CS 5330 Programming Assignment 3

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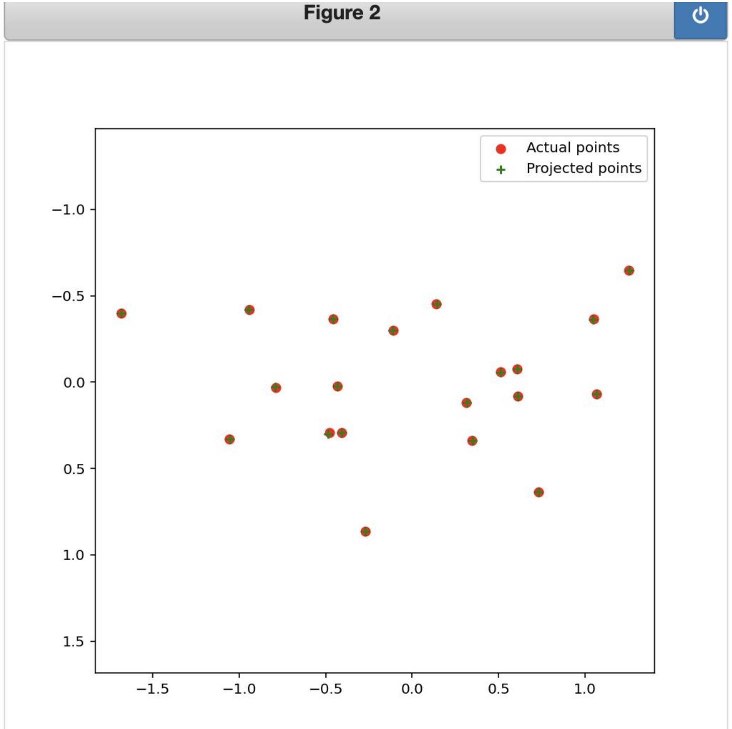
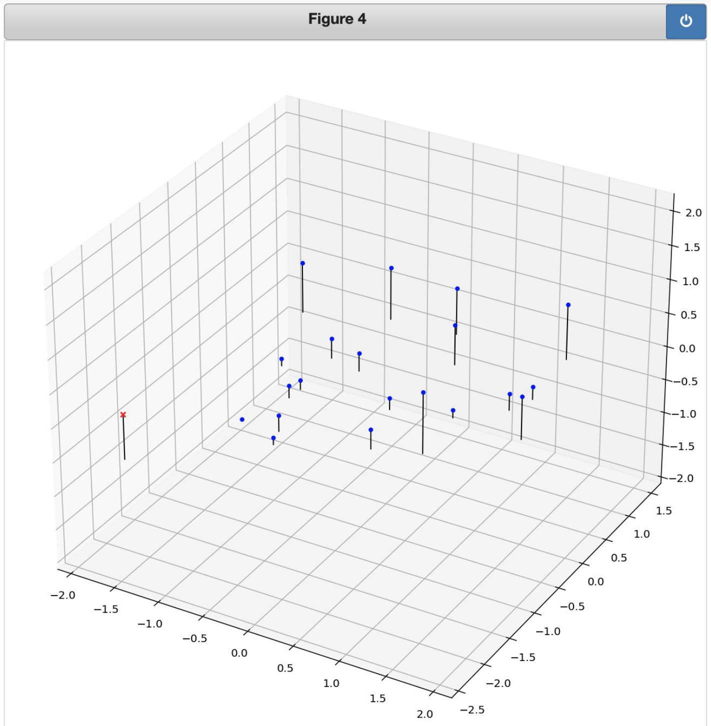
Part 1: Projection matrix

