Homework 3

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Part 1: Epipolar Geometry

Question:

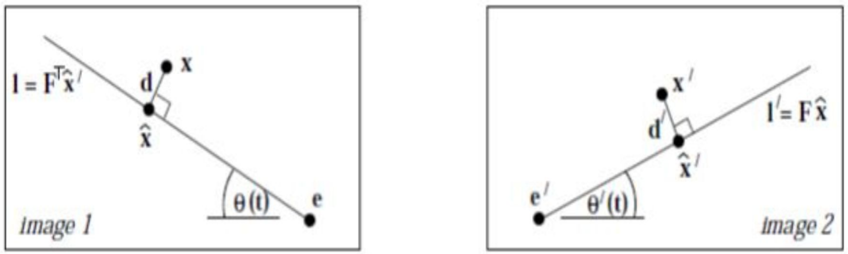
- Describe what test you used for deciding inlier vs. outlier.
- Display the estimated fundamental matrix F after normalizing to unit length
- Plot the outlier keypoints with green dots on top of the first image `plot(x, y, '.g');`
- Randomly select 7 sets of matching points. Plot the corresponding epipolar lines ('g') and the points (with 'r+') on each image. Show the two images (with plotted points and lines) next to each other.

Answer:

Used the distances of points from the epipolar lines to classify the point as inliers or outliers.

$$\hat{\boldsymbol{x}}'^{T}\boldsymbol{F}\hat{\boldsymbol{x}}=0$$

$$cost(\boldsymbol{X}) = dist(\boldsymbol{x},\hat{\boldsymbol{x}})^2 + dist(\boldsymbol{x}',\hat{\boldsymbol{x}}')^2$$



Here, Line 1 and Line 2 are computed using matched points from image 1 and image 2 and multiplying them with the fundamental matrix. The multiplication gives us the coefficients of the line of form ax + by + c = 0;

We know that, an epipolar line is obtained by,

$$l = F * x \text{ (where F = Fundamental Matrix and x = point.)}$$

To find if a point p in an image is an outlier, the following steps are followed:

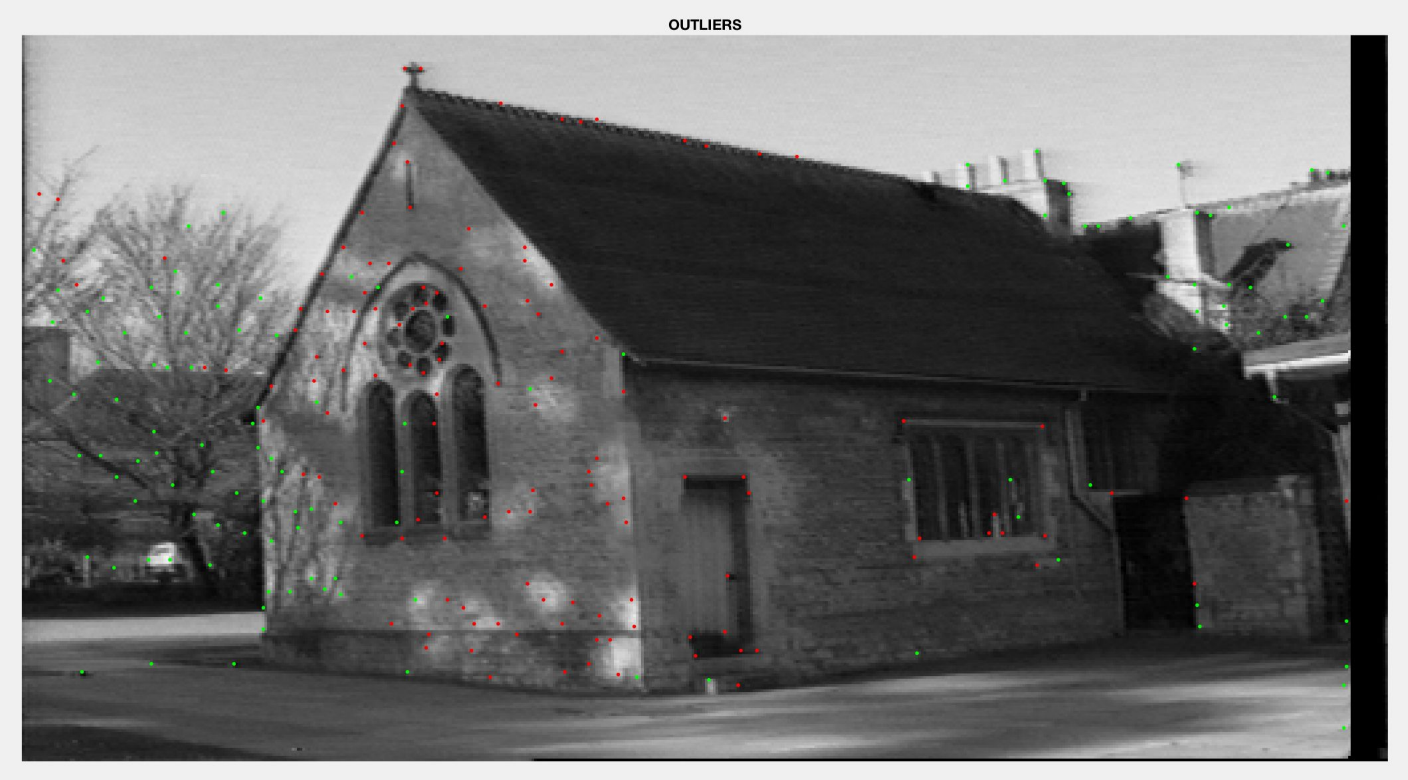
1. Find the corresponding point in image 2.
2. Multiply F by that point.
3. Find the distance of the point from this line in image 1.
4. Check if the distance is greater than a threshold, if the distance is greater, then this point is an outlier.

