CSci 4270 and 6270
Computational Vision,
Spring Semester, 2022
Homework 6
Due: Wednesday, April 24 at 11:59pm

Overview

This is the final homework of the semester, and it is worth **100 points** toward your overall homework grade. You may use at most ONE up late day on this assignment. If you have no late days remaining and hand in the assignment late then 15 points will be taken off your graded score. **No homework will be accepted after 11:59:59 pm on Thursday, April 25.**

We focus on an important problem for self-driving cars that you have all the tools to solve. This is the detection of independently moving objects. For this assignment, do not expect perfect results — you will not get them. Instead, please do your best in the time you have available and implement a solution to each stage of the algorithm.

Problem Description

Consider two images, I_0 and I_1, taken by a single camera while it is either stationary or moving through a scene. Importantly, other objects may be moving as well. The technical problems you must solve are:

1. estimate the image motion vectors at a sparse set of points
2. determine whether or not the camera is moving by estimating the "focus of expansion" induced by the camera's motion
3. determine which points are moving independent of the camera's movement, and
4. cluster such points into coherent objects

Looking in more detail:

- You may choose the points where you estimate motion using the Harris criteria, the KLT criteria, or any other method you wish (e.g. SIFT). You may use OpenCV algorithms to do this, but you already have the tools to do this going back to early in the semester.
- Estimate the image motion at these points. You may use the algorithm discussed in the Lecture 23 (and 24) notes (You may also use descriptor matchingg.) Once again there is OpenCV code to do this (`calcOpticalFlowPyrLK`), which implements the techniques discussed in class. You can also "roll your own".
- Determine the motion of the camera, if any, by estimating the focus of expansions (FOE) using the algorithm sketched in the end of the lecture notes on motion. The explanation for how to do this is in the Lecture 23 and 24 notes.
- Once the FOE is found, motion lines that do not come close to this point correspond either to errors in motion estimation or independently moving objects. Similarly, if the camera is not moving, all non-trivial estimated motion vectors correspond to errors or independently

moving objects. In either case, see if you can figure out a way to identify the points from independently moving objects and group them, throwing out groups that are too small. One challenge to doing so is that the motion vectors of points with small apparent motions are fairly unstable — so that the orientations of the lines you generate can have a great deal of error. We will discuss this in class.

For each pair of input images, I_0 and I_1 please generate two output images:

- An image with the points, the motion vectors, and the focus of expansion drawn over top of image I_1. If there is no motion of the camera, show no focus of expansion, but make sure the fact that there is no motion is documented and justified in your diagnostic output (see below).
- A second image, similar to the first, but this one showing the independently moving objects you detected. For each independently moving object, select a random color and use this to color the points and motion vectors determined to be part of that cluster and to draw a bounding box around the points.

In addition to the image output, please show brief but clear diagnostic output from your program.

What to Submit

Submit a sing;e Jupyter notebook containing your Python code, your results, and a description of your algorithms for motion estimation and for the detection of independently moving objects. This should (a) explain your design decisions and any trade-offs involved, (b) demonstrate your results, and (c) evaluate the strengths and weaknesses of your algorithm as highlighted by these results. How many results will be needed? My answer is that this should be enough to justify each of the claims in your write-up without being redundant. You should clearly illustrate how well each step works and when and why might it fail (or at least produce lower quality results).

Evaluation

We will use the following rubric in grading your submission, so be sure your submission highlights them

- (12 points) Selection of points to estimate motion
- (12 points) Estimation of apparent motion
- (20 points) Estimation of the focus of expansion, or deciding that the camera did not move.
- (12 points) Clustering of independently moving objects
- (10 points) Quality of code
- (12 points) Clarity of explanation
- (12 points) Highlight of strengths and weaknesses
- (10 points) Selection of illustrative examples.