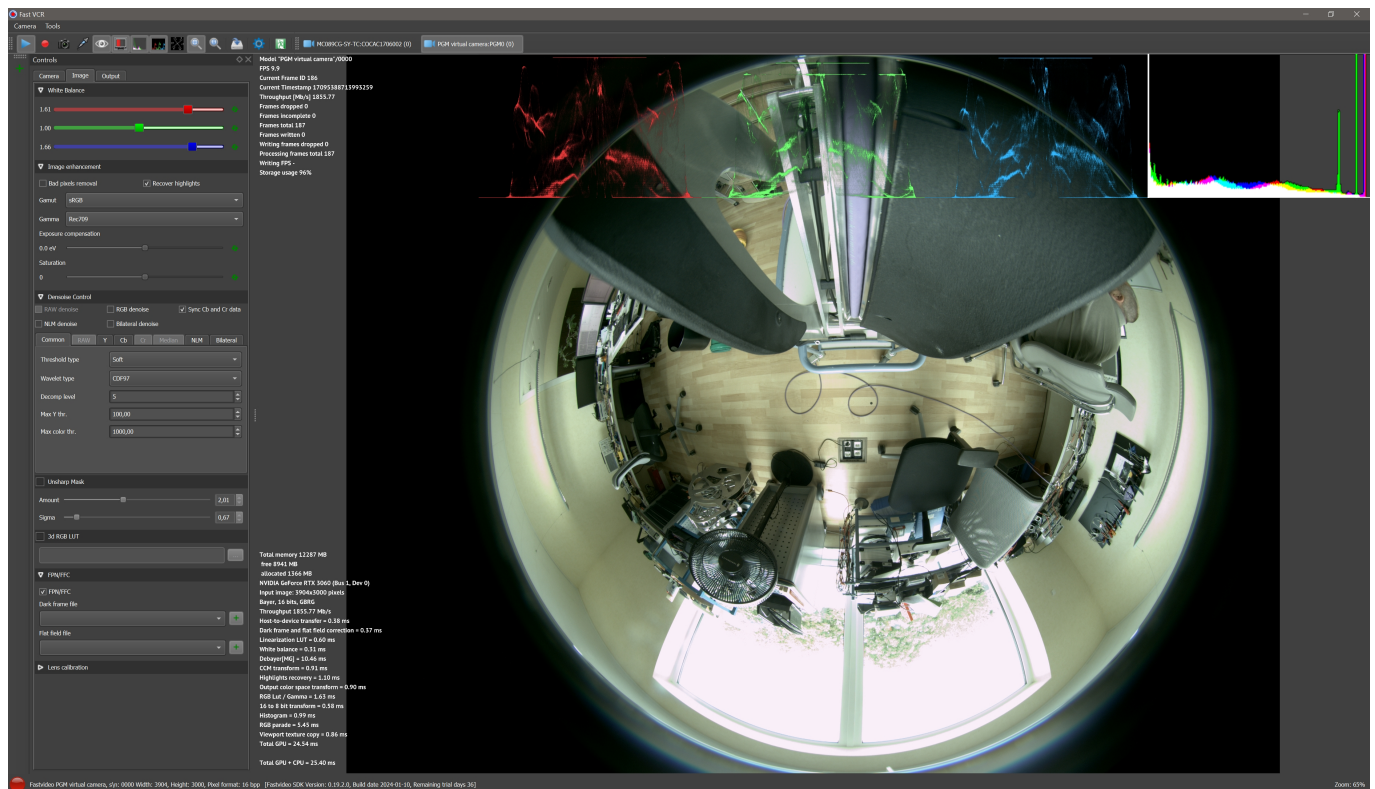

Figure 2.3: Application main windows

All controls are organised as dockable windows (widgets) that can be docked to any side of the main application window.

A dockable window has two possible states:

Docked. In the docked state, the window is pinned to the edge of the main window. A docked window has a special control panel appearance; you can use this as a regular title bar to drag the window to a new location.

