State Estimation - Assignment 4

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1 Question 1

The objective of this course is to learn how to distinguish inliers from outliers in statistical inference. For more information, refer to 'Ch 5.3 Handling Outliers' of your textbook.

Given the source and destination 2d points below, compute a homography that maps the source points to the destination. a minimum of 10 inliers needed to be detected by the RANSAC algorithm. The re-projection error of the inliers need to be less than 0.005.

To learn about homography, see

https://www.cs.toronto.edu/ lindell/teaching/420/slides/lecture8.pdf

or read 'Multiple View Geometry in Computer Vision' textbook. Report your normalized homography transformation. Write your code in Python, do not use OpenCV. Plot a scatter plot, showing inliers (marked by o) and outliers (marked by x), where inliers of source and destination are connected via a line. Include the plot in your report. You should only use the following modules:
import numpy as np
import random
import matplotlib.pyplot as plt

Answer:

The RANSAC (Random Sample Consensus) algorithm is a robust method for estimating parameters of a mathematical model from a set of observed data points that may contain outliers. It is commonly used in computer vision and image processing tasks, such as estimating geometric transformations like the homography matrix.
Here's an explanation of the RANSAC algorithm used in the code:

1. Randomly select a minimal subset of data points from the input data. In the case of estimating a homography matrix, the minimal subset typically consists of four corresponding points: two from the source image and two from the destination image.
2. Compute the homography matrix using the selected subset of points. This is done by solving a set of linear equations, which is stated here.

$$\begin{bmatrix} x_i & y_i & 1 & 0 & 0 & 0 & -x'_i x_i & -x'_i y_i & -x'_i \\ 0 & 0 & 0 & x_i & y_i & 1 & -y'_i x_i & -y'_i y_i & -y'_i \end{bmatrix} \begin{bmatrix} h_{00} \\ h_{01} \\ h_{02} \\ h_{10} \\ h_{11} \\ h_{12} \\ h_{20} \\ h_{21} \\ h_{22} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

3. Use the computed homography matrix to transform the remaining data points from the source image to the destination image.

4. Measure the error or distance between the transformed points and their corresponding actual points in the destination image. This error metric is often the Euclidean distance.

5. Determine the inliers: Consider the transformed points as inliers if their error is below a predefined threshold. These inliers are potential matches that fit the estimated transformation.

6. Repeat steps 1-5 a sufficient number of iterations (in the code, 1000 iterations are used) and keep track of the set of inliers that provides the best fit.

7. After the iterations, return the set of inliers that produced the highest number of inliers.

The RANSAC algorithm iteratively repeats the process of selecting random subsets, computing the transformation, measuring the error, and updating the set of inliers. By repeatedly sampling and fitting the model, RANSAC robustly estimates the transformation parameters while mitigating the impact of outliers.

In the given code, the **find_inliers** function implements the RANSAC algorithm by randomly selecting subsets of four points, computing the homography matrix, measuring the error using the re-projection error, and updating the set of inliers based on the threshold. The best set of inliers is returned as the final result.

In Figure 11, the plotted dots represent the source and destination points. Here's a breakdown of the different markers used:

Dots marked with 'x': These represent the outlier points. They correspond to the source and destination points that were not identified as inliers by the RANSAC algorithm.

Dots marked with 'o': These represent the inlier points. They correspond to the source and destination points that were identified as inliers by the RANSAC algorithm. These points are considered to be part of the consistent set that fits the homography transformation.

The lines connecting the inlier points represent the correspondence between the source and destination points based on the computed homography matrix. These lines visually illustrate the transformation from the source image to the destination image.

The scatter plot helps visualize the inliers and outliers, allowing you to see the effectiveness of the RANSAC algorithm in identifying the points that fit the homography transformation.

In Figure 2, the normalized homography matrix is shown.

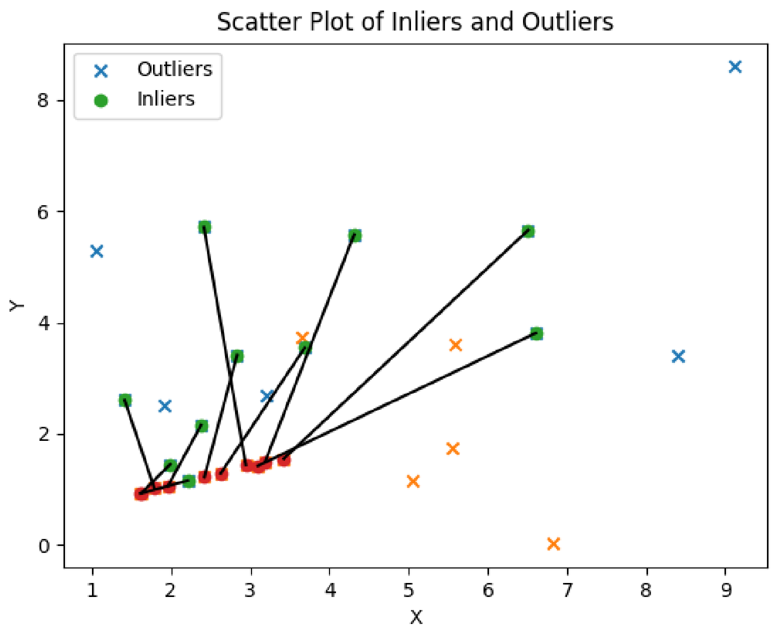

Figure 1: Marker 'x' represents the outlier points. Marker 'o' represents the inlier points.

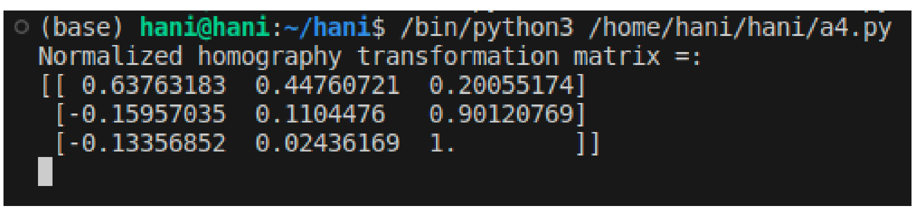

Figure 2: Normalized homography transformation matrix