Nimbus Documentation

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Contents:

Nimbus is a 3D-TOF Raspberry Pi camera frontend and an open source software platform allowing to capture and calcualte 3D point-clouds based on raw TOF data.

CHAPTER 1

Quickstart

1.1 Safety instructions

Follow the instructions for safe use provided by the raspberry pi foundation, see qsg.pdf The camera emits strong, almost invisible IR light. Don't look straight into the LEDs from a short distance.

1.2 Functions and features

Nimbus 3D is a time of flight sensor measuring the distance between the device and the nearest object/surface. Nimbus 3D illuminates the scene with a modulated infrared light source. The distance is calculated by the phase shift between the illumination unit and the reflected light. Nimbus 3D only works with a Raspberry Pi 3B and higher, which is not part of the product. The measured data is available via Ethernet and canbe evaluated by the user. The nimbus 3D sensor may only be used under the operating conditions specified by the Raspberry Pi foundation,see qsg.pdf Nimbus 3D is designed for indoor use only.

1.3 Items supplied

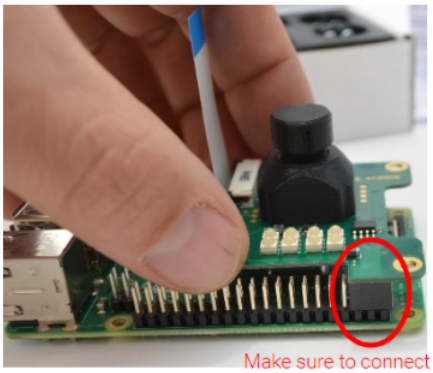
- nimbus 3D
- safety instructions (get a copy here https://tinyurl.com/yykf6bc4)
- FFC jumper cable
- 2x spacers with screws

1.4 Mounting

The following images illustrate the mounting process of nimbus 3D. The device must be powered off, while mounting the camera.

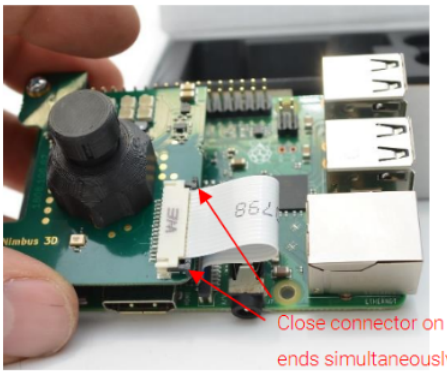
1. Mount FFC cable on raspberry

2. Connect to pinheader



3. Mount spacers

4. Mount FFC cable on raspberry



1.5 Operation

Fllow these two fundamental rules in order to get optimal performance: * Use a strong power supply (minimum 2.5A). The quality of onboard illumination highly depends on the supply (we recommend to use the official power supply) * Use a gigabit ethernet cable (cat6 and higher)

1.6 Technical data

Resolution	352 x 288
Measurement range	0,1 - 5m
Viewing angle	66° x 54° (H x V)
Framerate	up to 30fps
Interface	CSI2, I2C, 5V
Output	amplitude, radial, confidence, point cloud
Size	44mm x 56mm x 23mm
Imager	Infineon Real3 IRS1125A
Power supply	Min. 2.5 A
Network connection	Gigabit ethernet cable cat6 or higher

1.7 Compliance information

Nimbus 3D complies with the relevant provisions of the RoHS Directive for the European Union. In common with all Electrical and Electronic Equipment (EEE) Nimbus 3D should not be disposed of as household waste. Alternative arrangements may apply in other jurisdictions.

CHAPTER 2

Overview about the Nimbus Software

In general there are two ways to work with nimbus which are discussed in the following chapters:

1. Working directly on the Raspberry Pi (embedded)
2. Working on a desktop machine or edge computing hardware connected to a Raspberry Pi over the network

The following graphic shows the underlying architecture of the Nimbus software. The imager takes the image and the Linux kernel module developed by us makes it available via Video4Linux. Now two possibilities are available. Either the nimbus-server can be used, which makes the data available in the network via web sockets and lets you change parameters via JSON RPC. nimbus-python and nimbus-web both use this interface. In this way the data can be used asynchronously locally and in the network and a distributed system can be realized. The Python interface is particularly suitable for easy use of the data. The web interface especially to get a live image and simply adjust the exposure.

