Computational Star-Tracking Compensation in Astrophotography

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1 Motivation

Astrophotography is a field that has been typically confined to a small subset of hobbyists and professionals with specialized equipment. Part of this is due to the low light conditions - long exposure times are needed to capture enough light, but this causes artifacts called "star trails" due to the rotation of the earth. To overcome this, equipment such as tracking mounts for telescopes are often used to physically move the camera with the star's rotation.

Figure 1: Image demonstrating star trail artifacts in a long exposure

Our aim is to utilize advances in computational imaging algorithms to enable us to use a normal DSLR camera on a tripod to capture night sky images with good clarity, comparable to images captured with more expensive tracking mounts.

2 Related Work

Our initial approach was inspired by work done for motion deblurring using coded exposures [1]. We wanted to apply this method to astrophotography by taking a sequence of night images with coded exposure times and forming a deblurred result. However, because objects which are being blurred in this case are essentially points of light, a simpler approach of aligning and stacking the images to compose a single scene should be sufficient. Google has implemented a similar method on its pixel smartphone camera in which a sequence of short exposure images are captured, individually processed for hot pixel suppression, and composed together to form a single scene [2]. For pre-processing the individual shots, Richardson-Lucy deblurring has been applied effectively to star images [3], and quadratic programming optimization methods have been shown for denoising [4].

3 Project Overview

Traditional techniques for capturing astronomical images in low-light conditions either involve stacking many short exposures [2], which has the downside of introducing photon shot/Poisson noise, or direct deconvolution of motion blur on a long exposure image, which tends to be more difficult the longer the exposure. Our proposal is to combine the best of both techniques to achieve better results than these methods individually.

3.1 Data acquisition

We will use a DSLR camera to capture sequential images of the night sky with medium length exposure. We estimate this will be around 1-2 minutes. From [2], exposure times of under 16 seconds resulted in images with stars still appearing as points of light, and an exposure time of 2 minutes produced an image with noticeable motion blur. The magnitude of star motion blur observed will also depend on the level of zoom - stars imaged at a higher zoom level will appear to move more across the field of view in the same period of time.

3.2 Deblurring and denoising

In order to remove the motion blur in each individual image captured in the sequence, we apply Richardson-Lucy deconvolution. First we must construct the blur PSF induced by motion of the stars. We first assume that the exposures are short enough such that this blur is more or less linear, but if necessary, the circular motion can be compensated for by performing a polar coordinate transformation on the image. We can deduce the shape of this PSF using knowledge astronomical motion and methods from [3]. Next, to denoise the image, we again implement deconvolution but this time deconvolving a noise kernel. One approache to implementing this deconvolution would be ADMM with a sparsity prior. We could also try using non-local means or bilateral filtering.

3.3 Image stacking

After deblurring and denoising the individual exposures, we stack the full image sequence to form the final target image. To do this, we plan to use techniques as in [2], where a reference image is selected, and then the remaining exposures are aligned to this target and then merged.

4 Milestones, Timelines & Goals

- 2/12-2/19: Find existing astrophotography images to use as ground truth, and simulate motion blurring to test the algorithm on. Create a baseline for motion blur deconvolution
- 2/19-2/26: Test motion blur deconvolution on simulated images. Create a baseline for image stacking.
- 2/26-3/4: Test baseline for image stacking on simulated images, and combine motion blur deconvolution and image stacking baselines. Capture some real data when conditions are good.
- 3/4-3/11: Capture more real data when conditions are good, test and refine algorithm.

References

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