



# PAL Person & Object Detection Starter Kit

## Evaluation Setup Manual

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The DreamVu PAL camera uses a single sensor to capture stereoscopic 360° panoramic images of the scene. These images can be used for surround situational awareness and dense 360° 3D reconstruction of the scene. The PAL Detection Kit is equipped with real-time 360° person detection and multi-class object detection with depth information for the detected objects.

The DreamVu PAL camera has a broad dynamic range and can be operated in both day and night conditions. The Explorer application shipped with the camera includes a range of parameters that can be controlled for ideal operating conditions in different environments, including an 'Auto' mode that identifies the best camera properties for each scene. This document provides a step by step guide for using the PAL Detection Kit.

Please follow the step-by-step recommendation provided below

**Step 1:** Software Installation

**Step 2:** Mounting the PAL Camera

**Step 3:** Running the Explorer

**Step 4:** Running the Code Samples

**Step 5:** Running the ROS package

## Step 1. v3.0 Software Installation

**Step 1.1** Please follow the instructions given below on the already available Jetson NX to install the latest v3 software.

- Download and Extract the software file from this [link](#).
- Open a terminal with the extracted folder as the current working directory.
- Run the following commands

```
$ cd installations  
$ chmod +x /*.sh  
$ ./install.sh
```

- Once complete, please reboot the Jetson board.

## Step 1.2

Download and extract the camera data zip file and run these commands:

```
$ chmod +x setup.sh  
$ ./setup.sh
```

## Step 1.3

Follow these steps to disable previous installations if any:

- Open bashrc file using this command:

```
$ gedit ~/.bashrc
```

- Locate this line at the end of the file and comment it using # to disable previous firmware versions.

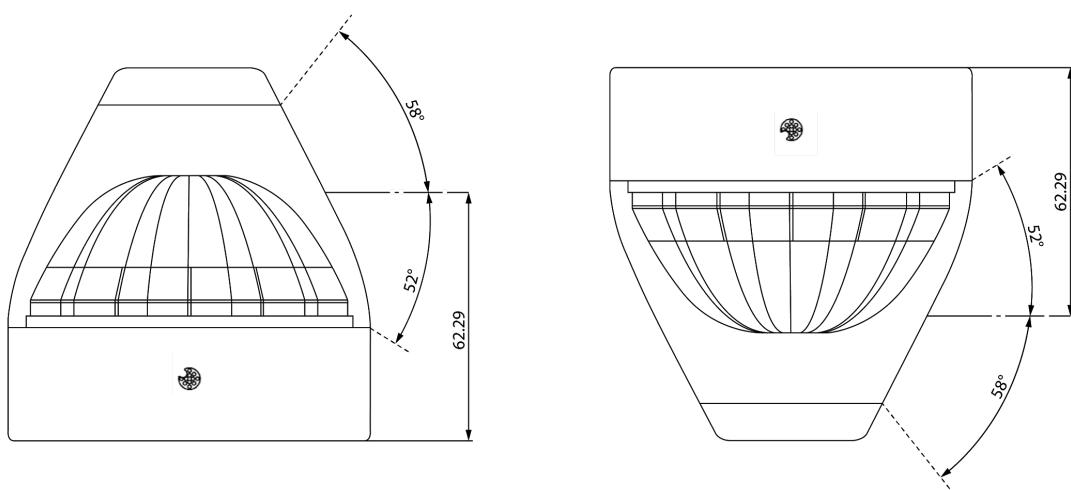
*export*

*LD\_LIBRARY\_PATH=\$LD\_LIBRARY\_PATH:/home/dreamvu/Desktop/PAL-Firmware-v1.2-NX-J4.4/installations/..//lib*