Alternatively the local synchronous C-interface can be used, which allows the integration of own calculations into the processing stage. So you have direct low-level access to the point cloud in C. The ROS (Robot Operating System) driver is based on this interface.

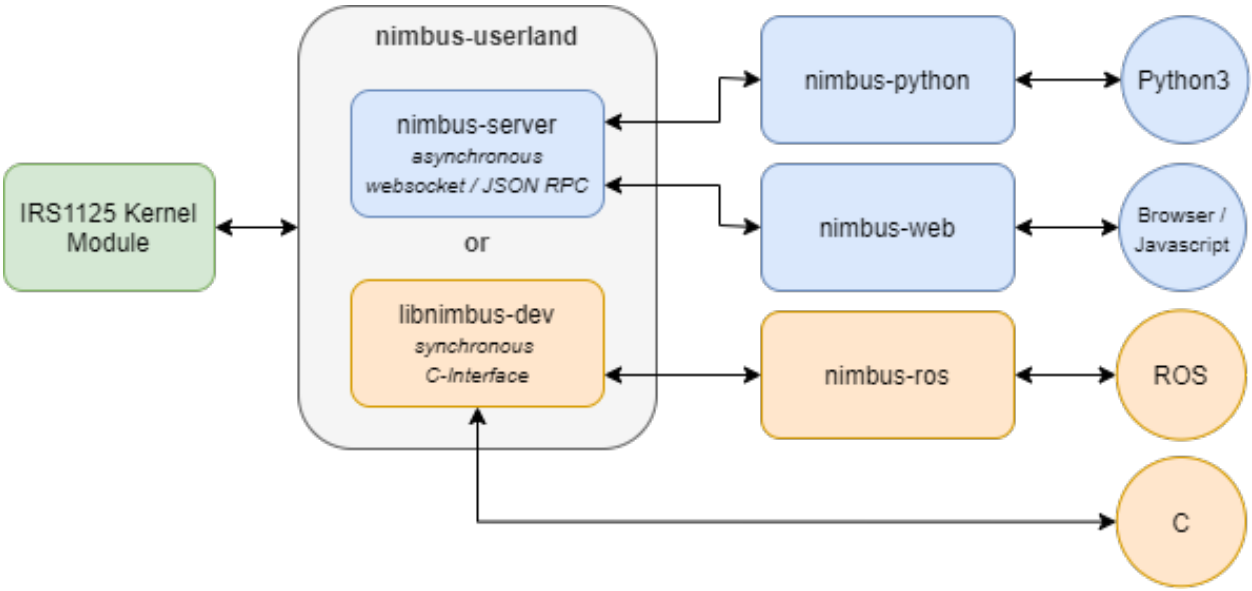
You can use the prepared Raspberry Pi OS (buster) images with the already installed nimbus software.

