CS x476 Project 5

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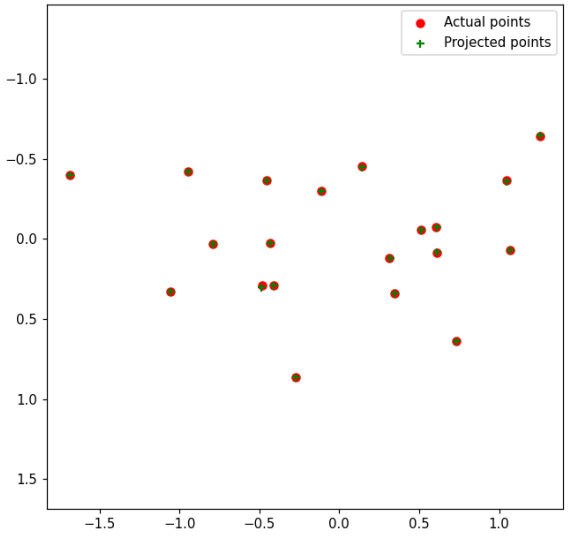
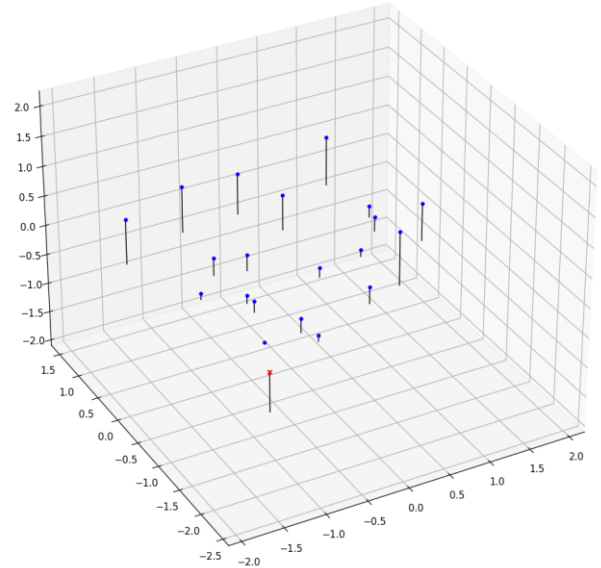
[Section - 6476]

Part 1: Projection matrix

[insert visualization of projected 3D points and actual 2D points for the CCB image we provided here]

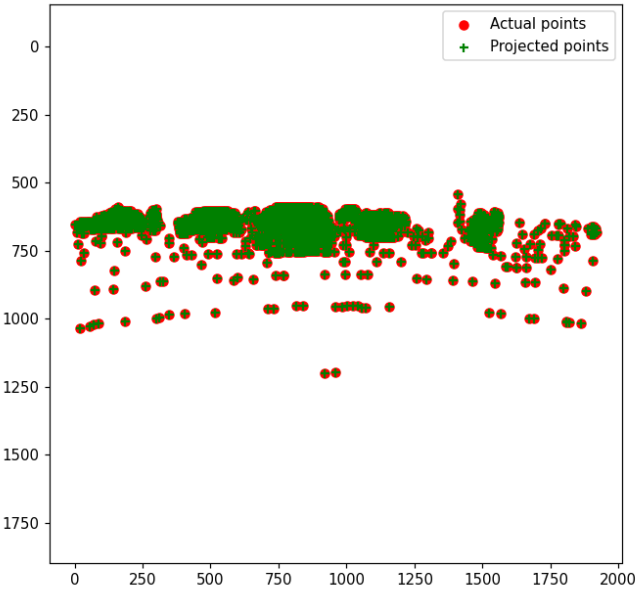


[insert visualization of camera center for the CCB image here]

