Computer Vision

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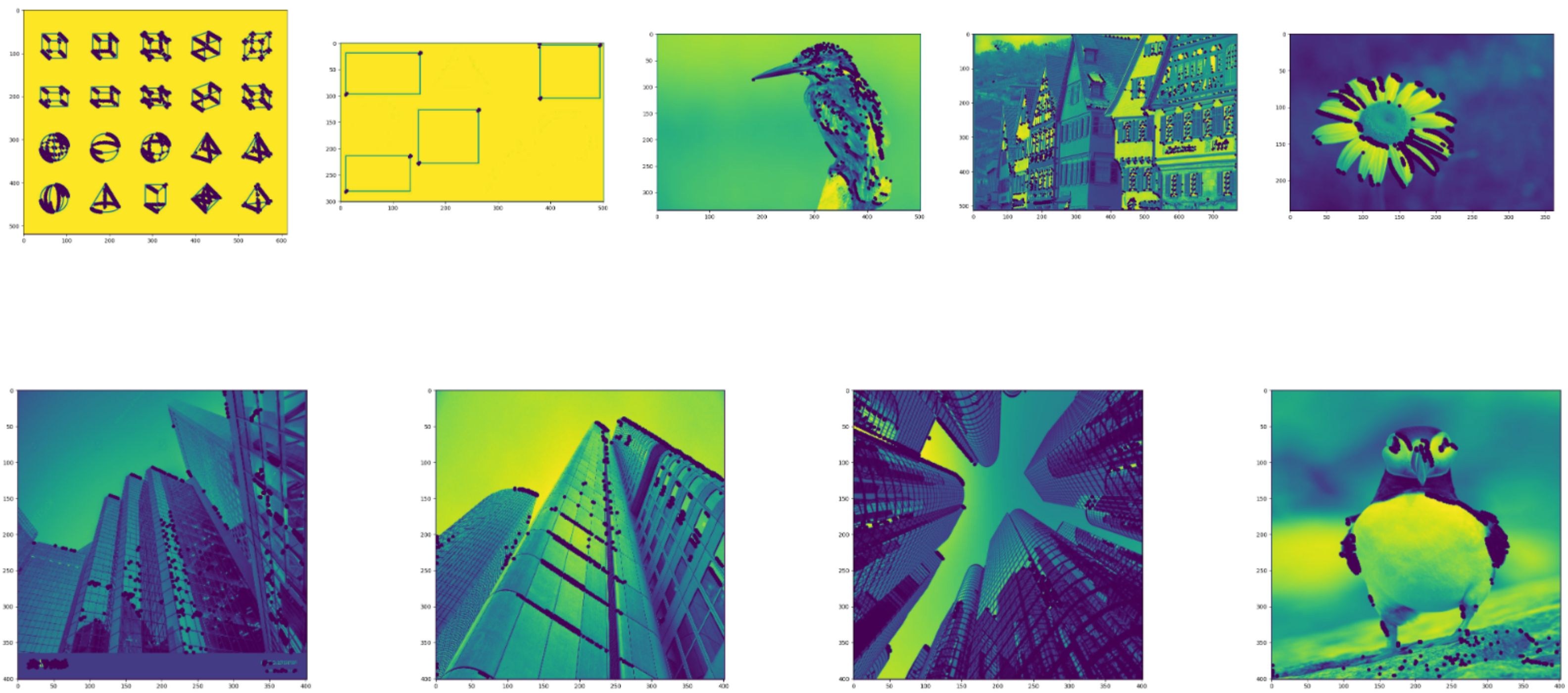
Question - 1 Harris Corner detection:

I have implemented Harris corner detection from scratch in a Python notebook. The process involves preprocessing the input image by applying a Gaussian filter to reduce noise. Subsequently, I computed the gradients in both the X and Y directions using the separable property of Sobel filters, thereby optimizing the computational efficiency from O(n^2) to O(2n).

