uRAD

User Manual

SMART TRAFFIC RPi

VEHICLE MONITORING

Product

Hardware: uRAD Smart Traffic RPi v2.0

Firmware: Vehicle Monitoring v2.4

Manufacturer

ANTERAL SL
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31620 Huarte, Navarra
Spain

Original document

This is an original document of ANTERAL SL.

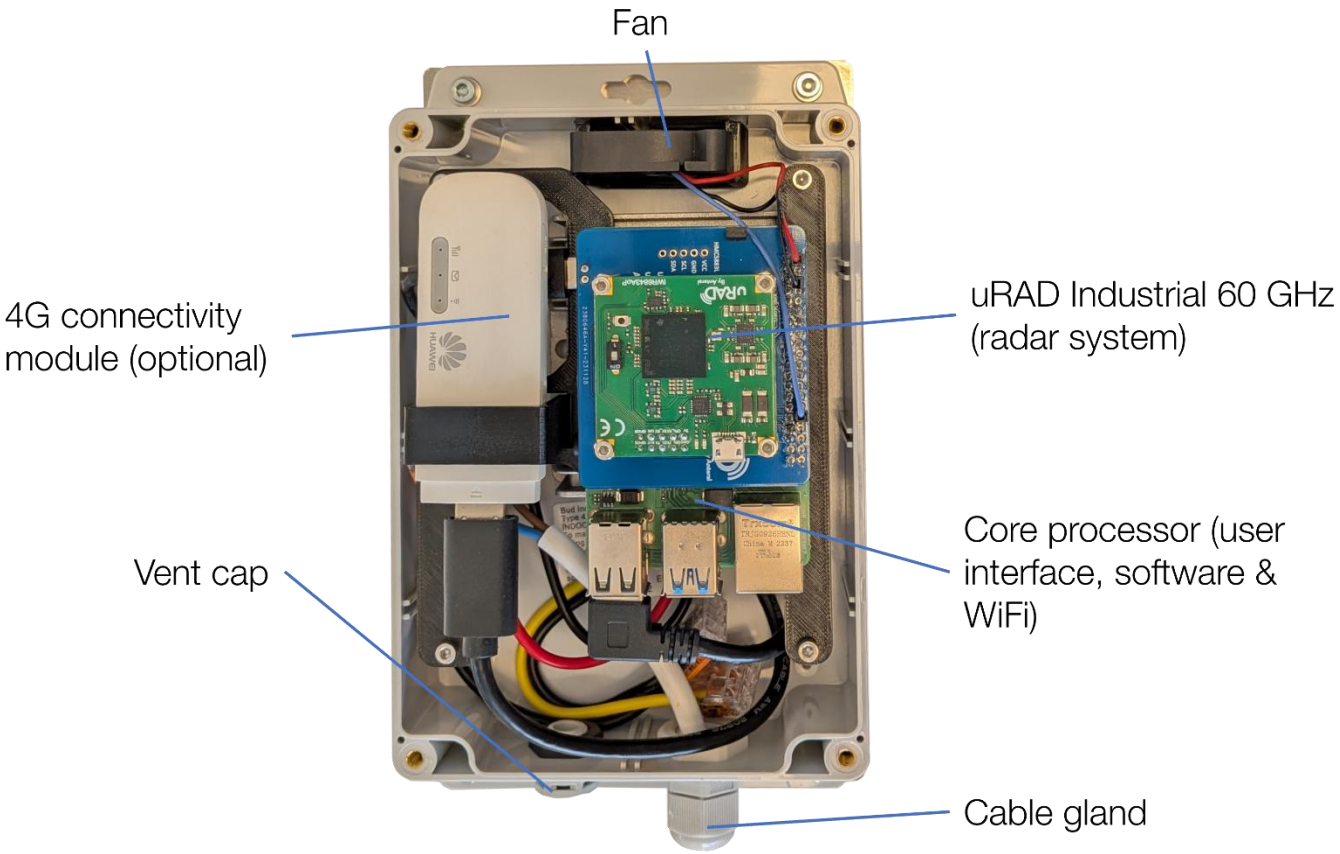
Version date 28/10/2025.

Contents

Components 1

The device contains the following main components:

- Policarbonate enclosure IP66, NEMA 4X,12,13, UL-508, UL94 HB. Dimmensions 17 x 12 x 8 cm.
- Linux processor based on Raspberry Pi (RPi).
- Radar model uRAD Industrial 60 GHz.
- Power adapter 8-40V DC.
- 4G dongle (optional)
- Fan and vent cap.
- Cable gland.



Technical Features 2

RF Parameters	
Frequency	60 – 64 GHz
Modulation	FMCW
Emitting power	15 dBm
Field of view	160 º

Power Supply	
Voltage	8 - 40V DC or 5V DC on the RPi
Connector	Cable gland
Consumption	4.5 W

Mechanical Parameters	
Dimensions	171 x 121 x 80 mm
Weight	1.1 kg
Material	Polycarbonate
Protection	IP66, NEMA 4X,12,13, UL-508, UL94 HB
Installation	Anchorage and clamps included. System for vertical adjustment.

