CS543/ECE549 Assignment 4

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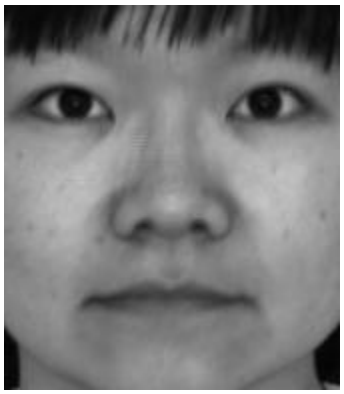
Part 1 Shape from Shading:

A: Estimate the albedo and surface normals

1) Insert the albedo image of your test image here:
   YaleB05:



   YaleB01:

   YaleB02:

YaleB07:

2) What implementation choices did you make? How did it affect the quality and speed of your solution?
   For this assignment, I feel implementation choices were mostly guided by prescription in the assignment description, but I took some decisions that aimed to optimize quality and computational efficiency of the result. For example, after extracting surface normals, I normalize them to unit length. Also, by applying vectorized reshaping and matrix operations, computational overhead is reduced. For example, processing the pixel's data in a single call instead of iterating over them individually. This decision increased the quality and speed of the solution effectively.

3) What are some artifacts and/or limitations of your implementation, and what are possible reasons for them?
   I think one limitation is the loss of small details which exhibit very low intensities due to the clipping and normalization of values to [0, 1]

4) Display the surface normal estimation images below:
   YaleB05:
   x normals

y normals

z normals

YaleB01:
x normals:

y normals:

z normals:

YaleB02:
x normals

y normals:

z normals:

YaleB07:

x normals

y normals

z normals

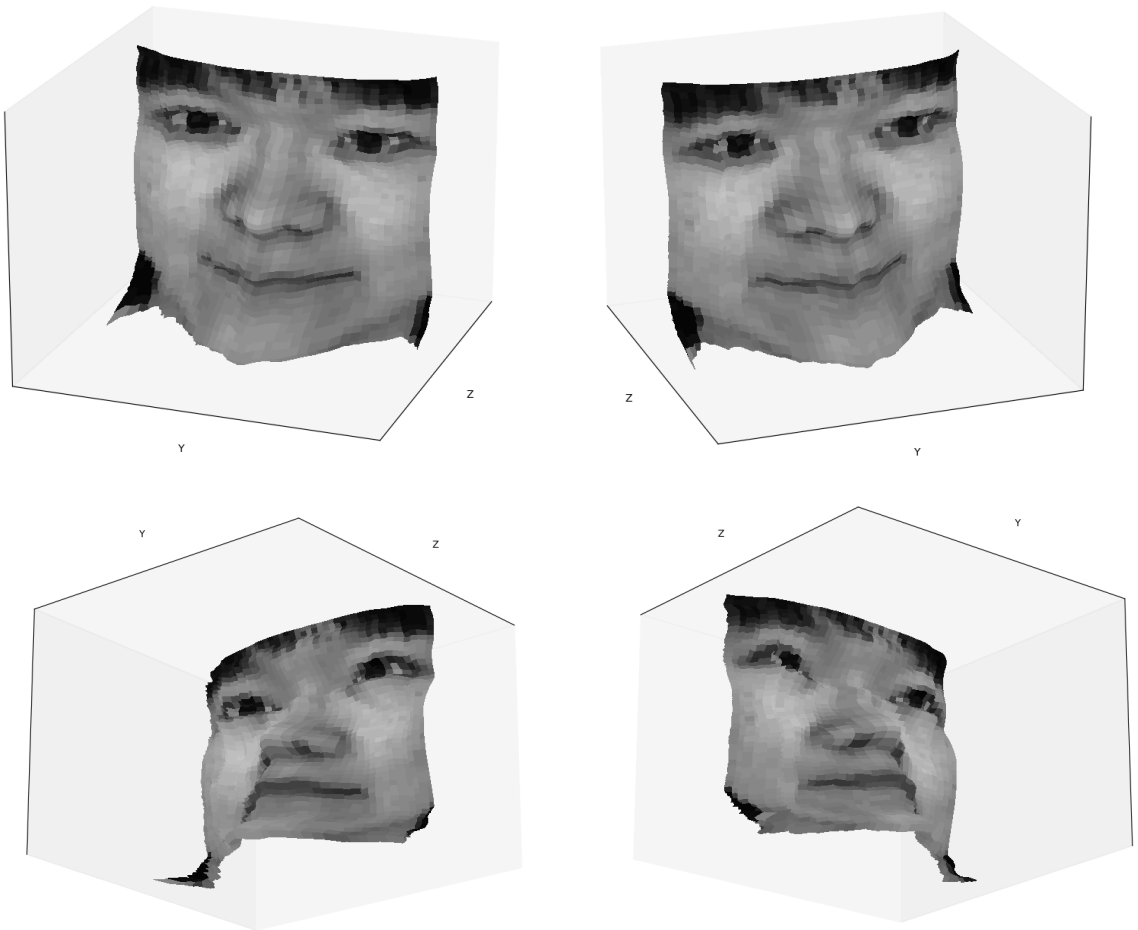
B: Compute Height Map

5) For every subject, display the surface height map by integration. Select one subject, list height map images computed using different integration methods and from different views; for other subjects, only from different views, using the method that you think performs best. When inserting results images into your report, you should

resize/compress them appropriately to keep the file size manageable -- but make sure that the correctness and quality of your output can be clearly and easily judged.

YaleB05:

Row:

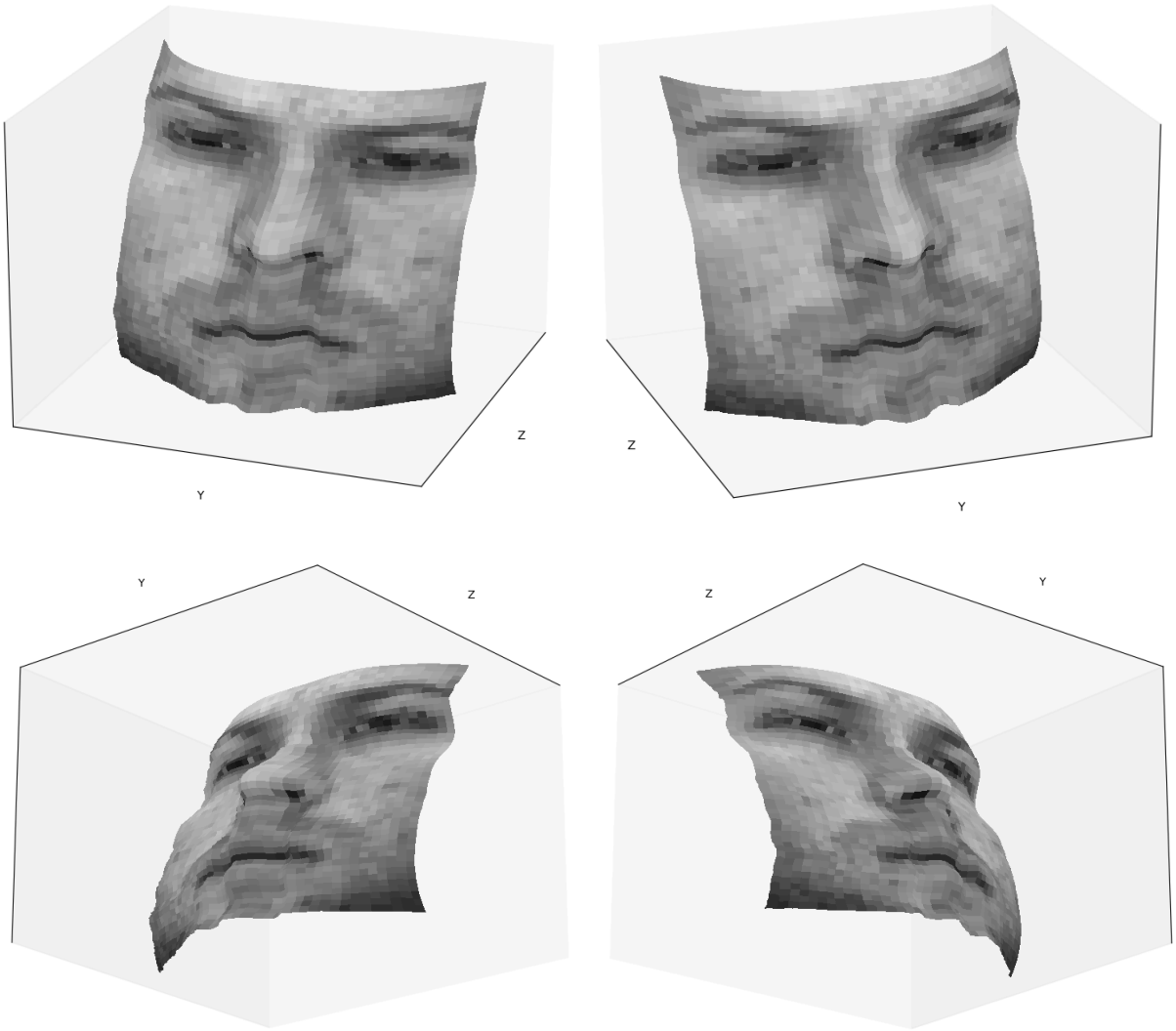


Column:

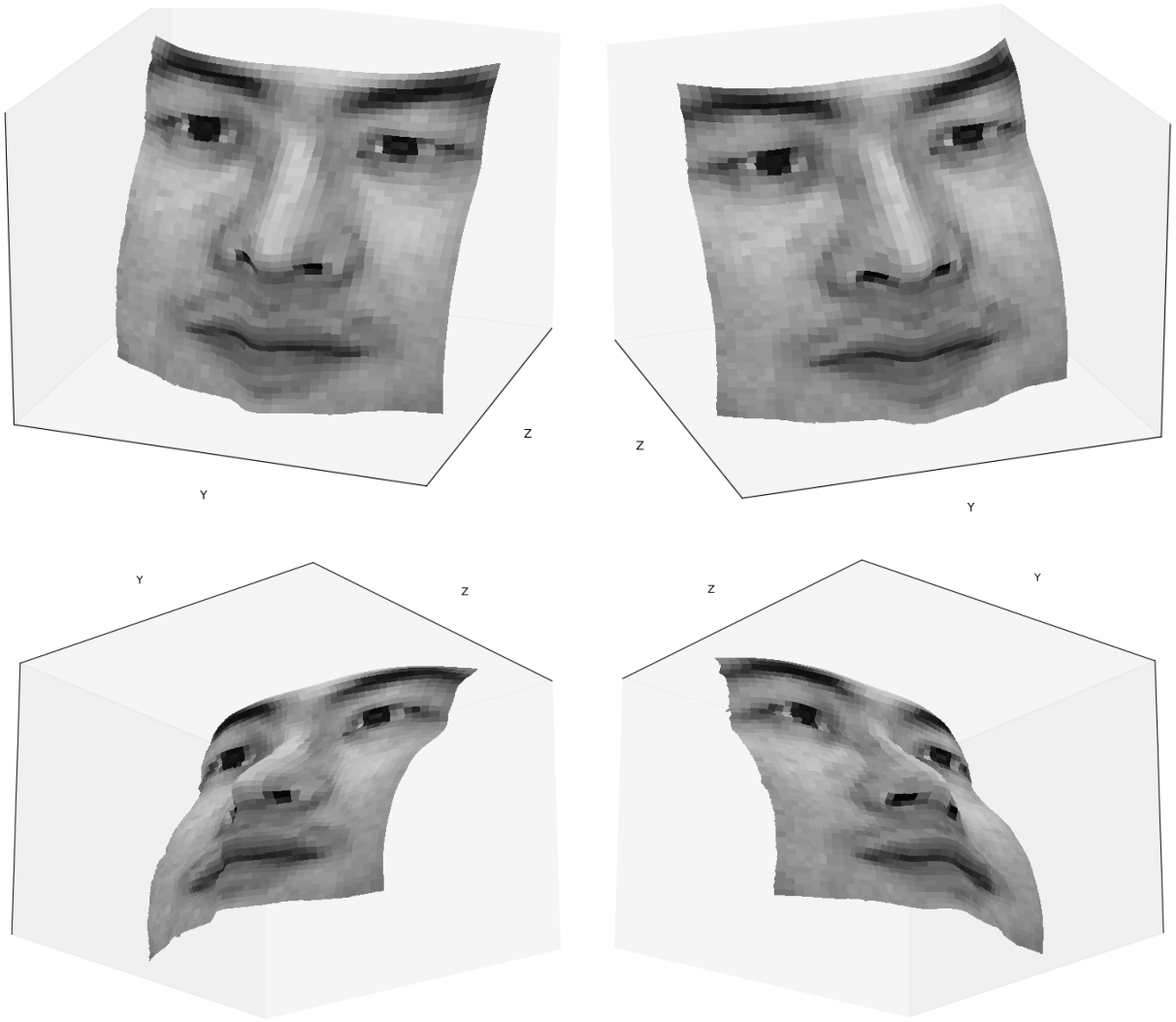
Average:

Random:

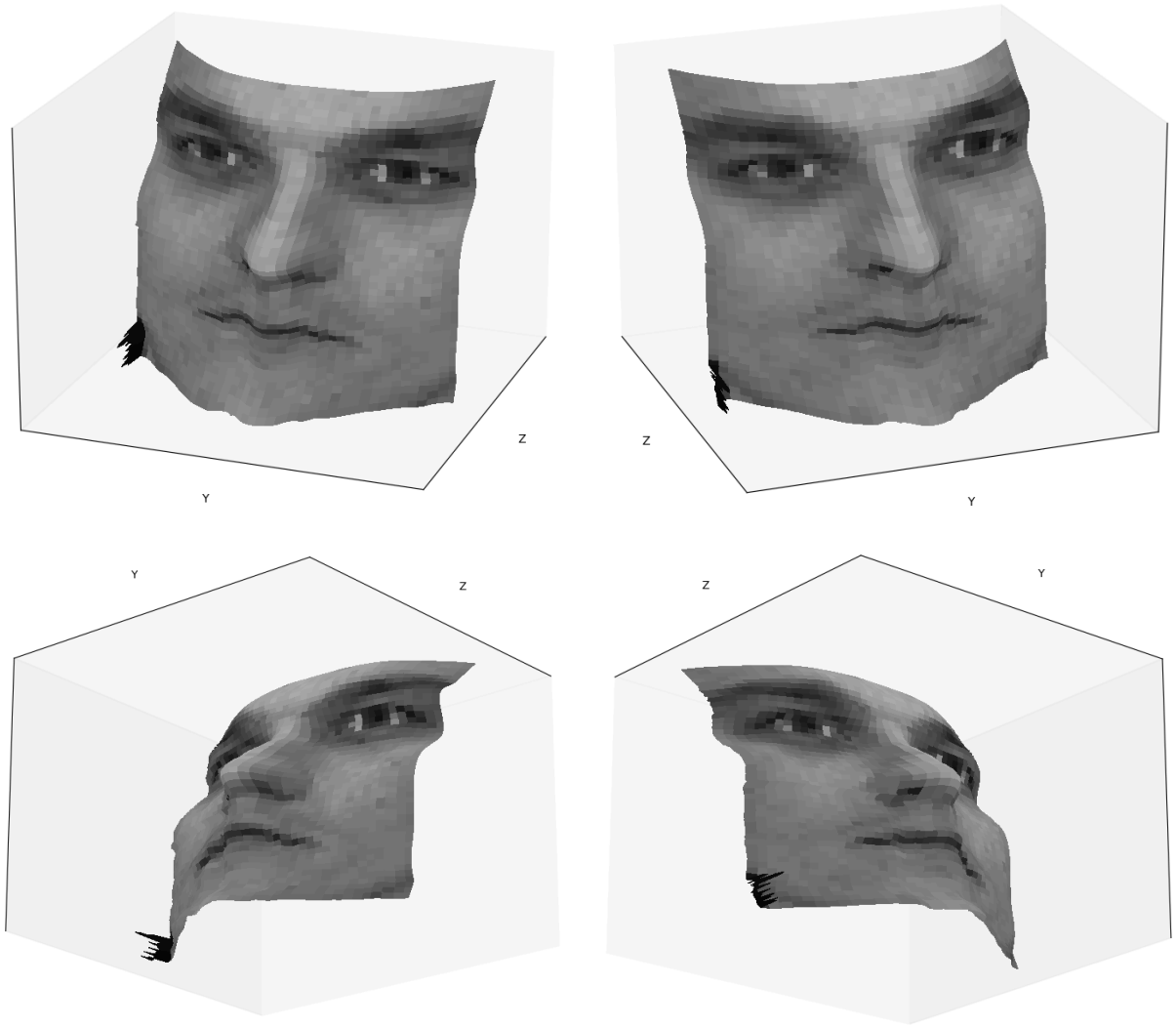
YaleB01
Average:



YaleB02
Average



YaleB07:
Average



6) Which integration method produces the best result and why?
   In my opinion, the average integration method produces the best result in limited trials. I say limited trials because with the random one you could spend enough time searching for actually the best result that can be achieved. I say the average is the best one because it combines both, the row and the column methods resulting in a smoother result since it takes into account both directions and reduces the bias they both provide. Also, I am talking from the point of view of my implementation and not the hegemonic one.

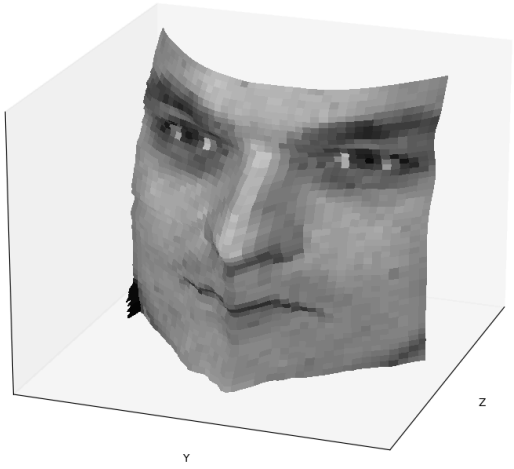
7) Compare the average execution time (only on your selected subject, “average” here means you should repeat the execution for several times to reduce random error) with each integration method, and analyze the cause of what you’ve observed:

Integration method	Execution time
row	0.001010
column	0.001068
average	0.001121
random	0.598454

From my experiments, I found that the average, row, and column gave almost the same execution time, which I was not expecting. I would have thought that the average integration method would have a bigger execution time, like the random one since it does more operations and is more computationally expensive.

