

Computational Star-Tracking Compensation in Astrophotography

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Motivation

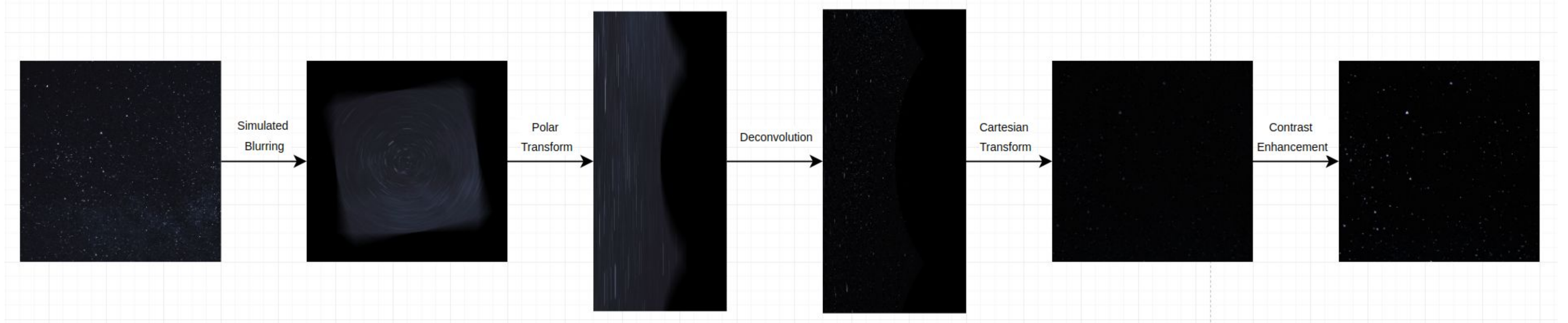
Astrophotography is a field that has been typically confined to a small subset of hobbyists and professionals with specialized equipment. Part of this is due to the low light conditions - long exposure times are needed to capture enough light, but this causes artifacts called “star trails” due to the rotation of the earth.



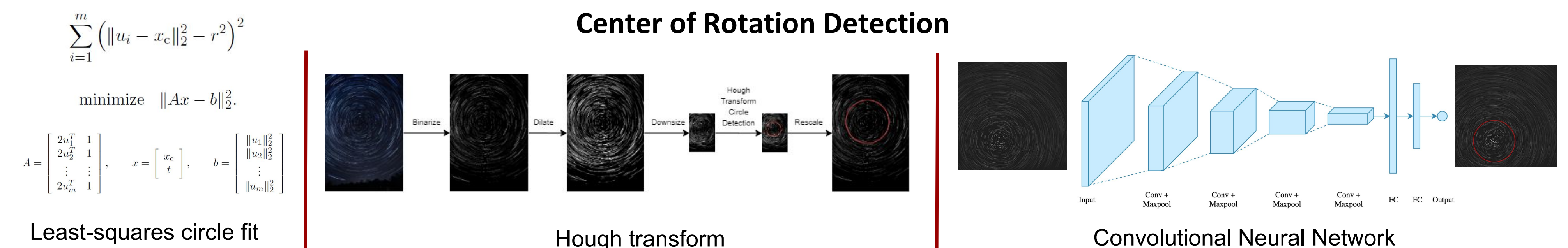
To overcome this, equipment such as tracking mounts for telescopes are often used to physically move the camera with the star's rotation. However, these mounts can be very expensive, which makes post-processing computational methods for eliminating these star trails more attractive for the hobbyist, especially if they are more concerned with visually appealing images than strictly accurate ones.

Methods

Deblurring Pipeline



Center of Rotation Detection



Related Work

- Polar transformations are used in [1] in order to process long exposure images of space objects.
- Richardson-Lucy deconvolution has been used in prior work in deblurring star images [2]. In our work, we tried ADMM deconvolution as well, which has not been as well explored, as well as different choices of priors.
- A previous EE367 project [3] also addressed the problem of deblurring astrophotography, however they did not computationally estimate the center of rotation of star trails, and they did not pursue the deconvolution method.

