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Project Title:
Artificial refocusing of high resolution SLR images from Time of Flight Depth Maps

Motivation/Background:

The ability to digitally refocus images based on depth in post production is a powerful tool for professional and hobbyist photographers. Currently, few conventional methods exist for accurate refocusing of high resolution images. Light field cameras, such as the Lytro Illum, are able to create depth maps and thus refocus from the numerous perspectives at which images are taken; however, they suffer from poor image quality.

Current solutions for computing depth maps of scenes include ToF (Time-of-Flight) cameras and LiDAR (Light Detection and Ranging). These solutions estimate the depth of a scene by illuminating a scene with light (solutions exist that utilize various wavelengths). The camera measures the amount of time between the initial pulse of light and the amount of time it takes for the camera's sensor to detect the reflected light. The varying time of flights across a scene from the pulses allow the camera to create a depth map.

Due to current work in the literature, depths maps provide the potential for refocusing in the post processing stage. It is worth addressing the current gap provided by current imaging paradigms related to depth refocusing.

Project Overview:

We propose a novel method for digitally refocusing high resolution SLR images in conjunction with Time of Flight computed depth maps. By gathering depth estimation of a scene from Time of Flight depth maps, it is possible to combine the depth information with high resolution images of the scene.

Thus, we propose the following pipeline for the artificial refocusing of high resolution SLR images based on depth maps.

A Time of Flight depth map of a scene will be acquired with a Microsoft Kinect; this is a depth map of the scene that the photographer wishes to photograph. Once the depth map has been gathered, the photographer will capture that exact scene with an SLR camera (cropping if necessary).

There are very specific components in the pipeline that we need to implement beyond the initial image acquisition. The first is ensuring that the photograph we capture with the SLR camera corresponds exactly to the depth map. The depth map needs to be upsampled and mapped to the SLR image; once this is done, the higher resolution photograph will contain all of the necessary depth information acquired via the Microsoft Kinect. Once the mapping has been created, an additional component in the pipeline is necessary to create realistic refocusing between the different depths in the image based on the depth mapping. The specified refocusing should be easily tunable by the user, based on the desired focus with respect to range.

Qualitative metrics are best for evaluating the accuracy and exactness of our dynamically refocused images. We will compare them against images of the same scene, captured at a variety of different depths, so that we can evaluate the differences in our refocused images and those taken by a camera at different depths. Due to potential errors in the refocusing algorithm (e.g. invalid depth assignments to objects at the same depth), it will be useful to compare pixel by pixel regions between our original images and those we refocused.

Related Work:

Researchers at Columbia University's department of Electrical Engineering and Computer Science have done work in active refocusing of images and their associated depth maps, using a series of illuminated dots in [1]. However this depth estimation has limitations as it uses active illumination and is more suitable for indoor or studio shots, whereas using a LiDAR system would allow us to expand the environments this method of refocusing could be used, since LiDAR works well with sunlight and outdoor settings. Additionally, the work done on artificial refocusing in the post processing stage, given the depths maps they computed with their method, could be useful in developing our algorithm for refocusing from the LiDAR depth maps.

[3] presents a novel approach to the single image refocusing-and-defocusing technique by computing a refocus map. This approach is very different as depth data is computed directly from the original photograph; however, their method for refocusing once the depth data has been acquired may also be useful. [4] Relies on several images in order to compute a focal stack and refocus appropriately with a simple Gaussian blur kernel. This may be an appropriate strategy once we have valid depth maps; further research will go a long way in determining the optimal method for refocusing given target metrics.

Milestones/Timeline:

2/13/17 Project Proposal Due
2/20/17 Acquisition of ToF/LiDAR devices and cameras
2/27/17 Preliminary work on image processing pipeline for depth estimation
3/5/17 Finalize refocusing algorithm; completion of mapping photograph to subsection of depth map
3/12/17 Implementation of refocusing algorithm; completion of GUI for modifying focus.
3/15/17 Poster Presentation
3/17/17 Project Report and Code Due

Additional References:

[1] F. Moreno-Noguer, P. Belhumeur, S. Nayar, 'Active Refocusing of Images and Videos.'

[2] C. Premebida, L. Garrote, A. Asvadi, A. P. Ribeiro, U. Nunes, ‘High-resolution LIDAR-based Depth Mapping using Bilateral Filter.’
[3] W. Zhang, W. Cham, ‘Single-Image Refocusing and Defocusing.’
[4] B. Wiberg, ‘A Method for Refocusing Photos using Depth from Defocus.’