LUNAR TOPOGRAPHIC MAPS DERIVED FROM CLEMENTINE IMAGERY. M. R. Rosiek, R. Kirk, and A. Howington-Kraus , United States Geological Survey, Astrogeology Team, Flagstaff AZ 86001, (e-mail: mrosiek@usgs.gov).

Introduction: Stereo multispectral images of the lunar surface were collected during the Clementine Mission. These stereo images provide a view of the same area from two different viewing locations. The elevation of the surface can be derived from stereo images by using the sensor geometry at the time of image acquisition. This elevation information can be used to fill in the areas where the Clementine altimeter did not collect elevation data. Two main areas are the North and South Poles. This report provides a review of the photogrammetric techniques used to derive elevation information from Clementine imagery and a summary of the initial results.

Clementine Data: In 1994, the Clementine spacecraft acquired digital images of the moon at visible and near infrared wavelengths [1]. On board there were four camera systems and a laser altimeter. During the first pass, periapsis was at 30˚S and the highest resolution images were obtained in the southern hemisphere [2]. Over the northern polar area a series of oblique and nadir images were obtained with the ultraviolet-visible (UVVIS) camera on each orbit. During the second pass, periapsis was at 30˚N and image acquisition was reversed, with high resolution images in the north and oblique and nadir images in the south.

Imagery. Stereo multispectral data from which we derived lunar topography were acquired by the UVVIS camera. The UVVIS camera image size was 384x288 pixels with five spectral bands and one broad band. The 750 nm band oblique/nadir pairs were the primary image source for this study. On an oblique image the ground sample distance (GSD) ranged from 300 to 400 meters. The GSD for the nadir images acquired at the end of an orbit were slightly larger and ranged from 325 to 450 meters. Using the formula for stereo height accuracy [2] an estimate of height accuracy is 180 m. This formula is $IFOV_{max}/(K \cdot B/H)$ with $IFOV_{max}$ defined as Maximum Instantaneous Field of View, B/H is the base-to-height ratio, and K is an estimate of pixel measurement accuracy on the imagery.

Altimeter. The Clementine laser altimeter (LIDAR) data were used previously to produce a global topographic model of the Moon [3]. The model has a vertical accuracy of approximately 100 m and a spatial resolution of 2.5˚. Altimetry data were collected between 79˚S and 81˚N. Over some smooth mare surfaces an along-track spacing of 20 km was achieved. This spacing varied. Where the instrument lost lock over some rough highland terrain the spacing degraded to 100 km. The across-track spacing was based on the orbital track and is approximately 60 km at the equator and less elsewhere. A filter was applied to LIDAR data to reduce the range information to a single range value for each bounce point. The filtered data was then interpolated to fill in the polar regions where the altimeter did not collect data. A global topography model was then derived on the basis of spherical harmonic expansion [3].

Image Mosaic. A global image mosaic of the moon was produced from the 750 nm Clementine data [4,5]. Match points were picked to tie the imagery together, and the camera pointing angles were adjusted to align the imagery. This adjustment used a spherical surface, and the elevation of all points was held to a constant value, 1737.4 km. This produced a seamless image mosaic with latitude and longitude information but no information on the elevation [4,5].

Analytical Aerotriagulation: The imagery and support information were downloaded to our digital photogrammetric workstation using the Integrated Software for Imagers and Spectrometers (ISIS.) The support data included the camera location and pointing angles. Match points used to produce the image mosaic were also downloaded. The camera angles needed to be adjusted to account for the elevation of the match points. This was accomplished with the HATS software from LH Systems SOCET Set software package [6.] The revised camera angles allowed for the derivation of digital elevation model (DEM) from the stereo imagery.

Initial estimate. The match point latitude and longitude from the global image mosaic are accurate and used for an initial estimate of the horizontal position. The elevations of the match points were then estimated from the altimetry data. The camera angles used in the altimetry processing and in the creation of the image mosaic were adjusted independently. Hence, the horizontal position of the altimetry data and the image mosaic are not aligned correctly. Clementine was designed so the altimeter shared the optical system of the HIRES camera system. The HIRES and UVVIS camera system were aligned so the HIRES image was centered in the UVVIS image [1]. We therefore made an adjustment so that the altimetry points would fall near the center line of the UVVIS imagery.

