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# PIMOD: A Tool for Configuring Single-Board Computer Operating System Images

*Connectivity and Communication 3: Image Enhancement Techniques*

*Jonas Höchst*

*Sat, Oct 31 2020*

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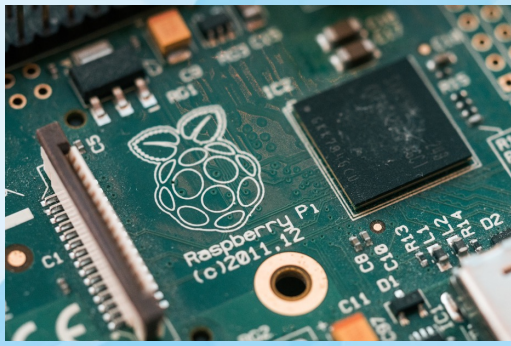


# PIMOD: A Tool for Configuring Single-Board Computer Operating System Images

*Jonas Höchst, Alvar Penning, Patrick Lampe and Bernd Freisleben*

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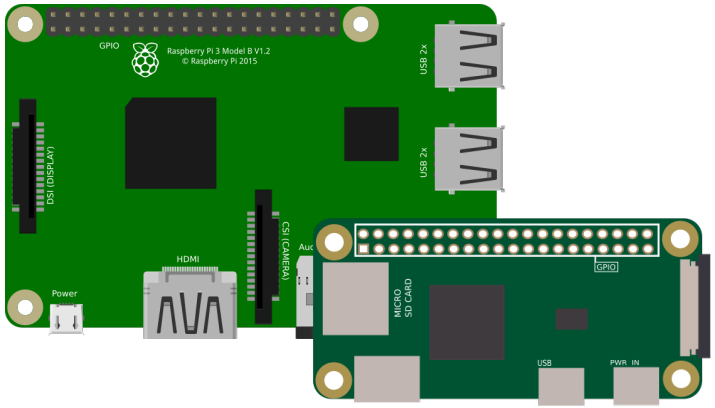
# Technology Prototyping in the Humanitarian Sector

## How does your research project prototype new ideas?

ROCKPI




NVIDIA

LIBRE COMPUTER

range pi

IEEE

Logos: ALLNET GmbH Computersysteme, Libre Computer, Raspberry Pi Foundation, NVIDIA CORPORATION, Xunlong Software Co., Limited

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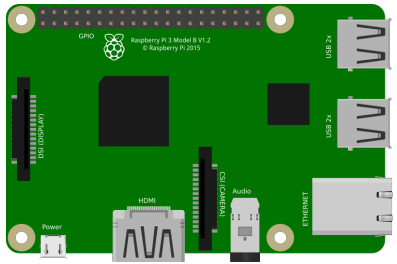
# Setting Up Single-Board Computers (for Research)

