# Report: Model Fitting

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## 1 Line Fitting

Line fitting was done on generated noisy points using least square method and RANSAC. The resulting plot can be seen in Figure 1. The black line shows the real model. Least square fit is shown in green while RANSAC fit is shown in red line. Clearly, RANSAC gives a better fir than the Least Square method as it is closer in resemblance to the real model.

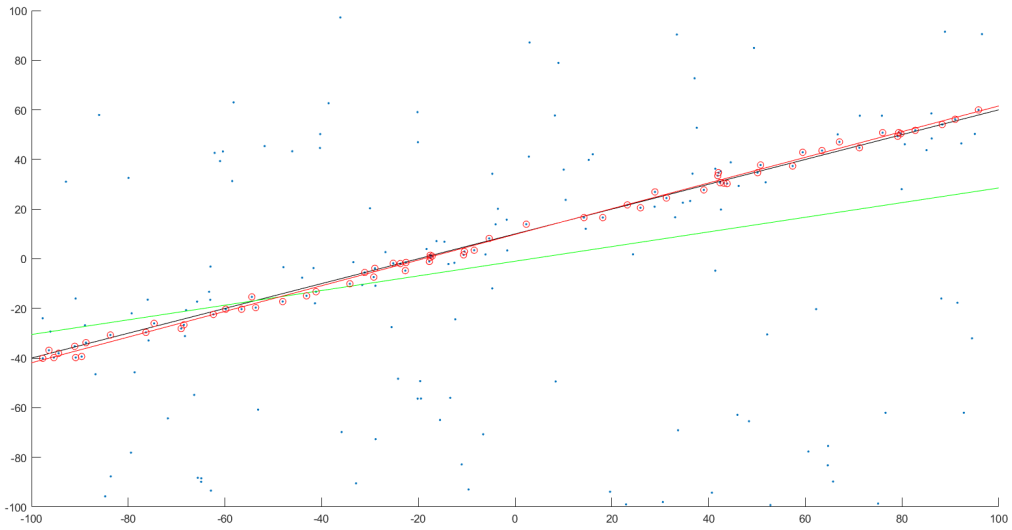



Figure 1: Real model (black); Least square (green), RANSAC (red) fit on sample points.

The error measured on the true inliers are:

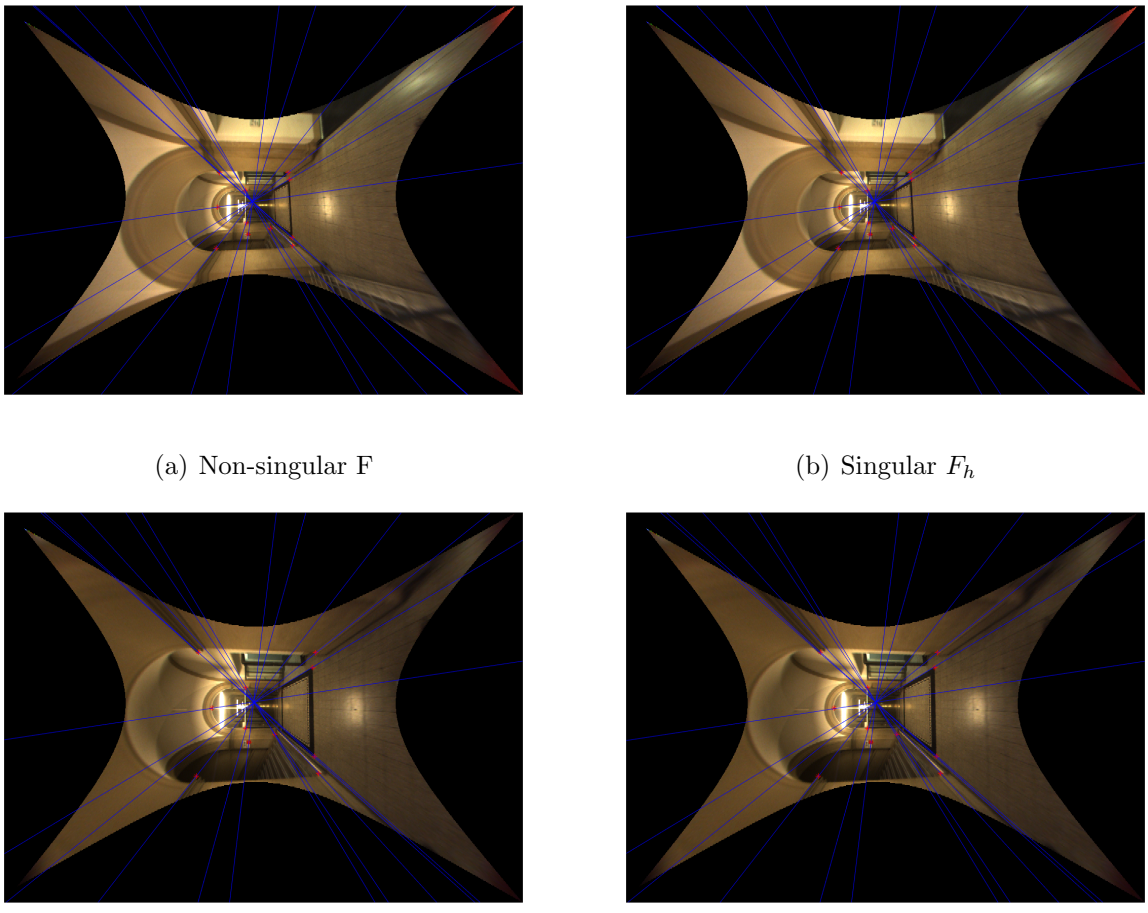
- Real model: 41.6710 units
- Least Square: 156.9632 units