Fundamental Matrix after normalization to unit length:

normF =

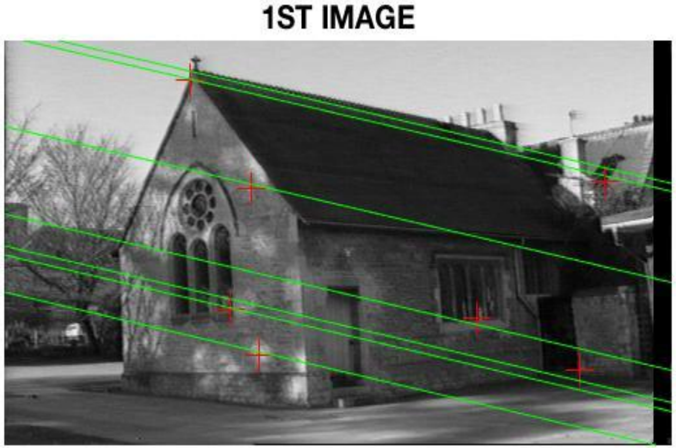
0.0000	-0.0000	-0.0449
-0.0000	0.0001	0.2109
0.0580	-0.2342	0.9462

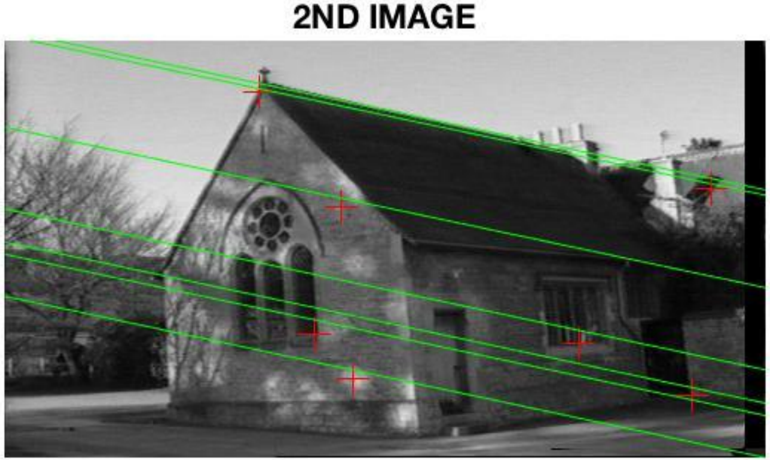
Plot of Outlier Keypoints on 1st Image



Green = Outliers ; Red = Inliers.

- Randomly select 7 sets of matching points. Plot the corresponding epipolar lines ('g') and the points (with 'r+') on each image. Show the two images (with plotted points and lines) next to each other.