Undocked. In this state, the window looks like a normal window, except that it has a slightly smaller title bar. A non-pinned window pops up above all other windows.

If you want to change the docking position of an anchored or unanchored window, click on the window title bar (or on the special control bar if it is already anchored somewhere) and drag the window in the same

way as you move any regular window. Move the mouse cursor to where you want to dock the window, and possible new docking positions will be highlighted.

You can dock windows so that each window has the full width or height of the edge. To do this, dock the first window in the desired location. Then drag the second window so that it is along the same edge, inside the frame of the first window. For example, pin a window to the bottom edge, and then drag the other window so that it is directly above the first window. Use the tabs on the bottom edge to switch between the stacked pinned windows.

You can change the order of the tabs with the mouse.

To move a composite pinned window, drag the corresponding tab with the mouse. Dragging the title bar will move the entire stack.

To hide a pinned window, click the close button in the upper right corner. To display a pinned window, right-click the image display window and select the desired pinned window from the context menu.

Some processing parameters (for example, scaling of red, green, or blue components) are tied to sliders. To change these parameters, drag the appropriate slider until the desired effect is achieved. To reset a parameter to its default value, click the reset button.

Some parameters (e.g. ROI parameters) are linked to counters (a combination of a text box and an up-down arrow control). The counter is for entering integers and floating point values.

The counter allows you to select a value by pressing the up/down keys on the keyboard or by pressing the up/down arrows or rotating the mouse wheel to increase/decrease the currently displayed value. You can also enter a value manually.

Once started, the application searches for the first XIMEA camera connected to the system. If more than one camera is connected, only the first camera will be used.

The processing parameters are stored in the "%AppData%\Fastvideo LLC\Fast VCR.ini" file

2.4 Main menu buttons

 – start image acquisition from a camera or from a local device

 – recording the image from the camera with post-processing to internal storage media

 – setting the white balance according to the selected "gray" pixel in the resulting image

 – switching viewing mode (real-time preview on/off)