A DEM was created from the altimetry data using the adjusted position and the match points elevations were estimated from the adjusted DEM. These points were used in the HATS software, which allows for the use of weights on the estimated position based on the accuracy of the point. The horizontal positions were given a weight of 1 km, and the vertical estimates were weighted on the basis of their distance from an altimetry point (weight of 1 - 5 km.)

Stereo Adjustment. There were over 3,600 images and 29,000 match points for the southern polar region, an area defined as 64˚S or less. This was too much data for the memory of the computer (a Silicon Graphics computer with 126 Mbytes of memory and 476 Mbytes of swap space.) An estimate of the amount of memory to perform this adjustment is over 6 gigabytes. The images were therefore broken up into a number of blocks and adjusted in a systematic way. The initial block formed a web over the entire area (Fig 1). This web consisted of an outer circle and eight legs. One leg consists of data from two orbits because there was a break in the circle. The remaining blocks were formed by using two legs of this web and the outer images of the web and filling in the interior with the images to complete the coverage for that block.

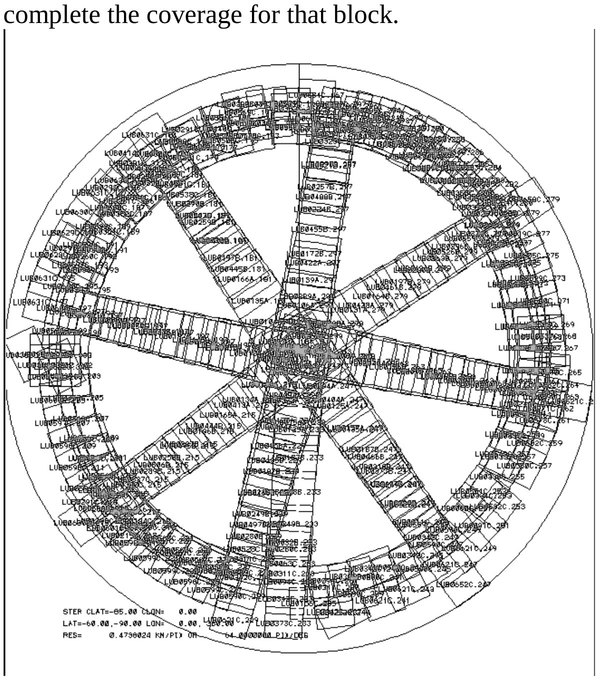

Figure 1 Web Layout

For the adjustment of the initial block, the camera angles for all images were allowed to be changed by the adjustment process. For the remaining blocks the camera angles of the images that were part of the initial block were held fixed and the camera angles of the interior images were allowed to change.

Elevation extraction: Elevation data were extracted from a stereo pair consisting of an oblique and a nadir image. The SOCET SET software provides an automated routine to extract elevation data. The routine uses an image patch from one image and a search window from the other image, and then the correlation between the two image areas can be determined. The strategy files (which define the patch size, area searched and match strategy) were modified to work with the UVVIS imagery. For every stereo model a correlation point was determined every 1 km in ground distance. These patches of the DEM were first merged along an orbit path, and then the DEM from adjacent orbits were merged together. The oblique/nadir stereo pairs do not completely cover the entire South Pole, and these small gaps could be filled with other stereo pairs or by using other techniques such as photoclinometry. The elevation data from the oblique/nadir stereo pairs will be collected first and then the gap areas will be looked at.

Initial Results: The initial elevation data identified some problems between stereo models within an orbit and between the orbits. These errors were likely caused by the layout of the match points. When the images were divided into different blocks, some of the match points were only on one image, and not all stereo pairs had points linking them. To rectify this, match points will be transferred to all images in which they occur (besides the two images in which they were originally measured), and additional match points will be selected where needed. The analytical aerotriagulation will be performed with this revised match point data. Elevation data will be collected and presented after the analytical aerotriagulation is completed.

References:

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