EE735: Computer Vision
Programming Assignment # 01

Part 1: Depth from Focus

Dated: 13th October 2019

Code Explanation

Step 1: Image Alignment

The first step is to align images using Image Alignment Toolbox on MATLAB. Feature-based alignment[1] algorithm is used to align images for creating focal stack. It basically employs the detection of interest point in images and the descriptor describing the area around those interest points. A matching function then find correspondences between the images based on the similarities between the respective descriptors. The final optimal transform is defined (up to tolerance = 0.7 in this case) by the following optimization equation:

$$\arg\min_W D(X_1, WX_2),$$

where D defines the average point-wise distance between the two point-sets (X1, X2) and W is the transform (affine in this case) from on image plane to other.

Fig. 1: Feature Correspondences Before Affine Transformation

[1] https://sites.google.com/site/imagealignment/tutorials/feature-based-alignment

Fig. 2: Feature Correspondences after affine transformation

Error Maps: error maps are the difference between two images to show how aligned two images are. One image is taken as reference and all the images are aligned according to that. We can align images in consecutive manner such that the aligned image is taken as reference for the next image to be aligned. However, that seem not to give better result in this case. The first and last image has great difference. Hence, I chose to take one image as reference and aligned all according to that image.

Error Maps Before and After Alignment of the reference (last image) and the other image: second figure in both cases clearly shows the images are aligned since there is little difference between the images.

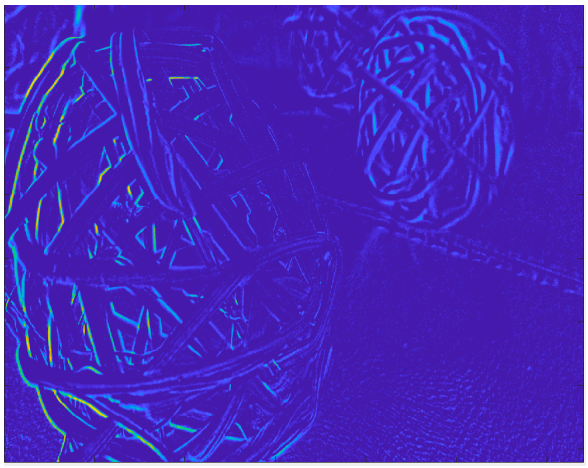

Fig. 3: Before Alignment

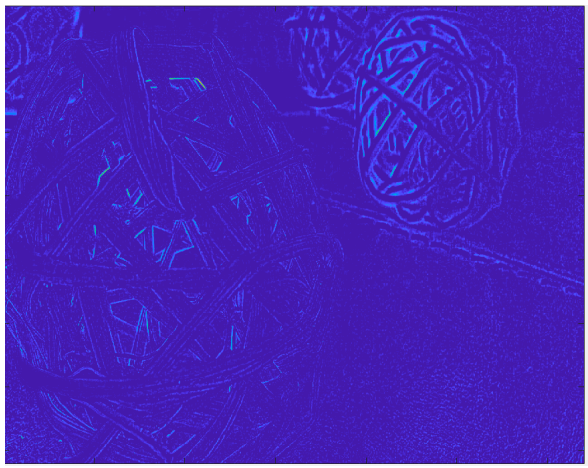

Fig. 4: After Alignment

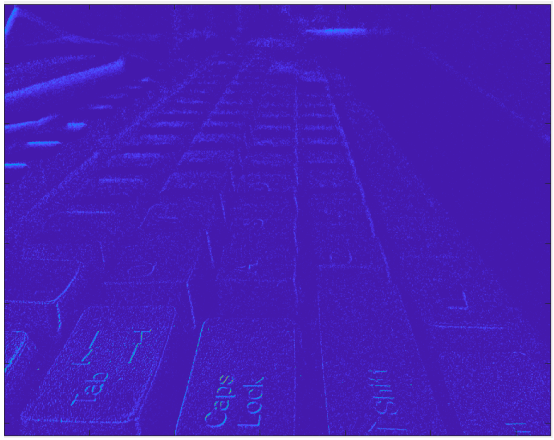

Fig. 5: Before Alignment

Fig. 6: After Alignment

Step 2: Focus Measure

Focus measure calculates the best focused point in an image. Hence, it is used in extracting all the focused points from various images of same image type and using them to create an all-in-focused image. Below is the figure that shows the best focused points in all the frames of keyboards and balls.

