IMAGE RESTORATION OF LUNAR NEUTRON ALBEDO MAPS FOR THE LUNAR EXPLORATION NEUTRON DETECTOR (LEND)

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Introduction: The Lunar Exploration Neutron Detector (LEND) onboard the Lunar Reconnaissance Orbiter (LRO) will measure the flux of neutrons from the Moon, which are produced by the continuous and isotropic cosmic ray bombardment of the lunar surface. When cosmic rays hit the regolith, they release high-energy neutrons that are then slowed down and absorbed by the nuclei of elements in the regolith. However, not all neutrons are captured by the soil and many escape, which creates a leakage of flux of neutrons detectable by the LEND instrument. [Vondrak, 2007] Orbital measurements of the neutron energies are used to infer the geochemistry of the lunar regolith. The main goal of LEND is to observe hydrogen, which has a significant impact on the neutron leakage energies and is detectable in concentrations greater than 100 pm. [Mitrofanov, 2008]

The lunar surface neutron flux rates are low and variable as a function of cosmic ray induced activation energies, soil composition and geochemistry. It is estimated that the collimator of LEND will collect approximately .88 counts/second with a field of view (FOV) at a 50 kilometer altitude, spanning 5.6 kilometer full width at half maximum (FWHM), across the lunar surface. Primary science mission will cover 382 days with a possible extension for a second year of science mapping.

Problem: Due to the mission mandated polar obit, accumulated spatial coverage will be high at the poles and decrease as a function of latitude. The process of detecting and accumulating neutrons is a Poisson process and the spatial distribution of signals will be degraded by pixel statistical uncertainties and blurred by the LEND collimator. This process degrades the spatial resolutions of mapped neutron signals. Methods for image restoration of planetary neutron albedo maps have been proposed by [Elphic, 2007] and [Lawrence, 2006] for analysis of Lunar Prospector Neutron data. This research evaluates several methods to determine both applicability and configuration of methods.

Objective: To determine the optimal image restoration technique for restoring the hydrogen lunar albedo maps for LEND and to identify appropriate processing constraints. Finally, identify conditions where processing artifacts may be introduced, so that future lunar mission planners may not misinterpret restored images. Four methods that are proposed include:

- PIXON (R. Peutter): University of California
- Regularized Filter (V. Ivatury): University of Michigan, GSFC
- Optimized Gaussian Smoothing (T. McClanahan): GSFC
- Conjugate Gradient (G. Milikh, G. Nandikotkur, R. Sagdeev): University of Maryland

Solution: Two sets of synthetic models will be produced using quasi-randomly generated lunar pole neutron albedo maps that reflect expected LEND signals and statistical uncertainties. There will be an initial training phase, followed by a blind study. During the training phase, each team will be provided a set of modeled LEND signals as well as true signal imagery to configure and optimize their method. During the blind study phase, each team will receive 120 random lunar crater images (40 random crater, 40 north pole and 40 south pole) , without the true signal imagery [Bussey, 2004].

Four images [620,620] pixels, projecting 80-90 degrees on the lunar north and south poles that will be used in the study are:

- True Signal: Crater (non-overlap) epithermal intensities will vary from 5–25 percent decreases from background signals. Includes randomly generated cold trap positions, intensities and total cold trap coverage. Not present in blind study phase.
- Point Spread Function: FOV [10,10] kilometers across, where 7 pixels at diameter FWHM. Average of 50 kilometers in altitude.
- Counts Image: Factors in LEND instrument angular response with orbital ephemerides as a function of time, map resolution, instrument and altitude factors.
- Time Normalized Image: Includes random statistical uncertainty (used as input image when testing methods)

The final restored images from each method will be analyzed using error metrics and performance criteria.

Performance Criteria: Error metrics will be used to quantify the differences between restored images and true signal images a function of modeling factors integrated into blind study data. These include statistical uncertainty; signals in craters, crater areas, background variability and epithermal count rates. Proposed error metrics will be defined using the root mean square error and mean signal to noise.

Validation: Measurement of how closely restored images are to true signal images. Analysis of error metrics will be used in validation to conclude which image processing technique will be best suited to restore lunar albedo maps for LEND.

Discussion: The regularized filter method can be used effectively when restrictions are applied on the recovered image and little information is known about the additive noise. A constrained least square restoration algorithm that uses a regularized filter restores the blurred and statistically uncertain image. The regularized filter algorithm makes use of the least square error between the estimated and true signal images, preserving image smoothness [Poggio, 1985]. It is assumed that the true signal image is convolved with a point-spread function.

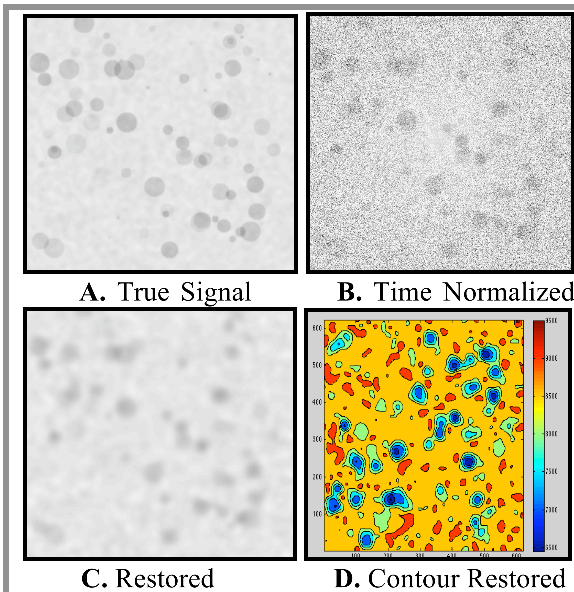

Fig. 1. A-D, Restored Image compared to True Signal Image using Regularized Filter (V. Ivatury)

Fig. 1 shows a restored image using the regularized filter. An optimization method is performed after the method, followed by an edge detection technique. This process guarantees a restored image that closely resembles the counts image and true signal image.

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