User Manual

SANSAERO Portable Camera System

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1 Network Setup

To start the camera system, you have to do the following steps:

1. Turn on the router. Make shure the antennas are unfolded!
2. Turn on the cameras by pressing the on switch on the power bank. Make shure to plug the USB cable in! The ring light will turn on. Double pressing the power button will turn off the camera and the ring light.
3. Wait until the router and the cameras are booted. This may take a while (around 2 minutes). Be aware that booting a *Raspberry Pi Zero* takes much longer than booting a *Raspberry Pi 4*.
4. Look for the SSID "*NETGEAR94*", "*NETGEAR94-5G-1*" or "*NETGEAR94-5G-2*" and log into the network. The password is "*melodicviolet891*".

After you logged into the network, there are 5 cameras available:

Camera Name	WLAN IP-Address	Type/Description
camera00	192.168.1.10	Raspberry Pi 4 **(Debugging camera, not send)**
camera01	192.168.1.11	Raspberry Pi 4
camera02	192.168.1.12	Raspberry Pi Zero 2
camera03	192.168.1.13	Raspberry Pi Zero 2
camera04	192.168.1.14	Raspberry Pi Zero 2
camera05	192.168.1.15	Raspberry Pi 3 Type A

2 User Interface

The camera interface can be reached by using a standard web browser. We are using the *Chromium* browser but other should also work fine. The cameras are available starting at IP address *192.168.1.10* via port *5000*. Just enter http://192.168.1.11:5000 to access the interface of the first camera.

2.1 Camera Interface

User interface description:

(1) **Camera View:** Shows the camera live view. The rectangle in the center is the selected passe-partout measurment area/volume. On-screen information on the top left: *Volume*: The measurment volume calculated from the passe-partout and the light courtain thickness. *Particles*: Number of particles detected. *Particle flow*: This the estimated particle flow rate. See section Particle Flow for more information.

(2) **Recording Name:** Sets the name of the recording. This name will be displayed in the recording table below the camera image. It's also used as a file name for the recording. If no name was provided a default one will be used.

(3) **Description Text:** An additional description text for the recording.

(4) **Detector:** Sets the active object detector. Currently two detectors are selectable:

1. *Threshold*: Sets the basic threshold algorithm. Three sub-types are supported: *Standard*, *Otsu* and *Triangle* (sub-types are selected with the threshold slider).

2. *Difference*: Uses difference images to identify objects. Every movement or change is detected as an object.

(5) **Threshold:** Sets the detector threshold. There are two specific values for automatic threshold selection: -2: *Triangle*-Method and -1: *Otsu*-Method. Default is *Otsu*.

(6) **Capture Interval:** Sets the capture interval for image sequences and the object detection functionality.

(7) **Capture Still Image:** Captures a single image and saves it as a *PNG (Portable Network Graphics)* file.

(8) **Record Video:** Records a video file. Video files are raw *h264*-Streams.

(9) **Capture Image Sequence:** Captures an image sequence.

(10) **Detect Objects:** Runs the object detection algorithm with the given settings.

(11) **Sync Time:** Synchronizes the time and date of the camera with the client system.

(12) **Delete All Recordings:** Deletes all the recordings. This can not be undone!

(13) **Reset Camera Settings:** Resets all camera settings to it's default values.

(14) **User Manual:** Shows the user manual PDF. This file here.

(15) **Update Firmware:** Uploads a firmware file. Firmwares are provided as tar.gz files. After uploading the file reload the camera interface in your browser to make shure the update was succesfully.

(16) **Resolution:** Select a camera resolution. Standard camera used is a *Raspberry V2 Camera*.

(17) **Shutter Speed:** Shutter speed in µs. Sets the exposure time length for a single frame.

(18) **ISO:** Sets the *ISO* value. An *ISO*-value of 0 means aromatic *ISO* control.

(19) **Brightness:** Controls the brightness of the image. It's a software based brightness correction.

(20) **Contrast:** Controls the contrast of the image. It's a software based contrast control.

(21) **Zoom:** Zooms to the centre of the live view. This control only affects the live view! It has no affect on the captured image sizes, videos or the detected objects within the current view!

(22) **X-Resolution:** Resolution of the camera in x-direction in µm per pixel.

(23) **Y-Resolution:** Resolution in y-direction in µm per pixel.

(24) **Ruler Length:** The length of the ruler shown in the left bottom corner of the live view in µm. It is used only as a size reference for the user.

(25) **Horizontal Passe-Partout:** Defines the horizontal detection area within the camera view. Default value is 30%.

(26) **Vertical Passe-Partout:** Defines the vertical detection area within the camera view. Default value is 30%.

2.2 Camera Administration

The Camera Administration page is used to control multiple cameras at once. It consist of the following user interface elements:

(1) **Show Overview:** Shows **a l**ive view of all cameras.

(2) **Capture Still Image:** Captures a still image. For all cameras or for an individual camera.

(3) **Record Video:** Records a *h264*-Stream. For all cameras or for an individual camera.

(4) **Capture Image Sequence:** Captures an image sequence. For all cameras or for an individual camera.

(5) **Start Object Detection:** Starts the object detection. For all cameras or for an individual camera.

(6) **Sync Time:** Synchronizes the time and date for all cameras.

(7) **Reset:** Resets all parameters of the cameras to the defaults.

(8) **Delete All Recordings:** Deletes all the recordings. This can not be undone!

(9) **Update State:** Queries the current state of all cameras.

(10) **Recording Name:** Sets the name of the recording. It's also used as a file name for the recording. If no name was provided a default one will be used.

(11) **Description Text:** An additional description text for the recording.

(12) **Detector:** Sets the active object detector. See Chapter 2.1 for selectable detectors.