Various techniques can be used for calculating the focus of an image i.e. Laplacian, modified Laplacian, sum of the modified Laplacian, Tenenbaum focus measure. Most of them employ taking derivatives which basically helps in extracting edges, hence the sharp point in image. However, I used the focus measure implemented in the reference paper[2] mentioned in assignment. It basically involves convolving the spectrum of the intensity image with the optical transfer function (OTF), which is the Fourier transform of the point spread function (PSF). OTF performs filtering operation here and it depends on values of sigma1 and sigma2. They can be adjusted to avoid the effects of noise and give a sharp image, since they decide which frequencies are blocked by the filter.

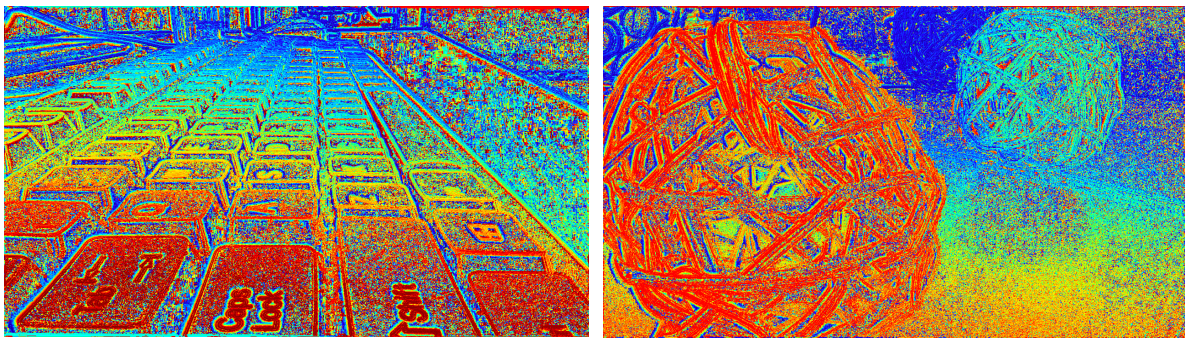

Fig. 7: Focal Map of Keyboard and Balls

[2] A novel algorithm for estimation of depth map using image focus for 3D shape recovery in the presence of noise, A. Malik and T.-SChoi, Pattern Recognition2008

Step 3: Graph-Cuts

Graph-cuts include min-cut/max-flow algorithm that are used for image segmentation and various other applications. It basically involves the optimization (minimization) of energy-cost function which comprised of data cost term and smoothness cost term. Both data-cost and smoothness cost terms have threshold values assigned according to which the data and smoothness terms are initialized. Smoothness term ensures similar depth is assigned to neighbouring pixels while data term assign close-by-value depth for known pixels. MATLAB graph-cut library[3] was used to implement this function and the results are shown below for balls and keyboards.

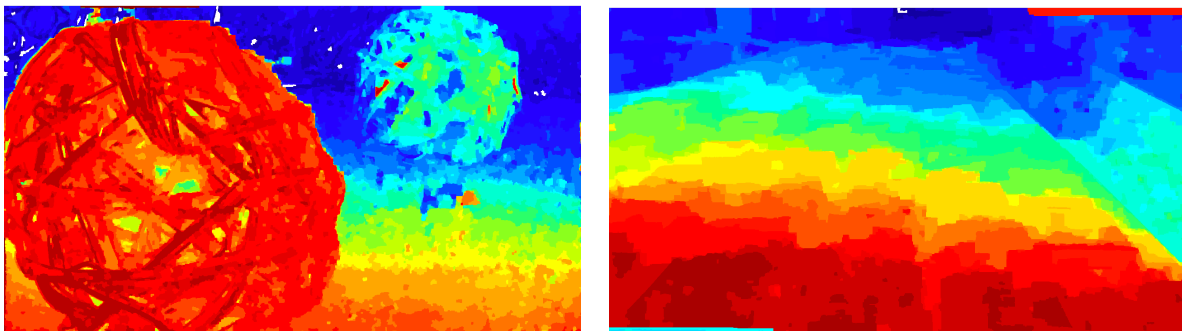

Fig. 8: Depth Maps using Graph-cuts

Step 4: Image Stitching using Initial Focus Map and Graph-cuts

Stitching function basically extract the focused point in various frames and combine them to give an all-in-focus image. Focal map formed from focal measure using OTF and graph-cut focal map were used to stitch image. There is not much apparent difference between the two in both cases, however, theoretically, graph-cuts are known to give better results.