- RANSAC: 43.3016 units

The error obtained in RANSAC fitting is very close to the real model and is significantly better than the least square solution.

## 2 Fundamental Matrix Estimation

Fundamental matrix estimation was done using 8 points algorithm. Given an image pair, 8 or more points were selected by manually clicking the corresponding interest points. These points were normalised using mean centring and scaling. A solution $f$ to the equation $Af = 0$ was found using Singular Value Decomposition on matrix A (as discussed in slides). Singularity constraint was imposed to find solution $f_h$ such that $det(f_h) = 0$.These matrices were rescaled for input image coordinates as $F$ and $F_h$ respectively. The epipoles and the epipolar lines for some pair of images are shown in Fig. 2-5:



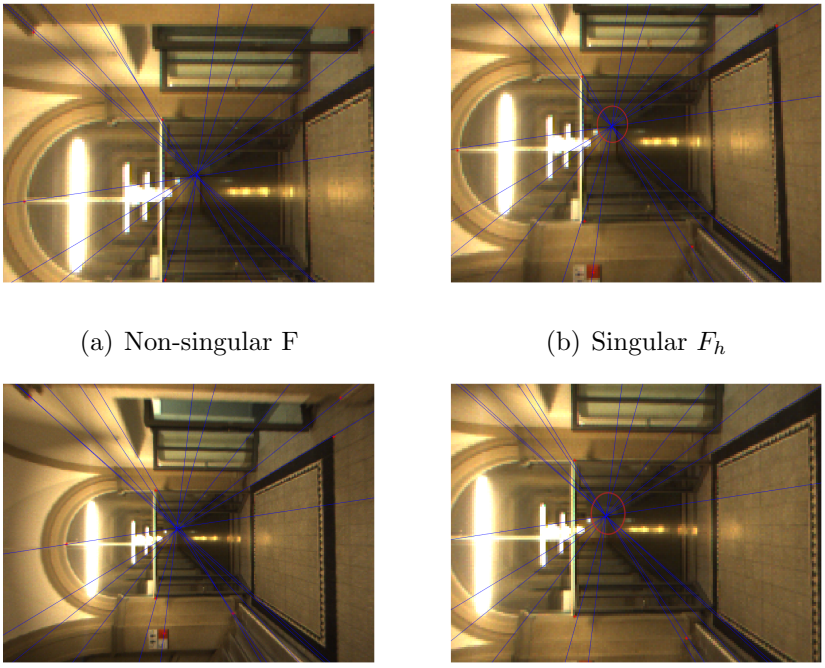
(a) Non-singular F

(b) Singular $F_h$

(c) Non-singular F

(d) Singular $F_h$

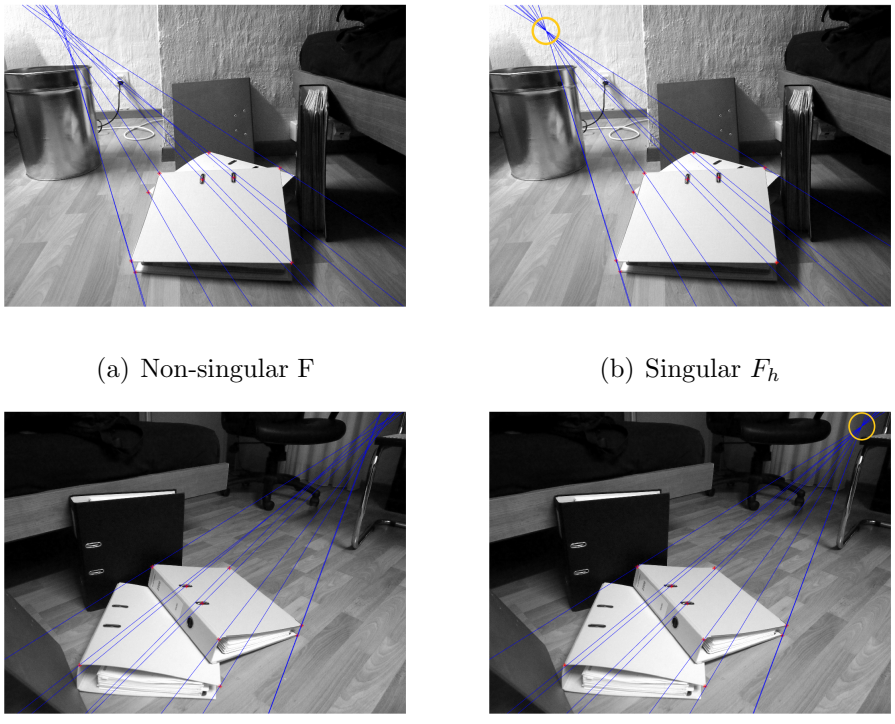
Figure 2: The epipolar lines obtained for $image_1(top)$ and $image_2(bottom)$



(a) Non-singular F (b) Singular $F_h$

(c) Non-singular F (d) Singular $F_h$

Figure 3: Clear intersection of epipolar lines is seen in the case of Singular $F_h$ (red circles)



(a) Non-singular F (b) Singular $F_h$

(c) Non-singular F (d) Singluar $F_h$

Figure 4: The epipolar lines obtained for $image_1(top)$ and $image_2(bottom)$. The epipoles obtained are shown in yellow circles.

(a) Non-singular F

(b) Singular $F_h$

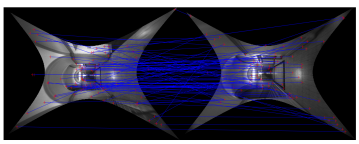
(c) Non-singular F

(d) Singluar $F_h$

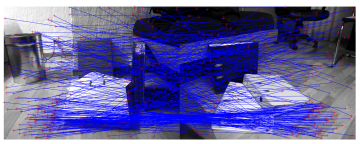
Figure 5: The epipolar lines obtained for $image_1(top)$ and $image_2(bottom)$. No epipoles were visible in these images, the epipolar lines were parallel.

# 3 Feature extraction and matching

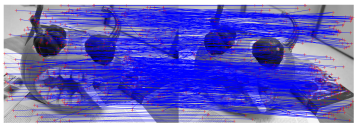
SIFT features were extracted and matched in the corresponding sample image pairs using VLFeat. The results obtained are shown in Fig.6:



(a) ladybug



(b) rect



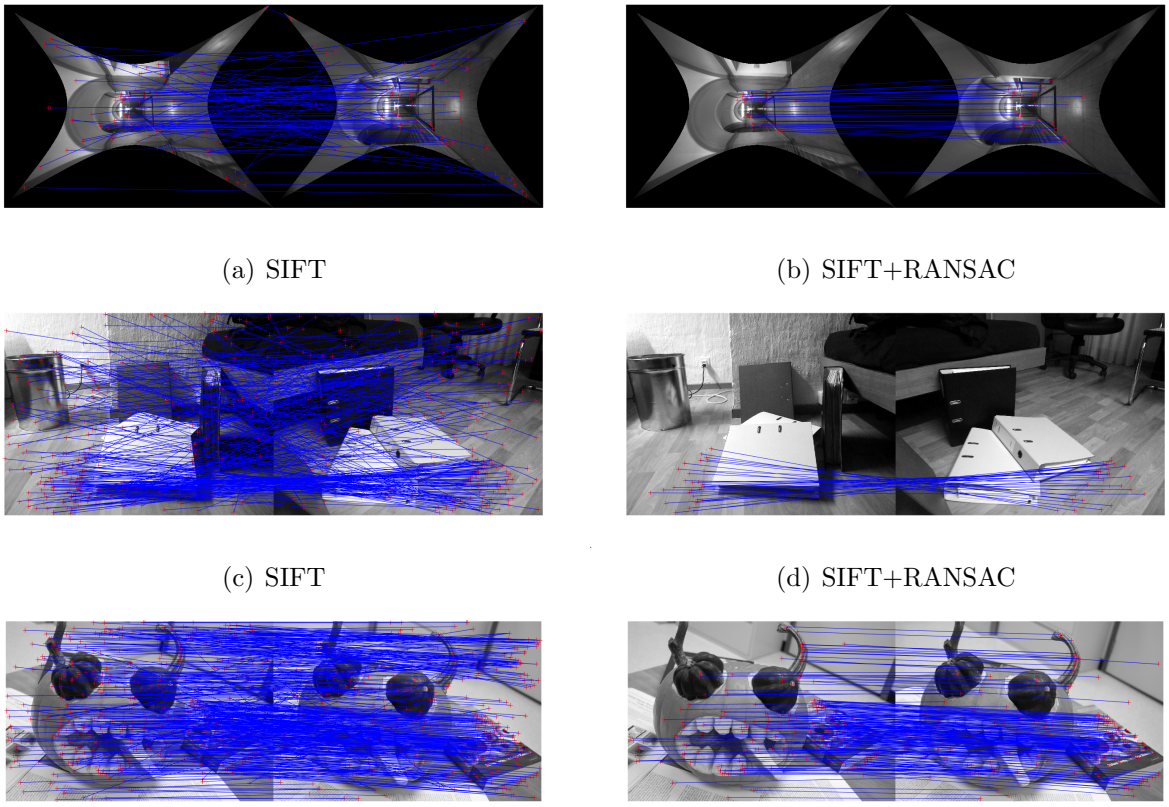
(c) pumpkin

Figure 6: The SIFT matching obtained in the case of sample pairs

# 4 Eight-point RANSAC

## 4.1 Simple RANSAC

We randomly selected 8 point correspondences in the given image pair and estimated fundamental matrix using them. Sampson distance was computed for all the points and their corresponding epipolar lines. Points with a distance value lesser than a given threshold were labelled as inliers. This process was repeated for 1000 iterations until the best model was obtained. The number of outlier matches was considerably reduced after this step and the comparison with the naive SIFT matches is shown in Figure 7 for each image pair.



(a) SIFT

(b) SIFT+RANSAC

(c) SIFT

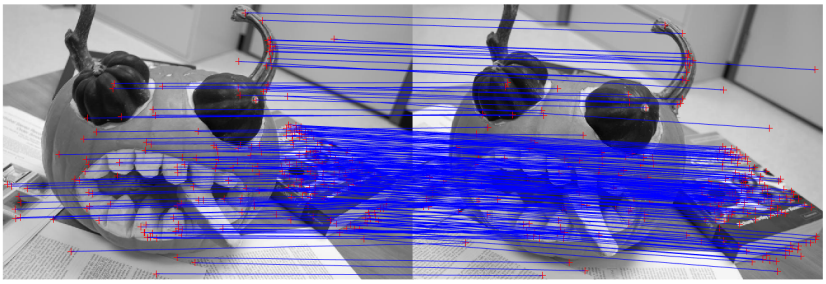
(d) SIFT+RANSAC

(e) SIFT

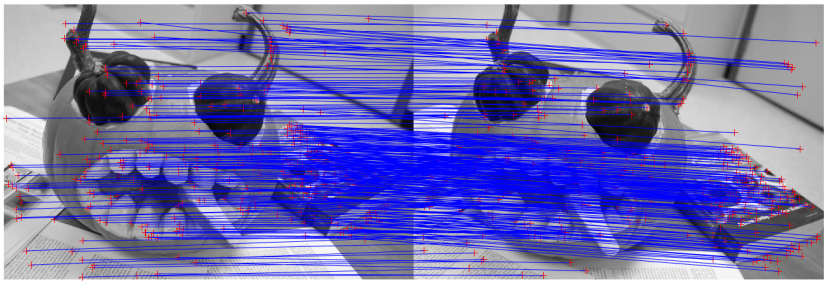
(f) SIFT+RANSAC

Figure 7: The number of outliers were reduced when best model was obtained using RANSAC and fundamental matrix estimation (threshold=2)

