Building of a Rectangular Panorama

Introduction

The panorama is the stitched image which combines a couple of images with different view of angle to elongate the field of view. In the computer vision field, the panorama stitching can be done by performing feature extraction, feature matching and image aligning techniques. In this project, our goal is to implement the building of a rectangular panorama and color mixing using the Burt-Adelson's algorithm. The different number images can be used to compute different level rectangular panorama, from two images to ten images. All the concepts relevant to fulfill this goal are implement in Opencv 3.7.10 on python 4.4.0.

Methodology

The general procedures to reach our goal is to dectect feature using Harris, SIFT, etc. Then match the feature after feature extraction by applying the Brute-Force and Lowe criteria to refine the matched points. Moreover, the homography matrix can be computed via RANSAC. In the final, the images could be warped onto each other by using homography matrix. Multiple images are warped together, the mosaic images can be arranged into a large canvas to show.

The task can be divided into several parts:
Detecting and computing the keypoints
Computing feature description from keypoints
Matching features
Computing homography matrix
Transforming images using homography matrix
Panorama composition (avoid to use stitching module)

Implementation

xfeatures2d.SIFT_create(): This method creates an object that can be used for both interest point detection and feature description. detect() and compute() methods are used for interest point detection and feature description, respectively.

cv2.BFMatcher(): This method creates a Brute Force descriptor object. There are Matcher() and KnnMatch() methods are available to choose. knnMatch() approach is designed to find k best matches in matched features. Therefore, cross-check Brute-Force can be done with cv2.BFMatcher(). For Lowe criteria, the matched feature is selected by defined Lowe's ratio.

findHomography(): This is used for homography matrix based on selected two adjacent images. There are different methods for computation, the RANSAC is used in this case. In the end , the error of RANSAC is decreased to 1.

warpPerspective(): Transport each image into the canvas using the corresponding homography. The flags = cv2.INTER_CUBIC, borderMode=cv2.BORDER_TRANSPARENT are used.

For panorama composition, the matrix operations are performed.

Experiment results

In following figure, we computed keypoints by using SIFT for two tested images for demonstrating the detecting process.

Figure 1. Detected keypoints in two images respectively

For the feature matching, we used Brute Force with crossCheck to produces best results with minimal number of outliers when there are enough matches. Besides, we applied Lowe criteria to compute best matched pairs for comparison.

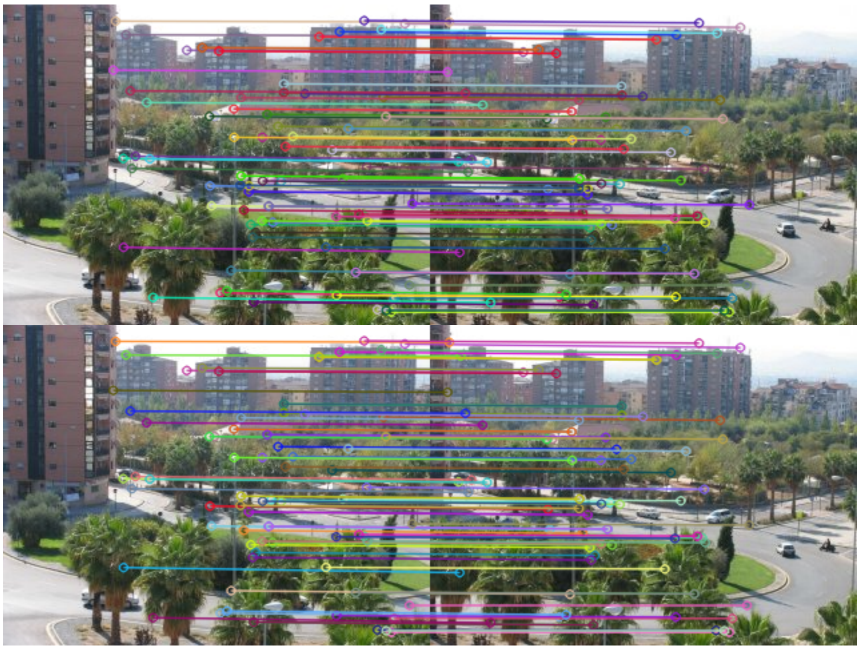

Figure 2. Features matching best 80 pairs are selecting, by Brute Force with crossCheck and without crossCheck but Lowe criteria, respectively.