 – fit the image into the output window

 – actual image size

 – save the current settings

 – GPU selection settings and selection of video stream processing modules

 – exit

2.5 Adjusting the camera settings

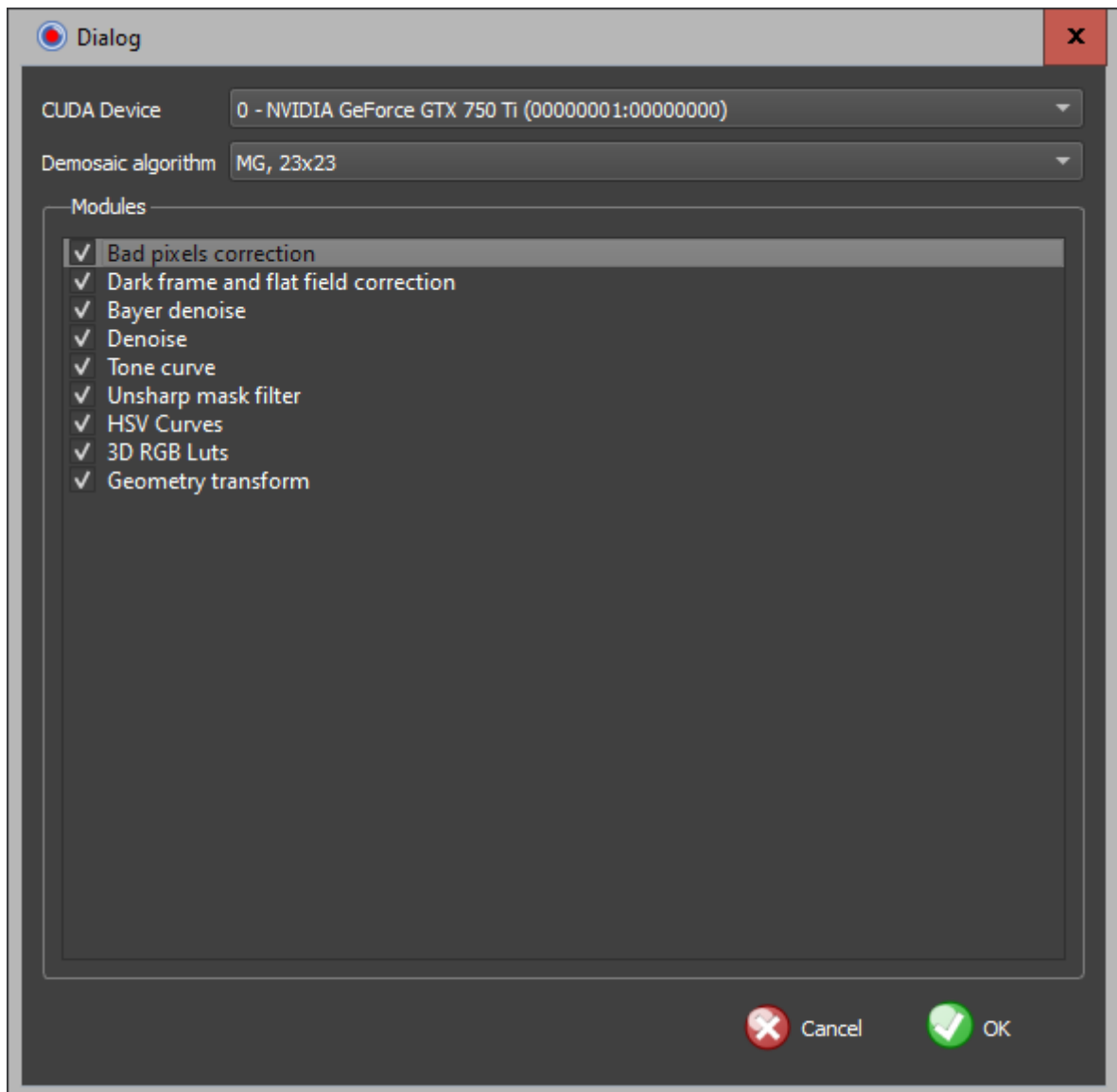Use the "Camera" tab on the "Control" panel to set the recording parameters.

Figure 2.4: Window for selecting a video card and video stream processing modules
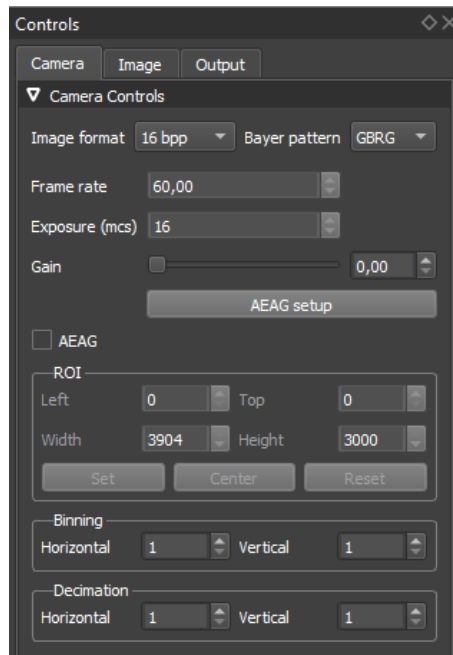
Figure 2.5: Camera control, ROI, Binning, Decimation

This panel allows you to set the following camera parameters:

Image format (bit depth) image bit depth.

Bayer pattern (RGGB / BGGR / GBRG / GRBG) The arrangement of red, blue and green pixels on the camera sensor (Bayer pattern). It is usually determined by interrogating the camera registers and does not require adjustment.

Frame rate Camera frame rate. Limited from above by interface bandwidth and image size.