Other Parameters	
Core processor	Quad-core 64-bit ARM Cortex-A72, 1.8 GHz, 2 GB SDRAM (Raspberry Pi)
Operating temperature	-20ºC a +80ºC
Communication	WiFi and 4G (optional)
Operating system	Linux (Raspberry Pi OS)

Performance	
Maximum velocity	180 km/h
Maximum distance	30 m (counting), 60 m (other applications)
Side distance	±15 m

Power Supply 3

The device has a cable gland through which the power cable is inserted. This power cable must be two-wire, VCC and GND. It must be powered with a DC voltage between 8 and 40 volts.

The DC-DC converter has two internal cables that must be connected. Open the cover and connect the power supply as follows:

- Red cable = VCC
- Black cable = GND.

The device can be delivered with an external two-wire connection cable already inserted through the cable gland, which is connected internally as follows:

- Blue cable = VCC
- Brown cable = GND

Clamping Structure 4

A support bracket is included for the placement of the device outdoors in cylindrical supports.

The central joint has a screw that allows you to set the required tilt angle for installation. Clamps are also included with the structure.

WiFi Connection 5

To control the device, it is necessary to connect via Wi-Fi to the Rapsberry Pi (RPi) that is inside it and that is the core of the device. The RPi automatically connects to a certain Wi-Fi network when the device is turned on. Once connected, you must do remote desktop to control it.

Therefore, follow these steps to access the RPi and launch the measurement programs:

1. Create a Wi-Fi hotspot with a mobile or laptop with the following credentials:
    - Network name: uRAD_SN****
    - Network password: *********

    These data are provided in a separate document with the purchase.

    The RPi will connect automatically.
2. You can access the device by establishing an SSH connection or via remote desktop using, for example, VNC. The connection credentials are as follows.
    - User name: pi
    - Password: Anteral
3. If accessing via VNC, you will need to find out the RPi's IP address on the device that created the Wi-Fi hotspot
4. Once inside, you will visualize the desktop with the software.

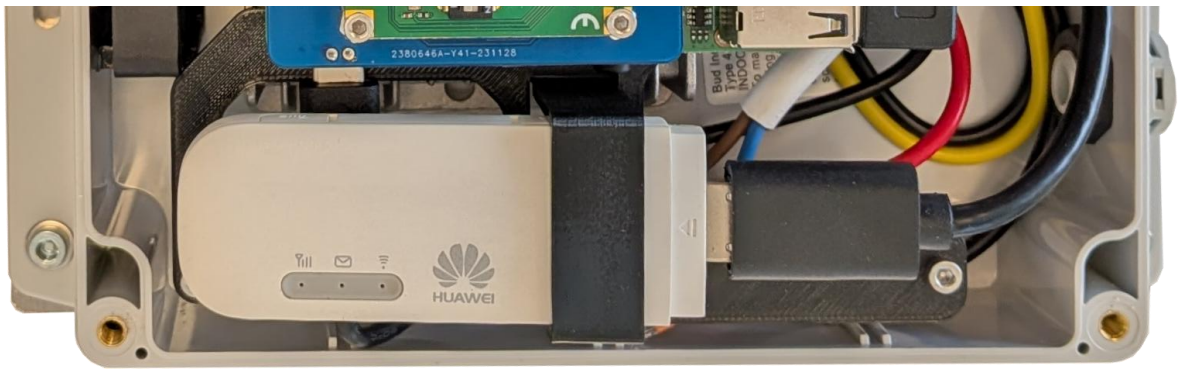
In the desktop, there is a folder named *uRAD_Tracking_v2_x* with Python files for the measurements. The main program is vehicleCounter_smartcities_v2_x.py, and it is used for vehicle counting.

There are also several ***.so files that correspond to the compiled libraries needed for processing and a *Results* folder where the results are saved.

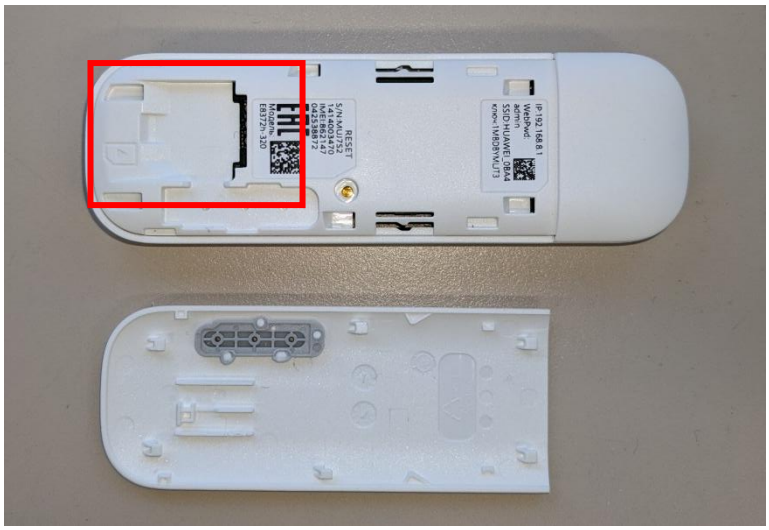
4G Connection 6

Optionally, the device has a 4G dongle to provide the system with 4G connection as an alternative method for wireless control.

If you bought the system without a SIM card, you have to open the box by unscrewing the screws on its front cover.



Once open, you will see the USB dongle. Open the dongle and insert your SIM card. See the following image for guiding.



With an active 4G connection, data can be uploaded to the uRAD database and accessed via an API. More information is provided upon purchase.