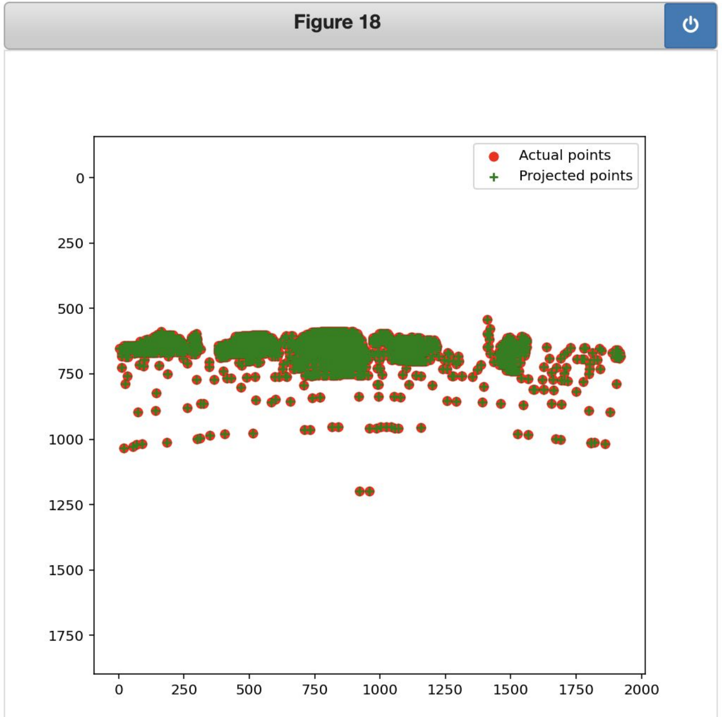


Projected 3D and Actual 2D points CCB

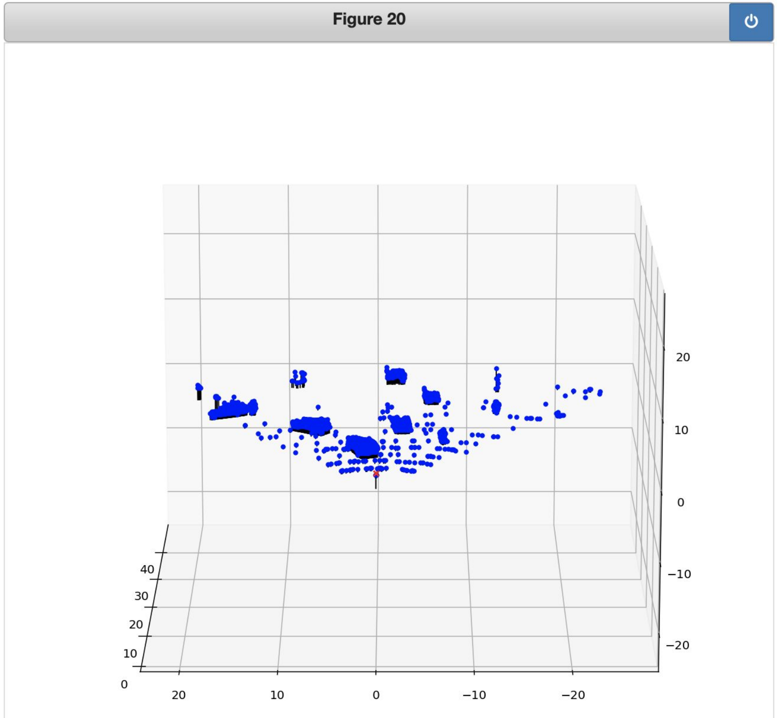


CCB Camera Center Visualization

Part 1: Projection matrix



Projected 3D and Actual 2D points Argoverse



Argoverse Camera Center Visualization

Part 1: Projection matrix

What two quantities does the camera matrix relate?