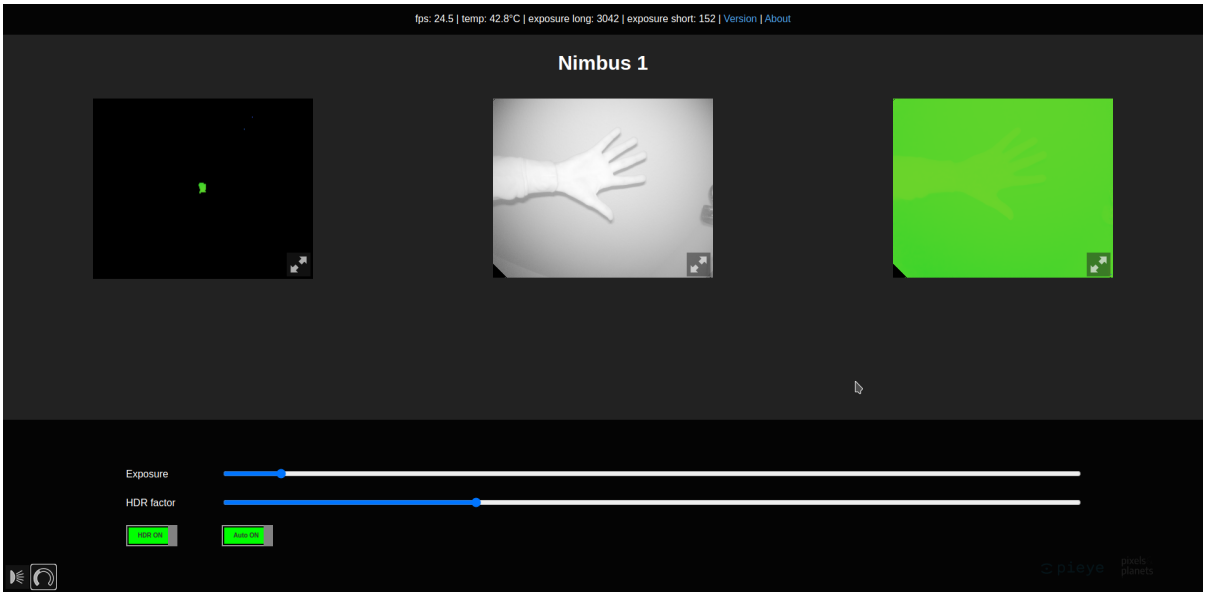
2.1 nimbus-web

After successful installation and setup of nimbus-web it can be accessed in the browser via the IP address of the Raspberry Pi. On the left side the point cloud is visible, in the middle a grey value image and on the right side a depth image. With a click on the buttons below, the exposure settings and information about the current image can be opened.

2.2 nimbus-ros

Robot Operating System (ROS or ros) is robotics middleware. Although ROS is not an operating system, it provides services designed for a heterogeneous computer cluster such as hardware abstraction, low-level device control, imple-

