Lunar Orbiter Frame Mosaics
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Lunar Orbiter (LO) digital frame mosaics with cosmetic processing (mostly destriping) at high, moderate and very high ground resolution [1-3] are available at **ftp://pdsimage2.wr.usgs.gov/pub/pigpen/moon/lunar_orbiter/Frames/ISIS2/**. This online data collection includes versions of the global medium (~200-1000 m) and high (~40-200 m) resolution LO frames that were used to create the LO global mosaic (60 m/pixel; see Gaddis et al., 2009). These mosaics are map-projected in ISIS2 cube format, and they have been 'gzipped' to reduce file size. See info below for using ISIS3 to work with these data.

The global mosaic is available at Map a Planet (see **http://www.mapaplanet.org/explorer/moon.html**). Note that the global mosaic has not yet been recreated using these newly released, destriped LO frame mosaics.

Background

Five Lunar Orbiter missions were launched by the U.S. in 1966 and 1967 to study the Moon. Lunar Orbiter images were photographic products acquired on the spacecraft during those five missions (LO-I through -V; Hansen, 1970; Bowker and Hughes, 1971). The first three missions mapped potential Apollo lunar landing sites. Lunar Orbiter IV photographed most of the near and far sides of the Moon medium and high resolutions. Lunar Orbiter V completed the photography of the far side and collected additional images of 36 sites of scientific interest.

The Lunar Orbiter (LO) global mosaic of the Moon was constructed using photographs acquired by LO III, IV and V. Work towards constructing the global mosaic spanned over seven years. Earlier work involved scanning (at 25 microns) and processing (at 50 microns) more than 30,000 35-mm film strips from the LO high- and medium-resolution cameras (HR and MR, respectively). Digital film strips were cartographically processed to construct more than 200 individual frames and then geodetically corrected using the most recent lunar control network and topographic model (the Unified Lunar Control Network 2005 or ULCN 2005; Archinal et al., 2006, USGS Open-File Report 2006-1367, available at **http://pubs.usgs.gov/of/2006/1367/**). The result of this work is a moderate resolution (60 m/pixel), near-global, cartographically controlled digital mosaic of the Moon (Gaddis et al., 2001, 2003, 2009; Becker et al., 2004, 2005; Weller et al., 2006, 2007).

Unprojected LO frame mosaics (at 100 micron resolution) in jpeg and raw formats without the destriping can be found at **http://astrogeology.usgs.gov/Projects/LunarOrbiterDigitization/**. Data at this site include a number of LO frames that were not used in the global mosaic because of redundant coverage or poor quality. All frames were included in the global photogrammetric solution with updated spacecraft orbits and camera angles tied to the ULCN 2005 control network.

Data Coverage

Coverage maps for the ‘global’ LO data are available here:
http://astrogeology.usgs.gov/Projects/LunarOrbiterDigitization/statusmaps.html

The near side (pole-to-pole) LO mosaic is comprised largely of LO IV HR camera data. Far side coverage is dominated by limb and terminator views acquired by LO V HR and MR cameras. Also included is a single view obtained by LO III HR and MR cameras that provides coverage at the southern far side (centered on crater Tsiolkovsky). To fill in gaps where possible, LO IV MR data are included. The mid-latitude empty area across the far side is a LO data gap. Data coverage in this region acquired by LO I, II and IV could not be cartographically processed due to poor quality, lack of reseau marks on film, or unexposed fiducial marks.

Cosmetic Processing

Following cartographic construction of the LO frame mosaics, cosmetic processing for the LO frame mosaics included removal of the synchronized read-out (white) dashes and destriping.

Cosmetic processing was not applied to the data included the global mosaic. Only a high-pass filter was applied to the frames before mosaicking to normalize the relative brightness, especially in terminator regions across the far side. The results accentuate the high frequency information by retaining only 10% of the low frequency brightness variation.

Observed Artifacts

Spacecraft faults: A majority of the frames contain random spacecraft processing faults, and these artifacts often look like "water mark" or "coffee ring" patterns. The faults occurred during processing of the film onboard the spacecraft. Data in these areas are lost and not recoverable. An overlapping frame covering the same area often does not have a processing fault. No attempt was made to remove these artifacts.

White Dashes: Every frame contains synchronized read-out (white) dashes along the film strip margins. The global mosaic was constructed with non-cosmetic "raw" frames containing these dashes. A first-order cosmetic enhancement process later removed the dashes on many of the constructed frames. Successful "no-dash" versions of the frames are available on the LO website listed above. Due to the difficulty of isolating the dashes from original data, the removal was not 100% successful for all frames and the no-dash LO data collection is incomplete. The no-dash LO frames were not included in the mosaic at the present time.

