Counting people with the VL53L1X long-distance ranging Time-of-Flight sensor

Introduction

This user manual explains how to use a VL53L1X long-distance ranging Time-of-Flight (ToF) sensor to count people crossing a specific predefined area, like a meeting room entrance or a particular location in a corridor. It also describes an algorithm used to count the people. The algorithm is provided as an example and can be downloaded from st.com, in the VL53L1X embedded SW section, under the reference STSW-IMG010.

In addition, this document presents the details of a counting application where a sensor is set on the top, not the side, of the area to be tracked.

1 Acronyms and abbreviations

Table 1. Acronyms and abbreviations

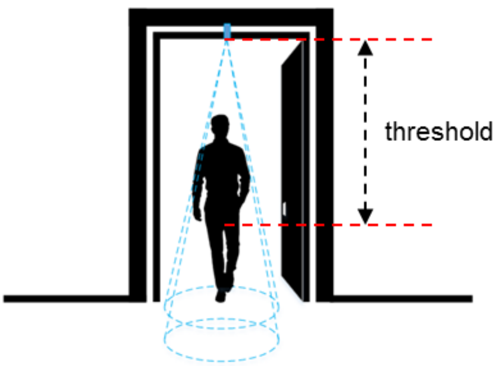
Acronym/abbreviation	Definition
FoV	field of view
SPAD	single photon avalanche diode
SW	software
ToF	Time-of-Flight

2 Overview

Counting people with the VL53L1X consists of using the multiple zones of the sensor receiving SPAD area, and of configuring it with two distinct fields of view (FoV), to alternatively get a ranging distance from them and consequently recognize the movements of a person. Using this method, the number of people occupying a meeting room, accessible from a reasonably narrow access, is known at all times by detecting the entrances and exits of the attendees.

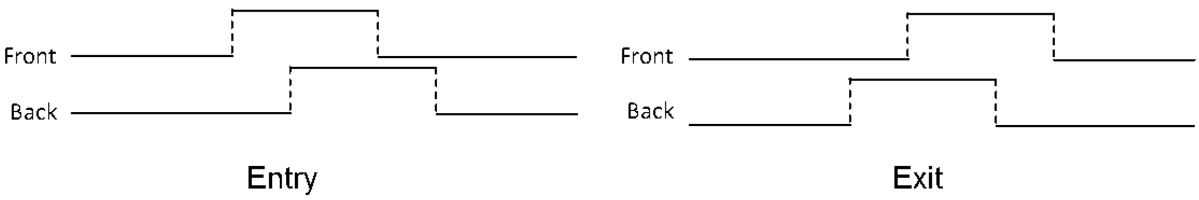
By measuring and analyzing the distances of targets within the FoVs of a front and back zone (see figure below and Figure 3. Front and back zones), a simple algorithm can detect the direction a person crosses the area under the two FoVs. This algorithm "understands" that someone is under one of the FoV as long as the distance measured by the sensor under this FoV is between 0 and a threshold value specified in mm.

Figure 1. VL53L1X FoV divided in two subfields of view



From a timing perspective, the sensor alternatively ranges on each of the two zones, for a very short period of time in milliseconds. It is possible to determine in which direction a person crosses the area, depending in which order this person has been detected in the two zones, as shown in the figure below.

Figure 2. Person counting chronogram



3 Algorithm description

The counting algorithm example relies on a list of states that have to occur in a certain order to detect if a person has crossed the specified area and in which direction this area has been crossed. These states are stored in a list and compared to two default lists of states that represent how the area is crossed in two different directions. When no-one is seen in either of the two zones, the list of states is reset.

If we consider that a person detected in the front zone equals 2, and a person detected in the back zone equals 1, the algorithm adds the value of the two states and stores the result as soon as it changes.

Eventually, if the consecutive states in the list are 0, 1, 3, 2, 0 or 0, 2, 3, 1, 0 this means a person has been detected in one direction or the other, as described in the figures below.