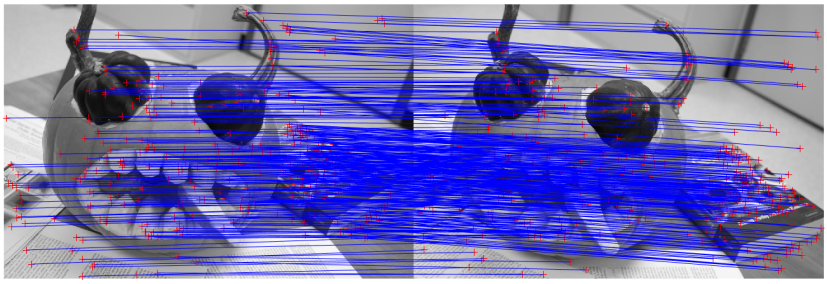
The threshold for inlier detection was varied and effect on matches is shown in Figure 8.



(a) thresh=2

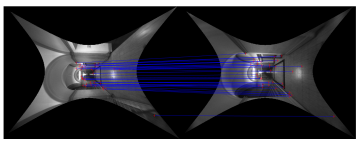


(b) thresh=5

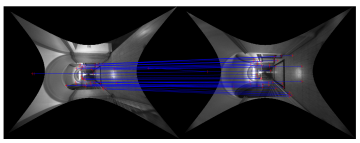


(c) thresh=10

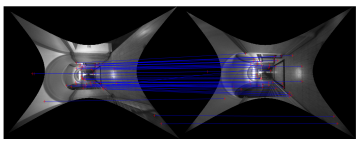
Figure 8: More matches were obtained on increasing threshold. Some outliers were detected in higher threshold models.