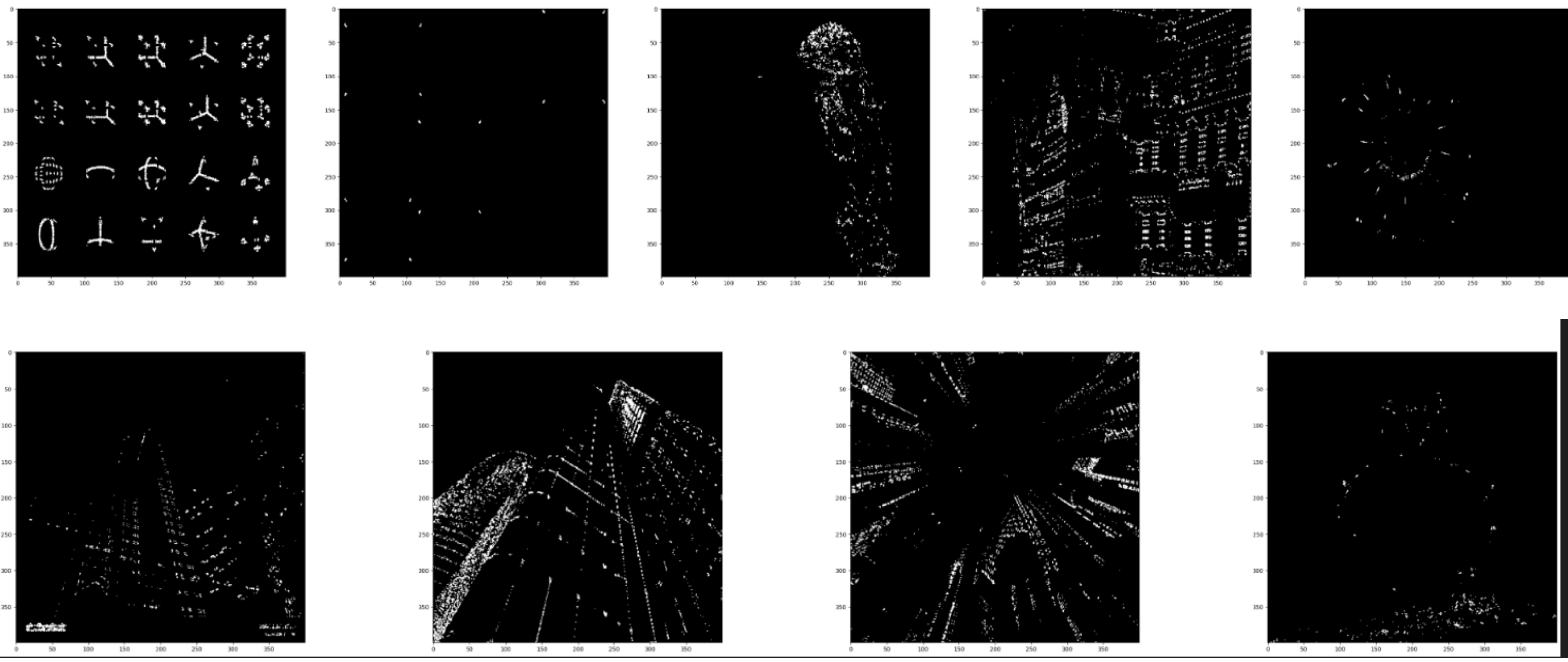
To detect corners, I utilized a sliding window approach, where a patch instance of the image is slid across the entire image. At each position, I computed the response function value using the Harris corner detection formula (det(M) - k * trace(M)^2). By applying a threshold to this response function, I identified the corresponding corner points in the image.

This methodology not only enhances computational speed but also maintains accuracy in corner detection.

Scratch result



Using inbuilt



Question - 2

In the context of stereo vision, we were tasked with computing the disparity, depth, and generating a 3D point cloud from a pair of stereo images captured by cameras with known intrinsic matrices and a given baseline (translation along the x-axis).