Figure 3. Front and back zones

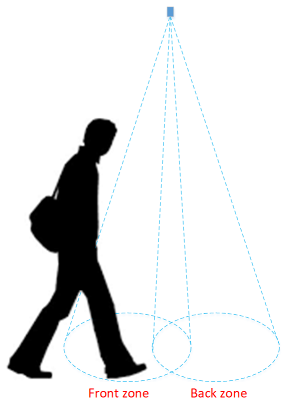
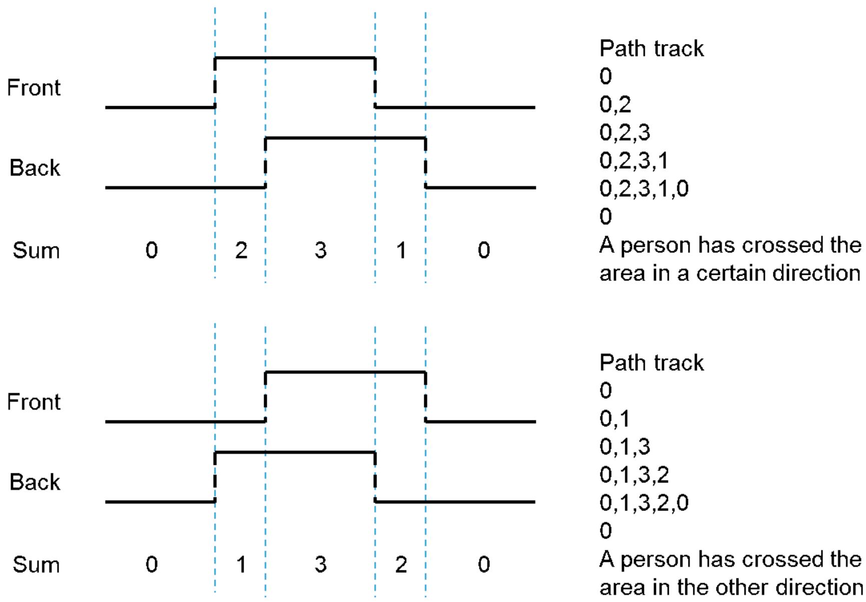


Figure 4. List of status vales

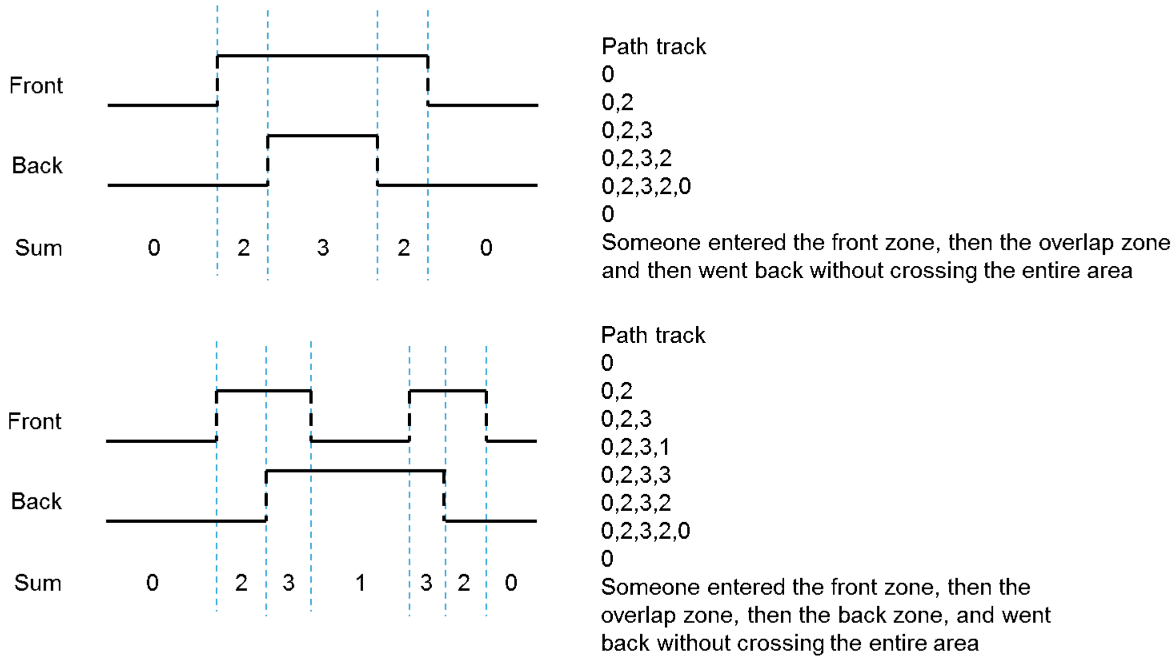


4 Hysteresis

The algorithm validates a crossing event only when a person has fully crossed the two zones. It does not validate the event when the person remains for a long time under the FoV or when the person decides to return from the place he came from.

