Project Proposal - ECE 285

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1 Introduction

Astrophotography is a captivating and rewarding hobby, which offers space enthusiasts a window into the beauty of the universe. However, it has its own set of challenges, particularly the need to balance the low-light conditions required to photograph objects in the night sky with the image degradation caused by insufficient light entering the camera.

Long exposure times are necessary to capture sufficient light, but this often results in motion blur artifacts known as "star trails". Star trails occur due to the Earth's rotation during the exposure time, causing celestial objects to appear as streaks or arcs in the final image. These trails are most often seen as a circular motion blur centered on the celestial north pole. While star trails can be used for artistic effect, the general goal is to minimize them.

Traditionally, mitigating star trails requires the use of mechanical tracking mounts, which can counteract the Earth's rotation by precisely moving the camera to follow the apparent motion of the stars. These mounts are effective but may also be prohibitively expensive for beginners or amateur astrophotographers.

With the advancement of smartphone camera capabilities, especially low-light performance and image stabilization, anybody can capture stars (and star-trails). Keeping in mind the persistent challenge posed by star trails in smartphone astrophotography, we aim to remove star trails from the captured images while maintaining the long-exposure effect of more visible stars by leveraging computational imaging techniques.

2 Related Work

Several approaches have been proposed to address the problem of star trail removal.

Tai et al. (2011) presented a Richardson-Lucy deblurring algorithm with regularization priors. The proposed algorithm also used a projective motion path blur model to capture spatially varying blur.

Whisler and Dai (2020) developed a similar method for removing spatially varying motion blur, which can be used to remove star trails. They experimented with more priors and deblurring algorithms and obtained good results with ADMM and a TV prior.

Wang et al. (2018) proposed an algorithm to reduce motion blur in star images captured by a sensor. They used a MEMS gyroscope to deduce motion trajectory, and correct blur kernels and employed a reconstruction method for efficiency.

Hou et al. (2021) introduced a real-time method to tackle motion blur in star sensors under high dynamics. By employing fast blur kernel estimation and area filtering techniques, they were able to remove trailing stars in a computationally efficient way, even under low SNR conditions.

More recently, Fan et al. (2023) proposed a method for restoring motion-blurred star images with elliptical star streaks using a projective transformation to convert elliptical paths to circular ones and later using a deconvolution algorithm. This deviation from working with circular star trails might help us approach our additional deliverables.

3 Deliverables

We plan to deliver:

- Automating detection of the Pole star/Polaris in an image.
- Estimating the blur kernel for each star/radius with respect to Polaris.
- Using deconvolution or iterative methods to get images devoid of star-trails.

These goals will be achieved using on images containing sparse star-trails.

Additional deliverables (as time permits):

- Extrapolating our results from sparse star-trail images to images with dense star-trails or non-circular star-trails.
- Comparing different image priors and optimization algorithms to achieve the best perceptual and PSNR results.

References

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