C: Violation of the assumptions

8) Discuss how the Yale Face data violate the assumptions of the shape-from-shading method covered in the slides.
   The Yale Face violates the Lambertian assumption which states that the surface should reflect light uniformly in all directions, something that doesn't happen on human faces nor skin.
9) Choose one subject and attempt to select a subset of all viewpoints that better match the assumptions of the method. Show your results for that subset.



   I tried choosing images with a high light intensity so there would be a less amount of shadows in the dataset.

10) Discuss whether you were able to get any improvement over a reconstruction computed from all the viewpoints.
   From the previous image, we can clearly see that the face is more bright, especially in the zones that protrude more. For example, the nose and the forehead. Although these

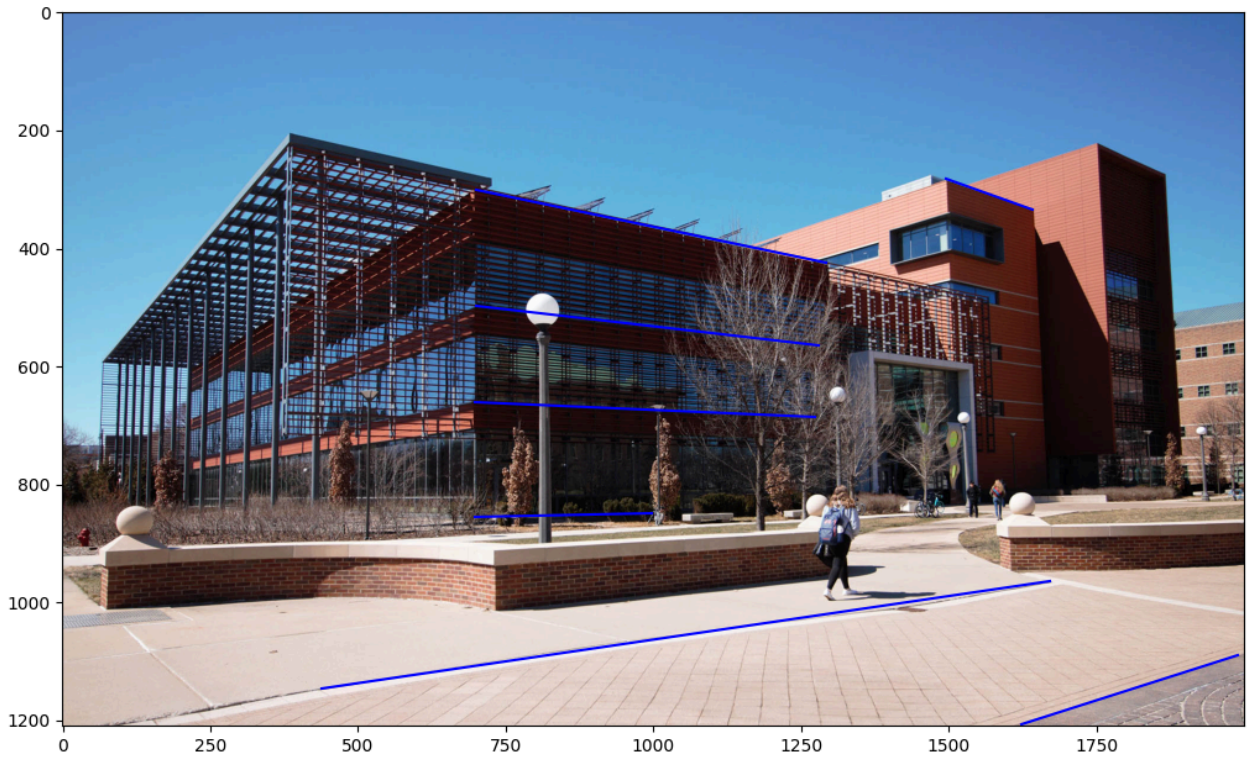
areas seem to be more bright. It also has more defined face features like the eyes, but when looking at the mouth, we can clearly see that it has a strange shape, indicating that the reconstruction is optimal.