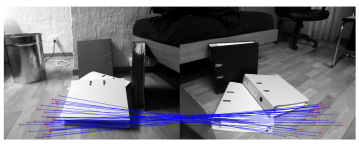
(a) thresh=2



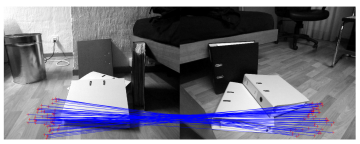
(b) thresh=5



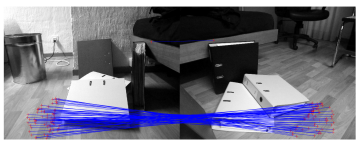
(c) thresh=10



(d) thresh=2

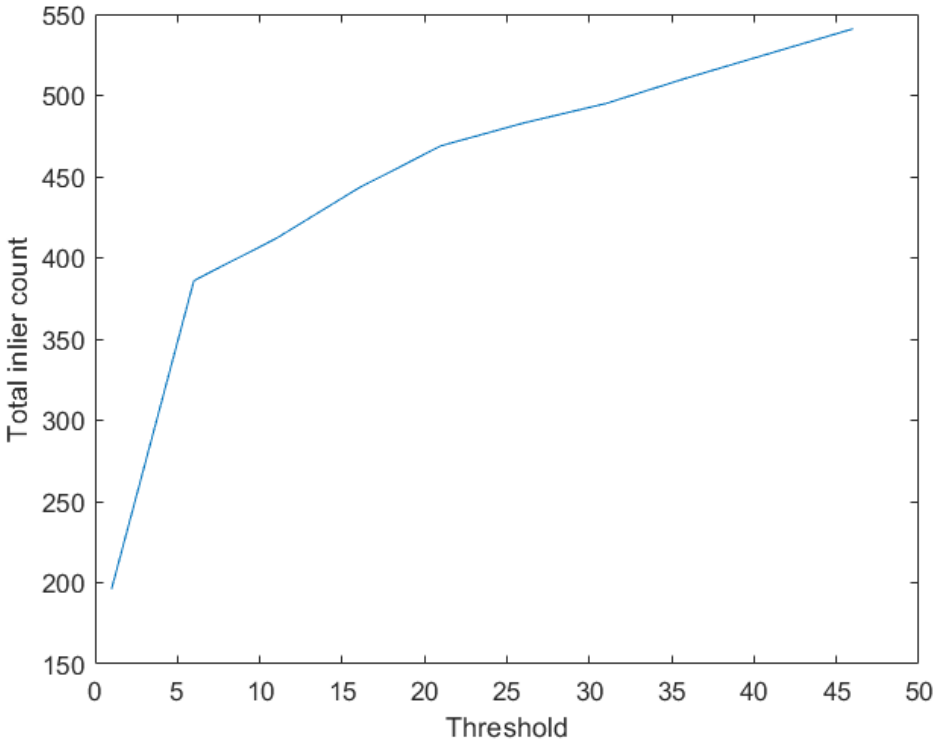


(e) thresh=5

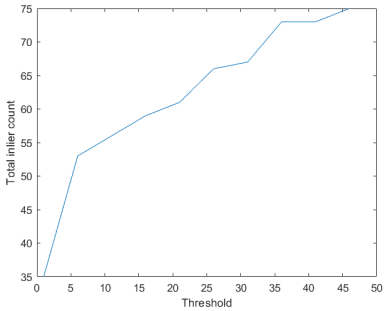


(f) thresh=10

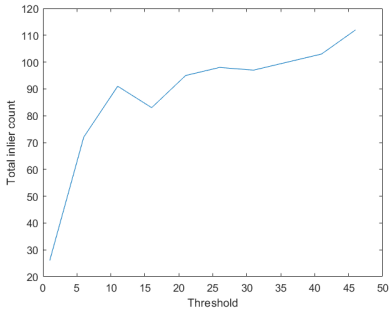