Installation 7

The system is very versatile and can be used in many counting scenarios:

- Urban or interurban roads.
- Velocity measurement up to 180 km/h.
- Up to 6 lanes monitoring with a single device.
- Counting vehicles with positive velocity (moving away) and negative velocity (approaching) at the same time.
- Dense or light traffic scenarios

Several aspects have to be taken into account when mounting your vehicle counting system:

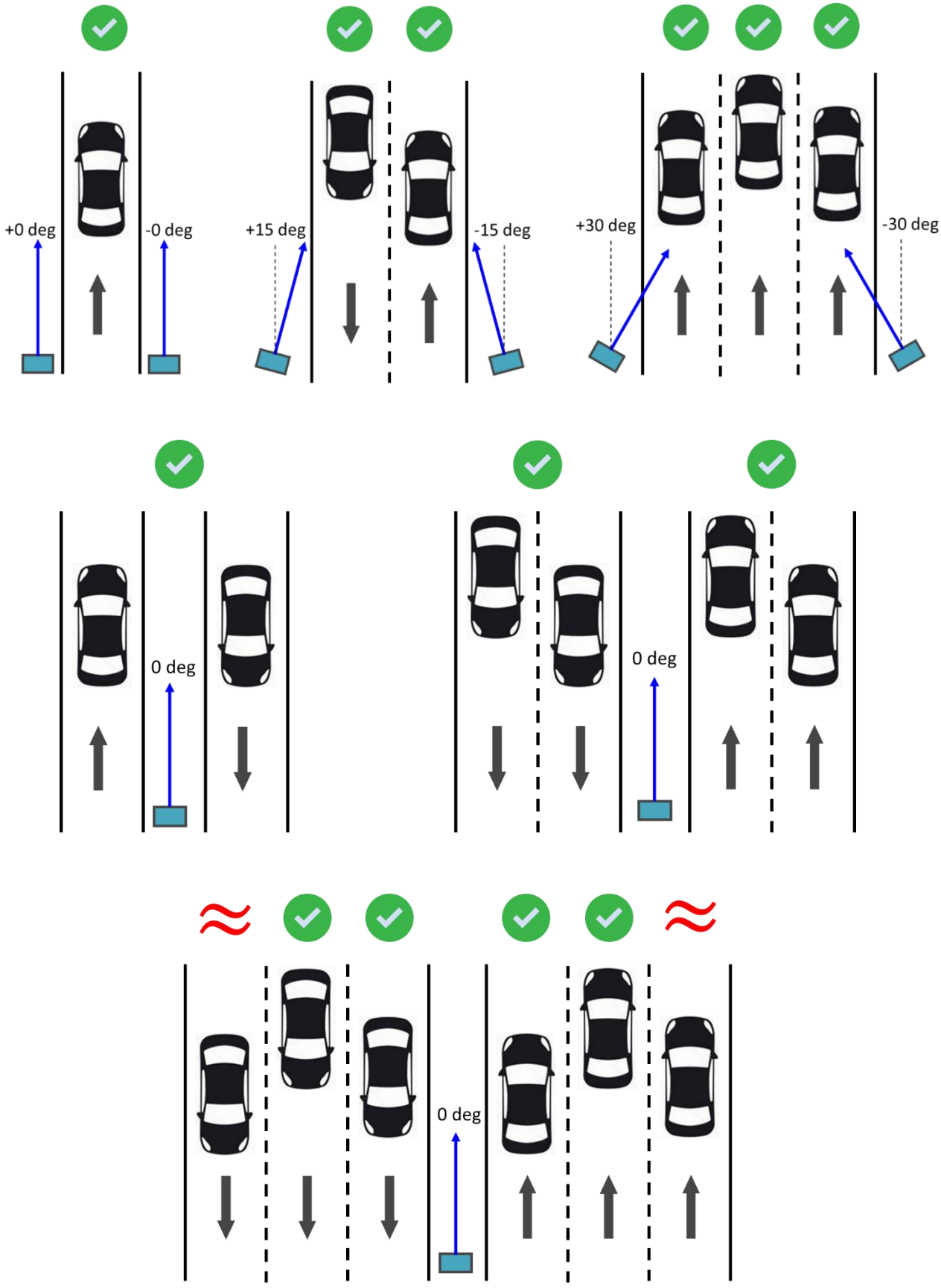
- Device orientation

The device has to be mounted with the power supply connector downwards.