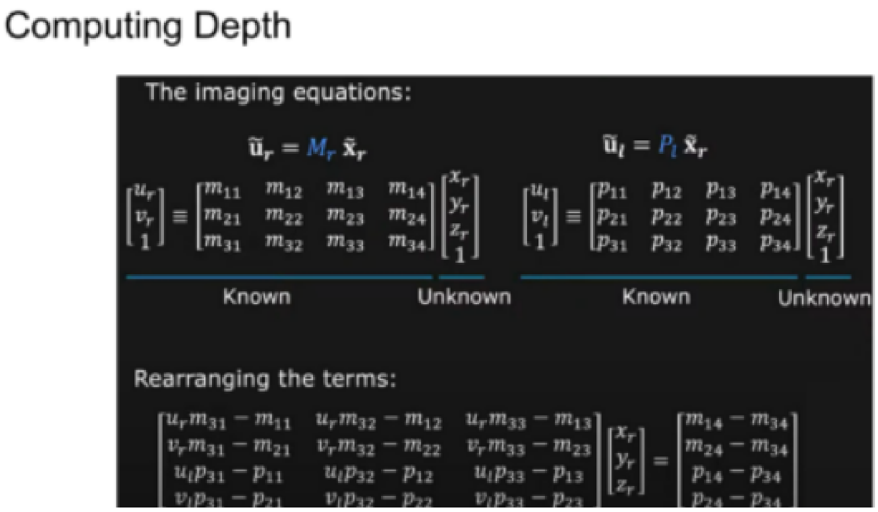
To start, we leveraged the provided intrinsic matrices and baseline information to derive the Essential matrix using the formula E = Tx @ R, where R is the identity matrix (no rotation) and Tx is the translation matrix with the x component set to the baseline value. This Essential matrix encapsulates the geometric relationship between the two camera views.

With the Essential matrix in hand, we further computed the Fundamental matrix, which describes the epipolar geometry between the two images. This Fundamental matrix allowed us to establish epipolar lines in the right image corresponding to each point in the left image, facilitating the matching of corresponding points between the stereo images.

By systematically searching for corresponding points in the left and right images, we established a correspondence map. This correspondence map then enabled us to calculate the 3D coordinates of each point in the left image using triangulation techniques. Specifically, we employed the triangulation formula to compute the 3D point coordinates, thus reconstructing the scene in three dimensions based on the stereo image pair and camera parameters.

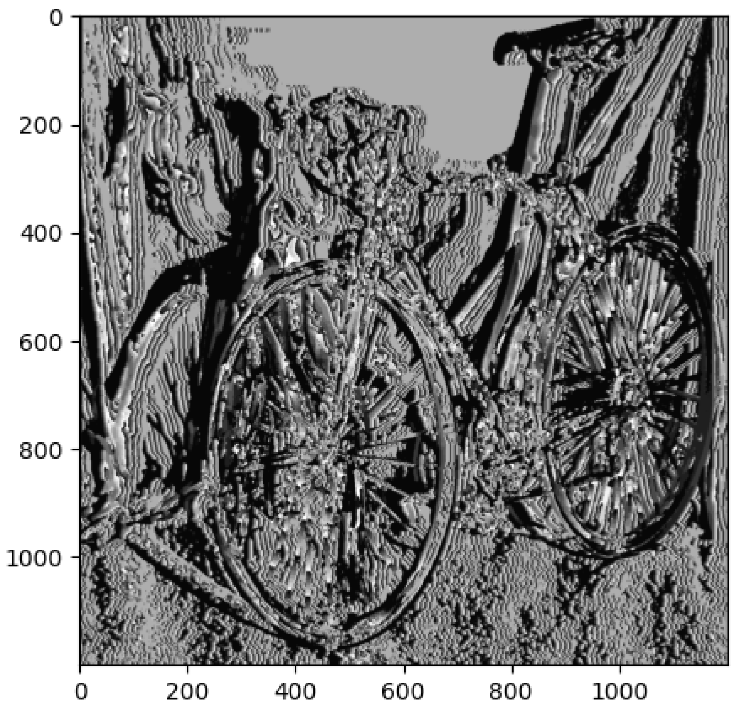
This comprehensive process, driven by principles of stereo vision and geometry, enabled us to derive meaningful depth information, compute disparities between corresponding points, and ultimately reconstruct a detailed 3D representation of the scene captured by the stereo cameras.