Part 2: Affine Structure From Motion

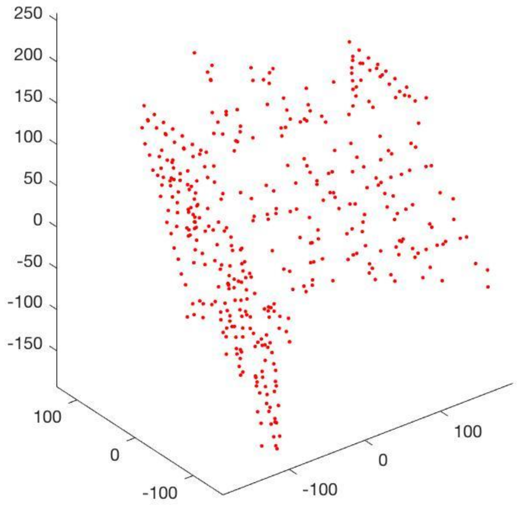
Question:

- Include pseudocode in your report.
- Plot the predicted 3D locations of the tracked points for 3 different viewpoints. Choose the viewpoints so that the 3D structure is clearly visible.
- Plot the predicted 3D path of the cameras. The camera position for each frame is given by the cross product a_k = a_i x a_j. Normalize a_k to be unit length for consistent results. Give 3 plots, one for each dimension of a_k We provide the function `plotSfM.m` for visualizing the recovered 3D shape and camera positions in each frame.

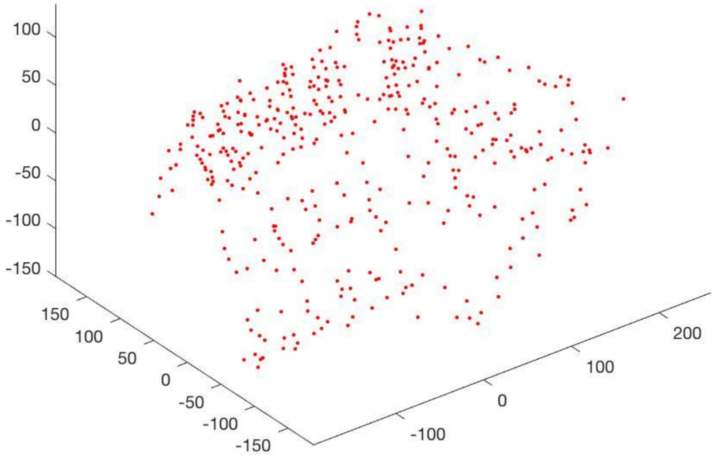
Pseudocode:

1. Get valid keypoints from KLT Tracker.
2. Normalize X, Y coordinates to zero mean to remove translation effect.
3. Create the measurement matrix with upper half containing X coordinates and lower half containing Y coordinates.
4. Find solution to the $D = AX$ where A = motion matrix and X = shape matrix.
5. Decompose using SVD.
6. Enforce SVD output matrics, U, W and V to rank 3.
7. Decompose U, V and W into A and X matrices by choosing the following decompositions: $A = UW^{1/2}$ and $X = W^{1/2}V$.
8. Resolve affine ambiguity, using the Euclidean constraints. $AL = b$, where $L = CC^T$ and $b = [...0\ 0\ 1\ 0\ 0\ 1...0\ 0\ 1]$ (Euclidean Constraint)
9. Use Cholesky decomposition to find the value of C
10. Use $A = AC$ and $X = C^{-1}X$

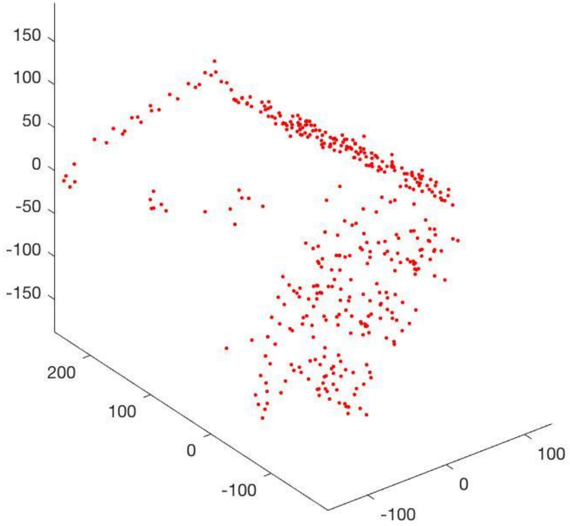
- Plot the predicted 3D locations of the tracked points for 3 different viewpoints. Choose the viewpoints so that the 3D structure is clearly visible.