- Radar installation in relation to the roadway

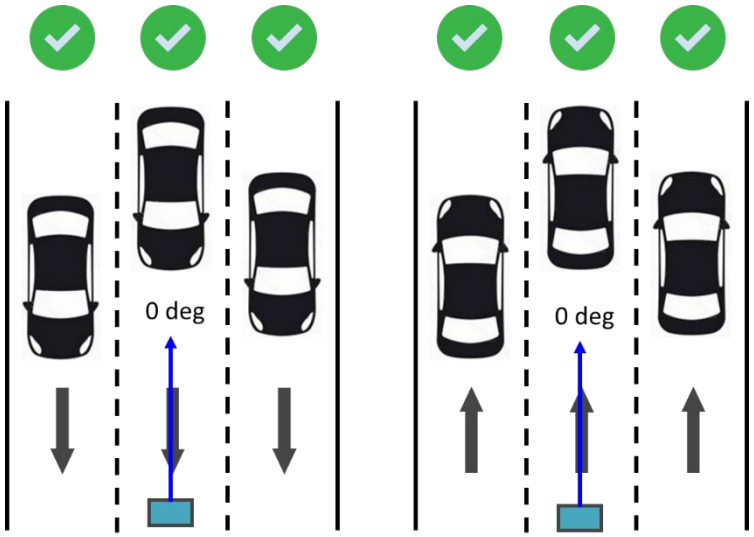
The device can be mounted on the side of the road, either to the left or to the right, or above it. Depending on the use case, the general mounting recommendation is as follows: to measure 1 lane on one side of the radar, mount it at a 0-degree angle, for 2 lanes, at a 15-degree angle, and for 3 lanes, at 30-degree angle.

The following images illustrate the primary use cases and how the radar should be mounted.

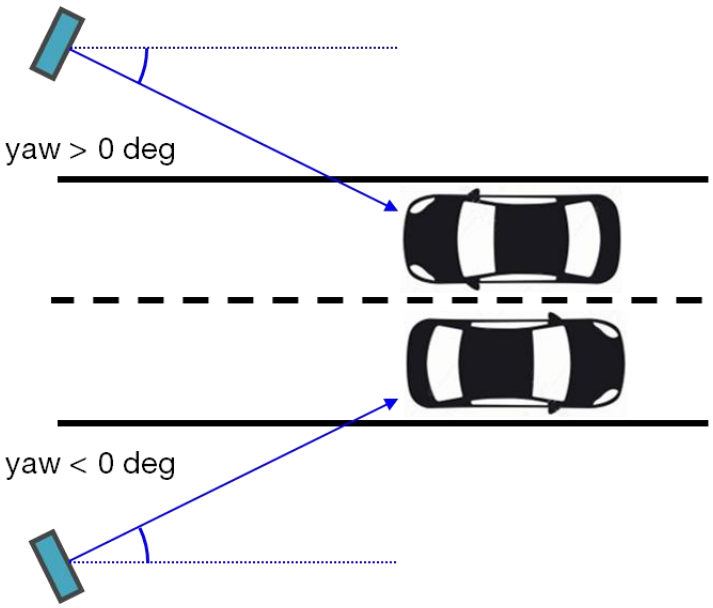


In the case of 6 lanes, the accuracy of counting in the outer lanes may be compromised depending on lane size and traffic density. As a general rule, the device offers good accuracy up to 8 meters lateral distance.

For this scenario, we recommend a radar for each direction.



In cases where it's necessary to provide a YAW angle, for example, in the case of 2 o 3 lanes or when an object obstructs the field of view, please consider the sign of the angle for configuration parameters according to the following image.



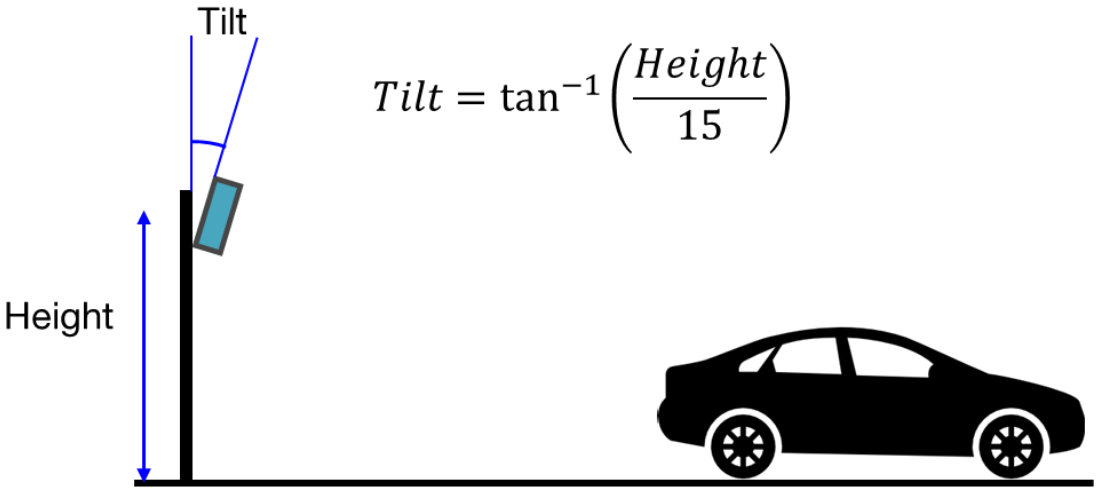
The radar is mounted on the left side of the roadway, and thus, cars pass by the right side of the radar (from an observer positioned behind the radar) → YAW angle with a positive sign.

The radar is mounted on the right side of the roadway, and thus, cars pass by the left side of the radar (from an observer positioned behind the radar) → YAW angle with a negative sign.

- Device height and tilt

For a proper view of vehicles and thus, to prevent one vehicle from blocking another, the radar should be positioned at a height of 3 meters or more. Depending on the mounting height, the radar should be tilted downwards, but only slightly. Please follow these recommendations.

