Precision Navigation of Cassini Images Using Rings and Icy Satellites

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1. Introduction

The Cassini Orbiter has taken more than 350,000 pictures of the Saturn environment. Before an image can be used for research, it is necessary to know where the Cassini camera was pointing in space at that time. Approximate pointing information is provided through SPICE C-kernels, but pointing errors can approach 0.04° (~100 pixels), requiring the researcher to embark on a labor-intensive and time-consuming process to determine the correct pointing. Our goal is to automatically navigate most images to an accuracy of ~1 pixel (and track uncertainty when less precision is available) and generate a new set of accurate C-kernels. The results will be made publicly available through the PDS Ring-Moon Systems Node.

2. Methodology

Based on available SPICE information, we predict which bodies, rings, and stars will be present in the image. We generate a model of how the known bodies should appear and perform a 2-D correlation to find the optimal offset that most accurately aligns the model with the image. As necessary, we apply digital filters and other techniques necessary to make the various features easier to detect. Our previous poster at the 2014 DPS described navigation using stars and simple bodies. Here we describe the more sophisticated techniques used to navigate up-close images of rings and icy satellites.

3. Solicitation of Community Involvement

If you have a research project that involves the navigation of Cassini data, we would like to talk to you. We are looking for early adopters and volunteer peer reviewers who will work with us to ensure the usefulness and quality of our data products.

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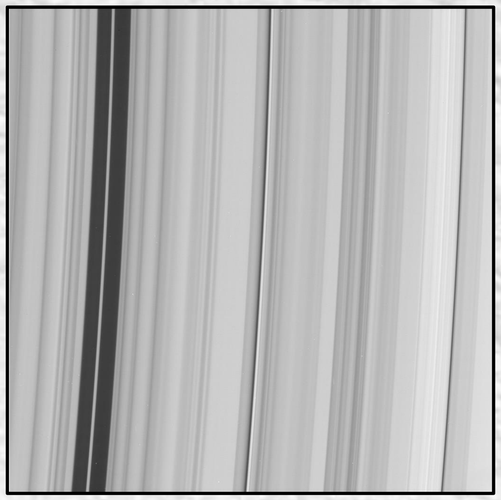
Rings

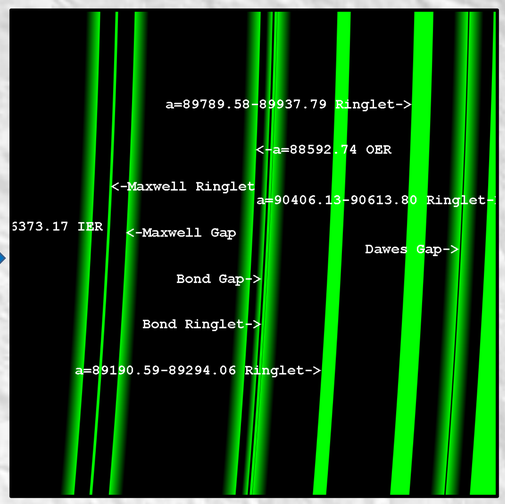
Saturn's rings are a complex dynamical system. Resonances, self-gravity wakes, and the effects of embedded moonlets result in rings that are highly variable both spatially and temporally. Different illumination and viewing geometries also make the rings appear very different. For the purposes of navigation, there are few predictable features that can be used as references for an image. To create a model of the rings, we use all of the circular and near-circular features that are known. As the layout of the rest of the rings is unknown, we must be careful not to include more data than necessary in the model. Since our correlation function is especially good at matching edges, we mark the sharp edges of ringlets or gaps and then shade the model away from each edge so that no false sharp edges are introduced.

Some of the known features have non-trivial residuals on their orbital elements. In some cases we need to apply a Gaussian blur to both the image and the model to allow the correlation to succeed, resulting in a navigation accuracy worse than ~1 pixel. This technique is especially important for the outer edges of the A and B rings, which have complex time-varying orbits.

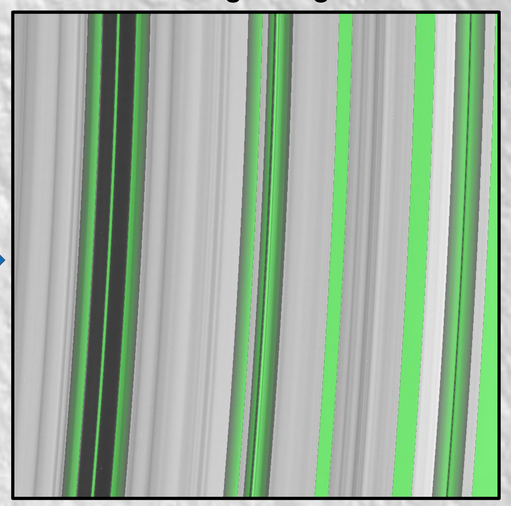
Original Image



Model with Known Features



Resulting Navigation



Icy Satellites

Some images of icy satellites do not have enough limb showing to allow navigation using a simple Lambert-shaded model. In these cases, surface features must be used. We automatically create our own maps that are geographically precise. Different maps are created for different illumination geometries because the shadowing of craters affects the image navigation.

1. Moons in "seed" images, which have been successfully navigated using limbs or stars **(A),** are reprojected into longitude/latitude space **(B)** and combined to form a map of the moon's surface **(C)**. The map shown here is the combination of 449 images of Rhea and is color-coded to show the different images used to create the map. The sub-solar point for this map is approximately 180° longitude and –15° latitude.

2. When an image **(D)** can only be navigated using surface features, the appropriate area of the map is projected onto the sphere of the moon in the image, creating a new model **(E)** that is used to navigate the image **(F)**.

3. The newly-navigated image can be used as a "seed" image and is added to the map for future use **(G)**.

The accuracy of the map is limited by the accuracy of the navigation of the original seed images. Although the images later navigated using surface features may be much higher resolution, the navigation accuracy of the resulting map can never improve. When a high-resolution image is navigated using a low-resolution map, both the map and the image must be blurred to allow correlation to succeed. Any resulting reduction in navigation accuracy is propagated to later images.