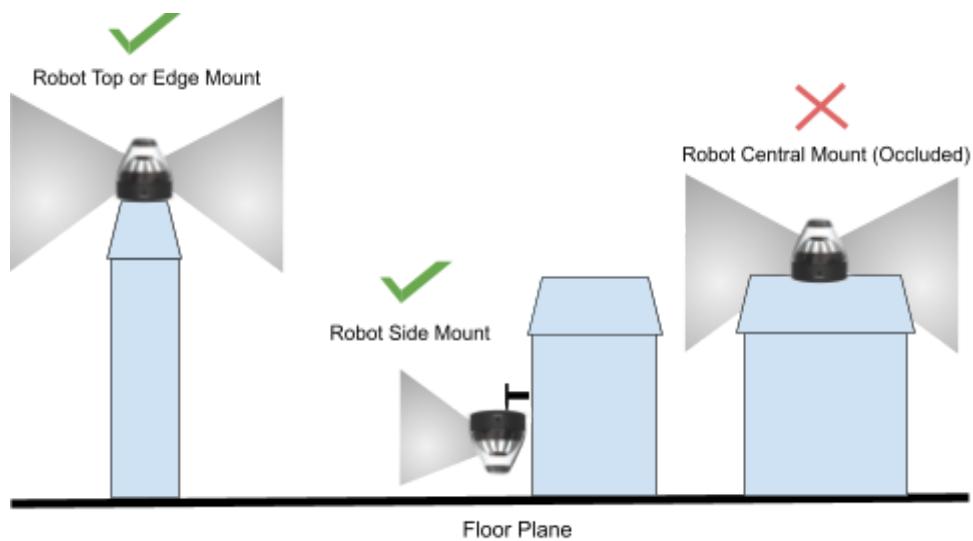
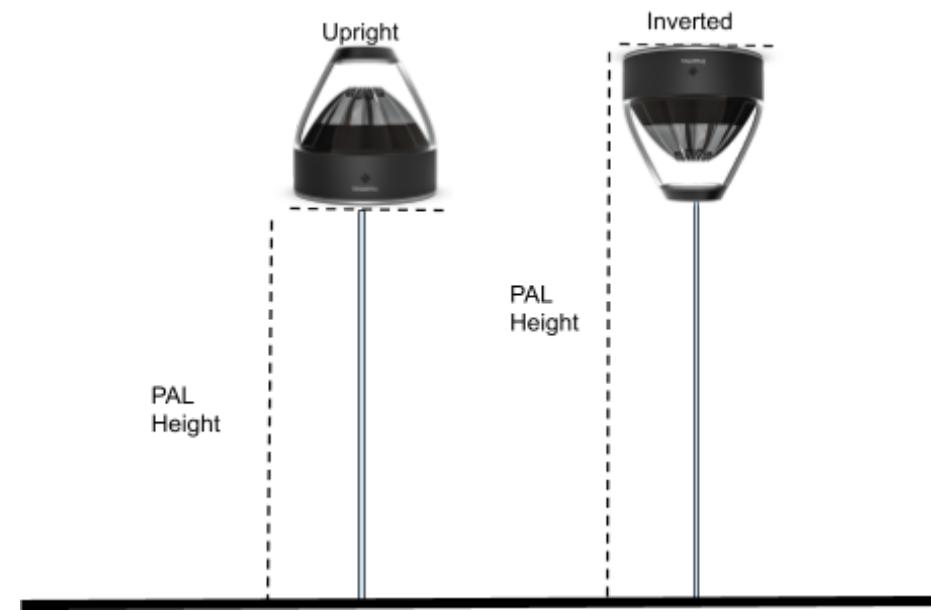
- Reopen terminal for changes to take effect.

## Step 2. Mounting the PAL Camera

The DreamVu PAL camera has a full  $360^\circ$  horizontal field-of-view and a large  $110^\circ$  degree vertical field-of-view. The vertical field-of-view of the PAL Camera is asymmetric about the horizon. The PAL camera can therefore be mounted in both the upright as well as the inverted orientation as shown in the figure below



Before evaluating the PAL camera, is it important to mount the camera appropriately on a robot as shown in the figure below. During mounting, it is important to avoid any occlusions in the field of view caused by the parts of the robot or the mounting assembly. The height of the PAL Camera from the floor plane must be measured and provided as a property as indicated in the forthcoming sections and shown in the figure below.



The PAL Camera must be mounted appropriately on the robot. It may be mounted on the top or at the edge of the robot with an unobstructed field-of-view or at the side of the robot. Do not mount the camera in the center of the robot or where the field of view is completely occluded.