HEIGHT	TILT
3 m	11 degrees
4 m	15 degrees
5 m	18 degrees
6 m	22 degrees



$$Tilt = \tan^{-1}\left(\frac{Height}{15}\right)$$

Additionally, two conditions are important to consider during installation:

1. Install the device on a straight section of roadway along the detection distance, meaning between 0 and 25 meters from the radar. Avoid installation on curved sections.
2. Install the device on a section where vehicles do not stop along the detection distance. If vehicles come to a complete stop, duplicates may occur.

Software 8

In the RPi desktop there is on folder with the measurement software *uRAD_tracking_v2_x*.

Inside this folder, there are three files:

- vehicleCounter_smartcities_v2_x.py is the Python program for vehicle counting.
- Several files ***.so that are the libraries that the counting script uses, compiled for the corresponding Python version.

There is also a *Results* folder where the results are saved.

Before running the script, you have to set the configuration parameters and the output results. Open the scripts and modify them.

- Mode selection

There are two operating modes that correspond to two different scenarios. The mode is selected with the following variable:

```
### MODE SELECTION ###
HIGHWAY_SCENARIO = True
```

- HIGHWAY_SCENARIO = True: for installations on highways or high-speed roads where vehicles travel above 120 km/h. In this mode, the RF configuration allows for higher speed but with lower spatial resolution. Vehicle type classification is less accurate.
- HIGHWAY_SCENARIO = False: for installations in urban or interurban environments where vehicles travel below 120 km/h. In this case, the configuration offers better spatial resolution at the cost of lower maximum speed. Vehicle type classification is more accurate.

- Communication interface

The radar communicates with the RPi through the UART port. Therefore, USB communication is not used:

```
#### COMMUNICATION INTERFACE ####
USB_COMMUNICATION = False
USE_FAN = True
```

The software is configured to utilize a PWM fan connected to pin 12 of the RPi. If an excessive radar temperature is detected, the fan is activated to reduce it.

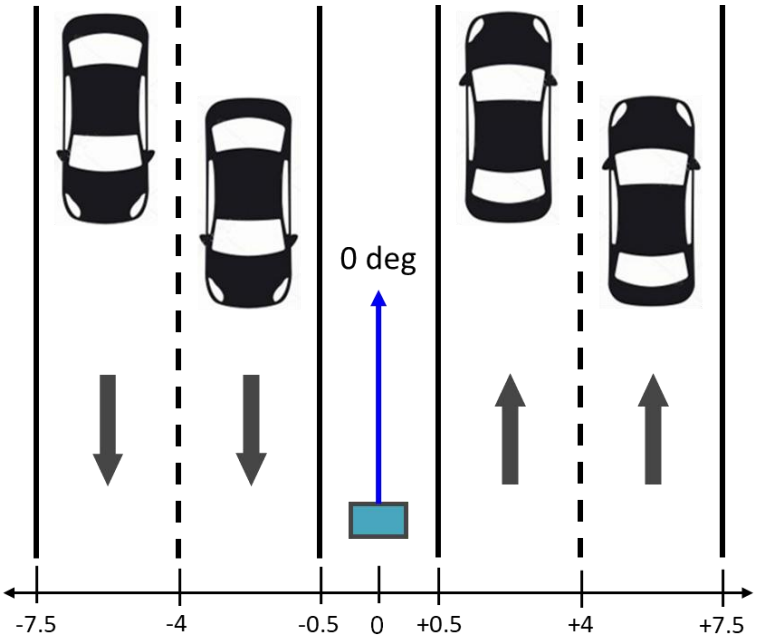
- Configuration parameters

Just a few input configuration parameters have to be set in *vehicleCounter_smartcities_v2_x.py*. At the beginning of the script, there are some lines to introduce the configuration variables:

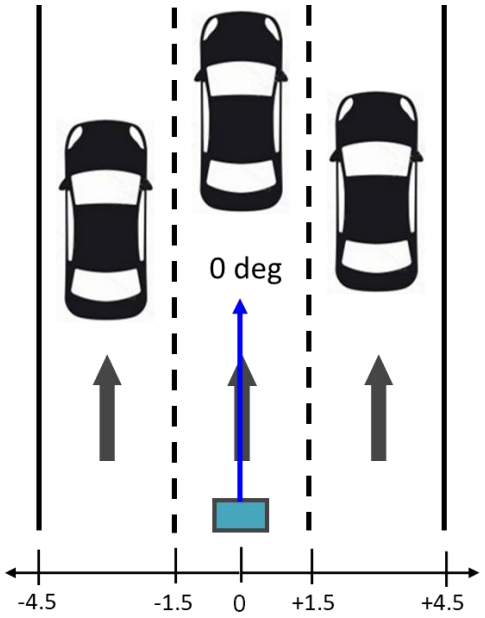
```
#### CONFIGURATION PARAMETERS ####
USB_CONNECTOR_UPWARD = False
pitch_angle = 3
yaw_angle = 0

VELOCITY_POSITIVE = True
VELOCITY_NEGATIVE = True

X_MINIMUM_NEGATIVE_VELOCITY = 0
X_MAXIMUM_NEGATIVE_VELOCITY = 4

X_MINIMUM_POSITIVE_VELOCITY = 4
X_MAXIMUM_POSITIVE_VELOCITY = 8
```