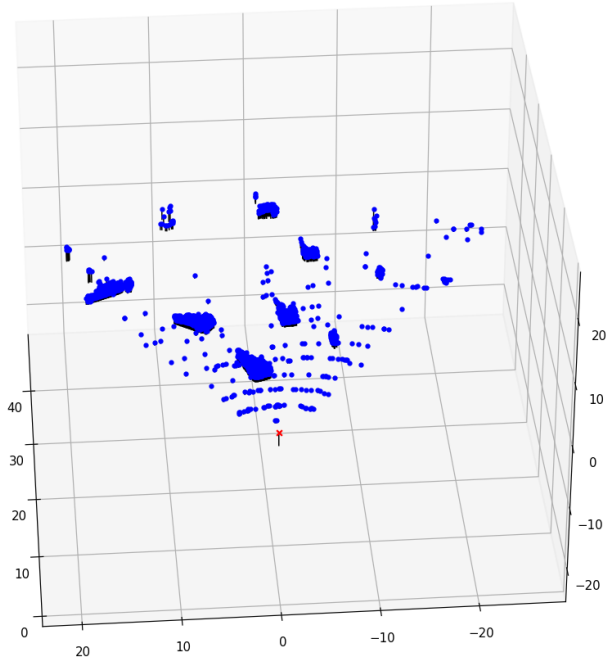


Part 1: Projection matrix

[insert visualization of projected 3D points and actual 2D points for the Argoverse image we provided here]



[insert visualization of camera center for the Argoverse image here]



Part 1: Projection matrix

[What two quantities does the camera matrix relate?]

3D points and 2D image points

[What quantities can the camera matrix be decomposed into?]

P= K[R|t]

[List any 3 factors that affect the camera projection matrix.]

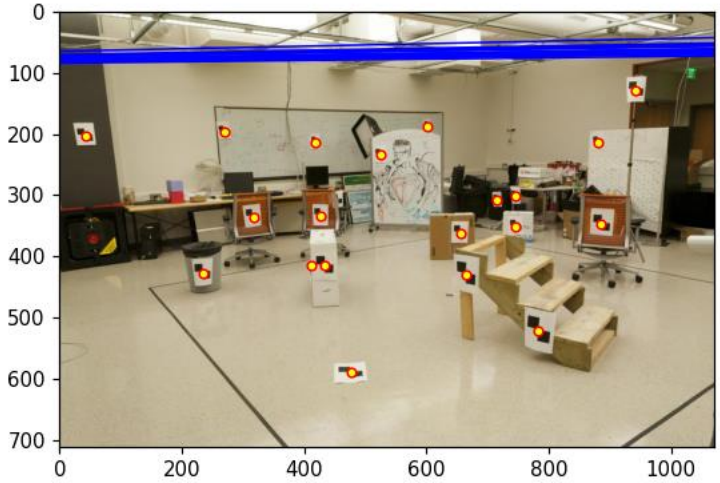
The intrinsics of camera.

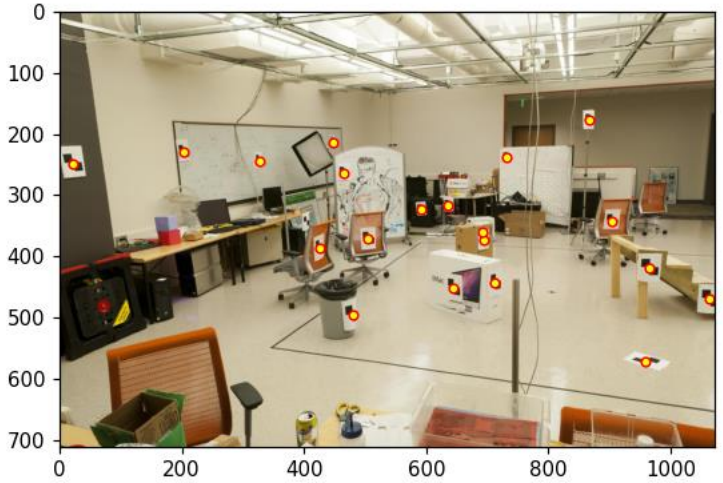
The rotation of camera frame from the world frame.

The transition of camera frame from the world frame.

Part 2: Fundamental matrix

[insert visualization of epipolar lines on the CCB image pair]





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?]

Because epipolar lines are the intersection of epipolar plane and image plane. The epipolar plane is the plane defined by the two camera centers and a 3D point. The projection of the 3D point must lie in epipolar plane and the image. Then the projection point must lie in the epipolar line.

[How many minimum points do we need to estimate the Fundamental matrix. Explain?]

We need 8 correspondances of points to solve the Fundamental matrix. Because we can assume the f33 of Fundamental matrix as 1. So we still have 8 parameters to solve. Then we'll need 8 equations, which needs 8 correspondances of points to form.

Part 2: Fundamental matrix

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

It means the two image planes are parallel.

[Why is the fundamental matrix defined up to a scale?] (Hint: you can reason using the equation for F)

X’FX = 0. So there’s actually many solutions of F. If we have a valid solution F*, then F’ = aF* could also be the solution.