The orientation of the PAL camera on the robot depends on the height of mounting as well as the type of illumination existing in the target environment. In the presence of harsh outdoor illumination, it is recommended that the PAL camera should be mounted in the inverted orientation. However, in typical indoor environments, the PAL camera adaptively adjusts to the type of illumination and therefore the orientation only depends on the height of mounting. For low mounting positions, the inverted orientation is recommended. For high mounting positions, the upright orientation is recommended as specified in the table below.

The mounting height of the PAL camera is related to the range of person detection. The following table describes the relationship between the ideal detection range for mounting the PAL camera at different heights.

Mounting Type	Mounting Height	Orientation	Detection Range
Very Low Mounting	Less than 40cm	Inverted	2m
Low Mounting	40 - 100cm	Inverted	3m
Intermediate Mounting	100-180cm	Upright	5m
High Mounting	More than 180cm	Upright	7m

Once the PAL camera is mounted appropriately, one may launch one of the several options provided in the PAL Detection Kit to evaluate the camera. The SDK comes equipped with an Explorer application (described in Step 3), as well as code samples in C++ (described in Step 4), and a ROS package is also provided (described in Step 5).

## Step 3. Running the Explorer Application

The Explorer application allows you to preview the live feed of the person detection application, stereoscopic panoramas, depth map and the point cloud. It also enables the user to save images and record videos as well as access or change the resolution and other camera parameters. To launch the Explorer application, navigate to the *Explorer* folder and in a terminal window, run the following command:

```
$ ./Explorer
```

There are four viewing modes in the Explorer to view the output from the PAL camera. The following sections of the document describe the Person Detection Mode provided in the Explorer of the PAL Detection Kit.

On selecting the Person Detection Mode in the Explorer, the user will see a full 360 panorama with a bounding box drawn around the detected persons using PAL's person detection software.

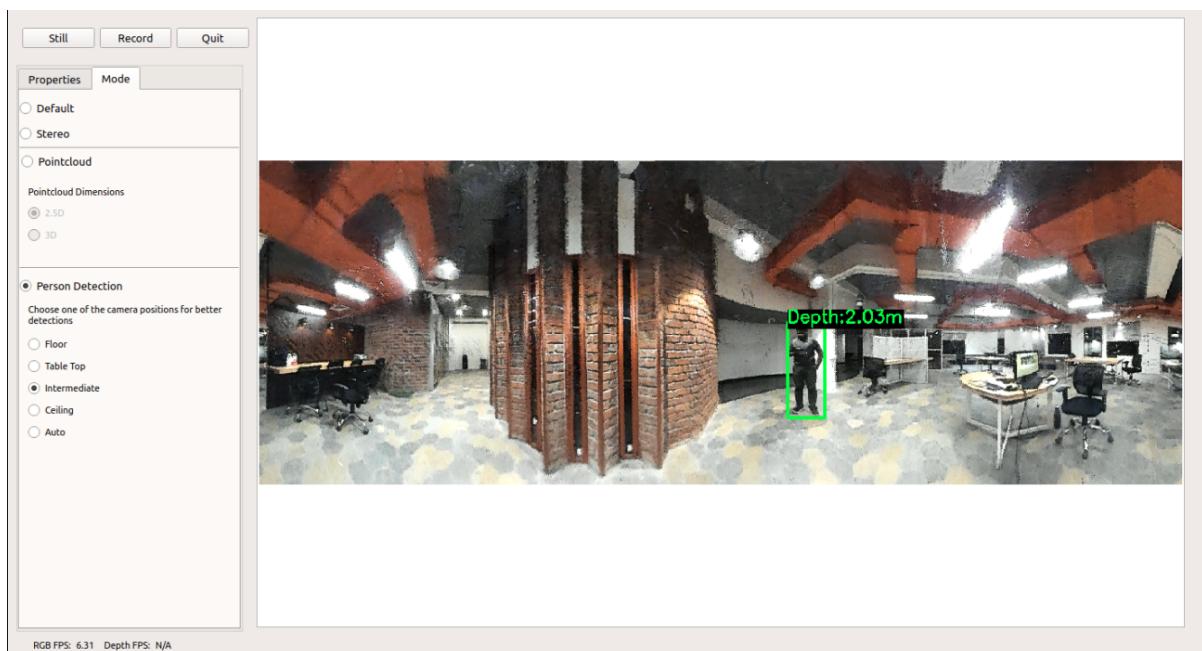


Figure 3.1: Person Detection mode

By selecting the mounting position of the PAL camera, the ideal parameters for person detection are automatically assigned by the Explorer application. The available mounting positions are:

Floor Mode: Suitable for camera mounting at low height (0-40cm from floor) with the camera kept in the inverted orientation.

Table-Top Mode: Suitable for camera kept on a table-top (40cm-100cm from floor) and kept in the inverted orientation.

Intermediate Mode: Suitable for camera at intermediate mounting heights (100cm-180cm from floor) and kept in the upright orientation.

Ceiling Mode: Suitable for camera mounting at high mounting locations (>180cm from floor) and camera kept in the upright orientation.

Auto Mode: Automatically selects the appropriate mounting position between *Floor*, *Table-Top*, *Intermediate* or *Ceiling* based on the *camera\_height* parameter.

## 3.1 Depth Properties:

The PAL Detection Kit consists of two properties that control the performance and quality attributes of depth estimation from PAL stereoscopic panoramas. These are the *Fast Depth* and the *Near Range* properties. Both these properties can be directly controlled from the Explorer. For code samples and the ROS package, these properties can be edited in the properties file or controlled using toggle flags while running the code samples. The following table provides a brief description of these parameters.

Property	Description
FAST DEPTH	ON Implies High FPS and Reduced-Quality Depth OFF Implies Reduced FPS and High Quality Depth
NEAR RANGE	ON Implies Very Close Objects are considered OFF Implies Very Close Objects are Ignored

## Step 4. Running the Code Samples

The PAL Detection Kit includes a suite of code samples that demonstrate different applications and use-cases that are enabled by rich 360° 3D information from the PAL camera. The code samples provide a framework to access the stereoscopic images, the depth map and the object detection capabilities in the

PAL Detection Kit. To run the code samples, the user must navigate to the `code_samples` directory in the root folder of the SDK. To compile all the code samples present in the folder, the following command should be executed in a terminal window.

```
$ ./compile.sh
```

The code samples provided with the PAL Detection Kit include a suite of applications that may be directly useful for surround situational awareness and robot navigation, as listed in the table below:

Code Sample	Description
Person Detection	Person detection with bounding box and depth overlay for the detected persons.
Occupancy Mapping	1D-Occupancy array highlighting the occupied regions and the free-space around the camera with respect to a user-defined threshold.
3D Person Locations	3D world coordinates for the person detection application with bounding box overlay.
Social Distancing	Persons closer than a user-specified distance of each other are identified and labelled.
Object Detection	Multi-class object detection with bounding box and depth overlay.
Safe Zone Detection	Persons closer than a user-specified threshold from the camera are identified and labelled.

## 4.1 Person Detection

The Person Detection Code sample provides an example of the person detection application supported with the PAL Detection Kit. This code sample overlays a bounding box around the persons detected in the image. It also supports depth overlay on the detected persons. The depth value for each box accurately

represents the depth of the person within the box. To run this application, the following command can be executed in a terminal window. The detection threshold can be passed as a command line argument (default detection threshold = 0.35).

```
$ ./005_person_detection.out <detection_threshold>
```



The following flags can be toggled at run-time while using the code sample:

- q/Q to toggle depth detection mode
- f/F to toggle filter rgb property
- d/D to toggle fast depth property
- v/V to toggle vertical flip property
- r/R to toggle near range property
- l/L to switch floor mode
- i/I to switch intermediate mode
- t/T to switch table-top mode
- c/C to switch ceiling mode
- a/A to switch auto mode

To exit the code sample, the user may press the ESC key.