Exposure (mcs) Exposure time in microseconds. Limited from above by 1 / Framerate.

Gain Analogue gain in dB.

AEAG setup Control parameters of the automatic exposure time and analogue gain control mode.
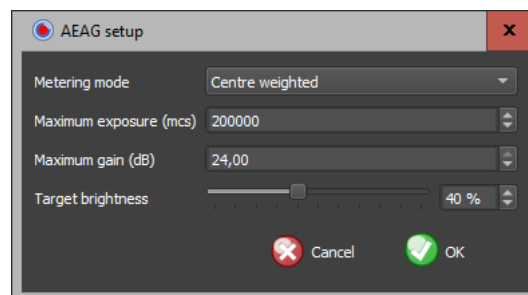

Figure 2.6: AEAG setup

Metering mode Calculation algorithm

Maximum exposure (mcs) Maximum exposure in microseconds

Maximum gain (dB) Maximum analogue gain in dB

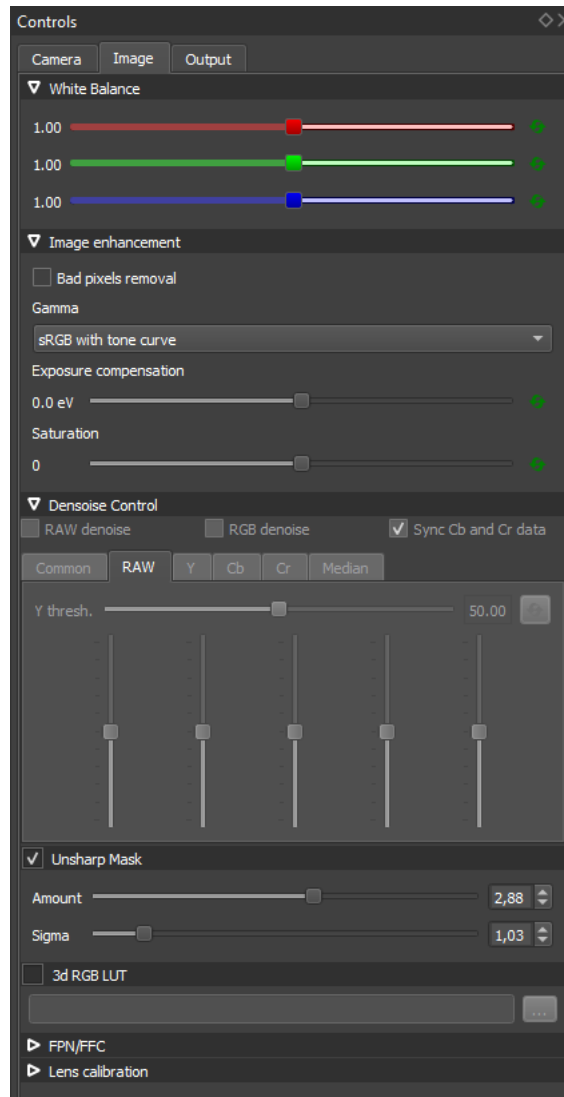**Target brightness** Maximum preset for signal brightness

Figure 2.7: White balance, Image enhancement, Denoise control, Unsharp Mask, 3d RGB LUT

AEAG - automatic exposure control and analogue gain control mode

ROI Size of the Region Of Interest. The area of the sensor bounded by the Left, Top, Width, Height rectangle from which the camera acquires an image. Reducing the area relative to the full frame increases the maximum frame rate. Use the Set button to set the selected area. To centre the area relative to the full frame use the Center button. Use the Reset button to return the area to the full frame.

Binning Setting up binning. Binning is a way to group and average several pixels into fewer groups, "bins". Typically, binning is 2 or 4 pixels in a horizontal and/or vertical direction. The Horizontal and Vertical values specify the number of pixels in the group horizontally and vertically. The maximum values of pixels in the group are determined by the hardware binning parameters of the particular camera model.