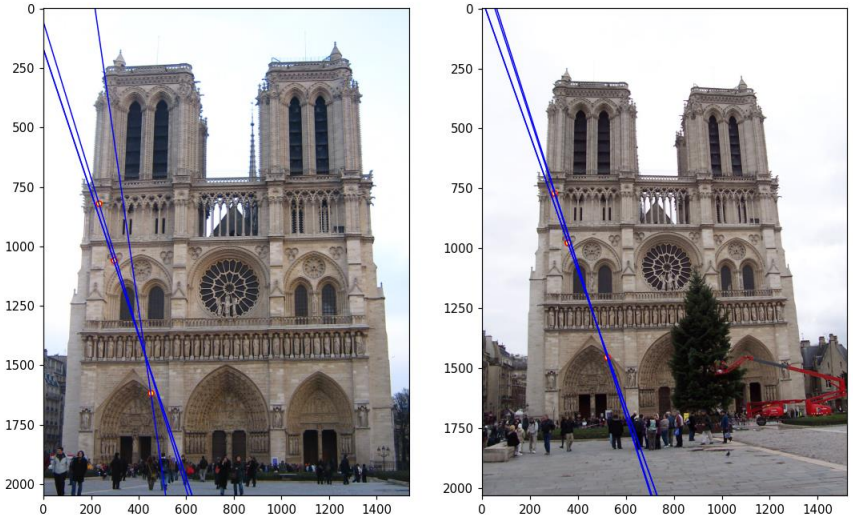
[Why is the fundamental matrix rank 2?]

Because epipoles lie on the epipolar line, which makes the epipole (e^T)F = 0. So F has a nullspace which is not just zero vector. F is rank deficient. F is just rank 2.

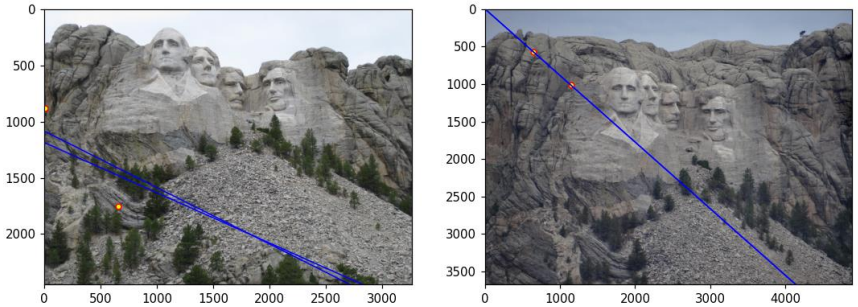
Part 4a: Visualize Fundamental Matrices

(EC for 4476, required for 6476)

[insert visualization of epipolar lines for Notre Dame]



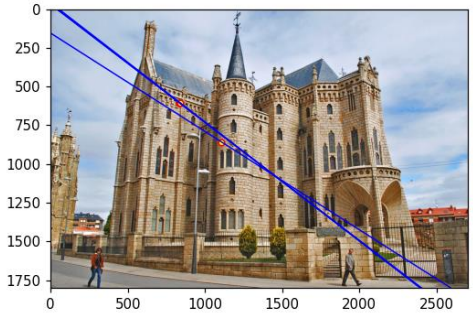
[insert visualization of epipolar lines for Mount Rushmore]

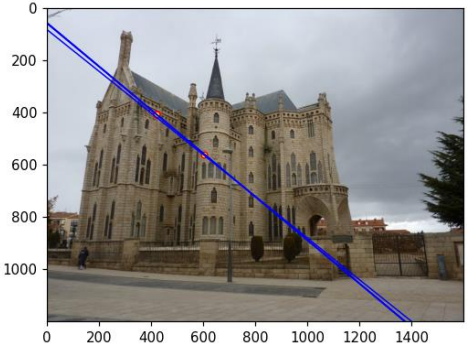


Part 4a: Visualize Fundamental Matrices

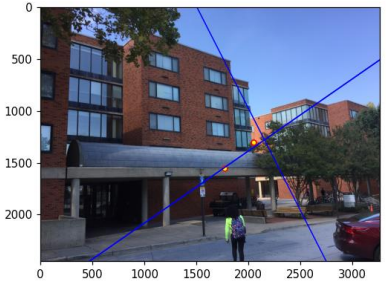
(EC for 4476, required for 6476)

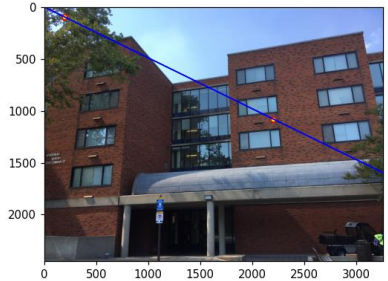
[insert visualization of epipolar lines for Gaudi]