This is illustrated in the figure below: the algorithm stops and the list of states is reset as soon as no-one is detected in any of the two FoVs.

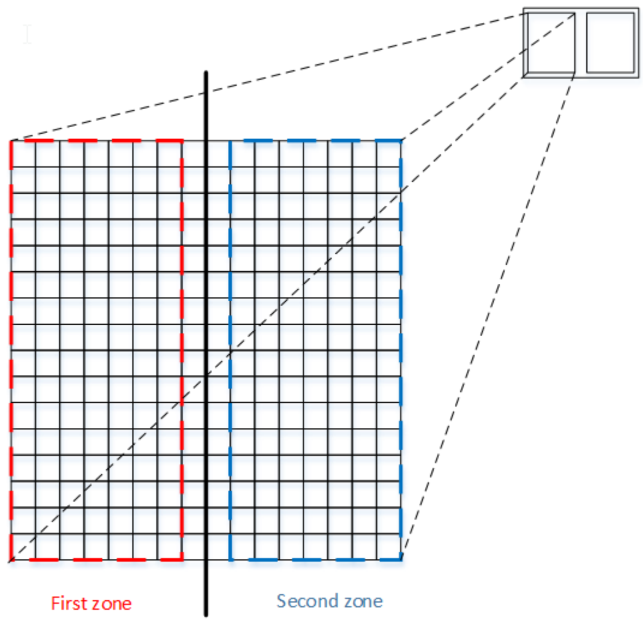
Figure 5. **Hysteresis principle**



5 VL53L1X sensor and algorithm configuration

It is sufficient to set the two FoVs by dividing the 16*16 SPAD array of the VL53L1X sensor into two sub N*16 arrays. For example, N can be chosen within the interval [4, 8]. This means that it is not necessary to use the same SPADs for front and back ranging. Alternatively, enabling 7*16 SPADs is sufficient to see a person in the two zones at the same time when this person stands directly under the sensor, in the middle of the two FoVs.

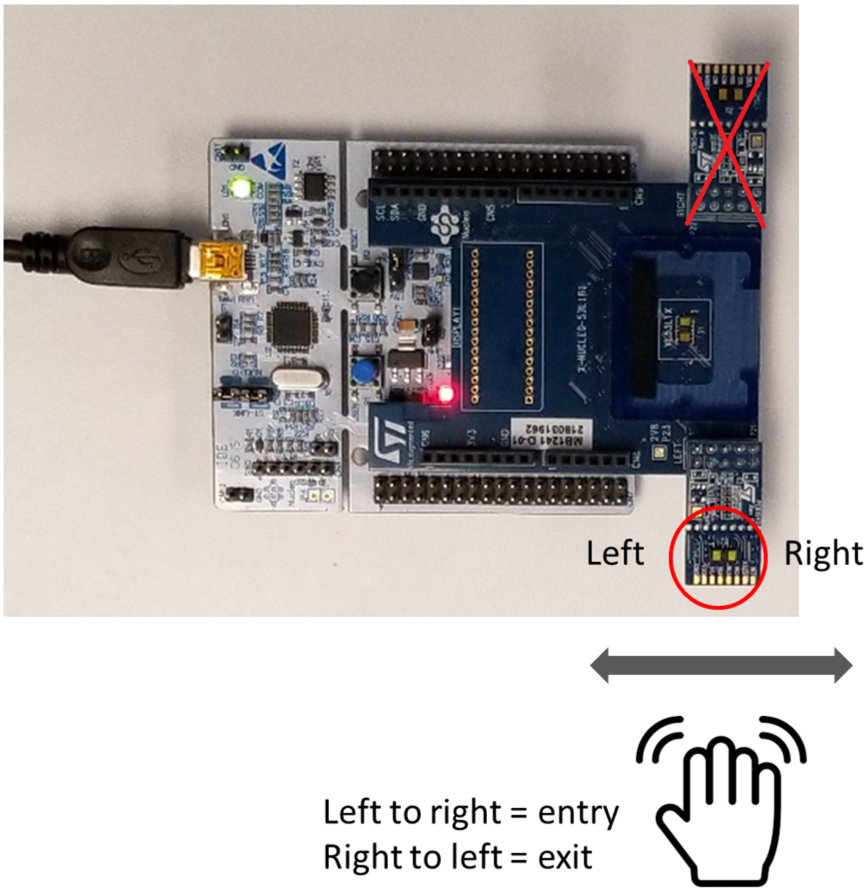
Figure 6. **Example of configuration of the SPAD array**