Now we have z coordinate for every pixel we can calculate the depth map, disparity map and 3d cloud of image.

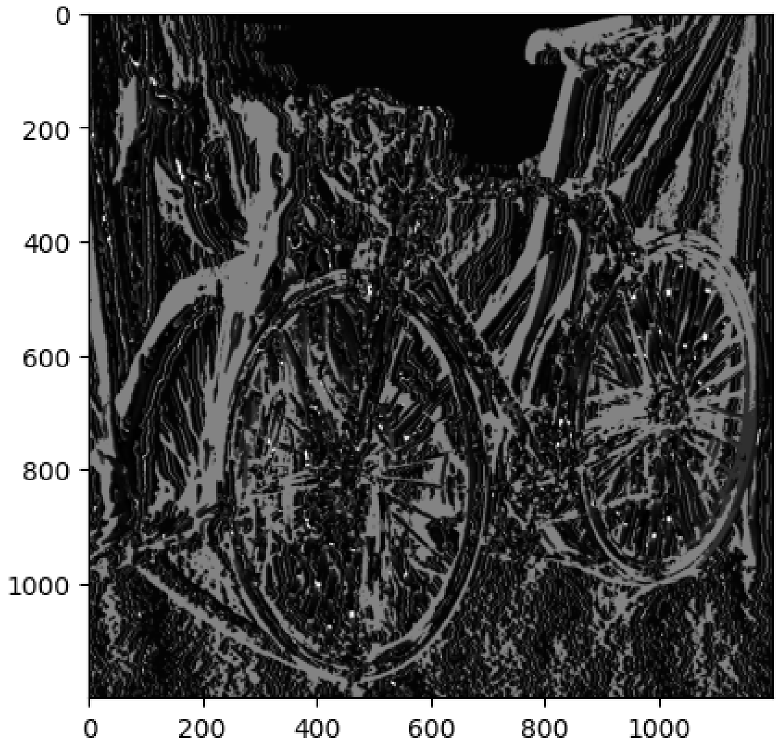


RESULTS

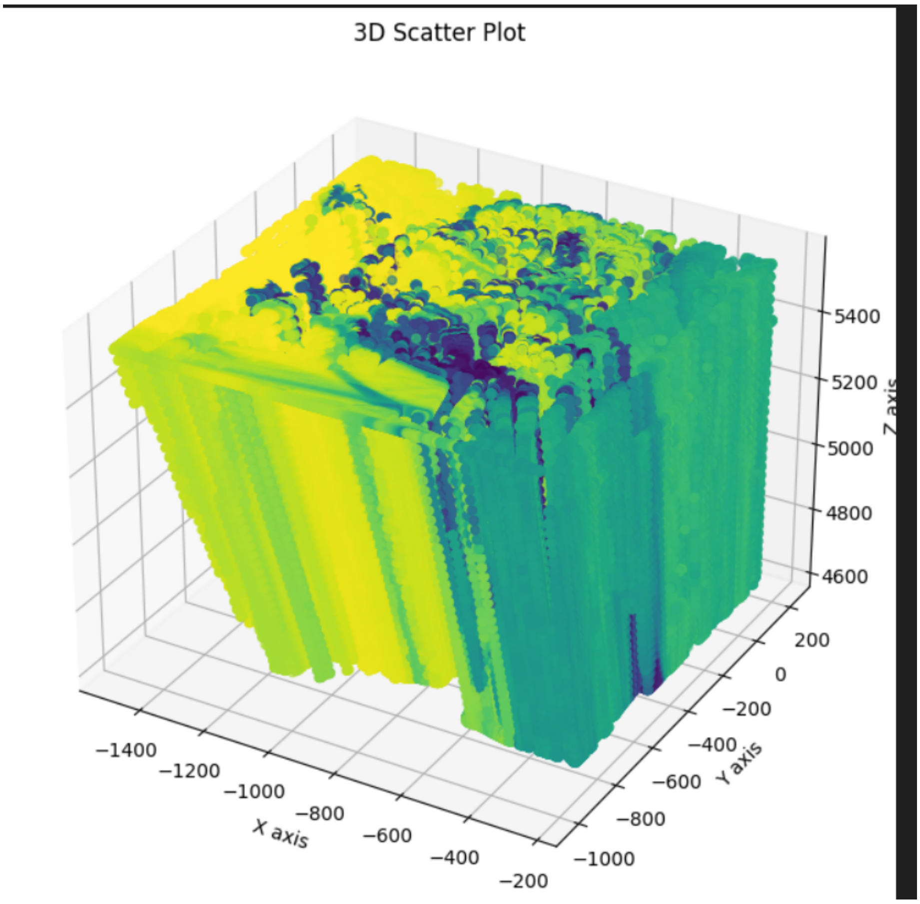
Depth Map



Disparity Map



3D point cloud



Question - 3

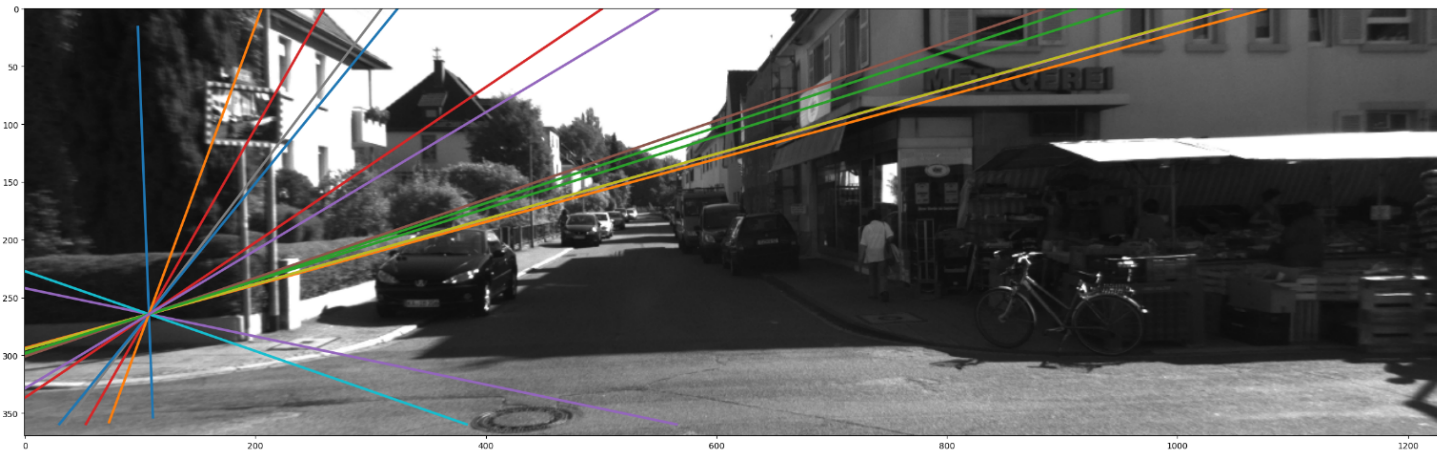
After obtaining the Fundamental matrix, we proceeded to sample points from the left image. Using the Fundamental matrix, we computed the corresponding epipolar lines in the right image using the formula U @ F @ V = 0 where U and V are homogeneous coordinates of points in the left and right images, respectively.

Subsequently, we plotted these computed epipolar lines on the right image. This process allowed us to visually understand the relationship between points in the left and right images, showcasing how a point in the left image corresponds to a line (epipolar line) in the right image.