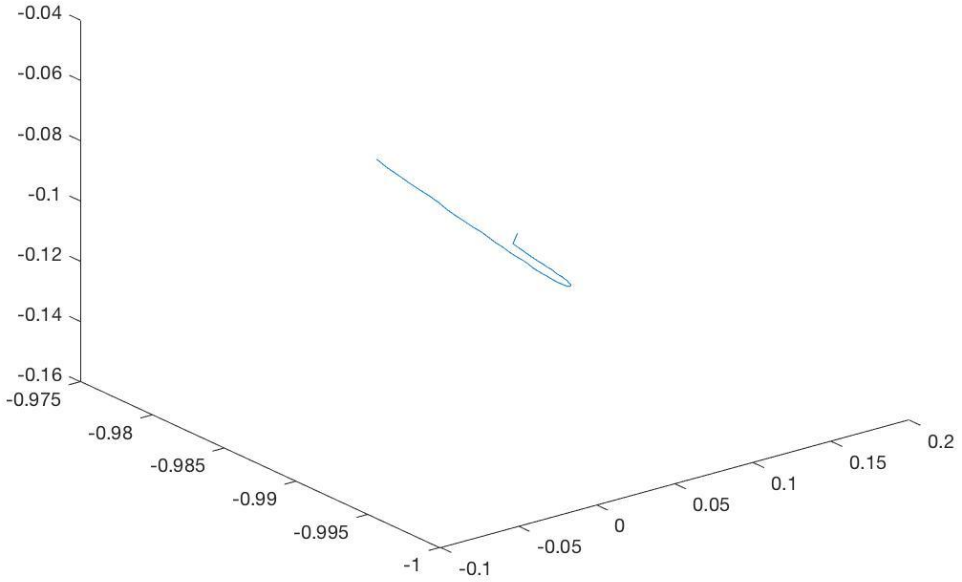
- Plot the predicted 3D locations of the tracked points for 3 different viewpoints. Choose the viewpoints so that the 3D structure is clearly visible.



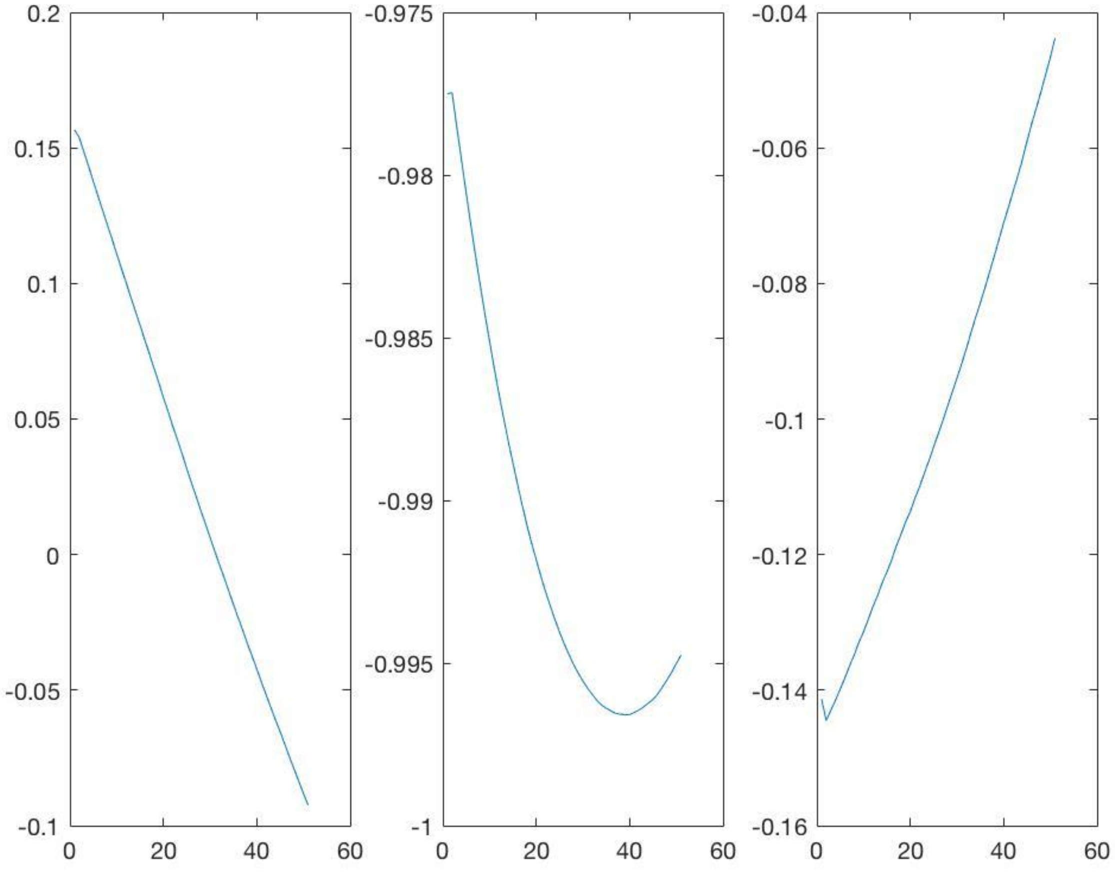
- Plot the predicted 3D locations of the tracked points for 3 different viewpoints. Choose the viewpoints so that the 3D structure is clearly visible.