3 Recommendations

1. Keep shutter speeds low for a good contrast: 100-400 µs.
2. Always synchronize time before you start! The Rasperry Pi doesn't have a real-time clock. Time synchronization is necessary!
3. Default threshold value is -1. This means Otsu-method is enabled for thresholding. Should be good enough for the most cases. Sometimes, depeding on the light condition, you want to use a fixed value. Something around 180 is a good value if shutter is under 400 µs.
4. Calibration values are around: 53 µm/px for x- and x-resolution of the passe-partout settings.
5. Default Resolution is 1640x1232 with 2x2 bins. Other resolutions are possible. Keep in mind that you need to recalibrate the X- and Y-Resolution for cropped camera formats.

4 File Formats

4.1 Meta Data Format

The meta-data format is generated for each captured image, video or image sequence. Meta-data files are stored in the JSON format. They contain the actual setteings of the software when the recording was made.

A typical JSON- file for a captured image looks like this:

```
{
    "id": "Image_2022-05-18_07-09-00_883397",
    "metafile": "Image_2022-05-18_07-09-00_883397.json",
    "imagefile": "Image_2022-05-18_07-09-00_883397.png",
    "name": "Image",
```

```
    "description": "(no description provided)",
    "datetime": "2022-05-18 07:09:00.883397",
    "shutter_speed": 293,
    "fps": 30.0,
    "iso": 0,
    "brightness": 50,
    "contrast": 0,
    "ruler_xres": 5.0,
    "ruler_yres": 5.0,
    "passe_partout_h": 25.0,
    "passe_partout_v": 25.0
}
```


4.2 Still Image Captures

Still images are save as standard *Portable Network Graphic* files (*PNG*).

4.3 Video Recording

Video Recordings are saved as raw *h264*-stream. Can be viewed with the *VLC Media Player*[1].

4.4 Image Sequences

Image sequences are saved in *ZIP*-files. The archive contains the recorded images as a sequence of *PNG*-files and a single `timings.csv` file. This file contains the timings for each image.

The `timings.csv` file looks like this:

```
image;    time
[nr];     [s]
0;   0.0
1;   1.5
2;   2.0
3;   3.5
4;   5.0
...
```

Row Description:

- image [nr]: image number starting with image 0.
- time [s]: Time when the the image was taken in seconds.

4.5 Object Detection

Object detections are saved in a *ZIP*-file. The archive contains an `objects.csv` and a `particleflow.csv.`

The `objects.csv` which looks like that:

```
image;    time; cx;   cy;   bx;   by;    bw;  bh;   bws;  bhs;  area;  areas; equidiams
[nr];     [s];  [px]; [px];   [px]; [px]; [px]; [px]; [µm]; [µm]; [px²]; [µm²]; [µm]
0;   0;      10;    121; 16;   11;   1;    1;    5;    5;   12412;    23423;    15
0;   0;      44;    55;  264;  116;  1;    1;    5;    5;   5125;     63464;    155
0;   0;      49;    345; 74;   14;   1;    1;    5;    5;   63450;    23533;    51
...
```

Row Description:

- image [nr]: image number starting with image 0.
- time [s]: Time when the the image was taken in seconds.
- cx [px]: Center x-coordinate of object

1 https://www.videolan.org

- cy [px]: Center y-coordinate of the object.
- bx [px]: Bounding box x-cooedinate of the detected object.
- by [px]: Bounding box y-coordinate of the detected object.
- bw [px]: Bounding box width of the object in pixels.
- bh [px]: Bounding box height of the detected object in pixels.
- bws [µm]: Bounding box width of the object in µm.
- bhs [µm]: Bounding box height of the object µm.
- area [px²]: Area of the obejct in pixels.
- areas [µm²]: Area of the object in µm².
- equidiams [µm]: Equivalent Diameter calculated from area in µm.

The `particleflow.csv` which looks like that:

```
image;    time;     particles;     particleflow
[nr];     [s]; [num];         [particles/s]
0;   0;         10;            51
0;   1;         20;            102
...
```

Row Description:

- image [nr]: image number starting with image 0.
- time [s]: Time when the the image was taken in seconds.
- particles [num]: Number of detected particles per frame.
- particleflow [particles/s]: Particle flow in particles per second.

5 Particle Flow

This section gives a brief overview of how the particle flow rate is calculated.

Volumetric flow rate ist defined as $\dot{V} = \frac{\mathrm{d}V}{\mathrm{d}t}$.

We define the particle flow as $\dot{p} = n \cdot \dot{V}$, where n is the particle density and it's defined as the number of particles per volume $n = \frac{N}{V_m}$. Please note that this is an analoge definition of the mass flow rate ($\dot{m} = \varrho \cdot \dot{V}$). The value of $\dot{p}$ is the number of detected particles per second.

A short example: The volumetric flow rate $\dot{V}$ through the inhale inlet is 125 cm³/s, where the typical tidal volume of an adult is 500 cm³ and the breathing time is 4 seconds (2 seconds to breath in and 2 to breath out, or ~15 breaths per minute). We multiply the estimated volumetric flow rate $\dot{V}$ with the particle density of the measuring volume V_m. The measuring volume is defined using the viewport passe-partout and the light courtain thickness of around 20 mm. For a passe-partout of 59.9x45.5 mm we get a volume of around 54.5 cm³. Particle density is 0.18 particles/cm³ for 10 detected particles. The particle flow rate is around 23 particles per second, assuming your estimated volumetric flow rate is 125 cm³/s.

The tidal volume, breathing frequency and light curtain width can be changed using the following URLs:

- Tidal volume: http://<ip_address>:5000/set_param/tidal_volume?value=470
- Breathing frequency: http://<ip_address>:5000/set_param/breath_freq?value=14
- Light curtain width: http://192.168.1.10:5000/set_param/light_curtain_width?value=20