## The manual approach: iterate configuration for every device.

Raspbian

1. Flash OS


2. Access Device

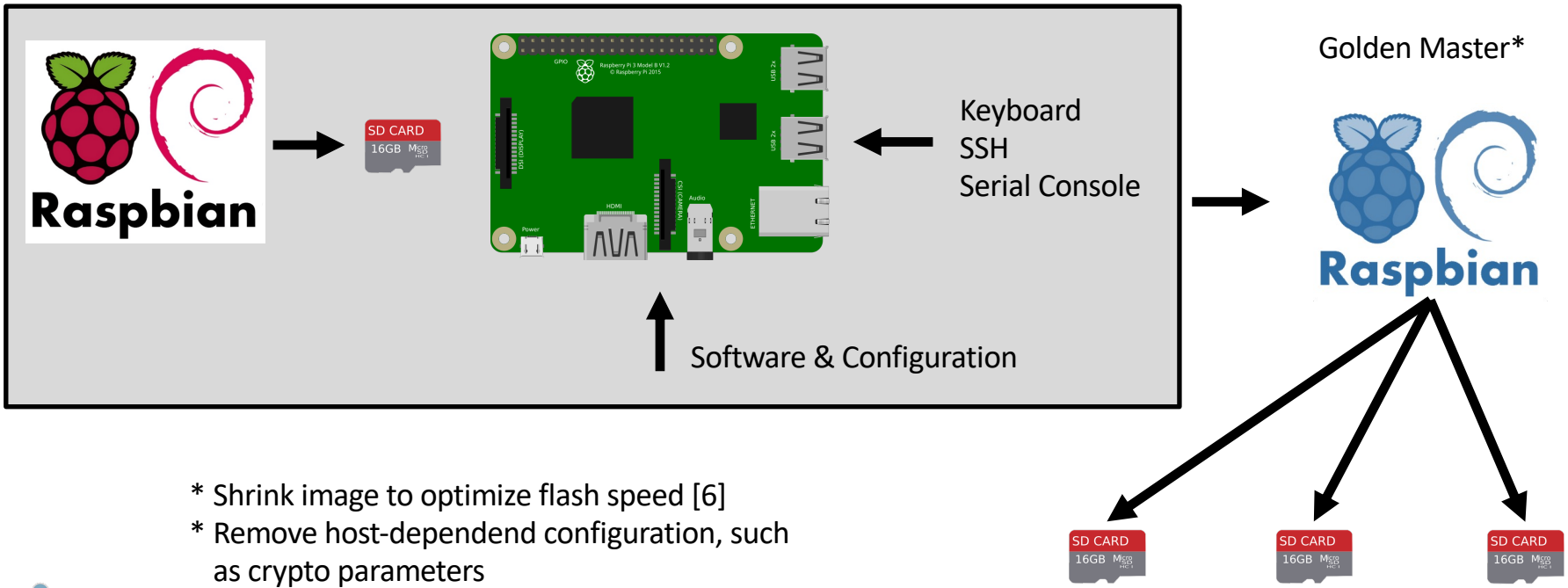
Keyboard
SSH
Serial Console

3. Install & Configure Software*

* use custom scripts to proceed faster

# Setting Up Single-Board Computers (for Research)

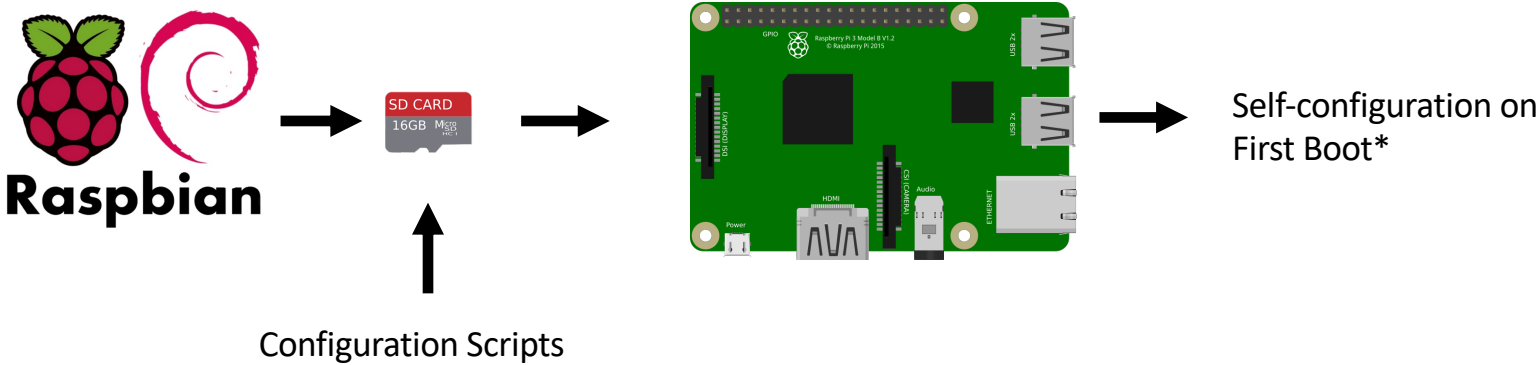
## Replicate a configured operating system: configure once, use often.