"Venetian Blind" Striping: Low-contrast striping across each frame remains in the LO mosaic. This "venetian blind" effect is a familiar characteristic of Lunar Orbiter data and it was caused by systematic variations in brightness levels across each film strip. The white dashes along the filmstrip margins also contribute to this apparent banding.

Film Strip Gaps: A number of frames display narrow data gaps between film strips. The gaps were not removed before mosaicking and can be particularly obvious where an overlapping

frame shows through in the mosaic. These gaps were likely caused by data or film distortion during a mission readout process either onboard or transfer to Earth. Although the pre-exposed reseau marks (+) on the film were used rectify each digital film strip for frame construction, the number and spacing of the reseau marks were inadequate to fully remove the distortion in severe cases.

DEM Artifacts: There are a few areas in the global mosaic where spikes or artifacts in the ULCN 2005 topographic or digital elevation model (DEM) caused artifacts or errors in the LO mosaic. For each pixel in a LO frame, radius values from the same site in the DEM file are used to project the pixel onto the surface. Pronounced artifacts in the DEM were propagated to the projected LO image data. The resulting pattern in the LO mosaic is a "log cabin" or "checkerboard" effect where the image data is compromised in a few isolated areas. The ULCN 2005 DEM will continue to be evaluated and "smoothed" to remove these artifacts in the future.

Geometric Control

The LO spacecraft orbit and camera angles for each frame were adjusted to the ULCN 2005 using a least squares photogrammetric triangulation. Overlapping frames share control point pixel measurements in addition to measurements to existing points within the ULCN 2005. Selected NASA Clementine 750-nm basemap image tiles were used as the image reference for the ULCN 2005 points measured in LO frames. The latitude, longitude and radius values for the ULCN 2005 control points were fixed as .ground truth. in the LO global solution. For each LO exposure, adjusting both the LO spacecraft position and the camera angles reduced the maximum RMS errors by a factor of two.

As each frame was projected into the equirectangular map projection, the ULCN 2005 DEM was used to map every pixel to the surface topography according to the radius value within the DEM. This orthorectifation of the frames resulted in a high-order registration of features across and within overlapping projected frames. The LO global mosaic is the first digital map product constructed based on both the horizontal (latitude, longitude) and vertical (topography) ULCN 2005 geometry and DEM. Other lunar products have been warped to the UCLN 2005 horizontal geometry (LPSC 2008; B. Archinal and T. Hare; see **http://www.lpi.usra.edu/meetings/lpsc2008/pdf/2245.pdf** and **http://www.lpi.usra.edu/meetings/lpsc2008/pdf/2337.pdf**).

ISIS3 Processing

To use ISIS3 for working with the LO frame mosaics, first retrieve and unzip the ISIS2 files:

- Download the desired ISIS2 frames from **ftp://pdsimage2.wr.usgs.gov/pub/pigpen/moon/lunar_orbiter/Frames/ISIS2/**
- On a linux box (prompt is indicated by % below), unzip the cube(s)
  - % gunzip *.cub.gz
- Initiate ISIS3:
  - % setisis isis3 or % setisis isis3.1.2 (the latter will change as ISIS3 changes)
- Within ISIS3, run the following for each file (change filenames as necessary):
  - % pds2isis from=*isis2_frame1.cub* to=*isis3_frame1.cub*

- **NOTE:** The frame mosaics were created in ISIS2 using the lat/lon range of the frames, so each will have different resolutions and coordinate ranges. Because the mosaic programs 'mapmos' and 'automos' require that incoming files have the same mapping parameters, you'll need to reproject the frames of interest using the same map file prior to mosaicking them. If other lunar data (e.g., Clementine color mosaics) are to be included in a mosaic, they would also need to be reprojected to a common lat/lon using the same map file. A map.map file contains the output mapping parameters; it can be created from an existing cube label with the desired Mapping Group, by editing a text file, or using 'maptemplate'. For example:
    - % map2map from=*isis3_frame1.cub* map=*map.map* to=*isis3_frame1_newmap.cub*
- To mosaic frames, create an ASCII file containing the list of converted ISIS3 frames:
    - % ls -1 **frames*.cub* > *any_frames.lis*
- Then run the following:
    - % automos fromlist=*any_frames.lis* to=*your_mosaic.cub*
    - % map2map (to reproject if desired)
- Refer to the ISIS online help for more information on ISIS2 and ISIS3:
    - **http://isis.astrogeology.usgs.gov/index.html**

References

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