## 4.2 Occupancy Mapping

The Occupancy Code sample provides a one-dimensional occupancy representation of the environment surrounding the camera. Based on a user-defined distance threshold, the occupancy code sample classifies each column of the panorama as either *occupied* (red overlay) or *free-space* (no overlay). The one-dimensional occupancy array can be used for free-space identification,

navigation and to identify the directions occluded by obstacles close to the camera. To run this application, the following command can be executed in a terminal window

```
$ ./006_occupancy_map.out
```



There are two parameters that can be controlled by the user during occupancy mapping, defined in the table below:

Occupancy Parameter	Description
threshold_cm (in centimetres) (L128 in 006_occupancy_mat.cpp)	If obstacles are found closer than <i>threshold</i> in any column, then the column is occupied (Recommended values - 100-150cm)
context_threshold (in percentage) (L131 in 006_occupancy_mat.cpp)	The amount of vertical context in each column to decide if the column is occupied or not - 50% indicates a column will be occupied only if 50% of the pixels in the column are closer than the <i>threshold</i>

The following flags can be toggled at run-time while using the code sample:

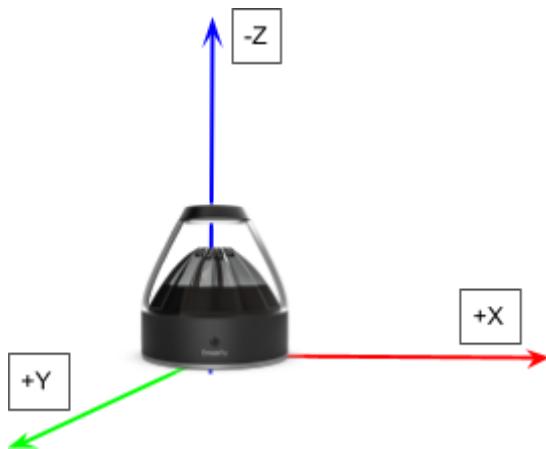
- v/V to toggle the vertical flip property

- f/F to toggle the filter rgb property
- d/D to toggle the fast depth property
- r/R to toggle the near range property

To exit the code sample, the user may press the ESC key.

## 4.3 3D Person Locations

The PAL Detection Kit provides surround situational awareness in 3D. The 3D (X,Y,Z) locations of detected objects in world-coordinates are provided in the 3D person location code sample. The PAL camera is assumed to be situated at the origin of the world coordinate system which is defined in the diagram below. A right-handed convention is followed where  $0^\circ$  corresponds to the positive X-axis ( $X=1, Y=0, Z=0$ ) and  $90^\circ$  corresponds to the positive Y-axis ( $X=0, Y=1, Z=0$ ).



To run the 3D person locations code sample, the following command can be executed in a terminal window. The detection threshold can be passed as a command line argument (default detection threshold = 0.35).

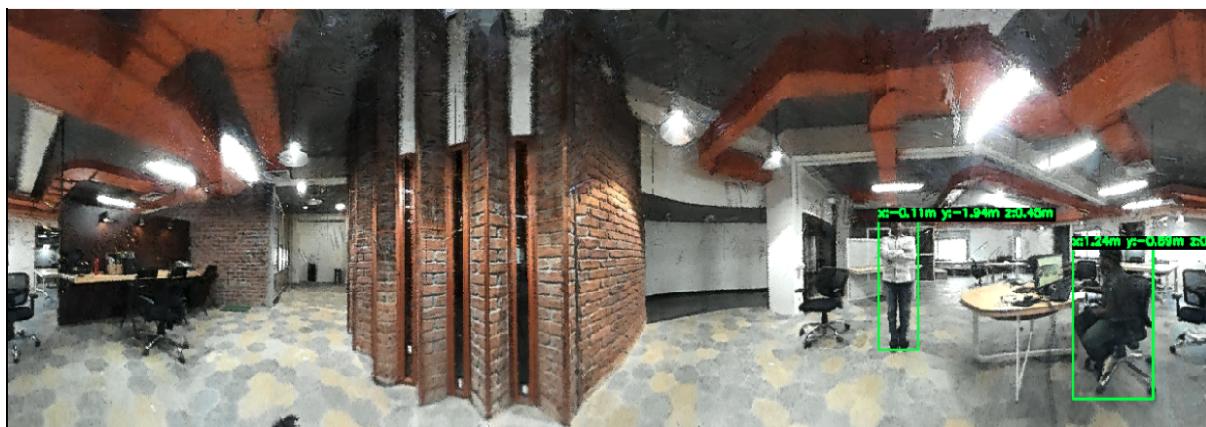
```
$ ./007_3d_person_locations.out <detection_threshold>
```