We can see that both two methods allow us to compute good matches.

Figure 3. First two original images

Figure 4. Rectangular panorama with two images

Figure 5. First three original images

Figure 6. Rectangular panorama with three images

Figure 7. Rectangular panorama with all ten images

From the panorama, generally, the most information is represented in canvas properly. There are some regions without image information after we excluded the zero pixels because the original images are not taken in same horizontal levels. And the canvas has rectangular shape, so when zero pixels in different row or column, it is hard to discard them. We can also observe some distortion in the panorama image.

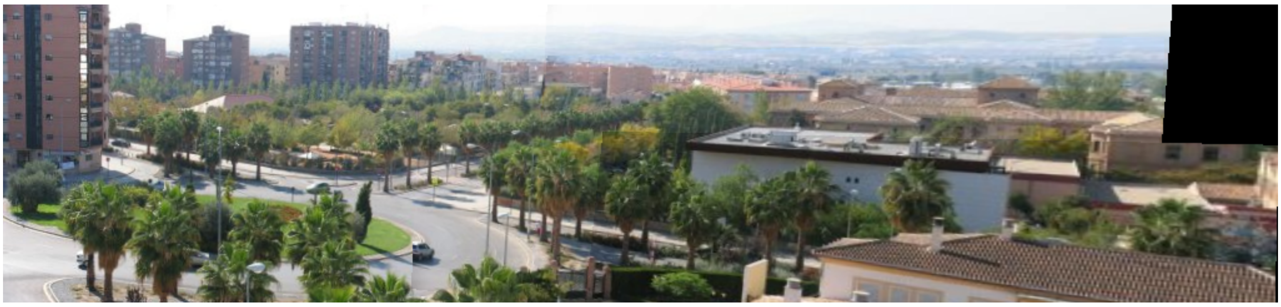

Figure 7. Rectangular panorama with all ten images after cropping

We can crop the panorama to exclude zero region but in this case we will also lose more information which we are interested in at the meantime.

Evaluation metrics

Since we do not have stitching ground truth image, we mainly use no-reference image quality metrics: Referenceless Image Spatial Quality (BRISQUE) and Naturalness Image Quality (NIQE) to evaluate our results.

The BRISQUE compares input image to a default model computed from images of natural scenes with similar distortions. A smaller score indicates better perceptual quality. The NIQE compares input image to a default model computed from images of natural scenes. A smaller score also indicates better perceptual quality.

Panorama image	2 images based	3 images based	10 images based
BRISQUE metric	13.9660	14.1242	34.2267
NIQE metric	3.1569	3.1000	3.0055

Table 1. BRISQUE and NIQE metric

For the BRISQUE metric, we can notice that when we increase the number of images building the panorama, the perceptual quality of image decreased. This is because that the BRISQUE metric compares input images with similar distorted images computed from natural scenes by BRISQUE algorithm. In this case, the 10 images-based panorama has worst perceptual quality.

For the NIQE metric, there are no big difference among three output images. This model actually measures the difference in the multivariate distribution of the input image and compares with the image computed from natural scenes but without distorted.

Proposal for improvement

The classical image stitching result based on the SIFT feature descriptor has distortion errors. Generally, the more images are stitched during the process, more distortion errors we will get. The quality of the panoramic image is affected significantly by the accuracy of image registration. The main point of image registration is transformation matrix. Therefore, a precise transformation matrix is important. Some researchers proposed a new mathematical model to compute the transformation matrix [1].

Another problem with the SIFT is that the stitching results could be bad if there are some errors in detected keypoints. Besides, our images are actually taken in the 3D scene. The 3D depth information is discarded when keypoints are projected in 2D. By doing in this way, some errors are introduced into the results. Some researchers introduced a method based on optical flow algorithm to improve the 3D perception of the panorama image [2].

Conclusion

In this project, we built the rectangular panorama by using feature-based descriptor SIFT with 2, 3 and 10 images. For future work, we can focus on reducing the distortion error and improve the 3D perception of the panorama results.

Reference

[1] Qu, Z., Lin, S. P., Ju, F. R., & Liu, L. (2015). The improved algorithm of fast panorama stitching for image sequence and reducing the distortion errors. Mathematical Problems in Engineering, 2015.
[2] Lee, H., Lee, S., & Choi, O. (2020). Improved method on image stitching based on optical flow algorithm. International Journal of Engineering Business Management, 12, 1847979020980928.