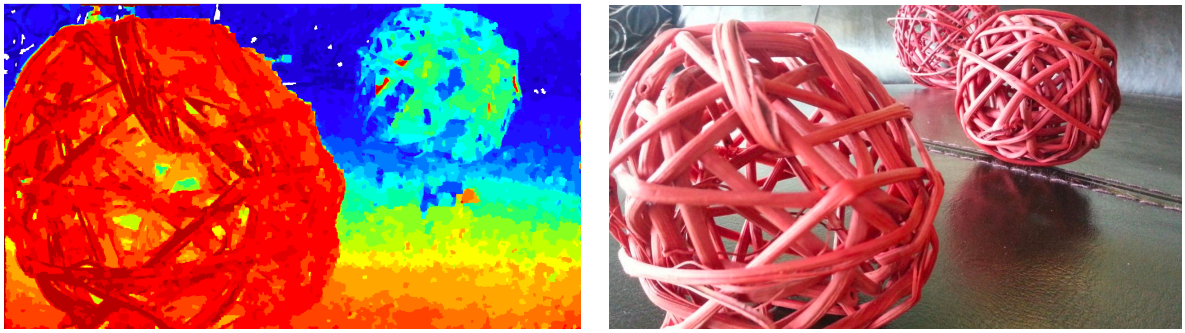

Fig. 9: Ball Image Stitching using graph-cut focal map

[3] http://www.wisdom.weizmann.ac.il/~bagon/matlab.html

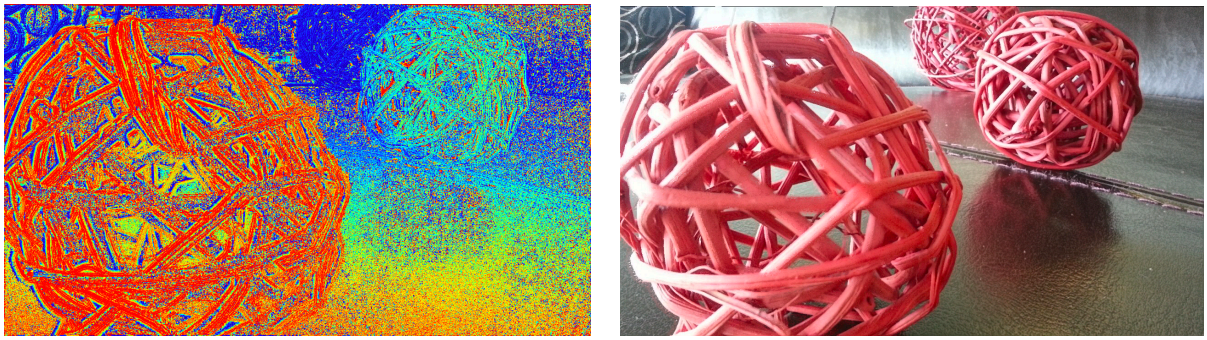

Fig. 10: Ball Image Stitching using initial focal map

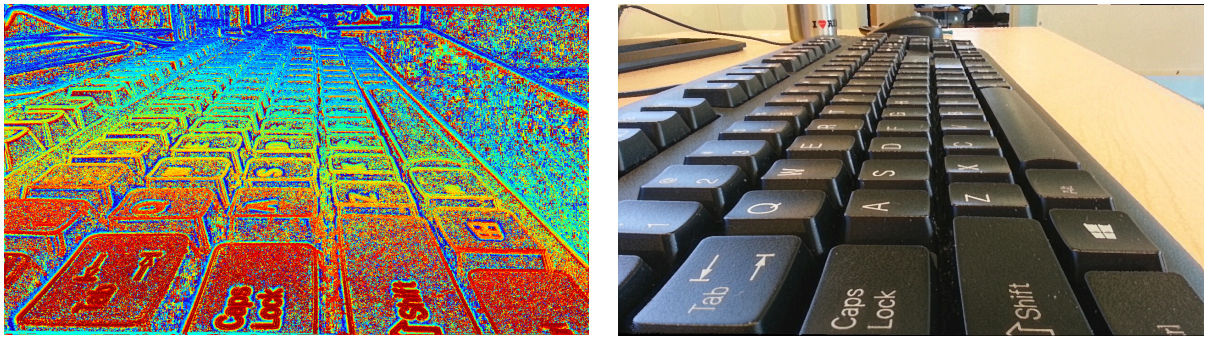

Fig. 11: Keyboard Image Stitching using initial focal map

Fig. 12: Keyboard Image Stitching using Graph-cuts focal map

Step 5: Depth Refinement using Weighted Median Filtering

Depth refinement involves use of weighted median filter (WMF), whereby the all-in-focus image acts as a guide for refining the graph-cut focal map. The guide image is used to assign corresponding weights to patches where filter is applied (on graph-cut focal map in this case). Median filters are in general good at removing noise from the image, hence, it plays somewhat similar role in depth refinement as well.
