Lidar-Lidar Extrinsic Matrix Manual Calibration User Guide

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1 Notation

Consider a point in left lidar's frame $P_l = (x_l, y_l, z_l)^T$, its corresponding 3D point in top-center lidar's frame is $P_t = (x_t, y_t, z_t)^T$. The extrinsic matrix from left lidar to top-center lidar's frame is $\boldsymbol{E}_{l2t}$. Therefore, we have:

$$P_t = \boldsymbol{E}_{l2t} P_l \tag{1}$$

Consider a point in right lidar's frame $P_r = (x_r, y_r, z_r)^T$, its corresponding 3D point in top-center lidar's frame is $P_t = (x_t, y_t, z_t)^T$. The extrinsic matrix from right lidar to top-center lidar's frame is $\boldsymbol{E}_{r2t}$. Therefore, we have:

$$P_t = \boldsymbol{E}_{r2t} P_r \tag{2}$$

$\boldsymbol{E}_{l2t}$ and $\boldsymbol{E}_{r2t}$ could be formualted as:

$$\boldsymbol{E}_{l2t} = \begin{bmatrix} \boldsymbol{R}_{l2t}^{(3\times3)} & \boldsymbol{T}_{l2t}^{(3\times1)} \\ \boldsymbol{0}_{1\times3} & \boldsymbol{1}_{1\times1} \end{bmatrix}, \boldsymbol{E}_{r2t} = \begin{bmatrix} \boldsymbol{R}_{r2t}^{(3\times3)} & \boldsymbol{T}_{r2t}^{(3\times1)} \\ \boldsymbol{0}_{1\times3} & \boldsymbol{1}_{1\times1} \end{bmatrix} \tag{3}$$

$\boldsymbol{T}_{l2t}^{(3\times1)}$ is the coordinate of the left lidar's origin in top-center lidar's frame.
$\boldsymbol{T}_{r2t}^{(3\times1)}$ is the coordinate of the right lidar's origin in top-center lidar's frame.

2 Extrinsic Matrix to Euler Angles

Use tool lidar2lidar calibration tool (`https://github.com/gaowexu/SensorsCalibration`) to manually calibrate point cloud frames captured at the same timestamp and then could obtain the typical extrinsic matrix as below:

$$\boldsymbol{E}_{l2t} = \begin{bmatrix} -0.184349 & -0.98286 & 0.0 & 0.54602 \\ 0.98286 & -0.184349 & 0.0 & 0.90732 \\ 0.0 & 0.0 & 1.0 & -0.642478 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix} \tag{4}$$

$$\boldsymbol{E}_{r2t} = \begin{bmatrix} -0.228178 & 0.972368 & 0.0 & 0.636313 \\ -0.972088 & -0.230317 & 0.0 & -0.78358 \\ 0.0 & 0.0 & 1.0 & -0.642478 \\ 0.0 & 0.0 & 0.0 & 1.0 \end{bmatrix} \tag{5}$$

When the extrinsic parameter matrixs are obtained, then we could convert it to yaw, pitch, roll based on the code below:

```
import math

yaw = math.atan2(rotation_matrix[1][0], rotation_matrix[0][0])
pitch = math.atan2(-rotation_matrix[2][0], \
        np.sqrt(rotation_matrix[2][1] ** 2 + \
        rotation_matrix[2][2] ** 2))
roll = math.atan2(rotation_matrix[2][1], rotation_matrix[2][2])
```

3 ROS2 Bag Play

Run the two commands below to associate the left, right frames with front frame.

```
ros2 run tf2_ros static_transform_publisher \
0.54602 0.90732 -0.642478 1.7562059520717546 -0.0 0.0 front left
```

```
ros2 run tf2_ros static_transform_publisher \
0.636313 -0.78358 -0.642478 -1.801352191383159 -0.0 0.0 front right
```

Then the points cloud in three lidars could be visualized at the same time in top-center lidar's coordinate system in rviz2.