- Rotation and translation of one camera view to the other

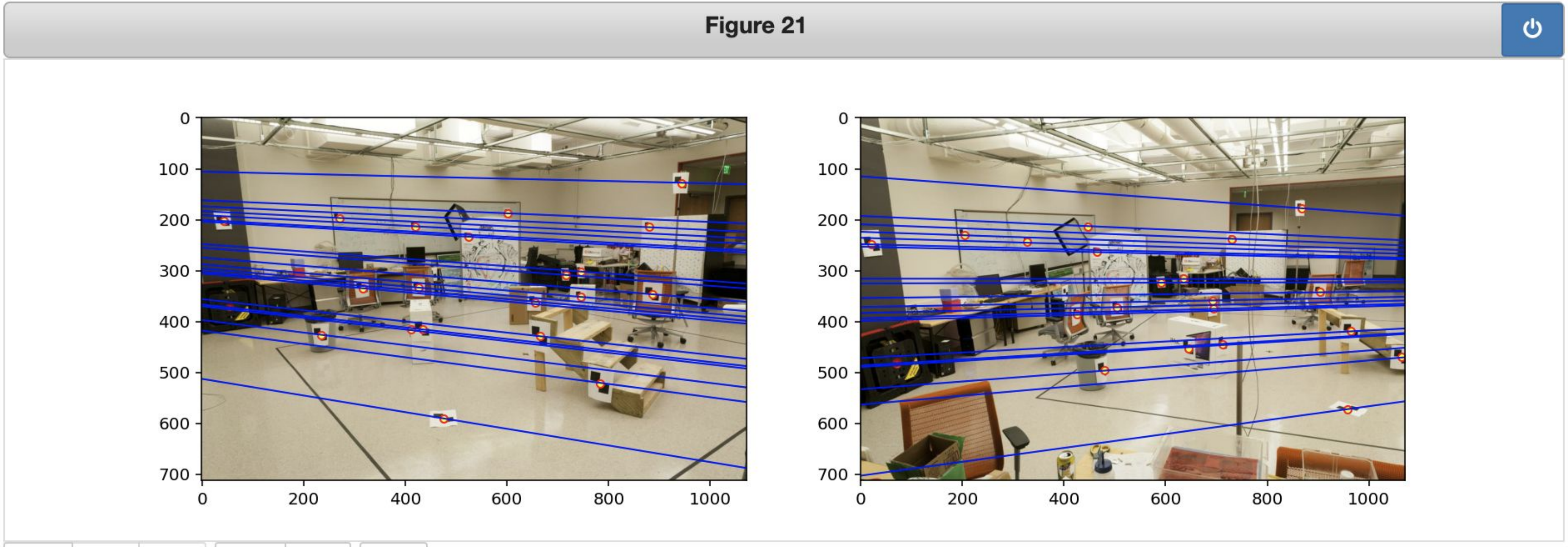
What quantities can the camera matrix be decomposed into?

- The intrinsic calibration matrix and the transformation matrix

List any 3 factors that affect the camera projection matrix.

1. Rotation
2. Translation
3. Focal length
4. Camera center location

Part 2: Fundamental matrix



Visualization of epipolar lines on the CCB image

Part 2: Fundamental matrix

Why is it that points in one image are projected by the fundamental matrix onto epipolar lines in the other image?

- Points in one image are projected onto epipolar lines in the other image because the fundamental matrix defines the mapping of corresponding points. It maps a point to a 1D line in the other image, thus making it easier to search for point correspondences (1D line vs 2D plane). This is also done to help assess an error that correlates the image point pairs together. Points in one image, projected by the fundamental matrix onto epipolar lines in the other image will be close in distance, and therefore will be correlated point pairs. This helps in evaluating camera centers and geometry needed to analyze a moving system.

What happens to the epipoles and epipolar lines when you take two images where the camera centers are within the images? Why?

- If the camera centers are within the images, the epipoles would be coincident with the camera centers because that would be the location of the intersection of the baseline and the image planes. This would also mean the epipolar lines would become length 0, because the projection of points, epipoles, and camera center would all be the same point.

Part 2: Fundamental matrix

What does it mean when your epipolar lines are all horizontal across the two images?