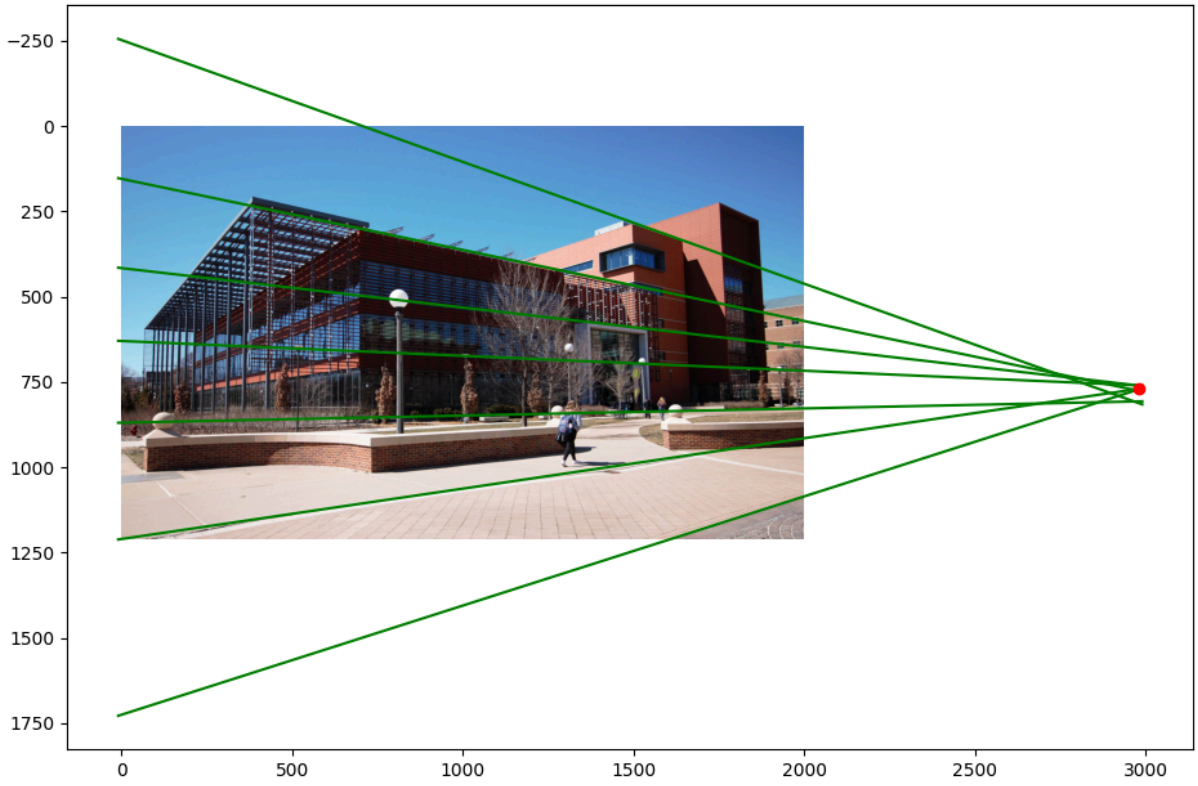
Part 2 Single-View Geometry:

1. Estimate the three major vanishing points.

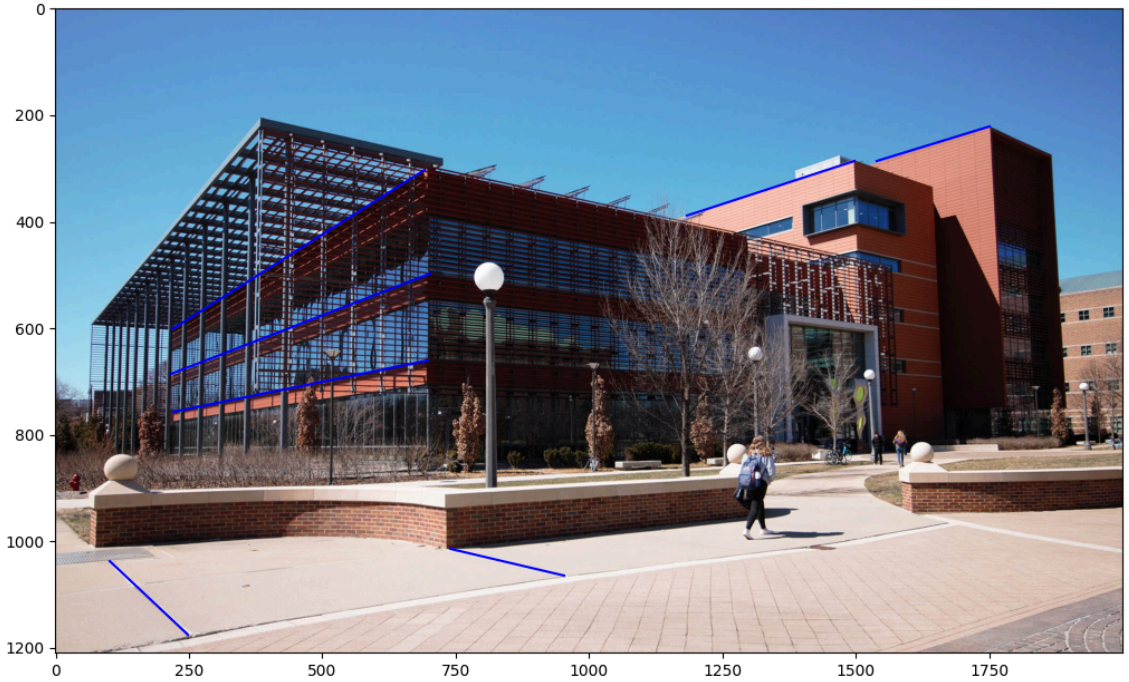
    a. Plot the VPs and the lines used to estimate them on the image plane using the provided code.