References

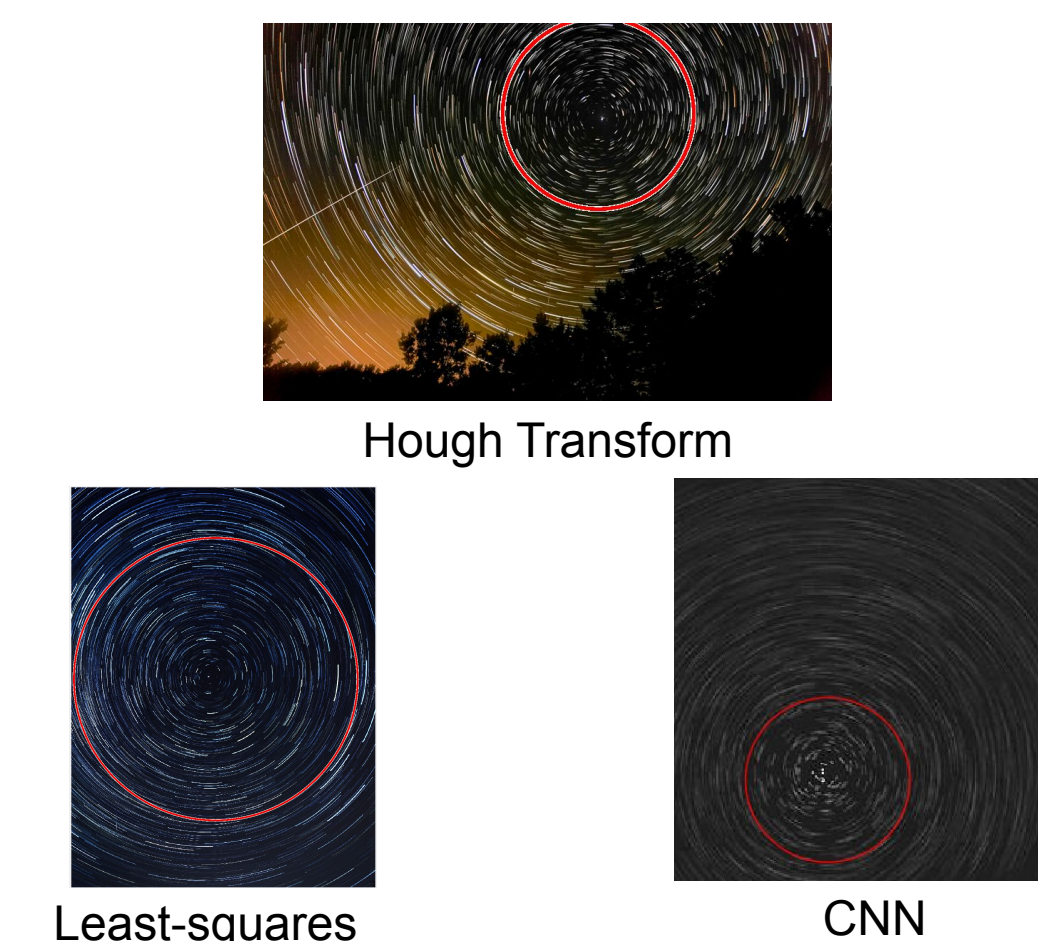
- [1] Sease and Flewelling, Polar and spherical image transformations for star localization and RSO discrimination, *25th AAS/AIAA Space Flight Mechanics Meeting*, 2015.
- [2] Su et al., Richardson-Lucy deblurring for the star scene under a thinning motion path, *Satellite Data Compression, Communications, and Processing XI*, 2015.
- [3] Yen and Bryan, Low-Cost Computational Astrophotography, EE367 Project, 2019

Experimental Results

Deconvolution Comparison

Deconvolution Method	$\theta = 5^\circ$			$\theta = 15^\circ$		
	PSNR	SSIM	Result	PSNR	SSIM	Result
Ground truth	-	-		-	-	
ADMM with sparsity prior	17.9594	0.44894		20.1671	0.19097	
ADMM with TV prior	16.4092	0.48085		20.8521	0.53328	
Richardson-Lucy	20.8218	0.32276		21.5177	0.31575	
Richardson-Lucy with TV prior	20.8293	0.3341		21.3758	0.32558	

Center Detection



MSE Comparison

Center Localization Method	Simulated Stars	Simulated Blurs	Real Star Trails	Overall	Notes
CNN	0.000677	0.0535	0.0826	0.0455	Biased toward the image center of mass
Hough Transform	0.000101	0.0000121	0.00062	0.000198	Did not perform well for sparse images
Least Squares	0.0430	0.105	0.00847	0.0522	Did not generalize to real data very well

Real Star Trails



Related Work Comparison