Decimation Decimation settings. Decimation allows you to read not every pixel, but one from a specified group. Horizontal and Vertical values set the number of pixels in the group horizontally and vertically. The maximum values of pixels in the group are determined by the hardware binning parameters of a particular camera model. Decimation, as well as ROI, allows you to increase the frame rate, but unlike ROI, preserves the entire field of view.

2.6 Setting image processing parameters
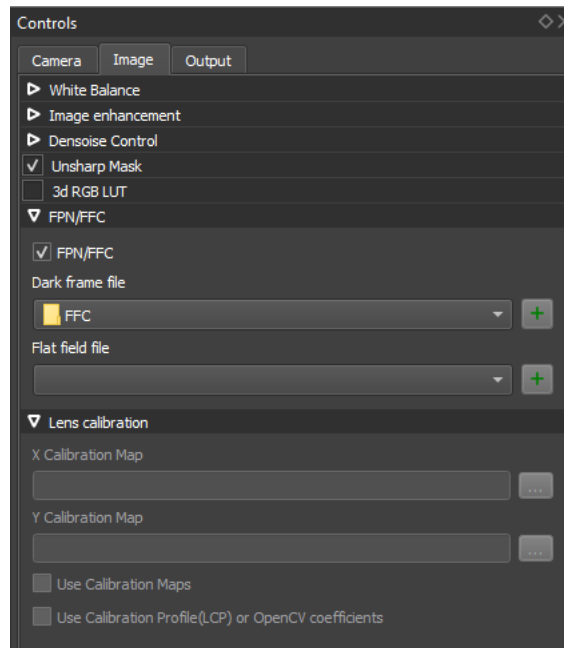
White balance White balance

Figure 2.8: FPN/FFC & Lens calibration

Image enhancement Image Enhancement

> **Bad pixel removal** Adaptive bad pixel suppression
>
> **Gamma** (Linear / sRGB / sRGB with tone curve) - output gamma (linear, sRGB, sRGB with tone curve)
>
> **Exposure compensation** Exposure compensation control
>
> **Saturation** Control Saturation

Denoise control (RAW denoise / RGB denoise / Sync Cb and Cr) - Denoising parameters

Unsharp Mask Sharpness control

> **Amount** Amount value in the sharpness control algorithm
>
> **Sigma** Sigma (parameter of the sharpness control algorithm)

3D RGB LUT 3D LUT for RGB

FPN/FFC Static noise reduction / vignetting reduction

> **Dark field file** Dark frame to subtract dark noise. A dark frame is an image taken by the image sensor in total darkness (i.e., with zero exposure or with the lens and viewfinder closed). Such a dark frame is essentially an image of sensor noise. Sensor noise includes "hot pixels" that glow brighter than surrounding pixels. Subtracting the average dark frame is a way to reduce noise in images. To activate the correction, select the FPN/FFC checkbox in the Processing options panel and specify the path to such a file.
>
> **Flat field file** File for flat field correction. Flat Field Correction (FFC) is a technique used to improve the quality of digital images. It removes the effects of image artefacts caused by variations in the inter-pixel sensitivity of the detector and distortions in the optical path. Typically, these artefacts appear as shadows of the image in the corners. To activate the correction, select the FPN/FFC checkbox in the Processing options panel and specify the path to such a file.

