Depth from Defocus for Misaligned Mobile Photos Subject to Parallax Effects

Robert Mahieu
Department of Electrical Engineering, Stanford University

Depth from Defocus (DfD)

- A depth map for a photograph can be acquired by taking the same photo several times with the camera set to different focal distances (creating a set of images referred to as the *focal stack*) and analyzing the level of blur at each pixel as the focal plane sweeps through the scene.

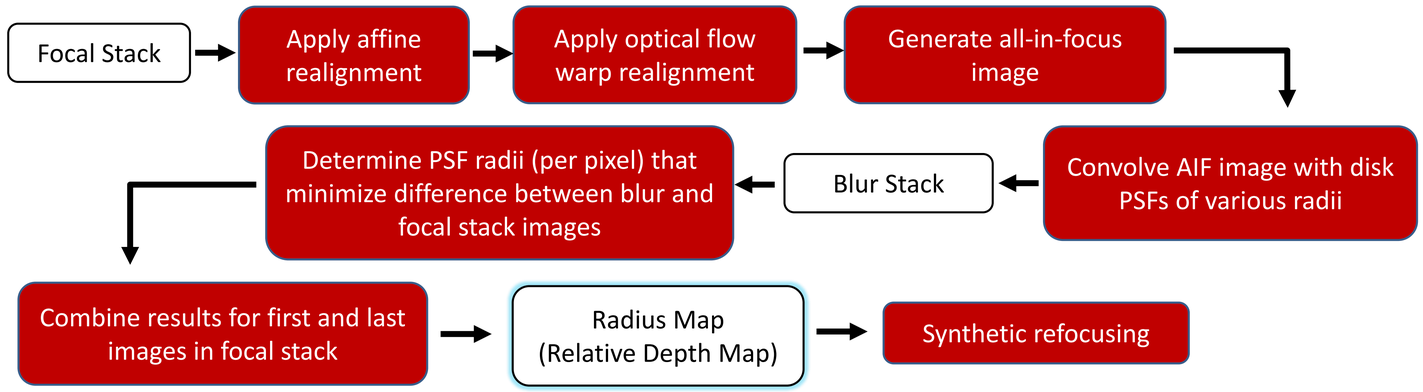
Problem

- This requires each object in the photo to be in the same location throughout the focal stack, which becomes difficult when using a handheld camera since hand movement can lead to parallax effects in the resulting images which cause significant errors in DfD.
- While affine realignment techniques are generally successful for handling very small motion, the effects of parallax in large motion are too substantial to correct with simple affine transformation [1].
- Also assume camera calibration is unknown, which makes traditional approaches utilizing aperture, focal length, and focal distance values infeasible [2].

Proposed Solution

- Use a novel realignment technique combining affine transformation and optical flow fields to register images in the focal stack before DfD [1].

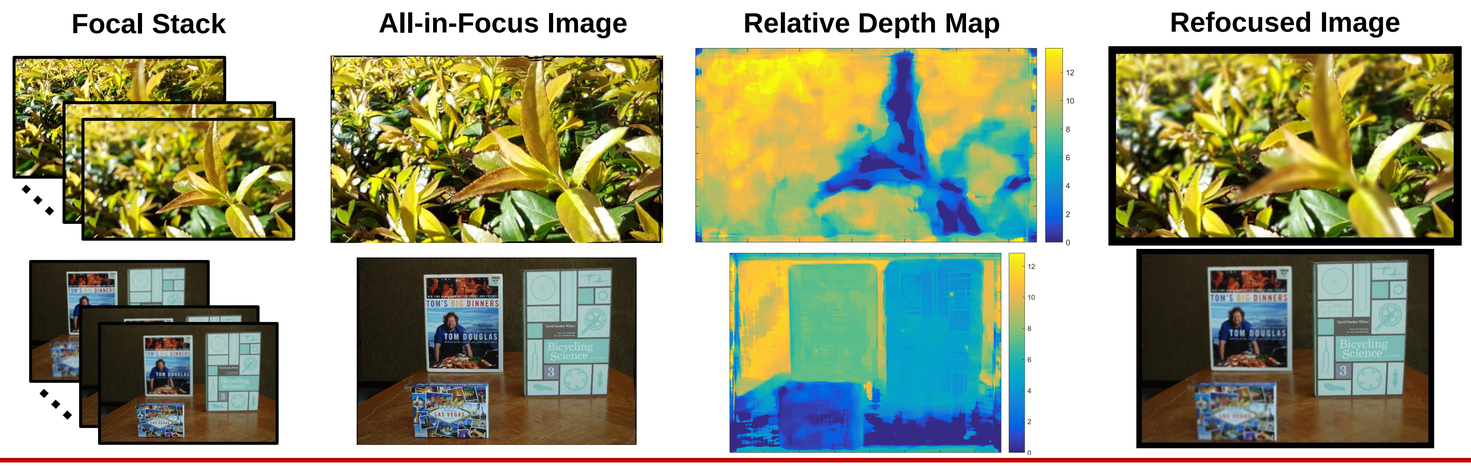
Algorithm Pipeline



Notes:

- *Affine realignment* computed using Lucas-Kanade (inverse compositional) iterative image registration algorithm.
- *Optical flow warping* performed using warp function $\mathcal{W}_{\mathcal{F}}(I(u,v)) = I(u+\mathcal{F}(u,v)_x, v+\mathcal{F}(u,v)_y)$, for flow field $\mathcal{F}$.
- *All-in-focus image* formulated as a Markov Random Field (MRF) optimization problem with data term as the sum of image gradient magnitude within pixel local neighborhood and the smoothness term as linear total variation in frame indices. This problem is solved using an α-expansion graph cuts algorithm.
- *Complete radius map* is constructed as $R_{complete} = R_{first} + (\max(R_{last}) - R_{last})$.
- *Synthetic refocusing* is done by convolving the AIF image with a spatially-varying PSF kernel of radius $r(x,y) = |R_{complete}(x,y) - \text{desiredRelativeDepth}|$.

Results



Discussion

- Realignment performs very well even when camera movement is significant. However, it often produces blurry flow artifacts when movement is large.
- Algorithm performs well when depth changes are generally discrete.
- For a focal stack of 13 518x774 images, entire pipeline runs in roughly 2.5min + 48sec per refocused image.

References

[1] Suwajanakorn, Supasorn, Carlos Hernandez, and Steven M. Seitz. "Depth from focus with your mobile phone." *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*. 2015.

[2] Ens, John, and Peter Lawrence. "An investigation of methods for determining depth from focus." *IEEE Transactions on pattern analysis and machine intelligence* 15.2 (1993): 97-108.