The following flags can be toggled at run-time while using the code sample:

- f/F to toggle filter rgb property
- d/D to toggle fast depth property
- v/V to toggle vertical flip property

- r/R to toggle near range property
- I/L to switch floor mode
- i/I to switch intermediate mode
- t/T to switch table-top mode
- c/C to switch ceiling mode
- a/A to switch auto mode

To exit the code sample, the user may press the ESC key.

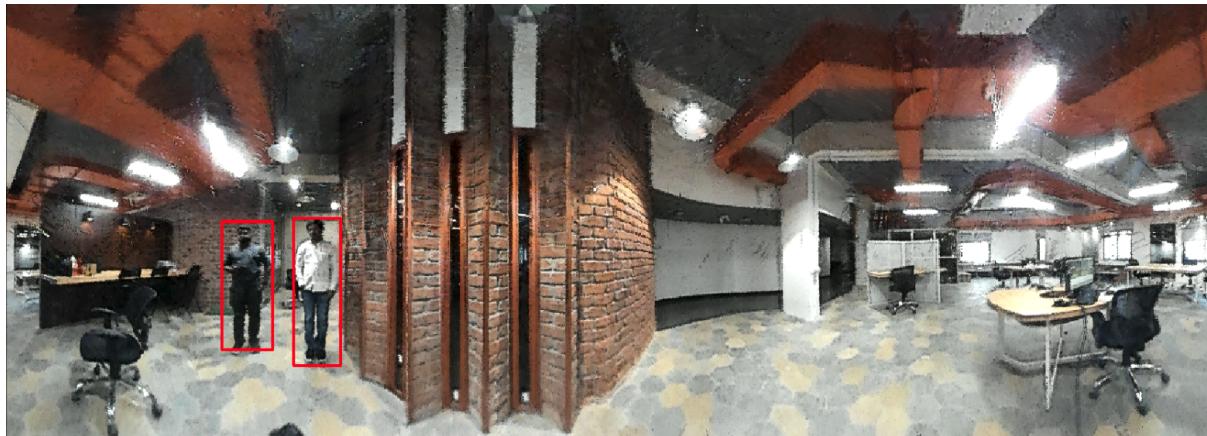


## 4.4 Social Distancing

Using the 3D coordinates of detected persons in the scene, the absolute 3D distance between the persons in the scene can be computed as shown in the social distancing code sample. In this code sample, if any pair of persons are closer than a user defined threshold, they are indicated using a **red** bounding box, while persons maintaining a larger distance between each other are shown in a **green** bounding box. To run this application, the following command can be executed in a terminal window. The detection threshold (default = 0.35) and the distance threshold for social distancing (default = 100cm) can be provided as a command line argument as shown below:

```
$ ./008_social_distancing.out <detection_threshold> <distance_threshold>
```

The threshold for social distancing calculation can be controlled using the *threshold* parameter provided in the code sample.



The following flags can be toggled at run-time while using the code sample:

- f/F to toggle filter rgb property
- d/D to toggle fast depth property
- v/V to toggle vertical flip property
- r/R to toggle near range property
- l/L to switch floor mode
- i/I to switch intermediate mode
- t/T to switch table-top mode
- c/C to switch ceiling mode
- a/A to switch auto mode

To exit the code sample, the user may press the ESC key.

## 4.5 Object Detection

The PAL Detection Kit also provides general class object detection capabilities. These can be accessed using the object detection code sample. The object categories supported in this version include:

Person, Bicycle, Car, Motorcycle, Bus, Train, Truck, Traffic Light, Fire hydrant, Street sign, Stop sign, Parking meter, Bench.