6 Software and board package

The software code example runs a proof of concept, implementing the algorithm as described in the sections above. This software runs on a NUCLEO F401RE board and is accompanied by one X-NUCLEO 53L1A1 expansion board. The VL53L1X “left” satellite (see figure below) is the one enabled by the software example.

Figure 7. **NUCLEO F401RE, X-NUCLEO, and VL53L1X satellite sensors**

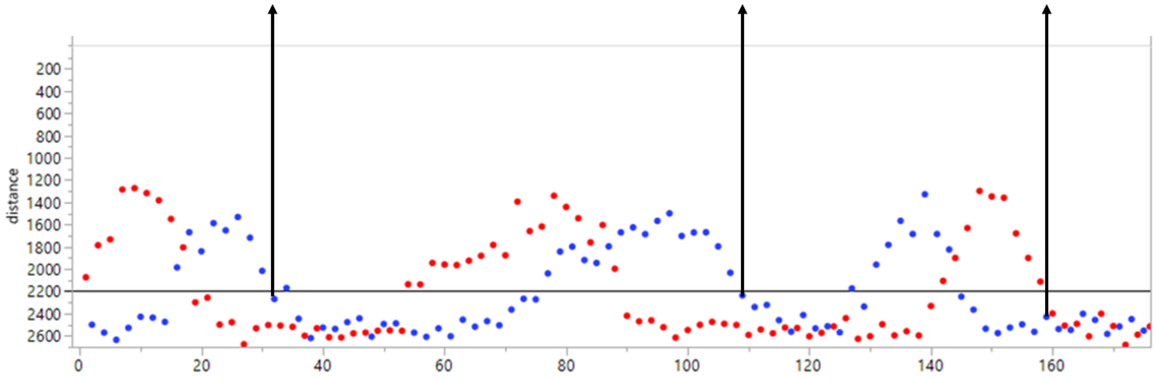


To test the software, you can move your hand from right to left or from left to right, at a distance of around 30 cm above the sensor at a reasonable speed. Moving your hand simulates a person crossing a specified area which gives an output on a counter.

The serial speed is set at the 460800 bauds per second.

The figure below shows the captured distances from two zones, where the VL53L1X is set at 2600 mm from the floor. The black arrows correspond to the times when a person was detected entering or exiting the area being tracked. Three crossings are visible. The first two arrows correspond to two entries and the last one corresponds to an exit. The red and blue dots are distances measured by the sensor from the front and back zones.