The count of total number of inliers increased with increasing threshold. The count value saturates after certain threshold (Fig. 9)




(g) pumpkin



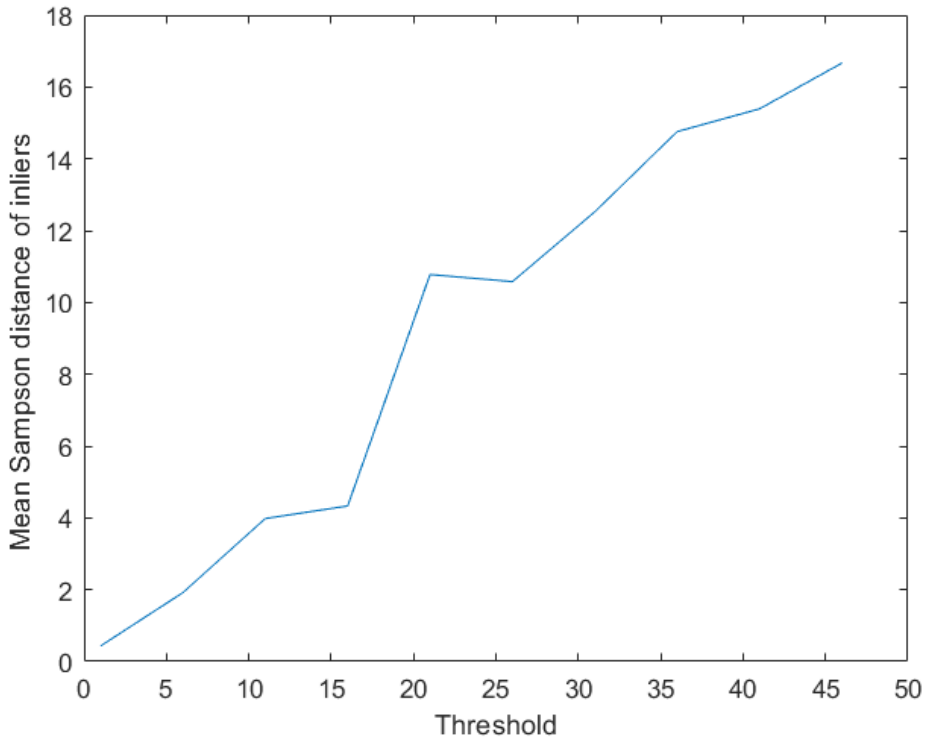

(h) ladybug



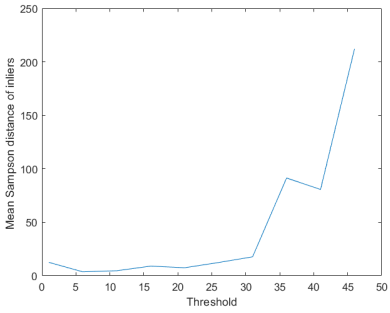

(i) rect

Figure 9: The number of inliers increased on increasing the threshold value. After a particular threshold value, this count tends to saturate and growth becomes gradual.