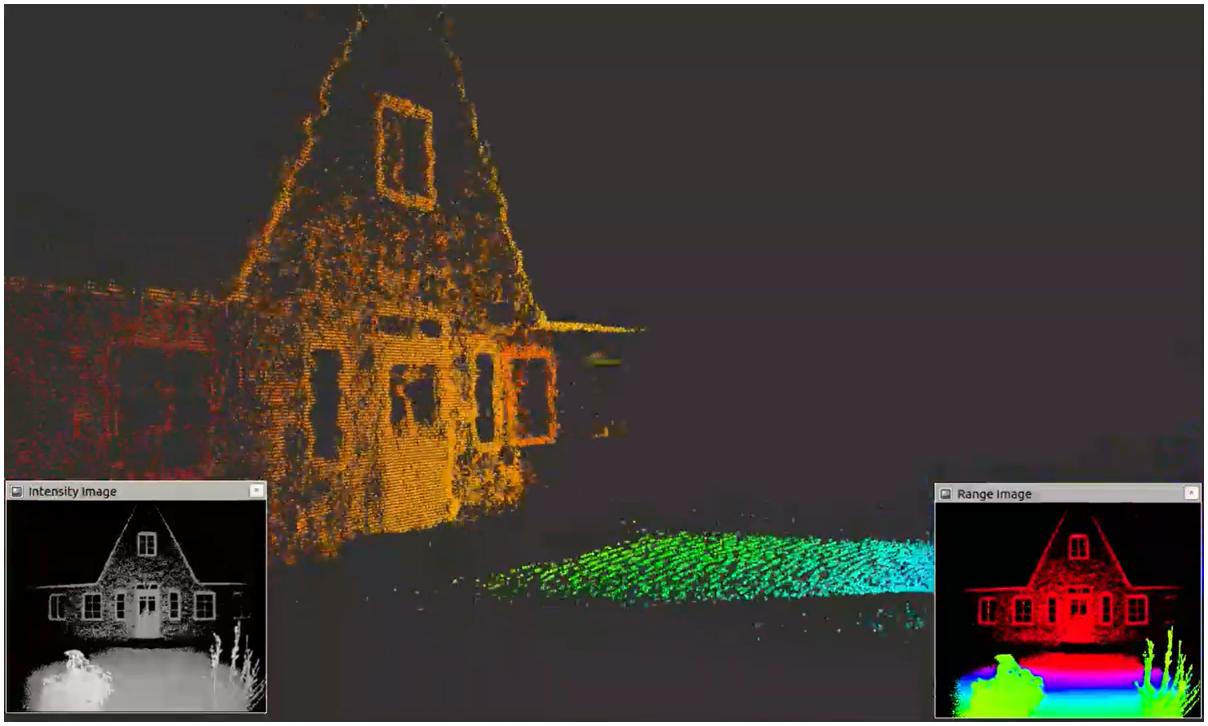

nimbus-userland
nimbus-server
asynchronous
websocket / JSON RPC
or
libnimbus-dev
synchronous
C-Interface
IRS1125 Kernel Module
nimbus-python
Python3
nimbus-web
Browser / Javascript
nimbus-ros
ROS
C


fps: 24.5 | temp: 42.8°C | exposure long: 3042 | exposure short: 152 | Version | About
Nimbus 1
Exposure
HDR factor
HDR ON
Auto ON

mentation of commonly used functionality, message-passing between processes, and package management. Running sets of ROS-based processes are represented in a graph architecture where processing takes place in nodes that may receive, post and multiplex sensor data, control, state, planning, actuator, and other messages. Despite the importance of reactivity and low latency in robot control, ROS itself is not a real-time OS.

In order to use the Nimbus in ROS you need the nimbus-ros and ROS itself on your Rasperry Pi.

ROS is particularly useful for more extensive projects, such as industrial robotics and autonomous systems, as well as the use of existing algorithms. The ROS driver provides point cloud, intensity image and depth image which can be visualized with RVIZ or RQT.



Furthermore, settings can be easily changed using the ROS parameter server. Access and location transparency is easily achieved in the local network because ROS uses and abstracts the network interface.

CHAPTER 3

Installation

3.1 Raspberry Pi

Nimbus 3D is a time-of-flight camera for the Raspberry Pi that captures high-resolution 3D point clouds. The Raspberry Pi4 is recommended for the best experience. Prepared Raspberry OS images are available. If these are used, the following installation can be skipped.

3.2 nimbus-userland

The official Raspberry OS kernel includes an implementation for the Nimbus 3D. To use it, the corresponding embedded sources must be installed.

1. Update to bleeding edge kernel

```
sudo rpi-update
```

2. Add the Nimbus 3D apt repository

```
echo 'deb http://apt.pieye.org/debian/ nimbus-stable main' | sudo tee -a /etc/apt/
↪sources.list

wget -O - -q http://apt.pieye.org/apt.pieye.org.gpg.key | sudo apt-key add -

sudo apt update
```

3. Add the Imager to your boot config

```
sudo echo 'dtoverlay=irs1125' | sudo tee -a /boot/config.txt
```

4. Install the nimbus-server or libnimbus-dev

```
sudo apt-get install nimbus-server

sudo apt-get install libnimbus-dev
```

4. Reboot the Raspberry Pi

```
sudo reboot now
```

3.3 nimbus-web

Nimbus-web is the webinterface for the Nimbus 3D. There it is possible to see in real time the point cloud, depth images and intensity images. Furthermore it is possible to adjust the exposure and read the log. The source code is available here: Github.