* Shrink image to optimize flash speed [6]
* Remove host-dependend configuration, such as crypto parameters
* Initial installation remains mostly manual

# Setting Up Single-Board Computers (for Research)

## First-boot self-configuration: add scripts to configure device on first boot



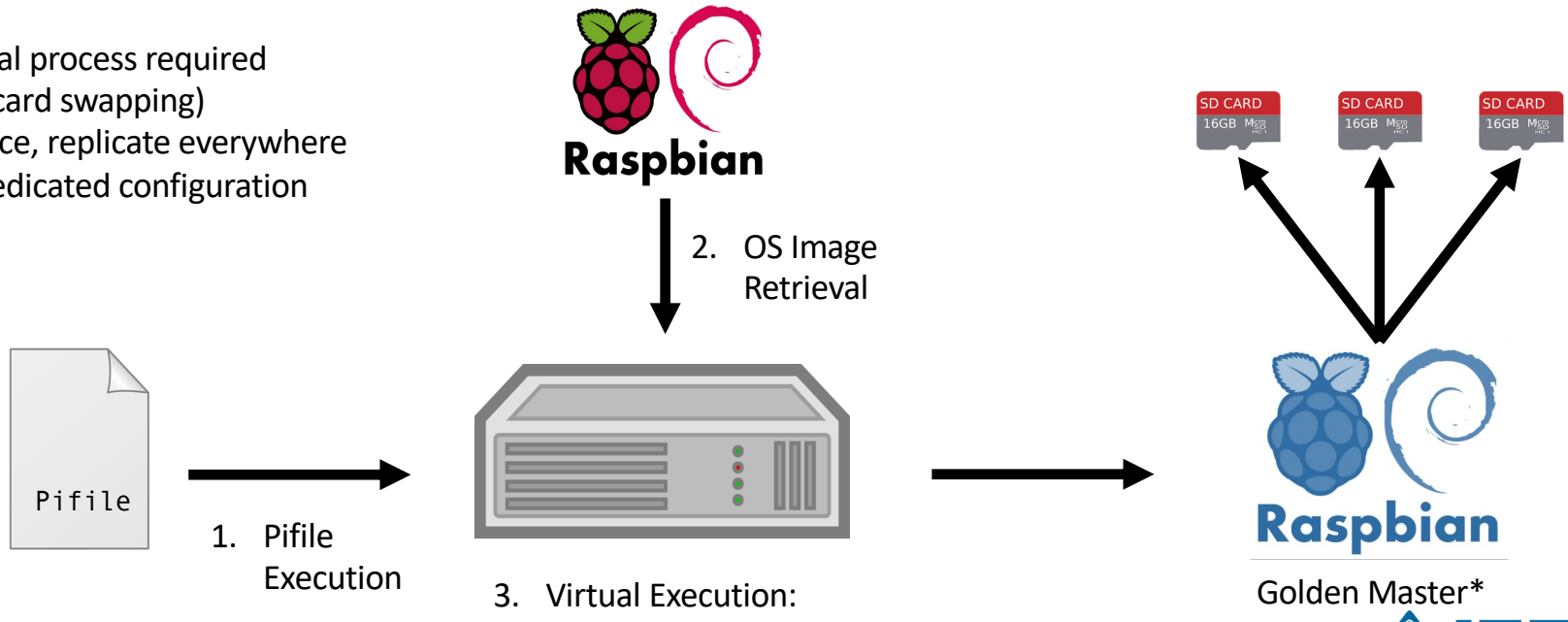

* Software is installed on every device independently, overhead

* System needs to be online

# Introducing PIMOD

## Enhance OS images using virtualization

* Image generation on a generic x86 server
* No manual process required (e.g., SD card swapping)
* Install-once, replicate everywhere
* Simple dedicated configuration language



