Submitted By: Nafis Neehal

RIN: 661990881

HW7, Part 2: Independent Motion Detection

Working Steps and Decision Criteria:

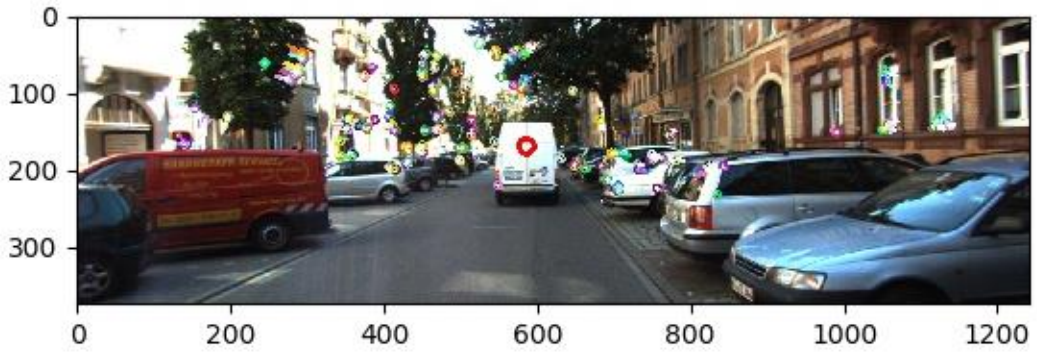
- Take input a pair of images
- Find out the key points and descriptors using ORB
- Apply BF Matcher to find out the keypoint matches. Here threshold for BF-matcher is 1.0
- Generate the locations of the matched keypoints from the source image (first image). These are selected points to estimate motion.
- Generate Optical Flow between source and destination image
- Generate Motion vectors, U = p_new-p_old
- Keep only those motion vectors which have magnitude larger than a certain threshold. Here the threshold that has been mostly used is .50.
- Draw the optical flow tracks on the source image
- Calculate the normal vector to each motion vector
- Using RANSAC, calculate the intersection point that has the maximum number of inliers.
- If number of inliers is greater than a certain threshold, then it is decided that the camera is moving. Generally, this threshold is selected based on distance of a point from the intersection to become an inlier/outlier. For most cases I have used 30 as the distance value. These decisions have been taken on each test case basis by analyzing the histogram of distance values.
- If the camera is moving, for all the inliers of the preliminary intersection point, the final intersection point is generated using least-squares method. Camera movement is decided since if we have at least 20% of total number of inliers from the primary intersection point candidate. This value is also chosen based on trial and error.
- Then the final intersection point is plotted in the first output image with all the motion vectors. If camera is not moving, then only motion vectors are plotted.
- Those, which are outliers are clustered using Mean-Shift algorithm and shown. Any cluster than has lower than the minimum threshold number of points to generate a cluster were discarded. For most cases, this cluster value has been 3 or 5.
- Finally, the clustered points are shown inside a red bounding box.
- All the threshold values were chosen after several rounds of trial and error for each image pair on a test case basis.

Test Case 1:

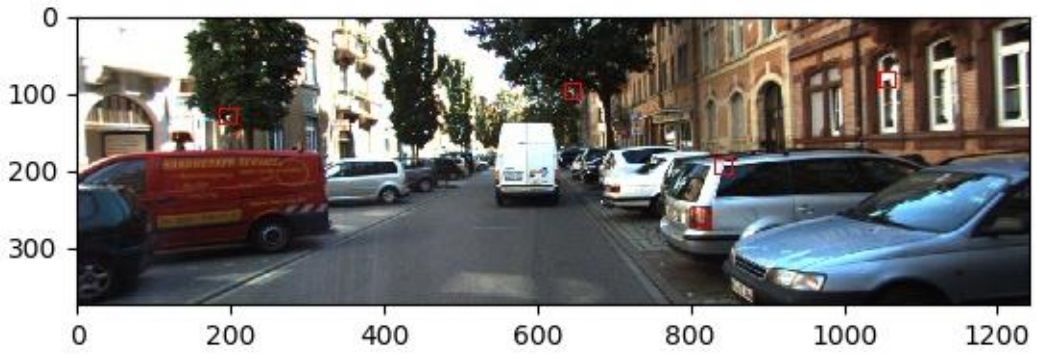
File: 000005_10.png, 000005_11.png

Type: Camera Moving

Output 1: Motion Vectors + FOE



Output 2: Clustered Outliers – Independently moving objects



Issues and Discussion about this test case:

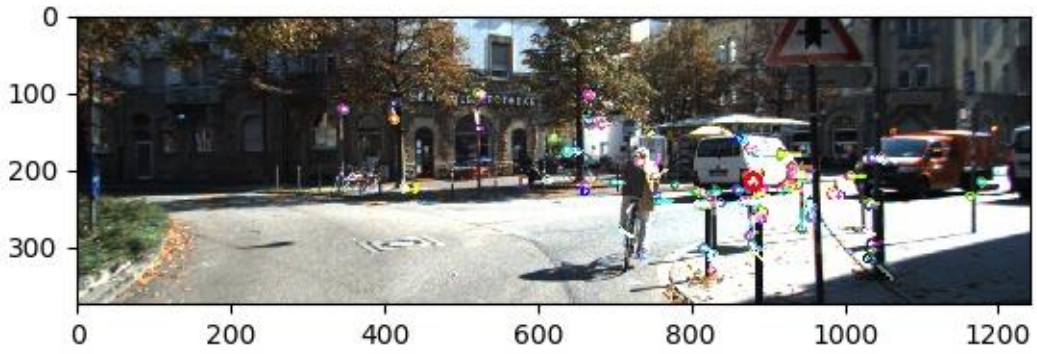
The camera is moving in this test case, and the FOE is right in the middle of the center of the white van which apparently is the most highly probable intersection point of the relevant motion vectors. This test case produces one of the best results for my code, as most of the major keypoints were related to the moving van and so the FOE didn't get disoriented. About the independently moving objects, my approach detects 4 different significant clusters which definitely is not of good quality result.

Test Case 2:

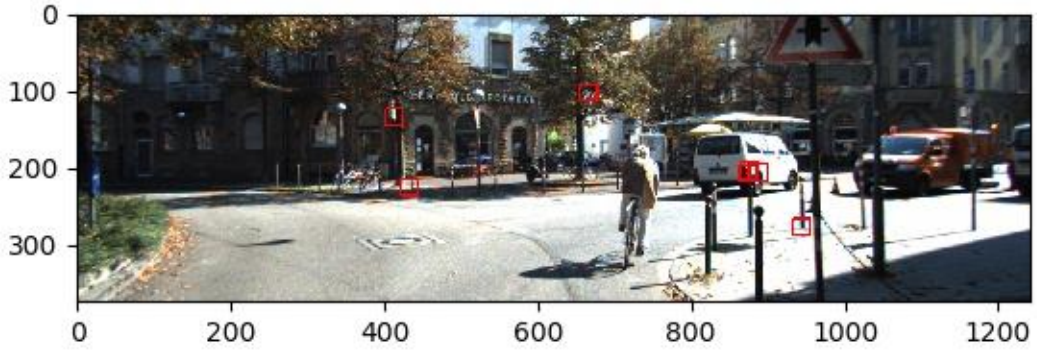
File: 000003_10.png, 000003_11.png

Type: Camera Moving

Output 1: Motion Vectors + FOE



Output 2: Clustered Outliers – Independently moving objects



Issues and Discussion about this test case:

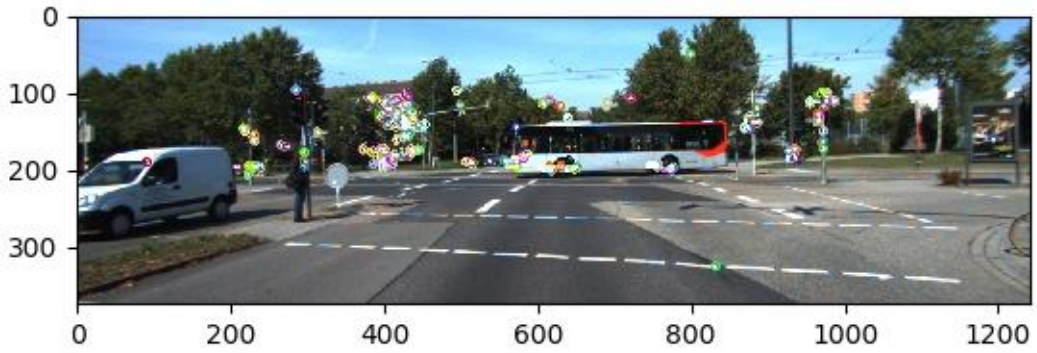
The camera is moving in this test case, and the FOE is bottom right corner of the white van which apparently is not the most highly probable intersection point of the relevant motion vectors. The intersection point here should be on the middle-left portion of the image where two clusters are formed This test case moderate results, it produces most of the motion vectors correctly but the FOE got misplaced and this is because there are way too much ORB keypoints near the white van detected as opposed to the point where FOE should be. About the independently moving objects, my approach detects 7 different significant clusters which again definitely is not of good quality result.

Test Case 3:

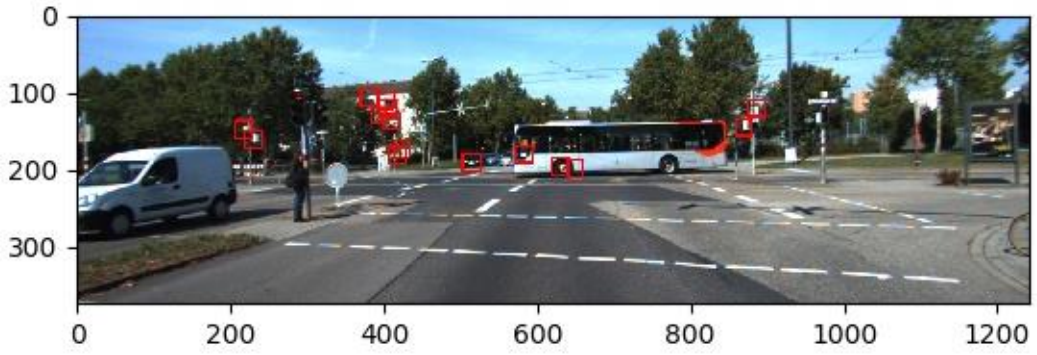
File: 000017_10.png, 000017_11.png

Type: Camera Not Moving

Output 1: Motion Vectors + FOE



Output 2: Clustered Outliers – Independently moving objects



Issues and Discussion about this test case:

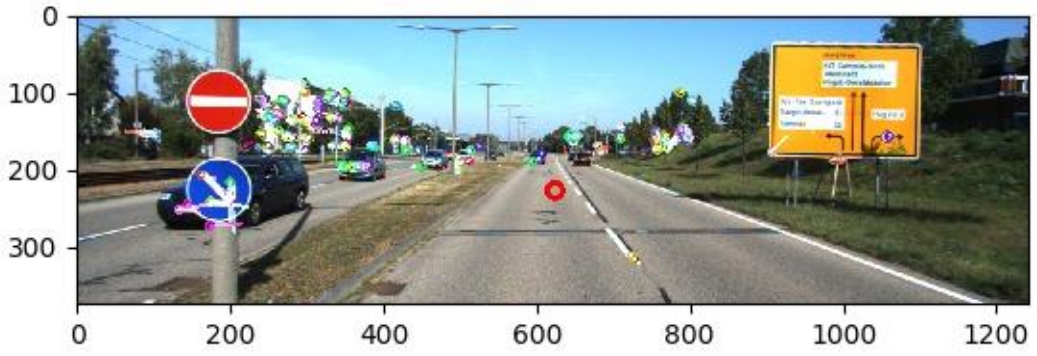
The camera is not moving in this test case, and the so there is no FOE this is because there are way too much ORB keypoints near the white van detected as opposed to the point where FOE should be. About the independently moving objects, my approach detects 15 different significant clusters if I allow at least 5 points per cluster formation. Here expected result was that most of the clusters would be on the bus here as this is a significant moving object despite of no camera movement, but only 3 clusters were detected here, because of the ORB keypoint finding.