Figure 8. Example of captured distances



7 Setup reliability

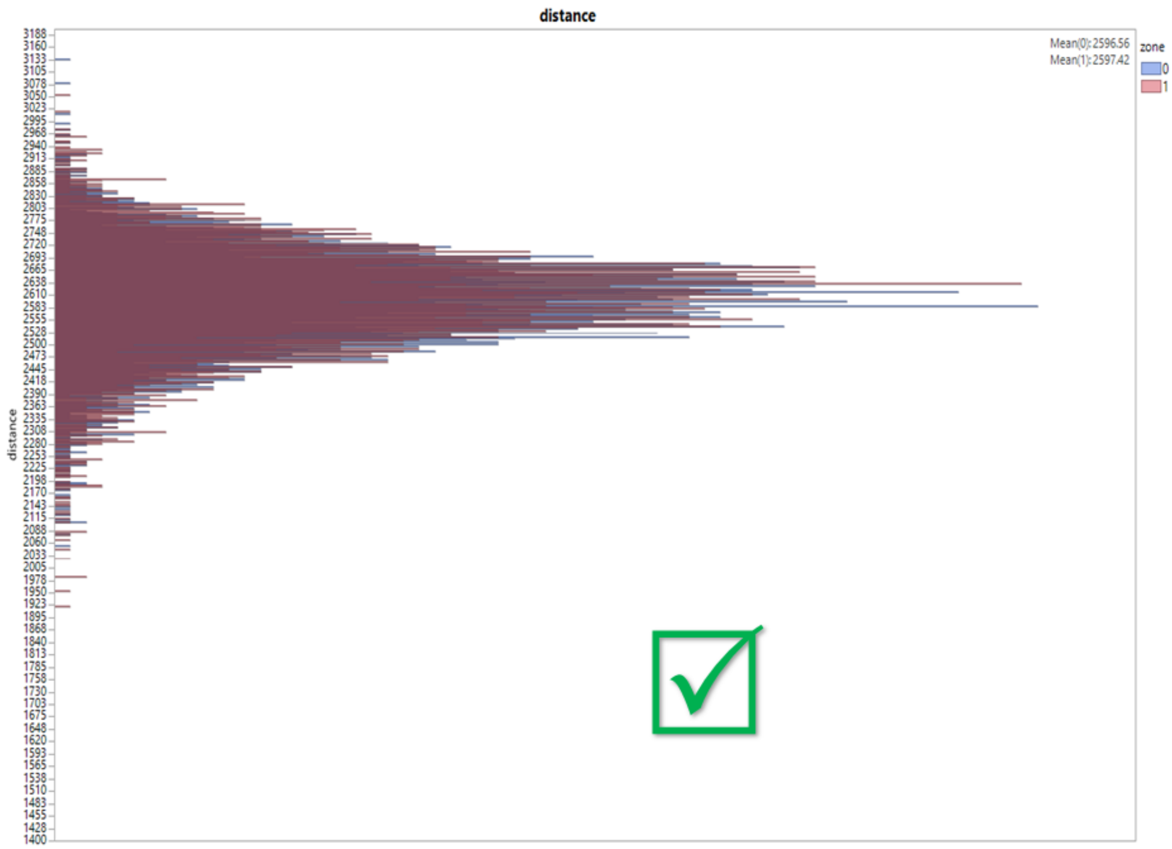
7.1 Ranging on the floor

Reliability of the algorithm relies on the accuracy of the setup which detects the distance between the sensor and the floor. This can be ensured only if nothing (e.g. no obstacle or static object) blocks the front and back FoVs. The two figures below illustrate two cases where the distance to the floor is measured over many measurements. The mean of the measured distances (if they equal the real distance between the sensor and the floor) and the standard deviation, are an indication of the reliability of the setup.

It is recommended to consider a minimum distance of 700 mm between the floor and the sensor threshold as this validates a person crossing the FoV under the sensor. This 700 mm is a good estimate of the maximum standard deviation that we can consider in a noisy environment to define if a setup is reliable or not (see the real test examples in the following figures).