- It means the image planes are parallel to each other and to the baseline (stereovision)

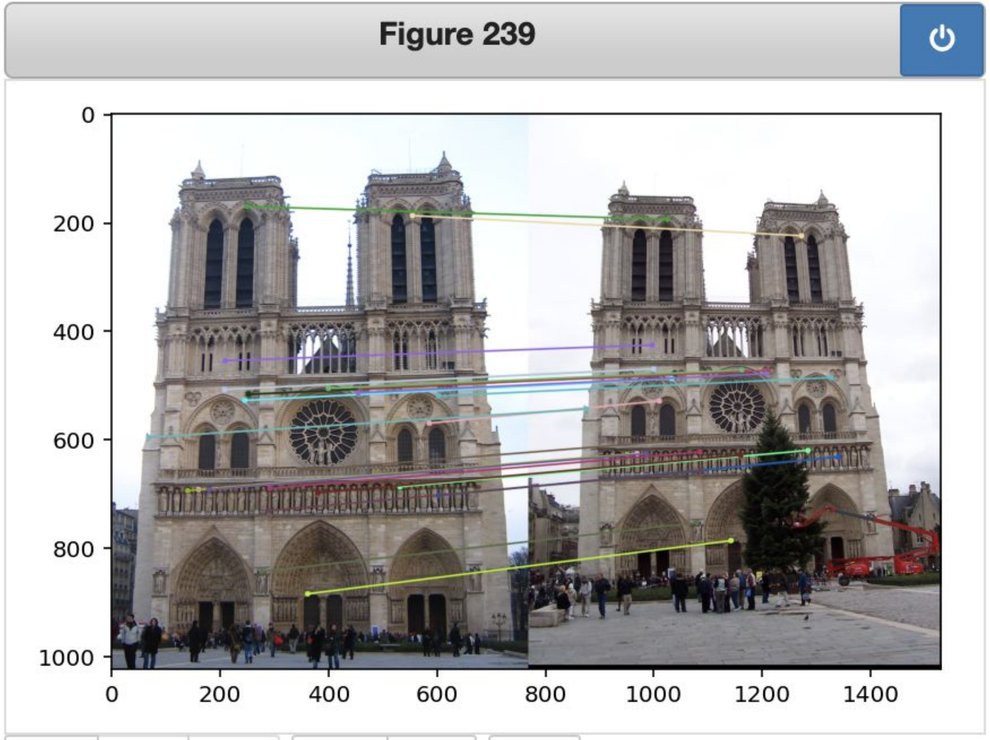
Why is the fundamental matrix defined up to a scale?

- It is defined up to a scale because since the fundamental matrix projection between two points is equal to zero, any scale applied has the ability to be factored out.

Why is the fundamental matrix rank 2?