1. Install nginx and git

```
sudo apt-get install nginx git
```

2. Clone the code

```
git clone https://github.com/pieye/nimbus-web.git
```

3. Edit file /etc/nginx/sites-available/default (with sudo) and change line 41 from

```
root /var/www/html;
```

to

```
root /home/pi/nimbus-web;
```

4. Restart nginx

```
sudo service nginx restart
```

5. Open a browser with the IP address of your Raspberry Pi and you should see the webinterface.

3.4 nimbus-python

Nimbus-Python is the Python interface for the Nimbus 3D. Here it is possible to get the 3D data in Python within the local network. The source code is available here, but the package can also be installed directly via pip.

```
pip install nimbus-python
```

3.5 nimbus-ros

The Nimbus 3D can also provide data directly in ROS (Robot Operating System), which requires the installation of nimbus-ros. It is strongly recommended to use the finished image, because the process is quite time-consuming.

To use the low level c interface it is necessary to stop the nimbus-server. Check with the following command if it is running and stop it. For the next use of nimbus-python or nimbus-web the nimbus-server must be activated again.

```
sudo systemctl status nimbusServer.service
sudo systemctl stop nimbusServer.service
```

1. Clone this Repository in the src folder of your ROS workspace.

```
mkdir -p ~/catkin_ws/src
cd ~/catkin_ws/src
git clone https://github.com/pieye/nimbus-ros.git
```

2. To perform the following installation 4GB memory is required. If this is not available, the swap size must be increased accordingly:

```
sudo dphys-swapfile swapoff
sudo nano /etc/dphys-swapfile
```

3. Change these lines CONF_SWAPSIZE=3000 CONF_MAXSWAP=4096

```
dphys-swapfile setup
sudo dphys-swapfile swapon
```

4. Install ROS Melodic from Source manually OR run the following install script:

```
./nimbus-ros/scripts/install.sh
```

5. Build the nimbus_3d_driver

```
cd ~/catkin_ws
catkin_make
```

6. Configure ROS to run accros multiple machines The following diagram shows the possible architectures for using your Nimbus 3D. The ROS driver "nimbus_3d_driver" is running on the Raspberry Pi and publishes the pointcloud. In this guide the ROS master is also running on the Pi, but it could run on any other machine in your local network. The Pointcloud is afterwards visualized on another Computer with a Display connected e.g. Laptop. Your algorithms to process the captured data can run locally on your Raspberry or any other device in the local network.

We now configure ROS to run the master on the Raspberry and access the data via another machine running ROS Melodic with RVIZ installed Add this line to the .bashrc of your other machine (laptop), after adapting the IP to your Raspberry Pi if you are using Linux. You also need to add the IP of your local machine (ROS_IP):

```
nano ~/.bashrc

export ROS_MASTER_URI=http://192.168.1.1:11311
export ROS_IP=192.168.1.1
```

If you are using Windows you need to set it up as an enviroment variable:

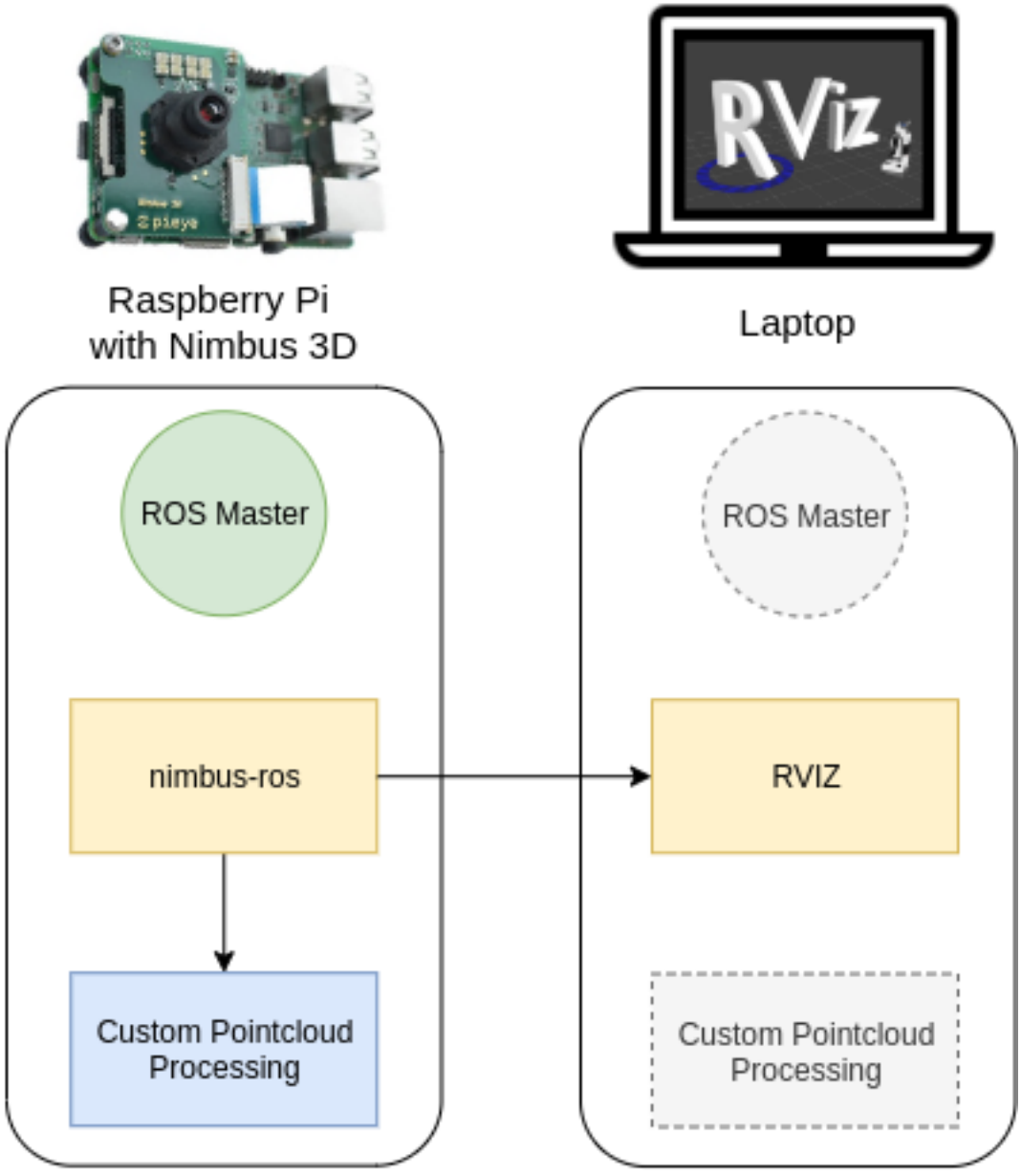
```
Name: ROS_MASTER_URI      Value: http://192.168.1.1:11311
Name: ROS_IP              Value: 192.168.1.1
```

SSH into your Raspberry and run:

```
roscore
```

Start RVIZ on your machine:

```
rviz
```


Raspberry Pi
with Nimbus 3D
Laptop
ROS Master
nimbus-ros
Custom Pointcloud
Processing
ROS Master
RVIZ
Custom Pointcloud
Processing

It should start if everything works as expected.

7. Start the Nimbus ROS Driver The given launch file starts the nimbus node and a static coordinate transform after executing it on the Raspberry.

```
source devel/setup.bash
roslaunch nimbus_3d_driver nimbus.launch
```

It is possible to adjust the topics where the Pointcloud, Intensity Image, and Range Image are published. Simply set a new topic name in the launch file. This is necessary when using multiple Nimbus cameras in your local network at the same time.

3.6 nimbus-ros (optional)

3.6.1 Clock synchronization

Each pointcloud includes the timestamp of the initial image aquisition. If this is needed across devices, a clock synchronization protocal such as NTP should be used. PTP hardware timestamping is not available on the Raspberry Pi. Chrony is as often used tool for that task.

3.6.2 Configuration

It is possible to adjust the parameters that have an impact on the amount of transmitted data.