- USB_CONNECTOR_UPWARD: defines the orientation of the radar by the position of its USB connector. Set this variable to False.
- pitch_angle: defines the tilt angle of the radar with respect to the vertical (in degrees). Enter this parameter according to your installation.
- yaw_angle: define the pointing angle on the horizontal axis (yaw) relative to the road (in degrees). Follow the pointing recommendations provided in the installation chapter. Remember: to the left of the road, the yaw angle is positive; to the right of the road, the yaw angle is negative.
- VELOCITY_POSITIVE: enter True/False to count/discard vehicles moving away from the radar.
- VELOCITY_NEGATIVE: enter True/False to count/discard vehicles approaching the radar.
- X_MINIMUM_NEGATIVE_VELOCITY: define the minimum distance in meters in the horizontal direction that you want to consider for counting vehicles with negative velocity (approaching).
- X_MAXIMUM_NEGATIVE_VELOCITY: Define the maximum distance in meters in the horizontal direction that you want to consider for counting vehicles with negative velocity (approaching).
- X_MINIMUM_POSITIVE_VELOCITY: Define the minimum distance in meters in the horizontal direction that you want to consider for counting vehicles with positive velocity (moving away).
- X_MAXIMUM_POSITIVE_VELOCITY: Define the maximum distance in meters in the horizontal direction that you want to consider for counting vehicles with positive velocity (moving away).

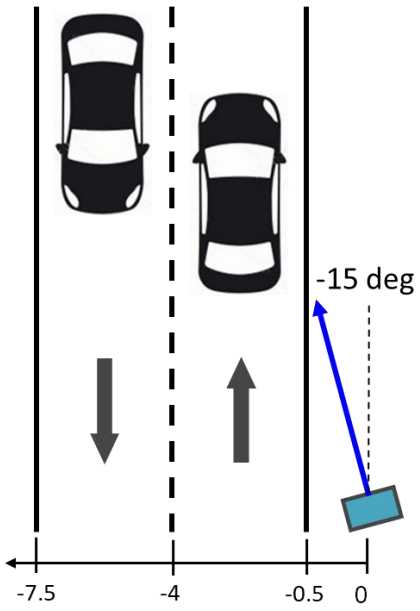
Please refer to the following usage examples.



X_MINIMUM_NEGATIVE_VELOCITY = -7.5
X_MAXIMUM_NEGATIVE_VELOCITY = -0.5
X_MINIMUM_POSITIVE_VELOCITY = 0.5
X_MAXIMUM_POSITIVE_VELOCITY = +7.5



X_MINIMUM_NEGATIVE_VELOCITY = no aplica
X_MAXIMUM_NEGATIVE_VELOCITY = no aplica
X_MINIMUM_POSITIVE_VELOCITY = -4.5
X_MAXIMUM_POSITIVE_VELOCITY = +4.5



X_MINIMUM_NEGATIVE_VELOCITY = -7.5
X_MAXIMUM_NEGATIVE_VELOCITY = -4
X_MINIMUM_POSITIVE_VELOCITY = -4
X_MAXIMUM_POSITIVE_VELOCITY = 0

- Output results

User can select to save two types of results:

```
#### OUTPUT RESULTS ####
SAVE_RESULTS = True
SAVE_RAW_DATA = False
OUTPUT_DATE_TIME_FORMAT = 1
# files name
FOLDERNAME = 'Results'
OUTPUT_FILENAME = 'Vehicle_results.txt'
POINTCLOUD_FILENAME = 'PointCloud.txt'
```

- SAVE_RESULTS: Create a .txt file named OUTPUT_FILENAME in the folder named FOLDERNAME with the most relevant information. Each line of this text file corresponds to a detected vehicle. The information for each column is as follows:

  Timestamp Velocity x_distance Vehicle_type

  Timestamp: date and time (yyyy/mm/dd HH:MM:SS) or timestamp (UNIX) the vehicle is detected. It is taken from the device system. Don't forget to connect the system to the internet to keep the date and time updated.

  Velocity: velocity in km/h of the vehicle. Positive velocity means vehicle driving away and negative velocity means vehicle approaching.

  x_distance: horizontal distance estimation in meters of the vehicle. Useful for lane identification.

  Vehicle_type: vehicle type identification. 1 = regular vehicle, 2 = medium vehicle, 3 = large vehicle, 4 = bicycle/motorbike, 5 = pedestrian.

  - A regular vehicle is any vehicle up to approximately 8 meters in length.
  - A medium vehicle is a vehicle between approximately 8 and 15 meters in length.
  - A large vehicle is a vehicle over approximately 15 meters in length.
  - Bicycles and motorcycles are classified as the same type. In HIGHWAY_SCENARIO = True mode, this type is classified as a regular vehicle.
  - A pedestrian is any detected target with a speed less than 10 km/h. In HIGHWAY_SCENARIO = True mode, this type is classified as a regular vehicle.

- SAVE_RAW_DATA: create a .txt file named POINTCLOUD_FILENAME. This information is useful for the uRAD team to verify the proper functioning of the radar. This file contains the complete 3D point cloud. Each line starts with the radar frame number and its corresponding timestamp. Subsequently, each line contains (X,Y,Z,velocity,SNR,noise) of all points in that frame.

- OUTPUT_DATE_TIME_FORMAT: to choose the format of the **Timestamp** field in .txt files. 0 for date and time (yyyy/mm/dd HH:MM:SS), 1 for timestamp (UNIX).