Lens calibration Lens calibration

> **X Calibration Map** X map

Y Calibration Map Y map

Use Calibration Map Use calibration map

Use Calibration Profile(LCP) or OpenCV coefficients Use LCP lens profile or coefficients from OpenCV algorithm

2.7 White balance

Usually images from machine vision cameras have a greenish color. To remove it, set the white balance in the Image section of the Controls dialogue box.
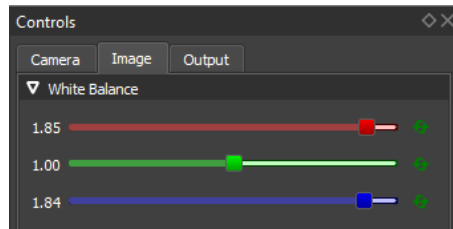
Figure 2.9: White balance

This dialogue has three sliders, blue, green and red, which adjust the brightness of the corresponding channel in the output image. You can also adjust the white balance automatically. To do this, use the Wb Picker ![icon] button on the toolbar. Click on this button, select an object in the frame that should be white or grey and click on it with the mouse. The program will set the values of the sliders so that the object becomes white (gray). You can use a piece of white paper or Macbeth Gray Card as such an object. During the procedure of white balance calibration you should pay attention not to overlight the object in the frame.

Broken camera pixels appear on the image as dots whose colour remains constant (most often white or black) in any illumination or which change their brightness arbitrarily. To remove such pixels, the application has a special filter. To activate it, set the "Bad Pixel Removal" checkbox on the "Image" tab of the "Controls" panel.

2.8 Setting the output parameters

Recording

FFmpeg Cmd Command line for external FFmpeg application

File format Allows you to set one of the formats for recording frames or video to disc

JPEG Records each frame from the camera to a separate file in JPEG format. The file name consists of the prefix set in the "File prefix" field with the image sequence number added.

Motion JPEG Records each frame to an AVI file in Motion JPEG format. The file name consists of the prefix set in the "File prefix" field with the extension "AVI" added.

PGM Writes the RAW data of each frame from the camera to a separate file in PGM format. The file name consists of the prefix set in the "File prefix" field with the image sequence number appended.

H264 Records each frame to MP4 file with H.264 compression. File name consists of prefix set in "File prefix" field with "MP4" extension added.

H265 Records each frame in MP4 with H.265 compression. File name consists of prefix set in "File prefix" field with "MP4" extension added.

AV1 Recording video with AV1 compression algorithm

Sampling (420 / 422 / 444) sets the colour subsampling when encoding to JPEG.
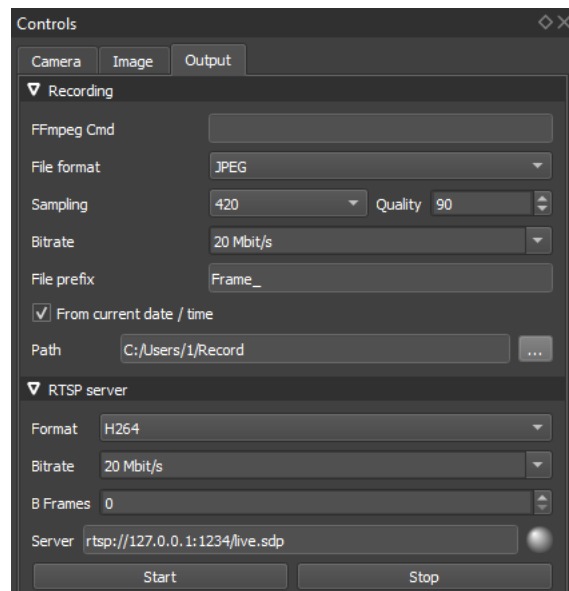
Figure 2.10: Output setting

Quality Sets the JPEG compression quality in the range 1 - 100. 1 corresponds to worst quality but smallest file size, 100 corresponds to maximum quality and largest file size.

Bitrate (1 / 5 / 10 / 20 / 50 / 100 Mbit/s) sets the bitrate when recording video in H.264 / H.265 / AV1 (Megabits per second).

File Prefix Specifies the prefix to be used when generating filenames.

From current date / time The current frame will be used as a prefix.

Path Path to the folder with recorded files.

RTSP server

Format (JPEG / H.264 / H.265 / AV1) - Frame or video compression algorithm.

Bitrate - Bitrate.

B Frames Use B-frames when encoding video.

Server Server address.