# PIMOD Design

## The language

- Simple language inspired by Docker
- Line-based commands written in caps:

a) FROM <source> [partition]
b) TO <destination image>
c) INPLACE <image>
d) PUMP <bytes>
e) PATH <location>
f) RUN <cmd>
g) INSTALL [mode] <source> <destination>
h) HOST <cmd>

```
1  FROM 2020-05-27-raspios-buster.img 2
2  TO raspbian-buster-upgraded.img
3
4  # Increase the image by 100 MB
5  PUMP 100M
6
7  # Enable serial console using built-in
       configuration tool
8  RUN raspi-config nonint do_serial 0
9
10 # Upgrade the operating system image
11 RUN apt-get update
12 RUN bash -c 'DEBIAN_FRONTEND=
       noninteractive apt-get -y dist-
       upgrade'
13
14 # Install an ssh key
15 INSTALL id_rsa.pub /home/pi/.ssh/
       authorized_keys
```

Listing 1: PIMOD example 1: upgrade Raspbian and enable the serial console.

# PIMOD Design

## Further design goals

- Fast execution
  - No full system emulation
  - No guest operating system booting, no accidental first boot script execution
- QEMU-based system emulation
  - Support for ELF binaries of different instruction set architectures
- Support for continuous integration approaches
  - Allow developers to build OS images asynchronously and reproducibly
- Host system support
  - Integrate into workflows on the host machine, e.g., building software with a native cross-compiler

# PIMOD Implementation

## Staged execution of a Pifile-based operating system configuration

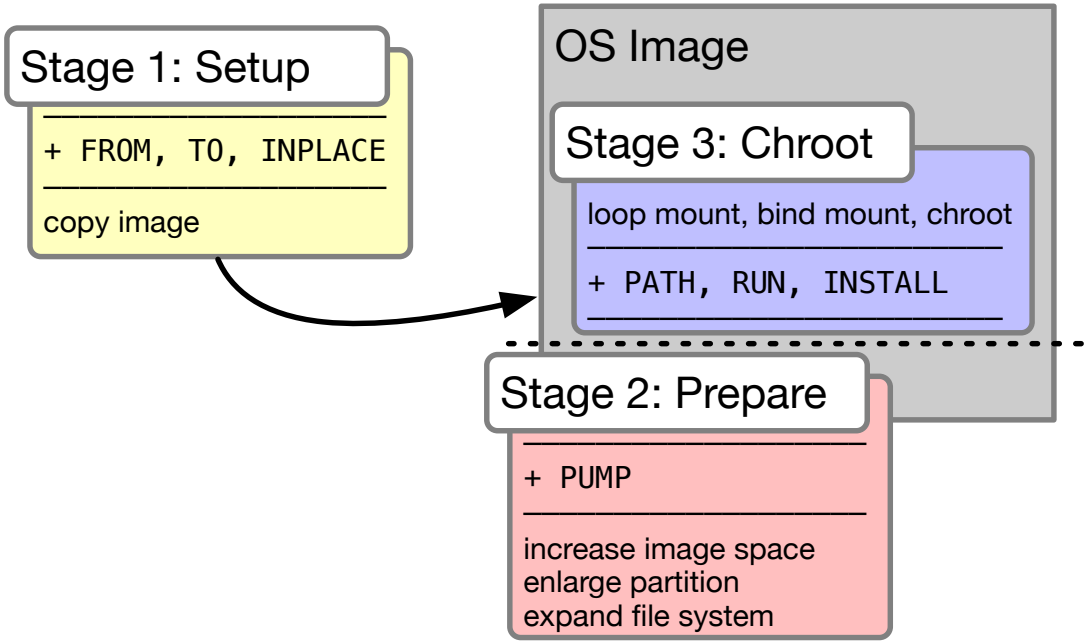



Fig. 1: Stages of PIMOD: preparation, commands, and post-processing.

