TI mmWave Labs – People Counting Demo

Setup and Customization Guide

The People Counting Demo demonstrates the use of TI mmWave Single Chip Radar IWR1642 to count and track multiple people simultaneously. Detection and tracking algorithms run onboard the IWR1642 device to localize and track the movement of people with a high degree of accuracy. Clutter removal enables static objects, like chairs, to be removed from the scene.

This guide will describe:

- EVM installation procedure
- Demo visualization-GUI considerations
- Tracker Parameter Customization
- Step by Step procedure for Demo Customization
- Examples of tuning the demo for common environments/observations

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People Tracking and Counting Demo Setup and Customization

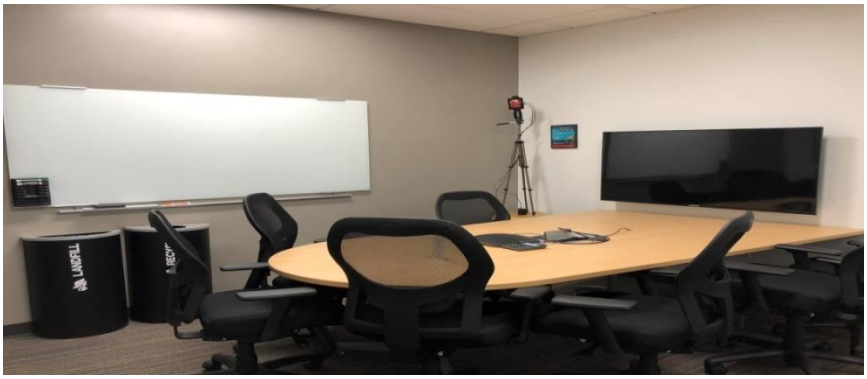
There are 2 major steps involved to get to a desired people counting demo:

1. EVM Installation
2. Demo Customization

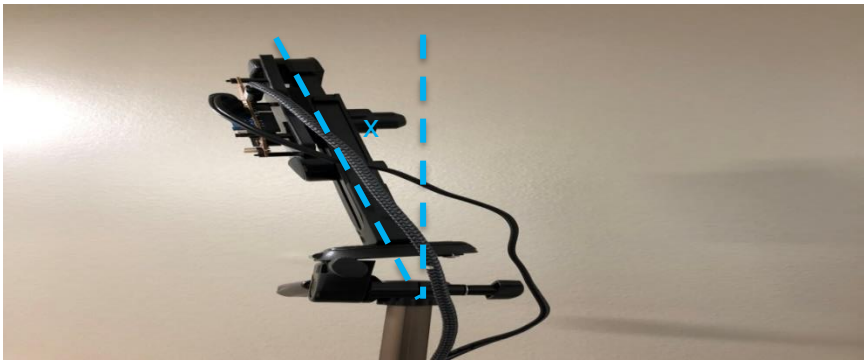
EVM Installation

The EVM needs to be installed at a proper height and with an elevation tilt to maximize the energy reflection from the objects to get to a rich point cloud. This means directing the majority of transmitted energy towards the area of interest for better reflected energy reception. The software must also be installed on the EVM.

- Height – 2 to 2.5 meters above the ground



- Tilt in Elevation – 10 to 45 degrees. 10 degrees works well in conference and meeting rooms.



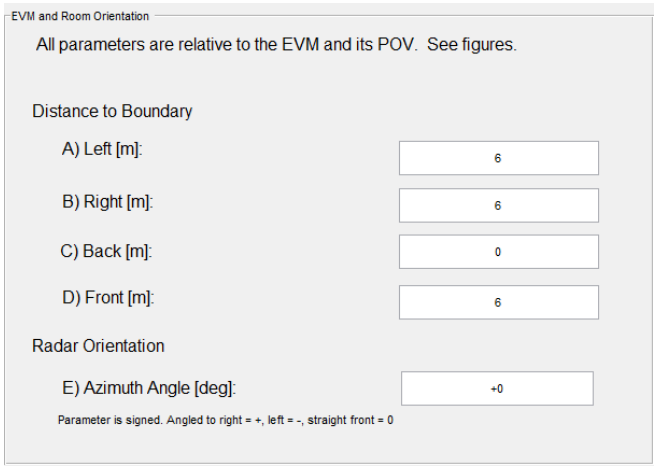
The EVM will also have to be flashed with the People Counting software, which can be found on TI-REX. You can find instructions there for flashing and running the demo.