To run the application, the following command can be executed in a terminal. The detection threshold can be passed as a command line argument (default detection threshold = 0.35).

```
$ ./009_object_detection.out <detection_threshold>
```



The following flags can be toggled at run-time while using the code sample:

- q/Q to toggle Depth detection mode
- s/S to toggle 3D location detection mode
- f/F to toggle filter rgb property
- d/D to toggle fast depth property
- v/V to toggle vertical flip property
- r/R to toggle near range property
- l/L to switch floor mode
- i/I to switch intermediate mode
- t/T to switch table-top mode
- c/C to switch ceiling mode

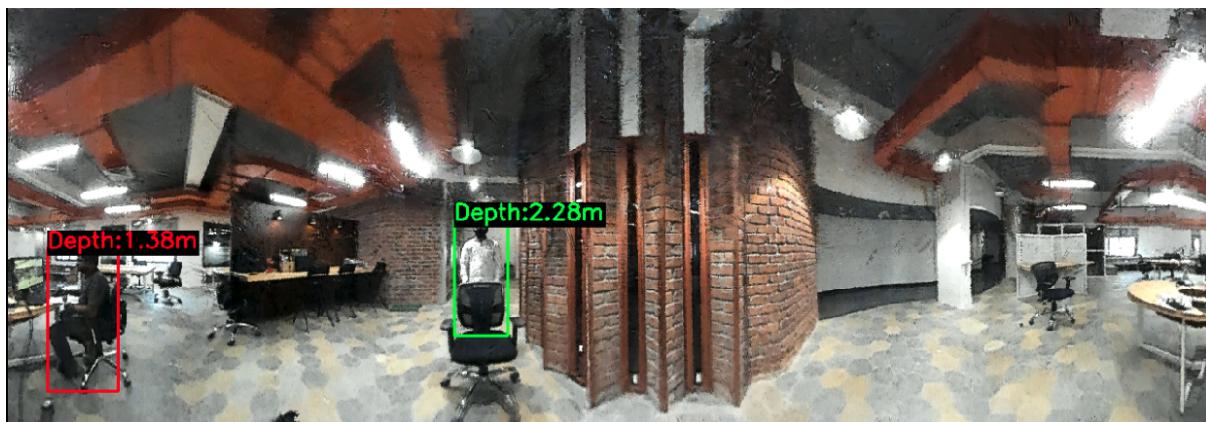
- a/A to switch auto mode

To exit the code sample, the user may press the ESC key.

## 4.6 Safe Zone Detection

In many applications, the proximity of detected persons from the camera or robot is of importance. The safe zone detection code sample provides an illustration where persons detected closer than a user-defined threshold are drawn with **red** bounding boxes, while persons at a safe distance from the camera are drawn in **green** bounding boxes. To run this code sample, the following command can be executed in a terminal window: The detection threshold (default = 0.35) and the safe distance threshold (default = 200cm) can be provided as a command line argument as shown below:

```
$ ./010_safe_zone_detection.out <detection_threshold> <safe_distance>
```



The following flags can be toggled at run-time while using the code sample:

- f/F to toggle filter rgb property
- d/D to toggle fast depth property
- v/V to toggle vertical flip property
- r/R to toggle near range property
- l/L to switch floor mode
- i/I to switch intermediate mode
- t/T to switch table-top mode
- c/C to switch ceiling mode

- a/A to switch auto mode

To exit the code sample, the user may press the ESC key.

## Step 5. Running the ROS package

The PAL Detection Kit includes a ROS package titled `dreamvu_pal_camera` in the root folder of the SDK. This package provides the support for accessing all the detection modes discussed above in the form of ROS topics that can be subscribed and integrated into the users' ROS application. To run the ROS demo, the user must follow these steps:

Step 1: Navigate to the `src` folder of the `dreamvu_pal_camera` package located in the root directory of the PAL Detection Kit.

```
$ cd dreamvu_pal_camera/src/
```

Step 2: Edit line number 444 in the `sample_ROS_node.cpp` file to indicate the mode that is desired. The following modes are available for selection.