- Additional Parameters

- DEBUG_VEHICLES_DEF: True/False to print or not, in the console, a line for each vehicle with the time, velocity, horizontal distance, and type.

```
New Vehicle: 2024/04/09 10:13:29; X: 5.37 m; Velocity: 32.65 km/h: Type 1
New Vehicle: 2024/04/09 10:13:31; X: 4.92 m; Velocity: 23.71 km/h: Type 1
New Vehicle: 2024/04/09 10:13:34; X: 5.51 m; Velocity: 31.02 km/h: Type 1
New Vehicle: 2024/04/09 10:13:36; X: -6.79 m; Velocity: -26.95 km/h: Type 1
New Vehicle: 2024/04/09 10:13:42; X: -6.66 m; Velocity: -32.57 km/h: Type 1
New Vehicle: 2024/04/09 10:13:50; X: -6.86 m; Velocity: -22.54 km/h: Type 1
...
```

- Running the scripts

There are two ways for running the scripts:

Python interface:

1. Double click on the file to open it with Python
2. Run with F5 or with *Run > Run Module*

With a terminal:

1. Open a terminal
2. Go to the folder with: *cd Desktop/uRAD_tracking_v2.x*
3. Run the script with: *python3 vehicleCounter_smartcities_v2.py*

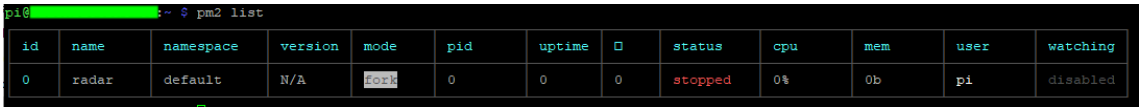
- pm2 services

The RPi is programmed with a pm2 service called “radar”. This service allows the measurement program to run automatically. Additionally, it can be configured to start automatically when the RPi is powered on. This is very useful for restarting the program if a reboot has occurred for any reason.

By default, this service is stopped. Run the following commands in the terminal to manage the pm2 service.

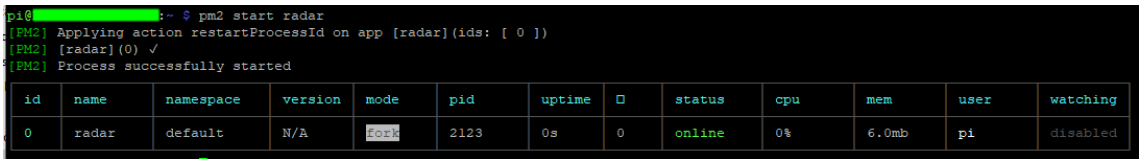
pm2 list

Lists the installed pm2 services and their status.



pm2 start radar

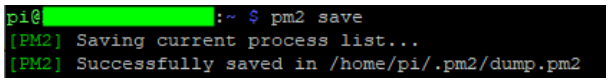
Starts the radar service. This command automatically runs the *vehicleCounter_smartcities_v2_x.py* program.



To ensure that pm2 services retain their current state when the RPi is powered on, run the following two commands:

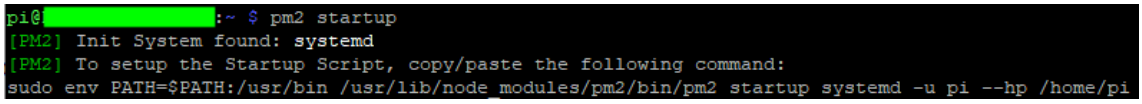
Pm2 save

Save the current status.



Pm2 startup

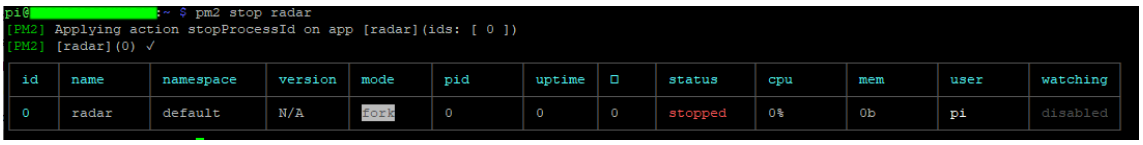
Ensures that on startup, the service begins with the saved status.



After running this command, copy the command that starts with `sudo env PATH…` paste it into the terminal, and execute it.

pm2 stop radar

Stop the pm2 service.



After stopping the service, don’t forget to run pm2 save and pm2 startup again to ensure that when the RPi starts, the service remains stopped, if that's what you want.

Safety & Handling 9

This chapter includes important safety and handling information for uRAD device.

Read all safety and handling information below as well as the operating instructions before using uRAD in order to avoid any injury or damage.

Keep this user guide on hand for future reference.

Important Safety Information

WARNING: Failure to follow this safety instructions could result in fire, electric shock, or other injury or damage.

Proper handling uRAD contains sensitive electronic components. Do not drop, disassemble, crush, bend, deform, puncture, shred, microwave, incinerate, paint, or insert foreign objects into uRAD.

Water and wet locations Do not expose any sensitive components of uRAD to water or rain, or handled near washbasins or other wet locations without a proper case. Take care not to spill any food or liquid on uRAD. In case uRAD gets wet, allow it to dry thoroughly before turning it on again. Do not attempt to dry uRAD with an external heat source, such as a microwave oven or hair dryer.

uRAD repairs Never attempt to repair or modify uRAD by yourself. Disassembling may cause damage that is not covered under the warranty. If uRAD is damaged, malfunctions, or comes in contact with liquid, contact us at contact@urad.es.