Test Case 4:

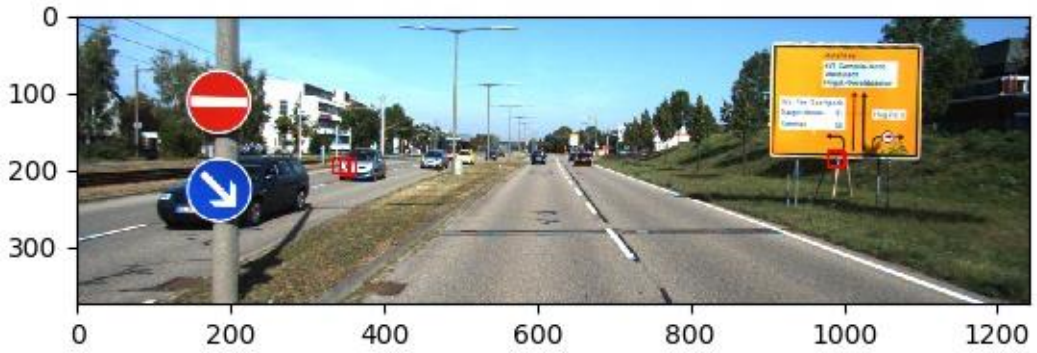
File: 000020_10.png, 000020_11.png

Type: Camera Moving

Output 1: Motion Vectors + FOE



Output 2: Clustered Outliers – Independently moving objects



Issues and Discussion about this test case:

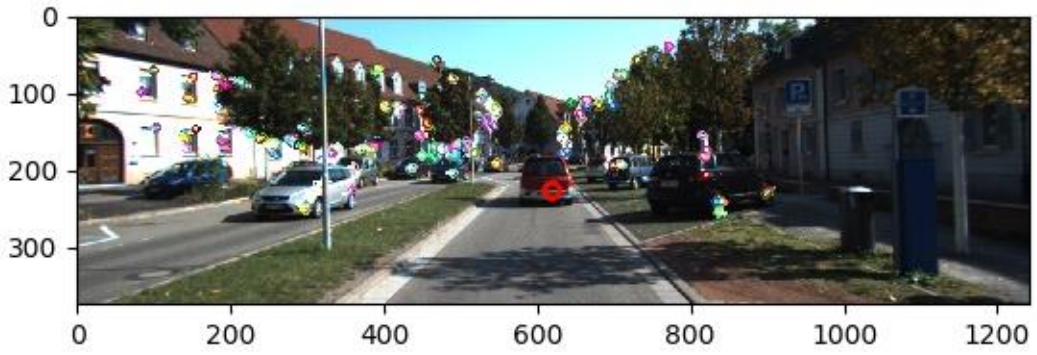
The camera is moving in this test case, and the FOE is in the middle of the right road which apparently is the most highly probable intersection point of the relevant motion vectors. This test case produces good results, it produces most of the motion vectors correctly and the FOE is almost correct. About the independently moving objects, my approach detects 3 different significant clusters if I allow at least 3 points per cluster formation. Here the clustering result is somewhat near to the expected result as the silver sedan really is another independently moving object.

