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Filtering and segmentation of the Cassini synthetic aperture radar images on Titan

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Abstract

A filtering technique is applied to obtain the restored synthetic aperture radar (SAR) images. One of the major problems hampering the derivation of meaningful texture information from SAR imagery is the speckle noise. It overlays “real” structures and causes gray value variations even in homogeneous parts of the image. Our method, the TSPR (total sum preserving regularization) filter, is based on probabilistic methods and regards an image as a random element drawn from a prespecified set of possible images optimized by a synchronous local iterative method. The despeckle filter can be used as intermediate stage for the extraction of meaningful regions that correspond to structural units in the scene or distinguish objects of interest like lakes, drainage networks, equatorial dunes or impact craters, where different textures appear.

1. Introduction

Cassini carries a multimode Ku-band (13.78 GHz, λ =2.17 cm) radar instrument designed to probe the surface of Titan and that of other targets in the Saturn system in four operating modes: imaging, altimetry, scatterometry, and radiometry. The SAR mode is used at altitudes under ~4000 km, resulting in spatial resolution ranging from ~350 m to >1 km. Images are acquired either left or right of nadir using 1–5 looks. A swath 120–450 km wide is created from 5 antenna beams. SAR coverage is dependent on spacecraft range and orbital geometry. Radar backscatter variations in SAR images can be interpreted in terms of variations of surface slope, near-surface roughness, or near-surface dielectric properties. The images obtained using SAR revealed that Titan has very complex surface [1], formed with features such as lakes, mountains, fluvial river networks, possible volcanic-like features and dunes which resemble Earth-like geomorphological structures [2]. However, both the material and the environmental conditions shaping their respective surfaces are considerably different.

2. Filtering and segmentation

Strip mapping SAR consists of a large antenna which is synthetisised from many small antennas and remains fixed with respect to the radar platform so that the large antenna illuminates a strip of the ground. This technique is used to improve the azimuthal resolution. As the platform moves, a sequence of closely spaced pulses is emitted and the returned waveforms are recorded. An image is computed after the coherent sum of reflected monochromatic microwaves. The image is distorted by a strong granulation, called speckle. Speckle noise exists in all types of coherent imaging systems and its presence reduces the resolution of the image and the detectability of the target. Speckle noise is not only signal dependent but is also spatially correlated and reduces the effectiveness of image reduction.

The TSPR filter used here is based on a membrane model Markov random field approximation with a Gaussian conditional probability density function optimized by a synchronous local iterative method. The final form of despeckling gives a sum-preserving regularization for the pixel values of the image. The TSPR method preserves the mean values of local homogeneous regions and decreases the standard deviation up to six times [3].

The TSPR filter can be used as intermediate stage for the segmentation. The purpose of segmentation is to divide the image into specific regions that correspond to structural units in the scene or distinguish objects of interest. These regions are characterized by spatially connected, non-overlapping sets of pixels sharing common properties. The supervised method of minimum Euclidean distance uses the mean values of each member and calculates the Euclidean distance from each classified object to the nearest class segmenting the image into different regions of interest or different labels.

We begin with the Cassini SAR image of lakes PIA08630. The image from the flyby T16 on July 22, 2006, covers an area 750x3100 in pixel size and the pixel scale is set to 175.558 meters per pixel. The actual SAR resolution is around 350 meters per pixel and the image contains some interpolation. SAR imaging shows lake-like features separated into 3 classes; dark lakes, granular lakes, and bright lakes [4]. Dark lakes are interpreted as liquid filled, while bright lakes are interpreted as empty basins and granular lakes are inferred as transitional between dark and bright lake features. After using the despeckling filter TSPR we apply the segmentation method [5]. We can see the results in figures 1 - 3. With blue label we can see the dark part of lakes, with green the granular part of lakes and with red the local background.

3. Figures

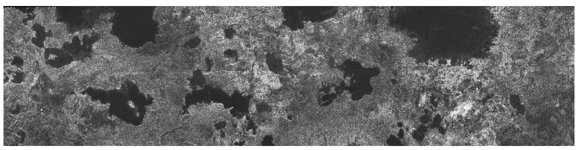

Figure 1: Initial image (PIA08630, NASA/JPL)

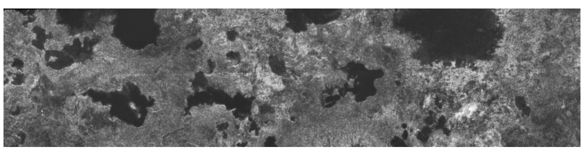

Figure 2: Filtered image

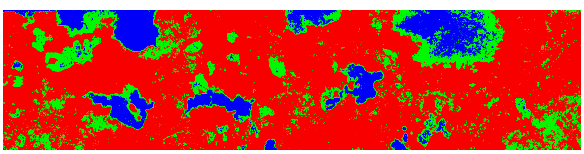

Figure 3: Segmenteted image after filtering

5. Summary and Conclusions

The TSPR filter, in combination with the minimum Euclidean distance method of supervised segmentation, can be used to extract regions of interest on the surface of Titan, such as lakes or seas using Cassini SAR images. Such despeckle filter can be applied in studying other surface features on Titan like the drainage networks, the equatorial dunes and the impact craters, where different textures appear.
Our approach allows to isolate each distinct surface feature from its surroundings and to study their distribution through out the surface. Then, in combination with radiative transfer modeling using Cassini visual and infrared mapping spectrometer (VIMS) data, we can infer about the relation between surface composition and morphotectonic structures. When we determine in a more accurate way the shapes of several surface structures, we will be able to study their global distribution and perform effectively classifications.
The proposed filtering and segmentation method would be a helpful tool in enhancing the return of the analysis of all SAR data acquired on Titan and other objects as well as in the exploitation of such data from future missions to Titan.

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