A 1GBit/s ethernet connection to the Raspberry Pi is highly recommended. If this is given you can launch the default configuration without making any changes. If you only have a 100MBit/s Interface you can load the given preset by changing the default.yaml to fast_ethernet.yaml in the launch file (launch/nimbus.launch). This will reduce the resolution! If you need to reduce the bandwitdh even further (e.g. wifi) but still need a reliable point cloud, you can replace the config against the low_bandwitdh.yaml This will heavily reduce the resolution! Furthermore it is possible to adjust the parameters to your own needs. Depending on the given setup it might be useful to adjust the auto exposure. If objects are moving fast or a minimum framerate should be achieved it can help do disable hdr and set a max value for the exposure time. The desired exposure can also be adjusted.

Furthermore it is possible to change the following parameters during runtime:

```
rosparam set /nimbus_3d_driver_node/XYZ_to_m                  [0.0 - 1.0]

rosparam set /nimbus_3d_driver_node/amplitude                 [0 - 3000]

rosparam set /nimbus_3d_driver_node/downsampling              [true | false]

rosparam set /nimbus_3d_driver_node/downsampling_voxel_size   [0.0 - 1.0]

rosparam set /nimbus_3d_driver_node/hdr_factor                [0.0 - 1.0]

rosparam set /nimbus_3d_driver_node/exposure_mode             [-1 (manual), 0␣
↪(default), 1 (Auto), 2 (HDR)]

rosparam set /nimbus_3d_driver_node/intensity_image           [true | false]

rosparam set /nimbus_3d_driver_node/max_exposure              [0 - 32766]

rosparam set /nimbus_3d_driver_node/pointcloud                [true | false]
```

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```
rosparam set /nimbus_3d_driver_node/range_image                [true | false]
```

CHAPTER 4

Working on the Raspberry Pi

This chapter contains all details about working with the Nimbus directly on the Raspberry Pi, such as:

- acquiring and accessing data
- change settings like exposure time and resolution
- adding a custom processing statge to the processing pipeline

You can either use the nimbus interface in a synchronous or in an asynchronous manner.

4.1 Synchronous vs. Asynchronous Interface

4.1.1 Synchronous Interface

In computer science and network technology, synchronous communication is a mode of communication in which the communication partners (processes) always synchronize when sending or receiving data. They wait (block) until the communication is completed. Waiting both when sending and receiving data corresponds to a rendezvous of the two processes involved.

Such a synchronous interface can be implemented with the C-Interface described below. It is not recommended to perform time-consuming calculations directly in the C-interface, since this reduces the frame rate due to the blocked main process.

In such a case the use of the ROS (Robot Operating System) driver or a similar implemenation is recommended. The ROS driver implements the C-interface and forms an abstraction of it. If the frame rate limit is set high enough, all new data will be provided directly in ROS. However, the preprocessing stage is no longer blocked when the data is available in ROS.

4.1.2 Asynchronous Interface

In computer science and network technology, asynchronous communication refers to a mode of communication in which the sending and receiving of data takes place with a time delay and without blocking the process. The Pyhton

interface (nimbus-python) represents such an asynchronous interface. The same applies to the web interface (nimbus-web). Both receive their data via websockets and settings are changed via JSON RPC.

4.2 Configuring nimbus

In the case of the nimbusServer, setting changes are made via the JSON RPC interface. In nimbus-python settings like exposure are already available as function calls. In addition, it is possible to change the exposure in the web browser and to observe the result directly. An implemenation for the C-Interface is shown below.

4.3 Adding a custom processing stage

4.3.1 C-Interface

After having built and installed nimbus-userland (make install), all libraries are installed under /usr/local/lib, all headers are installed under /usr/local/include The header nimbusPreprocessInterface.h contains a low level c interface to libnimbus-preprocessing.so. This is useful when you want to integrate nimbus with external applications.

4.3.2 Example

The following snippet demonstrates the interface