Demo Customization

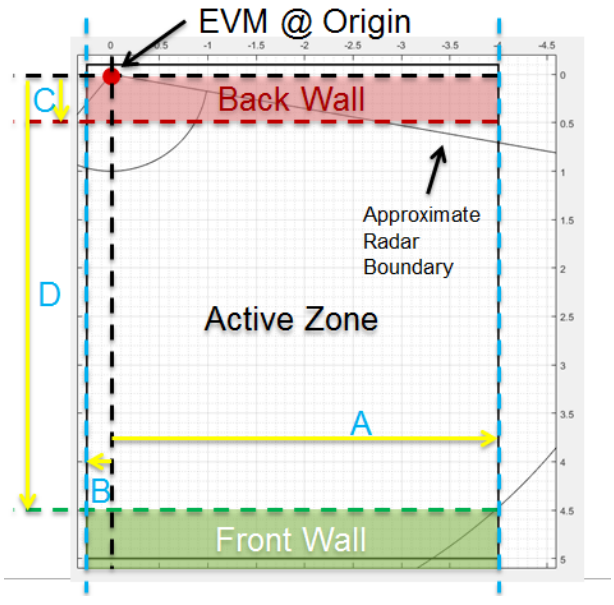
Demo Customization involves **Visualizer GUI** and **Tracker Parameter** customization explained as below

GUI Customization

Once the GUI is invoked using the .exe file the following customization needs to be done as per the area of interest. The area boundaries and the Azimuth angle needs to be input to the visualizer.



The Left, Right, Back, and Front parameters describe the area of interest where people need to be tracked and counted. These parameters form a rectangle, called the Active Zone, in which targets will be detected and tracked in. Objects outside of this area are ignored. The EVM faces the front wall. The values input are the distance to each wall. In the default configuration, the EVM is touching the Back wall, and every other wall is 6 meters away. These parameters are described visually in the figure below.



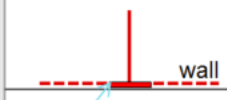
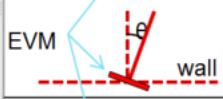
A – Left Wall

B – Right Wall

C – Back Wall

D – Front Wall

The Azimuth angle is the angle of the EVM with respect to the Back wall. When the EVM is facing directly away from the wall, its Azimuth angle is said to be 0 degrees. Note this convention is different from the chirp configuration parameters, where this position is 90 degrees. Tilting the EVM towards the left wall is a positive change in angle, and tilting towards the right wall is a negative change in angle. This parameter is described visually in the figure below.

Top view Depiction	Azimuth Angle Tilt	.cfg file convention
	0	90
	+20	70
	-20	110

This value also needs to be fed to the configuration file (.cfg) in the below said API.

trackingCfg 1 2 250 20 200 50 90

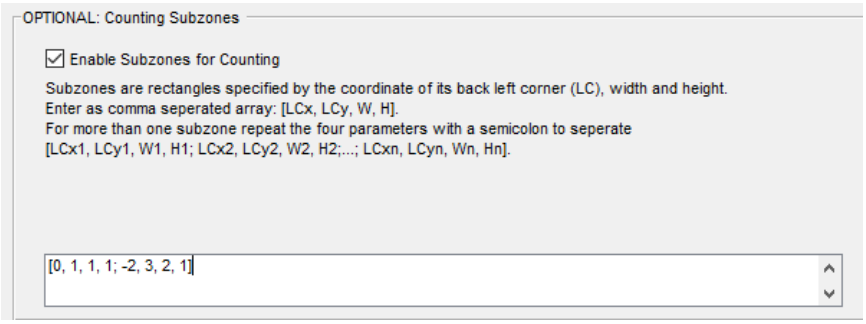
Change the last value (highlighted in blue) to change the EVM Azimuth angle.

