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On the Value of JunoCam's Marble Movie Images

G. Eichstädt (1), and C. J. Hansen (2).
(1) Independent scholar, Stuttgart, Germany (ge@junocam.pictures), (2) Planetary Science Institute, Tucson, Arizona, USA,

Abstract

JunoCam took thousands of "Marble Movie" images of Jupiter. Those can be evaluated for accurate in-flight camera calibration, as well as for map renditions based on this calibration. Accurate camera calibration increases the science return of wind field analysis from close-up stereo pairs, since global displacements can be interpreted as target data rather than as calibration inaccuracies. Alternative lense distortion models, other than the straightforward Brown-Conrady approach, are considered and investigated.

1. Introduction

NASA's Juno spacecraft has successfully completed several perijove passes. JunoCam [2] is Juno's visible light and infrared camera. It was added to the instrument complement to investigate Jupiter's polar regions, and for education and public outreach purposes.

JunoCam has taken several thousand images of Jupiter from a distance. In most of these images, Jupiter has an apparent size of less the 100 raw pixels. These images are informally called "Marble Movie" images. About half of the images are in RGB. Their renditions can be tested for their centroid alignment of the three color channels of a Jupiter image, and for Jupiter's position and shape relative to its expected position and shape derived from SPICE kernel data. Defining a formal distance between actual rendition and anticipated rendition is the key to minimization methods applied to a family of camera models. This is an approach for in-flight JunoCam calibration.

An accurately calibrated camera model can then be used to create maps from marble movie images. It is also useful to infer cloud dynamics from pairs or n-tuples of close-up Jupiter images. Resolving inaccurate camera calibration by band pass filtering the cloud displacement field would remove low-frequency properties of the cloud feature velocity field. With an accurate geometrical camera model, the radius of the the low frequency boundary of the band pass filter can be enlarged, or even completely removed.

2. JunoCam Marble Movie Images

Especially during Juno's Jupiter approach phase, and between the first few orbits, JunoCam took a large number of images of Jupiter from a distance. Those images are informally called "Marble Movie" images, since Jupiter looks like a small marble in those images with a horizontal field of view of about 58 degrees.

Figure 1 shows an image of the Perijove-12 approach phase. In that image, Jupiter appears a little larger than in typical marble movie images. But it's well-suited to show the effect of varying camera parameters. For calibration purposes, the respective centroid positions of the red, green, and blue channel of the rendered Jupiter image can be compared. The centroid position of each color is described by its x and y pixel position. The deltas of the red and the blue centroid position with respect to the green centroid position form a 4-tuple of real numbers. In general, this allows pinning down four geometrical camera parameters, provided all other parameters are known.

If at most three image-specific unknowns are to be determined, with a larger number of marble movie images, additional stable camera parameters can be approximated.

3. Alternative Geometrical Lense Distortion Models

The widely applied Brownian lense distortion model [1] can get unstable for wide-angle cameras, since it's essentially a class of Taylor polynomials. Those polynomials tend to oscillate for higher degree approximations presumably needed for accurate JunoCam calibration, and they diverge rapidly to infinity beyond some radius like shown in Figure 1 for some hypothetical radial lense distortion.

Therefore, alternative classes of distortion models will be defined and investigated. One straightforward example is using cosine series. The cosine function is smooth without diverging to infinity for increasing arguments, and it encodes an infinite set of Brownian distortion coefficients.

Figure 1: PJ12 approach image `JNCE_2018090_12C00001_V01` with the raw in the left column, and two renditions in the right column, the upper rendition with well-chosen camera paramaters, the lower one with a less appropriate Brownian K1 parameter.

Within the family of radial distortion functions described by

$$R(r) = r \cdot \sum_{j=0}^{n} a_j \cos(n \cdot b \cdot r), \qquad (1)$$

the hypothetical lense distortion presumed in Figure 2 could be described accurately by two coefficients, the wavelength and the amplitude of the oscillation. All a_j except $a_1 := 1$ would be zero, and b would be set to $b := 1$.

4. Applications

Accurate camera calibration improves the accuracy of maps or reprojections derived from JunoCam images. Maps of Jupiter close-ups can be used to infer cloud velocity fields. An example is shown in Figure 3. With accurate maps, velocities can be determined in a more global fashion, than just relative to a regional mean velocity.

5. Summary and Conclusions

Marble movie images help calibrating camera models. Models other than the immediate Brownian lense distortion model appear appropriate for JunoCam. Good geometric calibration improves the quality of derived products, including maps and velocity fields.

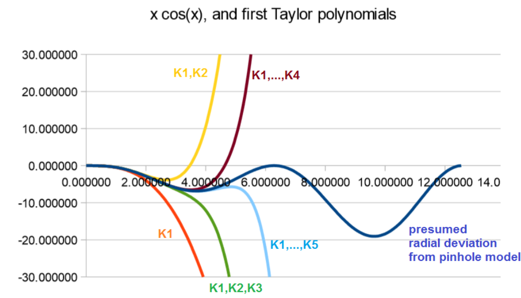

Figure 2: Approximation of a hypothetical radial lense distortion with increasing order of polynomial.

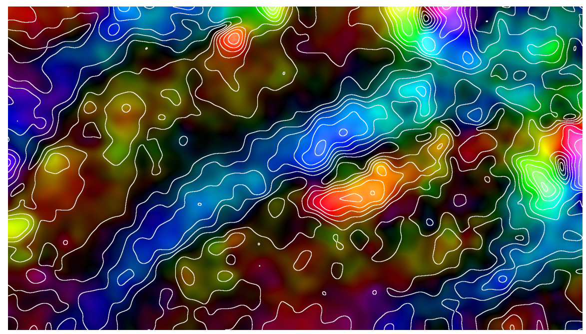

Figure 3: Approximate isotachs derived from a pair of Perijove-12 JunoCam images.

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