However, my implementation of WMF did not quite give comparable results. Hence, I implemented another median filter, where I define 3-by-3 weight filter with centre value having greater weight than the rest of the values. The results of that filter are shown below. They do not show any pronounced differences.

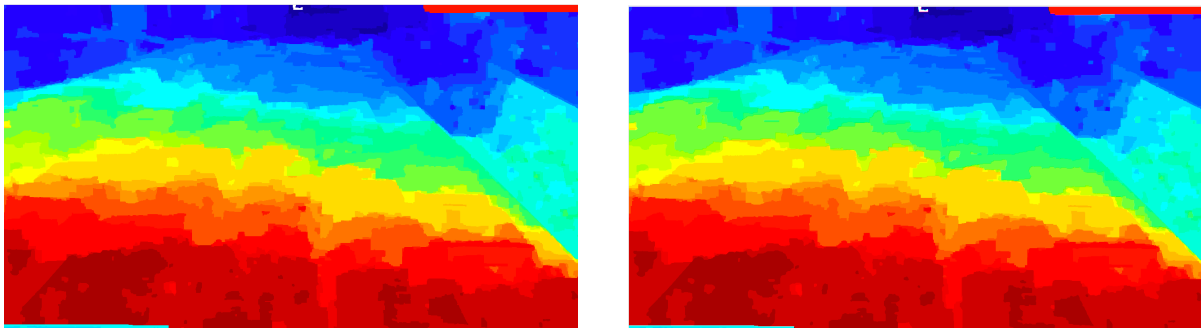

Fig. 13: keyboard graph-cut before and after depth definement

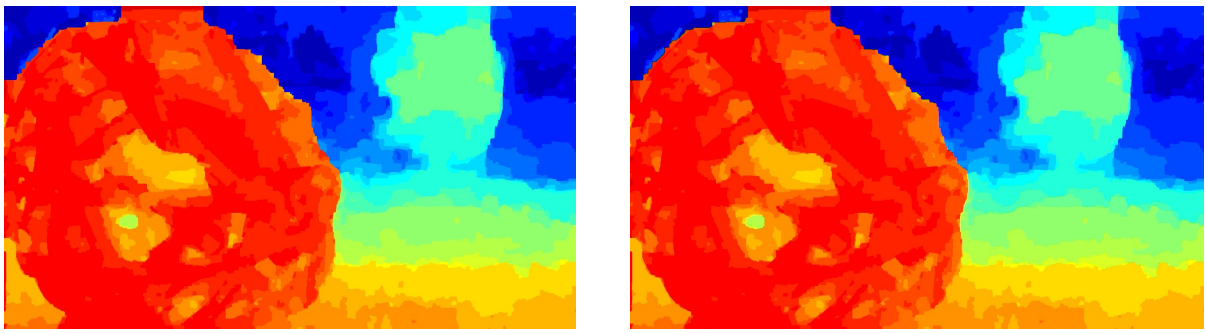

Fig. 14: Ball graph-cut before and after depth definement

Conclusion

This assignment shows how to recover depth from focus by employing the use of multiple images taken from almost same position but with different focus positions. The images are first aligned using feature-based alignment and then they are used to create focal map using one of the techniques of focal measure. Graph-cuts algorithm is used to create a depth map from the focal map, which is the ultimately used to generate an all-in-focus image. Depth map could be refined using weighted median filtering.