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EE 367/368

Low-cost computational astrophotography

Introduction/Motivation

Astrophotography is a widespread hobby in which DSLR cameras are used to take images of objects in space. Certain factors make this a very expensive hobby. One of these is the rotation of the earth. Very long exposure times are required to capture photos of faint celestial bodies, and the earth's rotation causes these objects to "move" in the sky during the exposure. To compensate for this motion, astrophotographers use moving camera and telescope mounts to keep the object steady in the frame. These mounts can cost thousands of dollars, making astrophotography prohibitively expensive for most people. We hope to be able to use computational techniques to remove the need for these rotating mounts, and instead post-process these images.

Related Work

Currently, most astrophotographers compensate for the rotation of the earth by physically moving the camera along with the earth. However, some attempts have been made to remove this requirement. To accurately localize stars in streaked images, one researcher has re-mapped the star streak to polar coordinates, so that all stars will have the same "point-spread function." This technique was designed for locating specific stars for the purpose of identifying specific stars, but will be useful for our purposes, and we plan to use this algorithm [1]. Other factors besides streaking can cause blurring in star images, and attempts have been made to correct this. These have used such techniques as Richardson-Lucy deblurring [2] and maximally sparse optimization [4]

Data Collection

We anticipate that a significant amount of time will be spent gathering the image data for this project. We will first need to learn the basics of astrophotography to take quality images of the night sky. In addition, taking photos with different parameters will be time-consuming as we are dealing with long exposure images, and the results can be easily affected by external factors such as weather conditions. We hope to have images that will need post-processing based on varied parameters such as exposure, foreground/background elements, illumination, and noise.

Proposed Models/Algorithms

1. Modified PSF calculation based on time of day and exposure time [1]
2. Image segmentation of background & foreground, comparing results from global thresholding by Otsu's method vs. locally adaptive thresholding
3. Contrast and color enhancement, comparing results from global histogram equalization vs. locally adaptive histogram equalization
4. Image denoising using local linear smoothing, median filtering (weighted vs. non-weighted), bilateral filtering, and non-local means
5. Image deblurring using the following techniques:
    - Estimation of additive noise/impulse responses from potential degradation of image
    - Convolution with image sparseness prior
    - Naive inverse filtering/wiener filtering
    - Richardson-Lucy deblurring [2]
    - Dilation/erosion techniques

Evaluation

These post-processing computational techniques are relatively inexpensive. We plan to evaluate our algorithms first by just conducting qualitative visual analysis, noting the effectiveness of the deblurring and denoising while preserving the details and color. We also will look at quantitative evaluation metrics such as Peak Signal to Noise Ratio (PSNR). Finally, we plan to compare the computational time of our results to evaluate the efficiency.

Milestones/Timelines

2/13: Project Proposal Due
2/13 - 2/27: Capture initial images with different parameters/settings, implement baseline models and algorithms for processing captured images
2/27 - 3/13: Capture final images during next new moon, implement enhanced/polished techniques and evaluation methods
3/13: Project Presentation Due

References

1) https://www.researchgate.net/publication/278714144_Polar_and_spherical_image_transformations_for_star_localization_and_RSO_discrimination
2) https://www.spiedigitallibrary.org/conference-proceedings-of-spie/9501/1/Richardson-Lucy-deblurring-for-the-star-scene-under-a-thinning/10.1117/12.2176782.full
3) http://www2.compute.dtu.dk/~pcha/HNO/ChallD.pdf
4) https://pdfs.semanticscholar.org/57ee/8f0bb76705ef3b26b6e6ef1d3a8ed617c481.pdf