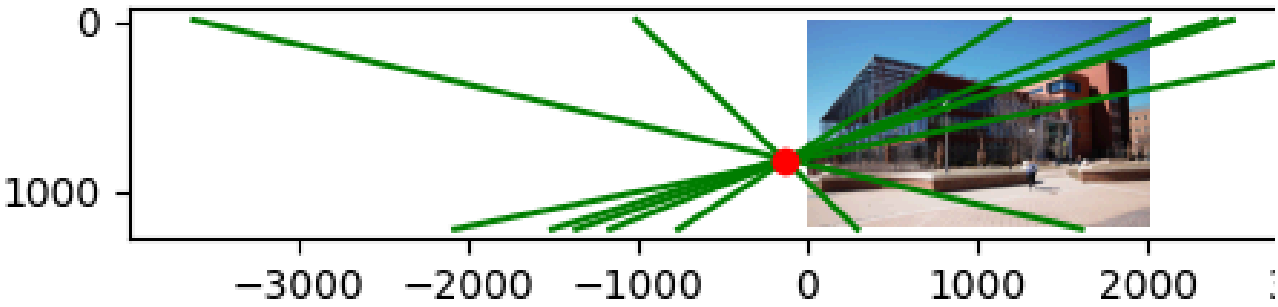
Vanishing lines and point 1:



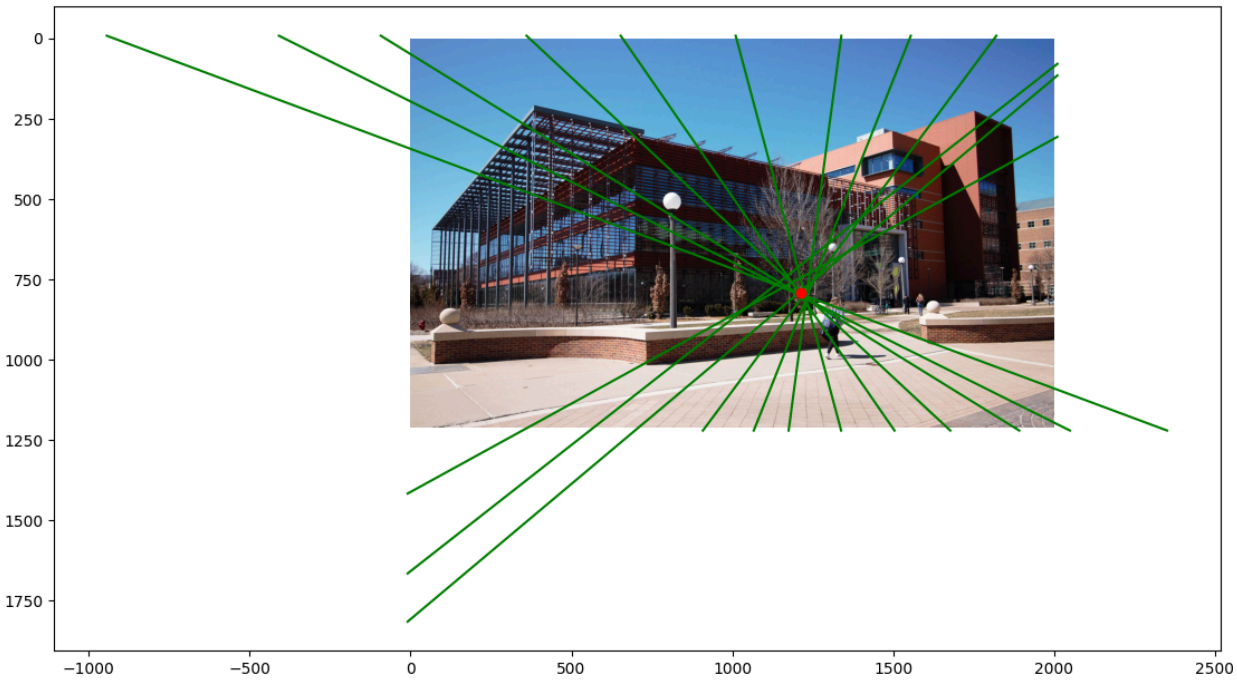


Vanishing lines and point 2:





Vanishing lines and point 3:



b. Specify the VP pixel coordinates. Discuss how you estimated them.