```
#include <stdio.h>
#include <unistd.h>
#include "nimbusPreprocessInterface.h"

int g_cnt;

void imageCallback(void* unused0, void* img, void* unused1) {
    uint16_t* ampl = nimbus_seq_get_amplitude(img);
    uint8_t* conf = nimbus_seq_get_confidence(img);
    ImgHeader_t* header = nimbus_seq_get_header(img);
    printf("got an image\n");
    g_cnt++;
    nimbus_seq_del(img); //<- free the image pointer this call is necessary to return␣
↪img resource to nimbus
}

int main(int argc, char** argv) {
int i;

printf("nimbus-userland version: %s\n", nimbus_get_version());

if (nimbus_preproc_init()) {
    nimbus_preproc_seq_cb(imageCallback);
    g_cnt = 0;
    while (g_cnt < 100) {
        usleep(10000);
    }
}
else {
    printf("init nimbus failed!\n");
```

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```
}
    return 0;
}
```

In case you want to adjust the auto exposure we provide the following interface:

```
AutoExposureParams_t m_params;
m_params.amplitude     = amplitude;     //0.0 - ~1500.0
m_params.max_exposure  = max_exposure;  //0-32767
m_params.hdr_factor    = hdr_factor;    //0.0 - 1.0
m_params.exposure_mode = exposure_mode; //MANUAL = 0, MANUAL_HDR  = 1, AUTO = 2, AUTO_
↪HDR = 3
bool set_exposure = nimbus_autoexposure_set_params(&m_params);
```

Furthermore the following functions are available to get the pointcloud data.

```
uint16_t* nimbus_seq_get_radial_dist(void* image);
int16_t* nimbus_seq_get_x(void* image);
int16_t* nimbus_seq_get_y(void* image);
int16_t* nimbus_seq_get_z(void* image);
```

We assume that the previous snipped is stored in a file called main.cpp. You can than build this file with gcc main.cpp -o myApp -lnimbus-preprocessing and run it ./myApp. If nimbus-proprocessing lib cannot be found, either add -L/usr/local/lib to gcc options or run sudo ldconfig.

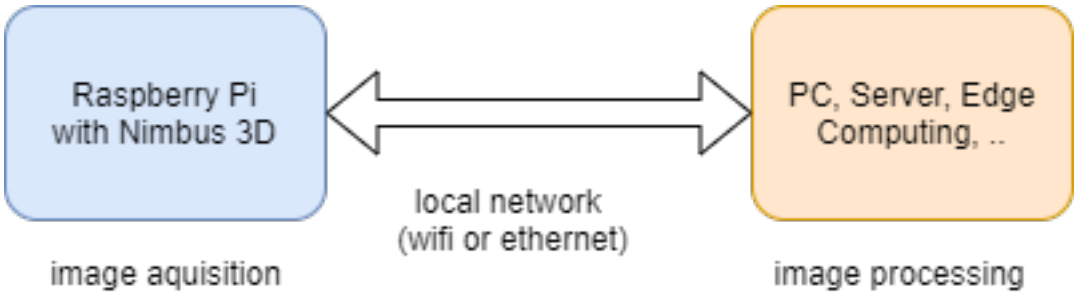
CHAPTER 5

Nimbus over the network

To use nimbus over the network install the **nimbus-server** package. nimbus-python use nimbus-web this Interface.

This way it is very easy to use the Nimbus over the network. However, it is important that a sufficiently fast connection is available. For the best user experience a 1GBit/s connection is recommended.

When using nimbus-python it is recommended to use nimbus-web in parallel to see live changes. Both are accessed via the local IP and receive the data via websockets. See nimbus-python for the exact implementation of the interface.



For use in a large system, such as a robot, the use of ROS (Robot Operating System) is recommended. This framework provides a large number of helpful tools such as visualization and data recording. ROS also makes it possible to write code that runs both locally on the Raspberry and remotely on a PC without any changes to the program.

CHAPTER 6

3rd party libraries and licenses

Please check the README.md file of repository https://github.com/pieye/nimbus-userland to get a list of all 3rd party libraries and their licenses used by the nimbus-userland project.

CHAPTER 7

Indices and tables

- genindex
- modindex
- search