When the recording is complete, a <File prefix>.json file containing the following information is written to the output folder:

GUID Globally unique identifier received from the server at the start of the record or an empty string.

recStart The recording time of the first frame in UTC/GMT. Contains the following fields:

year

month

day

hour

minute

second

millisecond

recStop The recording time of the last frame in UTC/GMT. Contains the following fields:

year

month

day

hour

minute

second

millisecond

avgFPS Average frame rate during recording

framesWritten Number of recorded frames

2.9 Camera operation statistics

During camera operation, the operation statistics are displayed in the "Camera Statistics" window
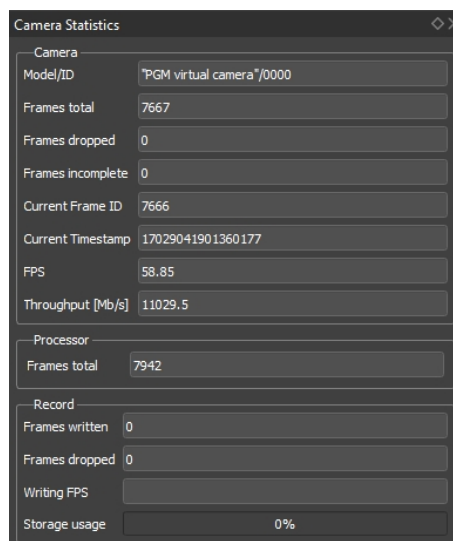

Figure 2.11: Camera Statistics

Model/ID Camera model and serial number.

Frames total The number of frames received from the camera.

Frames dropped Number of dropeed frames (white weren't received from a camera).

Frames incomplete Number of incomplete frames

Current Frame ID ID of the last received frame set by the camera.

Current Timestamp The timestamp of the last frame received.

FPS The frame rate measured as the ratio of the time elapsed since the camera was started to the number of frames received during that time.

Throughput Throughput of the bandwidth in Mbps

Processor - Frame processing on the GPU

  Frames total Total number of processed frames

Record - Recording

  Frames written Number of recorded frames

  Frames dropped Number of missed frames

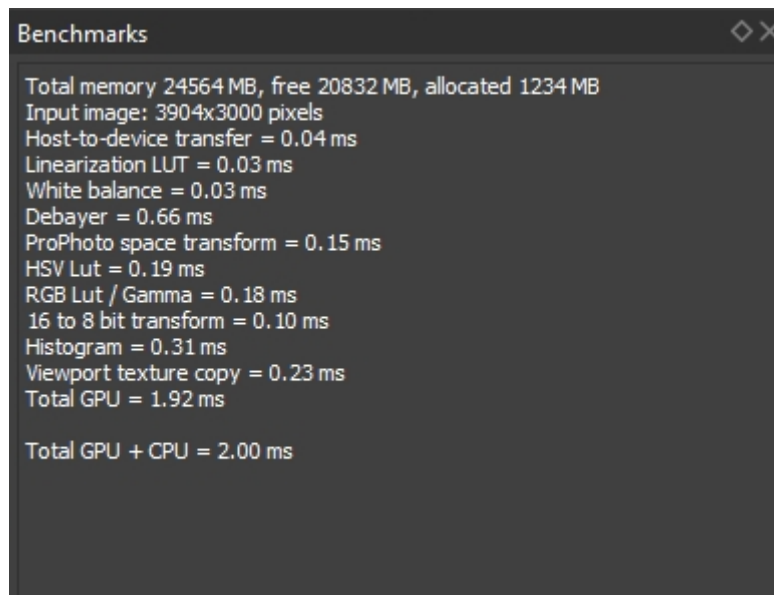 **Storage usage** Percentage of disc usage in the recording folder.