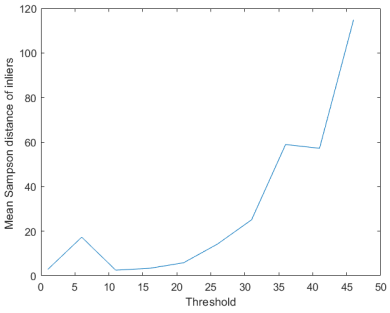
The mean Sampson error of the inliers showed some random variations with increasing threshold. The trend of the plots was increasing though.




(a) pumpkin




(b) ladybug




(c) rect

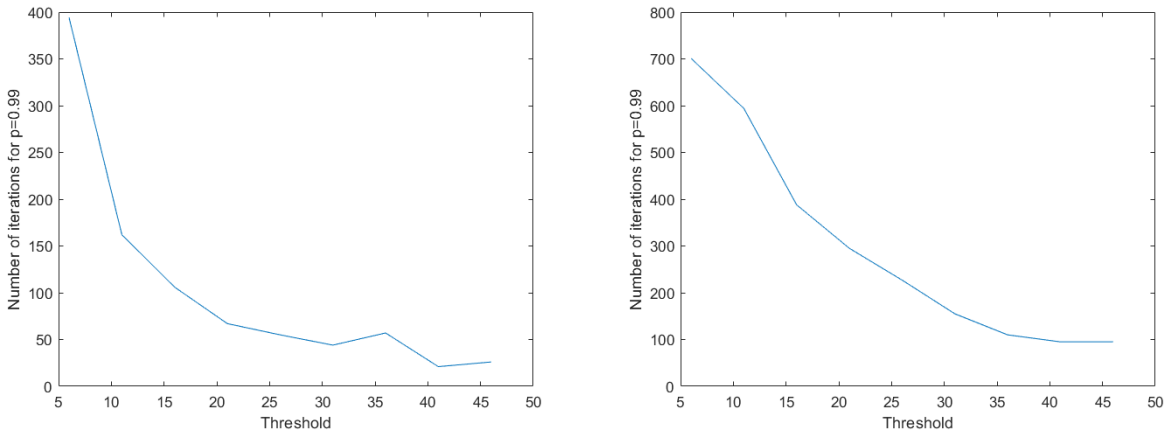
Figure 10: Although the variation in mean Sampson distance of inliers is zig-zag, the overall trend was increasing with increase in the value of threshold.

## 4.2 Adaptive RANSAC

In order to increase the efficiency of the above method, the RANSAC iteration was terminated after M trials when the probability of atleast one of the 8 random samples from M trials being free from outliers exceeded 0.99. The value of M for different image pairs:

- ladybug: M=799 for thresh=5
- pumpkin: M=471 for thresh=5
- rect: M=140792 for thresh=5

The variation of M with the threshold is shown in Figure 11.




(a) pumpkin (b) ladybug

Figure 11: Lesser number of trials were required for achieving p=0.99 when the threshold was increased.

# 5 Discussion

- Fit obtained through RANSAC resembles the true fit better than the Least Square fit. The error measured on true inliers was considerably lesser for RANSAC.
- Least square fit is susceptible to noise in data while RANSAC handles outlier points efficiently.
- The epipolar lines obtained from non-singluar fundamental matrix did not meet at a point. Intersection of epipolar lines was clear and distinct in the case of singular fundamental matrix.
- SIFT feature-based matching generated a lot of outlier matches.

- RANSAC fit along with fundamental matrix estimation improved the performance of matching of SIFT features. Wrong matches were rejected as outliers based on a threshold value.
- Increasing threshold increased the number of inliers but at the risk of introducing few false positives.
- Increase in count of inliers saturates after certain threshold.
- The mean Sampson distance of inliers, in general, increases with threshold.
- The number of trials to attain p=0.99 in the case of adaptive RANSAC decreases with increase in threshold.