Mode Identifier	Mode Name	Enabled Topics
1	Mode::STEREO	Left, Right Images
2	Mode::DETECTION	All Code Samples (except Occupancy)
3	Mode::FAST_DEPTH	Left, Right, Depth, Occupancy
4	Mode::HIGH_QUALITY_DEPTH	Left, Right, HQ-Depth, Occupancy
5	Mode::POINT_CLOUD_3D	3D Point Cloud, Left, Right, Depth
6	Mode::POINT_CLOUD_2.5D	2.5D Point Cloud, Left, Right, Depth

```
l444: prop.mode = PAL::Mode::DETECTION;
```

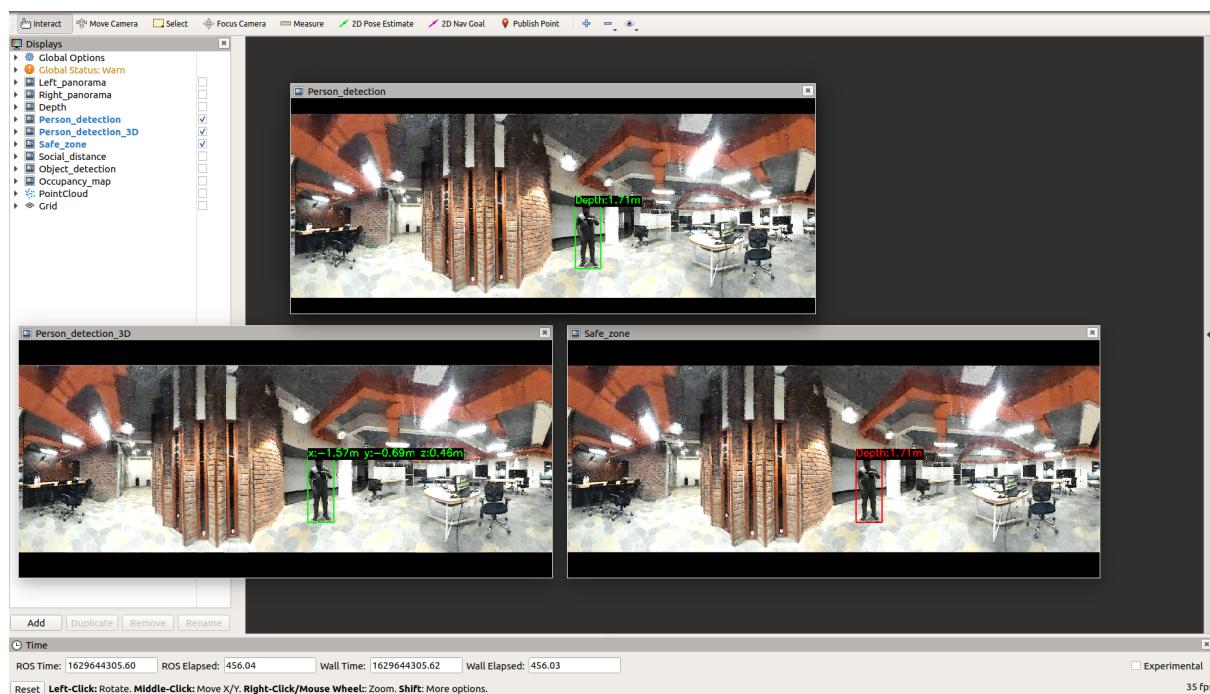
Step 3: In the root folder of the PAL Detection Kit, run the following demo file. This will display an Rviz window that will include the different topics that are supported in the mode that was selected by the user in step 2.

```
$ ./ros_demo.sh
```

The thresholds for different applications can be controlled in the sample\_ROS\_node.cpp file on lines 459 to 465. The values for the threshold are the same as those defined in Section 4 of this document describing the code samples.

The camera properties can be edited in the SavedPALProperties.txt which is also located in the dreamvu\_pal\_camera/src folder.

The images shown below illustrate the ros\_demo.sh script executed for the PAL::Mode::DETECTION and PAL::Mode::HIGH\_QUALITY\_DEPTH respectively



# PAL Detection Kit