Figure 2.12: Benchmarks

2.10 Benchmarks

Total memory Size of memory on the GPU

Input image Frame resolution

Host-to-device transfer Time to transfer data from system memory to graphics card memory

Dark frame and flat field correction Static noise and vignetting suppression

Linearization LUT Use linearisation LUT

Bad pixel correction Bit pixel correction algorithm

White balance White balance

Bayer splitter Split source image into 4 channels according to Bayer pattern

Bayer denoiser Denoiser for RAW data

Bayer merger Reconstruct image from 4 channels according to Bayer pattern

Debayer Demosaicing algorithm (debayer)

Denoise Denoiser for RGB data

sRGB space transform Transform data into sRGB colour space

HSV Lut HSV image conversion LUT

RGB Lut / Gamma Image conversion LUT in RGB / Gamma curve

Sharpening

16 to 8 bit transform Converting RGB 16-bit data into 8-bit per channel format

Histogram Historgam

Viewport texture copy Screen resize

Total GPU Total execution time of all image processing modules on the GPU

Total GPU + CPU Total execution time of all image processing modules on the CPU and GPU

2.11 Histogram

The histogram shows the brightness distribution of the image for each RGB channel.
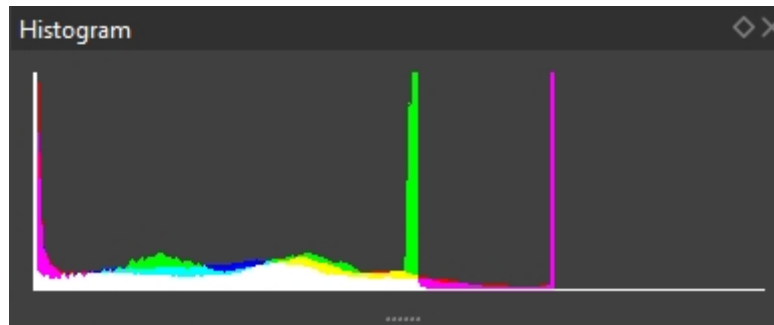
Figure 2.13: Histogram

2.12 Remote control of video recording and viewing

FastVCR allows you to control the viewing and recording of video from another application using the Windows named pipes mechanism. The named channel used for this purpose is the \\.\pipe\Medicom channel. The application that is to control FastVCR must open the channel as follows:

```
DWORD dwTimeOut = 10;
const unsigned long dwBuffSize = 255;
HANDLE hPipe = CreateNamedPipe(L"\\\\.\\pipe\\Medicom",
    PIPE_ACCESS_OUTBOUND | FILE_FLAG_FIRST_PIPE_INSTANCE,
    PIPE_TYPE_BYTE | PIPE_READMODE_BYTE | PIPE_NOWAIT | PIPE_ACCEPT_REMOTE_CLIENTS,
    1,
    dwBuffSize,
    dwBuffSize,
    dwTimeOut,
    nullptr);
```

After successfully opening a channel, the application sends the command as a text in json format, which contains the following fields:

GUID A globally unique identifier.

time The time to send the command in UTC/GMT. Used to generate the file name prefix for the record. Contains the following fields:

> **year**
>
> **month**
>
> **day**
>
> **hour**
>
> **minute**
>
> **second**
>
> **millisecond**

command_id Command. Can have the following values

> **1** Start viewing
>
> **2** Start recording
>
> **3** Stopping viewing and recording

If the open channel application (server) is running, a green icon is displayed in the lower left corner of the Fast VCR, otherwise a red icon is displayed.

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- NVIDIA CUDA-12.1

CUDA Image Processing library.
http://developer.nvidia.com/cuda-downloads

- Fastvideo GPU Image & Video Processing SDK (ver. 0.19.0.0)

NVIDIA GPU fast video processing libraries.
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https://www.fastcompression.com

- FFmpeg (LGPL, ver. 2.1)

Wrapper for MJPEG, MJ2K bitstream writers to AVI, MJ2K and MXF containers (LGPL 2.1 version)
http://ffmpeg.org
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