Radio frequency interference Observe signs and notices that prohibit or restrict the use of radio frequency devices. Emissions from uRAD can negatively affect the operation of other radio frequency equipment operating in the same frequency band. Turn off uRAD when use is prohibited, such as traveling in aircraft, or when asked to do so by authorities.

Important Handling Information

WARNING: Failure to follow this handling instructions could result in damage to uRAD or other property.

Carrying uRAD contains sensitive electronic components. Do not bend, drop or crush it.

Cleaning To clean use a soft lint-free tip and isopropyl alcohol. Dust can be removed with compressed air of low power.

Plugging Never force the connectors or apply excessive pressure because this may cause damage that is not covered under the warranty. Check for obstructions.

Operating Temperature Keeping uRAD within acceptable temperatures. uRAD components operate from -40ºC to 85ºC but we recommend operates uRAD in the range from -20ºC to 65ºC.

Disposal and Recycling Information Your uRAD must be disposed of properly according to local laws and regulations. Because this product contains electric components, the product must be disposed of separately from household waste. Contact your local authorities to learn about recycling options.

Product Warranty 10

Manufacturing

All components and solder alloys used in this product comply with the RoHS Directive. The RoHS Directive prevents all new electrical and electronic equipment placed on the market in the European Economic Area from containing more than agreed levels of lead, cadmium, mercury, hexavalent chromium, poly-brominated biphenyls (PBB) and poly-brominated diphenyl ethers (PBDE).

Certification

uRAD Industrial module is CE marked under EU-Type examination certificate n. 803416897303 and fulfills with the corresponding directives:

- RED Article 3.1 (a): Health and Safety of the User
  Test EN 62368-1: 2014 +AC: 2015 Safety
  Test EN 62311:2008 - EMF Human exposure
- RED Article 3.1 (b): Electromagnetic compatibility
  Test EN 301 489-3 V2.1.1 EMC Short-Range Devices SRD
- RED Article 3.2 :Effective use of spectrum allocated
  Test EN 305 550-2 V1.2.1_Radio equip. 40 GHz to 246 GHz
- Notified body
  EU-Type Examination Certificate RED - N.B. 2559 (en)
- RoHS
  Test EN 63000: 2018 RoHS documental assesment

Testing

Each uRAD shield is subject to strict tests to make sure they are not faulty:

- First, it is thoroughly tested for short circuits and open connections.
- Second, it is powered to check there are no over-range voltage.
- Then, the microcontroller is programmed and debugged.
- Finally, the board is plugged in a computer and several test programs are run to check its overall functionality.

Limited Warranty Statement

IMPORTANT: BY USING uRAD PRODUCTS YOU ARE AGREEING TO BE BOUNDED BY THE TERMS OF THIS LIMITED WARRANTY STATEMENT. DO NOT USE YOUR PRODUCTS UNTIL YOU HAVE READ THE TERMS OF THE

WARRANTY. IF YOU DO NOT AGREE TO THE TERMS OF WARRANTY, DO NOT USE THE PRODUCTS AND RETURN THEM. THIS LIMITED WARRANTY IS THE END-USER'S SOLE AND EXCLUSIVE REMEDY AGAINST uRAD, WHERE PERMITTED BY LAW.

1. Warranties

1.1 uRAD warrants that its products will conform the specifications detailed in the corresponding datasheet. Warranty lasts for 1 year from the date of sale if the shield is bought outside the EU and last for 2 years if bought in the EU. uRAD shall not be liable for any defects that are caused by neglect, misuse or mistreatment, including any products that have been altered or modified by any way by the Customer.

1.2 If any uRAD product fails to conform to the warranty set forth above, uRAD's sole liability shall be to replace or repair such products. uRAD's liability shall be limited to products that are determined by uRAD not to conform to such warranty. If uRAD elects to replace or repair such products, uRAD shall be given a reasonable time to provide replacements. Replaced or repaired products shall be warranted for a new full warranty period.

1.3 The Customer agrees no to use uRAD products for any applications or in any components used in life support devices or to operate nuclear facilities or for use in other mission-critical applications or components where human life or property may be at stake. The Customer acknowledges and agrees that any such use is solely at the Customer's risk, and that the Customer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

1.4 uRAD may provide technical, applications or design advice. The Customer acknowledges and agrees that providing these services shall not expand or otherwise alter uRAD's warranties, as set forth above, and that no additional obligations or liabilities shall arise from uRAD providing such services.

1.5 uRAD disclaims all other warranties, expressed or implied, regarding products, including, but not limited to, any implied warranties of merchantability or fitness for a particular purpose.

1.6 The Customer acknowledges and agrees that the Customer is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning the products and any use of uRAD products in the Customer's applications, not with- standing any applications-related information or support that may be provided by uRAD.

1.7 In no event shall uRAD be liable to the Customer or any third parties for any special, collateral, indirect, punitive, incidental, consequential or exemplary damages in connection with or arising out of the products provided hereunder, regardless of whether uRAD has been advised of the possibility of such damages. This section will survive the termination of the warranty period.

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