Optional Parameters

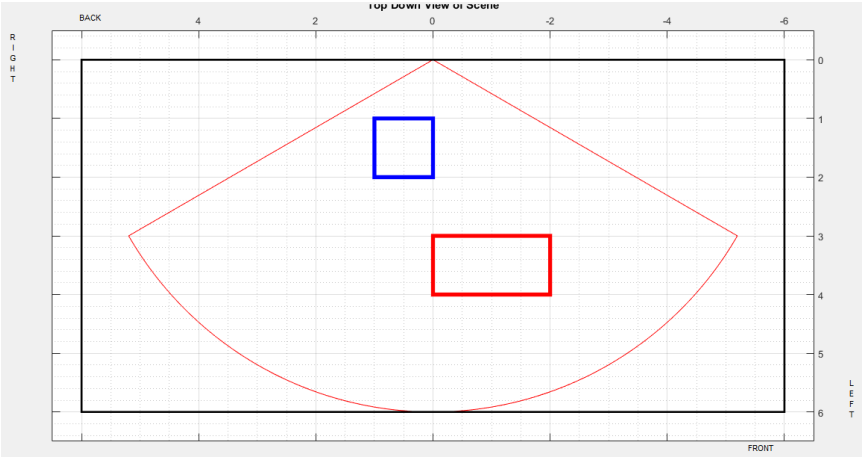
The GUI has optional subzones the user can activate. When active, each subzone will keep a separate count of occupants. The subzones are rectangular; the user can define their location and dimensions. The rectangle is defined with the coordinates of the bottom left corner, and the length and width of the sides. The bottom left corner is from the perspective of the EVM. In the GUI, it will appear as the top right corner. Notation is the Matlab matrix notation: each rectangle occupies its own row. For two rectangles, input would be as follows:

[R1Xc, R1Yc, R1X, R1Y; R2Xc, R2Yc, R2X, R2Y]

The user must also check the “Enable Subzones for Counting” check box.



The above input results in the below subzones:



Tracker Parameter Customization

The group tracker is Customized using CLI commands as part of the configuration file(.cfg) by programing the below said parameters. These commands change 5 different parameters:

- Scenery Parameters
- Gating Parameters
- State Parameters
- Allocation Parameters
- Variation Parameters

Tracker Parameter Description

There are 5 types of parameters that can be changed in this demo. These can be used to improve performance of the tracking and clustering software in different environments.

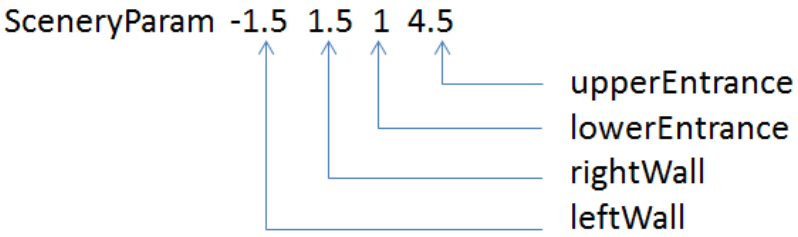
Scenery Parameters

The most important set of parameters to set are the Scenery Parameters. These define the space in which the demo is being used, and must be set in the GUI, chirp configuration, and the EVM software.

PARAMETER	DEFAULT	DIM	DESCRIPTION
lefWall	–1.5	m	Position of the left wall, in meters, set to -100 if no wall. Points behind the wall will be ignored
rightWall	1.5	m	Position of the right wall, in meters, set to 100 if no wall. Points behind the wall will be ignored
lowerEntrance	1	m	Entrance area lower boundary, in meters; set to 0 if not defined.
upperEntrance	4.5	m	Entrance area lower boundary, in meters; set to 100 if not defined.