Vanishing point 1: [-9.68195309e-01 -2.50195399e-01 -3.24805549e-04]

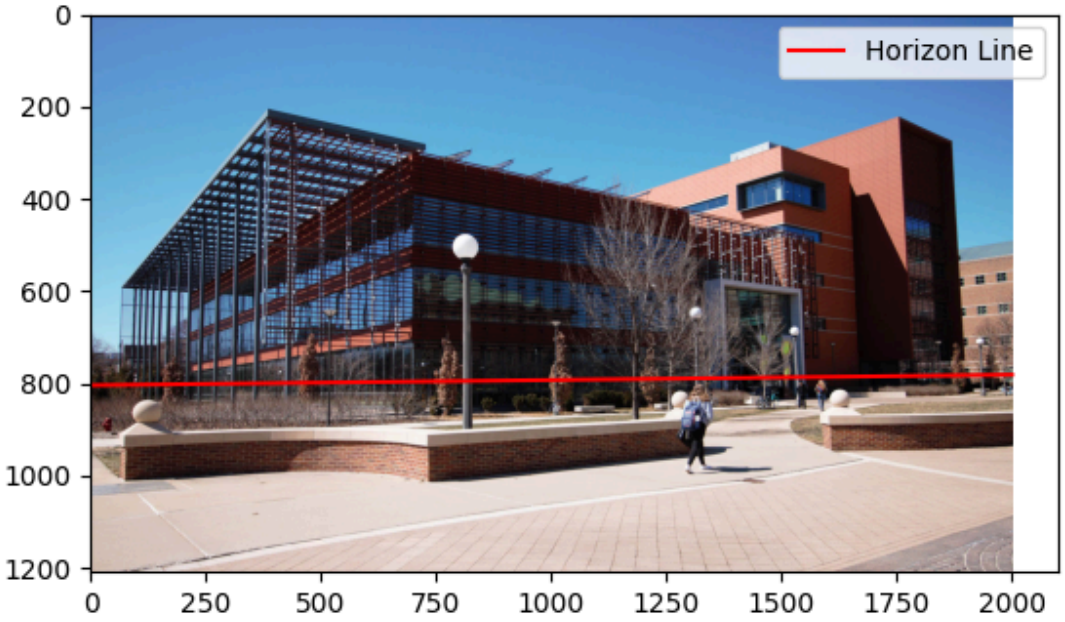
Vanishing point 2: [0.15270808 -0.98827061 -0.00120591]

Vanishing point 3: [8.37500456e-01 5.46436189e-01 6.91326697e-04]

To get the coordinates of the vanishing points, I apply SVD to decompose the matrix A and get the vector V that describes the point. Once I have the point, I traduce it to cartesian coordinates to plot it.

c. Plot the ground horizon line and specify its parameters in the form a * x + b * y + c = 0. Normalize the parameters so that: a^2 + b^2 = 1.

Horizon line:



Parameters a, b, c: [-2.01238624e+01 -1.76940648e+03 1.42294733e+06]

Normalized a and b: [-1.13724920e-02 -9.99935331e-01]

2. Using the fact that the vanishing directions are orthogonal, solve for the focal length and optical center (principal point) of the camera. Show all your work.
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3. Compute the rotation matrix for the camera.

R = [[0.70701806 -0.70701806 -0.13746947]

 [-0.01120082 0.01120082 -0.00286263]

[0.70710678 0.70710678 0.99050187]]

4. Estimate the following heights and show all the lines and measurements used to perform the calculation. As a reference measurement, assume that the person in the picture is 5ft 6in tall.

a. The left side of the ECE building.

Estimated height: 26.94 feet

b. The right side of the ECE building.

Estimated height: 21.21 feet

c. The lamp posts.

Estimated height: 10.78 feet

5. Recompute the answers in a-c above assuming that the person is 6ft tall.

Estimated height of left side: 28.87 feet
Estimated height of right side: 22.72 feet
Estimated height of lamp post: 11.55 feet