# PIMOD Implementation

*Demo*

# PIMOD Evaluation

## Reaching design goals

### Usability

- Large advantage compared to regular configuration schemes
- Utilization of more powerful hardware and/or network connection
- Modern software development with continuous integration

### General applicability

- Support for various Linux distributions:
  - Raspbian, Ubuntu Server, OpenWRT, CentOS, Fedora, Kali, OpenSUSE, …
- Support for multiple hardware platforms:
  - Libre computer boards ALL-H3- CC, AML-S805X-AC and ROC-RK3328-CC,
  - RaspberryPi (all models), BananaPi M4, OrangePi 3, RockPi 4,
  - Nvidia Jetson Nano (AI development board),
  - ODROID C2 and N2,
  - …

# PIMOD Evaluation

## Virtualization costs & benefits

### Evaluation setup:

- Raspberry Pi 3 Model B V1.2
  - 4 x 1.2 GHz, 1 GB Ram, 32 GB microSD class U1
- Mid-End build server
  - 2 x 16 x 2.6 GHz, 256 GB Ram, NVMe drive

### Results

- Faster execution of network and IO-bound tasks
  - Fast server network connection
  - Fast NVMe drive
- Overhead through non-native computations
  - Cryptographic operations, such as hashing, signing, ...
  - Limited by single-core performance and emulation overhead

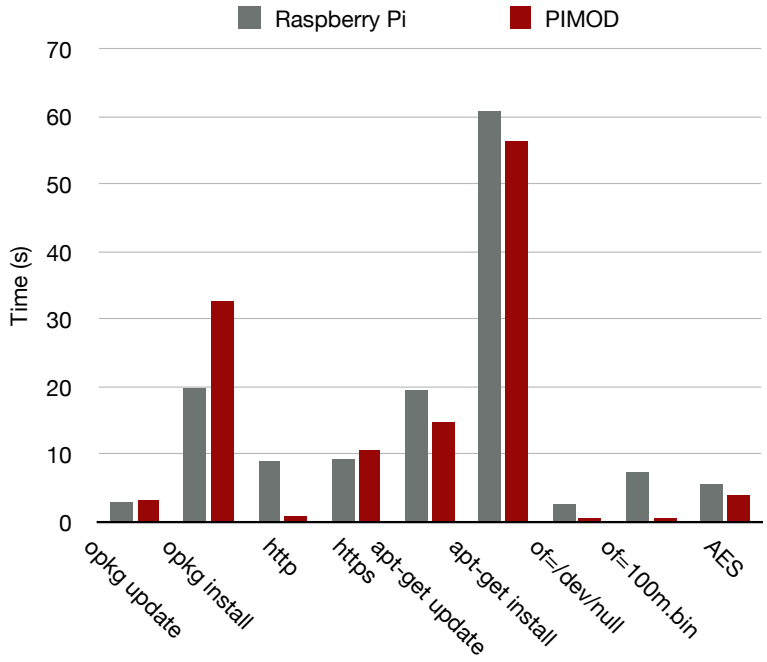



Fig. 2: Example executions times of different commands using a Raspberry Pi compared to PIMOD.

# PIMOD Evaluation

## Extensibility examples

Host Environment Variable

UNIX Pipes

Integration of Host Cross-compiler

```
1  FROM http://downloads.openwrt.org/
       releases/18.06.5/targets/brcm2708/
       bcm2710/openwrt-18.06.5-brcm2708-
       bcm2710-rpi-3-ext4-factory.img.gz
2
3  # Derive block device from environment
4  TO $DEVICE
5
6  # Include wifi configuration
7  source modules/wifi.Pifile
8
9  # Add local public ssh key
10 RUN tee -a /etc/dropbear/
       authorized_keys <$HOME/.ssh/id_rsa.
       pub
11
12 # Set DHCP client mode for eth0
13 RUN tee -a /etc/config/network <<EOF
14 config interface 'lan'
15         option type 'bridge'
16         option ifname 'eth0'
17         option proto 'dhcp'
18 EOF
19
20 # Cross-compile local software
21 HOST GOOS=linux GOARCH=arm GOARM=5 go
       build -o dtn7d ./dtn7-go/cmd/dtnd
22 INSTALL 755 dtn7d /usr/bin/dtn7d
```

Listing 2: PIMOD example 2: advanced scripting with Bash features.