The user defines the area boundaries the same way they do in the GUI. The lower entrance is closer to the EVM, and the upper entrance is farther from the EVM.

This configuration is done through the API as below



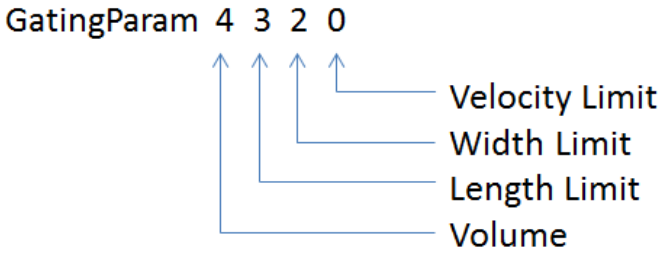
Gating Parameters

The gating parameters determine the maximum volume and velocity of a tracked object. Points detected near a centroid, but beyond the limits set by these parameters will not be included in the set of points that make up the tracked object. There are 4 parameters:

PARAMETER	DEFAULT	DIM	DESCRIPTION
Volume	4	—	Gating volume
LengthLimit	3	m	Gating limit in length
WidthLimit	2	m	Gating limit in width
VelocityLimit	0	m/s	Gating limit in velocity (0 – no limit)

Volume is defined as the volume of an ellipsoid: $V = \frac{4\pi}{3}abc$ where a is range (meters), b is angle (radians), and c is velocity (m/s). Length limit, width limit, and velocity limit also serve to limit the size of the ellipsoid. The Length and width limits limit the dimensions of the ellipsoid, and the velocity limit limits the velocity of the ellipsoid.

This configuration is done through the API as below



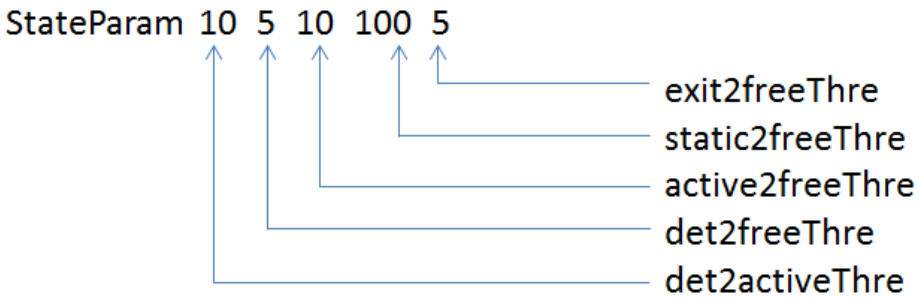
State Transition Parameters

The state transition parameters determine the state of a tracking instance. Any tracking instance can be in one of three states: FREE, DETECT, or ACTIVE. Instances in ACTIVE state produce tracks. Once per frame, each instance will get a hit (have one or more points associated with the instance), or a miss (have zero points associated with the instance). The state transition parameters are described in the table below:

PARAMETER	DEFAULT	DIM	DESCRIPTION
det2activeThre	10	—	In DETECT state; how many consecutive HIT events needed to transition to ACTIVE state
det2freeThre	5	—	In DETECT state; how many consecutive MISS events needed to transition to FREE state
active2freeThre	10	—	In ACTIVE state and NORMAL condition; how many consecutive MISS events needed to transition to FREE state
static2freeThre	100	—	In ACTIVE state and STATIC condition; how many consecutive MISS events needed to transition to FREE state
exit2freeThre	5	—	In ACTIVE state and EXIT condition; how many consecutive MISS events needed to transition to FREE state

In the table, STATIC, NORMAL, and EXIT conditions are mentioned. A target in STATIC condition is not moving, and a target in NORMAL condition is moving. A target in EXIT is near