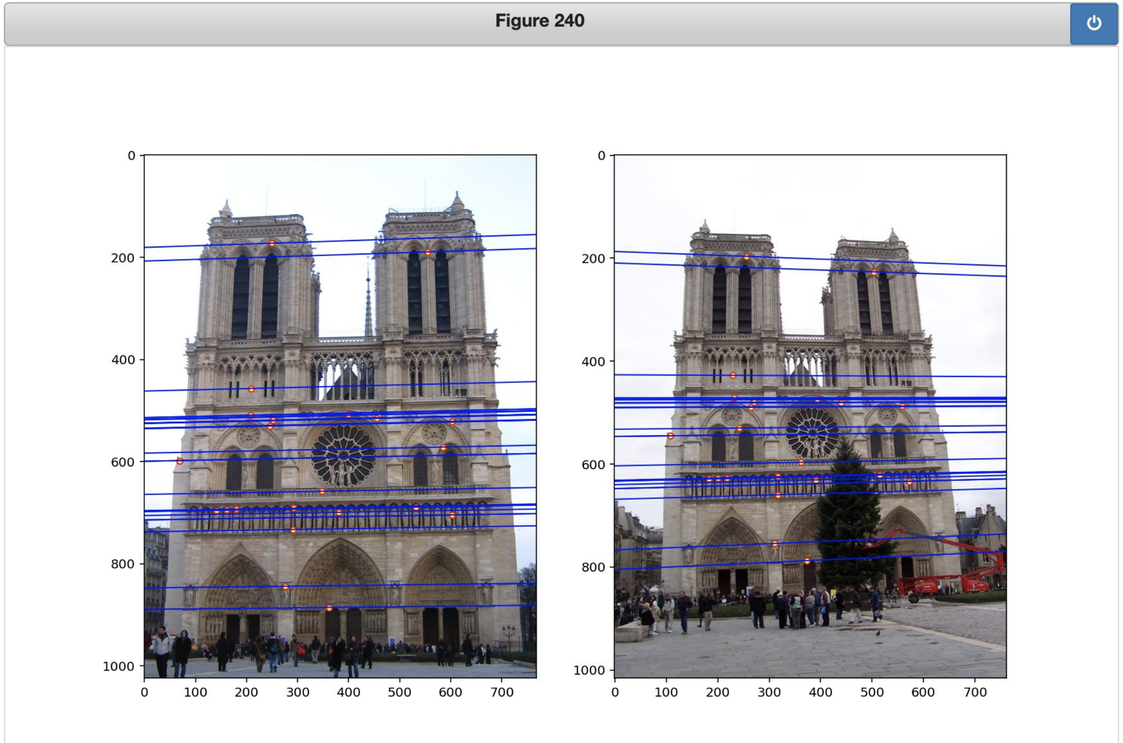
- The rank of a fundamental matrix is 2 because it represents the projection of an image plane to a point. The image plane is 2-dimensional, and the point is 1-dimensional, so therefore the rank of the projection between the two must be 2.

Part 3: RANSAC



Visualization of correspondences on Notre Dame after RANSAC

Part 3: RANSAC



Visualization of epipolar lines on the Notre Dame image pair

Part 3: RANSAC

How many RANSAC iterations would we need to find the fundamental matrix with 99.9% certainty from your Mt. Rushmore and Notre Dame SIFT results assuming that they had a 90% point correspondence accuracy?

RANSAC(0.99, 8, 0.9) = 8 iterations

One might imagine that if we had more than 9 point correspondences, it would be better to use more of them to solve for the fundamental matrix. Investigate this by finding the # of RANSAC iterations you would need to run with 18 points.

RANSAC(0.99, 9, 0.9) = 9 iterations

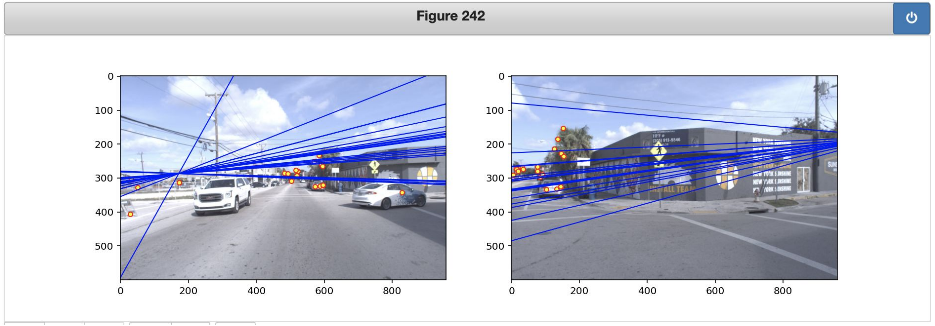
RANSAC(0.99, 18, 0.9) = 28 iterations

This would be better because it leads to a larger number of iterations than data points. The more iterations completed, the higher chance there is to calculate a fundamental matrix with less outliers/higher accuracy.

