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Photometric Corrections of Planetary Color-Image Data using GIS tools

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Introduction and Background

Planetary remote sensing image data is collected from orbital instruments by means of cameras and imaging spectrometers. All data usually suffer from various unwanted effects that are incorporated by (technical) characteristics of the employed optics and sensors as well as by exterior effects such as atmospheric and photometric characteristics. While optics and distortion effects introduced by the instrument are usually handled during radiometric correction using ground-based calibration data, atmospheric effects, such as clouds and aerosols and varying illumination conditions have to be treated separately.
Such effects usually change in the course of a mission if surfaces are imaged under different illumination and observation conditions, especially when the orbit design is non-synchronous and elliptical. These effects lead to unwanted problems that become dominant when seamless mosaics are created. Furthermore, also spectral analysis across neighboring orbits are influenced by such effects that may lead to misinterpretation of spectral data as the response of the surface signal is dependent on wavelength.
Apart from illumination and observation conditions, the terrain geometry plays an important role as solar incidence angles and therefore phase angles change significantly. There have been several attempts for treating such photometric effects (with or without atmospheric influences) and a variety of software implementations for planetary surfaces have been established (USGS ISIS2 and 3 package, VICAR environment). However, the rather complicated procedure has led to avoiding photometric corrections during systematic data processing.
Most of the software packages deal with frame camera properties mainly as these can be treated in an efficient way due to the fact that the geometry at a reference pixel is easily transferred to other pixels, i.e. it is fixed. Moreover, not all implementations are taking the true surface geometry into account but rather focus on the reference ellipsoid.
Apart from the geometric dependences, i.e., observation, illumination and terrain geometry, the spectral intensity of a given surface pixel depends on properties of the surface materials (e.g., roughness, composition, grain size, porosity). While the position of the Sun and the imaging instrument (including spacecraft) with respect to the observed surface at a given time is determined by navigation data for each pixel as obtained from NAIF/ SPICE, the observed and illuminated surface geometry at a given time is exactly described by terrain model data as derived from stereo or altimetry data.
To account for such variations in spectral intensities through time and changing geometry, several photometric functions have been employed in the past to correct such issues. Such models range from rather simplistic models parameterized by the incidence angle only to complex multi-parameter models that additionally take into account certain surface properties.
Application of such photometric functions provide improvements of image data with respect to pixel intensities and allow for normalizing image data taken at different times and under different observation geometries by correcting these data to a common reference geometry and observation conditions. This normalization of image data permits substantial improvements which allow for image mosaics that lack such photometric effects and which are much easier combined to form a homogeneous data mosaic.

Goals and Methodology

In the course of this work we set up an environment which will allow for performing end-user photometric corrections by implementing basic raster-tool routines within a commercial GIS environment (Arc-GIS by ESRI). The goal is to be able to load planetary raster image data into the GIS and perform selected corrections with user-defined parameterization so that photometric effects are minimized and subsequent image mosaicking by performing histogram matching and additional (non-photometric) color corrections and seam blending lead to best-possible results.
Notwithstanding highly efficient image correction and filtering/color correction methods, image seams caused by different observation and illumination geometries are still present and prohibit creation of image mosaics of high quality standards. This work is done in

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the context of the systematic processing of Mars Express High Resolution Stereo Camera data for which a proper selection of the 'correct' function and for which user-defined parametrization is of utmost importance. The HRSC instrument is a pushbroom scanning device with nine CCD line detectors which has been operating in an elliptical orbit about Mars since 2004. The instrument provides high-resolution stereo image data with a pixel scale of up to 12.5 m with a panchromatic nadir-looking channel, four colour channels and along-track triple stereo. The stereo performance of the instrument allows for derivation of high-resolution digital terrain models with a scale of up to 50 m/px. In the course of the mission several thousand images have been acquired which are affected by varying illumination and observation geometries and for which a systematic photometric correction needs to be applied. The pushbroom sensor allows for acquisition of long imaging strips but one has to take into account that each line of each channel is affected by different observation and illumination geometries so that a calculation for subsequent photometric corrections need to be made for each image line.

In the course of this work we make use of the pan-sharpened colour data and the terrain model data derived from the stereo channels. Additional auxiliary geometric information, i.e., incidence, emission, and phase angles, are generated by making use of the NAIF/SPICE toolkit using reconstructed orbit data. These data will be transferred to raster data that accompany image and terrain model data and which will be used for calculating proper geometries by taking the surface geometry, i.e., the terrain model, into account by deriving slope and azimuth raster data. This way we end up with a color-orthoimage dataset, a digital terrain model, observation/illumination vector dataset, and a derived set of surface geometries which are used within the ArcGIS environment to apply photometric functions to each raster cell and to calculate corrected brightness values using a reference geometry by making use of the onboard raster tools. As photometric functions, we will implement simple models, such as Lambert that treats incoming light as being scattered uniformly in all directions, whereby the reflected light only depends on the incidence angle of the illumination. Further implementations will make use of Minnaert's model which takes account of the emission angle and a roughness constant [1] and the Lommel-Seeliger function which also incorporates the emission angle [2]. More sophisticated models, such as the Hapke photometric function will require a thorough knowledge of the surface properties and will not be treated initially [3-6]. However, it has been shown by [7] that for planetary surfaces more simple models, such as Minnaert, provides good results.

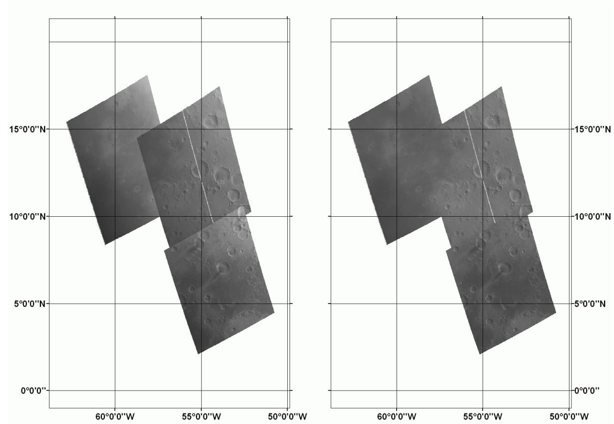

Figure 1: Mosaics of Viking images 646A65-67 showing the surroundings of Ister Chaos: before (left) an after (right) photometric correction (Minnaert, k=0.5)

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