This configuration is done through the API as below

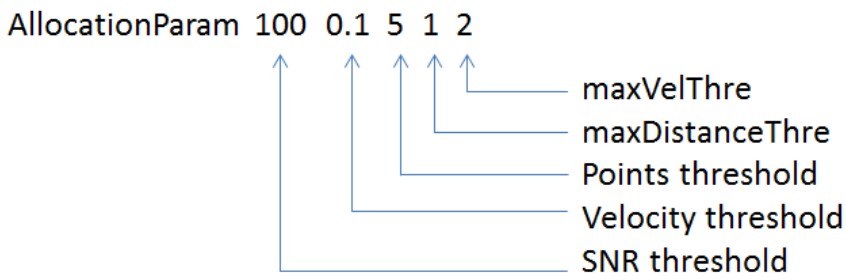


Allocation Parameters

The allocation parameters are used to determine when a point in the point cloud can be associated with a given track, and when a set can be considered for tracking. MaxDistanceThre and maxVelThre determine when the candidate point can be added to the allocation set. SNR Threshold, Velocity Threshold, and Points Threshold determine when an allocation set becomes a track.

PARAMETER	DEFAULT	DIM	DESCRIPTION
SNR threshold	100	—	Minimum total SNR for the allocation set, linear sum of power ratios
Velocity threshold	0.1	m/s	Minimum radial velocity of the allocation set centroid
Points threshold	5	—	Minimum number of points in the allocation set
maxDistanceThre	1	m^2	Maximum squared distance between candidate and centroid to be part of the allocation set
maxVelThre	2	m/s	Maximum velocity difference between candidate and centroid to be part of the allocation set

This configuration is done through the API as below

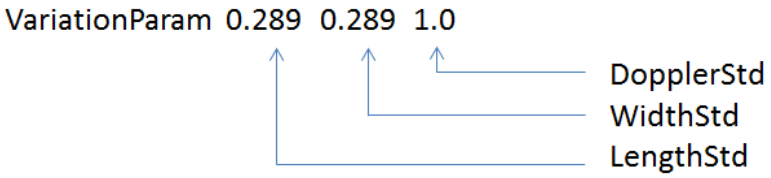


Variation Parameters

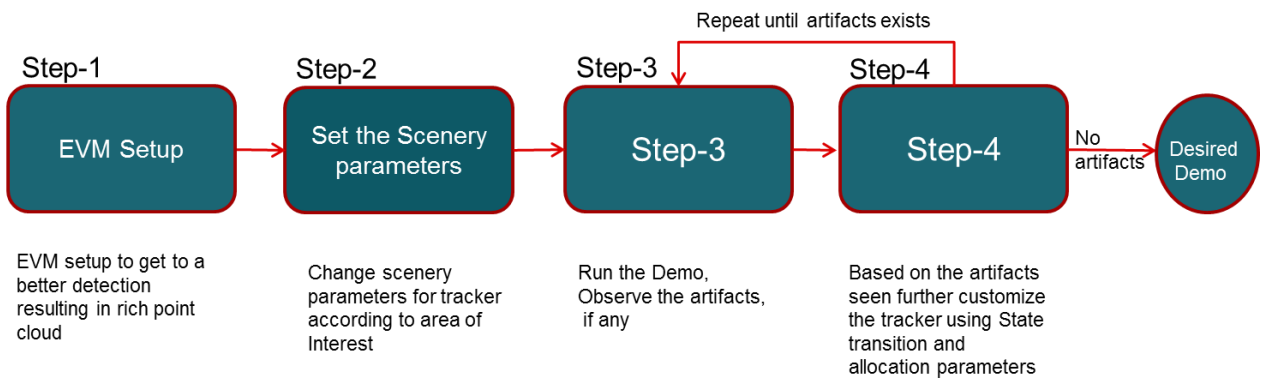
This set of parameters is used to estimate standard deviation of the reflection point measurements. Generally, these do not need to be changed.

