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Correcting Cassini pointing parameters from Saturn's ring edges

Altair Gomes-Júnior (1,2), Rafael Sfair (1) and Rodrigo Figueira (1)
(1) UNESP - São Paulo State University, Grupo de Dinâmica Orbital e Planetologia, Guaratinguetá, SP, Brazil (altair.gomes@unesp.br) ,
(2) Laboratório Interinstitucional de e-Astronomia - LIneA, Rio de Janeiro-RJ, Brazil

Abstract

Cassini spacecraft obtained thousands of observations of the ring system and satellites. For an accurate study of these objects it is important the correct pointing parameters of the observations. However, in many cases it is difficult to use a classical astrometry procedure due to the lack of reference stars on the field. In this work, we describe a new method that uses the ring edges to provide the astrometry of Cassini's ISS images. We identify Saturn's ring edges in the images and compare to their expected location given the pointing parameters from JPL kernels. Then, we apply offsets to the pointing coordinates until they match with the observable ring edges. The goal is to have good astrometry measurement in observations where it is not possible to use classical astrometry.

1. Introduction

The Imaging Science Subsystem (ISS) was the main Cassini instrument for optical observations. It was specifically designed to image bodies in the Saturn system [1]. The ISS had 2 cameras, being one for high resolution observations, the Narrow Angle Camera (NAC), and one for a wide view, the Wide Angle Camera (WAC). They extensively observed the Saturn, its satellites and rings.

Unfortunately, a lot of images does not have detectable reference stars. This can be due to the presence of the rings that may cover large parts of the image or when the exposure time is too short. Because of this, a classical astrometric procedure is not always possible.

2. Determining ring edges on the images

Stellar occultations observed by Cassini and ground-based observations has revealed a lot of features in Saturn's rings [2]. Unfortunately, the majority of these features are too close to each other to be easily distinguishable in the observations. Some others, however, can be very well determined, with sharp-edged features. This is the case, for instance, of the inner and outer edges of the Keeler and Encke Gap, as well as the outer edge of the A ring.

To calculate the location of the ring edges on the images, we first determine the position of Saturn relative to the spacecraft. Then we generate rings around Saturn with the radius given by the edges described. These rings are, of course, located at the equatorial plane of the planet, i.e. along the fundamental plane of the "IAU_SATURN" frame as defined by the JPL kernels.

Using the images downloaded from the OPUS web-service [1], we can obtain the position of the spacecraft on the Solar System and their pointing direction from the appropriate JPL kernels[2]. These parameters are the Right Ascension (α_c), Declination (δ_c) and Twist Angle. Finally, we use the distortion model of [3] to determine the positions in sample and line (row and column of the image, respectively, in pixels) for each given coordinate of the edges.

3. Correcting Cassini camera pointing

To compare the calculated positions with the real location we identify the edges on the images using the Canny edge detection algorithm [4].

To identify the correct (α_c, δ_c) we first calculate the displacement in the sample and line directions. We generate a matrix of displacement, in pixels, to be applied to the edges calculated from the JPL pointing coordinates.

For each displacement, a round function is applied

[1] Website: https://tools.pds-rings.seti.org/opus/
[2] Website: https://naif.jpl.nasa.gov/pub/naif/CASSINI/kernels/

to the model to generate an image that, similarly to that generate by the Canny filter, has a value of 1 in the pixels corresponding to the calculated edges and 0 elsewhere. The images are compared to identify the total number of pixels that corresponds to the edges in both. This process is repeated for all given displacements until the total number of pixels from the edges reach its maximum.

Figure 1 shows in the N1546720830 NAC image the location of the A-ring and Keeler gap edges before (red) and after (yellow) this process. The displacement found for this example was of -22.5 px and 0.75 px in sample and line, respectively. By the position of Prometheus, it is possible to see the fit was able to provide a better pointing direction.

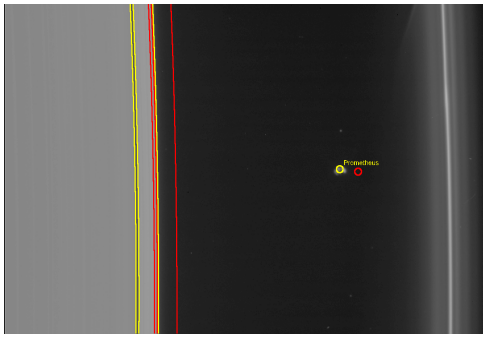

Figure 1: Region of N1546720830 NAC image after the fitting procedure. Red lines show the positions of the ring edges with the nominal pointing parameters. Yellow lines show the same with the corrected pointing parameters. Prometheus ephemeris position is also shown in both situations as a reference.

4. Results

To validate our technique, we compare our results to those obtained using CAVIAR [5]. Using 8 UCAC5 stars with magnitude between 9 and 13, CAVIAR found a correction in sample and line of -22.6 px and -1.0 px, respectively.

The comparison was made for other images and differences in the same order was obtained. It shows our method was able to correct the pointing parameters of Cassini ISS images. The difference between our results and CAVIAR is small compared to the correction identified and expected given the problems we aim to solve (observations without reference stars in the FoV).

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