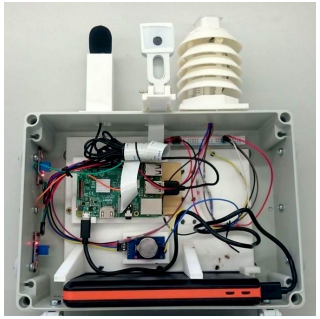
HTTP Image Source

Modularization of Redundant Parts

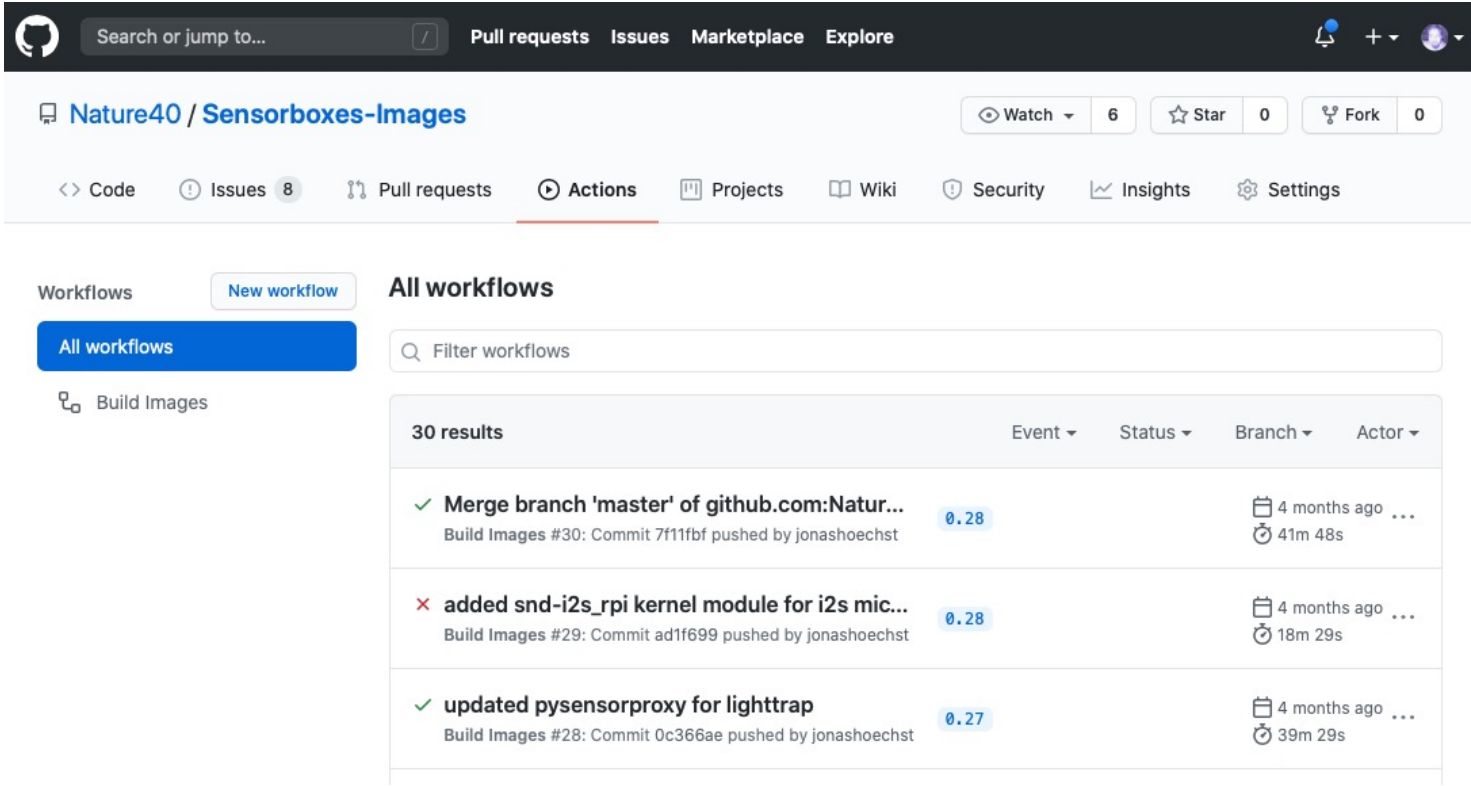
Here Documents

# PIMOD Applications

## Why we built and how we use PIMOD

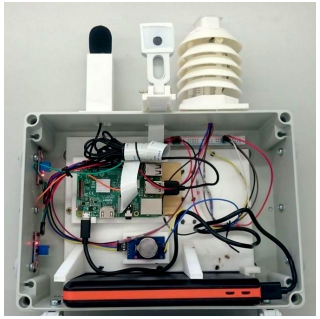


Nature 4.0
Sensing Biodiversity



# PIMOD Applications

## Why we built and how we use PIMOD



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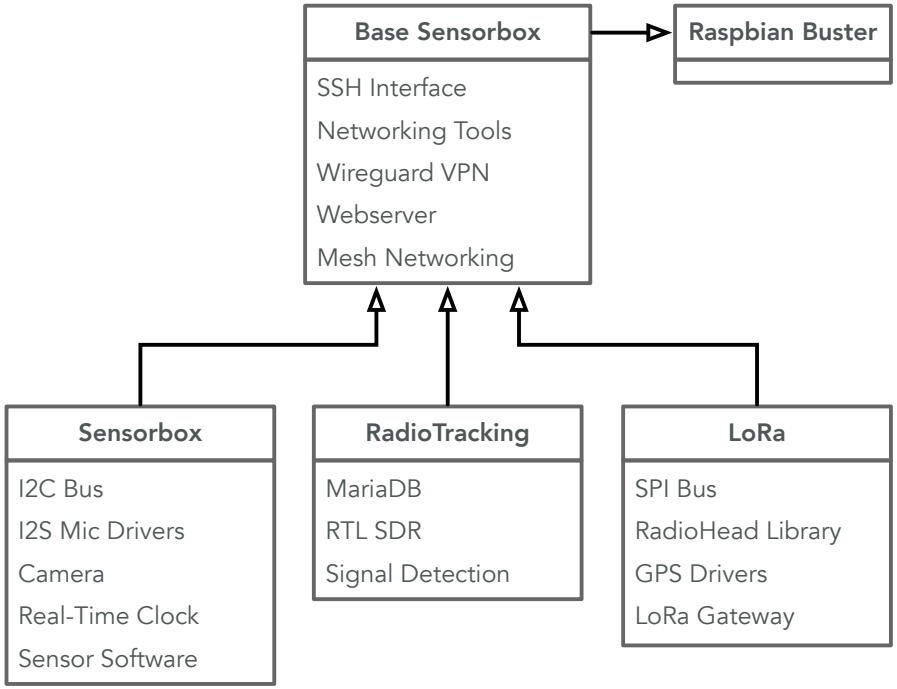


Fig. 3: Raspberry Pi Image configurations used for the Nature 4.0 Project

# Future Work & Acknowledgements

- Reproducible builds: Bit-identical builds require further adjustments:
  - Timestamps
  - Reproducibility of installed software itself
- Caching and staged builds
  - Only execute changed parts of a Pifile
  - Efficient implementation using snapshot filesystems

Testing & Evaluation in the wild and in other use cases

Questions and discussion:

- Right now via GHTC Stream
- via Mail: hoechst@mathematik.uni-marburg.de

Nature 4.0
Sensing Biodiversity

DFG Collaborative Research Centre 1053 – MAKI

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