[insert visualization of epipolar lines for Woodruff]





Part 4a: Visualize Fundamental Matrices

(EC for 4476, required for 6476)

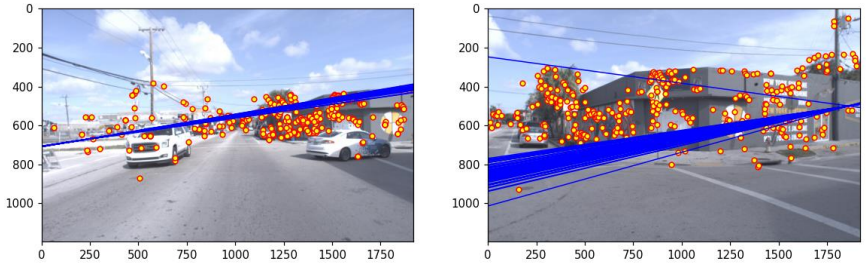
[Explain any one difference you noticed in the feature detection/matching for these 4 pair of images]

Some of the matches are not right. For example, the matches of Mount Rushmore and Woodruff. We can tell by our eyes it doesn’t match the same features, which makes the projection of points in one image far from their epipolar lines. But the match of Notre Dame and Gaudi seems right so all the points lie in epipolar lines.

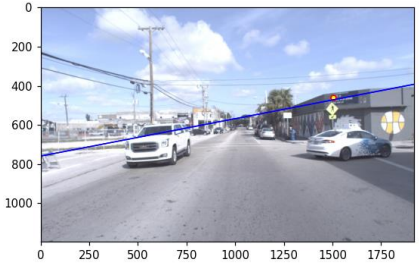
Part 4b: Performance comparison

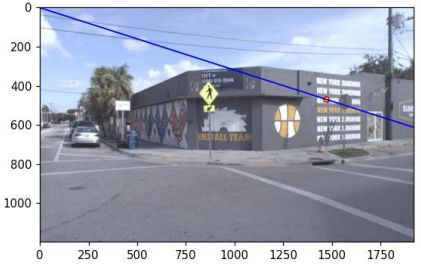
(EC for 4476, required for 6476)

[insert visualization of epipolar lines on the Argoverse image pair using the linear method]



[insert visualization of epipolar lines on the Argoverse image pair using RANSAC]





Part 4b: Performance comparison

(EC for 4476, required for 6476)

[Describe the different performance of the two methods.]

The linear method has lots of points far from their epipolar line. While the RANSAC has all the points lying in their epipolar line. The RANSAC performs better.

[Why do these differences appear?]

Because the linear method takes all matches as inliers, which contains more noise. But the RANSAC can find out which matches are outliers.

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

RANSAC should be more robust in real application. Because there are lots of noises like mismatch in real application and RANSAC could deal with it.

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)?]

We can calculate calculate the Fundamental matrix of two consecutive images, which is the Fundamental matrix of camera in two continuous positions. Then we can use the fundamental matrix to calculate the essential matrix and get the rotation and transition of the two positions. The rotation and transition is the motion of the camera.

[How many outputs (poses) does the get_visual_odometry function return?]

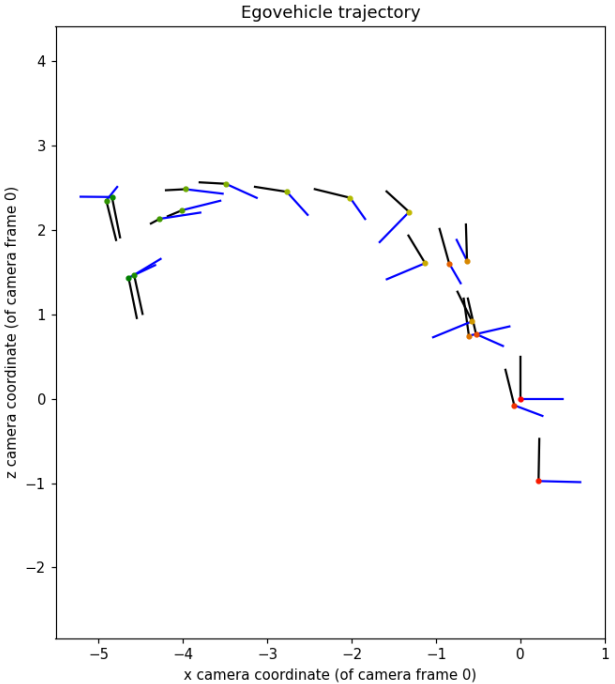
19

[How many outputs (poses) does the compute_absolute_poses function return?]