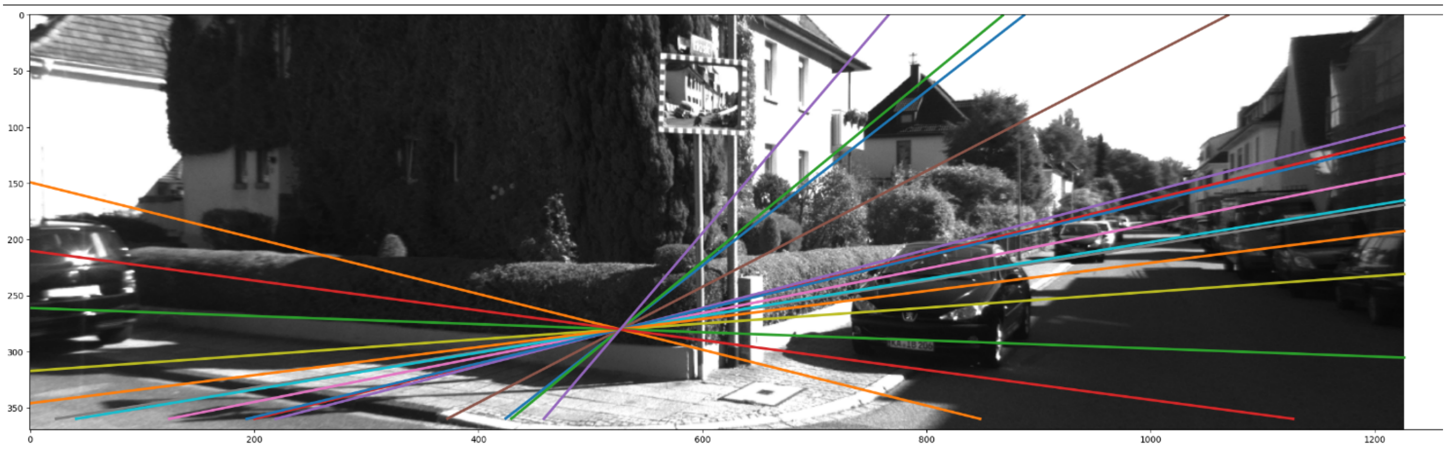
Similarly, we repeated this process for points sampled from the right image, computing their corresponding epipolar lines in the left image using the same formula. These epipolar lines were then plotted on the left image for visual inspection.

Also one thing to note was that all the epipolar lines passes through the same point which is known as epipoles as shown in the output.

Right Image



LEFT Image

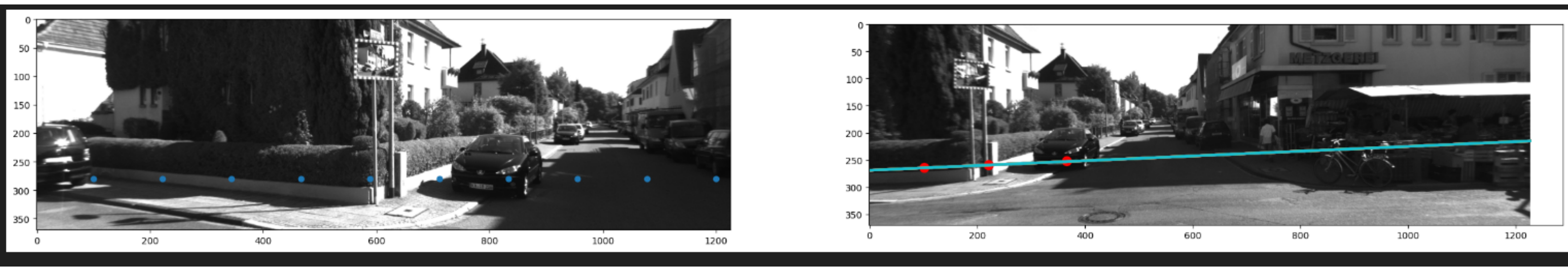


We conducted an analysis where we sampled 10 points along the epipolar line of the left image and subsequently determined their corresponding epipolar lines in the right image. This process was repeated for the right image as well.

One of the key observations from this analysis was the consistent outcome that emerged: all sampled points along the epipolar line in the left image resulted in the same epipolar line in the right image. This uniformity in the epipolar lines across the sampled points underscored a crucial aspect of the underlying geometry and the accuracy of our computations.

Moreover, we visualized these corresponding points on the epipolar lines by plotting them, which provided a tangible representation of the stereo correspondence between the left and right images. This visualization not only reinforced our analytical findings but also facilitated a clearer understanding of the correspondence mapping established through the Fundamental matrix and epipolar geometry principles.

Left image correspondence on right image



Right image correspondence on left image