CMPE 537 Assignment #2 – Homography And Image Stitching

In order to find the homography between two images, we need at least 4 corresponding point pairs.

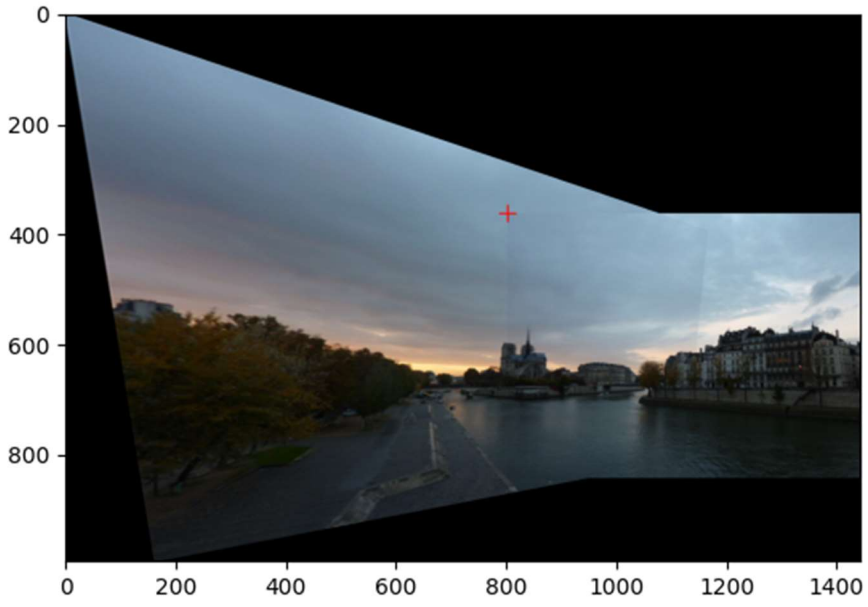
$$PH = \begin{bmatrix} -x_1 & -y_1 & -1 & 0 & 0 & 0 & x_1x'_1 & y_1x'_1 & x'_1 \\ 0 & 0 & 0 & -x_1 & -y_1 & -1 & x_1y'_1 & y_1y'_1 & y'_1 \\ -x_2 & -y_2 & -1 & 0 & 0 & 0 & x_2x'_2 & y_2x'_2 & x'_2 \\ 0 & 0 & 0 & -x_2 & -y_2 & -1 & x_2y'_2 & y_2y'_2 & y'_2 \\ -x_3 & -y_3 & -1 & 0 & 0 & 0 & x_3x'_3 & y_3x'_3 & x'_3 \\ 0 & 0 & 0 & -x_3 & -y_3 & -1 & x_3y'_3 & y_3y'_3 & y'_3 \\ -x_4 & -y_4 & -1 & 0 & 0 & 0 & x_4x'_4 & y_4x'_4 & x'_4 \\ 0 & 0 & 0 & -x_4 & -y_4 & -1 & x_4y'_4 & y_4y'_4 & y'_4 \end{bmatrix} \begin{bmatrix} h1 \\ h2 \\ h3 \\ h4 \\ h5 \\ h6 \\ h7 \\ h8 \\ h9 \end{bmatrix} = 0$$

(x,y) is point from source image and (x',y') is corresponding point from destination image.

We need to choose 4 points from all corresponding point pairs. In order to find the best matching pairs, we apply RANSAC algorithm while computing homography.

The implemented algorithm compares the distances between destination and resulting points, then chooses the one that has the most number of points under inlier threshold with minimum average distance.

After finding the correct homography transformation matrix, we need to warp the source image correctly to stitch it to the other image. The important point here is to keep track of the shift amount of the origin. The reason why origin is shifted is because the indices of matrix that we make calculations on must be non-negative and we do not want to lose the part of the warped image that is outside the first quadrant.



Another concern while warping the image is that we need to interpolate the result of backward transform since we calculate it at discrete points. The most common approach here is bicubic interpolation because it eliminates fringe effects, and it is adequately fast.

After warping the source image and zero-padding to the right location, the next step is to blend the destination image with the warped one. There are many sophisticated algorithms for this part, but the easiest approach is to directly insert the pixels from either of the image.

The implemented algorithm is a notch better than direct insertion method. We take the average of the pixels where both are non-zero, called mean value blending.

One implementation detail is that at the contour boundary of the warped image, the color intensity is less than it should be because of the interpolation with zero padding. We equate the contour to solid black which then becomes useful at blending stage.

The implementation has lots of supplementary functions in order to test the performance, compare with the ideal results as well as visually inspect the possible mistakes and correct the parameters, such as editing corresponding point pairs according to the stitching result. Although not necessarily required for this assignment, the code is capable of stitching a warped image into another one, which makes it possible to obtain any planar panoramic view as long as the homography is correct.

Because there is no direct planar transformation between right and left images of North Campus dataset, only the first-out-then-middle method works in mosaic task.

To avoid exceeding the memory, there is an assertion in the warping function. Also, all operations are vectorized, so the code is optimized.

After evaluating the results of given tasks, we conclude that the correctness of corresponding point pairs is essential. The result does not change if the number of point pairs are increased where the initial point pairs are good, because we use RANSAC. Similarly, the homography is calculated correctly and the result is the same in point selection task where wrong corresponding point matches are added. However, noisy points affect the result. The implementation is vulnerable to this attack at any number of point pairs because always 4 of them are used. Finally, normalizing corresponding point pairs seems to have no significant improvement on the result.

Improvements and Future Work

- Warping seems to require more memory than it should have. Also, it is superfluous to calculate the interpolation for padded areas. Use available optimized functions.
- Automatically detect the corresponding point pairs using ORB or SIFT.
- Use more sophisticated techniques for blending such as weight maps or gradient domain blending.
- Add support for cylindrical and spherical panorama types.