20

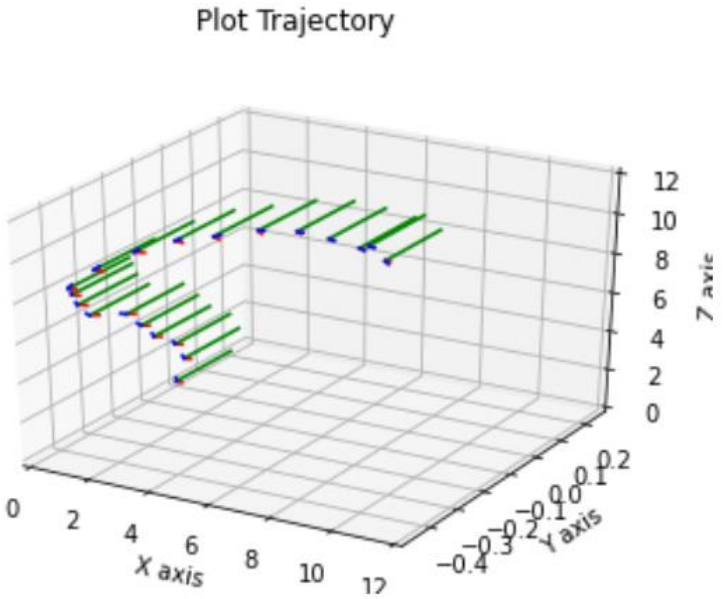
Part 5: Visual odometry

[Attach a plot of the camera's trajectory through time]



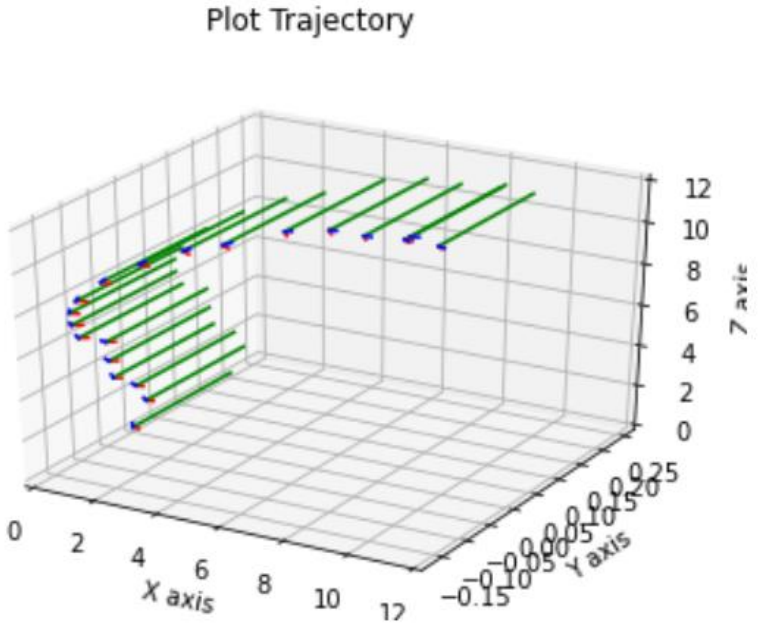
Part 6: gtSAM (EC for Grad Students Only, no credit for UG)

[Attach a plot of the camera's trajectory through time as computed using gtSAM w/o skip connections]



Part 6: gtSAM (EC for Grad Students Only, no credit for UG)

[Attach a plot of the camera's trajectory through time as computed using gtSAM with skip connections]



Part 6: gtSAM (EC for Grad Students Only, no credit for UG)

[Explain the differences in the individual factor errors in both the results (optimized_poses1 & optimized_poses2)]

The optimized_poses1 errors of non-skip factors, factor 0-19, are all zero, because optimized_poses1 only considered non-skip factors and optimized them. But the optimized_poses1 errors of skip factors, factor 20-37, are very large, because optimized_poses1 didn’t take them into consideration when optimizing. But the optimized_poses2 errors of all factors are around 1, because it considered all 0-37 factors when optimizing.

[Of all the factor errors, how many of these correspond to skip connections?]

18 for each optimized_poses. 36 for all two optimized_poses.