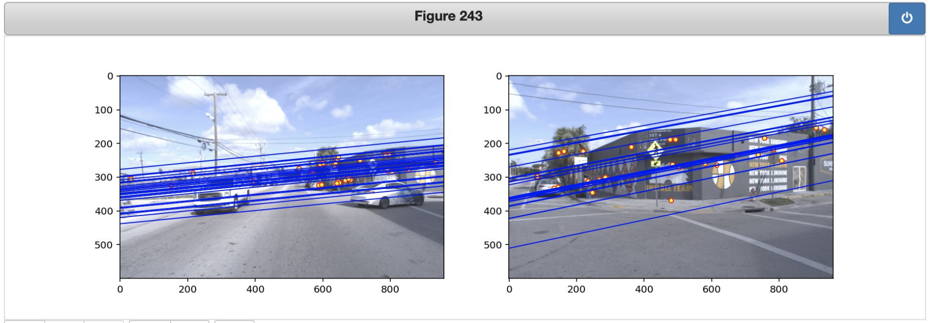
If our dataset had a lower point correspondence accuracy, say 70%, what is the minimum # of iterations needed to find the fundamental matrix with 99.9% certainty?

RANSAC(0.99,8,0.7) = 77 iterations

Part 4: Performance comparison



Visualization of epipolar lines on the Argoverse image pair using the linear method



Visualization of epipolar lines on the Argoverse image pair using RANSAC

Part 4: Performance comparison

Describe the different performance of the two methods.

- The differences shown include a large change in the epipolar lines between the image planes. This is due to different calculations of the camera centers and orientations, thus showing different epipolar lines between corresponding points.

Why do these differences appear?

- These differences appear because the two methods used find results based off of different underlying assumptions. RANSAC uses a different method of estimating the fundamental matrix compared to the linear system, thus changing the way in which points are mapped to epipolar lines. The two methods also use different methods of extracting corresponding points, which will also lead to differing results.

Which one should be more robust in real applications? Why?

- The RANSAC method should be more robust in real applications. In any application, there will be outlying data points that should be ignored when fitting a final model to the dataset. RANSAC is the best method that ignores these outliers and best fits a model to a specific data set with a desired accuracy.

Part 5: Visual odometry

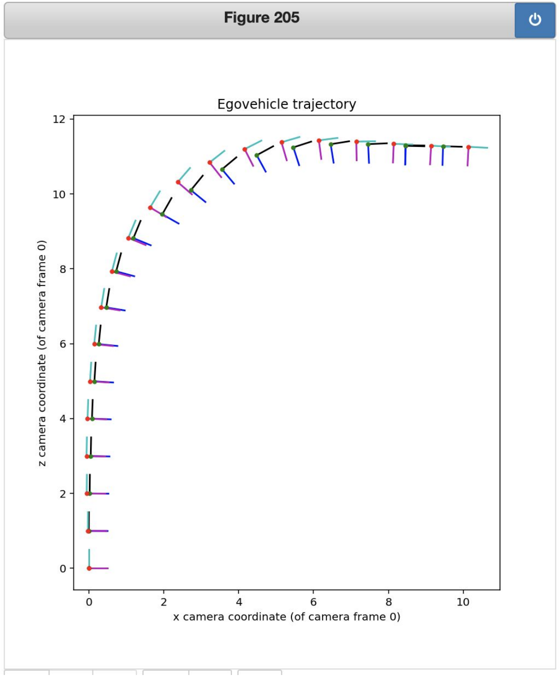
How can we use our code from part 2 and part 3 to determine the “ego-motion” of a camera attached to a robot (i.e., motion of the robot)?

- Our code from part 2 recovers the fundamental matrix, which helps project two image planes to create correspondences between them and helps analyze their motion in relation to each other. Our code from part 3 recovers an estimation of the fundamental matrix using RANSAC, optimizing this fundamental matrix by using a more accurate set of points, so that it best fits and defines the set of data.

In addition to the fundamental matrix, what additional camera information is required to recover the ego-motion?

- We will need the intrinsic matrices of both cameras, including focal length and camera optical position.

Part 5: Visual odometry



Plot of the camera’s trajectory through time