PARAMETER	DEFAULT	DIM	DESCRIPTION
LengthStd	1/3.46	m	Expected standard deviation of measurements in target length dimension
WidthStd	1/3.46	m	Expected standard deviation of measurements in target width dimension
DopplerStd	1.0f	m/s	Expected standard deviation of measurements of target radial velocity

This configuration is done through the API as below



Step by Step procedure for Demo Customization



Demo Customization Examples

Increasing Detection Range

There are multiple parameters that affect the range at which a person can be positively identified and tracked. First, make sure you are using a chirp that extends to the range at which you want to detect people. Find a Chirp development tool here. Then consider changing these three parameters:

1) Allocation Parameters – SNR Threshold
2) Allocation Parameters – Points Threshold
3) State Transition Parameters – Det2Active Threshold

At a distance, the reflected signal will be weaker. This will decrease the SNR of the target points, and potentially reduce the size of the point cloud. By lowering the Points threshold, fewer points are needed to allocate a track to the cluster. Lowering the SNR threshold will lower the cumulative SNR required for an allocation set to be considered a track. Be careful, as lowering these parameters increases the chance of false detection. Lowering the Det2Active threshold will not improve the software's ability to detect people. However, it will lower the amount of time for a detected person to enter ACTIVE tracking state. As a result, the track will appear farther away when a target is approaching.

Removing Multipath Reflections(Ghosts)

Sometimes, multipath reflections- Radar Energy reflected from a person being reflected again from a wall or some object, will cause the tracker to produce a false detection. These false detections are

called ghosts. Ghosts can be caused by multiple phenomena, but there are many tools in the People Counting software to minimize or completely remove ghosting.

Start by properly setting the scenery parameters. Many ghosts caused by multipath reflections will appear outside of the detection area. These can be immediately ruled out if the scenery parameters are properly set.

In cases where the ghost appears in the valid area, you may try changing other parameters:

1) Allocation Parameters – SNR Threshold
2) Allocation Parameters – Points Threshold
3) State Transition Parameters – Det2Active Threshold
4) State Transition Parameters – Det2Free, Static2Free, Active2Free, exit2Free

The first three parameters in the list can be used to reduce false detections. Ghosts will usually have fewer points with lower SNRs. Increasing the Points Threshold and SNR Threshold will stop the tracker from allocating these clusters as tracks. Increasing the Det2Active threshold will increase the amount of time the ghost has to exist before it is promoted to ACTIVE state. In the case where a ghost only appears momentarily, this can stop the tracker from tracking it.

If changing these parameters fails to stop ghosts from appearing, consider changing the parameters in the 4th bullet. By lowering these thresholds, tracks will be freed faster, so the ghost will be tracked for a shorter period of time. However, lowering these may reduce the ability of the tracker to properly maintain a track on a real target, especially in a cluttered environment.

Resolving Multiple People When Close Together

In some situations, the tracker may allocate one track for 2 or more people. This is likely to happen when they are near each other, and walking at the same pace in the same direction (a fairly common occurrence). Other times, the tracker may give one person multiple tracks. To prevent these situations, consider changing the following parameters:

1) Allocation – maxDistanceThre
2) Allocation – maxVelThre
3) Gating – Volume
4) Gating – Length Limit
5) Gating – Width Limit
6) Gating – Velocity Limit

All of these parameters will affect how points in the point cloud get distributed into different tracks. Changing the thresholds under Allocation will affect how points in the point cloud are initially added to tracks. Lowering these thresholds will increase differentiation of clusters, while raising them will decrease differentiation.

Gating parameters are used to associate points with tracks that already exist. By lowering these thresholds, points will have to be closer to a track to be counted as part of that track. Increasing these parameters will allow a track to take on points farther away. In situations where multiple people will be walking near each other, keeping these values low will make it easier for the algorithm to separate their individual point clouds.

Further Reading

To better understand the tracking and clustering process, please see the People Counting Reference Design. This will provide more in depth explanations of the tuning parameters, as well as a description of the People Counting algorithm. There is also a user's guide to help with setting up the People Counting Demo.