- Plot the predicted 3D path of the cameras. The camera position for each frame is given by the cross product a_k = a_i x a_j. Normalize a_k to be unit length for consistent results. Give 3 plots, one for each dimension of a_k We provide the function `plotSfM.m` for visualizing the recovered 3D shape and camera positions in each frame.



Normalized X, Y and Z axis plot of camera’s motion.



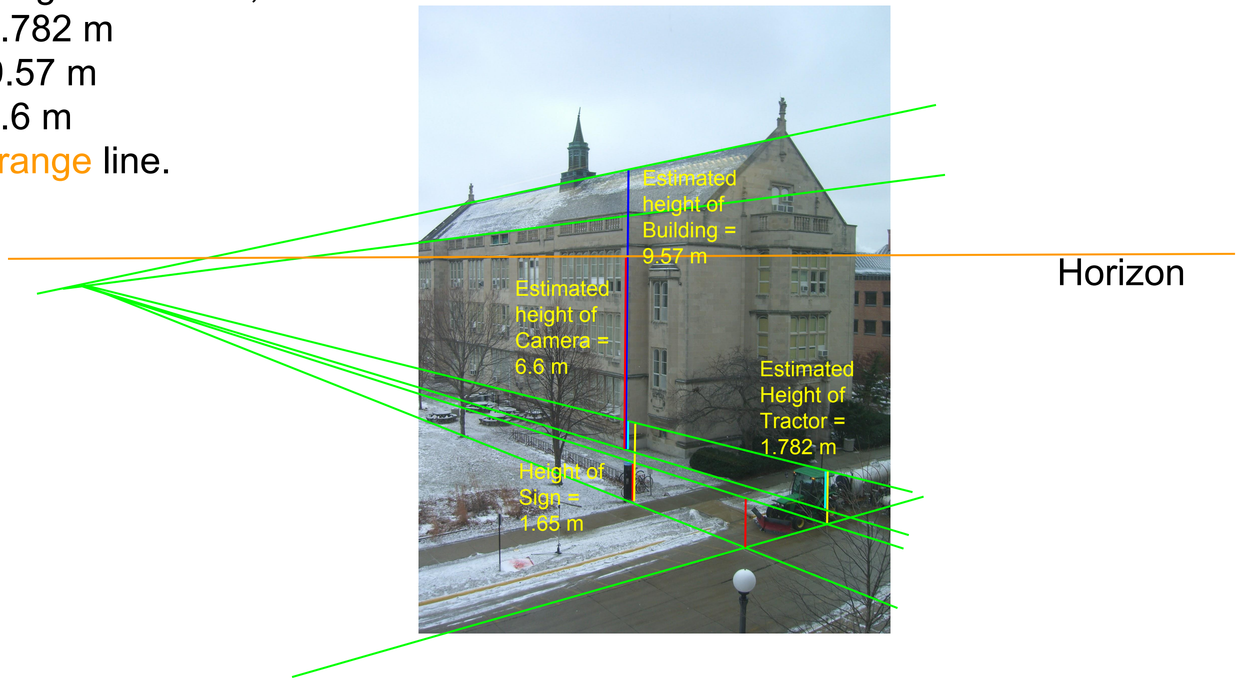
Graduate Credit

Question:

- Estimate the horizon and draw/plot it on the image. Assume that the sign is 1.65 meter. Estimate the heights of the tractor, the building, and the camera (in meters). This can be done with powerpoint, paper and a ruler, or Matlab.
- Turn in an illustration that shows the horizon line, and the lines and measurements used to estimate the heights of the building, tractor, and camera.
- Report the estimated heights of the building, tractor, and camera in meters.

