Automated Cosmetic Improvement of Mosaics from the Lunar Orbiter Atlas. Charles J. Byrne (formerly of Bellcomm), Image Again, Middletown, New Jersey; cjbyrne@monmouth.com.

Introduction: Since the Lunar Orbiter mission returned extensive photographic coverage of Earth's moon in 1966 and 1967, the pictures have been the basic reference for comprehensive, high-resolution topographic information, especially the set edited by Bowker and Hughes [1]. But the limited scanning technology of the time resulted in artifacts that distract a viewer. There are bright lines running across the mosaics between framelets and brightness variations from the spacecraft's scanner that appear as streaks within the framelets. The artifacts are particularly distracting when the images are printed at high contrast in order to show subtle topographic features. Figure 1 shows an example of a Lunar Orbiter frame as downloaded from the digital Lunar Orbiter atlas edited by Jeff Gillis [2].
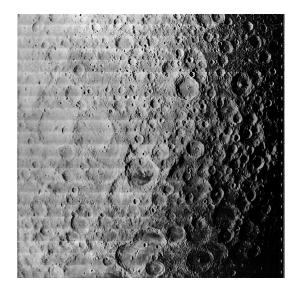

Figure 1: Lunar Orbiter Frame 2-33M, downloaded from the Lunar Orbiter atlas [2]

Current computing technology makes it possible to estimate and remove most of the artifacts. The best quality can be achieved by digitizing archival framelet data, creating mosaics, and removing residual image artifacts [3]. Until this process is carried to completion, the existing digitized mosaics of the Lunar Orbiter atlas [2] can be considerably improved by cosmetic processing.

One approach to processing the mosaics is to apply filters that detect and suppress most of the artifacts. as does the ISIS software developed by USGS [4]. This abstract reports on a somewhat different process that first detects and mimimizes the bright lines between

framelets within a mosaic. Then it averages the streaks within the framelets throughout the mosaic, and applies a correction to them. The non-linear characteristics of the high-contrast prints are modeled and taken into account. The program runs automatically on nearly all of the sampled images from the atlas.

Description of the Program: The analysis program was written in Visual Basic and runs in a Windows 98 environment. It uses utility routines from a book by Rod Stevens [5]. The program, running on a 233 MHz Pentium II PC, processes a typical frame of about 1 million pixels in less than two minutes. A processed frame corresponding to the downloaded frame is shown in Figure 2.
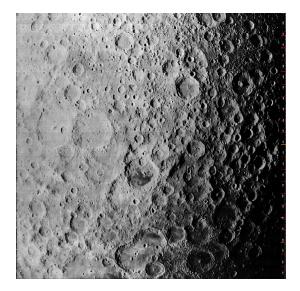

Figure 2: Lunar Orbiter Frame 2-33M, after cosmetic processing

The steps performed by the program are:
1. Search from the top of the mosaic image for the first identifiable bright line between framelets (a framelet edge)
2. Jump half a typical 40-pixel framelet width and search for the next identifiable framelet edge.
3. Repeat the jump-and-search process until the bottom of the image is reached
4. Calculate the precise framelet width of the image (which varies between 38 and 43 pixels on the currently sampled images) by averaging the framelet width between successive identified framelet

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edges. Successive edges are those separated by about one typical framelet width.

5. Extrapolate or interpolate those framelet edges which were not identified by search processes.

6. Each framelet edge is scanned and, for each horizontal coordinate of pixels, the excess brightness is estimated by comparison with the immediately adjacent pixels, The excess brightness is removed from the pixels of the affected scan lines.

7. Determine the average linearized brightness ratio of the pixels, as a function of their relative position between framelet edges, for the entire mosaic image. A model of the non-linear contrast function is used in the linearization process.

8. Correct the brightness of each pixel for the average normalized brightness ratio corresponding to its position between framelet edges. The contrast model is used in the correction.

9. Save the processed image.

Specific Techniques: The program addresses several problems that are specific to the mosaics.

Finding the edges of framelets. Usually, framelet edges are represented by bright lines caused by light shining between the framelet filmstrips as the mosaics were laid up. Although they are narrower than the distance between scans of the digital images, the lines appear in either two or three adjacent lines of pixels because the scan spot used in creating the digital images was larger than the distance between scans. The scan lines are usually tilted with respect to the framelet edges by two or more pixels across a frame and have curvature of the order of one pixel across a frame. In many frames, the white lines are obscured by saturation or overcome by image signal in large parts of the frame. Development artifacts and some valid signals can produce false segments of bright lines that are not at framelet edges.

The approach taken to find these lines is to search in a band of scan lines 17 pixels high, looking in 17 by 21 blocks of pixels for a bright white line segment of either two or three pixels in width. A quadratic best-fit line is calculated using the centers of the line segments. Successive fits are calculated, eliminating those centers that are most off the line until all remaining centers are within half a pixel of the line. If the remaining centers are at least 25% of the possible centers, the line is accepted as a framelet edge. If not, the band is moved down the picture to find an edge.

Removing each framelet edge line. For each horizontal pixel index, the pixels above and below the calculated vertical value of the best-fit line are examined to determine the probable value of the excess brightness of the line and a weighted value is subtracted from

the brightness of the two or three pixels near the line. This process preserves more detail in the image than simply averaging the brightness around the line.

Contrast model. The streaking artifact was applied in the spacecraft on a low contrast image, essentially linear in its relation between photographed brightness and density, However, the atlas images were printed at high contrast and are therefore nonlinear. Thus in order to determine and compensate for streaking, it is necessary to linearize the brightness by reversing the contrast function. The assumed contrast function is an "S" curve that has a contrast gain of 3.7 at an input brightness value of 0.7 times the maximum input brightness.

Sample Frames Processed: The program has been run on Lunar Orbiter frames 2-33M, 3-121H1, 4-98H3, 4-109H3, 4-110H1, 4-120H2, 4-120H3, 4-120M, 4-121H2, 4-124H2, and 4-126H2. In all cases except that of 4-109H3, a strong improvement in cosmetic appearance resulted. In a few cases, atypical artifacts were trimmed from the frames before the program was run. In one case the program was run on a negative image and then converted back to a positive image, with good results.

Summary: Several problems have been overcome in order to achieve automated processing of many frames of the atlas. The current program, which runs on a PC using Windows, minimizes the bright lines between framelet edges and the streaking that is systematic within a frame. Further improvements might be possible by processing the resulting images by ISIS or other filtering techniques that reduce localized streaking in parts of a frame.

References: [1] D. E. Bowker and J. K. Hughes (1971), *Lunar Orbiter Photographic Atlas of the Moon,* NASA SP 206. [2] J. Gillis (ed.), *Digital Lunar Orbiter Photographic Atlas of the Moon*, www.lpi.usra.edu/research/lunarorbiter, Lunar and Planetary Institute. [3] L. Gaddis, et al., *Cartographic Processing of Digital Lunar Orbiter Data,* LPS DXXII, Abstract #1892, Lunar and Planetary Institute, Houston (CDROM). [4] L. Gaddis, et al. (1997), *An Overview of the Integrated Software for Imaging Spectrometers (ISIS),* LPS XXVIII, 387. [5] Rod Stevens (1999) *Visual Basic Graphics Programming, Second Edition,* John Wiley and Sons, Inc., New York.