Test Case 5:

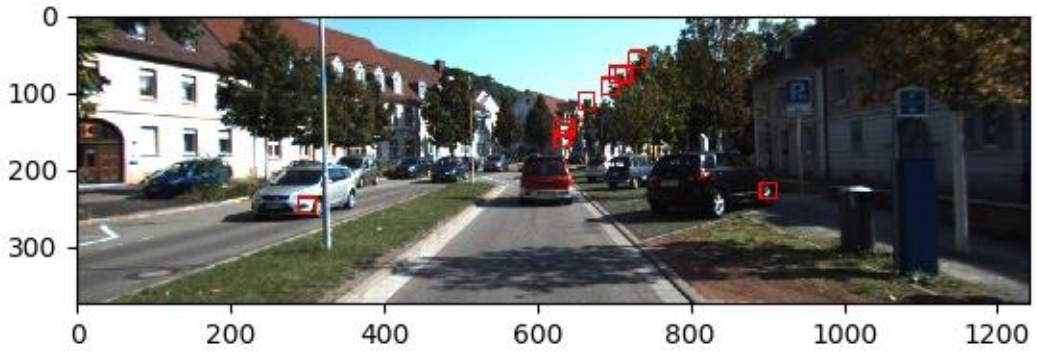
File: 000123_10.png, 000123_11.png

Type: Camera Moving

Output 1: Motion Vectors + FOE



Output 2: Clustered Outliers – Independently moving objects



Issues and Discussion about this test case:

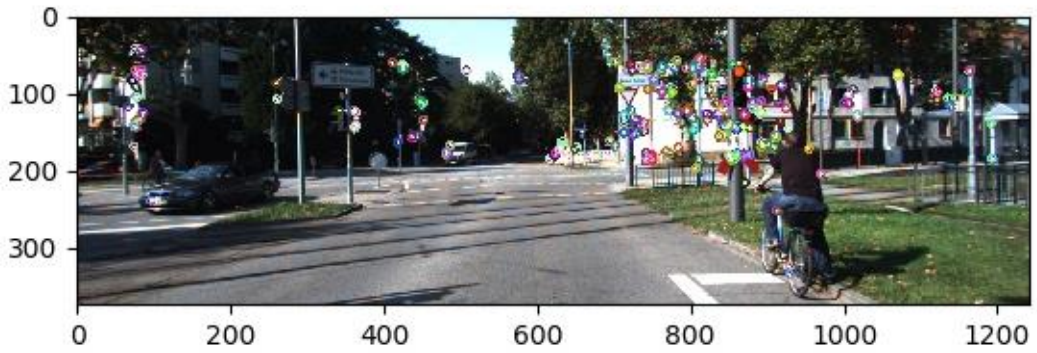
The camera is moving in this test case, and the FOE is in the middle red car which apparently is the most highly probable intersection point of the relevant motion vectors. This test case produces good results, it produces most of the motion vectors correctly and the FOE is almost correct. About the independently moving objects, my approach detects 10 different significant clusters if I allow at least 3 points per cluster formation. Here the clustering result is somewhat near to the expected result as the silver sedan really is another independently moving object. But the rest of them are not so good.

Test Case 6:

File: 000130_10.png, 000130_11.png

Type: Camera Not Moving

Output 1: Motion Vectors + FOE



Output 2: Clustered Outliers – Independently moving objects

Issues and Discussion about this test case:

The camera is not moving in this test case, and the so there is no FOE. This is because there are way too much ORB keypoints near the pole detected. About the independently moving objects, my approach detects 12 different significant clusters if I allow at least 5 points per cluster formation. Here expected result was that most of the clusters would be on the black sedan here as this is a significant moving object despite of no camera movement, but no clusters were detected here, because of the ORB keypoint finding which ends up producing bad result

Concluding remarks:

- **Performance Issue:** The algorithm which was developed according to the instruction certainly does not perform very well in case of finding independent motions, but it does a fair amount of good performance for finding the optical flow and the FOE. Most significant reason for my developed algorithm not behaving as better as it could within its limitations is I believe because of the keypoint detection. A more sophisticated approach, hence, is certainly needed for achieving better performance.
- **Number of test cases:** Although, I have tested for all the data given for multiple times, I have only represented 6 test cases here that captures all the variations throughout my whole experiment.

Finally, this has been an amazing journey. Although grades for my initial 1-2 assignments could have been better certainly, but I failed to do so as I am a new international student here and it took a lot of time and effort for me and my wife to settle down here. But, the grades, code-quality improvement, report quality improvement is very prominent in the rest of the assignments I believe. I have learnt a lot throughout this course. Thank you for everything.