Using the Sign as reference, whose height is 1.65 m,

1. Estimated Height of Tractor = 1.782 m
2. Estimated height of building = 9.57 m
3. Estimated height of camera = 6.6 m
4. Horizon is also shown by the Orange line.



Question:

Compare the results with **un-normalized** 8-point algorithm with RANSAC. For the inlier matches, report the averaged value of (x’^T F x)^2 (i.e. evaluating how well the recovered fundamental matrix F explains the inlier matches). Compare this value with the normalized 8-point algorithm.

Average Error for Normalized 8 Point Algorithm:

error1 =

1.0290

Average Error for Unnormalized 8 Point Algorithm:

error1 =

1.5932e+07

Fundamental Matrices:

Normalized Fundamental Matrix:

normF1 =

0.0000	-0.0002	0.0255
0.0001	0.0000	-0.0042
-0.0210	0.0103	-0.9994

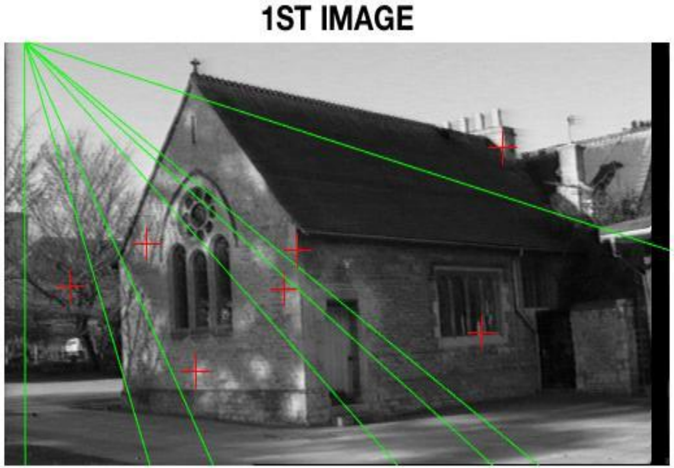
Unnormalized Fundamental Matrix:

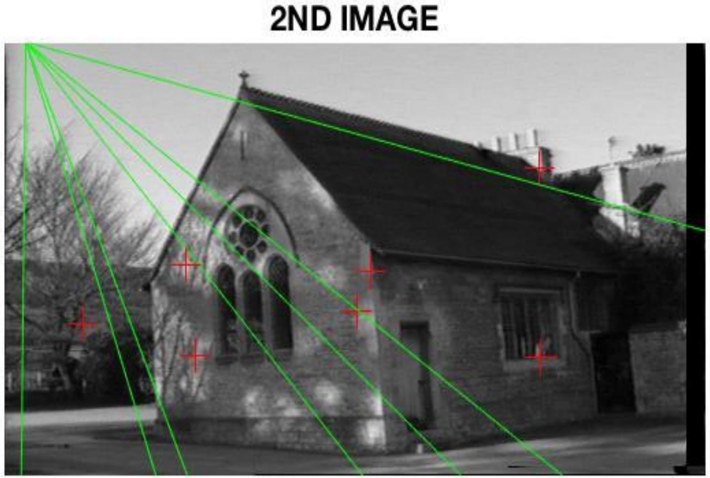
normF2 =

0.1324	-0.5261	0.0965
0.3515	0.0164	0.4669
0.1256	-0.5765	0.0800

This shows that normalized fundamental matrix is better as it has a better rank compared to unnormalized matrix.

Epipolar Lines generated using the unnormalized 8 point algorithm:





As observed, the matches are not good in comparison to normalized algorithm. This is due to diffiuclty in setting suitable threshold value to obtain inliers. Since, the points are far from epipolar line, the error is high.