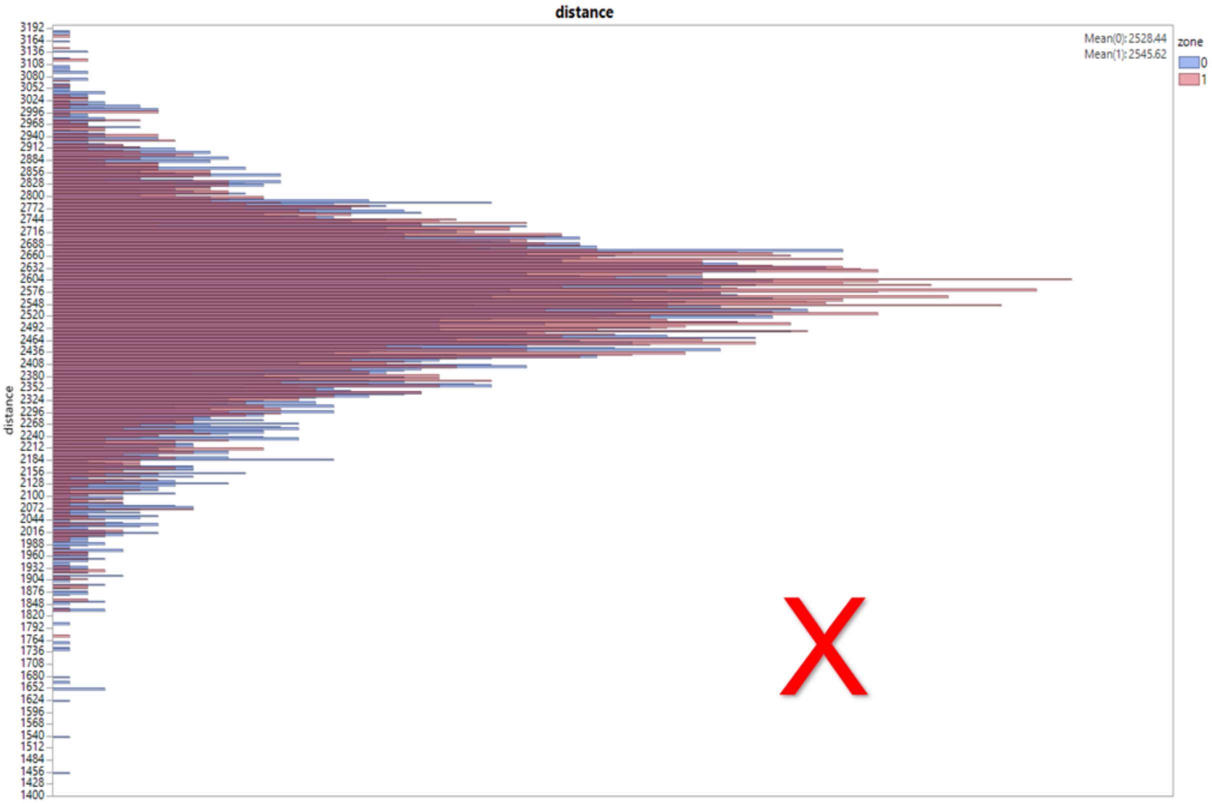
In Figure 9. Reliable setup, the mean of the measured distances from the two zones is the same and the minimum measured distance is less than the distance between the sensor and the floor (2600 mm) minus 700 mm. This indicates a reliable setup.

Figure 9. Reliable setup



In Figure 10. Unreliable setup, the mean of the measured distances from the two zones is significantly different and the minimum measured distance is greater than the distance between the sensor and the floor (2600 mm) minus 700 mm. This indicates an unreliable setup.

Figure 10. Unreliable setup



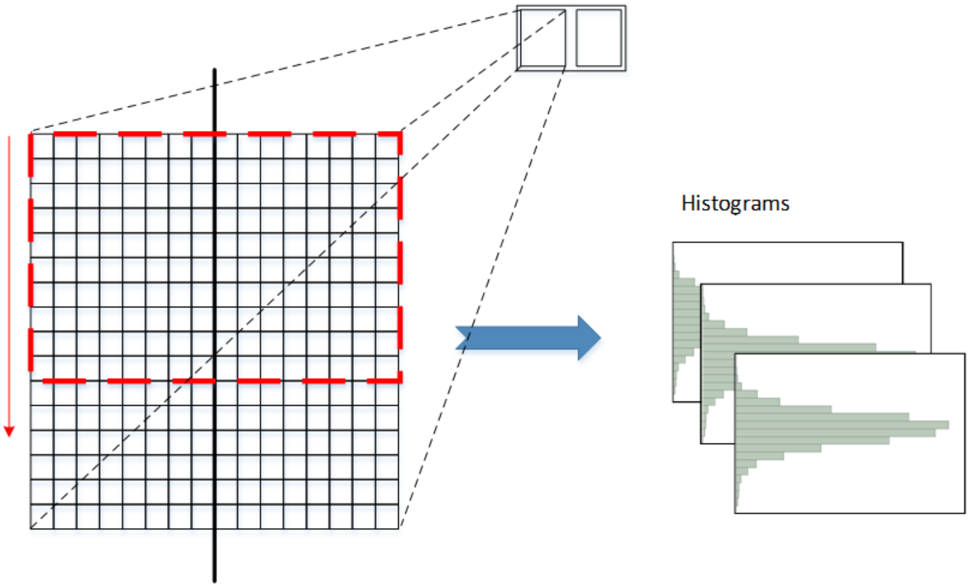
The "reliable" setup is considered good because the sensor detects only the floor in the two FoVs. Consequently, the verticality of the FoV is ensured. However, the tracking area must not be too narrow. In situations where the verticality cannot be fully ensured, or when the FoVs are narrow, it is advised to alternatively enable N*M SPADs as follows:

- N to be within the interval [4, 8] as described above and enabled SPADs should be centered
- M to be within the interval [8, 16] and the SPADs to remain centered for a narrow but non vertical setup. If the verticality of the FoV cannot be ensured, the SPADs do not have to be centered.

Floor detection reliability can be checked by running a trimming procedure to adjust the width of the back and front FoVs, by enabling the relevant SPADs. Analysis of the extracted histograms can help in detecting the SPADs belonging to the parts of the FoVs that do not range on the floor and should never be enabled. Note that the smaller the number of lines of SPADs used for this trimming, the larger the number of histogram values that have to be computed.

The figure below shows a trimming procedure example in which a significant number of distances have been extracted by ranging with the SPADs enabled within the red rectangle (10 SPADs lines). The red rectangle can be moved by one line or more between each test.

Figure 11. **Trimming procedure**



7.2 Ensure overlap in the two detection zones

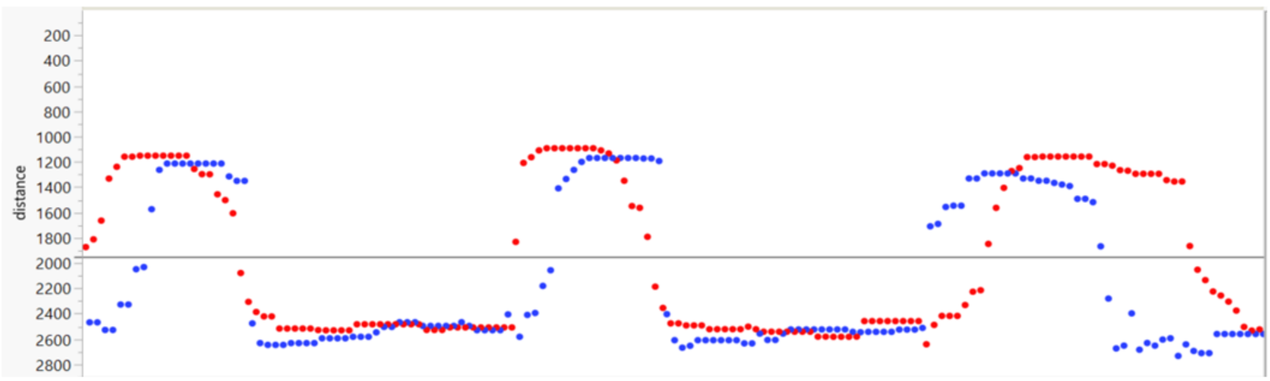
The algorithm example relies on the fact that a person crossing an area being tracked must first be detected in the first zone, then in both zones at the same time, and finally in the second zone. In Figure 8. Example of captured distances, both tracking paths have a few dots corresponding to the moment when a person was detected in both zones simultaneously. Increasing N, increases this number of dots, but could decrease the number of dots corresponding to the time when a person is detected only in the first or second zone.

To optimize the behavior of the algorithm, it is advised to choose N as small as possible and to apply a filter, on the detected distances, which consists of considering only the minimum distance value from the last Z measurements, up to the time where a person is detected in the last zone. This significantly optimizes the probability of detecting a person in each of the zones of the tracking path.

Note that this filter is not implemented in the source code example.

The figure below shows the well-defined detection of a person in each of the three zones.

Figure 12. **Filter on the measured distances with Z = 10, N = 6, M = 16**



Revision history

Table 2. **Document revision history**

Date	Version	Changes
26-Jun-2019	1	Initial release

Contents